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SURGICAL

DIAGNOSIS AND TREATMENT

BY AMERICAN AUTHORS

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GENERAL CONSIDERATION OF FRACTURES.

By WILLIAM LAWRENCE ESTES, A.M., M.D.

A fracture of any bone of a living human being is not simply "a solution of the continuity of the bone," but an injury which, in the large majority of instances, is a complex traumatic condition, consisting of the break in the bone and injury to the soft tissues of the part involved of greater or lesser severity. In some cases the injury to the soft tissues is of great importance, and in no instance, except perhaps in the rare cases of so-called "green-stick fracture," may they be neglected or forgotten in treating the case.

Causes of Fracture.—While it is generally true that a fracture is caused by some sort of violence, it is well known that much less force is required to produce a fracture in some individuals than in others. We must therefore recognize two general causes of fracture: (1) Predisposing; (2) determining.

Predisposing Causes of Fracture.—1. Old age certainly predisposes to certain classes of fractures, notably to fracture of the neck of the femur.

2. Some persons undoubtedly have bones which withstand strains less sturdily than do normal bones. This brittleness of bone, or "fragilitas ossium," may occur in all the age periods.

3. Disease conditions may impair the resistance of one bone only or the osseous system generally: (*a*) Malignant diseases, osteomyelitis, etc.; (*b*) rickets in childhood and in adults, osteomalacia; (*c*) rheumatoid arthritis, etc. All these serve as predisposing causes of fractures.

Determining or Immediate Cause of Fracture.—Force is always the immediate cause of a fracture. In civil life indirect violence is by far the most common cause.

The immediate cause of fractures is usually stated as (*a*) direct and (*b*) indirect violence. In civil life fracture by direct violence is comparatively rare. Of 739 cases analyzed 120 were from direct violence and 619 resulted from indirect violence.

I have analyzed the conditions and histories of a large number of fractures of indirect violence, and I feel sure, in nearly every instance, the fracture of the bone, if it were a long bone, was produced by incoordinate leverage.

When a human being uses his extremities voluntarily for motion and locomotion he accomplishes these acts by coördinate leverage, the motion to the levers (the bones) being applied by the coördinate use of the proper muscles. If taken unawares the position of the extremity or the position of the trunk may be such that even slight momentum results in violent incoördinate leverage, and a fracture may result.

As regards the number of fractures in the several age periods the British and American statistics differ somewhat. They are as follows:

American number of cases studied, 344		British number of cases studied, 716	
Under 10 years	90	Under 10 years	394
10 to 20 "	65	10 to 20 "	155
20 to 50 "	122	20 to 50 "	77
50 to 70 "	55	50 to 70 "	90
70 to 90 "	12	70 to 90 "	0
Total	344	Total	716

Diagnosis.—Distortion, "false mobility," great pain and local tenderness, ecchymosis, swelling and crepitus, if all are present in any case one may easily conclude a fracture has occurred. Sometimes distortion is difficult to appreciate; no crepitus is felt and there is fixity of the extremity; only great pain and local tenderness are present; perhaps considerable swelling and some ecchymosis. Such cases may be extremely difficult to determine, especially if the lesion be near a joint.

Careful ocular examination and comparison with the uninjured limb, if the uninjured one is a normal member, careful measurements and the gentlest possible manipulation, continued for only a very short time, may be employed. If this does not suffice to establish the diagnosis, fixation in the position assumed by the limb should be made as soon as practicable.

Prolonged manipulation and careless handling or forceful attempts to elicit crepitus should always be avoided. The dreadful pain from these methods of diagnosing causes spasm of the muscles, and on account of the incongruous positions which follow may make the determination doubly difficult.

In obscure cases difficult to diagnose, if manipulation is necessary to establish the diagnosis it should be postponed until the physician is prepared and ready to make his permanent dressing; then a general anesthetic should be given if the patient's general condition will admit of it, and setting should immediately follow the manipulation; or, better still, the manipulations should accomplish the setting and the permanent splint or dressing be applied at once. Much better, however, is it to reach the correct diagnosis by a skiagram or by fluoroscopic examination. I very much doubt that a physician who cannot give his patient the benefit of a well-taken skiagram, or himself be able to make a fluoroscopic examination, should in these modern days attempt to treat major fracture cases.

The first thing to do is to find out the condition of the individual as regards his strength, condition of shock, manifestations and result of his pain, etc. The general requirements should first be done and then the special ones be attended to.

Shock in many cases is marked and requires care and discrimination in managing it. The early shock, that which comes on immediately after the injury, is a psychical one or due to "noci-associations." This is best treated by morphin given in full doses. Persistent or late shock means hemorrhage as a rule. This may require exploration by incision, packing of the lacerated cavity or ligation of bleeding vessels.

Pain and muscular spasm are the special ever-present and overpowering immediate sequels of fractures. The pain is so severe and trying in many cases that it rapidly exhausts the patient. The position of the fragments sometimes aggravates the pain. One should try rapidly and gently to ascertain in a general way whether the fragments are pressing against the skin or the nerves and place the limb in such a position that this pressure shall be relieved. Then give a full dose of morphin and immobilize and fix the extremity, unless one is prepared at once to reduce and splint the fracture. In this latter case a general anesthetic should be given and all manipulations be done while under anesthesia.

Prolonged attempts at reduction, or manipulations for the establishment of the accurate relative positions of the fragments, when the examiner is not prepared immediately to put on his permanent or final dressing are reprehensible, because they are unnecessary and brutal.

When the patient must be transported the limb should be fixed in the position in which it is found unless the fragments are evidently pressing on the skin or on some nerve trunk. In the latter case sufficient variation of the position must be made to relieve this pressure, then the limb should be fixed. Experience of surgeons in the late war showed that traction and fixation should be employed. Thomas splints proved of immense value for this purpose.

General Management of Fractures.—It should always be borne in mind that text-book statements are at best average statements; as a rule, they try to note what the ordinary displacements, signs and indications of a particular fracture should be. Usually these statements are based on anatomical and mechanical considerations entirely. The physiological and pathological forces are not usually recognized or regarded. For instance, fractures of the upper third of the shaft of the femur are stated to be followed by upward and outward displacements of the proximal fragment and upward and inward displacements of the distal fragment, according to the books, and anatomically it should be so. As a matter of fact, in some cases almost the reverse condition prevails.

Displacements and distortion in every case will depend upon the extent and severity of the injury to the contiguous soft tissues. A muscle which ordinarily should produce a certain special deviation of the fragments may be almost or completely paralyzed by the severity of the injury, and another muscle which ordinarily cannot successfully oppose it may be stimulated to tetanic spasm; and by its superviolence produce an entirely different or widely varying distortion and displacement from what the text-books and ordinary experience have taught us to expect.

Again, most of the innervating nerves may be severed, or the main nerve trunk be almost crushed by the leverage and weight of a fractured bone. Paresis of the muscles may follow; gravity and leverage alone will then determine the displacement. Congenital or acquired previous distortions also influence displacements. Therefore a safe postulate for handling and treating any case of fracture is never to take anything for granted; determine each individual case accurately and carefully and treat it according to its individual requirements.

Some years ago I was called in consultation and asked to reduce a fracture of the lower third of the femur in the case of an old man. The physician in charge told me he had tried repeatedly, always unsuccessfully, to reduce the fracture. It was a fracture almost transverse and the old gentlemen was rather thin, I thought by etherizing him I should certainly be able to reduce and retain the fracture in place. I was astonished and greatly chagrined to find that my assistant and I by any of the ordinary means and methods could not reduce the fracture. Finally it occurred to me to examine the uninjured lower extremity, I found the most exaggerated case of bow-legs I had ever seen. This gave me the necessary indication. By changing the direction of the traction and using a fulcrum just above the knee-joint the adjustment was quickly and easily done.

The study of a large number of reports from some of the best and most experienced surgeons shows there are five points of great importance to be considered in establishing the proper treatment for every case of fracture of a bone of the human body:

1. The particular individuality and surroundings of each case.
2. The age period of the patient.
3. The time after the injury the permanent dressing or the restitution of the fragments is accomplished.
4. Proper alignment of the limb and good anatomical reduction of the fracture.
5. The method of fixation and the proper apparatus, splints or dressing necessary to maintain the fragments in proper position without serious injury to the soft parts and with the least discomfort to the patient.

1. The individuality, etc., of the patient. This point is so obvious it is not necessary to do more than to recall it to general attention.

2. The age period: A study of 1745 cases of end-results of fractures of the long bones indicates that the age period one to fifteen years shows an inherent tendency to recover from fractures with good functional results. The asymmetry produced by angulation is soon overcome by adjustment of the other members of the skeleton. Overlapping of fragments with resulting local bulge rounds off, and in process of time disappears, unless the fragments have been allowed to unite in an unpardonably bad position and the alignment is bad.

As the age periods advance it becomes more and more necessary to obtain good anatomical adjustment of the fragments in order to assure good functional results.

Senile cases demand attention to their general condition at once. They are usually in shock on account of the great pain produced and will require full doses of morphin the first twenty-four hours. While it is true that some old people do not stand confinement in bed well, it is not true of all cases by any means. One must early judge this feature and be guided in his treatment by this determination. As a rule a dressing and apparatus should be employed which will enable the patient to move about a little in bed and to change position from time to time. It is rigid fixation in one position in bed and pain which prove so exhausting to old people. Strong traction and the necessity of remaining fixed on the back are very irksome and are liable to be painful; hence the ordinary traction devices should not be used for any length of time in cases of old people.

3. The sooner the adjustment or setting is done after the injury the better and quicker the recovery.

Reparative processes begin early, much earlier than surgeons have hitherto seemed to think. If setting the fracture is delayed what already has been done by natural processes will be destroyed and the second attempt to do the osteocementation will not be as quick nor as energetic.

4. Anatomical or accurate adjustment of the fragments, other things being equal, always results in shorter disability and better function. This, however, is not always true when the open method is employed to secure accurate adjustment. Many cases of plating, with anatomical adjustments, take longer periods for recovery than do less accurately replaced fragments treated by the closed method. Except in children, however, the function is better in the accurately adjusted cases.

5. The method of fixation and the dressing of fractures, while most important, is today perhaps more varied and diverse than ever they were. From the great mass of material and methods it is impossible to cull any special one to recommend. None of them are applicable to every case, even to the fracture for which it was originally advised.

A surgeon of a mechanical turn of mind and training, if he has the necessary anatomical knowledge, usually can adopt a proper dressing and fixation for his cases of fracture, and he will be able to vary them as the individual case requires.

There are certain general principles, however, which should be kept in mind by every surgeon and should be sedulously practised by the average practitioner.

(*a*) If the surgeon be a practitioner not accustomed to treating fractures he should always consult an experienced man before doing anything.

(*b*) Never attempt to set a fracture unless there are at hand splints or apparatus to retain the fragments in place. It is unnecessary and it is brutal to subject a patient to the suffering produced by the necessary manipulations for temporary adjustments. The extremity should be fixed so that the ends of the fragments will do no further injury or occasion any unnecessary pain, and nothing else be done until the permanent dressing may be applied.

(*c*) If the patient's condition will permit, a general anesthetic should always be used in setting a fracture.

(*d*) Always try to obtain good alignment even though anatomical restitution is not practicable.

Proper apparatus after reduction, as was said before, must be adapted to each individual case. In my own clinic I find that plaster-of-Paris molded splints put on during general anesthesia, just as soon after the injury as possible, is the method of dressing usually employed.

The position of the limb as regards flexion, extension, abduction and adduction is maintained according to the indication of the case. When steady traction is necessary for reducing the fracture and maintaining it during the application of the splints a Lemon extension apparatus has been found exceedingly useful and efficient. A Hawley table is equally good. Bardenheuer extension and counter-extensions at various angles and in several directions are very irksome and trying for the patient, and they are seldom used in this country. For traction in difficult cases for continuous extension the Steinmann nail method is sometimes useful.

The old Buck's extension method or some modification of this method is still the favorite method of the older surgeons for continuous traction. Too little weight is used, as a rule, in Buck's extension. Analysis of reports of about 1000 cases of fracture of the femur shows the average weight employed has been less than ten pounds. Manifestly this is absurdly too little. "The gauge of the proper weight required is that necessary to overcome the shortening." As stated above, surgeons who served in the war are now using some form of Balkan frame and are suspending the fractured limb and at the same time employing traction by weight and pulley.

Daily measurements should be taken and weight added or reduced according to whether the limb shows shortening or elongation as compared with its fellow.

Rigid board or metal splints are rarely applicable for permanent dressings. They cannot be adapted to limbs without causing pain from irregular pressure (except perhaps the Thomas splint, of which Jones speaks so highly); extension with them is very uncertain and difficult to maintain. The forearm is a region which is an exception to this rule.

Championnière's method of treating fractures by massage carries with it many suggestions of great value, though it has not been at all generally employed in this country. The principle of keeping up the nutrition of the muscles and encouraging an active circulation of the injured part is certainly one to be recommended. The massage should, however, be begun after the spasmodic stages are passed. Then the fixed dressing may be temporarily removed, the limb massaged and the dressing reapplied. This should be repeated every few days. This massage shortens the period of weakness, prevents atrophy of the muscles and promotes bony union.

The question of operative or non-operative treatment must be determined by each surgeon in every individual case. Operative treatment requires skill and thorough aseptic technic and surroundings. It should not be attempted by a novice.

As was said, children under fifteen years of age do not require operative treatment of fractures as a rule.

The Committee on Fractures of the American Surgical Association collected 1745 cases of fractures, the end-results of which were ascertained and the patients examined. Of these, 1358 cases were non-operative and 387 were operative cases; 258 cases of simple fractures and 129 cases of compound fracture were subjected to operation, a little over 25 per cent.

I find that of every 100 major fractures of long bones treated in St. Luke's Hospital we operate upon about 37 per cent.

The Committee of the American Surgical Association found that the anatomical recoveries were better under operation, but that the percentage of functional recoveries were higher in the non-operated cases. In my own cases the functional and anatomical recoveries were higher in the operated cases.

There are certain regions in which fractures are particularly difficult to treat successfully without operation.

A. *In the Upper Extremity.*—(1) Fractures about the anatomical neck of the humerus. These fractures, as a rule, require an open operation for proper adjustment. Good functional results may be obtained without good anatomical adjustment, however.

2. Fractures about the condyles of the humerus are also trying ones to treat. Since Jones, of Liverpool, has taught us the value of fixation of the forearm in extreme flexion and the very general applicability of this method for most of the fractures of the lower end of the humerus, these fractures may be regarded with less apprehension than they formerly were.

3. Fracture of the bones of the forearm anywhere below the tuberosity of the radius to the middle of the lower third of the bones are exceedingly difficult ones to adjust. Fractures in this region in many cases are absolutely irreducible without an open operation.

B. *Lower Extremity.*—(1) Fractures of the neck of the femur within the capsular ligament. Royal Whitman gave us the key to this treatment when he showed the importance of abduction in treating these cases. Dr. John B. Murphy contended that it is absolutely necessary to have the distal and proximal fragments in apposition at their fragmented surfaces in order that the osteogenesis may extend from the shaft fragment to the head fragment. He thought the head fragment had no osteogenetic qualities at all and would atrophy if not so apposed. Therefore he recommended an open operation and nailing the fragments together. In practice a Nathan Smith anterior wire splint or perhaps, better still, a Hodgen wire apparatus to support the extremity while it is swung outward in abduction by proper placing of the overhead beam from which the extremity is swung, has proved especially efficient and agreeable to the patient.

2. Fractures of the upper third of the femur. These are always very difficult fractures to treat. Fractures in this region especially lend themselves to the open method of treatment. Direct fixation by means of a plate seems much the best way to meet the ever-present tendency to elevation and external rotation of the upper fragment. Besides, this region of the bone is much nearer the surface than those lower down, so the wound required will not be so deep, nor otherwise as extensive, as that which is required lower down.

3. Fractures of the lower third (supercondylar fractures), with posterior displacement of the distal fragment into the upper popliteal space, sometimes prove very intractable fractures to reduce. If one fails to reduce the fracture under general anesthesia by flexion and manipulation an open operation should be done at once, for the pressure of the distal fragment on the vessels is liable to result in thrombosis and possible loss of the leg. For this fracture Jones, of Liverpool, especially recommends the Thomas extension splint.

4. Fractures of the tibia below the level of the tuberosity if the fractures are spiral or very oblique are exceedingly difficult to retain in position if reduced. Reduction sometimes is practically impossible without an open operation. This is true also, but in a lesser degree, of fractures of both bones of the leg. This region, on account of the prominence of the tibia, is especially liable to be observed by the patient and his friends. A lack of proper apposition, with a local projection of bone and angulation, and the resulting distortion, are very objectionable. Hence open operations should be employed when careful attempts under anesthesia to reduce and hold the fragments have failed.

5. Pott's fracture, viz., fracture of the fibula in the lower third with a fracture at the lower part of the internal malleolus, or tearing away of the internal lateral ligaments, and always a luxation of the ankle-joint, is also a difficult fracture to treat. The important feature of this fracture is the proper reduction of the dislocation. When the lower end of the proximal fragment gets behind or between the tendons nothing short of direct vision will assure proper reduction. This can only be accomplished by an open operation.

The up-to-date treatment of fracture of the long bones therefore resolves itself into the two general methods.

1. The conservative, non-operative.
2. The open or operative method.

In this country the non-operative method still has by far the largest number of adherents.

The study of the reports of a large number of cases and persistent inquiry indicates that though numerically in the minority the surgeons who especially favor operative treatment of fractures are those who have a very large clientèle of fracture cases and who have special opportunities and facilities for noting and observing the end-results of fractures. Fractures of the femur, concerning which the statistics and reports are especially full and accurate, are those particularly recommended for the open method of treatment.

It is obvious that the treatment of fractures still requires a great deal of study.

I would urge the simplification of methods and the standardizing of results.

The mechanical devices for the treatment of fractures are entirely too many and too complex. The simpler the method usually the better it is. For this reason careful reduction under general anesthesia and the application of a plaster-of-Paris splint appeals to me. The fragments should be kept in place by strong mechanical unvarying traction (as by a Lemon or Lambotte or Hawley traction apparatus) while the plaster splint is applied.

Compound Fractures.—In civil practice a compound fracture is always not only a solution of the continuity of a bone, but also a lacerated wound of the soft tissues in continuity from the periosteum to and including the skin.

Violence necessary to produce a compound fracture of the bone of an extremity must be very great; hence the traumatism is extensive. Not infrequently the bone is comminuted and the laceration of the soft tissue very severe.

Compound fractures are practically always infected wounds.

The management of these injuries must include the treatment of the fractured bone and the treatment of a more or less extensive infected lacerated wound of the soft tissues of the same area.

An examination of 2089 fractures admitted into St. Luke's Hospital shows that 800 of these fractures were compound. In regions in which large manufacturing establishments are located, and also where railroads are many and active, the relative frequence of compound fractures to all fractures is therefore 1 to 2.6, or 38 per cent. of the fractures.

The management of compound fractures of the extremities must resolve itself into two general consideration, namely: (1) the treatment of the general condition of the patient brought about by the injury and (2) the treatment of the injury itself.

A patient's reaction to these severe traumatisms depends upon many individual peculiarities, upon his environment and upon the circumstances of the injury. Individual resistances to psychic shock, to "nociassociation," to loss of blood, must all enter into consideration. The horrors of a severe railroad or factory wreck and the conditions of the *locale* of the accident have also their effect. The treatment must be adapted to the circumstances of each case, not the case adapted to any set method of procedure. This I consider a most important matter and I try to emphasize it on all occasions.

First Aid.—The intelligence and skill of a practitioner in many instances will be taxed to the utmost to meet the necessities of first-aid treatment of compound fractures. One cannot too much emphasize the importance of the proper initial treatment of these injuries. The fate of the limb and perhaps the life of the patient depend on the manner of the first aid.

1. The general condition of the patient must be gauged as accurately and as rapidly as possible. Stimulants may be necessary and should be used (alcohol is not a stimulant and should not be given). An analgesic should be given; as a rule, morphin, in full dose, combined with a small dose of atropin and given hypodermically, I think, is the best. Hemorrhage should be controlled. If practicable to avoid it a tourniquet of any kind should not be used to control hemorrhage in these cases. If nothing else avails and a tourniquet must be used it should be applied at some distance away from the seat of fracture. In cases of compound fractures of the bones of the legs, for instance, the tourniquet should be applied to the lower third of the thigh, or if of the bones of the forearm, to the lower third of the arm. An elastic constrictor is best and much safer.

Hemorrhage may, as a rule, be controlled and at the same time another indication, namely, protecting the wound, may be carried out, by packing the open wound with sterile gauze or any sterile fabric, placing thick compresses of sterile cotton-wool or any other clean material over the wound and bandaging it firmly in place, from the extremity, over the wound, and to at least 12 cm. above the fracture. Great care must be used to prevent any further soiling of the wound. No effort should be made to "set the bones," and in no case should a projecting end or fragment of bone be allowed to recede under the skin unless means are at hand for making adjustment and proper fixation of the bones and limb, and *unless the projecting bone and the edges of the external wound have been carefully cleansed and disinfected beforehand.* Death has often resulted from the infection occasioned by unnecessary manipulation of a wound without previous sterilization of the hands. Never should a finger be thrust into any wound unless the finger and the wound have been previously cleansed and sterilized.

Careful fixation in the position assumed by the injured limb should be employed unless it is clear that the ends of the fragments are where they will surely do more damage unless their position is changed. The patient should then be transported where he may receive proper permanent dressing and such treatment as his case will require.

The surgeon should try to determine at the very beginning of his responsible management of every case of compound fracture the following points:

1. What will be the best treatment of this particular injury, considering (*a*) the individuality and the physical condition of the patient; (*b*) the environment of the patient; (*c*) the actual condition of the injured member.

2. What method of treatment or operation will most likely result in the shortest time of disability of the patient and give him afterward the best functional result?

Permanent Treatment.—1. SPECIAL CONSIDERATIONS.—*a. Individuality of the Patient.*—Before everything else I would place the consideration of the patient himself. That is to say, I would learn, if possible, not only the actual physical condition of the patient with regard to the tolerance of the trauma, its effects, and the extent and degree of the local injury, but also his habits, his temperamental peculiarities, and his general health and resistance. Obviously it would be highly improper to treat an exhausted patient, or a very old person, or a very young child, or a diseased and weak individual, as one would treat a vigorous adult in prime condition.

Thus, after assuring himself that hemorrhage has been thoroughly controlled and that the patient's suffering has been relieved as far as practicable, the surgeon should at once make a thorough physical examination of the patient. He should carefully note all organic lesions, indications of dycrasias, improper or delayed development or signs of marked senility. The blood-pressure should always be taken. The immediate subsequent procedures should be determined by this physical examination.

If the patient is in a condition of exhaustion from psychic shock, loss of blood or "noci-association," or if his blood-pressure is very low, all extensive and tedious manipulations and operations must be delayed. If he is very old a long operation with continued anesthesia will be dangerous. Also any method of treatment which will require long confinement to bed should be avoided. Bone repair in most dyscrasic individuals is very slow and always uncertain. Methods must be varied and adapted to meet the indications of the patient's condition.

b. Environment of the Patient.—The surroundings of the patient will have a very important bearing on the treatment to be employed. When at all practicable serious compound fracture cases should be treated in a first-class hospital. It is, as a rule, far better for the patient to endure the hardship of a one- or two-hour journey in order to reach a hospital than to be subjected to the discomforts and deprivations he would have if he were treated at his home, unless he were wealthy. A surgeon is sadly handicapped in trying to treat such patients outside of a well-equipped hospital.

c. The Actual Condition of the Injured Member.—As was said in the beginning a compound fracture is always a complicated injury of very grave severity and is practically always an infected wound. One must always bear this last fact in mind and treat the case with a full recognition of the importance of thorough cleansing and disinfection of the wound, and especially of thorough drainage.

General anesthesia is usually necessary for the proper examination, handling and dressing of a compound fracture of one of the principal long bones. This is particularly desirable, not so much for the relaxing effect as to obviate the dreadful pain of the examination and fixation. Compound fractures when not comminuted are much easier to reduce and to fix in place than simple fractures.

Tincture of iodine, for its rapid and very efficient action in disinfecting soiled skin and wounds, has great value in treating compound fractures. The remarkable results of Carrel and Dakin by the use of the Dakin chlorinated alkaline solution, diffuse through the injured tissues by means of deeply inserted radiating small rubber tubes, should induce civil surgeons to employ this method which has been so exceedingly useful in large infected wound in military surgery. It should be remembered that iodine is of little use over skin which is moist and sodden, as in such conditions it will not penetrate but will blister. The surface of the skin to which iodine is applied for disinfecting purposes should be dry. Therefore cleanse the skin of the limb about the wound with benzine, ether or turpentine, and alcohol, then dry carefully and paint it with tincture of iodine. Late experience has convinced me that the Carrell method of disinfecting and treating compound fractures is much better than the iodine method however.

Every compound fracture case will require some operative procedure. In rare instances measures for proper drainage only will be necessary, but in most instances much more will be required.

One must decide at the time of the first permanent dressing:

1. Can the limb be saved?
2. If saved, will the limb be left in a condition for practical use?
3. Will it be best for the patient to run the possible risk of his life, endure a period of long disability, and have probably a permanently disabled limb, or will it be best to amputate and thus practically assure his life and shorten the time of his disability by at least one-quarter?

1. *Conditions determining amputation* rather than attempts at *conservation*. (*a*) If the skin has been so crushed or lacerated it is evident that at least three-quarters of the periphery over the fracture will slough and the muscles beneath are badly lacerated or comminuted, amputation will be inevitable.

(*b*) If there has been a circular or annular destructive pressure on the whole periphery of the limb, at the site of fracture or very near it, amputation will be necessary.

(*c*) If in a case there should be a serious annular laceration of the skin and the subjacent muscles should be badly comminuted it will be best to amputate.

(*d*) If the injury has been produced by tremendous pressure, as by a car-wheel or heavy pillars of iron or steel, the limb may have the skin of its whole periphery, or nearly all of it, killed but not divided, but the muscles beneath will be torn across and the bone comminuted. Such injuries require amputation.

(*e*) If the main bloodvessels are torn across in the irregularly jagged way common in these injuries, amputation will be necessary. I do not think anastomoses or transplantation of bloodvessels will succeed in this class of injuries. The laceration of one of the chief vessels when there are two in an extremity does not necessitate amputation. The large nerve trunks will stand much more injury than bloodvessels and may successfully be sutured, unless a long segment of the nerve has been destroyed.

(*f*) If the bone or bones are comminuted so that the fragments are loose and deprived of periosteum, requiring the loss of as much as 6 cm. ($2\frac{1}{2}$ inches) of the shaft, this together with the lacerations of muscles and skin always present in such cases will require amputation.

2. *Probable Final Condition of the Limb.*—This is a very important matter and might profitably be considered with the third condition, namely, the best thing for the individual patient. Undoubtedly limbs may be saved which would be quite useless and sometimes be positively in the way afterward. Again for some persons even a useless limb might be considered best if it could be left in a painless condition. A man who has to earn his living by activity and manual labor should be placed in a different category from a man whose livelihood depends on sedentary work requiring very little or no activity. Also for some persons the long confinement and disability resulting from the treatment of a serious compound fracture might be so irksome and, indeed, so disastrous, that they might prefer an amputation, and this would be best.

With regard to the danger to life there is no question that conservation is much more hazardous. Analysis shows that in 8.8 per cent. of the cases of compound fractures treated conservatively, the patients died. The average mortality after single major amputation is but 4.54 per cent. The average disability from compound fractures of the femur and both bones of the leg is thirteen months. That of amputation is not quite five months. Of course, this means, in the amputated case, that the patient may get about, and through the use of an artifical limb may return to a life of comparative activity and much usefulness, though rarely will he be able to return to his former occupation if it were a laborious one.

Having decided to attempt conservative treatment of the extremity, the first consideration should be to cleanse the wound and surrounding skin. Disinfection (sterilization) of skin and wound should be done thoroughly, especially the ends of the fragments if one or more has penetrated through the skin, by the use of Dakin's fluid. Some extension apparatus, such as the Lemon or Lambotte extension bar or Hawley table, is very useful in these cases. Reduction is usually not difficult on account of the fact that one may see or directly feel the ends of the fragments and guide them by forceps or some kind of lever, and that the muscles are usually so badly lacerated that they do not offer the resistance which is nearly always present in cases of simple fractures.

The fingers should be kept out of the wound as much as possible. I think there can be no doubt that infection is most liable to occur from finger manipulation in the wounds. By a little practice and experience one will learn to perform all the necessary manipulations with the interposition of instruments.

Frequently the wound made by the injury, by a little extension or direction, may be used as a way of approach to the bone. The muscles usually are so much lacerated that an incision of the skin and fascia only is necessary. In short the injury has frequently prepared a way to the bone and if any further incision is necessary it may be so made as to assist in another cardinal object, namely, drainage. One objection to the open method of treating fractures of the long bones of the extremities, that is, the necessary wound, has in compound fractures been removed by the traumatic opening of the tissues.

Direct fixation of the fragments is nearly always best. A rigid splint or plate applied directly to the bone is better than wiring the fragments. In selected cases a nail or nails may be used. I cannot understand the objections and warnings of some otherwise very up-to-date and experienced surgeons against the use of plates in compound fracture cases. My experience and conviction have always been that these are the very cases which demand plates. No valid objection can be offered to sterile fixation instruments unless they in some way harm the fragments. If a proper plate is used in the proper manner it does not injure the bone.

Even if the wound cannot be thoroughly sterilized (and it is exceedingly difficult to do this), suppuration and the evils of infection are diminished locally by a proper metallic plate. Researches at Johns Hopkins Hospital over twenty years ago prove the inhibiting influence of many metals on bacterial growth. Iron and steel are not thus active, as they oxidize too readily, but silver, copper and nickel and their alloys are active inhibitors. Since 1886 I have used a plate of Wessel silver, and I have used Wessel silver pegs for many years to fasten this plate to the fragments. I am sure this plate has always seemed to exercise a beneficent effect in compound fractures even with active suppuration present. Besides, fixation relieves pain and further injury which might be caused by the excursions of the ends of the ragged fragments.

After fixing the ends of the fragments one must decide about suturing the lacerated soft tissues. As was said before, bloodvessels are injured in such a way, in compound fractures, that not only are long stretches absolutely destroyed, but the vasa vasorum are thrombosed for some distance on either side of the evidently destroyed area. The vessel walls will not bear tension or constriction. I think, therefore, that vascular anastomoses and implantations cannot be used. This is all the more true because these cases are always infected more or less, and vascular anastomoses do not succeed except in sterile fields. Arteries and large veins, therefore, should be ligated and not sutured. Divided nerve-trunks may be successfully sutured in these cases, and this should be done when necessary. Tendons and muscles may also be sutured, but not when they would seriously impede or block proper drainage. The lacerated fascia and skin should be pared along the margin of the original wound and then be closed with interrupted sutures, sufficiently close to prevent gaping of the wound, but not so as to interfere with free drainage. *Drainage is all-important.*

There will have been very considerable hemorrhage. In very painful lacerated wounds the muscular coats of the local arteries are usually in a condition of almost tetanic spasm. Relief of the pain and complete rest of the limb will be followed by relaxation of the arteries; the result will be that small vessels not perceived during the operation will bleed after the wound is closed. Considerable oozing will always occur. In addition to the oozing blood the opened lymph spaces will pour out quantities of serum. All this fluid should be released and drained out of the wound. Unless this is done, disaster will almost surely occur. The reasons for this are so well known it is not necessary to go further into this phase of the subject.

A very important point with regard to drainage is that it should always be done in such a way and the drains so placed as to avoid all tension and harmful pressure in the wound. This is particularly important when the skin has been torn from the fascia and turned back as a flap or raised up by a large effusion of blood. Most of the blood supply has been cut off from the skin in such cases, and any pressure or much tension on the skin will cause a slough. Multiple incisions should be made through the skin and drainage by canalization (without the use of any drain material) should be employed. The incision should be so placed as to assist in relieving tension.

Thus the bone having been fixed, the lacerated soft tissues sutured, the wound closed and proper drainage provided, a mass dressing of dry, sterile, absorbent material should be applied with fairly firm pressure, and over all a gypsum splint with strips of flexible wood or light metallic strips worked into it should be molded and so placed as to give support and some elasticity to the dressing. If all goes well the dressing may remain on for three weeks, then be removed and a similar one reapplied. Usually all drainage tubes and gauze packs may be removed and left out at this first dressing. Also, it is my custom at this dressing to remove the pegs which hold the plate unless it be a fracture of the femur. If the wound has not closed over it the plate may also be removed. If the plate is well enclosed and buried by union of the flaps no effort should be made to remove it. As was said before the plate does not cause any irritation if allowed to remain; on the contrary, it seems to inhibit bacterial growth and hastens union of the wound.

2. As to Results.—One must always try to determine at the onset what method of treatment—(that is whether operative or not) is applicable in each individual case. The indications for amputations have already been given. The point to decide therefore, is whether it will be best to use direct fixation to the fragments or not. If direct fixation shall be employed which method or material shall be used?

The following 51 cases of compound fractures were treated in St. Luke's Hospital, the cases which could be traced and the final results definitely determined. They represent the following classes of compound fractures:

Femur	8 cases
Tibia and fibula	15 "
Tibia alone	10 "
Patella	2 "
Metatarsal bones	2 "
Humerus	4 "
Radius and ulna	7 "
Radius alone	1 "
Ulna alone	1 "
Humerus, radius and ulna	1 "
Total	51 "

Direct fixation of the fragments was made in 35 cases, of which 28 were plated and 7 wired. In 13 cases external fixation only was used; 3 patients were moribund when admitted and died within a few hours after admission. (No special treatment and not enumerated further.)

The cases in which plating was done were the following:

Femur	7 cases
Tibia and fibula	12 "
Tibia	5 "
Humerus	4 "
Total	28 "

The cases in which wiring was done were the following:

Tibia and fibula	2 cases
Radius and ulna	3 "
Humerus, radius and ulna	1 "
Patella	1 "
Total	7 "

The external fixation apparatus was practically the same in all the cases, namely, a reinforced gypsum splint carefully molded over a large masse dressing of sterile gauze and cotton-wool. The average length in days of confinement in bed in the various injuries was:

Forearm cases	6 days
Humerus cases	11 "
Leg cases	28 "
Femur cases	38 "

The average time in days spent in the hospital in the various injuries was:

Forearm cases	23 days
Humerus cases	48 "
Leg cases	53 "
Femur cases	69 "

The average length of time the patient was away from work, that is, until he returned to his occupation, was six months in leg fractures and thirteen months in fractures of the femur. For fractures of the upper extremity the time of disability has not yet been thoroughly worked out, but it appears to be about four months. All except three of the patients who had direct fixation were operated on within forty-eight hours. Two cases of compound fracture of both bones of the leg were plated on the fifteenth and eighteenth day after injury respectively, because the fragments could not be kept in place. The case of compound fracture of the humerus and both bones of the forearm was wired on the tenth day after injury, also because by other means the fragments could not be kept in apposition.

Though compound fractures should always be regarded as infected wounds it is noteworthy that it is recorded of these cases that suppuration occurred in only two of those which were fixed by direct application to the bones. One patient with compound fracture of the femur, plated, had a streptococcic infection, but made a good recovery; one patient with compound fracture of the humerus, radius and ulna, wired, had suppuration from a mixed infection, but also made a good recovery. Not one of the patients in the direct fixation cases died.

Prognosis.—It will be well for a surgeon always to be very cautious in predicting the result in any case of fracture of a human bone.

As was noted in the foregoing pages, many conditions, some of them very difficult to determine, may serve to modify or to prevent the expected average result of any given fracture.

The following statistics taken from the British and American Fracture Committees reports indicate the average result of fractures of the long bones:

NON-OPERATIVE.

	British.		American.	
	Good, Per cent.	Moderate, Per cent.	Good, Per cent.	Moderate, Per cent.
Humerus shaft	64.5	21.9	84.0	10.0
Radius and ulna shaft	55.2	31.5	90.0	4.0
Whole shaft	75.9	14.8	67.0	17.0
Tibia and fibula shafts	70.0	20.0	46.0	17.0

OPERATIVE.

Humerus shaft	83.3	16.6	13.0	62.0
Radius and ulna shaft	75.0	25.0	71.0	25.0
Whole shaft	63.0	28.0	66.0	23.0
Tibia and fibula shafts	68.0	22.7	13.0	4.0

The average period of disability (that is the time lost from work) in simple fractures is as follows:

For fracture of the shaft of the humerus	14.00 weeks
For fracture at the head and neck of the humerus	11.50 "
For fracture at the condyles of the humerus	9.00 "
For fracture of the shaft of both bones of the forearm	10.80 "
For fracture of the femur, all sites	7.37 months
For fracture of the leg, all sites	4.75 "

Note.—This determination must still be held as not quite conclusive on account of the comparatively few clear reports on this point.

The average period of disability for compound fractures:

For fractures of the femur	13 months
For fractures of the leg	6 "
For fractures of the upper extremity	4 "

These figures show that the result of treatment of the majority of fractures of the long bones is good; this refers to the functional result. Skiagrams show, however, that the anatomical results by the closed method are in about 90 per cent. of cases only moderate.

If one is to judge results, however, he should take functional results as his standard.

Unfortunately laymen are not convinced of this. So many opportunities are given them to obtain skiagrams that they not infrequently obtain an *x*-ray picture of their fractured bone, especially if they are not quite satisfied with the result of the treatment.

To forestall this and to protect himself as well as to obtain data for a positive diagnosis, a surgeon should always insist upon having a skiagram made and direct the patient to a first-class roentgenologist to take the picture.

The Workmen's Compensation Laws, now so general in the United States, will undoubtedly operate toward the better record, better study and better treatment of fractures. This will lead to the establishment of the average period of disability of fractures in the several regions of the extremities. Standard treatment and standard results will unquestionably follow.

The Fracture Committee of the American Surgical Association ends its report with the following recommendations, which I heartily endorse:

"Neither the non-operative nor the operative method is to be recommended exclusively. Each has its indication and should be employed when required. Generally speaking the age period under fifteen years is the period in which non-operative methods are especially effectual. In the other age periods up to sixty years, operative methods may with confidence be employed when non-operative treatment has proved ineffectual in reducing or controlling the fragments in proper position. The operation should not be delayed longer than one week after the injury.

"The open method when adopted should be employed early. It may be used at any age period, except in senile cases, whenever a skiagram shows a deformity or a position of the fragments which obviously cannot be reduced or when proper efforts at reduction and retention have proved unavailing.

"Some form of rigid plate applied directly to the bone or an Albee 'inlay' seems to be the best fixation method in operative cases.

"Open operations for simple fractures should be undertaken only by experienced surgeons who are thoroughly equipped by training and who have proper instruments and apparatus to meet all the possible indications of the operation."

FRACTURES.

By WILLIAM LAWRENCE ESTES, Jr., M.D.

FRACTURES OF THE HYOID BONE.

Fracture of the hyoid bone can be rated as among the rarest of all fractures. Since it is situated behind and beneath the chin, opportunity for injury is slight.

Etiology.—Gibbs's statistics are widely quoted: Of 13 cases collected, 7 followed strangulation, 3 a blow or fall, and 3 were due to muscular action. The usual causes are strangulation in criminal or accidental hanging, a blow upon the neck, or a fall in which the neck is struck. Muscular action, apparently, is not often held responsible, though Ashe,[1] in a recent report of a fracture of the left cornu of the hyoid following sudden extension of the head, holds muscular action to be more frequently a factor than is at present supposed.

Pathology.—The body of the hyoid may be broken, or the greater cornu split off at or near its juncture with the body. There may be great displacement of the fragments and the pharynx may be punctured. Edema of the larynx may occur at any time. Fractures of the body are due to direct injury; fractures of the cornu either to muscular action or direct injury. Fractures of the laryngeal and tracheal cartilages may occur in conjunction with hyoid fracture.

Diagnosis.—*Symptoms.*—1. Sharp pain over the hyoid, worse on moving the jaw, tongue or head.

2. Great difficulty and pain in swallowing, with choking and coughing.

3. Aphonia—sometimes mere hoarseness.

4. Dyspnea.

5. If the mucous membrane has been perforated, there will be hemorrhage from the pharynx, or bloody sputum.

Signs.—1. Swelling, tenderness and ecchymosis in the region of the hyoid or over the affected cornu.

2. Crepitus and abnormal motion.

3. The margin of a displaced fragment may be palpated.

In doubtful cases, a carefully taken roentgenograph—lateral view and preferably stereoscopic—will be of service. There are certain cases in which disability is very slight and in which intermittent hoarseness or speechlessness, local pain and tenderness are alone observed.

Laryngoscopic examination is useful in determining extent of secondary injuries in some cases.

[1] Jour. Am. Med. Assn., 1916, lxvi, 1618.

Treatment.—Reduction is readily accomplished when necessary by direct pressure with a finger in the pharynx or mouth, and external manipulation, but is very difficult to maintain. The head and neck are best immobilized in extension by sand-bags, or a high, stiff collar, or fixation bandage. With extensive injury, and especially when the pharyngeal mucous membrane is lacerated, the patient should not talk, and rectal feeding will be necessary for the first five days. Gradually liquids may be administered—by stomach tube if necessary. About four weeks are required for recovery.

Tracheotomy instruments should be kept constantly at hand as respiration may rapidly become so difficult from laryngeal edema that operative interference will be necessary to save life.

Fractures with transitory symptoms only, or as a result of muscular action, will require very little if any treatment.

FRACTURES OF THE STERNUM.

Occurrence.—Fractures of the sternum are rare. Bruns observed 17 cases in 8560 fractures, or 0.2 per cent.; Chudowsky, 6 in 2366 fractures, or 0.25 per cent.; Plageman, 5 in 1293 fractures or 0.38 per cent. (Roberts).[1] In our series of 2700, 8 of the sternum have been recorded (0.3 per cent.).

Etiology.—Fracture of the sternum may follow:

1. Direct violence—an extensive crush or comminution of the thorax. Moderate trauma to the sternum is not likely to cause a fracture on account of the elasticity of the ribs.

2. Indirect violence—a fall or blow on the head, causing sharp flexion of the cervical spine and forcing the chin down suddenly against the sternum; this has resulted from being thrown out of a motor-car (Mayet),[2] or being squeezed between a bridge floor and the top of a freight car.[3]

3. Great muscular action, as in heavy lifting or parturition—a very rare mode of injury.

4. Gunshot wound.

Pathology.—The fracture is almost invariably transverse—usually at the juncture of the manubrium and gladiolus. Displacement is not uncommon; the upper fragment is displaced backward into the mediastinum and the lower fragment rides upward over it (Fig. 1). The cervical or dorsal vertebræ may be fractured simultaneously, or the traumatic spondylitis of Kuemmel may follow.[4]

In massive crush of the chest, in which the sternum is involved, the heart, lungs, aorta or pulmonary vessels can scarcely escape without puncture or laceration. Hemorrhage into the mediastinum is inevitable: as a late result suppuration may develop. An open fracture except from

[1] Roberts and Kelly: Fractures, 1916.
[2] Paris Chir., 1912, iv, 871.
[3] Reimann: Deutsch. med. Wehnschr., 1918, xxxviii, 558.
[4] Eisendrath: Keen's Surgery.

a gunshot wound is very rare. In these cases the damage to the subjacent organs usually quite overshadows the importance of the fracture.

Diagnosis.—Without complication or much displacement, a fracture of the sternum is not unlikely to be confused with a simple contusion. Accurate and careful palpation affords the most reliable method of differentiation; the roentgenogram is very uncertain *unless stereoscopic plates are obtained.* Very great shock may follow fracture but is not an invariable accompaniment. An associated spinal lesion may overshadow the injury to the sternum itself.

Diagnosis of fracture of the sternum should be based upon:

1. *Symptoms.*—(*a*) Pain in chest over and above the sternum. (*b*) Dyspnea—painful, difficult and labored breathing.

2. *Signs.*—(*a*) Local swelling and tenderness. (*b*) Deformity: (1) A step-like deformity at fracture site from the projecting lower and depressed upper fragments. (2) Angular deformity—swelling about the lower projecting fragment hides the position of the upper fragment, and an angular prominence is alone observed. (*c*) The lower fragment margin may be felt projecting above the upper fragment. Crepitus and abnormal mobility may be detected during respiration or coughing but should not be persistently sought, particularly when displacement exists, as an intrathoracic lesion may be fatally intensified by unwise pressure or manipulation. (*d*) Hemoptysis and cyanosis, with irregular or rapid pulse if there is any injury to the thoracic viscera.

3. Stereoscopic roentgenograms.

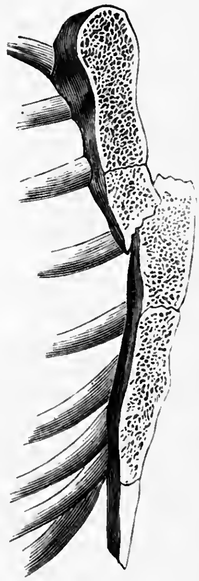


Fig. 1. — Transverse fracture of the body of the sternum. (Stimson.)

Prognosis.—The uncomplicated cases recover; the complicated cases usually die.

Treatment.—In very severe injuries, with alarming dyspnea or cyanosis, attempts at immediate reduction should be made, which should include open operation if simple reduction does not suffice. Cases in shock, and in which no severe lesion of the heart, bloodvessels or lungs is apparent, may be given supportive treatment until their condition justifies reduction.

Reduction is accomplished by suspension and extension of the head of the patient over the end of a table, and slow abduction of both arms with outward rotation; extension of the dorsal and cervical spine may be added. The displacement may tend to recur. Even though reduction is incomplete—if no pressure symptoms remain or supervene—no further procedure is necessary. If discomfort, disability, or marked deformity persists, open operation and direct reduction is indicated; even in old cases, reduction by open operation is not difficult. Spontaneous reduction has been known to occur.

The patient should be kept supine for three weeks. Circular thoracic adhesive straps should be applied and worn during this period. Then gentle movement and exercise should be gradually permitted. After six weeks the sternum should be well healed and all strapping may be removed. Scudder,[1] however, recommends that the Taylor brace be worn for from three weeks to two months after injury.

FRACTURES OF THE RIBS.

Occurrence.—Fracture of the ribs is a very common injury, comprising 9.5 per cent. (Bruns) or 8.15 per cent. (Chudowsky) of all fractures (Roberts).[2]

Children's ribs are very seldom fractured because of their great elasticity and because opportunity of severe injury is less likely in the young. Young and middle-aged adults, on account of their activity and greater exposure to violence, are the usual victims.

Fractures of the first and second, tenth, eleventh and twelfth ribs are rare—their size and situation making them less accessible to injury.

Ribs, as a rule, are fractured at or near the costal cartilage, or at the anterior or posterior axillary line.

Etiology.—It may be difficult to determine the type of violence in any given case. Fracture may result from:

1. Direct violence—the most common form of injury—such as a blow, a kick, or a squeeze or crush of the thorax.
2. Indirect violence—compression of the chest may or may not result in a fracture at the point of impact but frequently causes a snapping or splitting of the ribs at a point of least resistance—opposite to, or some distance from, the area of direct injury.
3. Muscular action—as in wrestling or heavy lifting.

Pathology.—The fracture may be partial or complete; even when complete, there is seldom much displacement. In partial or incomplete fracture, a single surface of the rib may alone be involved while the periosteum on the other side, remains intact. A complete fracture is usually transverse with irregular jagged margins. With much displacement, there is depression or elevation of the fracture ends; when several ribs are involved, there may be overlapping. An open fracture is rare. Multiple fractures of the same rib or bilateral fractures may occur.

When the lung is penetrated by a rib, air may gain entrance into the pleural cavity, producing a pneumothorax, or may pass along the rib into the subcutaneous tissue, producing subcutaneous emphysema if the lung when punctured remains adherent (Fig. 2). The lung may be lacerated by a palpably demonstrable displaced fragment or, if at the time of accident, the rib is driven into the lung, its elasticity causes it to rebound, no permanent displacement is detectable and is

[1] Fractures, 8th Edition.
[2] Roberts and Kelly: Fractures, 1916.

in fact very slight; subcutaneous emphysema, however, results and may be the only positive indication of fracture or lung injury.

When two or more ribs are fractured, the internal mammary artery or an intercostal vessel, or the lung tissue itself may be lacerated; hemothorax follows. A pleural friction rub or signs of consolidation may be noted as a result of direct injury to the pleura or lung, or from hematogenous infection. With massive injury or crush of many ribs may also occur fracture of the sternum or scapula, a pericardial or cardiac lesion, or rupture of the diaphragm or an abdominal viscus.

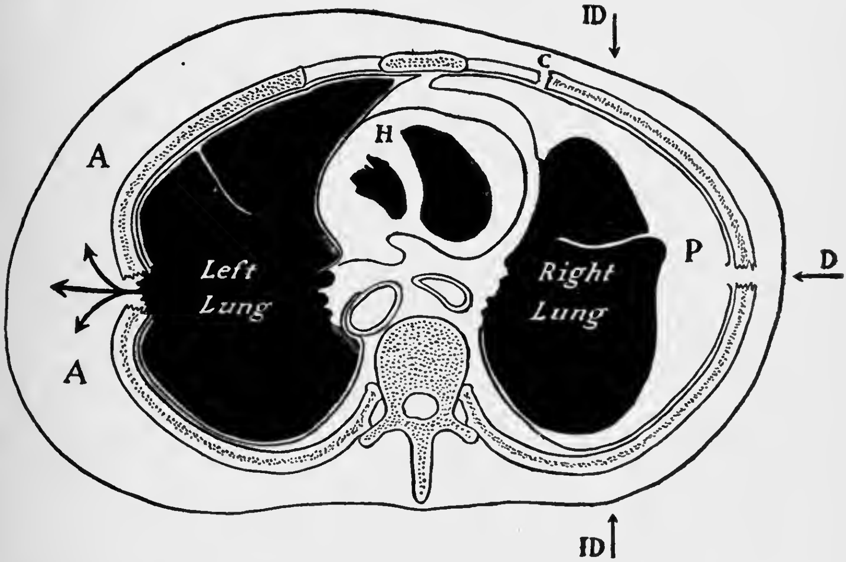


Fig. 2.—Cross-section of thorax (diagrammatic) to show mode of production of pneumothorax or hemothorax and of subcutaneous emphysema as a result of fractures of the ribs. *ID*, The arrow accompanying these letters shows the mode of action of indirect force in producing fracture of the ribs; *D*, mode of action of direct force in producing fracture of the ribs; *P*, pneumothorax as a result of fracture of the rib and laceration of the pleura on right side; *A*, extensive subcutaneous emphysema as a result of puncture of a lung by the sharp ends of a fractured rib fragment; the triple arrow shows the mode of egress of the air from the punctured lung into the subcutaneous tissues; *H*, cross-section of heart; *C*, fracture at costo-chondral junction without displacement. (After Eisendrath.)

Fractures of the ribs usually fall into one of the following groups:

1. A partial or complete fracture of the ribs—no displacement—no lung or pleural injury.

2. A fracture with no demonstrable displacement but with subcutaneous emphysema and at times a slight pleurisy.

3. Fracture of two or more ribs—moderate deformity or displacement accompanied by subcutaneous emphysema, with or without pneumothorax, hemothorax, pleurisy or pneumonia.

4. A crush of the chest; fracture of many ribs; possibly of the scapula or of the sternum with intrathoracic or intra-abdominal,

visceral lesions; hemothorax and multiple lung lacerations, usually a rapidly fatal condition.

Diagnosis.—The diagnosis depends upon evidences of fracture and evidences of complications.

A. Evidences of Fracture.—*Symptoms.*—(*a*) Pain on inspiration at the point of fracture.

(*b*) Inability to breathe deeply without pain.

Signs.—(1) *Inspection.*—(*a*) Short shallow inspiration with expiratory grunt.

(*b*) The hand is held to the fracture site to relieve the pain of inspiration.

(*c*) Local swelling over the fracture, and prominence or depression if there is displacement of the fragments.

Careful inspection must be followed by very gentle palpation; sudden prodding is brutal. The flats of the fingers should be passed along the ribs and points of local tenderness investigated.

(2) *Palpation.*—(*a*) Exquisite tenderness at the fracture site.

(*b*) Crepitus and abnormal mobility are best elicited during cough; less often by direct pressure than by pressure on the rib at some distance from the suspected area; *i. e.*, by bimanual antero-posterior compression. Even if crepitus is not detected by this procedure, fracture should be suspected if pain at the site of injury is increased by it.

(*c*) With displacement, the fragment margins may be felt.

Local pain, swelling and tenderness are most constantly present; crepitus and abnormal mobility are very often absent. The roentgenogram is of interest in those cases where displacement and indication of lung injury are lacking and the diagnosis is doubtful.

B. Evidences of Complications.—1. The most common complication is injury to the pleura and lungs, indicated by hemoptysis and subcutaneous emphysema. Hemoptysis is seldom excessive. Subcutaneous emphysema may be confined to a very small localized area or may spread through the thorax, neck and head in an alarming fashion. It is readily recognized by the characteristic soft, crackling, spongy crepitus. Persistent or increasing dyspnea, with rising pulse-rate, following a fracture of the rib, should indicate the need of a careful examination of the thorax for complicating lesions—pneumonia, pleurisy, pneumothorax, etc. The physical signs differ in no way from the usual. Signs of pleural effusion, however, should be considered indicative of hemothorax until proved otherwise. Hemothorax may form very rapidly and may result fatally if not promptly relieved by aspiration or incision.

2. *Traumatic Asphyxia.*—This condition results rapidly following an accident. The dusky cyanosis is confined to the head, neck and upper chest and may be accompanied by subconjunctival hemorrhages.

Prognosis.—The prognosis is especially dependent upon the age of the patient and the extent of the injury to the viscera. In the aged a pleurisy or pneumonia may be of very grave consequence though, as a rule, these are of a mild type and readily resolve. The outlook in an uncomplicated case is excellent. The usual hemo- or pneumothorax is not fatal. With many ribs involved, and extensive pulmonary laceration or abdominal or diaphragmatic lesion, recovery is very doubtful. Union occurs with permanent thickening of the rib, as exact restitution and immobilization of the fragments is impossible.

Treatment.—No attempt at reduction is necessary except in cases with extreme displacement when, if pressure and manipulation are of no avail, direct incision with replacement and suture may be practised. Treatment should be directed toward diminishing the pain of respiration by restricting the movement of the chest wall. This may best be accomplished, after shaving the affected area, by the application of adhesive strips three inches in width from beyond the midline posteriorly to beyond the midline anteriorly.[1] The posterior end of the strip is firmly applied or held by an assistant; on full expiration, the strip is rapidly, and with firm but not too strong traction, applied to the affected side at right angles to the long axis of the body. The lowest strip is placed first, and each strip overlaps its predecessor by half its width. Four or five strips are usually required and should extend from at least four inches below the fracture to a point well above it. Marked relief will be afforded by this simple dressing. If any pain, cough or discomfort persists, the patient is kept propped up in bed, and a full dose of morphin (gr. $\frac{1}{4}$–$\frac{1}{2}$) is given. A cough mixture may be administered regularly, or the opiate repeated, until the pain from breathing subsides.

In an uncomplicated case it is best for the patient to remain quietly in bed for from four to seven days, or until movement of the chest is not painful. The strips may remain in place two or three weeks or may be changed whenever cleanliness demands. After three weeks, the adhesive plaster is removed and a cloth binder is used if any pain persists; otherwise no dressing is necessary.

Complications.—Complications must be met as they arise. Hemoptysis rarely requires treatment; it is seldom severe except in rapidly fatal cases. Morphin to control the pain and cough will suffice.

Subcutaneous Emphysema.—Except in rare cases, subcutaneous emphysema is of little consequence. When excessive or alarming, aseptic multiple punctures of the skin with consequent release of air may be imperative.

Hemothorax will require aspiration and reaspiration if the fluid reaccumulates. The severity of the hemorrhage is rarely sufficient to demand an incision and ligature of the bleeding vessel.

Treatment of pleurisy and pneumonia differ in no way from the usual routine medical treatment.

[1] These strips, if preferred, may extend completely around the thorax. In many cases pain and dyspnea stop at once when these strips are carried entirely around the thorax although application short of complete encircling fails to benefit the patient. In case of multiple fractures especially, should the strip surround the entire chest. Respiration will then be carried on without pain by means of the diaphragm (EDITOR.)

Following the fracture of a rib, there may persist for many months a girdle pain of intercostal type; this usually yields to heat, hydrotherapy, electrotherapy and massage. Most,[1] however, has reported a case in which operation was necessary to relieve the pain produced by the pressure on the intercostal nerve of a persistent callus of the tenth rib. On removal of the callus, the pain completely disappeared.

FRACTURES OF THE SCAPULA.

Occurrence.—Bruns has recorded 100 cases of fracture of the scapula in 8560 fractures, or 1.1 per cent.; Chudowsky, 20 cases in 2366, or 0.8 per cent.; Immelman, 63 in 4048 fractures, or 0.16 per cent.; Plageman, 13 in 1393, or 0.93 per cent. (Roberts).[2]

The most frequent lesion of the scapula is fracture of the acromion process. Fractures of the spine, of the coracoid process, of the neck, of the superior and inferior angles, and of the rim of the glenoid fossa, are comparatively rare. Except for the spine and the coracoid and acromion processes, the scapula is well protected by thick muscle pads which prevent moderate injury from producing fracture.

Fig. 3.—Separation of the epiphysis of the acromion process. Separation of the upper epiphysis of the humerus and separation of the epiphysis of the coracoid process.

Fracture of the Acromion Process.—**Etiology.**—1. Direct violence—a fall or blow on the shoulder.

2. Indirect violence—a fall on the outstretched hand or on the elbow with the arm abducted, a very common football injury.

Pathology.—The fracture is:

1. Transverse split or chip near the tip of the acromion with very little displacement—a sprain fracture.
2. Separation of the acromial epiphysis (Fig. 3).
3. In rare instances the base of the process may be fractured.

[1] Berlin. klin. Wchnschr., 1910, xlvii, 1702.
[2] Roberts and Kelly, Fractures, 1916.

Acromion fracture may occur with other fractures of the scapula; with fracture of the upper end of the humerus; or with fracture or dislocation of the outer end of the clavicle.

Diagnosis.—*Symptoms.*—1. Pain over the tip of the shoulder.

2. Inability to abduct the arm without pain.

Signs.—1. Slight swelling and contusion, and very decided tenderness over the acromion process, especially near its articulation with the clavicle.

2. Crepitus may occasionally be detected by direct pressure, or by upward pressure on the elbow.

Passive abduction is painful but crepitus may be more readily elicited with the arm abducted (Roberts). Unguarded attempts to distinguish crepitus are not a completely proper procedure, for malposition of the fragments may result therefrom. Usually there is no deformity and very little swelling. Local tenderness and inability to abduct the arm are the most constant indications. The shoulder, however, may seem flattened when the base of the acromion is fractured, or the acromion may be unduly prominent when epiphyseal separation has occurred. When crepitus is unobtainable, the roentgenogram will be necessary to determine positively the presence of fracture, and may bring to light at the same time, unsuspected associated lesions.

Prognosis.—Union is likely to produce some persistent callus but, even if deformity occurs, no permanent impairment of function should result from a simple acromion fracture. Union is frequently delayed and in some instances will be only fibrous. With concomitant injuries, the prognosis will depend upon their character and severity.

Treatment.—Reduction is seldom necessary as displacement is rare. Immobilization of the shoulder and arm by a modified Velpeau or shoulder-elbow-figure-of-eight bandage (Figs. 4 and 5), which lifts the elbow upward and presses firmly downward over the acromion, will suffice in all cases; even with displacement, the direct pressure of this procedure will tend to restore the fragments to proper position. Strips of adhesive plaster over the shoulder, however, may be used to hold the fragment in place. The bandage should be reinforced by adhesive or plaster-of-Paris swathes, for a simple bandage easily becomes disarranged and requires frequent readjustment. In three weeks, all dressings may be removed and massage and passive motion begun.

Fractures of the Scapula Other than Acromial.—**Etiology.**—A severe direct injury is, in general, necessary to fracture the body, spine or coracoid process of the scapula, though muscular action has been known to cause fracture of the lower angle of the body and of the coracoid process. The neck, or the rim of the glenoid fossa, may be fractured not only by direct but also by indirect violence—as a blow against the head of the humerus or a fall on an abducted elbow.

Pathology.—Fractures of the body are linear splits—either transverse or longitudinal, frequently multiple and divergent—appearing just below the glenoid cavity or in the lower and superior angles. Displacement of the fragments may occur from the contraction of the attached muscle fibers. Compound or open fractures are practically unknown, except as the result of a gunshot wound. Often, dislocation of the shoulder and fracture of the clavicle, acromion process, ribs or upper ends of the humerus are associated.

Fractures of the spine and coracoid are fissured, and involve the base or crest of the spine, and the epiphyseal rim of the coracoid.

Fracture of the rim of the glenoid cavity not infrequently occurs with dislocation or fracture of the upper end of the humerus.

Fracture of the neck may or may not include the base of the coracoid process. Often there is marked deformity from downward displacement of the external fragment with the humerus.

FIG. 4.—Shoulder-elbow-figure-of-eight bandage.

FIG. 5. — Shoulder-elbow-figure-of-eight bandage, reinforced by adhesive plaster.

Diagnosis.—The diagnosis, on account of the contusion and swelling of the soft tissues, may be difficult. Local tenderness alone may suggest the possibility of fracture. With moderate swelling, crepitus and abnormal mobility may be detected.

In dislocation of the head of the humerus, when reduction is attempted, crepitus and a tendency to recurrence of the dislocation, following reduction, indicate fracture of the glenoid rim.

In fracture of the neck the depression or flattening of the shoulder resembles a dislocation of the head of the humerus. Crepitus and abnormal mobility, however, may be elicited by upward pressure on the elbow.

The obvious presence of fracture elsewhere may overshadow the scapular lesion. For accurate and exact diagnosis a roentgenogram is indispensable.

Treatment.—Treatment, as in acromial fracture, should be directed toward immobilization of the arm and forearm, with support to the elbow by means of a modified Velpeau or figure-of-eight-shoulder-elbow bandage, the folds of which may be sewed or basted together or reinforced by adhesive plaster or gypsum. In fractures of the neck of the scapula, reduction by lifting the elbow directly upward to elevate the displaced fragment must precede; the position is maintained by an assistant while the dressing is applied. The retentive dressing should be used for three weeks. Passive motion and massage should then be given gradually.

FRACTURES OF THE CLAVICLE.

Occurrence.—Fracture of the clavicle is very common and constitutes about 10 per cent. of all fractures. The fracture may occur in the inner, outer or middle third; fractures of the inner third are quite rare; fractures of the outer third are occasionally seen; those of the middle third are the most common.

Etiology.—Fractures of the clavicle are due to:

1. Direct violence—a fall or blow.
2. Indirect violence—by far the most common mode of injury—as a fall on the outstretched hand, elbow or shoulder or compression of the shoulders.
3. Muscular action—a sudden sharp contraction of the deltoid and pectoralis major muscles, as in lifting a heavy object or weight, or the rapid and violent contraction of the sternocleidomastoid muscle.
4. Gunshot or bullet wound.

Pathology.—Fractures of the inner third are usually transverse and, as a rule, show marked displacement of the inner fragment upward (Fig. 7) due to the tug of the sternocleidomastoid muscle; when the fracture is close to the sternum, however, there is a slight displacement, or upward angulation only.

Fractures of the middle third may be:

1. Greenstick or subperiosteal—these are fractures in children from indirect injury, with but slight upbending or no deformity until the callus produces a prominence ten to fourteen days after the accident.
2. Oblique or transverse—the displacement is usually marked; the sternocleidomastoid muscle pulls the inner fragment upward and backward and the weight of the extremity draws the outer fragment downward and inward so that overriding is present (Fig. 6). Occasionally a simple fissured fracture without displacement is observed.

Fractures of the outer third are usually transverse—occasionally oblique—and commonly show very little displacement because the fracture site lies within the coracoclavicular, coracoacromial, or the acromioclavicular ligaments. However, when the fracture is near

FIG. 6.—Fracture of the clavicle. Middle third displacement downward and forward of outer fragment.

FIG. 7.—Fracture of the inner third of the clavicle. Upward displacement of the medial fragment.

the juncture of the middle and outer third, marked displacement similar to that of a middle third fracture may be observed.

Fractures of the clavicle are seldom multiple, comminuted, or open except from gunshot injury.

Diagnosis.—The situation of the clavicle permits of ready inspection and palpation and renders diagnosis easy, though greenstick fractures in children may be overlooked, or attract little attention, until the callus appears and causes parental alarm. In general, a fractured clavicle may be recognized by the following:

Symptoms.—(*a*) Pain over the clavicle increased by any movement of the arm.

(*b*) Inability to raise the shoulder or abduct the arm. The forearm of the affected side is voluntarily supported by the hand of the sound side in order to immobilize and sustain the weight of the upper extremity and prevent further pain (Fig. 8).

FIG. 8.—Fracture of the clavicle. Weight of upper extremity of affected side instinctively supported by sound hand to relieve the pain of the downward drag upon the outer end of the clavicle.

Signs.—(*a*) Characteristic deformity—the shoulder is lower than that of the uninjured side and droops forward; the distance between the sternum and acromion process is shortened on the injured side.

(*b*) Swelling, and possibly ecchymosis, over the clavicle.

(*c*) Localized tenderness over the fracture site is very marked.

(*d*) Palpable loss of continuity of the bone. As the clavicle is so superficial, the margins of the fragments are readily detected and abnormal mobility and crepitus are easily elicited by direct pressure.

The roengenogram will be of importance in cases of doubtful diagnosis, especially in fractures of the inner and outer thirds, and in fracture following direct injury, where great swelling masks the shoulder area, accurate palpation is difficult, and multiple or concomitant fractures may be suspected.

Differentiation between dislocation of the ends of the clavicle and fracture of the inner and outer thirds should not be difficult when much displacement exists; the jagged fracture margins should be readily distinguished from the smooth clavicular terminations. The exact location of the lesion may be determined by measurement from the sternum, or the acromion process, and comparison with the sound side.

Prognosis.—Except in greenstick or subperiosteal fractures, or fractures without displacement, exact restitution of the fragments is rarely obtained and some deformity usually persists. Even with well-marked overlapping and shortening of the clavicle, no permanent impairment of function results. Non-union is exceedingly rare. The usual period of complete disability is about eight weeks. The development of post-traumatic pain in arm or forearm, as a result of the pressure of callus on the nerve trunks of the brachial plexus, is a very remote possibility in simple fracture but must be guarded against in open or gunshot fracture. When the subclavian or one of the larger vessels is injured, if early control of hemorrhage is not possible, the injury may prove fatal.

Treatment.—Subperiosteal and greenstick fractures, with no displacement, merely require a restraining bandage such as a modified Velpeau or shoulder-elbow-figure-of-eight. In greenstick fracture with deformity, reduction by direct pressure should precede application of the bandage.

Fig. 9.—Couteaux's method of treatment of fracture of the clavicle. First position.

For fractures with displacement, the treatment should be directed toward the reposition of the displaced external fragment. Reduction is not difficult but maintenance of accurate reduction is rarely possible.

Methods.—1. *Rest in Bed.*—The patient is placed on his back on a flat, firm bed with a pad between his shoulders so that the weight of the shoulder retracts the displaced outer fragment. Couteaux[1 2 3] has recently advocated a modification in which no pad between the shoulders is used; the patient lies supine on the edge of the bed in such a way as to allow the entire upper extremity of the affected side to hang over in abduction, unsupported (Fig. 9). In two to four hours[4]

[1] Rev. de Chir., 1909, xl, 570; Bull. Acad. de Méd. de Paris, 1914, 3d. S., lxxi, 645; Monde Méd., 1914, xxiv, 481.

[2] Bouchon: Jour. de Méd. et Chir. Prat., lxxxvi, 302.

[3] Quard: Soc. de Méd. Milfranc Bull., 1913, vii, 523.

[4] Couteaux recommends twenty-four hours. Experience has shown that the patient will rarely tolerate the unsupported position longer than four hours.

—sooner if the pain in, or swelling of, the extremity is severe—the forearm is flexed approximately to a right angle and a chair or stool is placed beneath the elbow which just barely sustains the weight of the extremity without upward lift or pressure, (Fig. 10). In this manner a gradual and excellent reduction is secured. The patient remains in bed for at least ten days or until union has begun. Then a retentive bandage, such as a modified Velpeau, is applied and the patient is allowed to get out of bed. At the end of three weeks all dressings may be removed and massage and passive motion begun. This method is applicable only in selected cases—in intelligent adults—since the acquiescence of the patient is indispensable to the success of the treatment. It has the advantage of obtaining more accurate reduction with less callus and permanent deformity than other methods; it is of particular value for girls and young women in whom deformity would prove a cosmetic calamity.

Fig. 10.—Couteaux's method. Second position.

2. *Sayre Dressing.*—This time-honored and time-tested method of maintaining reduction of the clavicle—consisting originally of the application of three large adhesive straps—has been most widely and generally used and has resulted in many modifications. The patient sits on a stool or straddles a chair. An assistant standing behind the patient grasps both shoulders firmly and retracts them; this lifts the outer fragment back into alignment with the inner. The first strip of adhesive plaster is then applied. A wide loop passes around the arm over a thin pad, care being taken to avoid constriction; with strong traction, the plaster is wound almost completely around the thorax beneath the opposite axilla (Figs. 11 to 13). This keeps the shoulder retracted and prevents it from falling forward. The second strip starts from the opposite shoulder posteriorly, passes back and downward under the elbow of the affected side and again anteriorly, and with traction, to the shoulder where it began (Figs. 12 and 13). This supports the weight of the upper extremity and assists in forcing the outer fragment up and back into position. The axilla and under surface of the

forearm should be carefully padded to prevent irritation of the skin by contact of the arm and forearm with the chest wall. The second

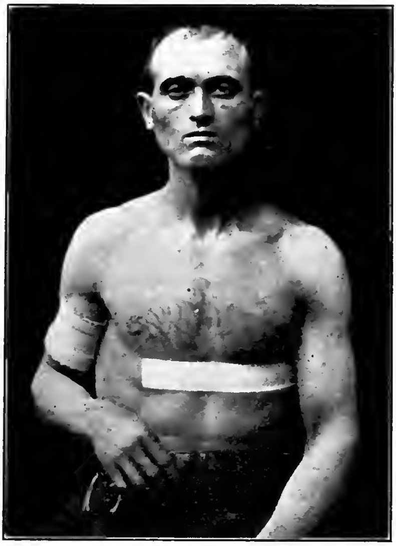


Fig. 11

Fig. 12

Figs. 11 and 12.—Modified Sayre dressing. Fracture of right clavicle—axillary pad omitted in anterior views to show dressing more clearly.

Fig. 13.—Fracture of the right clavicle. Modified Sayre dressing. Posterior view. Shoulder elevated and pulled backward. Folded towel seen in axilla for protection to skin. (Scudder.)

adhesive strip should also be split and padded at the elbow to avoid pressure upon the olecranon. The third strip starts over the fracture site, backward behind the shoulder and arm, and again anteriorly over the fracture site. This last strip is commonly omitted and in its place a modified Velpeau or shoulder-elbow-figure-of-eight bandage is used to supplement the strapping.

3. *Open Reduction.*—It is very seldom necessary to resort to an open operation. Multiple fractures, marked injury to the adjacent parts, and excessive displacement with an open fracture or an ununited fracture, are indications for operative interference. Fixation is best accomplished by an absorbable material such as kangaroo-tendon. Bone plates are seldom indicated. Roberts' drill method, in which a simple bone drill transfixes both fragments and is left *in situ*, has a limited but distinct field of usefulness. Prevention of pressure of callus upon large bloodvessels and nerves must take precedence over anatomical reduction as even marked deformity of the clavicle means little if any functional disturbance.

Firm union of a fractured clavicle should require three to four weeks. Passive motion and massage are then begun, and all dressings dispensed with, although a sling may be necessary until the normal position of the extremity can be tolerated.

The very rare cases of malunion with impaired function may be properly treated by an inlay bone graft—unless an underlying cause for non-union, such as syphilis, exists.

FRACTURES OF THE HUMERUS.

Fractures of the humerus may be divided into:

1. Fractures near the shoulder:[1]
   - (*a*) Fracture of the tuberosities.
   - (*b*) Fracture of the anatomical neck.
   - (*c*) Fracture through the tuberosities.
   - (*d*) Separation of the upper humeral epiphysis.
   - (*e*) Fracture of the surgical neck.
2. Fractures of the shaft:
   - (*a*) Upper third.
   - (*b*) Middle third.
   - (*c*) Lower third.
3. Fractures near the elbow:
   - (*a*) Supracondylar fracture.
   - (*b*) Separation of lower humeral epiphysis.
   - (*c*) T-fracture of the lower end of the humerus.
   - (*d*) Fracture of the internal condyle and epicondyle.
   - (*e*) Fracture of the external condyle and epicondyle.

[1] Linear fissured fractures of the head of the humerus are almost unknown but have been recorded, associated usually with dislocation of the shoulder, or anatomical neck and tuberosity fracture.

Fractures Near the Shoulder-joint.—Occurrence.—Plageman's statistics, quoted by Roberts, show 73 fractures of the upper end of the humerus divided into:

HUMERUS.

A. Fractures of the anatomical neck	4
B. Fractures of the greater tuberosity	30
C. Fractures through the tuberosities	10
D. Separation of the upper epiphysis	7
E. Fractures of the surgical neck	22

Hitzrot's tabulation concerns 393 cases which were divided as follows:

A. Fracture of the anatomical neck with dislocation of the head	4
B. Fracture of the greater tuberosity	11
C. Fracture through the tuberosities	101
D. Separation of the upper epiphysis	3
E. Fracture of the surgical neck	274

The ratio of occurrence of fracture through the tuberosities to fracture of the surgical neck is practically identical in both series. The glaring variation lies in fracture of the tuberosities.

Fracture of the Greater Tuberosity.—Occurrence.—Fracture of the greater tuberosity of the humerus is not uncommon. The variation in the statistics available may be explained by the fact that this fracture is frequently overlooked—lost among the "painful shoulder" cases in which fracture is not suspected and which do not receive surgical supervision.

Etiology.—This fracture may follow:

1. Direct violence—a fall or blow upon the shoulder.
2. Indirect violence—a fall on the abducted hand or elbow.
3. Muscular action—the external rotators of the arm, the supraspinatus, the infraspinatus and teres minor muscles are inserted in the greater tuberosity. Forcible outward rotation of the arm, especially with the arm fixed or restrained, may lead to a tearing off of the greater tuberosity—such as in heavy lifting.

Direct violence or muscular action, rather than indirect violence, is the usual etiological factor.

Pathology.—The fracture may be a splitting off of the entire tuberosity or the tearing away of a portion. It is sometimes associated with dislocation of the shoulder. Simple or solitary fracture may be an oblique fissure with no displacement, or the fragment may be displaced upward and backward beneath the deltoid muscle, or between the acromion process and the head of the humerus. When there is simultaneous dislocation of the humeral head, or fracture of the anatomical or surgical neck, the fragment is always displaced.

Diagnosis.—In any contusion of the shoulder area in which pain is excessive, or when localized tenderness exists with a "sprain or strain" of the shoulder, the possibility of fracture should be considered and a roentgenogram taken. The general practitioner should be warned also against regarding a vague injury or swelling about a joint as "arthritis or bursitis" until a roentgenogram has ruled out fracture. With concomitant dislocation or fracture of the upper end of the humerus, fracture of the tuberosity may be overlooked or unsuspected.

The distinctive symptoms and signs of fracture of the greater tuberosity are:

1. Pain in and swelling of the shoulder.
2. Outward rotation and abduction of the arm is impossible or very painful when attempted against resistance.
3. Tenderness over the greater tuberosity.
4. Passive rotation of the shoulder is painful and may produce crepitus. Crepitus is best elicited by rotation in abduction.

In the absence of crepitus, pain on pressure over the tuberosity and impaired movement at the shoulder should be sufficient to suggest fracture and the advisability of a roentgenogram for confirmation. Stereoscopic plates will distinguish calcification in a subacromial or subdeltoid bursitis from tuberosity fracture.

Prognosis.—In fracture of the entire tuberosity with displacement, unless accurate reduction is obtained, permanent impairment of abduction and external rotation will result. Simple reduction is difficult and the prognosis as regards complete restoration of function should be guarded. The outlook, following operative fixation, is excellent.

Treatment.—Fracture without displacement will require only a retentive bandage with axillary pad, such as the reinforced shoulder-elbow-figure-of-eight. After three weeks, massage and passive motion may be begun.

For fracture with displacement, apposition is sometimes obtained by abduction and external rotation of the arm—attempting to bring the fractured surface of the humerus in apposition with the displaced fragment. To maintain this position, the extremity may be suspended on a Thomas or wire splint, or by an arm sling and flexed forearm straps, from an overhead bar. Failing these, a firm bandage or light plaster cast can be applied in external rotation and abduction (to include the chest, shoulder, arm and forearm), with the elbow flexed and the hand on the back of the neck. In this—position, no callus can be laid down to prevent complete abduction and access to collar-buttons and hairpins,—which it is especially desirable to retain (Jones).[1] (Fig. 19.)

In all cases where simple reduction and manipulation fail—and especially when the fragment is wedged between the acromion process and the humeral head—open fixation should be undertaken, the displaced fragment replaced and held by a nail, screw, autogenous bone peg, or kangaroo-tendon suture, and immobilized again in abduction and external rotation by suspension or cast.

Fracture of the Lesser Tuberosity.—Fracture of the lesser tuberosity is exceedingly rare. It may follow direct or indirect violence, or be the result of forcible outward rotation of the arm against resistance,

[1] Injuries to Joints. Oxford War Primers 1917, p. 68-69.

or of a sudden contraction of the subscapularis muscle which is attached to it, or it may accompany a shoulder dislocation or an anatomical neck fracture.

Diagnosis.—The arm tends to assume a position of external rotation. Voluntary inward rotation is impossible. Tenderness and a palpable fragment may be felt in the region of the lesser tuberosity, where crepitus may be detected with rotatory arm movement. The lesion may be quite unsuspected until revealed by a roentgenogram. Stereoscopic plates may be necessary to demonstrate it.

Treatment.—The arm is placed in internal rotation and adduction, the forearm flexed, and the upper extremity immobilized, for four weeks. Operative fixation of a displaced fragment must be considered if the roentgenogram shows persistent displacement.

Fractures of the Anatomical Neck.—**Occurrence.**—In older classifications many fractures now described as fractures through the tuberosities were considered fractures of the anatomical neck. More accurate study of *x*-ray plates has led to a more refined differentiation of fractures in this region. True anatomical neck fracture is quite rare and occurs chiefly among older people. (Roberts,[1] Hitzrot[2] and Stimson.[3])

Etiology.—1. A direct injury—such as a fall upon the shoulder.

2. Indirect injury—a fall on the abducted elbow or outstretched hand—hyperabduction.

Pathology.—The line of fracture may adhere strictly to the anatomical neck or may include one or both tuberosities as a separate fragment. Impaction is not infrequent and lack of deformity may fail to arouse suspicion as to the actual lesion. There may, however, be well-marked deformity, with the head free in the axilla or in the glenoid cavity. Dislocation of the head is quite common, especially following an abduction indirect injury—when "if the dislocation occurred first, it is easy to understand how the head might be pried off by leverage against the edge of the glenoid fossa." (Hitzrot.[4])

Fractures through the Tuberosities.—**Etiology.**—1. Direct injury—a fall upon the shoulder.

2. Indirect injury—a fall forward or backward upon the elbow or hand with the arm in adduction.

Pathology.—This fracture occurs in advanced age and is almost always impacted. It is an oblique fracture in the line of the tuberosities; the head tends to slide distally and the shaft upward (Fig. 14). The displacement is often slight or entirely absent, but deformity may be observed as an anterior angulation, due to displacement of the upper end of the lower fragment forward. The head of the humerus may be dislocated.

Separation of the Upper Humeral Epiphysis.—**Occurrence.**—Separation of the upper humeral epiphysis is quite rare. It occurs from

[1] Fractures, 1916
[2] New York Med. Jour., 1914, c, 265.
[3] Fractures and Dislocations, 1917.
[4] New York Med. Jour., 1914, c, 265.

infancy up to eighteen to twenty years of age. It may result at birth from manipulation in a difficult labor.

Etiology.—1. Direct violence—a fall on the shoulder.

2. Indirect violence—a fall on the outstretched hand or abducted elbow—or hyperabduction of the arm.

Fig. 14.—Fracture of the humerus through the tuberosities. (Roberts and Kelly.)

Pathology.—The upper humeral epiphysis does not lie in a simple transverse plane but has at its center an upward projection like a flat inverted "V"—a pyramidal wedge projecting upward into a saucer-shaped concavity with shallow anterior and posterior edges. The epiphysis comprises both the head and the tuberosities. There may be merely a separation in the epiphyseal line or a splitting off of a bit of the diaphysis as well, which remains attached to the epiphysis (Fig. 15). With much displacement, there is also a stripping of the periosteum from the diaphysis.

In the majority of cases, displacement is slight, with scarcely any deformity; however, forward tilting of the upper end of the shaft to form a smooth anterior prominence about 2.5 cm. below the acro-

Fig. 15.—Separation of the epiphysis, with an oblique fragment from shaft. Outward displacement of shaft. (v. Bruns.)

mion is the peculiar and characteristic displacement of epiphyseal separation. Less commonly, the end of the diaphysis may be completely displaced into the axilla beneath the coracoid process. When a fragment of the shaft is also split off, the epiphysis is likely to be rotated upward and outward by the external rotators, similar to the upper fragment in surgical neck fracture.

Fractures of the Surgical Neck.—Occurrence.—Fracture of the surgical neck is the most common injury to the upper end of the humerus.

Etiology.—1. Direct violence—a fall or blow on the shoulder in which the shoulder is struck on its lateral or anterior surface—often when the arm is in an abducted position.

2. Indirect violence—a fall upon the elbow or hand, or hyperabduction of the arm and leverage against the acromion process.

3. Muscular action—this type is seldom observed. The fracture is produced in heavy lifting by a cross strain between the external rotators and the pectoralis major, latissimus dorsi and teres major muscles.

Pathology.—The surgical neck lies just below the level of the tuberosities and the epiphyseal line, tapering from the expanded tuberosities to the humeral shaft, comprising "an area free from muscular attachments." (Hitzrot.[1]) Fractures of this area are usually irregularly transverse, but may be either oblique or spiral, the line of the fracture extending into the shaft. There may be impaction, fissured splintering, or comminution, with the greater tuberosity split off as a separate fragment, or the head of the humerus may be dislocated.

When displacement occurs it is usually twofold:

1. The distal fragment is drawn, by the action of the pectoralis major, latissimus dorsi and teres major muscles, anteriorly and internally upward, in any degree from slight internal bending to complete overriding with penetration of the deltoid muscle or invasion of the axilla. Some internal rotation may also be evident.

2. The proximal fragment is rotated outward and abducted by the external rotators. Even with little or no displacement of the lower fragment the abduction and rotation of the upper fragment may be so extreme as to separate the fractured surfaces completely (Figs. 16 and 17). Thomas[2] asserts that, irrespective of muscle pull, the usual cause of surgical neck fracture is hyperabduction or a fall on the abducted elbow or hand, and the displacement is the result of the direction of the fracturing force.

In oblique fracture when the attachments of the pectoralis major group are included in the upper fragment the displacement may simulate upper third fracture, with internal displacement of the upper fragment, and outward and upward displacement of the lower fragment.

Diagnosis.—1. *Symptoms.*—All upper humeral fractures, with the exception of fractures of the tuberosities, possess practically identical symptoms in:

(*a*) Pain and swelling of the shoulder.
(*b*) Inability to use the arm.

[1] New York Med. Jour., 1914, c, 265.
[2] Thomas, T. T., Ann. Surg., 1919, lxx, 359.

FIG. 16.—Fracture of the surgical neck. Typical displacement except for slight inward angulation of the fragments.

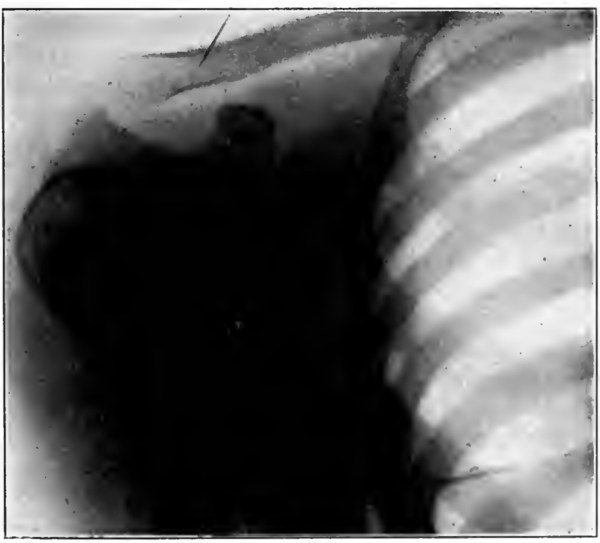


FIG. 17.—Surgical neck fracture. Partial impaction with marked rotation outward of the upper fragment.

2. *Signs.*—Differentiation of the types of upper humeral fractures can scarcely be made by the signs of fracture unless the swelling is so slight as to permit of very accurate palpation, or the deformity is significant.

(*a*) *Deformity.*—1. The deformity may be simple swelling about and thickening of the head of the humerus in impacted fracture.

2. Anterior prominence, just below the head, and especially observed in epiphyseal separation.

3. The normal contour of the shoulder may be preserved but the elbow is abducted and there is a depression below the shoulder curve, and swelling in the axilla or the subcoracoid space, to indicate the end of the displaced shaft—the usual deformity of surgical neck fracture.

4. With dislocation of the head the elbow is also abducted, but is not as rigid as in simple dislocation; there is flattening of the shoulder and swelling in the axilla.

(*b*) *Local Tenderness.*—Adequate knowledge of the surface anatomy and relation of the bony prominences about the shoulder is essential in locating the areas of tenderness. Pain will be intensified by direct pressure and pressure upward on the elbow.

(*c*) *With marked displacement* the fracture margins may be palpable and movable.

(*d*) The head in the glenoid cavity, or the dislocated head, does not move with rotation of the shaft.

(*e*) *Crepitus.*—Best elicited by gentle rotation of the shaft.

(*f*) With overriding, and sometimes with impaction, there is shortening of the arm, demonstrable by measurement from the acromion process to the external condyle.

Since these fractures possess common etiological factors and symptoms—unless palpation is facilitated by minimal swelling or crepitus is easily and exactly located—an accurate diagnosis of the type of upper humeral fracture is impossible without a roentgenogram. Even under an anesthetic the swelling may be so great that the exact site of the fracture cannot be ascertained. Fluoroscopic examination is less satisfactory than a roentgenogram; the latter possesses the advantage of permanency for prolonged scrutiny and careful study. Stereoscopic plates are of the greatest value and afford a more precise estimate of the displacement and better observation for proper reduction than the simple *x*-ray negative.

Prognosis.—The prognosis depends upon the age of the patient and the accuracy of reduction. After forty years of age there will usually be some impairment of function in abduction and external rotation. Following resection of the head of the humerus, abduction to 70 degrees should be possible but internal and external rotation will be restricted.

As a result of epiphyseal separation some interference with or abnormality in the growth of the humerus is always possible. In a comminuted fracture, or in fractures with delayed or inaccurate reduction, exuberant callus may interfere with the movement of the shoulder.

Treatment.—Reduction is best preceded by a roentgenographic examination and should be undertaken, if possible, within twenty-four hours after the injury. If the subsequent roentgenogram shows that faulty alignment is uncorrected, a second attempt at reduction should be made; if, following a second attempt, the position of the fragments makes a bad result seem likely, open operation should be employed. This will be found necessary in many oblique and spiral fractures in those with rotatory displacement and in those in which attempts at reduction have been delayed.

METHODS.—1. Simple fissured and impacted fractures require immobilization by a shoulder-elbow-figure-of-eight bandage over a small axillary pad.

2. Fractures in which there is little or no rotation of the head, no angulation of the fragments, and in which the displacement is less than one-quarter of the diameter of the shaft of the humerus—if the position cannot be improved by traction and simple direct pressure—are best not subjected to further efforts at reduction but straightway immobilized.

3. Fractures with much displacement will require reduction under a general anesthetic, unless contra-indicated by the condition of the patient. Fractures without rotation of the upper fragment require traction, countertraction and direct pressure for reduction. External rotation and abduction of the upper fragment, however, present the greatest difficulty. No direct alteration of the position of this fragment, without incision, is possible. The lower fragment must be brought into alignment with it. Apposition is obtained by traction on the arm and countertraction in the axilla, followed by extreme abduction, even to the point where the arm is parallel to the side of the head (Jones)[1]—external rotation and direct pressure on the fragments.

4. Fractures with dislocation and fractures with extreme displacement of the lower fragment through or into the deltoid muscle or beneath the coracoid that have proved irreducible, and all fractures in which, following attempts at reduction, a poor functional result seems likely, should be subjected to open operation.

If the dislocated head cannot be replaced it should be resected; if it can be restored to the joint cavity it may be fastened to the shaft by nail, screw or kangaroo-tendon. Reduction of the dislocated fragment may be facilitated by the use of the McBurney hook. In fractures of the surgical neck, should excision of the head be necessary, reattachment of the external rotator tendons to the shaft has been recommended. (Hitzrot.[2])

Resection of the head may be practised, with reasonable hope of obtaining adequate function, but should always be considered inferior to reduction. There is always some ankylosis or partial fibrous union with the margins of the glenoid cavity, but the movement of the scapula affords sufficient range of motion to give a fairly useful arm.

[1] Injuries to Joints. Oxford War Primers, 1915, p. 75.
[2] New York Med. Jour., 1914, c, 265.

5. In certain cases of overriding and shortening, where operation is refused or contra-indicated, abduction with continuous traction and suspension, with or without external rotation, may be used.

Epiphyseal separations require very accurate reduction. Open operation must be employed if manipulation in abduction fails. Cases of one to two weeks' standing may have detached diaphyseal periosteum, with new bone deposit that will prevent reduction except by operation. If reduction is complete no internal fixation material should be necessary. Apposition will be maintained by abduction and external rotation. When fixation after reduction is doubtful, chromic catgut or kangaroo-tendon sutures may be used, but never nails or screws, as injury to the epiphyseal cartilage is to be avoided.

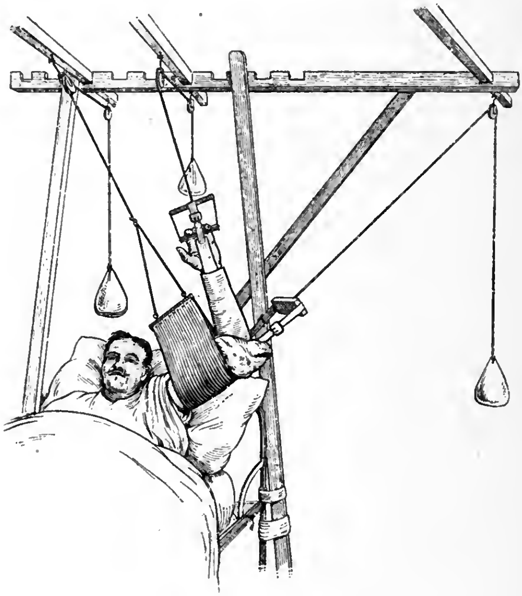


FIG. 18.—Position of extreme abduction and external rotation necessary in the treatment of some fractures at the surgical-neck of the humerus. (Blake.)

After-treatment.—Just as abduction is the position of choice for immobilization of fractures of the neck of the femur, *so is abduction the position of election* in fractures of the upper end of the humerus. In youth, or young adults, fractures with little or no displacement may be immobilized, with the arm at the side to avoid an unnecessary period in bed; but the rapid return of function after immobilization in abduction will justify its more extended use in even these cases.

Abduction is best maintained by some sort of suspension from an overhead bar or Balkan frame, with the patient in a sitting position in bed. A Thomas splint may be used or simply wide slings to support the arm; with the latter the forearm flexed to a right angle and held vertically maintains external rotation of the humerus and permits traction straps to be applied to the arm and traction made in the line of the upper fragment, as well as the easy overhead support of the forearm by adhesive or glued-strip suspension (Fig. 18). The type of apparatus preferred will vary with the familiarity with suspension methods.[1]

In refractory cases, and those that will not consent to suspension methods, recourse may be had to a plaster cast. The arm should always be abducted and rotated externally. The forearm may be flexed to permit the hand to rest on the neck, as recommended in tuberosity fracture (Jones), or flexed to a right angle and held vertically. Horizontal right-angled flexion does not maintain external

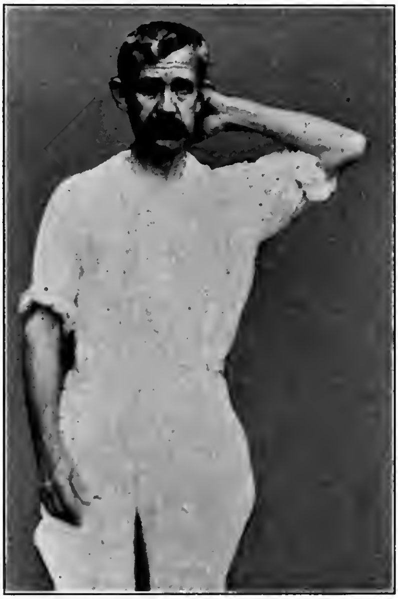


FIG. 19.—Jones's position for the immobilization of reduced fracture of the surgical neck.

rotation. The cast should include the entire upper extremity from the fingers to the shoulder and the axilla and chest.

In about three weeks, or when union is firm, abduction and external rotation may be gradually lessened, and at the end of the fourth week, all apparatus may be removed and active motion of the arm permitted. A sling should be used for support until the end of the sixth week or until the movement of the arm is fairly normal. The usual time of total disability is three months.

Complications.—Arthritis of the shoulder-joint may be an immediate or remote complication. When immediate it may not be mani-

[1] Unless a Thomas or wire splint is used, a portable x-ray apparatus should be available.

fested for two or three weeks and usually clears up in four or five weeks under applications of heat, massage and electrotherapy. As a late complication it may not appear for six to nine months following the injury and may be a progressive and permanent lesion. The injury may cause a flare-up in an old focus of joint infection.

Deltoid paralysis, from injury to the circumflex nerve, is not usually detected until the permanent dressing is removed; it should readily respond to massage, passive motion and electricity, though the atrophy not infrequently does persist. In elderly persons the paralysis may be unyielding to any or all treatment.

Fractures of the Shaft of the Humerus.—**Occurrence.**—Fractures of the shaft of the humerus comprise those fractures that occur between the surgical neck and the supracondylar ridges. They are described as occurring in the upper, middle and lower thirds. Fractures of the middle third, or at the juncture of the middle and lower thirds, are most common.

Etiology.—1. Direct violence—a blow or fall against the arm, often in abduction when the elbow is flexed, or a squeeze or crush of the arm.

2. Indirect violence—a fall or blow on the hand or elbow or a torsion of the arm.

3. Muscular action—during tests of strength or wrestling.

Fractures of the humeral shaft most frequently follow direct injury or muscular exertion. They are less common industrial injuries than fractures of the radius, ulna, femur or tibia. Pathological fractures, from metastatic carcinomata or systemic disease, may occur. Fractures of the humerus at birth are almost invariably the direct result of attempts to free an arm which has become extended over the head during a difficult breech extraction.[1]

Pathology.—The fracture is most often oblique, but may be transverse, spiral or longitudinal. There may be comminution or an open wound.

Displacement is common and depends upon the severity of the injury, the position of the fracture with respect to muscle attachments and the direction of the fracturing force.

(*a*) *In fracture of the upper third* the upper fragment is usually drawn inward and the lower fragment outward and upward by the action of the pectoralis major and the deltoid muscles, respectively, though (Fig. 20) if the external rotators are stronger, and if the force which produces the fracture is applied on the external surface of the arm, as in direct fracture it commonly is, a displacement similar to surgical neck fracture will occur—the upper fragment outward and the lower fragment inward.

(*b*) *In the middle third* the displacement will depend upon whether the fracture lies above or below the insertion of the deltoid. If above, the displacement will be similar to upper third fracture; if below there may be very little displacement, or the upper fragment

[1] Truesdell, Amer. Jour. Obst., 1914, lxix, 151.

will be carried outward by the deltoid muscle, and the lower fragment will tend to be drawn upward by the biceps and triceps.

(c) *In fracture of the lower third* the upper fragment will tend to veer outward by reason of the deltoid pull and the lower fragment will be carried upward by the triceps and biceps muscles and inward or anteriorly by the weight of the forearm, especially when flexed, as the flexors are attached to the internal condyle (Fig. 22).

Fig. 20.—Transverse fracture of the middle and upper third of the humerus. Displacement similar to surgical neck fracture. Upper fragment outward, lower fragment inward.

Fig. 21.—Fracture of the middle third of the humerus; displacement outward of the upper fragment; contraction of the deltoid.

Diagnosis.—The diagnosis presents but little difficulty, for all the cardinal symptoms and signs of fracture are readily obtained.

With definite deformity and disability the diagnosis may be made at a glance. A roentgenogram—a great aid to intelligent reduction—will indicate the exact position of the fragments. Two views from planes at right angles to each other should always be taken—lateral and antero-posterior—or failing this, stereoscopic plates. Longitudinal or subperiosteal fractures may not be recognized unless roentgen observations are made.

Prognosis.—Exact alignment and prevention of shortening are not such absolute essentials in fractures of the upper as in fractures of the lower extremity. Even with a permanent deformity an excellent functional result may be obtained, but excess callus, on account of subsequent musculospiral paralysis, is to be avoided.

Fig. 22.—Fracture of the lower third of the humerus. Displacement of the lower fragment anteriorly. Pull of weight of forearm.

With marked displacement, bits of fascia or muscle may be interposed between the fragments, which will prevent accurate reduction and lead to fibrous union or a pseudarthrosis. *Operative interference tends to delay union, especially if instituted late after injury.* Syphilis must always be considered a possible factor in delayed union. The duration of complete disability in an uncomplicated fracture should be three or four months. In an open suppurating or gunshot fracture the period of disability will vary with the individual case.

Treatment.—Reduction should not be delayed and should be attempted as soon as conveniently possible, following the accident—if the general condition of the patient is not a contra-indication. Late reduction, when the muscles have contracted and the swelling receded, is much more difficult and manipulation is less easy. Likewise, when late operative interference is necessary, the early attempts at bone repair which have already been well inaugurated will be disturbed and osteogenetic function and union delayed.

For a temporary or first-aid appliance, and especially for transport, a hinged Thomas arm splint is invaluable. Well-padded internal external lateral splints may be used instead, the elbow flexed and the entire extremity bandaged firmly, by a modified Velpeau, to the body.

Reduction is best obtained by traction, countertraction and direct manipulation under an anesthetic. Traction should be made with the elbow flexed to about 90°. When traction is made with the forearm in full extension the carrying angle or normal abduction at the elbow is likely to be overlooked and attempts made to render the upper extremity from shoulder to wrist straight; with this intent reduction is next to impossible. The reduction should be controlled and is greatly facilitated by the fluoroscope or by the study of *x*-ray pictures taken before and after reduction. It is exceedingly difficult to obtain and especially to maintain reduction in oblique or spiral fractures; in transverse fractures it is relatively easy.

A simple fracture without displacement will require care in handling to prevent derangement of the fragments and may be immobilized on a Jones arm splint or by well-padded anterior, internal, posterior and external apposition splints, a shoulder-cap of molded gypsum or cardboard and a triangular wedge-shaped axillary pad to maintain slight abduction; the forearm should be flexed with a *wrist* sling for its support and the arm and forearm bandaged to the thorax (Figs. 23, 24 and 25).

For a reduced transverse fracture a similar dressing usually suffices, or a plaster cast which includes the upper thorax, the shoulder, axilla and the entire upper extremity may be used. Molded tin splints for the axilla and arm may be incorporated in the cast to aid in maintaining proper abduction.

In oblique or spiral fracture, where reduction is difficult to maintain, some form of traction apparatus is indicated. This may be either:

1. Thomas splint with abduction, traction and overhead suspension.
2. Jones splint.
3. Arm sling; suspension in abduction with traction—Blake's method.[1]

1. A Thomas splint is adjusted in the usual manner and suspended in abduction, with the forearm extended and supinated—a con-

[1] Gunshot Fractures of the Extremities. Masson et Cie.

Fig. 23 Fig. 24 Fig. 25

Figs. 23, 24 and 25.—Method of applying dressing for fracture of shaft of humerus. Fig. 23. Axillary pad, arm protected by circular layers of sheet-wadding, cotton roller bandage to hand and forearm, coaptation splints about arm, and wrist-sling. Fig. 24. Padded shoulder cap and arm bound to chest by a broad strip of adhesive plaster. Fig. 25. Completed dressing. (Roberts and Kelly.)

veniently simple procedure, but admitting of one serious criticism, *i. e.*, immobilization of the arm, with the elbow extended, which prolongs convalescence by the time required for the elbow to regain normal function.

2. Jones's splint requires frequent adjustment, permits of no abduction and is best used in fractures of the lower half of the humerus and where a small degree of traction only is needed.

3. Arm sling traction-suspension is perhaps the best general method to employ in treating these fractures of the humeral shaft (Fig. 26). Traction should always be made in the axis of the upper fragment and ten to twelve pounds should suffice to overcome any overriding or shortening. No splint is necessary. It is important to prevent

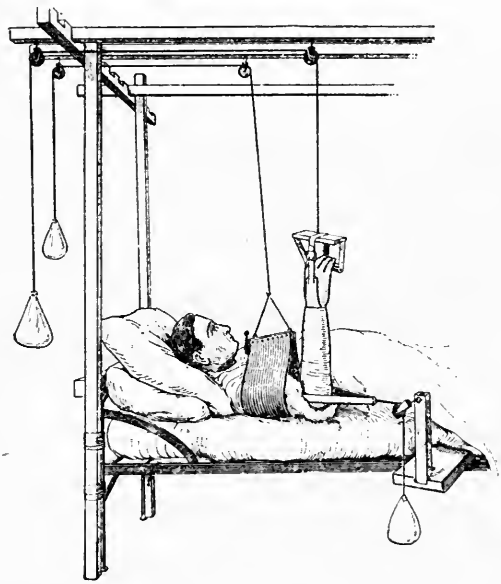


FIG. 26.—Sling suspension and traction for fracture of shaft of humerus. (Blake.)

wrinkling, foreshortening or drawing together of the sling by stretching and securing each end to a strip of wood from which suspension is made.

With any traction apparatus, reduction must be followed by frequent roentgenographs, for which a portable *x*-ray outfit is practically indispensable. Adequate reduction should be obtained in eight to ten days. Very *light* massage may be instituted after fourteen or fifteen days, or as soon as there seems no likelihood of altering the position of the fracture fragments thereby.

For fractures of the upper third with much displacement, immobilization or traction in abduction is especially indicated.

Lower third fracture tends to internal and anterior angulation of the fragments; in applying dressings care must be taken, therefore, to avoid upward pressure at the elbow. If an abduction-traction apparatus is used this tendency will be largely obviated.

Birth fracture of the humerus may be immobilized in abduction and external rotation on a long splint that passes from the finger tips behind both scapulæ—the position of crucifixion. The arm is thus fixed in abduction at a right angle to the vertical axis of the body giving as little interference as possible to the bathing and proper care of the child.

The maintenance of reduction in all fractures following immobilization should be verified by a roentgenogram. If at least one-half of the diameter of the bone is not in apposition or malalignment and overriding of the fragments make ultimate functional impairment probable, and if, with traction, reduction is not obtained in ten days, open operation and direct fixation of the fragments should be undertaken. Oblique and spiral fractures with much displacement are especially likely to resist simple reduction measures and should be considered from the outset possible candidates for operative procedure. The fragments may be fixed by permanent or removable metal plates with pegs or screws, Parham bands, kangaroo tendon or absorbable suture, intramedullary bone peg or inlay bone graft. Plates for middle third fracture must be placed so that neither plate, pins nor screws will injure the musculospiral nerve. Immobilization following operation is best made by a light plaster cast, and should be maintained for four weeks.

After-treatment.—All apparatus may be removed after four weeks. If union is firm, passive motion and massage may be regularly instituted and an arm-sling used for one or two weeks longer until the movement of the upper extremity justifies dispensing with all restraint. If movement at the fracture site can be detected a Jones splint or an ambulatory abduction splint will still be required, but massage and passive motion may be gently begun.

The treatment of fractures of the shaft of the humerus seems in a somewhat transitional stage at present. The difficulty in controlling the fragments and overcoming overriding, and the tendency to internal or anterior bowing under the usual forms of treatment has made the necessity for and incidence of operative interference high. A plaster cast tends to overlong impairment of function. The traction-suspension treatment as used in war fractures deserves an extended trial

Complications.—Grave complications of fractures of the shaft include.

1. Suppuration.
2. Laceration of the brachial vessels.
3. Injury to the nerves:
    (*a*) Musculospiral.
    (*b*) Median.
    (*c*) Ulnar.
4. Non-union.

1. Suppuration is especially likely to follow an open fracture with marked laceration of the soft tissue, *i. e.*, when a fragment protrudes

through the skin or when foreign matter has been carried into the wound, as in gunshot fracture, or when there has been delay in or improper first-aid treatment of an open fracture. It is also a possibility when open reduction is required and rigid asepsis is not properly observed. (See page 221.)

2. Laceration of the brachial vessels occurs with severe crush or comminution of the arm or with gunshot fracture. Ligation of the artery may be safely performed, provided compensatory circulation has not been impeded or prevented by extensive trauma of the soft tissues. If the superior profunda artery is intact, gangrene is not likely. In circular crush, with brachial laceration, amputation will be necessary.

3. Injury to the median and ulnar nerves is comparatively rare. By far the most important complication of fracture of the humeral shaft is musculospiral paralysis. It is found in 4 per cent. of all humeral shaft fractures (Scudder) and may result from:

1. Laceration of the nerve by a jagged bone fragment.
2. Contusion of the nerve.
3. Pressure upon or stretching of the nerve at the time of injury.
4. Pressure upon the nerve by callus at the fracture site, or incorporation of the nerve in a callus.

Paralysis occurs most frequently with fracture of the middle third, as the following table demonstrates:

MUSCULOSPIRAL PARALYSIS IN FRACTURES OF THE HUMERUS.

	Upper third. per cent.	Middle third. per cent.	Lower third. per cent.
Scudder[1]	7.0	69.0	23.0
von Bruns (quoted by Roberts[2])	10.0	52.0	38.0
Blenke (quoted by Roberts[2])	3.4	56.3	41.3

The characteristic sign of musculospiral injury is wrist-drop, due to paralysis of the extensor muscles of the hand and fingers which are supplied by the musculospiral nerve. Anesthesia of the thumb, index and middle fingers, the musculospiral skin area, is not constant.

Neuralgic pain in the arm and along the course of the nerve is at times observed, especially with late paralysis.

The paralysis may be:

1. Immediate or primary.
2. Late or secondary.

(*a*) Immediate paralysis follows laceration, contusion or stretching of the nerve at the time of injury. An intermediate type has been recognized in which the onset of paralysis may be delayed a few hours to several days after the accident. (Roberts.[3])

(*b*) Late paralysis is gradual in onset; it is caused by pressure or growth of excessive callus, and will therefore not be observed until four or five weeks after the injury.

[1] Ann. Surg., 1909, l, No. 2, p. 1118.
[2] Fractures, 1916.
[3] Ibid.

The mild forms of paralysis recover spontaneously as a rule. Persistent massage with electrotherapy and passive motion should be used, with support for the hand and wrist; a "cock-up" splint or overcorrection of the wrist-drop by a wire splint in extension is preferable. When the primary paralysis persists and increases, when the processes of degeneration can be demonstrated, in cases in which improvement is arrested and in the late cases from pressure of callus, operative exposure of the nerve should be practised and the nerve sutured, or excessive callus removed and the nerve freed. A fascial transplant may be used to cover a bone defect and to prevent adhesions and recurrence of the callus pressure. In doubtful cases in which the propriety and necessity of operative interference are not clear, the sign of regeneration emphasized by Ney[1]—Tinel's sign—will be useful. He asserts that evidence of nerve regeneration is indicated when the tingling and pain transmitted distally along the nerve following percussion of the nerve trunk can be obtained at a gradually lower level.

The prognosis with operation is excellent. Eight out of 11 cases operated upon by Scudder[2] recovered. Well-marked improvement should be evident three or four months after the operation and the cure should be complete in twelve to eighteen months.

4. *Non-union.*—The middle third of the humerus is one of the well-known sites of delayed union as well as non-union or pseudoarthrosis. In a small series of 27 humeral shaft fractures 2 cases of delayed union and 1 of non-union occurred in the middle third, and none in the upper and lower thirds. A compound comminuted fracture with osteomyelitis is often a predisposing factor. The tendency to anterior and internal displacement of the lower fragment in fractures of the lower half of the shaft, and the difficulty in controlling this displacement by the older methods of treatment, may also be considered as a possible factor.

The eager desire for prompt consolidation must not overbalance sound judgment and urge early open operation for non-union when the union may be merely delayed. Five or six months should elapse after the accident before non-union, or pseudarthrosis, is considered to have occurred. During this interval, syphilis, as a cause for delay, should be ruled out by a Wassermann test and appropriate treatment. A low meat and high milk diet or, as Albee[3] has recently advised, local injections of calcium triple phosphate may be tried. If after six months there is still well-marked mobility at the site of fracture the ends of the fragments should be exposed, the eburnated fibrous terminations cut away and an autogenous bone graft inserted by the Albee technic. Firm union should occur in four or five weeks after this operation.

Fractures of the Lower End of the Humerus.—Occurrence.—Ashhurst's and Plageman's statistics show:

[1] Jour. Am. Med. Assn., 1919, lxxiii, 1427.
[2] Ann. Surg., 1909, 1, No. 2, p. 1118.
[3] Ibid., lxxi, 32.

	Plageman.[1]	Ashhurst.[2]
1 Supracondylar fractures	43	29
2. Separation of the lower humeral epiphysis	10	7
3. "T"-fracture	11	1
4. Fracture of the external condyle	15	12
5. Fracture of internal condyle and epicondyle	24	7

The most common fractures of the humerus near the elbow are supracondylar fractures and fractures of the external condyle and internal epicondyle.

1. **Supracondylar Fractures.—Etiology.**—Supracondylar fractures of the humerus are usually observed in children. They may follow:

1. Direct violence—a blow just above the elbow—a rare adult fracture.

2. Indirect violence—the common fracture in children—a fall upon the outstretched hand, with the forearm in partial extension or hyperextension; from forceful abduction or adduction at the elbow; or from a fall upon the elbow, with the forearm flexed to a right angle—a flexion fracture.

Pathology.—Kocher[3] has divided supracondylar fractures into four classes:

1. Extension fractures.
2. Flexion fractures.
3. Abduction fractures.
4. Adduction fractures.

1. *The extension fracture* is the usual injury; the line of separation is slightly oblique from the anterior surface, backward and upward; the upper fragment is displaced anteriorly against the brachial vessels and the lower fragment is carried backward, upward and sometimes inward (Figs. 27 and 28).

2. *In the flexion fracture* the upper fragment is displaced backward and the lower fragment upward and forward and inward in the direction of the force applied to the elbow. (The line of fracture and the deformity is the reverse of the extension fracture.) (Fig. 29.)

3. The line of fracture in *the abduction type* is outward and upward from the internal condyle.

4. *The adduction type* shows the line of fracture inward and upward from the external condyle.

The last three types are exceedingly rare.

A diacondylar fracture has been described. (Ashhurst-Roberts.) The line of fracture passes through the condyles. It resembles in deformity the extension type of supracondylar fracture and can be differentiated only by a roentgenogram (Fig 30).

2. **Separation of the Lower Humeral Epiphysis.—Occurrence.**—Separation of the lower humeral epiphysis is not infrequent and occurs up to eighteen or twenty years of age.

[1] Quoted from Roberts and Kelly: Fractures, 1916.
[2] Fractures of the Lower End of Humerus, Samuel D. Gross Prize, 1910.
[3] Quoted from Roberts and Kelly: Fractures, 1916.

Etiology.—1. Direct violence—a blow upon the arm just above the elbow, with the elbow or forearm fixed.

Fig. 27.—Supracondylar fracture of the humerus. Marked posterior displacement of lower fragment. Extension fracture.

Fig. 28.—Supracondylar fracture of the humerus. Angulation of fragments. Only slight displacement.

2. Indirect violence—a fall on the hand, with the forearm in full or hyperextension.

Fig. 29.—Supracondylar fracture of humerus by flexion. (Stimson.)

Fig. 30.—Diacondylar fracture of the humerus.

Fig. 31.—Separation of the lower epiphysis of the humerus. Posterior and lateral displacement of the epiphysis.

Fig. 32.—Separation of the lower epiphysis of the humerus. Posterior and lateral displacement and rotation of the epiphysis.

Pathology.—The four centers of ossification of the lower end of the humerus form the epiphysis and separate, as a unit, from the diaphysis. The separation may be slight or there may be marked displacement of the epiphysis posteriorly and laterally. The line of separation may merely follow the epiphyseal cartilage, but there is usually a fracture of a small bit of the diaphysis also, with stripping of the periosteum from the shaft. The deformity and displacement are quite similar to the extension type of supracondylar fracture (Figs. 31 and 32).

3. **"T"-Fracture of the Lower End of the Humerus.—Occurrence.**—This fracture is found chiefly in adults following a direct injury—the most frequent adult elbow fracture (Jones).

Etiology.—1. Direct violence of great severity—machinery or mangling accident.

2. Indirect violence—a fall on the elbow, the olecranon being driven up between the condyles.

Pathology. — The fracture lines separate the condyles from the shaft and from each other (Fig. 33). There may be a simple fissured fracture or the end of the diaphysis is displaced forward, as in extension supracondylar fracture, or driven between the condyles. The displacement may be quite atypical, comminution extensive, and the skin perforated by a sharp fragment. Marked injury to the soft tissues is usual.

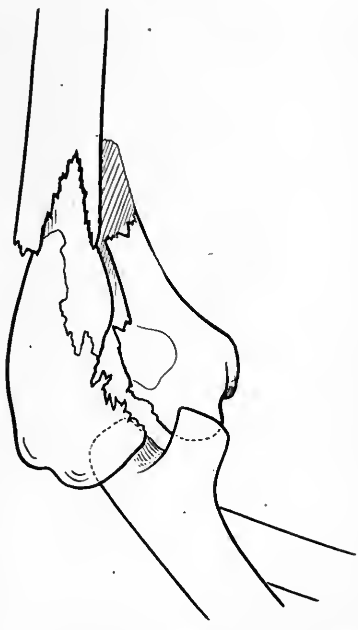


Fig. 33.—T-fracture of the lower end of the humerus. Some retention of fragments in position. (Speed.)

4. **Fracture of the External Condyle and Epicondyle.**—(*a*) *Fracture of the external epicondyle* is quite rare; it follows a fall or blow upon the external surface of the elbow.

(*b*) *Fracture of the external condyle* is not uncommon and is usually observed in children.

Etiology.—1. Direct violence—a fall directly on the external condyle.

2. Indirect violence—hyperadduction of the elbow or a fall upon the outstretched hand, when most of the impact is transmitted along the radius.

Pathology.—The fracture line follows an oblique course from the joint surface at the trochlea-capitellar ridge outward and upward, and may or may not include the epicondyle (Figs. 34 and 35). There may be simply a fissured fracture but some upward displacement of the external condyle is usual. The condylar fragment may even be rotated so that the fractured surface is facing upward.

5. **Fracture of the Internal Condyle and Epicondyle.**—(*a*) *Fracture of the internal epicondyle* is often a separation of its epiphysis, and is likely to occur between the ages of ten and eighteen years—usually with posterior dislocation of the elbow.

FIG. 34.—Fracture of the external condyle of the humerus.

FIG. 35.—Fracture of the external condyle of the humerus. Rotation and displacement of the fragment.

Etiology.—1. Direct fall or blow upon the internal condyle.

2. Indirect violence—hyperabduction of the elbow in full extension, when the pull of the flexor muscles, which are attached to it, may tear the epicondyle away.

Pathology.—When completely detached the fragment is displaced forward and downward and may be readily palpated (Fig. 36). Injury to the ulnar nerve is rare.

(*b*) *Fracture of the internal condyle* is uncommon.

Etiology.—1. Direct fall or blow upon the elbow on the ulnar side, with the elbow flexed.

2. Indirect violence—a fall upon the outstretched hand with the impact transmitted along the ulna—or hyperabduction or adduction of the elbow.

Pathology.—The line of fracture is oblique from the trochlea-capitellar ridge upward to include the epicondyle. There may be but little displacement or the condylar fragment may be displaced upward, backward and inward; the ulna may follow (Fig. 37).

(Fractures of the trochlea and capitellum alone have been described; they are exceedingly rare intra-articular fractures, revealed when the fragment is accurately palpable or by the rœntgenogram.)

Diagnosis.—Familiarity with the normal surface anatomy of the elbow-joint is of the greatest aid in detecting fractures in this region; the bony prominences and the carrying angle require special recognition. With the forearm flexed the supracondylar ridges of the humerus may be followed to their terminations in the condyles and epicondyles, which lie at the same level and normally form an equilateral

FIG. 36.—Fracture of the internal epicondyle of humerus. Displacement of a freely movable fragment.

triangle with the olecranon process of the ulna. The head of the radius may be felt just distal to the external condyle and may be identified by its rotation with the shaft of the radius in pronation and supination of the forearm. With the forearm completely extended, slight abduction at the elbow will always be observed. The angle indicating the amount of abduction is designated "the carrying angle."

Evidence of fracture may be more easily determined by comparison with the sound side and by noting alterations in the relationships of bony prominences.

The general characteristics of the lower humeral fractures are:

Symptoms.—1. Pain in and swelling of the elbow.
2. Loss of function of the elbow.

Signs.—1. Deformity.
2. Abnormal mobility—often lateral mobility at the elbow.
3. Crepitus.
4. Palpable fracture margins or fragments.

Fig. 37.—Fracture of internal condyle of the humerus, in an adult. (Stimson.)

1. *Supracondylar Fracture.*—The deformity in the extension type of fracture will show, anteriorly, marked swelling and prominence of the lower third of the arm, extending to the cubital fossa, and, posteriorly, prominence of the olecranon process with concavity above it. Any movement at the elbow will be painful, and crepitus and false motion may be distinguished. The fracture margins, on account of the swelling, are seldom actually palpable, but the condyles may be felt in normal relation with the olecranon process, which distinguishes this fracture from posterior dislocation of the elbow.

The flexion type will have greater swelling of the elbow-joint anteriorly and swelling and prominence just above the condyles posteriorly. The deformity is usually not great.

2. *The Deformity of Diacondylar Fractures and Epiphyseal Separation* is quite similar to extension supracondylar fractures.

3. *A "T"-Fracture of the Lower End of the Humerus* may be marked by great swelling of the elbow. The elbow is broadened; the condyles may be widely separated and movable, with crepitus; the comminution may be so great that the character of the displacement cannot be determined without a radiograph.

4. *Deformity in Fracture of the External Condyle.*—The swelling is especially observed on the external surface of the elbow. There is an increase in "the carrying angle" when there is much displacement, giving a marked cubitus valgus deformity. Distinct crepitus and motility of the fragment is usual. The fragment may be easily outlined; the position of the external condyle will be above the level of the internal condyle and farther from the olecranon process.

5. (*a*) *Fracture of the Internal Epicondyle.*—The swelling and ecchymosis of the elbow will be confined to or greatest at the internal condylar area. The fragment may be picked up between the fingers, is freely movable and crepitus is usually easy to distinguish. Voluntary extension of the hand—stretching the flexor muscles and pulling on the internal epicondyle—may be painful.

(*b*) *Fracture of the Internal Condyle* will show a typical gunstock deformity—cubitus varus—with decrease in the carrying angle. Swelling will be greater over the internal condyle, which will be posterior to and higher than the external condyle and farther from the olecranon process. Crepitus and increased lateral mobility of the elbow are present. All movements at the elbow are painful.

Prognosis.—In children, when accurate reduction has been obtained, the prognosis is excellent. A perfect result is considered to have been obtained when the motion in the elbow remains completely unrestricted, though slight deformity may be present. In skilful hands, following hyperflexion treatment, perfect results may be expected in 80 to 90 per cent. of all cases. (Ashhurst,[1] Ladd.[2]) Following marked displacement with great swelling, and in comminuted fractures, or when the accuracy of reduction is doubtful, and in adults, some permanent impairment may occur justifiably; here prognosis should be guarded. When extension falls short of the proper complete excursion, the functional deficiency is not great but even slight permanent restriction in flexion will prove a real handicap. Cubitus varus or valgus may be suspected when the right-angled or semiflexed position has been used for immobilization, but there is usually very little interference in function of the elbow. Osteotomy is necessary to correct a marked distortion.

[1] Fractures of the Lower End of the Humerus, Samuel D. Gross Prize, 1910.

[2] Boston Med. and Surg. Jour., 1916, clxxv, 220.

Treatment.—In fractures near the elbow it is exceptionally necessary to obtain complete reduction. Unless attempts at reduction are made early, reposition of the fragments may be very difficult. *X*-ray observations are a necessity in guiding the proper procedure for reduction and both lateral and antero-posterior roentgenograms should be obtained.

For supracondylar extension fractures and all fractures with similar displacement—diacondylar, simple "T"-fractures and epiphyseal separation—a general anesthetic should be used for reduction. An assistant should hold the arm firmly; the operator may then unlock the fragments by hyperextension, bringing them into apposition by traction on the condyles—countertraction by the assistant, with simultaneous direct pressure to correct lateral and anterior deformity, followed by hyperflexion to maintain apposition. The result of the manipulation must be confirmed by roentgenography.

In fractures of the condyles and epicondyles, and the rarer types of supracondylar fracture, after direct manipulation for reduction, hyperflexion should likewise be used for immobilization. Hyperflexion, therefore, is indicated in all fractures of the lower end of the humerus; it must be as complete as possible but must not cause either pain or impairment of circulation. The forearm in the hyperflexed position should be kept in complete supination.

A convenient dressing to maintain hyperflexion is afforded by an adhesive swathe from the forearm near the wrist to the upper arm, with a clove hitch about the wrist or a sling to suspend the extremity from the neck and a small pad in the cubital fossa to separate the skin surfaces and prevent excoriation (Figs. 38 and 39). This is best supplemented by a bandage which must especially maintain supination of the hand and forearm. If necessary a few turns of a gypsum bandage may be added to stiffen the dressing. The elbow should be well padded to prevent pressure or tightening of the bandage from postreduction swelling. The swelling before reduction may be so great that only partial flexion can at first be used. As the swelling subsides the dressing should be readjusted to obtain more acute flexion.

In supracondylar fractures that resist simple reduction, and in epiphyseal separations that are not in accurate position, open operation may be undertaken. It will seldom be necessary to use fixation material; simple freeing of the fragments and reduction, followed by hyperflexion, should suffice. The hyperflexed position, through the pull of the triceps and biceps muscles, maintains the reduction (chiefly because the triceps when under tension acts as a sturdy posterior splint).

In fracture of the internal epicondyle the fragment may be so movable that simple reduction will not control it. Incision and nailing or pegging the fragment in position should be considered.

In fracture of the external condyle, when the fragment is rotated outward and upward, open reduction will be necessary. (Ladd.) Atypical "T"-fractures may also require open reduction, and nail, screw, peg, bolt or drill fixation.

The elbow should remain flexed for three weeks; the dressing and forearm should be carefully and regularly inspected to avoid or forestall constriction. The retention dressing is then removed, and massage and active and passive motion begun. Jones's suggestions for passive motion should be followed and the elbow gradually extended. The sling or bandage of the forearm is released so that the wrist may drop three inches and the patient is allowed to practice active movements. If after two days the hand and forearm can be

Fig. 38.—Adhesive strip to maintain hyperflexion. (Roberts and Kelly.)

Fig. 39.—Dressing to maintain elbow in hyperflexion, completed. (Ashhurst.)

moved back to full flexion the sling may be lengthened three more inches. Lengthening of the sling is then permitted every two or three days until a right angle is reached, when it may be discarded entirely. If, on the other hand, two days after the initial release the elbow is stiff in the new position it must be put up again in acute flexion, as the structures about the joint evidently resent movement and repair is not sufficiently advanced for motion to be begun. In another week the test may be repeated. At the end of the sixth week good function should prevail.

Complications.—The complications may be:

1. Laceration of the brachial vessels.

2. Injury to the median, ulnar or musculospiral nerves.
3. Ischemic contracture—Volkmann's.
4. Myositis ossificans.

1. It is seldom that laceration of the brachial vessels occurs with a fracture near the elbow. When the brachial artery is divided it may be ligated with impunity, provided adequate compensatory circulation seems likely. Only with severe crush and extensive soft tissue injury will amputation be required. Unexpected recoveries have not infrequently followed conservative measures.

2. Median, ulnar or musculospiral paralysis is not often observed with fracture of the lower end of the humerus, but, as in fractures of the shaft, may be encountered: (*a*) Primary; (*b*) secondary.

(*a*) Primary paralysis is a result of the injury; it is usually caused by contusion; seldom by laceration of the nerve. If persistent, or the reaction of degeneration appears, laceration must be suspected and open operation undertaken. Primary paralysis is exceedingly rare; usually of a mild transitory type. It may not be observed for several days after the accident—an intermediate type (Roberts[1]).

(*b*) The secondary paralyses are observed three or four weeks after injury and are due to callus inclusion or pressure, following vicious union. A very late type of ulnar paralysis has been reported, having an insidious onset six to thirty-six years after the fracture—(Hunt-Panas)—especially in cases with permanent deformity, such as cubitus valgus in external condyle fracture. On very rare occasions the median nerve may be affected also (Bernhardt[2]). A few cases have been due to neuromata or cysts forming along the course of nerves and causing pressure paralysis (Murphy[3], Hunt[4]). Exposure of the nerve is indicated in all cases that do not respond to massage and electricity. Excision of callus, freeing from scar tissue, or, in the case of the ulna especially, transplantation may be undertaken.

3. *Ischemic or Volkmann's contracture occurs both with* fractures near the elbow and fractures of the forearm, and is caused by:

(*a*) Bandages or immobilization material—chiefly splints—that are applied too tightly.

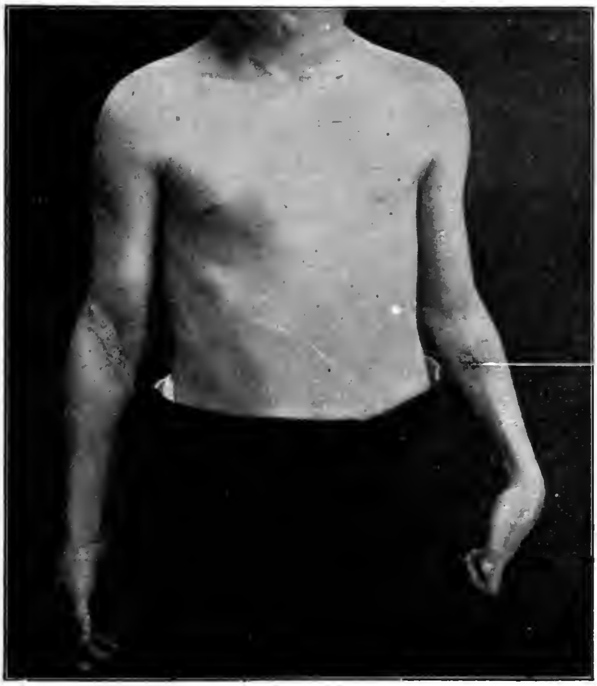
(*b*) Flexion of the forearm that is too acute.

(*c*) Idiopathic type—with no outward evidence of constriction, ischemia supervenes, "from pressure within the arm, either pressure of broken ends of bone, tearing of muscles or extensive hemorrhage," with intact aponeurosis (Jones[5]).

The lesion is primarily a venous congestion followed by an ischemia from the pressure of the restricting bandage or position of the extremity. Degeneration of the tissues—particularly the muscles—results from compression and insufficient nutrition. Muscles, tendons, nerves and fascia unite in a fibrous cicatricial mass; pressure necrosis will follow excessive local pressure, with sloughing of skin and even

[1] Fractures, 1916.
[2] Neur. Ol. Cent., 1910, xxix, 178.
[3] Murphy's Clinics, 1914, iii, No. 2.
[4] Jour. Am. Med. Assn., 1916, lxvi, 11.
[5] Injuries to Joints, Oxford War Primers, 1914.

of subjacent tissues. Atrophy and contracture then take place. The flexor muscles especially suffer. The fingers become stiffened and flexed at the phalangeal joints and extended at the phalangeal metacarpal joints, giving a typical "claw-like" appearance to the hand. The fingers can only be extended when the wrist is in extreme flexion. Wrist and elbow motion is limited. There is marked atrophy of the forearm and the interosseous muscles of the hand. Paralysis of the median or ulnar nerve is not infrequent (Thomas[1]) and wrist-drop—musculospiral paralysis—is rare.



Points to cicatrix.

FIG. 40.—Volkmann's contracture. Illustrating the evil result following too great compression of the forearm by ordinary wooden splints. Note cicatrix below elbow on the anterior surface of the forearm. Note permanent deformity of hand due to involvement of muscles and nerves in degenerative changes from pressure. (Scudder.)

There is almost always warning of impending ischemia in severe pain at the onset. This is excruciating and should never be mistaken or disregarded. If the circulation of the extremity is not properly observed after the application of the fixation dressing, if the splints are not properly padded or are too tightly applied, or if morphin is given for postreduction pain without first attempting relief by the division of all constricting bandages, ischemia may be well established before it can be prevented or moderated. Swelling and stiffness of the fingers, especially pain with attempts to move the fingers after

[1] Ann. Surg., 1909, xlix, 330.

reduction is completed, should suggest an impending ischemia. When well established the lesion is unmistakable. The claw-like appearance of the hand, the indurated atrophy of the forearm and limitation in motion of wrist and elbow are quite characteristic (Fig. 40).

The great predisposing factor to the production of Volkmann's contracture is incomplete reduction of a fracture which has proved difficult to manipulate; the tendency is to make the position of immobilization or the pressure of antero-posterior splints complete the reduction. Dressings and splints must be recognized as mere factors in immobilization, and *never* regarded as the means of reduction. If a fracture is properly reduced it will be difficult to alter its position, and splints applied without pressure or a flexed position just short of complete flexion will be ample to ensure adequate immobilization. If the fingers are swollen and cannot be moved painlessly, partial ischemia should be suspected, even in the absence of pain.

When ischemia is suspected or discovered every constriction of the extremity must be removed. Gentle massage, slight passive movements and electrotherapy should be freely employed. Any immobilizing material should be carefully applied to avoid pressure or constriction, and the extremity elevated. (In many cases the application of hot moist dressing kept warm by the use of an electric light in the form of a therapeutic lamp gives great relief, in others dry heat seems preferable or a change from moist to dry may be best—Ed.) Accurate position of the fragments must be subordinated to all measures that may restore or improve circulation to the part affected.

When contracture and fibrosis have occurred, massage, passive motion and electricity, with apparatus such as wire splints applied to correct the deformity, will accomplish much. Gradual stretching of the contracted flexor muscles and tendons by rigid splints, long advocated by Jones,[1] often gives surprising results. First the fingers are stretched and held by splints, then the wrist, until both hand and fingers are hyperextended. Taylor's[2] elastic-traction method may also be used: "The essential feature lies in putting the traction of rubber elastic against the resistance of the contractured cicatricial tissue." An adjustable brace in the "cock-up" or extended position of the wrist is used as a frame to which the contracted flexed fingers are gradually drawn by elastic bands (Figs. 41 and 42). This is removed daily for immersion in hot water for twenty minutes, massage and active and passive motion.

Flexor tendon transplantation or lengthening and the shortening of the ulna and radius by removal of a section of their shafts to conform to the shortened flexor tendons have fallen into the discard. Infection following operation results more readily in these tissues of reduced vitality, and the success in treatment depends after all entirely upon restoration of function of the affected muscles for which non-operative measures in the end are required.

[1] Ann. Surg., 1917, lxv, 28. [2] Ibid., 1909, xlix, 330.

However, when, after complete stretching, paralysis and evidence of nerve injury still persist, operative exposure of the nerve affected should be undertaken—the lesion is usually found close to the elbow-joint or at the site of fracture—and repair made as may be indicated—transplantations or simple freeing from scar tissue.

It may take many months to effect a complete cure and return of function must not be despaired of as long as any improvement, be it even slight, can be detected.

4. *Myositis ossificans* is a condition that results from trauma in and about the elbow, tearing muscle from bone, and with it bits of periosteum and osteoblastic tissue, which deposit bone in muscle or along the intermuscular septa. It is especially observed at the insertion of the brachialis anticus, in the biceps and lower part of the triceps muscles, and frequently occurs with a simple posterior dislocation of the elbow (Jones).

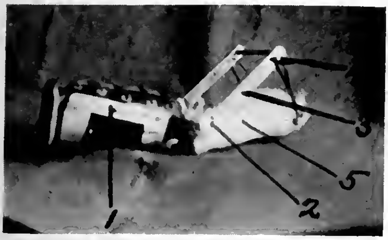


FIG. 41.—*1*, the sleeve portion of the brace extending from the elbow to wrist, made of steel and leather; *2*, an adjustable joint so that the direction of the traction may be changed as improvement occurs; *3*, adjustable offset; *4*, projecting knob to hold the elastic loop running to *5*, a pad to which the hand and fingers are bound when in full extension. This is done after the primary stretching is done. (After A. S. Taylor.)

FIG. 42.—Brace applied. This brace has no adjustable joint at the wrist like the improved one in the preceding figure. (A. S. Taylor.)

Unless systematic roentgenographs are taken it may not be suspected until four or five weeks after injury—the range of motion in the elbow becomes restricted instead of increasing and a thickening or callus deep in the lower biceps or triceps muscles may be palpated. The roentgenograms will confirm the vicarious deposit of bone.

Myositis ossificans is a serious complication because when osteogenesis has actually taken place there is very little that can be done. Operative removal of the new bone has been uniformly unsatisfactory, as there is prompt recurrence, and usually increase in impairment of function. Treatment is largely prophylactic. Care must be taken in the inauguration and conduct of passive motion of the elbow following injury, thus avoiding the stimulus to bone growth of early and overzealous efforts at manipulation. (Jones's rules for elbow movement are exceedingly valuable and should be followed.[1])

[1] Vide supra.

FRACTURES OF THE FOREARM.

Fractures of the forearm may be divided into:

1. Fractures near the elbow.
2. Fractures of the shafts of the radius and ulna.
3. Fractures near the wrist.

1. Fracture of the radius and ulna at or near the elbow, may be:
   (*a*) Fracture of the coronoid process of the ulna.
   (*b*) Fracture of the olecranon process of the ulna.
   (*c*) Fracture of the head or neck of the radius.
   (*d*) Fracture of the upper third of the ulna with dislocation of the head of the radius.

(A) **Fracture of the Coronoid Process of the Ulna.—Occurrence.**—Fracture of the coronoid process occurs more commonly with backward dislocation of the elbow but cases of fracture of the coronoid process alone have been reported: Kelly himself has observed 3 (Roberts and Kelly[1]). It is probable that fracture alone is of more frequent occurrence than is usually believed.

Etiology.—It may result from: (*a*) A fall upon the hand with the forearm partially flexed—the force being transmitted along the ulna to drive the coronoid process sharply against the trochlear surface of the humerus. When the force is great, posterior dislocation may result. (*b*) A tear fracture—by evulsion—when the brachialis anticus muscle, which is inserted in it, is forcibly contracted against resistance. (*c*) Hyperflexion of the forearm.

Pathology.—This fracture is a transverse separation of the base or tip of the process. In a tear fracture the tip is torn away. As the result of indirect violence or with posterior dislocation the base is fractured. There is but little displacement except with dislocation of the elbow, when the fragment of the coronoid process is carried anteriorly with the lower end of the humerus.

Diagnosis.—There is no characteristic symptomatology of this fracture. Swelling and tenderness on the anterior surface of the elbow over the coronoid process may be present and hyperextension may be painful. Crepitus will rarely be elicited.

With posterior dislocation, tendency of the dislocation to recur following reduction should suggest the presence of coronoid fracture. Positive diagnosis can be made only by the roentgenogram.

Treatment.—Simple fracture without displacement will require immobilization of the forearm in hyperflexion for two or three weeks. Then cautiously, in order to avoid excessive callus formation, passive motion and massage may be employed.

Fracture accompanying posterior dislocation of the elbow is also best immobilized in hyperflexion after the dislocation has been reduced. Accurate reduction can usually be obtained. If displacement of the fragment persists, resection may be necessary, in order to prevent permanent interference with elbow function from malunion.

[1] Fractures, 1916.

(B) **Fracture of the Olecranon Process.**—**Etiology.**—Fracture of the olecranon process is not very common; it usually results from a fall directly upon the flexed elbow—direct violence.

Fig. 43.—Epiphyseal separation of the olecranon process of the ulna.

Fig. 44.—Fissured fracture of the olecranon of the ulna. Comminuted fracture of the head and neck of the radius.

Very rarely a sudden, sharp contraction of the triceps muscle will tear off the tip of the olecranon process into which this muscle is inserted—muscular action.

The fracture may result from the combination of a direct injury and the contraction of the triceps muscle.

Pathology.—The fracture is always transverse; only the tip of the olecranon may be torn away (Fig. 43), or a true epiphyseal separation or a complete fracture involving the elbow-joint may occur (Fig. 44). With a severe, direct injury there may be marked separation of the fragments, comminution or an open wound; with moderate or indirect violence the separation may be very slight.

The amount of the separation depends upon two factors: Laceration of the deep fascia and position of the forearm. When there is extensive laceration of the overlying fascia and joint capsule the pull of the triceps is not restrained and wide separation results; with the fascia intact, though the fracture be complete, very little alteration in the position of the fragments is possible. Extension tends to approximate the fragments; flexion draws them asunder.

Diagnosis.—The diagnosis is not difficult in complete fracture. The symptoms and signs are:

1. Pain in elbow.
2. Swelling of the posterior surface of the elbow. The prominence of the point of the elbow may be displaced upward.
3. Tenderness over the olecranon.
4. Fragment margins and the gap between the fragments are palpable, and crepitus may be elicited by the approximation of the fragments with the forearm extended.
5. Flexion of the forearm is painful, and voluntary extension difficult or impossible.

Simple fissured fracture or a tear fracture may be suspected when there is much local tenderness, but will require a roentgenogram for definite identification.

Prognosis.—With accurate approximation of the fragments the prognosis, even in operative cases, is good. Union, however, may be fibrous. Return of elbow function is usually complete, though full extension may not be obtained.

Treatment.—1. In fracture without displacement, immobilization on a wooden or wire right-angled splint will suffice.

2. In fractures with but moderate or slight displacement, extension of the forearm on a long anterior splint and fixation of the olecranon fragment by adhesive strips may give satisfactory approximation. Immobilization must be just short of complete extension. The splint should extend from axilla to finger-tips, and be especially well padded at the elbow and wrist. It is held in position by three bands of adhesive plaster: one at the wrist, one at the elbow and one in the middle of the arm. A roller bandage completes the dressing (Fig. 45).

3. In cases of extensive injury to the elbow in open or compound fractures, and where there is marked displacement of the olecranon

and simple extension will not suffice, open operation is indicated. A longitudinal incision is made over the fracture site, the joint cavity is gently freed from clot and débris, the fragments brought into apposition and held in place by kangaroo tendon sutures—either through drill holes in the bone substance or, preferably, through the overlying periosteum, fascia and tendon of the triceps. Immobilization in extension, as for simple fracture, is then made by a long anterior splint.

The Murphy[1] subcutaneous method may occasionally be indicated. Four small longitudinal incisions, 1 cm. in length, are made in the form of a rectangle, on opposite sides of the two fragments. Each fragment is perforated by transverse drill holes. Kangaroo tendon or wire is threaded through them, and between them, subcutaneously,

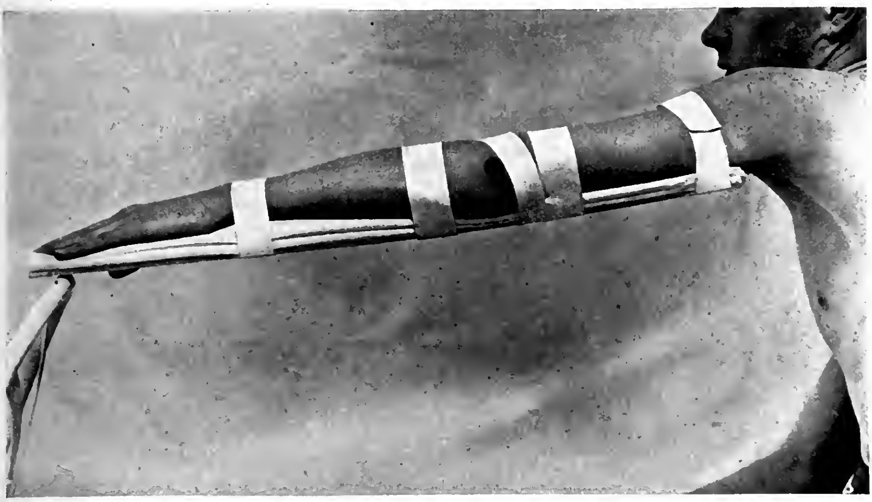


FIG. 45.—Posterior splint and dressing for closed reduction. Fracture of olecranon. Note oblique strip of adhesive holding fragment in position. (Roberts and Kelly.)

the ends tied, cut off and the knot buried. A single suture is sufficient to close each wound.

After-treatment.—The dressings are inspected and changed from time to time, as may be indicated by disarrangement or uncleanliness. The forearm is kept in extension four weeks. The splint is then removed and gentle, passive movement and massage cautiously begun. A roller bandage is applied to lend support to the extremity, but as soon as flexion of the forearm to a right-angle is possible a sling should be used. Movement of the elbow should be normal at the end of six or eight weeks.

(C) **Fracture of the Head or Neck of the Radius.**—Fracture of the head or neck of the radius belongs to that group of periarticular

[1] Jour. Am. Med. Assn., 1906, xlvi, 257.

lesions formerly regarded as rare but which systematic study of roentgenographs has shown to be not infrequent. Of 23 cases observed by Plageman, 4, and of 18 cases studied by Roberts, 9, involved the neck alone (Roberts[1]).

Etiology.—1. Direct violence—a blow or fall upon the radial head or neck. Direct crushing of the elbow-joint.

2. Indirect violence—a fall upon the pronated hand, with the forearm extended and the force of the impact transmitted largely along the radius, is the most common cause. In rare instances sharp abduction of the forearm may be responsible.

Fig. 46.—Fracture of the upper third of the ulna; fracture of the neck of the radius.

Posterior dislocation of the elbow may be accompanied by radial head or neck fracture. The greater the activating force, the more likely is fracture of the neck.

Pathology.—Fracture of the head is intracapsular and may be longitudinal, oblique or transverse; it is frequently impacted or comminuted. If the orbicular ligament remains intact there is but little displacement. Separation along the epiphyseal line may occur when the ligament is ruptured. The fragment may be displaced downward distally, backward or upward, and lie almost free in the joint cavity.

Fracture of the neck may be transverse or diagonal (Fig. 46); it

[1] Fractures, 1916.

is also frequently fragmented. If diagonal or longitudinal it may be both intra- and extracapsular, and may accompany a fracture of the head. The upper fragment may be impacted or rotated outward or displaced forward and inward.

Diagnosis.—Fracture of the radial head or neck may be recognized by:

1. Pain and swelling over the head of the radius and the anterior surface of the elbow.
2. Voluntary pronation, supination and flexion of the forearm is quite painful and limited.
3. The head, or a fragment, is found not to move with the shaft on passive pronation and supination.
4. Crepitus by passive pronation and supination.
5. Palpable displaced fragment.

This fracture must be differentiated from simple subluxation or dislocation of the head of the radius. With dislocation there will appear a prominence $\frac{1}{2}$ cm. below and internal to the external condyle which moves with the radial shaft on pronation or supination of the forearm. The alignment of the radius will be unaltered though the radial head is not palpable in its normal position.

In the majority of cases a roentgenogram can alone establish the diagnosis, especially when there is great swelling about the elbow-joint, when the fracture is impacted, or in multiple fractures in and about the elbow.

Prognosis.—With displacement better results are obtained by excision. Hitzrot[1] has shown that impairment of function is likely in non-operative cases. In 13 out of 15 cases there was loss of half of rotation, *i. e.*, pronation and supination. Four operative cases showed better function, especially when the entire head was excised. Thomas[2] reports 12 out of 18 non-operative cases which exhibited either non-union, ankylosis or markedly impaired function: In 8 of the 18 cases non-union resulted.

Treatment.—Careful study of the roentgenogram should precede attempts at reduction.

1. In some of these fractures there is little if any displacement. In minor displacements, to obtain approximation, strong supination and direct pressure upon the head of the radius, with the forearm in flexion to a right-angle will suffice. Immobilization in hyperflexion and supination for three weeks should follow. Passive motion and massage may then be begun.

2. In those fractures with marked displacement or comminution, where the orbicular ligament has been torn, accurate reposition and fixation of the fragments by manipulation is practically impossible. If the fragment is allowed to remain displaced, excessive callus forms and malunion will result, leading to permanent disability. It is best, therefore, to excise the displaced fragment or the entire head of the

[1] Ann. Surg., 1912, lv, 353.
[2] Univ., Pa. Med. Bull., 1915, xxviii, 184 and 221.

radius. Care should be taken to preserve the orbicular ligament. Passive motion should be begun as early as the fifth day after excision and very gently and gradually increased.

From the statistics available it would seem that resection is too seldom practised. Jones[1] states that resection is especially indicated when the head of the radius is dislocated as well as fractured and when supination cannot be or is not easily obtained.

When non-union of a fragment occurs, arthrotomy and removal of the fragment or fragments, or the entire head, is the procedure of choice.

(D) **Fracture of the Upper Third of the Ulna with Dislocation of the Head of the Radius.**—Dislocation of the head of the radius may occur not only with fracture of the upper third of the ulna but with fracture of the middle third as well.

Etiology.—It is usually the result of a direct injury or blow to the posterior surface of the upper forearm.

Pathology.—The head of the radius is displaced inward and forward. The upper fragment of the ulna similarly is displaced inward and upward. The fracture is transverse or irregularly oblique.

Diagnosis.—The fracture of the ulna is usually obvious. With much swelling of the forearm and elbow or in a stout subject the dislocation may be overlooked. An anterior prominence just below the cubital fold on the radial side, however, is significant. The radial head will not be found in the same relationship to the external condyle as on the sound side. Attempts to rotate the radius may produce pain at the site of the ulnar fracture.

Pain, swelling and ecchymosis at the fracture site, with alteration in alignment of the ulna, palpable fragment margins, and crepitus, with abnormal mobility of the upper fragment, make the fracture unmistakable.

Roentgenograms in two diameters, or stereoscopic plates, are especially necessary in all fractures of the upper third of the ulna, to facilitate detection of concomitant radial head subluxation or dislocation.

Treatment (after Ashhurst[2]).—Reduction of the dislocated radial head is the primary consideration: The fractured ulna may be *temporarily* ignored.

If the head of the radius cannot be replaced by simple forceful supination with direct pressure, operation should be undertaken and accurate reposition obtained. The forearm may then be acutely flexed and supinated and attempts made, by gentle manipulation and direct pressure, to reduce the ulnar fracture. If there is angulation of the fragments and proper alignment cannot be obtained, or if encroachment upon the interosseous space persists the ulna may be exposed—in the meantime maintaining the flexed and supinated position as far as possible—and the fragments brought into apposition and held by kangaroo-tendon suture, plate, bone-graft or intramedullary splint.

[1] Injuries of Joints. Oxford War Primers, 1915.
[2] Ann. Surg., 1912, lvi, 631.

Flexion and supination are maintained by a roller bandage, reinforced by a few turns of a plaster-of-Paris bandage.

In cases of long standing, when the ulna has united and dislocation of the radius persists, arthrotomy, reduction of the head of the radius and capsulorrhaphy are indicated. If reduction is impossible the head should be excised. For extreme deformity of the ulna, osteotomy may be necessary.

When there is non-union of the ulna with persistent dislocation, the ulna fragments may first be freed, followed by open operation to reduce the radial head, and finally the ulnar fracture may be sutured or an Albee bone graft or intramedullary bone splint used.

Three weeks after operation passive motion may be begun and gentle massage undertaken, with gradual decrease of flexion at the elbow. The time necessary for complete restoration of function will depend upon the individual case.

Fractures of the Shaft of the Radius and Ulna.—Fractures of the shaft of the radius and ulna may occur in:

1. The upper third.
2. The middle third.
3. The lower third.

Fractures of the upper third are infrequent; fractures of the lower third or near the juncture of the lower and middle thirds are most common. Fractures involving either the radius or ulna alone occur quite often, due usually to direct violence.

Etiology.—1. Direct violence—a fall with the forearm striking an irregular object, or a blow upon, or crush or squeeze of the forearm.

2. Indirect violence—a fall on the outstretched hand with the forearm extended.

3. Muscular action—very rare.

Some form of direct violence is the most common cause of these fractures.

Pathology.—The fractures are almost always transverse or slightly oblique, but may be spiral or longitudinal and, not infrequently, comminuted and compound. In children, bending, partial or greenstick fractures are seen. From direct injury the bones are fractured at the same level: from indirect violence at different levels—the ulna usually nearer the elbow than the radius. Some displacement is almost invariable; overriding is common.

The displacement of the fragments varies with the location of the fracture. In the upper third the upper radial fragment is thrust upward toward the palmar surface and rotated outward, due to the action of the biceps and supinator brevis muscles; and the ulnar upper fragment is displaced inward and upward, due to the action of the brachialis anticus, pronator radii teres and supinator brevis muscles. In the middle third the displacement depends upon the relation of the fracture site to the insertion of the pronator radii teres: if the fracture lies above, the upper fragment of the radius is displaced, as in upper third fracture, *i. e.,* anteriorly toward the palmar surface and outward or laterally, and the ulnar upper fragment similarly inward toward the radius, and upward or anteriorly; if below the insertion of the pronator teres, the upper radial fragment is carried inward and toward the flexor surface and the ulnar upper fragment may be carried either inward and anteriorly toward the palmar surface or externally and anteriorly. In fracture of the lower third the lower fragment of the radius is drawn over toward the ulna by the action of the pronator quadratus muscle and the lower ulna fragment is displaced outward and toward the extensor surface.

With overriding and persistent displacement the possibility of union of the lower radial callus with the upper ulnar callus always exists. In comminuted, multiple and compound or open fractures, which are not uncommon, atypical displacement may occur.

Diagnosis.—In complete fracture of both bones of the forearm the diagnosis is usually obvious.

The chief manifestations will be:

1. Pain, swelling and deformity of the forearm.
2. Abnormal mobility and crepitus at the fracture site.
3. Margins of the bone fragments palpable or protruding.
4. All movements of the wrist will be painful; active pronation and supination impossible. Passive attempts at pronation and supination will produce pain and crepitus at the seat of the fracture.
5. In complete unimpacted radius fracture, the head of the radius will be found not to rotate, even with considerable excursion of the lower radial shaft.

In partial or incomplete fracture of the radius and ulna, such as a greenstick fracture—unless a bending deformity be present—the diagnosis may be quite uncertain. *Local swelling and tenderness on palpation should be sufficient to arouse suspicion.* A roentgenogram will be necessary to make the diagnosis certain.

The roentgenogram—preferably stereoscopic plates, but failing these both antero-posterior and lateral views—should invariably be made to ascertain the exact displacement. Judgment of proper treatment and reduction may be made far more intelligently with this assistance.

Fracture of the lower or middle third of the radius alone must not be overlooked, especially if there be displacement: The lower fragment is drawn inward toward the ulna by the pronator quadratus. Overriding of the fragments is not infrequent, and, unless corrected, may be followed by impaired pronation and supination. With overriding there may also be abduction deformity at the wrist which is increased if the distal end of the ulna is dislocated outward. With obvious deformity the diagnosis is not difficult, but, with much local swelling, displacement and even overriding may be unobserved. With crepitus absent and with the ulna definitely intact, suspicion of fracture may be lulled. Upon the subsidence of the swelling the fracture may finally be discovered, with a callus large enough to interfere with the rotation necessary for pronation. Open operation will then be required for correction. Every local swelling, tenderness or contusion over the radius or ulna, should in themselves demand a roentgenograph, to prove or rule out the presence of fracture. If recognized early the radial displacement can be corrected and the dislocated ulna easily reduced by traction and adduction of the hand with local manipulation. If the ulnar dislocation remains unrecognized it will seriously interfere with late reduction of the radius. Even with open operation reduction will be exceedingly difficult.

Prognosis.—Fractures with but little permanent displacement and those in which anatomical restitution has been obtained should recover complete function. Excessive callus formation is to be avoided. Open operation should be performed in all doubtful adult cases. Early reduction assures a good result in a high percentage of cases. With late reduction, especially in adults, return of function may be slow. With marked displacement persisting and operation contra-indicated or refused, the likelihood of a return to complete normal function is small.

Treatment.—In the treatment of fracture of the shafts of the radius and ulna the retention or reacquisition of pronation and supination of the forearm, as well as the movements of the wrist and fingers, must be kept in mind. Displacement of fragments sufficient to encroach markedly upon the interosseous space, so that a resulting callus will impinge upon or approach the shaft of the adjacent bone, will most seriously interfere with the rotation of the radius about the ulna. Displacement so that the callus of the radial fracture may unite with the callus of the ulna fracture is especially inimical to proper function. It is therefore imperative, in fractures of the shafts of the radius and ulna, with marked or excessive interosseous displacement, to obtain *adequate* reduction.

However, in cases in which at least two-thirds of the diameter of the bones is in contact and the interosseous space is comparatively free, conservative measures should suffice. Manipulation and attempts at betterment in moderate displacements, providing alignment is good (especially in transverse fractures), are exceedingly precarious and, though possibly successful in skilled hands, may lead to a worse deformity in the hands of the unwary and make operative interference necessary in a case where a good functional though not a perfect anatomical result could have been expected.

For fractures where less than two-thirds of the diameter of the bone is in contact, but with no overriding, attempts at closed reduction by traction and manipulation under a general anesthetic are justifiable. Absolute anatomical restitution will seldom be obtained and it is not necessary for perfect functional result; but reduction should be considered a failure if the interosseous space is invaded by one or more fragments or the fragments are not in contact by at least one-half of their diameter. Ashhurst,[1] and Whipple and St. John[2] have shown that proper manipulatory reduction will suffice in the majority of

[1] Trans. Phila. Acad. of Surg., 1912, xiv, 1.
[2] Surg., Gynec. and Obst., 1917, xxv, 77.

cases, especially in children or young adults even if displacement persist.

In badly displaced and overriding, oblique or transverse fractures, open reduction is almost always necessary, though closed reduction may be first attempted. Especially in adults, early operation—as soon as the shock of the original injury is over and reparative action is beginning, within twenty-four to forty-eight hours or even as late as the fourth day—will usually prove the best procedure. With early operation there is less interference with normal repair, easier manipulation and traction of fragments is obtained and there is less likehood of delayed union. Much of the discredit appertaining to operative interference—delaying or preventing union—may be laid at the door of late operation, disturbance of callus already well inaugurated and the delay in resumption of repair after having been interrupted. With *early* open operation there is no difficulty in obtaining accurate apposition of fragments and no callus nor bone reparative processes to disturb.

Closed Reduction.—Closed reduction is much more likely to succeed when attempted soon after the accident, preferably within the first twenty-four hours.

METHODS.—1. *Splints.*—The forearm is held in extreme supination by an assistant, who grasps the hand of the patient as in shaking hands and traction is made, with countertraction on the arm by a second assistant. Palpation by the operator should confirm the roentgenographic findings of displacement and, by direct pressure on the fragments, better position should be obtained. The fluoroscope has been shown greatly to facilitate accurate restoration of the fragments. (Whipple and St. John.[1]) Well-padded antero-posterior splints are then applied for immobilization and held in place by adhesive strips. The palmar splint must extend from the metacarpo-phalangeal joints to within 3 cm. of the elbow, and the dorsal splint from the midmetacarpal region to 3 cm. below the olecranon. In cases of upper third or middle third fractures, instead of the simple palmar splint, an internal right-angled splint to immobilize the elbow should be used. These splints should be as wide as the forearm and should be very carefully and completely padded, especially at their ends, at the wrist, the elbow and at the fracture site. Three strips of adhesive plaster, about 5 cm. in width, should be used to hold them in place: one at the wrist, one in the middle third and one in the upper third of the forearm; also one above the elbow when a right-angled splint is used. A properly fitting roller bandage completes the dressing (Figs. 47 and 48). Extreme care must be taken to avoid drawing the adhesive plaster too tight. Some sag should occur when firm pressure is made upon the splints, which, be it remembered, are used *not to reduce* but merely to *maintain* the reduction. Too great pressure rapidly leads to local slough and is followed by Volkmann's contracture—an entirely

[1] Surg., Gynec. and Obst., 1917, xxv, 77.

avoidable calamity. The zeal inspired by a successful reduction and an enthusiastic desire to prevent change in position must never cloud

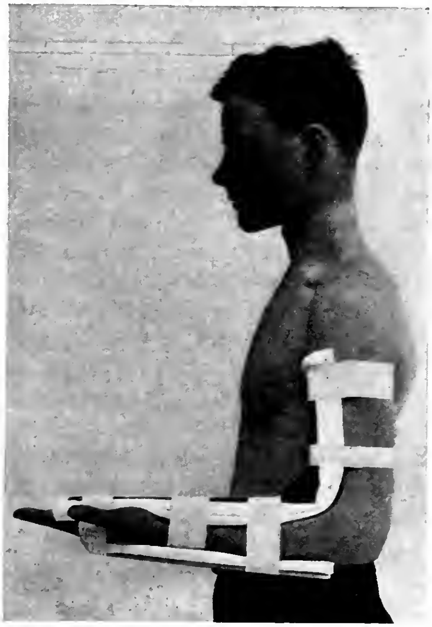


FIG. 47.—Dressing for upper and middle third fracture of shafts of radius and ulna. (Roberts and Kelly.)

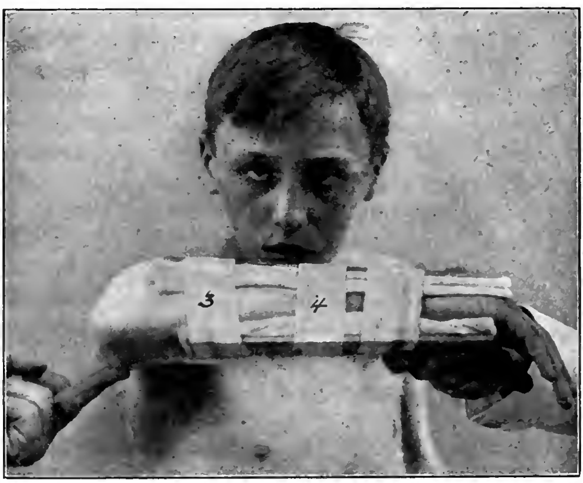


FIG. 48.—Dressing for lower third fracture of shafts of radius and ulna. (Scudder.)

the paramount necessity for avoiding pressure on the forearm by the splints.

2. *Plaster.*—A plaster cast or molded gypsum splints may be use for the primary dressing. Hitzrot[1] and Whipple and St. John[2] especially advocate Stimson's[3] molded antero-posterior "sugar tongs" splint. Sufficient padding should be used about the wrist, elbow and fracture site and excessive constriction avoided.

3. *Traction and Suspension.*—The advantage of traction and balanced suspension for treatment of *closed* fractures of the forearm, except when badly comminuted, remains to be demonstrated. It should certainly be tried in cases in which operation is contra-indicated or refused and in which overriding and displacement persist after efforts at reduction. It is distinctly indicated in comminuted fractures in which several or more fragments separate the terminal portions of the shaft. Blake's simple cradle suspension, with antero-posterior traction straps and countertraction at the elbow, is probably the best. The forearm should be held in full supination. The bent Thomas splint, as Blake also suggests, will serve as an ambulant traction apparatus and may be used after weight-traction has overcome the shortening and *union has begun.*

Open Reduction.—A separate incision is made over each fracture; the ulna should be exposed first as it holds the fixed position, the radius rotating around it. When it is secured the radius in turn may be exposed and its fragments brought into apposition.

Fixation of the fragments of both radius and ulna can be made by: (1) Metal plates fastened by screws or pegs. (2) Inlay bone graft (Albee). (3) Kangaroo suture through drill holes. (4) Intramedullary bone splint.

Preference is based largely upon individual experience, but the modern tendency seems to be away from foreign unabsorbable fixation material toward the bone graft or splint or the kangaroo tendon suture. For forearm fractures the intramedullary splint is especially useful. Following operation, with the elbow at a right-angle, a plaster cast is applied from the metacarpo-phalangeal joint to the lower third of the arm.

After-treatment.—If, in the first twenty-four hours after reduction, there is any swelling or cyanosis of the fingers, or if pain in the affected forearm is so severe as to prevent sleep, the fixation apparatus should be loosened, *i. e.*: (*a*) In the case of splints a complete lateral slit is cut in the dressing with bandage scissors, including not only the bandage but the adhesive strips, and another bandage is applied more loosely over the dressing.

(*b*) In the case of a cast, local pressure over the thumb or dorsum of the hand may cause pain and may be relieved by separation of the superimposed part of the cast. If no local tenderness is present or if such partial severance seems insufficient and pain and swelling are unrelieved, the cast and all bandages should be completely cut, allowed to gape and again lightly rebandage. In any doubtful case complete

[1] Ann. Surg., 1912, lv, 353.
[2] Surg., Gynec. and Obst., 1917, xxv, 77.
[3] Fractures and Dislocations, 1917.

division of all restraint should be practised. This procedure does not necessarily alter the position of the fragments, and the possibility of causing a Volkmann contracture by ignoring symptoms of pressure should not, and must not, lead to hesitancy in removing what may have been considered a permanent dressing.

Careful observation for at least forty-eight hours after the application of the fixation apparatus is imperative, so that relief of pain or pressure may be immediate. At the end of this time if the patient is comfortable the dressing as applied may be regarded as permanent. Following an open operation the patient should remain in bed for at least three days. Movement of the fingers should be encouraged during the entire convalescence. Daily observation of dressings should be made so that soiled or loose bandages may be changed or a loose or soiled cast may be removed, and a properly fitting one be applied, as rest atrophy supervenes or local swelling subsides.

At the end of three weeks all apparatus should be removed and passive motion begun. A single splint will suffice or the cast may be rebandaged in place for another week, but is removed for daily massage and gentle passive motion. Then only a simple roller bandage, with a sling for the support of the forearm, will be necessary. At the end of five weeks all support may be cast aside and active movement encouraged. Massage and passive motion should also be persisted in until all active movements are normal—especially pronation and supination.

The usual disability period for a simple fracture is eight to ten weeks.

Complications.—The complications of radial and ulnar shaft fractures may be:

1. Suppuration.
2. Mal-union.
3. Non-union and delayed union.
4. Volkmann's contracture.
5. Gangrene—laceration of radial and ulnar arteries.

1. *Suppuration* may occur with open fracture or following open reduction of a closed fracture.

2. *Mal-union.*—When mal-union has caused marked impairment in pronation and supination, such as results from union of the radius lower fragment with the ulna upper fragment or from excessive callus and fixing of the radial with the ulna seat of fracture or when excessive callus of the radius may impinge upon rotation on the ulna, thus preventing complete pronation, open operation, with removal of excessive or interfering bone growth, or refracture, approximation and suture or a bone inlay is indicated.

3. *Non-union and Delayed Union.*—In a small series of 45 radius and ulna shaft fractures there were 11 cases of delayed union and 1 of non-union, divided as follows:

		Delayed union.	Non-union.
Upper third . . .	8	1 (12 per cent.)	1 (12 per cent.)
Middle third . . .	9	3 (33 per cent.)	
Lower third . . .	28	7 (25 per cent.)	

It would be unwarranted to draw conclusions from the single case of non-union in the upper third of the ulna, but it seems fair to infer that *delayed* union is more prone to occur in the distal half of the radius and ulna. The bones here are less protected, more exposed to injury and more likely to have compound comminuted fractures, with resultant osteomyelitis, a well-known cause for delay in fracture repair. Syphilis, as an etiological factor in delayed union, must always be reckoned with. Plating is much less likely to cause delay in the forearm than in the lower extremity. Careful treatment of compound fractures, early and accurate reduction, and a routine Wassermann in all fractures, will do much to eliminate delayed union as well as prevent the occurrence of non-union.

For non-union, with exposure of the fracture site, removal of any tissues interposed and excision of all fibrous tissue about the fragment ends, an inlay graft is almost a specific. Chutro has laid emphasis upon the fact that a thin graft is more advantageous and more likely to be successful. (Willard.[1]) Intramedullary bone splinting also gives very satisfactory results.

4. *Volkmann's Contracture* will require the treatment as outlined under Fractures of the Lower End of the Humerus (page 84).

5. *Severe Crushing of the Forearm,* involving both radial and ulnar vessels, usually leads to gangrene of the hand; amputation is obviously necessary. If one artery is intact, conservative measures are usually successful.

Fractures of the Forearm Near the Wrist.—Fracture at or near the wrist-joint is one of the most common of all fractures.

The consistent use of roentgenography in injuries about the wrist has demonstrated the presence of many fractures in lesions usually considered sprains, and has revealed a surprisingly large variety of fractures heretofore unknown. Likewise the so-called Colles's fracture has been shown, from the study of roentgenographs, to be not a single definite entity but a deformity produced by a number of different lesions; it would seem therefore that the term "Colles's fracture" should either be abandoned or merely used to indicate the *type of deformity* that often results from these fractures.

Classification of fractures near the wrist may be made on the basis of (A) the anatomical lesion, (B) the deformity produced as:

A. 1. Fracture of the diaphysis of the radius and ulna close to the epiphyseal line.

2. Fracture of the styloid process of the radius.

3. Fracture of the styloid process of the ulna.

4. Fracture of the radius (diaphysis); epiphyseal separation, or comminution of the epiphysis, with or without fracture of the styloid process of the ulna.

5. Separation of the epiphyses of both radius and ulna.

6. Longitudinal fissured fracture of the radius.

[1] Ann. Surg., lxxi, 182.

7. A combination of one or more of the above fractures with or without fracture of one or more carpal bones.

B. 1. Fractures with simple swelling about the wrist without deformity.

2. Fractures with "Colles's fracture" or "silver-fork" deformity.

3. Fractures with reversed Colles's or "Smith's fracture" deformity.

It is readily understood that a lower radial fracture, when simply fissured, may show no deformity; but the identical fracture, with displacement of the fragments, may show a Colles's or reversed Colles's deformity. It will be convenient, therefore, to discuss these fractures grouped according to their deformities.

Fig. 49.—Fracture of the styloid of the radius.

Etiology.—*Direct Violence.*—A blow near the wrist from a heavy falling object; less commonly, a crush or squeeze of the wrist.

Indirect Violence.—By far the most common cause is a blow or fall upon the hand, with the type of fracture depending upon the position of the hand at the time of the fall—whether flexed or extended, abducted, or adducted; or a "kick-back" against the hand while cranking a motor (chauffeur's fracture).

Pathology.—A. In the fractures without deformity the lesions of the *radius* may be:

1. Oblique or transverse fracture through, or separation of, the entire styloid process—such as the "chauffeur's fracture" (Fig. 49).

2. An extension fracture or Barton's fracture—a chipping off of the posterior lip of the articular surface of the radius.

3. A flexion fracture or reversed "Barton's fracture"—a chipping off of the anterior lip of the articular surface of the radius.

4. Multiple fracture of the epiphysis—often with longitudinal fissures extending up into the diaphysis.

5. Slight epiphyseal separation.

6. Transverse fracture of the diaphysis just proximal to the epiphysis.

The ulnar lesions may be:

1. Fracture through the tip of the styloid process (Fig. 50).
2. Fracture through the base of the styloid process.
3. Transverse fracture above the epiphysis or epiphyseal separation.

Fig. 50.—Fracture of the styloid process of the ulna. Multiple fissured fracture of the epiphysis of the radius.

All these fractures may occur singly or a number of them may occur simultaneously. Fracture of the radial styloid and multiple fractures of the epiphysis are most common. Epiphyseal separation is quite rare.

B. The "Colles's" or "silver-fork" deformity results from an extension fracture—a fall or blow upon the hand in extension in which, as Pilcher has described, there is not only impact of the carpus against the lower end of the radius but there may be also splitting of the lower radial fragment by the descent of the upper fragment into it. The impact upon the lower end of the radius results in backward displacement of the lower fragment with, at times, outward displacement and a movement of rotation of the lower fragment in the direction of supination. There is usually a transverse fracture of the radius just above the epiphysis, within 2 or 3 cm. of the wrist-joint, with or without comminution or impaction of the fragments. There may be radiating or longitudinal fractures of the epiphysis or of the radial shaft, fracture in the epiphysis alone, fracture of the radius in the lower third, or simply a separation of the epiphysis (Figs. 51 to 53). Associated with any of these there may be:

Fig. 51

Fig. 52

Figs. 51 and 52.—Impacted fracture of the lower end of the radius; fracture of styloid of the ulna; slight Colles's deformity. Fig. 51, lateral view; Fig. 52, antero-posterior view.

1. Fracture of the base or tip of the styloid process of the ulna.
2. Separation of the ulnar epiphysis.
3. Laceration of the triangular, interarticular cartilage and internal lateral ligament of the ulna.
4. Fracture of the ulnar diaphysis just above the epiphysis.
5. Fracture of the scaphoid or semilunar.
6. Dislocation of the os magnum.

In children there may be a type of greenstick fracture in which there is anterior bending or bowing of the radius just proximal to the epiphysis. The lower fragment is not separated from but tipped anteriorly with the upper fragment (Figs. 54 and 55). Rarely, simple swelling of the soft parts may give a typical "Colles's deformity" without any bony displacement.

The outline of the forearm, wrist and hand resembles a silver fork, due to the lower fragment of the radius being displaced dorsally toward the extensor surface and the upper fragment anteriorly toward the palmar surface. Sometimes the lower fragment is also displaced laterally away from the ulna and rotated in the direction of supination,

Fig. 53.—Separation of the lower epiphysis of the radius. Colles's deformity. (Roberts and Kelly.)

causing abduction of the hand. When the styloid of the ulnar is involved the tip will be drawn distally by the contraction of the attached ligaments.

C. The reversed Colles's deformity results from a flexion fracture. It is comparatively rare. Cases have been described by Smith,[1] Roberts,[2] Pilcher[3] and Hitzrot.[4] The radius is fractured at or near the

[1] Fractures in the Vicinity of the Joints, 1847, p. 162.
[2] Tr. Am. Surg. Assn., 1896, xiv, 611.
[3] Ann. Surg., 1917, lxv, 1.
[4] Ibid., 1915, lxi, 740.

epiphysis, the lower fragment is displaced anteriorly toward the palmar surface and the upper fragment and the end of the ulna dorsally,

Fig. 54.—Abduction angulation in bending fracture of the radius near wrist, with separation of lower ulnar epiphysis.

increasing the normal radial curve of the flexor surface (Fig. 56). With this fracture there may also be fracture or dislocation of one or more carpal bones.

Fig. 55.—Bending fracture of the radius near the wrist. Colles's deformity.

Diagnosis.—1. *Fracture Without Displacement.*—Swelling of the wrist extending up the forearm and localized pain are suggestive. Movement of the wrist may be limited and painful. Localized tenderness, on palpation over the lower end of the radius and ulna, is the most definite evidence. The suspicious area may be located more accurately by comparison with the sound side.

No crepitus will be obtained. These fractures resemble sprains and cannot be differentiated from them except by persistent definite local tenderness. Absolute diagnosis can be obtained only by the roentgenogram. All supposed sprains therefore should be roentgenographed for fear some of these fractures be overlooked.

2. The diagnosis of *fracture with Colles's deformity* can usually be made at a glance; the distortion above the wrist-joint and the "silver-fork" appearance are characteristic. On the other hand the actual lesion is a difficult matter to determine except from a roentgeno-

Fig. 56.—Flexion fracture—reversed Colles's deformity. (Roberts and Kelly.)

graphic plate. Certain alterations in surface contour should be noted as they indicate the displacement and suggest those measures necessary to obtain complete reduction:

(*a*) The dorsal swelling is found chiefly over the radius, due to the projection of the lower fragment posteriorly. When the ulna shaft is also fractured the swelling extends equally across the forearm.

(*b*) The normal radial anterior curve is obliterated and a swollen prominence appears on the anterior or palmar radial surface to indicate the displaced upper fragment.

(*c*) The wrist is broader, the hand may be abducted and the end of the ulna is depressed and is laterally more prominent, due not to any real dislocation of the ulna but to the outward lateral displacement and backward rotation of the carpus with the radial lower fragment (Fig 57).

Usually, palpation will not determine the fracture margins accurately on account of the swelling. In impacted cases abnormal mobility and crepitus will not be obtained; any movement of the wrist is painful. The radial styloid is normally at a lower level than the ulnar; with Colles's deformity the radial styloid will be pushed proximally to about the same level as the ulnar styloid.

Posterior dislocation of the wrist is exceedingly rare but may be confused with a fracture showing Colles's deformity. The distortion of dislocation is greater and is found immediately at the joint; the normal relation of the styloid processes is unchanged.

Antero-posterior and lateral view roentgenograms should be taken to determine the exact location of and displacement in these fractures. With the actual lesion demonstrated, reduction is greatly facilitated.

3. *The reversed Colles's deformity* shows a marked dorsal prominence just above the wrist and an undue prominence of the radial styloid on the palmar surface. The radiogram will decide the precise lesion.

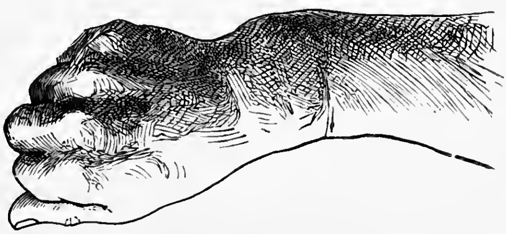


Fig. 57.—Bend of wrist to radial side, projection of ulna. (Pilcher, Annals of Surgery.)

Prognosis.—A reduced Colles's deformity should give no trouble. (Jones.[1]) A fracture without deformity, or a sprain fracture, if recognized early and subjected to sufficient immobilization, should yield perfect return of function. Fractures in which the displacement has not been completely reduced may be expected to give adequate function, even though a permanent deformity may result. Fractures completely unreduced, or with less than two-thirds of the diameter of the radius in contact, may show, however, some impairment in extension, with persistent deformity, and may possibly require a secondary or late effort at reduction.

It is surprising what remarkable return of function may be obtained in the case of even extreme deformity, particularly in the case of children. On the other hand, separation of the epiphysis of the radius may lead in rare cases to arrest of growth and to permanent deformity (Fig. 58). A guarded prognosis is indicated when the trauma includes epiphyseal separation.

[1] Injuries of the Joints. Oxford War Primers, 1915.

Treatment.—When a "sprain fracture" or a fracture without deformity is suspected the hand and forearm should be immobilized on an anterior palmar splint. If the roentgenogram shows a displaced fragment, direct pressure should suffice for reduction; a pad of felt or cotton is placed over it to maintain proper position and the anterior splint reapplied.

For a Colles's deformity, reduction is not always easy; however, every effort should be made to obtain complete reposition. The classical method of reduction consists of three maneuvers:

1. Hyperextension.
2. Traction.
3. Hyperflexion-adduction.

The surgeon grasps the patient's forearm with his left hand, the patient's hand with his right. Hyperextension is then made to disengage any impaction of the fragments, followed by strong traction

Fig. 58.—Deformity from obliteration of lower epiphysial cartilage of radius, following fracture of the base of the radius in a boy of twelve years; fragments put in good place and healed without deformity at the time. Gradual development of the condition shown in photograph with the growth to manhood of the boy; cast taken at age of thirty-two. Radius relatively short from lack of development in length; ulna prominent; hand inclined to radial side. (Pilcher, Annals of Surgery.)

and hyperflexion of the hand to bring the radius into alignment and to restore the radial arch. The hand is immobilized in strong adduction. Direct pressure toward the ulna on the lower portion of the radius may be necessary in those cases in which there is outward displacement of the lower fragment.

Jones[1] asserts that traction on the hand, acting through the ligaments of the carpus and the wrist, can have little effect upon the lower radial fragment and advocates simple direct pressure upon the fragments. Certainly, if the manipulatory method is not successful direct pressure should be tried. The thenar eminence of the operator's left hand presses against the anterior upper fragment and the thenar eminence of his right hand against the lower dorsal fragment; with

[1] Injuries of the Joints. Oxford War Primers, 1915.

slight traction and a "twist of the wrist" the radius is forced into alignment. "It requires knack rather than strength." (Fig. 59.)

If ulnar fracture is present, immobilization in adduction will be of assistance in approximating the styloid or neck fragments by relaxing the internal lateral ligaments and by the pressure of the carpus against the styloid tip.

Numerous splints have been devised for the maintenance of reduction. Two simple straight splints, however, if properly padded, are quite satisfactory. They should be applied in supination, one on the posterior or extensor surface and the other on the anterior or palmar. A splint made with the terminal three inches deviating to conform to

Fig. 59.—Colles's fracture, manual reduction of deformity. (Jones.)

the adducted position is a convenience. The palmar splint should extend from the upper forearm to the metacarpophalangeal joints and should be padded throughout its entire length by cotton wadding or felt—with special reinforcement or extra padding at the seat of fracture to preserve the lower radial curve. The extensor splint should extend from the upper forearm to a point just distal to the carpometacarpal joints, with uniform cotton wadding or felt padding and an extra pad over the epiphysis of the radius. Three adhesive plaster strips are used to hold the splints in position but should not be applied too tightly (Fig. 60). A roller bandage completes the dressing. The forearm is then flexed to a right angle and a sling is used for support.

Variations.—The dorsal splint is not always necessary and may be dispensed with in cases of moderate displacement.

A plaster-of-Paris cast or molded gypsum splints may be used for immobilization. Ample cotton padding should be used, particularly about the wrist. Thin malleable wooden splints may be incorporated in the cast to maintain sufficient rigidity until the plaster hardens.

In the reversed Colles's deformity reduction is readily accomplished by hyperflexion, traction and hyperextension, with countertraction

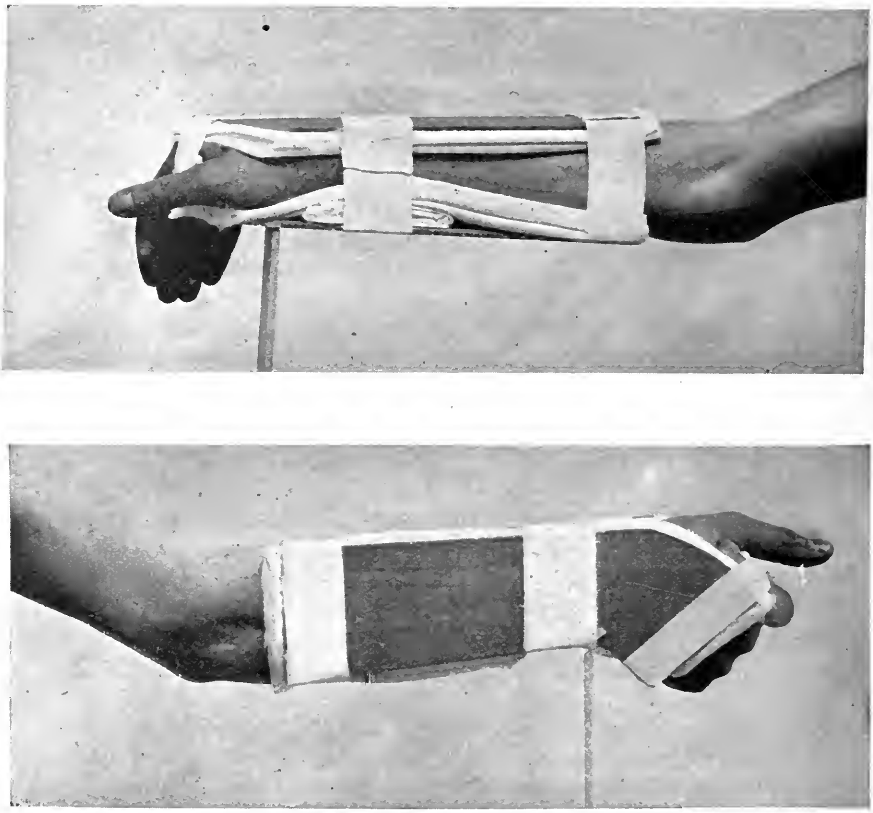


Fig. 60. —Dressing for fracture of lower end of radius and ulna. (Roberts and Kelly.)

by an assistant. As a final maneuver direct pressure may be necessary. Immobilization may be made, as in Colles's deformity, with splints, reversing the pads, or by a gypsum case.

After-treatment.—A roentgenogram should be taken within twenty-four hours after reduction to confirm adequate restitution of the fragments. If two-thirds of the diameter of the radius is not in contact, further attempts at reduction should be made. Very careful observation of the dressing for twenty-four to forty-eight hour afters reduction is advisable. Severe pain, swelling, or discoloration or cyanosis of the fingers requires division of all constriction, including bandages and adhesive straps, and search for areas of excessive pressure. The padding may then be amplified or adjusted if necessary and the fixation apparatus carefully reapplied.

After the second day the dressings should be inspected frequently and the bandages replaced if loose or displaced.

At the end of three weeks the splints should be removed and passive motion and massage gently begun. A bandage from the palm of the hand to the upper forearm may be used as a support for the wrist. In another week even this should be discarded and free use of the wrist and hand permitted. At the end of six weeks function should be practically normal.

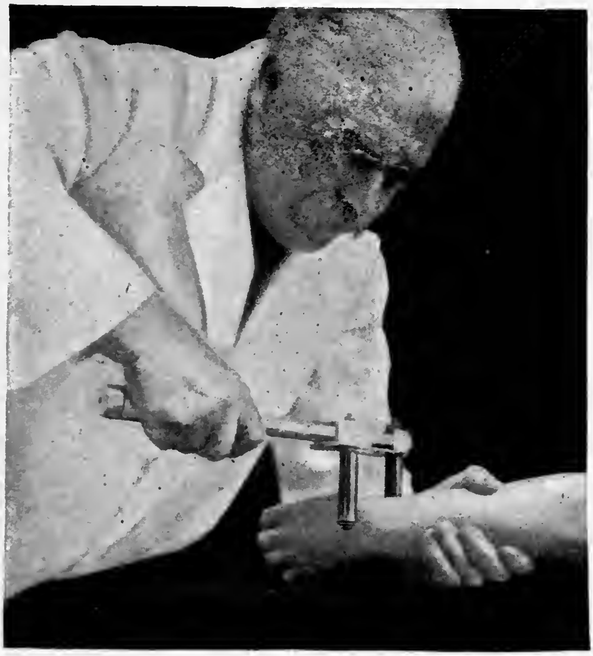


Fig. 61.—Colles's fracture, Thomas's wrench applied. (Jones.)

Complications.—The chief complications following fracture near the wrist are:

1. Mal-union.
2. Volkmann's contracture.

1. *Mal-union.*—A certain number of fractures, even those with deformity, are unrecognized and untreated, and a great many are incompletely reduced and unite with either a permanent "silver-fork" or abduction deformity. With persistence in active and passive motion satisfactory function may be obtained so that the wrist and hand are used as capably as before injury.

However a certain number of these cases are presented for treatment months after injury, with permanent stiffness, and limited and painful extension and flexion of the wrist. Recourse must be had, as a rule, to one of the following procedures to correct the deformity:

(*a*) *The Thomas Wrench or Closed Manipulation.*—In children or in thin subjects, and especially when observed within six or seven weeks of the injury, the Thomas wrench or a similar tool is a very satisfactory implement with which to restore proper alignment (Fig. 61). In the absence of this weapon, bloodless refracture, followed by manipulatory reduction, may be employed.

(*b*) *Open Operation.*—In large, muscular or stout individuals simple manipulation may not suffice. A dorsal longitudinal incision over the fracture should then be made, the radius exposed, the fragments chiselled apart and forced into proper position and held in place by nail, drill or suture if necessary.

2. *Volkmann's contracture* occurs less often in fracture near the wrist than in fracture of the upper third of the forearm or in fractures near the elbow. It has been previously described under Fracture of the Lower End of the Humerus, page 82.

FRACTURES OF THE CARPUS.

Etiology.—Fractures of the carpus are quite rare. They may result from:

1. Direct violence—a blow upon or squeeze of the wrist.
2. Indirect violence—a fall upon the outstretched hand, either sharply extended or flexed.

Pathology.—The fractures may be single or multiple and are often associated with fracture of the lower end of the radius. The scaphoid, the semilunar and the cuneiform—given in the order of frequency of injury—are the usual offenders. There is rarely any displacement.

The fractures are usually transverse near the center of the bone; rarely, small superficial slivers may be separated, as in evulsion or sprain fracture.

Diagnosis.—A carpal fracture without displacement may readily be confused with a simple sprain. Positive diagnosis can only be made from the study and comparison of careful roentgenograms of both wrists—is preferably stereoscopic (Codman[1]).

The symptoms are pain and swelling about the wrist and over the carpus; the signs, local swelling and tenderness on palpation over the bones involved. It is exceedingly uncommon to be able to detect crepitus. Extension of the wrist will be painful and limited.

Treatment.—Limitation of extension at the wrist which may result from these fractures is best prevented by the "dorsiflexed" position. (Jones.[2]) The wrist is therefore extended or "dorsiflexed" and immobilized in this position, either by a plaster-of-Paris cast or by a Jones's hand or "cock-up" splint. This position is maintained for three weeks,

[1] Am. Surg., 1905, xli, 321.
[2] Injuries of the Joints. Oxford War Primers, 1915.

the splint or cast is then removed, and massage and passive motion begun. In six weeks, normal function should be regained.

Fracture of the Scaphoid.—The scaphoid is by far the most frequently fractured bone in the carpus. The fracture is usually transverse near its center or narrow part (Fig. 62) and dorsal displacement of the proximal fragment may occur. There is not only swelling and tenderness over the scaphoid, but pain on pressure in the "anatomical snuff-box," *i. e.*, the hollow between the abductor pollicus longus and the extensor pollicus longus tendons.

For simple scaphoid fracture, immobilization in extension usually suffices. When dislocation or displacement of a fragment exists, however, reduction—or flexion, followed by hyperextension—should be attempted; if unsuccessful, and if forceful extension will not reduce the fragment, voluntary extension being still limited, immediate excision of the smaller fragment should be performed.

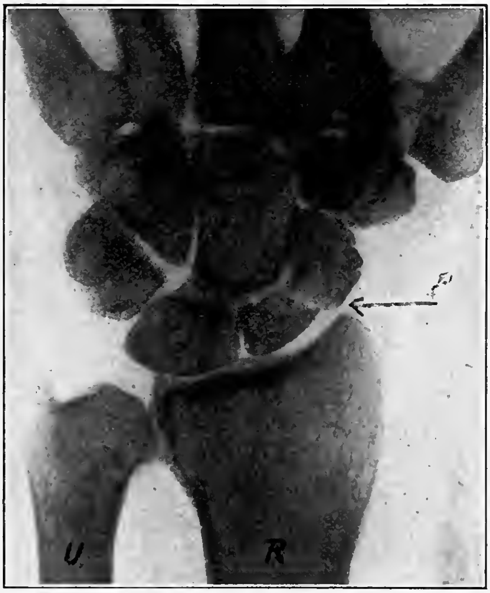


FIG. 62.—A transverse fracture of the scaphoid. Arrow points to the fracture line. (Scudder.)

If in old fractures there is non-union and limited movement, *though little or no pain*, excision is also indicated. In old fractures with stiff, painful wrist, forceful extension and immobilization in extension under an anesthetic should first be tried. If after three weeks no improvement has occurred, excision may be indicated, but may not yield as satisfactory a result as when practised early.

Fracture of the Metacarpal Bones.—Fractures of the metacarpal bones are exceedingly common, having been quoted as comprising as high as 10 per cent. of all fractures (Speese),[1] though Plageman's statistics show only 3.3 per cent. (Roberts and Kelly[2]). Men are more subject to them than women.

The first metacarpal is most frequently involved; next in order are the fifth, third, fourth and second.

Etiology.—Direct Violence—a crushing or squeezing of the hand—a blow with a mallet or hammer upon the hand.

Indirect Violence—a blow or fall upon the knuckles or the tip of the thumb; a "punch" fracture in boxing or fighting is exceedingly common. Torsion or twisting of a finger or fingers may lead to a spiral fracture.

Pathology.—The fracture may involve the shaft of the bone or its extremities and may extend into the joint.

Shaft fractures may be transverse or oblique—very rarely spiral—and occur near the center of the bone or near its bulbous terminations. They are frequently multiple, especially following direct injury.

Joint fractures are usually oblique—often impacted and comminuted, with a longitudinal split of the shaft, and are found usually at the metacarpo-phalangeal joints. Displacement is uncommon, but displacement near a joint, with two or more metacarpal bones involved, leads to impaired function.

A direct injury or gunshot is likely to cause a compound or open fracture with marked comminution and displacement, involving two or more bones simultaneously.

In a transverse shaft fracture the proximal fragment is displaced dorsally and the distal fragment margin depressed toward the palm of the hand, causing the corresponding "knuckle" or metacarpo-phalangeal joint to sink out of prominence.

Epiphyseal separation, particularly of the first metacarpal bone, may occur (Coues[3]).

Diagnosis.—In open comminuted fractures, the diagnosis may be made at a glance. In closed fracture with displacement, the pain, swelling and deformity are characteristic.

The usual symptoms and signs are:

1. Pain at the fracture site, and the inability to close the hand completely—"make a fist"—on account of the pain.
2. Swelling and dorsal prominence at the point of fracture.
3. Depression of the metacarpophalangeal joint of the bone affected, accentuated when the fingers are partially flexed.
4. Crepitus—The fracture margins are readily palpable unless the fracture is near a joint.

In joint fractures and those with no displacement, only pain, local tenderness and swelling may be present. In many cases a roentgenogram will be necessary for diagnosis. The reduction of all fractures should also be carefully confirmed by roentgenographs.

Treatment.—In fractures without displacement a palmar splint for immobilization will be sufficient.

[1] Univer. of Penna. Med. Bull., 1910, xxiii, 391.
[2] Fractures, 1916.
[3] Ann. Surg., 1912, 431; Boston Med. and Surg. Jour., clxix, 21.

Fractures of the shaft with displacement are readily reduced by direct pressure and traction on the finger corresponding to the metacarpal bone affected but reduction is *very difficult to maintain.* For maintenance of reduction some traction device is advisable, such as:

1. A piece of round wood or a roller bandage held in the hand; traction is then made over it by adhesive plaster strips applied to the finger or fingers. A bandage retains the dressing.
2. A palmar splint extending well beyond the finger tips is padded and fastened to the wrist by adhesive plaster. Adhesive or glued strips are applied to the finger or fingers and are attached by rubber tubing with traction to a pin or screw in the splint at its farthest end.
3. Grove's wire loop splint:[1] A large loop of stout wire is fastened into the margins of a palmar splint. The splint is adjusted so that the wire projects well beyond the fingers and is held in place by adhesive at the wrist and over the lower forearm. Adhesive strips from the fingers may be attached with strong traction to the wire. This apparatus is especially applicable to multiple, compound and gunshot fractures.

After-treatment.—The splints and bandages should be inspected daily for the first week and readjustment carefully made when indicated. After fourteen days, massage may be begun and passive movements very cautiously inaugurated. A simple splint should then suffice; after three weeks all apparatus may be dispensed with. In five to six weeks, normal function should have returned.

FIG. 63.—Bennett's fracture with deformity.

Bennett's Fracture.—Bennett's fracture is a stave fracture caused by a blow on the end of the thumb. It is an oblique fracture into the first metacarpal trapezium joint, involving the corner adjacent to the

[1] Gunshot Injuries of Bones. Oxford War Primers, 1915, p. 82.

FIG. 64.—Bennett's fracture. Transverse fracture of the proximal phalanx of the thumb near the metacarpophalangeal joint.

FIG. 65.—Gutter splint for immobilization of Bennett's fracture. (Roberts and Kelly.)

second metacarpal; it is frequently impacted (Figs. 63 and 64). There is usually an outward and dorsal displacement that leads to an angulated union when not reduced.

The symptoms and signs are:

1. Pain and swelling about the first carpo-metacarpal joint.
2. Attempts to appose thumb and little finger, or thumb and index finger, are very painful and difficult to accomplish; all movements of the joint are painful.
3. Marked tenderness—just distal to and at the joint, *and at the angle between the first and second metacarpals.*
4. Pressure on the thenar eminence is painful.
5. Angulation and prominence at the base of the first metacarpal; there is very rarely crepitus.

A roentgenogram is usually necessary to confirm the diagnosis and distinguish this fracture from epiphyseal separation or from an impacted fracture just distal to the joint.

Treatment.—Reduction is accomplished by traction, abduction and extension of the thumb, with direct pressure at the seat of the fracture. The thumb is immobilized in abduction on a palmar splint or a special gutter splint (Fig. 65). With little or no displacement the thumb may be immobilized in abduction immediately. The splint should remain in place three weeks. Robinson's elaborate apparatus, including lateral splints, a cast and traction strips, is seldom necessary.

Fractures of the Phalanges.—Phalangeal fractures are quite common and usually result from an industrial or athletic accident.

Etiology.—1. Direct violence—smash or crushing injury—the most common form of fracture, usually accompanied by an open wound.

2. Indirect violence—a blow on the end of the finger, especially common in baseball.

Pathology.—1. Fractures of the shaft are either transverse, oblique or longitudinal; often compound or open and comminuted.

2. Oblique or transverse fractures occur at the extremities of the phalanx and may involve the joints. Separation of the epiphyses is not infrequent.

Diagnosis.—Besides pain and swelling there may be lateral angulation or deformity. Crepitus is easily elicited in fractures of the shaft. Oblique fracture into the joints may be associated with dislocation. Transverse or epiphyseal fractures near the joints, especially when seen late after the injury, are difficult to diagnose: Crepitus can rarely be elicited and the swelling near the joint clouds the actual lesion. Positive evidence is given only by the *x*-ray.

Treatment (Reduction).—1. *Shaft.*—The correction of an overlapping or lateral deformity is important. Traction, pressure and manipulation will suffice.

2. *Joints.*—Small oblique fractures may prove difficult to reduce. Transverse or epiphyseal fractures should yield to manipulation. Often, when the fracture has been unrecognized, impairment of joint function persists.

Immobilization.—Apposition splints to the flexor surface, of wood, cardboard or wire, held in place by adhesive plaster, may be used, or a metal or plaster-of-Paris gutter splint.

The metacarpo-phalangeal joint of the affected finger or fingers should always be immobilized.

After-treatment.—Splints are used for two or three weeks, then massage and passive motion should be instituted.

Compound fractures require special care and good judgment. Conservative measures should prevail and amputation is to be avoided. If amputation eventually proves necessary every possible bit of finger must be saved.

FRACTURES OF THE PELVIS.

Fractures of the pelvis, in mining districts and where manufacturing and industrial plants abound, are not infrequent. They are usually regarded as serious injuries, due chiefly to the complications they produce or which accompany them. Uncomplicated fractures and minor fractures of the marginal portions of the pelvic bones, however, are seldom of grave portent.

Etiology.—*Direct Violence.*—A fall upon the buttocks or a squeezing, crushing injury is usually responsible for the major pelvic fractures. The pelvis is caught between a moving and immovable object, as between railroad cars or under a fall of rock; or when, as the result of a motor accident, the victim is pinned beneath the wreckage when the car turns turtle.

Indirect Violence.—In a fall from a height and landing on the feet a fracture of the pelvis may be caused by the force being transmitted through the lower extremities to the acetabula.

Muscular Action.—Muscle traction is responsible for the minor pelvic fractures, such as fracture of the anterior superior spine of the ilium from sharp contraction of the sartorius muscle.

Pathology.—Pelvic fractures may be:

1. *Ilium.*—(*a*) Multiple irregular fissured fractures.
   (*b*) Fracture of the crest.
   (*c*) Fracture of the anterior superior spine.
2. *Pubis.*—(*a*) Transverse or oblique fracture of the rami.
   (*b*) Fracture of the anterior superior spine.
   (*c*) Separation of the symphysis pubis.
3. *Ischium.*—(*a*) Transverse or oblique fracture of the ramus.
   (*b*) Fracture of the tuberosity.
   (*c*) Fracture of the body.
4. *Sacrum.*—(*a*) Fracture of the body.
   (*b*) Fracture of the lateral masses.
5. *Coccyx.*—(*a*) Fracture of the sacrococcygeal juncture.
   (*b*) Intracoccygeal fracture.
6. *Acetabulum.*—(*a*) Fracture of the rim of the acetabulum.
   (*b*) Fracture involving the entire acetabulum.
7. Separation of the sacro-iliac synchrondrosis.

These fractures are frequently multiple, many occurring simultaneously; notably, bilateral fracture of the rami of both the pubis and ischium, or fracture of the pubic rami with fissured fractures of the ilium and sacrum (Fig. 66). There may be comminution but an open or compound fracture is exceedingly rare.

Fracture of the pelvis may be accompanied by fracture elsewhere, usually of the spine or femur.

Clinically, fractures of the pelvis may be divided into four groups:

1. Marginal fractures.

Fig. 66.—Separation of the symphysis pubis. Comminuted fracture of the ascending and descending rami of the pubis.

2. Fractures of the pelvic ring, including fractures of the pubis, ischium, sacrum and body of the ilium.
3. Fractures of the coccyx.
4. Fractures of the acetabulum.

Fractures of the pelvic ring include the majority of pelvic fractures and those in which grave complications are likely to occur. These complications may be:

1. *Rupture of the Bladder.*—Rupture of the bladder usually results from antero-posterior compression of the pelvis; it may be extra- or intraperitoneal—extraperitoneal when it is caused by the puncture of a spicule of bone, intraperitoneal when due to the pressure and force of the traumatism itself.

2. *Rupture of the Urethra.*—Rupture of the urethra is likely to be produced by lateral or transverse pelvic compression—in which the jagged end of an ischial or descending pubic ramus fragment may actually lacerate the urethra—or by direct perineal injury or separation of the symphysis pubis.

3. *Laceration of the Large Bloodvessels.*—The iliacs, femoral and obturator vessels, or one of their branches.

4. *Rupture of the small or large intestine.*

1. **The Marginal Fractures.**—The marginal fractures are fractures of the anterior-superior spine or the crest of the ilium, and fracture of the tuberosity of the ischium.

A. **Fracture of the Anterior-superior Spine of the Ilium.**—Fracture of the anterior-superior spine may follow a direct blow, but is usually the result of forceful contraction of the sartorius muscle which rises from it, as in the effort to gain a stronger stride in running a close, hard race (Turner[1]). The fragment may not be completely detached but is usually drawn distally by the contracted sartorius.

The diagnosis may be made from: 1. The presence of local pain on flexion and adduction of the thigh.

2. Inability to run, or walk rapidly.

3. Swelling and local tenderness over the anterior-superior spine.

4. Abnormal mobility of the fragment, and crepitus.

The roentgenogram will confirm the presence of the fracture.

The *treatment* should consist of rest in bed for three weeks with the leg flexed, the thigh flexed and slightly adducted and held in this position if necessary by a plaster cast. The fragment may be held in place by a belt, a cotton pad with adhesive straps, or a firm bandage. Fixation of the fragment by a nail or bone peg should not be necessary.

After three weeks, use of the extremity may be gradually permitted. The return of function should be complete.

B. **Fracture of the Crest of the Ilium.**—Fracture of the crest of the ilium results from a direct blow and may be merely a fissured fracture or an epiphyseal separation of the rim, or the entire margin of the crest may be retracted upward and inward by the unrestricted contraction of the internal and external oblique muscles.

There is usually severe pain in the area of the contracted muscles—aggravated by any movement of the trunk—and with marked local swelling and tenderness. There is asymmetry of the iliac flare, due to the altered position and internal displacement of the iliac crest. Abnormal mobility of the fragment is common; crepitus can occasionally be detected.

With fissured fracture, merely pain and local tenderness, no deformity, and very little swelling may be observed. Thus the diagnosis from a simple contusion can be made only by the roentgenogram.

Treatment.—The displacement can rarely be corrected, but union with deformity results in no permanent disability. Circular adhesive

[1] Lancet, 1909, ii, 891.

swathes from above the fracture to a point well below—"splinting the muscles" will give great relief but tends to accentuate the displacement and should be carefully and not too snugly applied. The patient should be kept prone on a firm level bed or Bradford frame.

In three weeks, union should be sufficiently advanced to permit the upright position; walking and weight-bearing may be gradually allowed. Recovery should be complete in six to eight weeks.

C. **Fracture of the Tuberosity of the Ischium.**—Fracture of the tuberosity of the ischium is exceedingly rare. It results from direct injury—a fall upon the buttocks or, very rarely, from contraction of the hamstring muscles of the thigh that are inserted in it. The fragment may be displaced inward toward the rectum and backward toward the coccyx or, if the muscles are still attached, downward toward the lesser trochanter. There may be intense pain about the anus and the diagnosis may be made by palpating the displaced fragment per rectum and by the mobility and crepitus, with attempts at reduction. The fracture may be unrecognized until revealed by the roentgenogram; stereoscopic plates are preferable, especially in cases with little or no displacement. Reduction by direct pressure per rectum is comparatively easy. Following reduction, immobilization is best maintained by a plaster cast about the pelvis, and extending from the knees to the umbilicus. The cast should remain in place five to six weeks (Haines[1]).

When the fragment is drawn distally by the hamstrings, approximation may be obtained with the patient prone on his face, the thigh extended and the leg flexed; immobilization is made in this position. If pain persists, after incomplete reduction or in an old fracture, the fragment may be excised (Berry[2]).

2. **Fractures of the Pelvic Ring.**—The diagnosis of fracture of the pelvic ring depends upon: (*a*) Evidence of fracture. (*b*) Evidence of complications.

(*a*) **A Simple Uncomplicated Fracture** may require a circumspect and thorough examination for detection. The history and symptoms may be very vague; often the patient can walk after the injury. There may be no complaint to direct attention to the pelvis. Pain in the perineum, backache and a little difficulty in starting micturition may be the only symptoms. Fractures elsewhere may distract attention from the pelvis. However in pelvic fracture it is customary to find:

1. *Pain.*—The pain is usually located at the fracture site and is intensified by any movement of the trunk, by transverse manual compression of the pelvis, and by attempts to turn in bed or move the thigh.

2. *Signs of Local Injury.*—There may be general swelling, ecchymosis and contusion over the symphysis pubis and Poupart's ligaments or over the sacrum, or merely local induration and ecchymosis in the perineum.

[1] Ann. Surg., 1920, lxxi, 187.
[2] Jour. Am. Med. Assn., 1912, lxix, 1450.

3. *Local Tenderness.*—The entire pelvic outline and bony surface, including the perineum, should be carefully palpated for areas of tenderness and alteration of normal contours. With the finger in the rectum, the ischii, the lateral pelvic walls, the prostate and the neck of the bladder should be searched for painful points, projecting fragments or induration. Even if no fragment or fracture margin is palpable, there will be marked tenderness at the site of fracture.

4. *Abnormal Mobility and Crepitus* can seldom be obtained, and should never be actively sought by any manipulation, because of the possibility of visceral or bloodvessel injury by a sharp, projecting fragment and the needlessness of producing pain when a roentgenographic observation is a necessity.

Persistent localized pain, swelling and tenderness over the pubic or ischial rami, and increase in discomfort, with transverse compression of the pelvis, are the usual outstanding features. A roentgenogram is an invariable requisite to establish the diagnosis and to determine the character of the fracture.

(*b*) **A Complicated Pelvic Fracture** is a grave accident. There is profound shock and the pain is usually severe, though the patient may be semiconscious or comatose and complain but little. There may be vomiting. The earliest possible recognition of the complication in hand is imperative, as success in treatment depends upon early correctional measures.

1. *Rupture of the bladder* is perhaps the most common complication; it may be extra- or intraperitoneal.

(*a*) *Extraperitoneal rupture* is accompanied by suprapubic pain and swelling, induration and tenderness above the symphysis pubis and Poupart's ligaments, due not only to direct injury but the extravasation of urine in the tissues and fascial planes as well.

(*b*) *With intraperitoneal rupture* there will be severe abdominal pain marked abdominal distention, rigidity of the abdomen—especially in the lower zone—and dulness in the flanks, and gradual increase in pulse and respiratory rate accompanied by vomiting—the signs of a general peritonitis.

There is usually frequent desire to void, dysuria, and only small amounts of bloody urine are passed, or no urine at all. A catheter introduced into the bladder will withdraw a few drops or a very few cubic centimeters of bloody urine.

2. *Rupture of the urethra* may be indicated by pain, swelling and tenderness of the perineum, scrotum and groins. A symmetrical swelling above the symphysis will denote the bladder. There may be bleeding from the urethral meatus or it may be glued together by a thin blood clot. Retention of urine, dysuria or inability to void are suggestive. A silver catheter will meet an obstruction or rough area in the deep urethra and cannot penetrate to the bladder. In incomplete laceration the catheter, with a little manipulation, may be passed into the bladder.

3. *Vascular lesions,* such as laceration of the iliac vessels or one of their branches, are attended with great shock and may be rapidly fatal. But occasionally, even with a large retroperitoneal hemorrhage, the patient may live twenty-four to forty-eight hours. Rarely, recovery occurs with the formation of a large hematoma which later may become infected, forming a local abscess.

4. *Rupture of the bowel* is quite rare and is attended by the usual phenomena of general peritonitis, paroxysmal abdominal pain and vomiting, abdominal rigidity and marked tenderness, abdominal distention and dulness in the flanks, anxious expression, etc.

Prognosis.—The total disability period for simple fracture of the pelvis of moderate severity should be twelve to fourteen weeks; in complicated fractures, four to six months. Simple fracture of the pelvis is not of serious consequence and recovery is to be expected. The outlook in a complicated fracture is invariably grave and depends upon the extent and character of the complication. The mortality is about 30 per cent.

Though the average period of total disability has been suggested there are certain after-effects of these fractures, especially those in or about the sacro-iliac synchondrosis, that prolong the period of partial disability indefinitely. The fragments are often displaced and not reduced, and union occurs with a distortion or weakness in the pelvic bony framework. Fibrous union may occur. But even with apparent bony union a "sciatica" may supervene that is very resistant to treatment; persistent backache and pelvic or sacro-iliac pain on exertion is not uncommon. This may result in permanent injury to adult earning capacity, estimated by Steinthal from 10 per cent. to 50 per cent. (Burnham[1]).

Treatment.—Treatment likewise resolves itself into: (1) Treatment of the fracture; (2) treatment of the complications or visceral lesions.

(1) *Treatment of the Fracture.*—Reduction of the fragments of a pelvic fracture is rarely possible or indicated; simple immobilization usually suffices. The patient is best placed on a Bradford frame or firm flat bed; a broad adhesive swathe is wound firmly about the pelvis. If pain and discomfort persist, indicating insufficient immobilization, a plaster cast to include both thighs, both hips and the pelvis may be applied. In fracture of the pubic rami a retention apparatus may be difficult to apply, due to a concurrent ruptured bladder requiring suprapubic drainage; if simple rest on a frame or bilateral Thomas hip splint and suspension is insufficient to relieve pain, open reduction may be considered, but is only applicable for an occasional carefully selected case. The fragments are exposed and approximated and held in position by either Kangaroo tendon or steel plates (Quain[2]).

The patient should remain in the prone position for four or five weeks, according to the severity of the lesion. The fixation apparatus may then be removed and the upright position permitted. Massage

[1] Ann. Surg., 1915, lxi, 703.
[2] Surg., Gynec. and Obst., 1916, xxiii, 23.

should be begun as soon as it is tolerated and passive motion with the removal of the fixation apparatus. Weight-bearing should be cautiously begun. In bilateral or extensive pelvic fracture, walking may be permitted after the eighth week, but only with a frame or apparatus that gives continuous axillary support. Full weight-bearing should not be undertaken until the tenth or eleventh week.

2. *Treatment of the Visceral Lesions.*—(*a*) *Rupture of the Bladder.*—When rupture of the bladder is diagnosed, and unless the patient is moribund or in extreme shock, a suprapubic exploration should be made. If extraperitoneal rupture is found a suprapubic cystotomy is done; the rent may be inaccessible but should be closed if possible by purse-string or double row of Lembert sutures and the bladder drained by a suprapubic tube; the extravasated urine in the fascial planes is likewise thoroughly drained by multiple incisions and tube drains.

In intraperitoneal rupture a suprapubic cystotomy is likewise made, the rent closed with a double layer of sutures and the peritoneum and bladder are both drained. The upright position for dependent drainage—for seventy-eight hours after the operation—is an important adjunct, but must be employed with due regard for the fracture.

(*b*) *Rupture of the Urethra.*—When a ruptured urethra occurs a perineal incision and an external urethrotomy must be done rapidly and the ends of the urethra sutured over a catheter. If the proximal end of the urethra cannot be identified a suprapubic opening of the bladder with retrograde catheterization will be necessary; the proximal urethra is then grasped and sutured to the distal portion over a catheter introduced through the external meatus. With marked extravasation of urine, perineal drainage should be ample. The catheter may be removed at the end of a week.

When there is merely laceration of the urethra, without complete rupture, a silk catheter or a rubber catheter threaded on a stylet may be inserted and left *in situ* until the urethra has healed, five to seven days.

Following any urethral injury, after the catheter has been removed, sounds must be regularly passed to prevent stricture. From four to six months' treatment will be necessary to maintain an open urethra.

3. *Vascular pelvic lesions* will rarely be controlled sufficiently to permit treatment. Death may occur before surgical aid can be obtained. Infected hematomata should be incised and drained.

4. Rupture of an intestine will require immediate laparotomy with suture of the rent and pelvic drainage.

Fractures of the Coccyx.—Fracture of the coccyx is caused by direct violence, such as a fall upon the buttocks—upon the edge of a step. The fracture is transverse at the tip or center or at the sacrococcygeal articulation; there may be impaction or angulation, with the distal fragment turned inward.

Pain, swelling and discomfort are not great; the only treatment necessary consisting of simple rest for a week or ten days. Months or years later neuralgic rectal or sacral pain may be traced to the displaced coccyx and coccygectomy will be required for its relief.

Fracture of the Acetabulum.—**Etiology.**—Fracture of the acetabulum may occur as an isolated lesion or as a concomitant of other pelvic fractures. It results from *indirect violence,* a force acting through the trochanter or femoral shaft to drive the head of the femur against the acetabulum, such as a fall from a height upon the feet with the thigh abducted, or a blow or fall directly upon the trochanter.

Pathology.—There may be produced: 1. A fissured fracture of the acetabulum with no displacement.

Fig. 67.—Case of fracture of the acetabulum with intrapelvic displacement of the femoral head. Fracture also of ilium and of the ramus of the ischium. Fracture of ilium probably caused by great trochanter which is seen pressing against it. (Peet.)

2. Multiple fracture and inbending of the acetabulum with the head of the femur advanced against it.

3. Complete dislocation of the head of the femur, through a badly shattered acetabulum, the so-called central dislocation of the hip, which may cause laceration of the pelvic vessels, or rupture of the bladder, urethra or bowel (Fig. 67). The lower half of the acetabulum is weaker and is more commonly involved; hence the likelihood of

acetabular fracture when the trauma occurs with the thigh abducted. Muscular contraction increases the deformity.

Diagnosis.—*Fracture without displacement,* or with merely slight inbending, may be impossible to recognize without a roentgenogram. There will be pain in the hip, accentuated by pressure on the trochanter or weight-bearing; there may be swelling about or restriction of movement in the hip.

Fracture with displacement will be accompanied by pain in and great swelling about the hip, groin and even above Poupart's ligament. The *sunken appearance of the trochanter* and the *relaxed fascia* (Allis's sign) are characteristic. The trochanter will be higher on the affected side and Bryant's line will be shorter. The entire lower extremity may seem short and the distance from the anterior-superior spine of the ilium to the internal malleolus may measure less than the sound side. There will be marked tenderness about the trochanter and hip. Any attempt to move the thigh will be exceedingly painful unless there is a large opening in the acetabulum (Fuller[1]). A mass above Poupart's ligament or per rectum, that rotates with the femur, will indicate the femoral head. A roentgenogram should invariably be taken to confirm the diagnosis and to differentiate from fracture of the femoral neck or true dislocation.

Prognosis.—The prognosis depends upon the character and the kind of complications, their early recognition and prompt and appropriate treatment. The mortality is high, 30 per cent. (Vaughn[2]).

In uncomplicated cases, if reduction is complete, functional recovery is satisfactory. In many cases there may be limitation of abduction and shortening of the extremity. When the dislocation has not been reduced or it recurs, permanent incapacitation, partial ankylosis and a painful joint will result.

Treatment.—In *simple fracture without displacement,* immobilization by a plaster cast from the toes to umbilicus will suffice.

In fractures with slight inbending, simultaneous lateral and longitudinal traction on the thigh will be necessary. When reduction is complete, as demonstrated by the roentgenogram, a cast may be applied. Whitman's[3] method of extreme abduction of the thigh and immobilization by a cast in this position may also be efficacious.

In fractures with marked inbending or perforation of the acetabulum by the femoral head, any existing complications will have priority of treatment; this may of necessity postpone attention to the fracture itself. Immobilization on a Thomas splint will be a satisfactory temporary expedient. For reduction, a general anesthetic will be necessary. Simple manipulation will not suffice. The patient should be placed on the floor or a low table and a wide bandage or strap looped around the thigh. The thigh is flexed to a right angle and simultaneous traction upward and laterally—with adduction if necessary—

[1] Am. Jour. Med. Sc., 1911, cxli, 285.
[2] Surg., Gynec. and Obst., 1912, xv, 249.
[3] Ann. Surg., 1920, lxxi, 62.

should reduce the head of the femur. The thigh is then extended and lateral and longitudinal traction is maintained for one week to prevent recurrence of the deformity. A gypsum cast from the toes to umbilicus may then be substituted for five weeks, after which all apparatus is removed, and massage and passive motion begun. Weight-bearing should not be permitted until four to six months after the injury.

Reduction may be difficult if delayed, or if there is infolding or locking of the acetabular fragments about the femoral head. Whitman[1] has recently suggested that extreme forceful abduction of the thigh, as in the treatment of fracture of the femoral neck, will not only reduce the displaced head but immobilization in this position will prevent recurrence and tend to restore abduction—the motion which is most difficult to regain following this injury. In difficult or refractory cases it is worthy of trial, and it may prove the method of choice.

If simple reduction fails open operation may be undertaken. The femoral neck and rim of the acetabulum are exposed; the fragments of the acetabular floor are elevated; manipulation should then complete the reduction. In old cases simple manipulation may be considered. Peet[2] has reported the successful use of manipulation in a case of forty days' standing and recommends it for "those cases in which the head cannot be reduced, either because of insurmountable mechanical obstacles or where complications exist which preclude the possibility or advisability of more strenuous measures."

Fracture of the Rim of the Acetabulum.—Fracture of the rim of the acetabulum alone is very seldom observed. It occurs with posterior dislocation of the hip and may be suspected when the dislocation tends to recur or if crepitus is detected with reduction. It may be difficult to diagnose even with the roentgenogram. Stereoscopic plates should be taken.

Maintenance of reduction of the dislocated hip is effective treatment for this fracture. Fixation should be prolonged until union is firm—four to six weeks—and motion and weight-bearing cautiously permitted.

FRACTURES OF THE FEMUR.

Fractures of the femur may be divided into:

A. Fractures near the hip.
B. Fractures of the shaft.
C. Fractures near the knee.

(A) Fractures of the Femur Near the Hip.—Fractures of the femur near the hip comprise: (1) Fractures of the head; (2) separation of the upper epiphysis of the femur; (3) fracture of the neck; (4) fracture through the trochanters; (5) fracture of the trochanters; (6) subtrochanteric fracture.

1. *Fractures of the head of the femur* are exceedingly rare and result from direct injury or in connection with dislocation of the hip. The

[1] Ann. Surg., 1920, lxxi, 62.
[2] Ibid., 1919, lxx, 296.

head may be markedly displaced or there is a longitudinal splitting of both head and neck.

The diagnosis is made from the roentgenogram. Fracture of the pelvis or other fractures of the femur may accompany and overshadow this lesion. The treatment will depend upon the individual case. With displacement, excision of the head may be necessary; ankylosis or flail hip may follow.

2. Separation of the upper epiphysis of the femur.

3. Fracture of the neck.

4. Fracture through the trochanters.

Separation of the upper epiphysis of the femur and fracture through the trochanters may properly be discussed in connection with fracture of the neck. Fracture of the neck of the femur is a very common fracture, especially in youth and old age, though it exacts its toll from every decade of life. Its frequency in persons over fifty years of age is due to the thinning out—or osteoporosis—and consequent brittleness of the femoral neck. At this period it is found in women more often than in men.

Fig. 68.—Epiphyseal separation of upper end of femur. Rotation of lower fragment. (Whitman.)

Fig. 69.—Fracture of the neck of the femur in a child. (Whitman.)

(*a*) **Fractures of the Neck of the Femur in Children.**—*Etiology.*—The fracture results from indirect violence; a fall from a height—striking or landing upon the trochanter and the lateral surface of the upper thigh; a fall or blow upon the foot or knee.

Pathology.—The actual lesion may be either: (1) An epiphyseal separation of the upper end of the femur; (2) fracture of the neck of the femur.

Authorities differ as to their relative frequency. Sprengel and

Hoffa[1] believe epiphyseal separation is more common, and fracture of the neck comparatively rare, but Whitman has asserted that fracture of the neck is present in the majority of instances, and very seldom epiphyseal separation.

The fracture is, as a rule, subperiosteal, greenstick or impacted, and rarely complete; there is but partial separation of the epiphysis (Figs. 68 and 69).

Diagnosis.—The condition is very often overlooked. The injury seems trivial. Following a fall, slight swelling and pain in the hip persist for a day or two; the child is then able to be up and about, but walks with a slight limp. No further evidence of abnormality appears until several months or years later, when a coxa vara deformity becomes apparent. In another type several repeated strains or falls may occur before disability becomes sufficient to attract attention and shortening is discovered (Jones[2]).

An outspoken case, however, will present:

Symptoms.—(*a*) Pain in the hip—worse with weight-bearing; (*b*) inability to walk or to use the affected extremity.

Signs.—A. *Inspection.*—(*a*) Swelling about the hip. (*b*) Outward rotation of the leg and thigh—slight. (*c*) Slight apparent shortening of the affected extremity. (*d*) Trochanter of the affected side more prominent and higher.

B. *Palpation.*—(*a*) Tenderness in the groin. (*b*) Movement of the hip somewhat limited, especially abduction when the thigh is flexed. (*c*) Shortening demonstrated by measurement—shortening of Bryant's line.

The trochanter is higher and more prominent in fracture than in epiphyseal separation, but in most cases diagnosis and differentiation can only be made by the roentgenograph. Information as to the exact lesion and the position of the fragments cannot be accurately obtained except in this manner. Any injury or disability of the hip in childhood should never be explained away as a "contusion" until a roentgenograph has ruled out definitely the possibility of early tuberculosis or fracture.

Treatment.—By far the best method of treatment is the abduction method of Whitman.[3] A general anesthetic is usually necessary. The sound thigh is completely abducted; this fixes the pelvis and determines the amount of abduction to be obtained on the injured side. With strong traction, the affected thigh is then abducted—forcibly if necessary—until the same degree of abduction is obtained as the sound side indicates. Any outward rotation is corrected and a plaster cast applied from the toes to the umbilicus (Fig. 70).

In four or five weeks the cast is removed, abduction is gradually lessened and massage and passive movement begun. In seven weeks crutches may be used with a high shoe on the sound side. No direct

[1] Quoted by Eisendrath, Keen's Surgery, Vol. 2, p. 238.
[2] Injuries to Joints. Oxford War Primers, 1914.
[3] Surg., Gynec., and Obst., 1918, xxvii, 578.

weight-bearing should be permitted until twelve weeks after the injury.

If the case is first seen when coxa vara is well developed, with persistent pain and limping and limitation of motion in the hip, and if the injury has occurred within two weeks of the first visit, the forced abduction method may be employed. With marked deformity or disability in late fracture, refracture or open operation—with osteotomy—must be considered.

FIG. 70.—The plaster spica properly applied in complete abduction, complete extension and slight inward rotation. (Whitman.)

(*b*) **Fracture of the Neck of the Femur in Adults.**—*Etiology.*—Indirect violence—fracture of the femoral neck, is caused most often by *impact* upon the *trochanter;* frequently the foot is caught, is unable to sustain the body weight and the blow or fall applies force upon the trochanter, with the thigh sharply adducted.

Also, indirectly, fracture of the neck of the femur may occur from a fall on the foot or knee, with the thigh abducted.

Muscular action in the aged, an accident—often of the most trivial sort, as simply tripping or stumbling and the muscular effort to prevent a fall—results in femoral neck fracture.

Pathology.—The fracture may be: 1. Subcapital.—Near the juncture of the head and neck of the femur, formerly termed an intracapsular fracture, the customary old age fracture (Fig. 71). It is usually transverse but may be oblique. The periosteum near the epiphyseal line may be disturbed or torn loose, and the only line of circulation and source of nourishment to the head that remains intact is through the ligamentum teres. Union is usually very slow and impaction rare.

2. Fracture at the juncture of the neck with the trochanters—the "extracapsular" fracture, more recently designated by Kocher the "intertrochanteric" fracture. Impaction is frequent and normal union usually occurs. It is found in active adults up to late middle age.

FIG. 71.—Subcapital fracture of the neck of the femur.

3. Pertrochanteric fracture—or a fracture through the trochanters—frequently comminuted, with the trochanters separated from the main fragments. Union, as a rule, is not delayed. This fracture is often combined with a fracture of the base of the neck, usually in one of three ways:

(*a*) An uncomplicated, impacted fracture of the neck.

(*b*) Fracture of the neck with partial comminution, only one trochanter as a detached fragment.

(*c*) Fracture of the neck with comminuted fracture of both trochanters—"the typical pertrochanteric fracture." (Ashhurst.[1]) (Fig. 72.)

[1] Ann. Surg., lviii, 494.

In all these types the displacement is similar. The greater trochanter and lower fragment are driven upward—proximally, rotate outward and sag backward—posteriorly; shortening and eversion of the extremity result, due to the unrestricted action of the external rotators, which are attached to the greater trochanter. When impaction takes place, there is less shortening and rotation. Impaction usually implies crushing and penetration of the neck into the head or into the trochanter area; often, almost a telescoping of the neck, bringing the head and trochanter closer together. Impaction is never flat; there is usually more posterior crushing which permits the eversion deformity. Very rarely, there is excessive crushing anteriorly, and an inversion deformity.

Fig. 72.—Pertrochanteric fracture of the neck of the femur with comminuted trochanter fragments.

Diagnosis.—The diagnosis depends upon:

Symptoms.—1. Pain in the hip, following an injury. 2. Inability to move the thigh. 3. Inability to walk. 4. Shock—in old people, shock may be very severe and overshadow the actual injury.

Examination.—A careful and painstaking examination is especially essential in coming to a diagnosis. The patient should lie on a firm, flat surface and the clothing should be entirely removed. The pelvis and body should be so placed that the line joining the anterior-superior spines of the iliac crests will be at right angles to the longitudinal axis of the body. The bony prominences about both hips should be palpated and their relations noted. Nélaton has called attention to the fact that the line drawn from the anterior-superior spine of the ilium to the tuberosity of the ischium passes through, or just above, the greater trochanter. This is called Nélaton's line. Measurements with a steel tape should be made from the anterior-superior spine of the ilium to the internal malleolus of the ankle on each side to demonstrate the shortening of the lower extremity. The distance from the anterior-superior spine to the line drawn through the tip of the greater trochanter, parallel to the line joining the anterior-superior spines, is designated as Bryant's line.

Signs.—Inspection.—1. Swelling of the hip, groin, and upper thigh. 2. Outward rotation of the extremity in unimpacted cases is very marked and there is complete eversion. In impacted cases, there is slight eversion; very rarely, inversion. 3. Shortening of the affected extremity is apparent. 4. Relaxation of the fascia lata, and the gluteal muscles.

Palpation.—1. The trochanter of the injured side is higher. 2. The trochanter of the injured side is above Nélaton's line. 3. Bryant's line is shorter on the affected side. 4. The distance from the anterior-superior spine to the internal malleolus is shorter on the affected side. 5. Passive movement of the hip will be very painful. In unimpacted cases, crepitus and abnormal external rotation are readily obtained. In impacted cases, attempts to ascertain the degree of movement possible at the hip, unless carefully done, may break up the impaction, increase the deformity, and lessen the chance of good union. It is very difficult to tell whether or not impaction is firm. Therefore, any test for crepitus or abnormal mobility must be cautiously made.

With this routine examination, fracture of the femoral neck can usually be diagnosed, but in every case a roentgenogram is indispensable. The exact site of the lesion and the degree of displacement or impaction may be accurately determined—a great asset in the consideration of proper treatment.

Prognosis.—In the aged and feeble, mortality in fracture of the femoral neck is high—in our short series of cases over sixty years of age, 18 per cent.; in Cotton's series, 25 per cent. Physical shock, fat embolism, hypostatic pneumonia, sepsis from bed-sores and acute dilatation of the heart are the usual causes of death. Bed treatment and the recumbent posture are not readily tolerated. Lowered resistance, as a result of injury, predisposes to unrestrained pyogenic infection. On the other hand Whitman[1] has reported, in 241 consecutive cases of all ages, but 3 deaths, 1.24 per cent.

The neck of the femur is notoriously liable to non-union. In the aged, if there is not definite non-union, fibrous union is to be suspected. Non-union may occur at any time in adult life, even as early as the second decade. Impairment of circulation to the head fragment has commonly been assigned as the cause of the sluggishness and difficulty in union but Henderson[2] has asserted it is more likely to be due to the

[1] Am. Jour. Med. Sci., 1905, cxxx, i.
[2] Mayo Clinic, 1918, x, 856.

fracture remaining undiagnosed or improperly treated until too late to obtain proper union.

With early reduction, abduction treatment, and good callus formation in patients that tolerate the immobilization well, adequate function can be expected. In cases under fifty years, practically a complete return of function may be obtained. Over fifty, even with union, some restriction of motion is to be expected.

Subcapital fractures require a longer time for union and are more likely to be ununited. A more favorable outlook is to be anticipated in fractures near the trochanters.

Statistics of end-results are few. The British Medical Association Committee on Fractures[1] tabulated 91 cases.

	Good, per cent.	Moderate, per cent.	Bad.
Anatomical results	18.0	18.0	39
Functional results	24.0	28.0	39
Good anatomical and functional results	16.4		
Moderate and bad anatomical results with good function	....	9.8	
Duration of incapacitation under fifteen years of age, weeks	....	26.5	
Over fifteen years of age, weeks	....	53.2	

Treatment.—In no other fracture does the individual judgment of the surgeon play such an important part. No routine treatment can be prescribed. The patient's general condition, as well as the fracture, requires consideration, and often the treatment must be what can be tolerated and not what the surgeon may most desire to employ. But *mere advanced age should not be used to excuse an inept effort* to treat the fracture. Hale old individuals will stand immobilization better than is usually supposed.

The general condition of the patient, however, should be the first consideration. Shock should not only be combated by the usual methods but by immediate immobilization of the affected extremity. A Thomas hip splint is the simplest and by far the best means to be employed; it can be quickly applied and is usually borne with equanimity. It will suffice until a roentgenogram can be taken and accurate information of the type of fracture can be obtained.

When a patient's general condition is satisfactory, the procedure for treatment must be guided by: 1. The amount of deformity and shortening. 2. The position and character of the fracture.

With little or no shortening and no eversion in a fissured or an impacted fracture, in which the roentgenogram shows that displacement of the fragments, especially coxa vara, has not occurred, manipulations or alterations of position are obviously contra-indicated. Immobilization and maintenance of position in slight abduction, by a plaster cast from the toes to umbilicus, is sufficient.

[1] The British practise longer immobilization than the American Surgeons. Roberts and Kelly, Fractures, 1916.

Impacted cases should not be treated differently from unimpacted cases save that care should be taken *not* to *disturb* the *impaction* until *reduction* and the *permanent dressing are* to be *undertaken.* Coxa vara is the deformity to be avoided and if impaction occurs with coxa vara or eversion, the position should be corrected.

In fractures with displacement, the methods of immobilization and reduction that may be employed are:

1. *Thomas Hip Splint.*—This may be used as a permanent dressing and is especially applicable to old, feeble, and weak individuals who require early ambulant treatment, and who will not tolerate long, bed-ridden intervals. This splint immobilizes the knee and ankle, gives steady traction and countertraction, and enables the extremity to be suspended, or the patient to be moved readily in bed, or it may even be modified so that, with a high heel on the sound side, walking with crutches is possible. Complete reduction is rarely obtained. The splint should be worn for from ten to twelve weeks. Then it is removed, and crutches are used until the patient can walk well without them. If union is doubtful, a hip brace will be required which should be discarded only when function of the hip seems approximately normal.

2. *Ruth-Maxwell Double Traction.*[1]—The salient features of this method are:

1. Reduction under light general anesthesia.
2. The thigh is flexed to a right angle with the body—the fragments are thus disengaged.
3. Traction laterally on the thigh, correction of the eversion, and raising of the trochanter by an assistant tends to overcome the shortening and brings the trochanter into position.
4. Extension of the thigh, and longitudinal and lateral upward traction follow.

Maintenance of reduction is obtained by permanent and continuous longitudinal and lateral traction. For the latter, a padded binder's board is placed on the inferior and mesial surface of the thigh, and by a wide swathe over it, outward and upward, traction is maintained (Fig. 73). Ruth has recently modified the position so that the longitudinal traction is made in abduction—closely resembling the Whitman principle. The traction is maintained for six to eight weeks. If union seems firm, passive motion and massage are then begun and the patient is up on crutches in the ninth or tenth week. If union is doubtful or incomplete, traction is again applied until satisfactory union has occurred; then massage and movement are permitted.

3. *Whitman's Abduction Method.*—Reduction should be made under a general anesthetic and the patient should be placed on a Hawley table, or Lemon apparatus, or similar device, with a perineal bar and buttock plate, or sacral support, and foot traction bars.

1. The uninjured limb is abducted to its normal limit to ascertain the degree of abduction possible—which varies with individuals—and to fix the pelvis.

[1] Jour. Am. Med. Assn., 1899, xxxiii, 519.

2. The operator gently flexes the thigh to disengage the fragments.

3. An assistant then extends the extremity and makes traction until the shortening is overcome; *i. e.,* when the greater trochanters are at the same level.

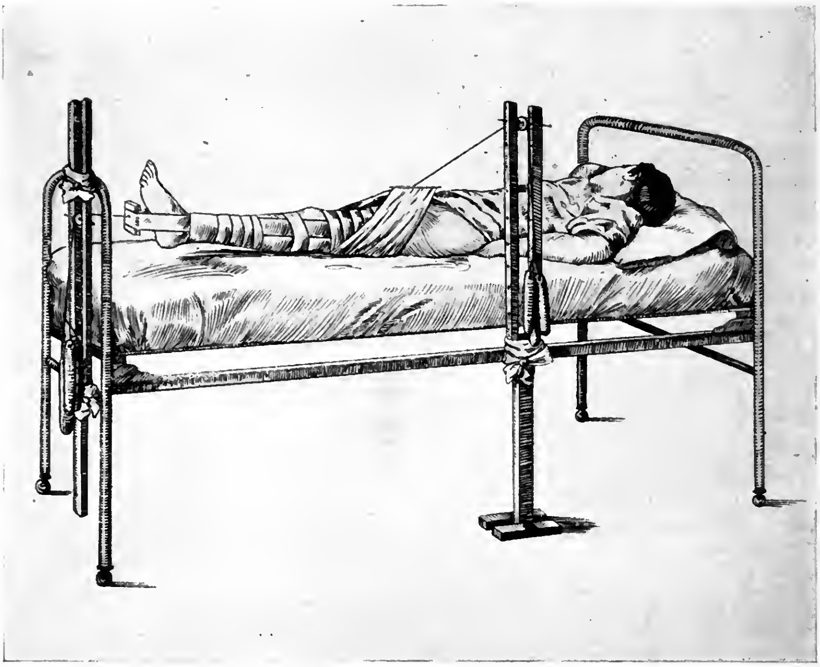


Fig. 73.—The Ruth-Maxwell method. Longitudinal, lateral, and forward traction. (Henderson.)

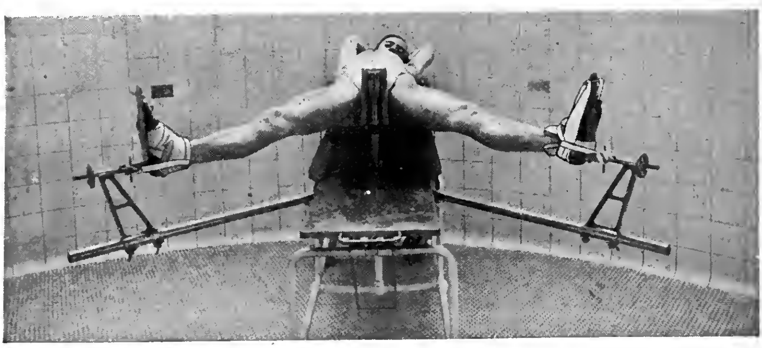


Fig. 74.—Patient with the legs in extreme abduction, the Whitman position for the treatment of fracture of the neck of the femur. Hawley table. (Speed.)

4. Abduction with traction is then made by the assistant until the same amount of abduction is obtained as the uninjured side shows,

with lifting of the thigh from beneath and gentle manipulation by the operator to correct any remaining eversion; the foot is fastened in the traction foot cuff, and a plaster cast is applied from the toes to the umbilicus.

The fragments are thus *gently* disengaged if impacted; it is not a rough breaking-up of impaction; the shortening is corrected; reduction is obtained and maintained by extreme abduction, because the trochanter is brought against the acetabular margin and ilium, and any tendency to riding-up—or coxa vara—is prevented, and the normal angle of the head and neck of the femur is preserved; the external rotators are relaxed and eversion is avoided; the adductors of the thigh are taut and thus help hold the femoral shaft in place, and against the upper fragment.

This is the best method for routine treatment of all femoral fractures but is of special value in treatment of subcapital fractures of the neck.

Cotton's suggestion of impaction, apparently unnecessary in the intertrochanteric variety, has some value also in the treatment of these subcapital fractures. Cotton[1] follows Whitman's method but, after flexion of the thigh, when traction in extension is being made and when shortening has been overcome, two or three blows over the trochanter with a heavy wooden mallet, well-padded with felt—with counterpressure from an assistant on the opposite side of the pelvis—serves to produce an impaction of the head and neck. Then the extremity is abducted and the cast applied. Cotton believes that, in a majority of instances following impaction, union occurs and that open operation should be undertaken only when this procedure has failed.

A convenient addendum to the abduction method is a suspension canvas swing, similar to the Hodgen splint. The abducted extremity is held suspended in it just free of the bed, which makes the position and cast much more comfortable and less irksome, especially in the aged.

At the end of the sixth or seventh week, the body portion of the cast is removed and the abduction gradually decreased. At the eighth week, the entire cast is done away with, and passive motion and massage cautiously begun. At the ninth week, the patient may be out of bed on a wheel chair, and at the end of the tenth week may begin to walk with crutches. No weight-bearing should be permitted until a full twelve weeks following the accident. In the aged, an ambulant hip splint and brace should be used for the first three months out of bed, and then gradually discontinued when union seems solid and weight-bearing, without it, painless.

4. In feeble or bed-ridden cases, where a cast or Thomas splint cannot be used or has to be abandoned, a great deal of relief and comfort may be obtained by simple abduction in the suspensory swing. A Balkan frame lends itself very well to this suspension and may be adjusted to prevent external rotation and permit traction in abduction at the same time.

[1] Ann. Surg., 1917, lxxi, 380.

Complications— Non-union.—With non-union, there may be marked atrophy of the neck, or, sometimes, complete absorption of it so that the head comes in close proximity to the trochanters (Fig. 75.) Weight-bearing is usually painful. Walking is possible with crutches or a limp, but sustained effort is difficult because of weakness and pain in the hip. In those cases in which operation seems justifiable—*i. e.*, general health is good, age is not a contra-indication, and the neck is not atrophied, the femoral neck is exposed, the fracture margins are freshened, interposed fibrous tissue is removed and apposition obtained, and an autogenous bone peg from the tibia, or preferably the fibula (Davison-Henderson),[1] is then driven through the trochanter and neck

Fig. 75.—Ununited fracture of the neck of the femur one year after the accident Marked absorption of the neck. Man, aged thirty-three. (Henderson.)

into the head. The fibula gives a thicker graft and is less liable to fracture before union takes place. Bone graft pegs apparently give better results than metal nails or screws. A certain operative skill and experience in bone graft technic is required for success in this operation, together with adequate postoperative fixation. Henderson shows that early success may be turned into late failure by atrophy or fracture of the graft. He reports of 120 cases but 26 in which operation was deemed advisable; in 10 firm union was obtained. Cases in which the neck of the femur has been absorbed or atrophied are poor subjects

[1] Davison: Surg. Gynec. and Obst. 2919, xxix, 142; Henderson; Surg. Gynec. and Obst., 1920, xxx, 145.

for a pegging operation. For them, Brackett's[1] head transplantation to trochanter (Speed[2]) may be considered.

General complications such as shock, hypostatic pneumonia, and acute dilatation of the heart, must be combated by the accepted routine treatment for these conditions. Bed-sores may be successfully prevented and sacral pressure avoided by early suspension, which may include, if necessary, a body sling or hammock.

5. **Fracture of the Trochanters.**—A. Greater Trochanter.—Fractures of the greater trochanter may be found in conjunction with other fractures of the femur, especially with intertrochanteric or upper third fracture. Very rarely, a fracture of the greater trochanter alone occurs.

Etiology.—A direct injury to the trochanter may result in fracture; but the usual cause of simple fracture of the *greater* trochanter is indirect violence by muscular action from attempts at forceful external rotation with the thigh fixed. The external rotators, pyriformis and gemelli, as well as the gluteus medius muscles, are inserted in the greater trochanter; when they are sharply contracted against strong resistance a splitting off of the greater trochanter results.

Pathology.—The fragment usually remains partly attached to the femur but is movable and may be comminuted. It may also be separated widely—four or more centimeters—and may be drawn backward and upward by the attached external rotators. There may be a true separation of the trochanteric epiphysis.

Diagnosis.—There is pain in the trochanteric region and signs of injury to the trochanter; *i. e.*: 1. Swelling over the trochanter. 2. Slight inversion of the thigh. 3. Active external rotation and abduction is limited or impossible. 4. Tenderness on pressure over the trochanter. 5. Pain on internal rotation of the thigh in the trochanteric region.

Very seldom can crepitus or abnormal mobility of the fragment be elicited. There may be no characteristic evidence of fracture present and diagnosis can only be made by the roentgenogram.

Treatment.—The thigh is immobilized for three or four weeks in abduction, outward rotation, and slight flexion. When the swelling is moderate, adhesive plaster strips over the detached fragment to maintain approximation may be of service. With marked displacement, open operation—nailing or pegging the fragment in place—may be practised.

B. Fracture of the Lesser Trochanter.—As a result of the assiduous use of the *x*-ray in injuries about the hip, a number of cases of isolated fracture of the lesser trochanter have been reported in recent years.

Etiology.—*Muscular Action.*—A sharp contraction of the iliopsoas muscle to prevent a fall—usually when the thigh is abducted. Frequently, in games or drills, or while running, a sudden stop or halt,

[1] Brackett and New: Boston Med. and Surg. Jour., 1917, clxxvii, 351.
[2] Speed: Archiv. Surg., 1921, ii, 45.

with a sudden contraction of the iliopsoas, may result in an evulsion of the lesser trochanter.

Pathology.—The lesser trochanter is split off from the femur and is separated and drawn inward and upward about $\frac{1}{2}$ to 2 cm. (Fig. 76).

Diagnosis.—Following an accident, there is pain in the groin and hip, worse with walking or extending the thigh, relieved by flexion and adduction. It may be impossible to walk, though standing and weight-bearing are possible.

Signs on Examination.—1. There may or may not be swelling of the groin.

Fig. 76.—Fracture of the lesser trochanter. Displaced peritrochanteric fracture.

2. Ludloff's sign will be present unless the iliacus muscle remains intact; *i. e.*, when prone all movements of the thigh are somewhat painful but are possible, including flexion, but when sitting, the thigh cannot be voluntarily raised or flexed.

3. There is tenderness and pain on pressure over the lesser trochanter.

4. Passive movements of the hip may be free but abduction is painful.

It is unusual to detect crepitus or mobility of the fragment. Positive diagnosis can be made only from the radiogram and the displacement is best determined from stereoscopic plates.

Treatment.—Rest in bed in a sitting posture for three to four weeks may be sufficient. Ross[1] suggests immobilization in a plaster cast

[1] Ann. Surg., 1917, p. 241.

with adduction and semiflexion of the thigh for three weeks. No excessive callus and no impairment of function should result.

6. **Subtrochanteric Fracture.**—Fractures just distal to the trochanters are not infrequent.

Etiology.—1. Direct violence—a blow upon the thigh just below the trochanter.

2. Indirect violence—a fall on the knee or foot, or a torsion of the upper thigh.

Pathology.—The fracture may be transverse, especially following direct injury, or oblique, or spiral. There is usually marked displacement, angulation, or overriding; the upper fragment is abducted and rotated externally by the external rotators, and sometimes flexed by the contraction of the iliopsoas muscle; the lower fragment is drawn upward by the adductors and hamstring muscles. With transverse fracture, there may be very little displacement but never impaction.

Diagnosis.—The *signs* of fracture are quite definite but, because of swelling about the trochanters, rendering palpation of the bony prominences difficult, the exact lesion may be difficult to determine by examination alone.

There is pain in the hip and upper thigh, and total disability and loss of function of the extremity. The usual signs are:

Inspection.—1. Swelling of the thigh and hip at the trochanter level.

2. Marked outward rotation of the thigh and leg, due to the unrestrained action of gravity.

3. Shortening.

4. Deformity at the site of fracture.

Palpation.—1. Marked local tenderness about and below the trochanters.

2. Trochanter does not move with rotation of the thigh and shaft of the femur.

3. Abnormal mobility and crepitus at the site of fracture. In an oblique fracture, crepitus may be difficult to detect.

4. Shortening by measurement.

A roentgenogram is essential to determine the exact location and type of the fracture.

Prognosis.—There is usually good union in subtrochanteric fracture but there may be angulation and persistent deformity, outward or anterior bowing, particularly if reduction has not been complete or if weight-bearing is permitted too early.

Treatment.—Small or moderate displacement, especially with a transverse fracture, will merely require abduction, direct manipulation, and a cast from toes to umbilicus, applied in abduction.

The problem of reduction in fractures with much displacement is to bring the lower fragment in alignment with the upper, whose position of abduction and flexion can be but little influenced by direct measures. The relative position of the fragments is ascertained from the radiograph. With traction, the thigh and lower fragment are brought by the necessary amount of abduction, rotation and flexion into proper alignment with the upper, and with direct pressure, reduction is accomplished. If the shortening is overcome and reduction obtained, a plaster cast from the toes to umbilicus may be immediately applied, especially in oblique fracture. If reduction is questionable, the extremity may be swung from a Balkan frame and continuous traction applied with the thigh abducted and flexed. Direct skeletal traction (Steinman pins, etc.) may be necessary. If after manipulation, followed by traction for ten days, the shortening is not corrected and the reduction as demonstrated by the radiograph is not satisfactory, open operation may be done, the fragments exposed, brought into alignment and plated. As a great deal of strain may be placed on the fixation material, plates are usually to be preferred to intramedullary pegs or bone-grafts.[1] Open operation will be also indicated when there is wide separation of, and marked penetration of muscle by, the displaced fragments.

After reduction, immobilization should be kept up for seven to eight weeks; then active and passive motion and massage are permitted but weight-bearing should not be allowed until a full twelve weeks after reduction, and then very cautiously. A close watch must be kept for any tendency to angulation or delay in consolidation; if detected, the extremity must again be immobilized on a Thomas or an ambulant splin until union is absolutely firm.

B. Fractures of the Shaft of the Femur.—Fractures of the shaft of the femur occur at any age but are most frequently found in young children and in adults in the early decades of life. They may be divided into fractures of the upper, middle and lower third. Fractures of the middle third are the most common. Plageman's 55 cases and a like number of our series show:

Site.	Plageman.[2]	Estes.[3]
Upper third	9	13
Middle third	40	30
Lower third	6	12

Etiology.—1. Direct violence—a blow or a fall upon the thigh, or a thigh squeezing injury.

2. Indirect violence—a fall on the feet, causing a bending or a twist of the femur, or both.

3. Muscular action—torsion of the femur—a twist of the body and upper thigh, with the foot fixed. Both indirect violence and muscular action may be combined to cause fracture.

Pathology.—Femoral shaft fractures may be either transverse, oblique or spiral, and are frequently comminuted. A transverse fracture is usually a result of direct injury; oblique and spiral fractures

[1] Plating of this fracture is a formidable operation and should be undertaken only by the experienced surgeon under strict aseptic instrumental technic, as infection in this region and inefficient open reduction are especially liable to disastrous results, *i. e.*, non-union and osteomyelitis.

[2] Roberts and Kelly: Fractures, 1916.

[3] Ann. Surg., 1920, lxxi, 40.

result from indirect or muscular violence. There is always more or less injury to the soft tissues and especially in the lower third, there may be serious lesions of nerves and bloodvessels. Compound fracture, open wounds, and lacerations of the muscles are not uncommon.

There may be multiple fractures, linear—hairline or fissured—fractures, or incomplete fissures in the bone.

Fractures of the upper third are usually oblique from above downward and outward, and there is marked displacement. The gluteals and the external rotators draw the upper fragment upward and rotate it outward and the iliopsoas muscle pulls it anteriorly to a position of flexion. The lower fragment is carried inward and upward by the adductors and hamstring muscles.

Fig 77.—Fracture of the middle third of the femur. Comminuted slight outward displacement. Upper fragment overlapping.

Fig. 78.—Comminuted fracture of the lower third of the femur. Backward and outward displacement of lower fragment.

Fractures of the middle third are most frequently transverse and comminuted. Their displacement is inconstant. However, the upper fragment tends to be displaced outward and anteriorly, and overriding is the rule (Fig. 77).

Fractures of the lower third are commonly transverse or slightly oblique. The lower fragment is tilted backward by the action of the hamstring and gastrocnemius muscles, the upper fragment may be drawn inward by the adductors, and there is overriding due to the strong contraction of the quadriceps femoris (Fig. 78, 79 and 80). The posterior tilting of the lower fragment may cause pressure upon

Fig. 79.—Low fracture of the shaft of the femur. Displacement of the lower fragment backward by the gastrocnemius muscle, and of the upper fragment forward. Overlapping of fragments. (Scudder.)

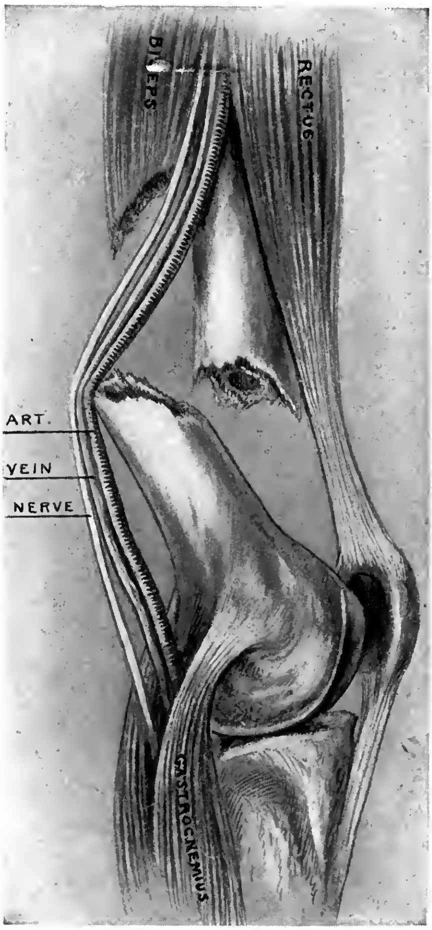


Fig. 80.—Demonstrating the pull of the gastrocnemius in fracture of lower third of femur. Backward displacement, lower fragment. (Roberts and Kelly.)

the popliteal vessels and nerves; if reduction is delayed, thrombosis of the vessels and gangrene may set in.

Diagnosis.—The diagnosis of a complete fracture of the shaft of the femur presents no difficulty. It is almost always attended by shock, of which the outstanding features are pallor and a low tension pulse. There is marked pain in the thigh and inability to move the extremity.

Signs of fracture as determined by examination are:

Inspection.—1. Swelling of the thigh with ecchymosis.

2. Deformity or alteration of the normal alignment of the thigh, and abnormal position of the leg or foot.

3. Shortening of the affected extremity.

Palpation.—1. Marked local tenderness at the fracture site. The deep muscle swelling and infiltration are so extensive that the fracture margins can scarcely ever be felt.

2. Crepitus and abnormal mobility are easily obtained and should be elicited very gently.

3. Actual measured shortening.

The patient should be on a firm bed or table and, as in fracture of the femoral neck, the position of the pelvis must first be ascertained and corrected so that the midline of the body through the sternum, umbilicus, and symphysis is at right angles to the line joining the anterior-superior spines. The distance from the internal malleolus of the ankle to the anterior-superior spine of the ilium should be measured and compared to the measurement of the sound side.

In partial or incomplete fractures without displacement, the signs may be only those of a contusion—local swelling and tenderness. The true condition is revealed only by the roentgenograph.

Despite any obvious indication of fracture, a roentgenogram should always be taken. Both antero-posterior and lateral views are necessary. A careful study of the x-ray plate should always precede any attempt at reduction, except in severe gunshot and compound fractures, and fractures of the lower third with marked displacement of the distal fragment. In these cases, the character of the circulation in the leg and foot should be ascertained, the dorsalis pedis or posterior tibial arteries palpated, and any swelling or cyanosis noted. When impaired circulation evidently exists, reduction should be undertaken as soon as possible. If access to a fluoroscope may be had or a rapid roentgenogram is feasible, it is well to have their assistance but no excessive delay should be tolerated.

Prognosis.—Complete return of function depends upon the final position of the fragments—whether or not they have been adequately reduced, and whether proper alignment has been obtained.

Adequate apposition and proper alignment are especially important in the lower extremity because of the weight-bearing demanded of it; open operation may be indicated more often than in the upper extremity, to obtain the apposition a painless weight-bearing union requires.

Shortening up to $2\frac{1}{2}$ cm. will give but little disability. In a displaced fracture, treated by the closed method, some shortening is to be expected.

The usual period or disability has been estimated by the Committee on Fractures of the American Surgical Association to be six months in simple fracture, and thirteen months in open or compound fracture. Fractures of the lower third, in which posterior displacement persists, are especially prone to be delayed in uniting. Systemic disease such as syphilis, a compound fracture with or without osteomyelitis or necrosis, delayed reduction, inefficient immobilization, or late open reduction, will tend to delay union and prolong disability. There is likewise an occasional case in which union is delayed for no determinable cause, in spite of excellent approximation, but in which sound union eventually takes place.

Non-union of shaft fractures is not common. Failure of reduction, insufficient fixation after open operation, and osteomyelitis, or necrosis in compound fractures, are the usual causes.

Treatment.—Patients with fracture of the shaft of the femur usually suffer from shock, *which is aggravated* by any movement of the lacerated thigh muscles. It is obvious that the first move in treatment must be directed toward the relief of shock which should, therefore, include immobilization of the fracture. A Thomas splint is by far the best and quickest means for accomplishing this end, and when it is well tolerated and there is little or no displacement of the fragments, may even serve as a permanent dressing. If a Thomas splint is not available, two well-padded, long lateral splints may be applied—an external splint from the toes to the axilla and an internal splint from the toes to the perineum, held in place by a roller bandage or separate bandage straps. (This method has not the advantage of extension or traction which the Thomas splint offers.) With these dressings, the patient may be readily transported without discomfort or injury, and sufficient fixation is given to permit the preliminary roentgenograph to be made and to control the fragments until permanent reduction can be undertaken. Reduction should not be delayed longer than the time necessary to overcome shock and to obtain a roentgenograph.

Reduction.—1. For fissured, longitudinal, or partial fractures without displacement, a Thomas splint or a plaster cast from the toes to the umbilicus will suffice. The Thomas splint has the advantage of permitting light massage and suspension which will aid in promoting an early return of function. (Fig. 81.)

2. Fractures, whether oblique or transverse, that have no more than 1 cm. shortening and in which at least two-thirds of the diameter of the femur is in apposition, require correction of any angulation by direct pressure at the fracture site, followed by the application of a cast while moderate, longitudinal traction is maintained. With two-thirds of the diameter of the bone in contact, good callus and functional result can be expected if proper alignment is obtained. It is precarious to attempt to better by manipulation a moderate displacement of this kind, especially in oblique or jagged transverse fractures, as the second

state may be far worse than the first and a late open operation which could have been avoided may eventually be required. For these fractures, a Thomas splint, with or without suspension, is also applicable.

3. For fracture with greater displacement or overriding, the following methods of reduction and immobilization may be used:

(*A*) *Rapid Traction and Cast.*—This method is especially applicable in fractures with displacement or angulation and little overriding or shortening, and also for those cases which are restive or ignorant and will not coöperate in suspension-traction treatment. The patient is stretched on a Hawley or McKenna table, or a Lemon traction apparatus. It is convenient to have an ankle and lower leg cast applied

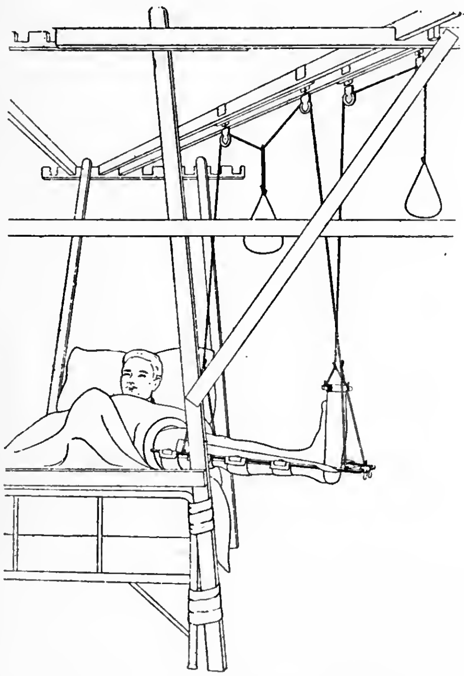


Fig. 81.—Thomas's splint suspension in abduction. (Splint Manual, U. S. A.)

previously so that the canvas or leather traction foot-piece will not impede circulation nor require removal for completion of the cast at the time of reduction. The thighs are slightly and equally abducted, and equal, steady traction on both lower extremities is made. Any degree of abduction desired may be obtained. When both extremities are equal in length, by measurement from the anterior-superior spine to the internal malleolus, proper manipulations—as indicated by the roentgenograph—are made, to correct angulation, overlapping or deficient apposition, and deviation of the fragments. In fracture of the middle and lower third due regard must be had for the normal anterior bowing of the femur. A plaster-of-Paris cast, carefully moulded at the knee and hip, is applied from the umbilicus to include the cast previously applied to the ankle and foot. When the cast has begun to harden, traction is very gradually released. A roentgenogram is then taken. If a portable x-ray outfit is at hand, brief fluoroscopy or roentgenograms may be made before the cast is put on, to ascertain the position of the fragments so that, if necessary, correction may be made at the same sitting. If the position obtained is unsatisfactory, a second attempt may be made; if still unsuccessful, another method had best be employed. If the position is satisfactory, the cast is undisturbed for from four to five weeks; it is then removed and the condition of the fracture and the amount of union is observed. Massage and passive motion are begun, the body portion is cut away and the remainder of the cast is rebandaged in place and removed daily for massage, or a Thomas splint may be used until union is firm—usually from six to eight weeks.

(*B*) *Suspension-traction.*—This method is especially applicable in overriding or badly comminuted, open or closed, fracture. It may be used, with direct traction on the femur, late in fracture treatment and before union has occurred, when other methods have proved unsuccessful.

A preliminary roentgenograph is practically a necessity. The position of the upper fragment, especially in the upper half of the thigh, is not susceptible to permanent change by other than direct means—operative exposure; therefore, the problem—to bring the fragments into position—is met by making traction upon the lower fragment in the longitudinal axis of the upper. Lateral traction straps are applied or glued to the thigh and leg. A Thomas splint—preferably a half ring Keller-Blake modification[1] may be used—or a Hodgen splint is adjusted and by it the entire extremity is suspended from a Balkan frame, with traction from a pulley on the frame by a weight of at least thirty pounds. The weight required will vary with the individual case but enough weight to overcome the shortening must be used. Any degree of flexion, abduction, or rotation of the thigh can be obtained so that the lower fragment can easily be brought into alignment with the upper. Particularly in the upper third, the rotation outward of the upper fragment must be met by the lower. Countertraction is made by the weight of the patient and by raising the foot of the bed. The head and shoulders of the patient should be raised to prevent any pulmonary complications from hypostatic congestion. The correction of the shortening or overlapping must be verified by roentgenographs for which a portable bedside unit is well nigh indispensable.

If marked overlapping exists, it is not likely that complete correction can be obtained unless some form of skeletal traction is used; *i. e.*, direct traction on the femur itself, either by a Besley or Ransohoff tongs or similar device, or a Steinmann pin or nail. The tongs must be constructed so that they clutch but do not penetrate the bone. After careful skin disinfection, they are applied 1 to 2 cm. proximal to

[1] Gunshot Fractures of the Extremities. Masson et Cie., 1918.

the condyles and the epiphyseal line. Traction is made directly from them. Dressings are placed around the skin perforations. With the Steinmann pin, the lower fragment of the femur is transfixed and traction is made directly from the pin by a pair of special tongs. Without preliminary incision, and with careful skin disinfection and under aseptic precautions, a nail 12 to 15 cm. in length, with bevelled edged point, is screwed, by hand drill or brace, completely through the lower end of the femur, one finger's breadth proximal to the condyles, and out through the skin of the opposite side. The tongs are applied to the ends of the nail and traction is made from them.

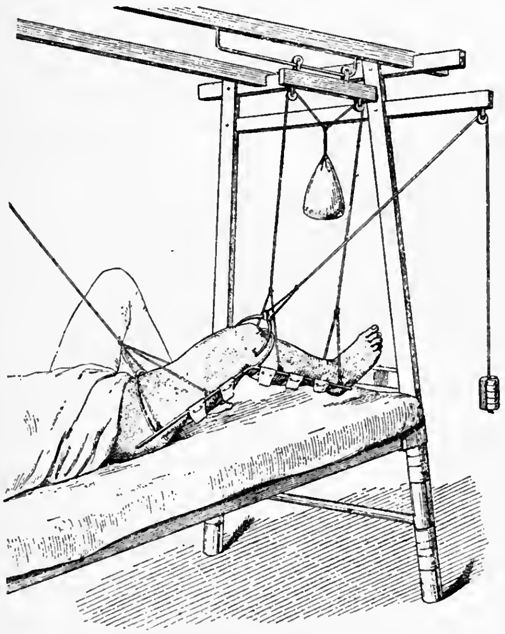


Fig. 82.—Method of treating high fractures of the femur with the Hodgen's splint and traction by the Codavilla (Steinmann) pin or Besley tongs. Abduction is obtained by placing the pulley for the traction cord on an outrider, and outward rotation by tilting the splint. The suspension attachment for preventing foot-drop has not been drawn. (The more proximal of the distal suspension cords should have been attached to the splint at the proximal side of the knee). (Blake.)

After insertion of the nail or tongs, suspension is made with the thigh and leg flexed; this relaxes both the hamstrings and the gastrocnemius muscles and less weight is necessary to overcome shortening (Fig. 82). Sufficient weight should be used to "overstretch the muscles in the first few hours or at least in the first day" (Blake[1]); in fresh fracture about 20 to 25 pounds, but so rapid a reduction may be difficult in an old fracture. If overlapping has entirely disappeared, as indicated by the roentgenograph, the weight may be diminished by one-

[1] Gunshot Fractures of the Extremities. Masson et Cie.

third. If in two or three days, the reduction is still well-maintained, a further gradual decrease in weight is indicated until just sufficient is employed to maintain proper reduction. Nail or tongs traction should not be continued more than four weeks. If union is not complete when skeletal traction is discontinued, a Thomas splint will be sufficient until firm union is established.

For fracture of the upper and middle third, when the use of nails or tongs is deemed inadvisable, a well-padded light cast may be applied to the knee in the flexed position; traction on the lower fragment being made directly by a wide sling or sheet folded in a figure-of-eight over it (Fig. 83). If much weight is required for reduction, however, it may not be a comfortable apparatus for the patient because of pressure upon the calf of the leg.

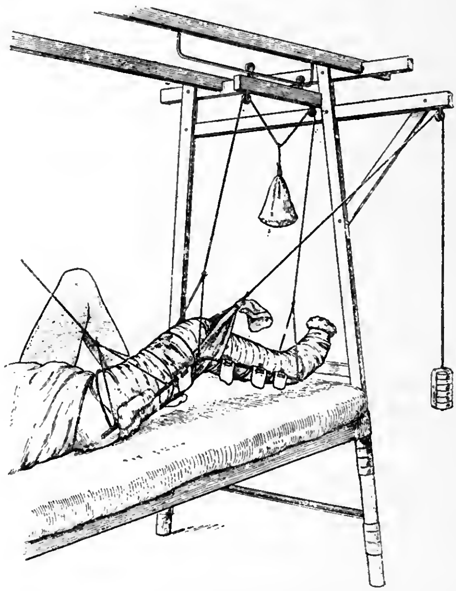


Fig. 83.—Hennequin's method in conjunction with Hodgen's splint in the treatment of fracture of the femur. (Blake.)

For fractures of the lower third with displacement of the lower fragment backward, traction had best be made by transfixion of the tibia just below the tubercle and in an axis below that of the upper fragment. Two methods of additional direct traction may be used when the shortening has been overcome by longitudinal traction. A well-padded suspension-sling may be placed directly beneath the sagging fragment, and traction made directly upward by it, or tongs may be used to grasp this lower fragment and, by traction straight upward, the backward inclination is corrected. If neither of these methods is successful, occasional late direct manipulation may improve the position when shortening has been overcome.

This method should supplant the old Buck's or Bardenheuer's extension, and the use of the inclined plane, as it embodies the principles for which they were of value, and has the additional advantage of permitting slight active motion in all joints and early massage and passive motion, thereby yielding an earlier return of function to the extremity and decreasing the average disability resulting from fracture.

In children, because of frequent soiling of dressings and apparatus by urine and feces, and difficulty in maintaining immobilization, Bryant's vertical extension or traction is most useful. Long glue or moleskin straps, applied to the lateral surfaces of the thigh and leg and fixed by smaller spiral strips, are looped and joined beyond the foot over a "spreader," by which direct, vertical traction is made with rope, pulley, and weight, from an overhead beam or support. A roller bandage is applied from the ankle to hip. Counter-extension is made by the weight of the child or by a wide, abdominal band fastening the child to a Bradford frame. In addition, coaptation splints may be applied to the thigh and held in place by three strips of bandage. In some cases, these splints and the Bradford frame may be dispensed with. After four to five weeks, the extremity is gradually lowered, massage and passive motion begun, and in two or three weeks more the patient may be ambulant, with a high shoe on the sound side. No weight-bearing should be permitted, however, until twelve weeks after the accident.

Birth fractures of the femoral shaft may result from a difficult breech extraction. Immobilization for three to four weeks by a long lateral splint or miniature Liston or Thomas splint will usually suffice.

3. *Open Reduction.*[1]—When overriding cannot be overcome by traction, when other methods have not been successful or are not tolerated, and when there is marked displacement of the fragments with interposed soft tissues, open operation is indicated. Lane's admonitions as to technic must be especially observed in fracture of the thigh.[2] All manipulations should be made by instruments; not even the gloved finger should be inserted in the wound. Incision is made along the lateral surface of the thigh, the site of the fracture exposed, and the fragments brought into apposition. Fixation may be made by:

1. Bone graft.
2. Intramedullary splint.
3. Bone pegs.
4. Plates.
5. Bands (Parham).

Though the pegs, splints, or grafts of bone are more ideal material than metal, the strong muscles of the thigh put such a great strain on the fixation apparatus that it may itself be fractured or displaced. It is in fractures of the femur that plates may especially be used to advantage, either with screws or pegs, or bolts. Lane advises two

[1] For open reduction of compound fracture see page 240.

[2] Operative Treatment of Fracture, London, 1914.

plates if there is likely to be excessive strain. In oblique fracture, circular metal bands have at times proved very successful (Parham[1]). For complete immobilization, fixation of the fragments must be supplemented by a plaster cast from the toes to the umbilicus.

After-treatment.—No use of crutches or walking is permitted until union has taken place. Weight-bearing is gradually permitted but crutches should be used for a full month and there should be very careful observation of the fracture for this period because, though union be firm, there may be incomplete consolidation and too early or too great weight-bearing may lead to bowing, even when—on examination—the fragments seem solidly united. A roentgenograph taken during this interval will indicate the character of the bony union and may be of valuable prognostic benefit in determining the time when complete weight-bearing is safe.

Complications.—Complications, other than delay in union, are very uncommon. It is very seldom that actual bloodvessel or nerve injury occurs with fracture of the shaft except in a complete crush of the thigh, when the trauma is so extensive that amputation is demanded. Fractures of the lower third with posterior, lower fragment displacement may, by pressure upon the popliteal vessels, cause impeded circulation, or may, very occasionally, be accompanied by foot drop, external popliteal paralysis—which clears up following reduction of the fracture.

Following open reduction or an open fracture, infection of the soft tissues or osteomyelitis may result. (See p. 242.)

In delayed union, the cause must be carefully sought, syphilis ruled out by a Wassermann test, and immobilization maintained by a Thomas or ambulant splint until union is firm, or definite non-union has occurred. In cases with good approximation but indolent repair, calcium salts may be administered by mouth, triple calcium phosphate may be injected locally as Albee[2] has recently suggested, or fibrin or blood serum may be injected between the fragments. For definite non-union, an intramedullary bone splint or inlay graft is almost a specific.

In cases of *prolonged immobilization,* stiffness and partial ankylosis of the knee may prove an obstinate sequela. Baking, electrotherapy, massage and passive motion, may have to be augmented by manipulation under ether. Slight permanent loss of function may result, especially in the rheumatic and elderly, but even in these cases 90 degrees of flexion is usually possible.

C. Fracture of the Lower End of the Femur.—Fractures of the lower end of the femur comprise:

1. Separation of the lower femoral epiphysis.
2. T-fracture of the lower end of the femur.
3. Fracture of the condyles.
4. Fracture of the epicondyles.

[1] New Orleans Med. and Surg. Jour., 1913, lxvi, 451.
[2] Ann. Surg., 1920, lxxi, 32.

1. **Separation of the Lower Femoral Epiphysis.**—*Etiology.*—Separation of the lower epiphysis of the femur may occur up to the age of twenty-one, when the epiphysis and diaphysis unite. Of epiphyseal separations it is one of the most frequent. It is usually due to great violence applied directly above the knee, such as results when the leg is caught in the spokes of a moving wheel (Binney and Lund[1]). It may also result from hyperextension of the knee from forcible attempts to manipulate an ankylosed knee.

Pathology.—The displacement may be very slight or extreme. In characteristic displacement, the diaphysis is forced directly backward. into the popliteal space and held there by the contracted gastrocnemius muscle, whose upper attachment extends to the shaft, not infrequently causing injury to the popliteal vessels and the external popliteal nerve; the lower end of the femur is carried forward and upward by the contraction of the quadriceps femoris muscle and is rotated toward the diaphysis so that the fractured surface almost faces the popliteal space beneath (Fig. 84).

Fig. 84.—Separation of lower epiphysis of femur; displacement forward with rotation about the transverse axis. (Stimson.)

Because of the great direct violence that usually produces this lesion, there is, in 30 to 50 per cent., an open wound (Binney and Lund).

The pressure upon the popliteal vessels may lead to popliteal thrombosis and cerebral embolism, or gangrene of the foot and leg. Actual laceration of the vessels may occur. Occasionally, the external popliteal nerve is injured, leading to paralysis of the peroneal and extensor muscles, and causing foot-drop. The paralysis usually clears up after

[1] Boston Med. and Surg. Jour., clxix, 49.

reduction of the fragments. Laceration of the nerve is exceedingly rare.

Diagnosis.—In cases with deformity, the diagnosis on examination is not difficult. There is loss of motion, and excessive pain in and above the knee.

The characteristic signs are: (1) Swelling about the knee and especially swelling and deformity just proximal to it. (2) Prominence of the patella. (3) Transverse depression above the patella across the thigh. (4) Bony prominence in the popliteal space. (5) Mobility above the knee with soft crepitus.

With little or no displacement, deformity is absent. Loss of function, local tenderness and swelling over the epiphyseal line alone may suggest the lesion. Without deformity, a roentgenogram is especially valuable for diagnosis. It is equally valuable in obvious separation, to determine the exact relative position of the fragments. Both anteroposterior and lateral views, or lateral stereoscopic plates should be taken.

Prognosis.—When reduction is accurate, a good functional result should be obtained. Very seldom, abnormal or deficient development of the epiphysis may occur and permanent shortening result (Binney and Lund).

Treatment.—In every case in which the separation of the lower femoral epiphysis has been suspected or diagnosed, the condition of the circulation of the leg must be carefully observed. Absence of pulsation in the dorsalis pedis or posterior tibial arteries, cyanosis of the foot, or extreme blanching or sluggish circulation, indicated by slow return of color after pressure, should demand *immediate* reduction. Even with unimpaired circulation, reduction should be undertaken as soon as the result of the roentgenogram can be ascertained; *i. e.*, the interval between the accident and reduction should be as short as possible.

1. In simple separation with little or no deformity, a plaster-of-Paris cast from the toes to the groin will suffice.

2. Cases of moderate displacement will require traction on the flexed leg, with direct pressure upon the displaced fragment, and immobilization in extension or semiflexion.

3. In cases with considerable displacement, an anesthetic is necessary. The leg is flexed to a right angle. Strong traction is made by an assistant grasping the leg just below the knee, and direct pressure upward on the depressed proximal fragment is made by the operator (Fig. 85). By this maneuver, replacement should occur. The leg is then slowly extended and the fracture site carefully palpated to determine whether proper reduction has been obtained. If reduction has been accomplished and is maintained, a well-padded cast may be applied with the knee in slight flexion. If the displacement recurs, or is only partially relieved, the procedure should be repeated with the leg maintained in flexion, or even acute flexion, if the deformity still tends to recur.

Should the fracture remain unreduced, as demonstrated by the roentgenograph, or sufficient flexion cannot be maintained, due to an open wound requiring dressing, or to extreme laceration of the soft parts, direct exposure of the fracture should be made, reduction accomplished by direct manipulation, and the fragments nailed in position, the nail to be removed in three or four weeks. A cast from the toes to the umbilicus is applied in partial flexion.

In old cases with malunion, open reposition, or perhaps excision of the joint, or arthrotomy may be necessary.

After-treatment.—In no other fracture is it more important to have roentgenograms following the reduction. Very often accurate reduction is not maintained, and further attempts are necessary. When reposition is accurate, the cast under daily surveillance is allowed to remain for three to four weeks. It is then removed, massage and slight

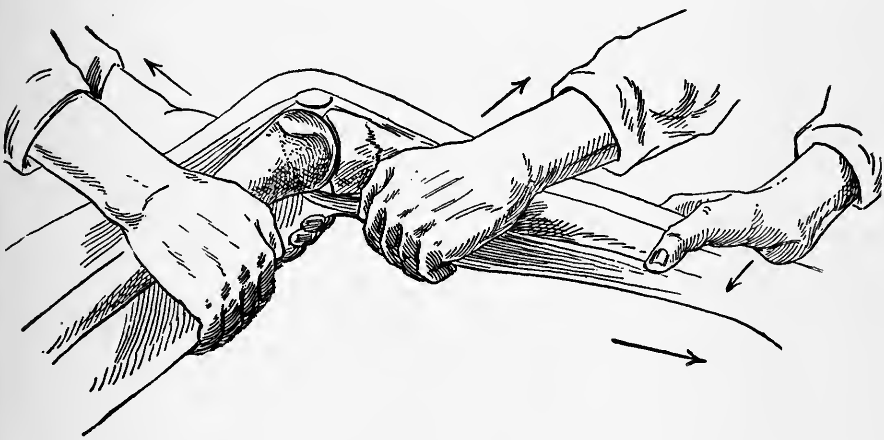


Fig. 85.—Method of reduction of separation of the lower epiphysis of the femur. (Roberts and Kelly.)

passive motion begun, and the cast without the pelvic portion rebandaged in place. At five weeks, the patient may be out of bed on a chair, a bandage applied, and the cast left off. At six weeks, crutches are permitted without weight-bearing; at eight weeks walking may be begun.

Complications.—The most serious complication of the lower femoral epiphyseal separation is popliteal vessel injury. When the circulation of the leg is not improved by reduction and gangrene sets in, amputation above the fracture level will be necessary. Popliteal aneurism may be a late result in cases in which normal circulation is restored.

The injury to the external popliteal nerve is less serious. The paralysis—foot-drop—usually clears up after reduction.

2. **T-Fracture of the Lower End of the Femur.**—"T," or "Y," or intercondyloid, fracture of the lower end of the femur is not at all common.

Etiology.—It usually results from indirect violence, a fall or a blow on the foot with the knee flexed or overextended; and very rarely from direct violence, such as a blow or fall on the flexed knee.

Pathology.—The fracture is T- or Y-shaped; in T-fracture the lines of cleavage are inter- and supracondylar, splitting or separating the lower end of the femur roughly into its two condyles. Y-fracture is

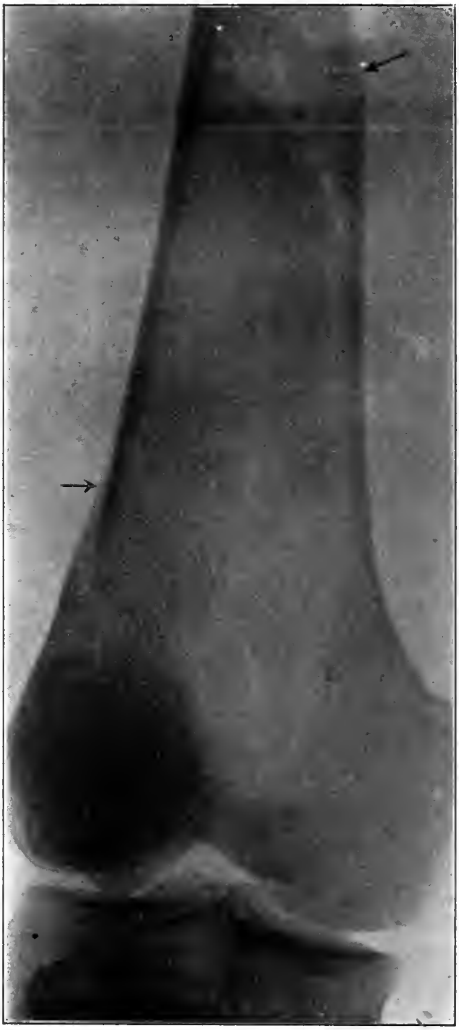


Fig. 86.—Y-fracture of the lower end of the femur. No displacement.

more common. The condyles are split but the oblique arms are not always confined to the supracondylar area but may extend high into the femoral shaft. With displacement, the fragments tend to slip laterally and posteriorly. There may be extensive comminution, laceration of the crucial ligaments or an open wound; with oblique fractures, pressure upon or laceration of the popliteal vessels is not unusual. Great hemorrhage or a large hematoma of the thigh may result, or thrombosis or gangrene may supervene.

Diagnosis.—As a rule there will be pain and inability to move the knee.

Signs.—(1) Swelling of and above the knee—effusion into the joint. (2) Passive flexion or any movement of the knee is very limited and painful. (3) Tenderness over the condyles. (4) Pressure on the condyles may reveal crepitus or abnormal mobility. The condyles may be independently movable. (5) Palpable displaced fragment

Fig. 87.—T-fracture of the lower end of the femur. External displacement of the shaft.

margins. The effusion into the knee-joint shields the true condition and unless crepitus or abnormal mobility is present, or alteration in the contour of the condyles—by comparison with the normal knee—is demonstrable, the condition may be only suspected until the roentgenogram is studied.

Prognosis.—Some permanent loss of function of the knee is likely; the degree of function obtained depends upon the accuracy of reduction. There is high mortality reported by Hennequin (Stimson[1])—apparently

[1] Fractures and Dislocations, 1917.

as a result of bloodvessel injury or of suppuration of a wound extending to the knee-joint—7 deaths in 26 cases; amputation was necessary in 3.

Treatment.—The treatment hinges upon the amount of displacement of the fragments. With slight displacement, the knee is extended, traction is made on the leg by an assistant, and lateral pressure and compression by the palms of the operator's hands, to push the fragments into position. Traction must be maintained or the condyles may pop out of place. Circular adhesive strips will tend to maintain reduction but must be supplemented by a plaster cast or Thomas splint. Passive motion and massage is begun in three weeks and no weight-bearing is allowed for twelve weeks. With fragments out of alignment, and with direct pressure and traction unsuccessful for reduction after several attempts, open operation, and pegging or nailing the fragments in position must be considered. Return of function is slow.

If gangrene of the leg sets in, amputation will be necessary. Careful aseptic treatment is particularly indicated in an open fracture because if suppuration occurs in the wound the knee-joint is very likely to be secondarily involved.

3–4.—**Fracture of the Condyles and Epicondyles.**—Fracture of a single femoral condyle is exceedingly rare. It may occur as an isolated lesion or with fracture of a tibial tuberosity.

Etiology.—It may result from direct injury but more commonly from forced hyperabduction or adduction of the knee, or from a twist of the leg.

Pathology.—There is an oblique split from the intercondylar notch to include just the condyle or a long projection into the shaft. The condyle may be displaced backward, upward and laterally.

Diagnosis.—There is disability and pain and swelling of the knee, especially about the affected condyle, and effusion into the joint. With the condyle displaced, a varus or valgus deformity, according as to whether the internal or external condyle is involved will be unmistakable evidence. There is always local tenderness, but mobility of the fragment and crepitus is unusual. Without displacement the roentgenograph will be necessary to give a positive indication of fracture.

Treatment.—A plaster cast from the toes to the groin is sufficient in fracture without displacement. With displacement, restoration of the fragment to its normal position may be very difficult. Traction on a Thomas splint should be tried. Lateral traction straps are applied to the leg, the Thomas splint is fitted in place and strong traction on the leg is made by an assistant, and the straps fastened over the end of the splint in the usual manner. The operator with the palm of his hand presses the fragment into place. Circular adhesive strips will hold it in place. There will be no tendency to recurrence as long as traction on the tibia is maintained. If the first attempt is not successful, an anesthetic and further manipulation should be tried before recourse is had to open operation. At times a few hours of traction is necessary before reduction is possible.

Failing approximation by repeated closed effort, the fragment may be exposed, reduced, and nailed in place. The nail is removed in three to four weeks, and massage and passive motion begun. A splint or cast is necessary until the sixth or seventh week. No weight-bearing should be permitted for twelve weeks.

Fractures of the epicondyles are not common. They are usually tear-fractures and result from the strain and tearing of attached ligaments. Direct injury is the cause of very few.

Fig. 88.—Sesamoid bone in the tendon of the gastrocnemius. (Not to be mistaken for fracture of the epicondyle.)

There is local tenderness and severe pain over the epicondyle, swelling of the knee, and pain and swelling along the lateral ligament of the involved side. Mobility of the fragment and crepitus may be difficult to determine because of local swelling, and fracture may not be suspected until revealed by a roentgenogram. In the roentgenographic examination an occasional accessory sesamoid bone in the tendon of the gastrocnemius muscle must not be mistaken for fracture. Simple immobilization for three weeks, followed by massage and passive motion, should give a return of normal function.

FRACTURES OF THE PATELLA.

The patella is a sesamoid bone in the tendon of the quadriceps femoris muscle and in intimate relationship with the capsule of the knee-joint. Fracture of the patella occurs most commonly in adult males; less often in women; very rarely in children.

Etiology.—Fractures of the patella result either from:

1. Direct violence—a fall upon the flexed knee.

2. Muscular contraction—sharp violent contraction of the quadriceps femoris muscle, usually when the knee is partially flexed and the foot is fixed. It may be produced by an attempt to prevent a fall following a misstep or by forcible flexion of the leg against muscular resistance. Muscular contraction is the more common cause but it may be difficult to decide in an individual case which factor is at fault. In some instances, both direct violence and muscular contraction may be implicated.

FIG. 89.—Comminuted fracture of the patella.

Pathology.—The fracture may be oblique, longitudinal, or comminuted, usually as a result of direct violence (Fig. 89), but the most common lesion is a transverse fracture near the middle of the patella with separation and retraction of the fragments. This is the result of the violent contraction of the quadriceps femoris muscle. The fracture may be near the distal tip or in the proximal portion of the bone (Fig. 90). It may be subperiosteal with no displacement, or the fragments may be markedly separated and rotated, or tilted anteriorly or posteriorly. When there is transverse fracture with the fragments widely separated, the line of fracture is continued laterally by tears completely through the joint capsule itself, causing hemorrhage and great effusion into the knee-joint, and increasing the separation of the fragments. The periosteum, fascia, and aponeurosis over the patella is likewise torn across, and the ragged edges overhang the fractured surfaces and are folded in between the fragments.

There may be an abrasion of the skin, or a prepatellar bursitis, or an open wound following a direct injury. There are numerous instances of simultaneous fracture of both patellæ.

Diagnosis.—The diagnosis in transverse fracture usually presents no difficulty.

FIG. 90.—Transverse fracture of the patella near the distal tip. Rotation of the lower fragment.

The *symptoms* are: 1. Pain in the knee.

2. Inability to use or move the knee because of pain.

3. Extension of the knee is difficult but may be possible by swinging the thigh, but the leg, when extended, cannot be lifted off the bed.

Signs.—1. Marked swelling and effusion in the knee.

2. Pain on palpation, and local tenderness over the patella.

3. Fracture margins palpable and one or two fingers may easily be sunk in the interval or space between them.

4. Abnormal mobility of the fragments—crepitus can usually be obtained but is quite painful to elicit; it is not needed to establish the diagnosis.

When there is extensive laceration of the capsule, there is great effusion and fluctuation, not only in the joint but superficially in the subcutaneous tissues continuous with joint fluctuation. Marked ecchymosis may appear.

In fractures without displacement, pain, abrasions or sign of local injury and tenderness about the patella may be the only indication of fracture. A roentgenogram will be necessary for diagnosis. A roentgenogram is also important in any fracture to determine its exact location and character, and to ascertain any concomitant bony abnormality.

Prognosis.—A good functional result can be expected in fractures without displacement. In fractures with displacement, better results follow open operation. Quinby's[1] oft-quoted statistics are of interest. In a series of 30 cases, 24 were sutured and 6 treated conservatively. Serviceable knees were obtained in 84.5 per cent. of the sutured and in 66.5 per cent. of the closed.

The frequency with which fibrous instead of bony union occurs makes refracture not uncommon. When function is impaired, there may be not only a lack of full flexion but also full extension, with fibrous adhesions in the joint or subquadriceps bursitis leading to persistent pain and stiffness.

The usual period of disability is eight to ten weeks after an open operation; twelve weeks after closed reduction. Return of function is more rapid following open reduction.

Treatment.—A temporary dressing, to serve for transportation or until a roentgenogram is taken, or until permanent dressing preparations are complete, should comprise a carefully applied bandage with cotton wadding about the knee and a posterior splint from the upper thigh to the heel.

As soon as a positive diagnosis has been made, treatment should be instituted. Treatment may be either by closed or open methods. Closed reduction is indicated in fissured fractures or those without much displacement, ½ cm. or less, and in the elderly and feeble. It must also be resorted to in patients who refuse operation or in cases in which an operation is contra-indicated.

Transverse fracture with moderate or marked separation, a compound fracture, a fracture with laceration of the joint capsule, *i. e.*, 80 per cent. of all fractures (of the patella), are best treated by open operation. Better and more certain approximation is obtained and the joint more accurately restored. Asepsis, however, must be assured and the operation performed only under the most favorable circumstances.

1. *Closed Reduction.*—The leg is extended and elevated to relax the quadriceps femoris muscle. An assistant holds the fragments of the patella in apposition. An adhesive strap is looped behind the upper fragment to draw it distally; another strap is similarly looped behind the lower fragment which is drawn proximally. A cast or well-padded pos-

[1] Boston Med. and Surg. Jour., 1905, cliii, 22.

terior splint is then applied with the leg in a position just short of complete extension (Fig. 91). The extremity is suspended to maintain relaxation of the quadriceps extensor muscle. A splint has an advantage over a cast in that massage may be given early. All apparatus should be removed after five weeks, active movement encouraged, and massage and passive motion regularly given. After eight weeks walking is permitted.

2. *Open Operation.*—Under tourniquet hemostasis, a transverse incision is made, or a flattened U-incision, convex side upward, curving over or above the upper fragment. This brings the resultant scar away from the line of fracture and the weight or pressure-bearing surface of the knee. The fracture site is carefully exposed and bits of

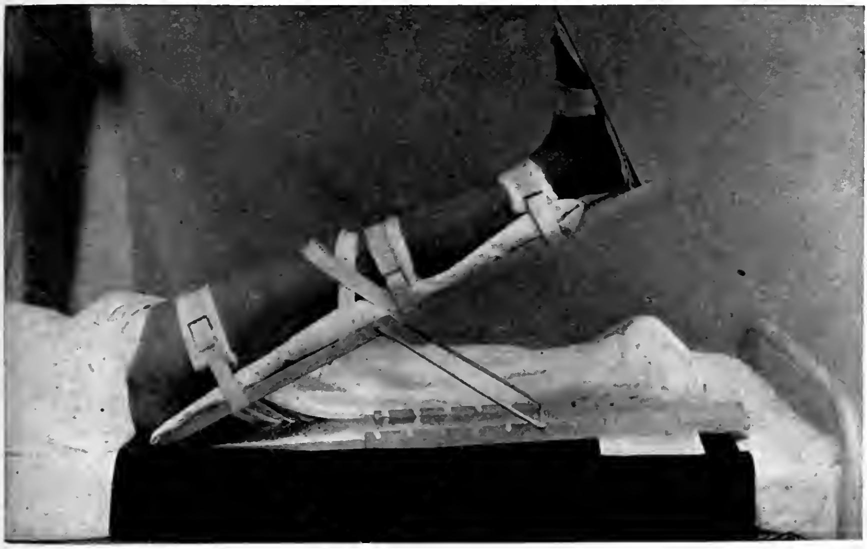


Fig. 91—Method of non-operative treatment of fracture of the patella on inclined plane. The leg is fixed securely by straps of adhesive plaster to the splint, and the fragments of the patella are approximated by two strips of adhesive plaster shown. Elevation of the leg is then made to relax the quadriceps extensor muscle. (Roberts and Kelly.)

interposed periosteum drawn aside and clots removed. The joint cavity is flushed with a normal saline solution to remove detritus and clots, or gently sponged free of clot and débris. The lateral tears of the joint capsule are sutured with interrupted chromic catgut and the fracture fragments replaced and fixed by interrupted suture of kangaroo tendon or chromic gut through the periosteum and fascia. Wire has been, and can be, used to maintain reduction, but it has the disadvantage of requiring drill-holes through the patella or a large amount of wire for complete encirclement of the bone, and the wire may act as a foreign body and must be removed at a subsequent operation. The tourniquet is removed, the bleeding vessels controlled by ligature, the skin incision closed, with a rubber tissue drain at each angle or without drainage. A cast is applied from the toes to the groin, with the leg extended. At the end of three weeks the cast should be cut and massage and passive motion begun. Crutches may be allowed with the cast rebandaged in place for protection, for two more weeks, and a simple bandage or adhesive plaster strips may then be substituted.

Complications.—Refracture during convalescence or from a subsequent fall is not uncommon. In convalescence, conservative treatment usually is sufficient, *i. e.*, approximation, adhesive plaster, and a posterior splint. If several months have elapsed, it may be regarded as a fresh fracture and treated accordingly; *i. e.*, open operation if there is separation of the fragments.

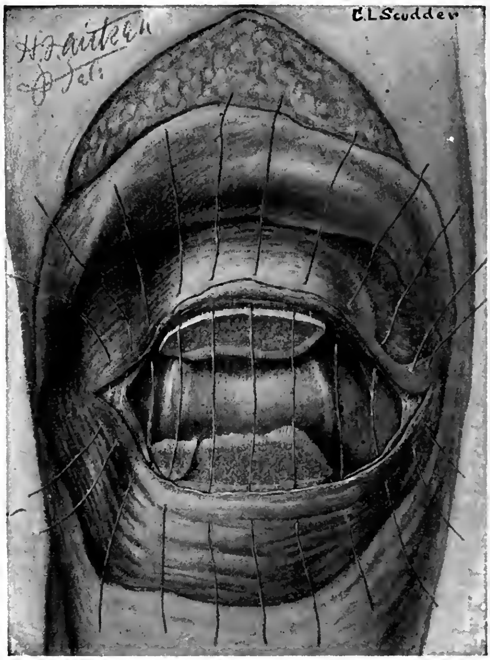


FIG. 92.—Note the sutures carried through the fasciæ torn about knee in fracture of patella. None of the sutures enter the knee-joint. This method of suture is efficient in approximating most fractured patellæ. (Scudder.)

Old Fracture of the Patella.—There are numerous instances where conservative treatment with poor anatomical result—persistent separation of the fragments of 2 cm. or more—have yielded excellent function. Impaired function only, and not malposition of the fragments, is an indication for interference and treatment. Only open operation is of avail. Various methods may be employed. Approximation of the fragments by direct traction should first be tried; wire may be of service in these old fractures. If impossible to accomplish, then either:

1. Lengthening of the quadriceps femoris tendon by zigzag incisions so that the fragments may be brought in contact; or

2. Autoplastic periosteal or tendinous flaps from above and below may be overlapped to bridge the gap (Wolf[1]-Ferraresi[2]).

3. Tenorrhaphy of the tendon of the quadriceps femoris muscle to permit contact of the fragments (Quenu and Gotellier[3]).

Even an inlay bone-graft has been suggested as a possible method of obtaining union in these old fractures.

FRACTURES OF THE TIBIA AND FIBULA.

Fractures of the tibia and fibula may be divided into:

1. Fracture of the upper end.
2. Fracture of the shaft.
3. Fracture of the lower end.

Fracture of the Upper End.—Fractures of the upper end of the tibia and fibula comprise:

(*a*) Fracture of the spine of the tibia.
(*b*) Separation of the upper epiphysis of the tibia.
(*c*) Fracture of the tuberosities.
(*d*) T-fracture of the tibia.
(*e*) Fracture of the tubercle of the tibia.
(*f*) Fracture of the head and neck of the fibula.

(*a*) **Fracture of the Spine of the Tibia.**—Fracture of the spine of the tibia is very rare. It is the result of indirect violence.

Etiology.—1. Forced acute flexion—hyperflexion—of the knee which by a sudden pull of the crucial ligaments evulses the spine of the tibia.

2. A twist of the knee—"a combined slide and twist of the femoral condyles on the tibia" (Jones[4]).

Diagnosis.—The diagnosis from simple rupture of the crucial ligaments is practically impossible without the *x*-ray. There is great swelling and pain in the knee; later, preternatural mobility of the knee. It is possible, with the leg in extension, to displace the tibia at the knee backward or forward, or rotate it inward.

Treatment.—The leg must be extended; if the fragment interferes, manipulation and forceful extension may drive it up between the condyles and full extension is obtained. The knee may be immobilized in this position, by splint or cast. The functional result is usually good though there may be some limitation of flexion (Jones).

If extension is not possible after a primary injury, or there has been repeated and recurrent trauma and disability, operation is indicated. The joint is opened under rigid asepsis and tourniquet hemostasis, and the fragment and crucial ligaments excised. Good function followed operation in Lewis' case.[5]

(*b*) **Separation of the Upper Epiphysis of Tibia and Fibula.**—Separation of the upper tibial epiphysis is exceedingly rare. Roberts has found

[1] Verhandl. d. Deutsch. Gesell. f. Chir., 1901, 27 ver beil, 44.
[2] Policlin. Roma, 1902, ix, Sez Chir., 550.
[3] Rev. de Chir., 1913–2, xlviii, 173.
[4] Injuries of Joints. Oxford War Primers, 1917.
[5] International Clinics, 1918, xxvii, S. ii, 67.

but 26 cases reported. It may occur up to twenty years of age. It results from hyperextension or violent abduction or adduction of the knee.

Pathology.—The entire epiphysis, including the tubercle tongue is separated, usually displaced forward or laterally. There may be an open wound.

Diagnosis.—Unless the forward deformity is suggestive, the radiogram alone will reveal the true lesion. Pain, swelling of the knee, tenderness over the epiphysis, and abnormal mobility just distal to the joint with soft crepitus may be present.

Treatment.—By traction and direct manipulation, reduction is accomplished. The leg from the toes to the groin is immobilized in a plaster cast. In three to four weeks this is removed and passive motion and massage begun. No weight-bearing should be permitted for eight weeks.

(*c*) **Fracture of the Tuberosities of the Tibia,** and

(*d*) **T-fracture of the Upper End of the Tibia.**—Fracture of a tuberosity is the common upper tibial fracture.

Etiology.—Direct violence—a fall or blow upon, or a crush of the upper leg.

Indirect violence—hyperabduction will produce an external tuberosity fracture; hyperadduction, an internal tuberosity fracture. A fall from a height upon the foot may cause a fracture of either tuberosity or a T-fracture of the upper end of the tibia.

Pathology.—Fractures of the tuberosities are almost always oblique (Fig. 93) and there may be but little displacement or the fragment is displaced distally and outward. T-fracture may be merely a fissured fracture or the diaphysis may be driven upward to cause crushing and marked separation of the tuberosity fragments.

With fracture of one tuberosity, there may be a fracture of the corresponding condyle of the femur. Fractures from direct violence may have an open wound. If infection results, joint involvement is very likely.

Diagnosis.—Pain and swelling at and just below the knee and loss of function of the knee are suggestive symptoms. The signs that usually accompany tuberosity fracture are:

1. Swelling of the knee and effusion into the joint.
2. Swelling and ecchymosis over one or both tuberosities; *i. e.*, the site of the fracture.
3. Tendency to genu valgum, if there is displacement with external tuberosity fracture; genu varum with displacement in internal tuberosity fractures.
4. Widening just below the knee, especially in T-fracture.
5. Any movement at the knee is exceedingly painful.
6. Marked local tenderness over the affected tuberosity or tuberosities.

Crepitus and abnormal mobility are very seldom obtained, and without deformity, it is unwise to seek actively to demonstrate them. Under an anesthetic, abnormal lateral mobility when the fragment is displaced may be very evident.

If deformity is present, fracture may be readily suspected; in its absence, loss of voluntary motion, local swelling and tenderness are presumptive evidence. A roentgenogram is necessary to determine the exact lesion and amount of displacement, and will differentiate in any confusion from traumatic arthritis or dislocation of the semilunar cartilage.

Prognosis.—Fracture of one or both tuberosities with displacement is very likely to lead to some permanent loss of function of the knee; the range of flexion is diminished but usually a right angle—90 degrees—or better is obtained.

With open fractures and sepsis especially in T-fracture, suppuration of the knee-joint itself is likely, adding immediately a grave mortality and likelihood of permanent disability and ankylosis.

FIG. 93.—Fracture of the internal tuberosity of the tibia. Downward and inward displacement of the fragment.

Treatment.—1. With little, or no displacement of the fragments a plaster cast from the toes to the groin is sufficient.

2. With displacement and deformity, the leg should be extended and strong traction on a Thomas knee splint with direct pressure and manipulation should first be tried. By firm pressure with the palms of the hands, and after traction, the tuberosities may be coaxed together. Several attempts may be necessary for complete reduction but there is very little tendency to recurrence if traction is maintained (Jones[1]).

[1] Injuries of Joints. Oxford War Primers, 1917.

Careful confirmation of replacement of the fragment must be made by roentgenograms. A posterior splint incorporated with the Thomas splint will tend to correct any inclination toward sagging or overextension of the knee. Traction on a Lemon or Hawley table with direct pressure and application of a cast may also be employed. If displacement persists, which is but seldom, open operation with reduction and nailing the fragments in position is indicated (Jones). Acute flexion of the knee will not be of service in these fractures as accurate reduction cannot be maintained by it. Precise reposition is imperative, for genu varum or genu valgum is prone to occur when the displacement persists, and permanent pain in the knee and impairment of function results.

After-treatment.—With a cast or Thomas splint, early massage and passive movement must be instituted. As early as the end of the second week, the cast may be cut and gentle massage and movement begun. With a Thomas splint, light massage may be used after the first few days. Weight-bearing should be allowed very cautiously after the seventh week when the splint or cast can be dispensed with. Crutches are best used from ten to twelve weeks.

(*e*) **Fracture of the Tubercle of the Tibia.**—The tubercle of the tibia is an anterior tongue-like prolongation of the upper tibial epiphysis which ossifies or unites with the diaphysis about the twenty-first year. Occasionally the tubercle is a separate epiphysis. Injuries to the tubercle are found in youth or young adults.

Etiology.—The patellar tendon is attached to the tibial tubercle but only a portion is inserted directly into it. Violent contraction of the quadriceps femoris has been known to cause evulsion and separation of the tubercle from the tibia.

A direct blow upon the tubercle may, very rarely, result in its separation from the tibia.

Pathology.—In youth, a separation of the epiphysis of the tubercle is likely, in adults actual fracture.

Diagnosis.—Direct evidence is usually not lacking. There is pain below the knee at the tibial tubercle, worse with extreme flexion and extension, swelling and local tenderness below the patella and independent mobility of the tubercle.

The roentgenogram should be used to confirm a suspected lesion but may be of doubtful value in slight epiphyseal separation.

Treatment.—Treatment consists in pressure over the tubercle by strips of adhesive and immobilization of the knee for from three to four weeks. If union fails or separation persists, the fragments may be pegged or nailed in place or removed. This is rarely necessary.

Persistent pain and tenderness after tibial tubercle fracture may be relieved by a linear incision in the tubercle with a chisel (Jones).

(*f*) **Fracture of the Head or Neck of the Fibula.**—Fracture of the fibular head or neck may occur with fracture of the external tibial tuberosity or upper third of the tibia (Fig. 94). It is almost unknown as an isolated lesion. There is usually no displacement. Local tenderness, pain and swelling are the only suggestion of fracture. The roentgenogram may reveal the fibular fracture as an incident to other fractures near the knee.

Immobilization for three weeks on a wire or posterior splint is all that is required.

Fig. 94.—Fracture of the head and neck of the fibula. Spiral fracture of the upper third of the tibia.

Fractures of the Shaft of the Tibia and Fibula.—In industrial accidents, the shafts of the tibia and fibula seem more prone to injury than that of any other long bone. In a series of 246 shaft fractures, there were 27 of the humerus, 45 of the radius and ulna, 55 of the femur, and 119 of the tibia and fibula. It is customary to consider shaft fracture as occurring in the upper, middle or lower third. Fractures of the lower third of the tibia or the junction of the middle and lower third are most common; fracture of the upper third is infrequent. Fracture of the shaft of the tibia alone, or of the fibula alone is not often encountered.

Etiology.—1. Direct violence—a crush, blow, or squeezing injury of the leg.

2. Indirect violence—a fall upon the foot.

3. Muscular violence—very rare, the fracture is caused by fixation of the foot and torsion of the leg and thigh.

The most frequent cause of fracture of the tibial and fibular shafts is direct violence.

Pathology.—The fracture is most often transverse or oblique, but may be spiral, longitudinal, or V-shaped; fissured or partial fracture is rare. There is, as a rule, well marked displacement; the upper or proximal fragment of the tibia is displaced anteriorly and mesially toward the internal surface of the leg, and the lower or distal fragment externally or laterally in the direction of the fibula (Figs. 95 and 96). The lower fragment of the fibula, also, is usually displaced outward—laterally. The tibia is so superficially placed that displacement may cause puncture of the skin by a sharp bony edge or spicule—or a laceration or open wound may result from the traumatism itself. Often, especially in open fractures, the lower fragment may be so badly rotated that the foot is turned out, the lower leg rests on its lateral aspect, or is bent double under the upper fragment, while the upper fragment remains in its normal extended position.

Fig. 95.—Fracture of the middle third of the tibia and fibula. External displacement of the lower fragments.

Fig. 96.—V-shaped fracture of the tibia. Oblique fracture of the fibula. Middle third. Direct violence.

An open wound, comminution and multiple fractures are not uncommon.

After direct injury, the tibia and fibula are usually broken at or about the same level. From indirect violence they are broken, as a rule, at different levels; the fracture of the fibula at a higher level—nearer the knee—than the tibia. There may be a double fracture of the fibula with a single fracture of the tibia and *vice versa*.

Diagnosis.—Deformity is usual with fracture of the shafts of the tibia and fibula. With any deformity or wound, the diagnosis presents no difficulty. Palpation at the site of deformity, in a closed fracture, will assist in ascertaining the displacement. Manipulations and movement without an anesthetic must be very gently and cautiously made.

When the position of the leg is to be changed, steady, gentle traction is made by an assistant holding the foot at the heel and toes and at the same time the leg is firmly grasped above and below the fracture, and the entire leg moved simultaneously as one. To elicit every cardinal sign when fracture is certain is not justifiable; it causes unnecessary pain and increased shock to the patient.

In cases with doubtful deformity or mere fissured fractures, the evidence of the fracture should be considered in detail:

Symptoms.—1. Pain in the leg usually along the shin.

2. Inability to walk or bear weight on the leg, or to move the leg without pain.

Examination.—Both legs should always be examined. An apparent deformity may be in reality a bilateral congenital abnormality—as exaggerated bow-legs, with which the injury must not be confused.

Inspection.—1. Swelling and ecchymosis at the fracture site.

2. A deviation from the normal alignment, recognized by comparison with the sound leg.

Palpation.—1. Local tenderness at the point of fracture. Fracture margins or irregularity may possibly be detected.

2. Abnormal mobility or crepitus must be gently sought. In fissured or incomplete fracture neither will be obtained, but the pressure upon or manipulation of the tibia elsewhere will give pain at the fracture site.

3. Shortening of the affected leg measured from the internal malleolus to the internal tuberosity.

The roentgenogram is of importance, not only in determining the exact character of the apparent fracture and in identifying fractures without deformity, but also in revealing multiple fractures that may be overshadowed by the gross lesion, such as longitudinal lines of fracture when only a transverse fracture has been otherwise identified (Figs. 97 and 98), double fracture of the fibula with single fracture of the tibia, etc.

Prognosis.—The usual total disability period in fractures of the shaft of the tibia and fibula is four months in simple fracture and six months in open or compound fracture. An open wound and even open reduction tends to prolong the period required for union. Insufficient reduction, inefficient and over-long immobilization will delay union and return of function; syphilis, and, in open fractures, necrosis and osteomyelitis are often factors. The tibia seems particularly prone to show delay in union. Blake[1] has observed in war fractures that repair is more indolent than elsewhere in the body and ascribes it to the lack of soft parts over the bone. It is in the tibia especially that Jones[2] has noted an unaccountable delay in union even when apposition is excellent; after an unduly long period of six or eight weeks, with very little sign of union, the dormant osteogenetic ability is aroused and union eventually, and fairly rapidly in the end takes place.

An open fracture, especially if comminuted, is likely to develop

[1] Gunshot Fractures of the Extremities, p. 14. Masson et Cie.

[2] British Med. Jour., 1912, p. 1598.

necrosis of one or more fragments—"bone fistulæ," or chronic osteomyelitis—with delay in union and occasionally non-union.

If proper after-care is not received, angulation of the fragments or eversion of the foot, due to rotation outward of the lower fragment, may occur, leading to permanent or intermittent pain at the seat of fracture. Outward rotation and eversion in addition to pain and impaired function in the ankle will provide a real disability in walking—very little if any true adduction or inversion will be possible. Refracture or an osteotomy may be necessary for relief.

Fig. 97.—Multiple tibial fractures. Antero-posterior view.

Fig. 98.—Multiple tibial fractures. Lateral View.

Treatment.—In fracture of both the tibia and fibular shafts the tibia, as the weight-bearing support, is the chief consideration. The fracture of the fibula in general may be ignored. When there is fracture at the same level in both tibia and fibula, measures to correct the tibial defect will tend at the same time to relieve the fibular displacement.

Preliminary or first-aid treatment instituted until reduction amid favorable surroundings can take place should include immobilization of the fracture by a pillow and long lateral splints. If there is any deformity, marked deviation, angulation or rotation of the lower fragment, it is first corrected by traction on the foot in the axis of the upper fragment, and as good alignment as possible obtained. The entire extremity from the lower third of the thigh to the toes is placed

FIG. 99.—Fracture of the leg. Pillow and side splints with straps and towels. Compare Fig. 100.

upon a pillow, the pillow folded to include the foot, leg and knee; internal and external long, lateral splints are applied from the soles of the feet to the lower third of the thigh, with the pillow as padding, and are strapped or bandaged in place (Figs. 99 and 100). This dressing gives sufficient immobilization so that the patient may be transported and roentgenographed.

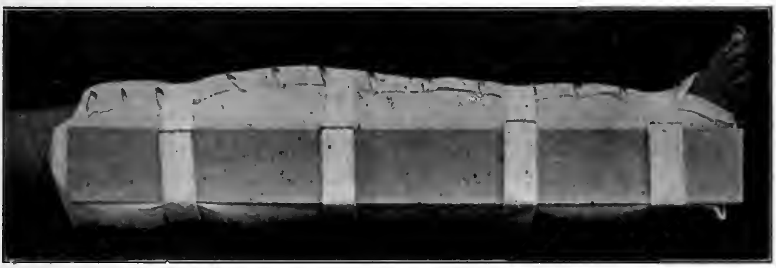


FIG. 100.—Fracture of the leg. Temporary or emergency dressing. Pillow, side splints and straps. Pillow held by shield-pins. (Scudder.)

In default of a pillow, simple well-padded long, lateral splints which should extend beyond the plantar surface of the foot and above the knee are held in place and the foot also firmly supported by a bandage.

Following the roentgenograph, reduction should take place as soon as possible. Compound fractures with protrusion of a fragment through the skin, or simple fractures with obvious overlapping and overriding will demand immediate reduction.

Simple fissured fracture without displacement needs only a well-padded gypsum cast from the toes to the lower thigh. The leg should be almost completely extended and the foot held in approximately 90 degrees of extension or dorsal flexion.

It is important in immobilizing the ankle to avoid plantar flexion—contraction of the Achilles tendon during immobilization is thereby prevented. The recovery of dorsal flexion or extension and the stretching of a contracted heel cord is difficult, and at times, with long immobilization, permanent loss of extension may result, so that in standing or walking the sole of the foot cannot be placed flat upon the ground except by advancing it beyond the plane of the body, *i. e.*, in the position of "attention" and the position of a soldier the heel of the affected side will not touch the ground.

Fractures with displacement usually require an anesthetic for proper reduction, though in phlegmatic individuals or in transverse fractures it may not be necessary. An assistant grasps the foot by the heel and toes, making traction on the heel but none on the toes, merely steadying the foot at right angles to the leg by the toe-hold, to avoid the tendency to plantar flexion. Countertraction is made by a second assistant at the knee. The operator grasps the leg above and below the fracture, and, by direct manipulation and traction, and, if necessary, angulation of the fragments toward the internal surface of the leg, corrects the displacement. Steady traction is then maintained on the foot—and no countertraction but simply support above and below the knee—and with ample padding a cast is applied from the toes to the lower third of the thigh.

In fractures of the lower third or at the juncture of the lower and middle third, due regard must be paid to the normal bowing of the tibia, the amount of which may be inferred by the bowing of the sound leg.

If the subsequent roentgenogram or fluoroscopic examination does not show at least two-thirds of the diameter of the tibia in contact and good alignment, further manipulations should be made. If after several attempts reduction has not been accomplished, open operation must be considered. If the fragments of the tibia are not in contact by at least one-half of their diameter—open operation is indicated; if between one-half to two-thirds is in contact it is debatable ground—open operation may be indicated in many instances; two-thirds contact and good alignment should give an excellent result.

In badly comminuted or multiple fractures with displacement of the fragments suspension by a Thomas or Hodgen splint from a Balkan frame with weight traction by lateral adhesive-plaster strips or a Sinclair skate may be of service.

Open Reduction.—The tibia has long been the plaything of the bone-surgeon's art. Easy of access it submits readily to the mechanical onslaught of the innovator. In spite of the facility of approach and ease of manipulation it is best to cling to standard methods in the treatment of fractures. These methods include:

1. Simple incision with direct seizure and reduction of fragments.
2. Incision—direct reduction and fixation by:
    (*a*) Plates.
    (*b*) Bone grafts.
    (*c*) Intramedullary splints.
    (*d*) Bone pegs.

The ease and rapidity with which plates may be applied and later removed and the firm fixation which they afford have long made them a favorite in tibial fracture. In three or four weeks after operation they may be removed or, as Lane has suggested, the plate may be applied along the lateral surface of the tibia, covered by muscle and allowed to remain.

The absorbability of bone material when used for fixation has more recently established it as the ideal medium when the danger of infection can be completely eliminated.

It is best to use a slightly curved incision along the lateral margin of the crest of the tibia which permits the skin flap over the tibia to be dissected free, gives easy access to the entire mesial surface and brings the skin wound away from the site of the bone operation. An inlay bone graft or intramedullary splints are applicable to all fractures, bone pegs especially to oblique fractures.

Following open operation a cast from the toes to the lower thigh should be applied.

After-treatment.—In seven to ten days after final reduction the patient may be up on a wheel chair. The cast must be inspected daily. If it becomes too loose as a result of rest atrophy and the subsidence of swelling or edema of the leg a new cast must be applied. At the end of four weeks the cast should be removed and the degree of union ascertained. If firm the cast is rebandaged in place and removed each day for massage and passive motion or a new cast, excluding the knee, is applied and cut the following day to permit massage. If there is still false mobility at the seat of fracture the cast is rebandaged and in another week it is removed and the fracture again inspected. At six weeks, or when union is firm, the patient is allowed up on crutches but no weight-bearing is permitted for ten to twelve weeks. After six weeks there is usually no mobility at the fracture site—the cast can be dispensed with and small padded apposition splints may be used until complete consolidation has taken place.

Complications.—Vessel and nerve injury is exceedingly rare unless there is so severe a crush of the leg as to require amputation. The tibia, particularly in children, may be the seat of delayed union. Indolent repair, in spite of excellent apposition, and syphilis are likely to cause delay in union, especially in the tibia. Compound tibial fractures are exceedingly prone to that form of chronic osteomyelitis or necrosis termed by Chutro "bone fistulæ"—delaying union and occasionally resulting in non-union. The treatment of this condition is discussed elsewhere, page 199.

Delayed union requires that the cause be sought and eradicated.

In the idiopathic type, as has been elsewhere emphasized, calcium salts by mouth, in the form of milk, or locally injected may be of use. Local injections of fibrin or blood serum may be tried.

For non-union, excision and freshening the ends of the fragments, removal of any interposed soft parts and a bone graft are the usual specific. An intramedullary splint by the Hogland method or the usual procedure may also be applicable. In children the ends of the fragments may be bevelled, fitted together and fastened by beef bone screws or pegs—the shortening may be ignored (Henderson.)[1]

FIG. 101.—Supramalleolar fracture of the tibia. Lateral view.

FIG. 102.—Supramalleolar fracture of the tibia. Antero-posterior view.

Fractures of Tibia and Fibula Near Ankle.—Fractures of the tibia and fibula near the ankle comprise:

1. Supramalleolar fractures of tibia and fibula.
2. Separation of the lower epiphysis of tibia and fibula.
3. Fractures of the malleoli with or without involvement of the lower end of the tibia or the shaft of the fibula.

1. **Supramalleolar Fractures of Tibia and Fibula.**—*Etiology.*—1. Direct violence—a blow on the leg at or above the ankle—often by a falling object, such as a stone or log, or a runover accident.

2. Indirect violence—a fall from a height upon the foot.

Pathology.—These fractures may be transverse, oblique or spiral, and are found in the lower 3 to 5 cm. of the tibia and in the lower third of the fibula (Figs. 101 and 102). The lines of fracture may involve the joint. There may be comminution or Y-fractures or diastasis of

[1] Jour. Am. Med. Assn., 1920, lxxiv, 715.

the tibia and fibula. When displacement occurs the foot, tarsus and lower fragments are carried outward (toward the fibula) and backward. The end of the diaphysis becomes prominent on the internal surface of the leg beneath the skin or may not infrequently puncture it. The astragulus may be forced up between fragments of the tibia or between the tibia and fibula.

Diagnosis.—In the absence of marked displacement it may be exceedingly difficult to differentiate supramalleolar fracture from other ankle fractures except by a roentgenogram. In fracture without displacement, pain, swelling and tenderness above the internal malleolus and ankle may be significant; but often there is joint swelling that clouds even these distinguishing features. With displacement the deformity, crepitus and lateral abnormal mobility above the ankle—the foot moving with the malleoli and lower fragment—are characteristic of supramalleolar fracture. In their absence in young adults or children epiphyseal separation must be suspected. The roentgenogram will reveal the exact lesion and will prove a great aid in planning adequate reduction.

Prognosis.—With comminution, joint involvement or mal-union some permanent impairment of joint function may be expected.

Treatment.—Reduction by traction and direct manipulation, pressure and counterpressure should be closely followed by roentgenographs—the usual antero-posterior and lateral views or lateral stereoscopic plates—and efforts at reduction renewed until satisfactory replacement is obtained. Exact reduction because of weight-bearing and ankle function is especially desirable—anterior or posterior bowing of the tibia and displacement of the tarsus are to be avoided. The foot is overcorrected in full extension if any posterior subluxation is present. If marked displacement persists open reduction, pegging or nailing the fragments in place may be considered. A cast well padded from toes to include the knee should supplement reduction, and immobilization is maintained for three or four weeks. Daily massage and passive motion is then permitted and the cast rebandaged for protection until the completion of the sixth week; when a roller bandage is sufficient and active motion is allowed. Weight-bearing should not be attempted for ten weeks or in joint fractures twelve weeks.

2. **Separation of the Lower Epiphysis of the Tibia and Fibula.**—Separation of the lower epiphysis of the tibia and fibula is quite rare, but is found more often than separation of the upper epiphysis.

Etiology.—Separation by direct violence is almost unknown. The usual cause is *indirect violence,* as in jumping or a fall from a height—a cross-strain with the foot in eversion or inversion or a twisting of the foot (Stimson.)[1]

Pathology.—There is very seldom simple separation of the epiphysis, a fragment of the diaphysis also is usually torn away. There may be no epiphyseal separation of the fibula but a fracture of the shaft (Fig.

[1] Fractures and Dislocations, 1917.

103). The usual displacement is internal (mesial) or anterior sliding of the diaphysis of the tibia. With an open wound the lower margin of the diaphysis may be protruding.

Diagnosis.—As the local tenderness, deformity and swelling about the joint resemble supramalleolar fracture, the diagnosis in most instances depends upon the x-ray findings. As the epiphysis unites with the diaphysis about the twentieth year, suspicion of epiphyseal separation must rest among those below that age. If the rounded edge of the diaphysis or soft crepitus may be detected, epiphyseal separation may be inferred.

Prognosis.—Instances of arrest of growth after this injury leading to deformity and inversion of the foot have been reported. (Stimson.)

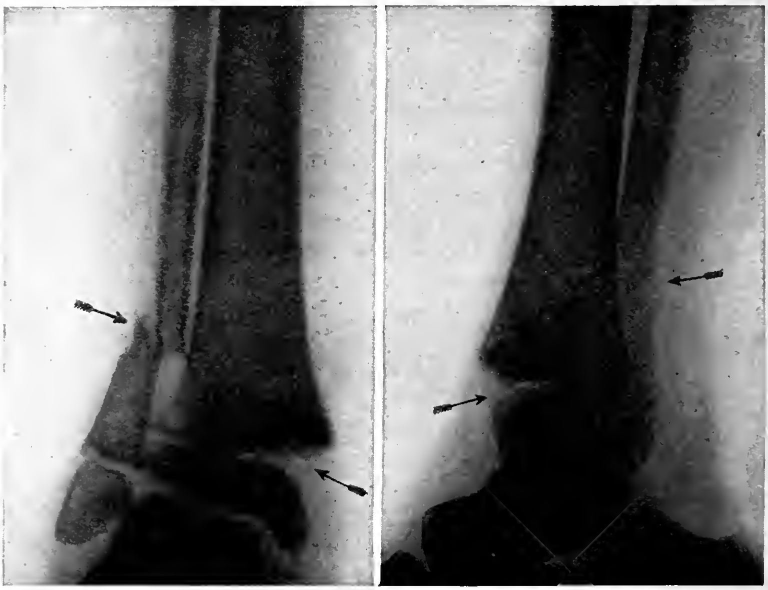


Fig. 103.—Separation of the lower epiphysis of the tibia and fracture of lower third fibula. (Roberts and Kelly.)

Treatment.—Traction and direct pressure and counterpressure should bring the diaphysis and epiphysis into apposition. Immobilization in a plaster-of-Paris cast for three to four weeks should follow. Active motion is then permitted with a bandage or adhesive strips for support, and weight-bearing allowed after the eighth week.

3. **Fractures of the Malleoli.**—Under malleolar fractures may be grouped a variety of fractures which have been recognized through the routine use of the roentgenograph in ankle injuries, and which are best classified according to the deformity and the direction of the fracturing force.

1. Fracture of the internal or external malleolus alone.
2. Inversion or adduction fractures.

3. Eversion or abduction fractures.
4. Flexion fractures.
5. Extension fractures.

Etiology.—1. Direct violence as the cause of a malleolar fracture is an exceedingly great exception.

2. Indirect violence is by far the most common culprit implicated in fracture in and near the ankle; a fall upon or a twist of the foot in adduction or abduction or in extension or flexion, or often a combination of two, such as abduction and flexion.

Fig. 104.—Fracture of the internal malleolus, and lower third of the fibula, with lateral external subluxation of the ankle. Abduction fracture.

Pathology.—The lesion that results depends upon the severity, duration and direction of the activating force. A quick, short strain in abduction will produce a fracture of the internal malleolus with no deformity. If the force applied in abduction is continued there will also be a fracture of the shaft or external malleolus of the fibula with external dislocation of the tarsus and definite deformity (Fig. 104); or simple laceration of the internal lateral ligament may occur instead of fracture of the internal malleolus. If the same force has flexion added to it a posterior or lateral fragment of the lower end of the tibia may be broken off and a posterior subluxation of the ankle result, if extension, an anterior fragment and anterior dislocation. A diastasis of the tibia and fibula may also be produced. Moderate adduction

Fig. 105.—Fracture of the internal malleolus. Multiple fractures of the fibula. Very little if any subluxation of the ankle.

Fig. 106.—Fracture of the base of the internal malleolus; fracture of the external malleolus; adduction fracture.

Fig. 107.—Fracture of the internal malleolus, lateral view. Fragment not to be confused with fracture of anterior articular surface. (Roberts and Kelly.)

and inversion causes fracture of the external malleolus, and, if continued, fracture through the base of the internal malleolus as well (Fig. 106), or the entire mesial lower end of the tibia may be separated with mesial subluxation of the ankle. An open fracture may occur.

Clinically these fractures may be grouped:

1. Fractures with simple swelling of the ankle without deformity.

(*a*) Fracture of the internal malleolus—this is a transverse splitting off of the malleolus near but not at its base and usually the fragment is slightly separated downward and forward. The forward displacement is important to recognize in the interpretation of a lateral roentgenogram, so that malleolar fracture is not mistaken for a fracture of the anterior articular margin of the tibia. Lateral stereoscopic plates makes the actual lesion unmistakable (Fig. 107).

(*b*) Fracture of the external malleolus—there is little or no separation of the fragment.

(*c*) Fracture of the internal and external malleolus, with or without linear fracture of the anterior, posterior or external lateral margin of the tibial articulating surface (Fig. 108).

(*d*) Fracture of the internal malleolus with subperiosteal fracture of the fibula above the malleolus.

(*e*) Fracture of the anterior articular margin of tibia.

2. Fracture with abduction—eversion—deformity.

(*a*) Fracture of the shaft of the fibula usually in the lower third with laceration of the internal lateral ligament of the ankle with or without external or posterior subluxation of the tarsus, or tibiofibular diastasis—true Pott's fracture would fall in this group.

Fig. 108.—Fracture of lateral external surface of the tibia with comminution of fibula and fracture of internal malleolus. (Roberts and Kelly.)

(*b*) Fracture of the internal malleolus with fracture of the lower third of the fibula or multiple fractures of the fibula with or without tibiofibular diastasis, external or posterior partial dislocation of ankle or fracture of the posterior articular margin of the tibia.

(*c*) Fracture of both malleoli and diastasis of the tibia and fibula with or without subluxation of the ankle.

(*d*) Fracture of both malleoli and fracture of the external lateral articular surface of the tibia with or without dislocation of the tarsus upward or outward.

3. Fractures with adduction or inversion deformity.

(*a*) Fracture of the external malleolus and fracture of the base of the internal malleolus with or without internal, mesial, dislocation of the ankle.

(*b*) Fracture of the external malleolus, fracture of the internal lower end of the tibia, and internal dislocation.

4. Fractures with anterior deformity at the joint and shortening of the foot—flexion deformity.

(*a*) Fracture of both malleoli and the posterior articular margin of the tibia with posterior subluxation of the ankle. The internal malleolus is not always involved.

5. Fracture with anterior deformity at the joint with lengthening of the foot—extension deformity.

(*a*) Fracture of the anterior articulating surface of the tibia with partial anterior subluxation of the ankle with or without fracture of the malleoli.

Abduction deformity is the most common, often combined with a slight flexion deformity. Adduction or inversion deformity is less common, and simple flexion and especially extension deformity is seldom observed.

Pott's Fracture.—The fracture originally described by Pott was a fracture of the fibula two or three inches above the external malleolus, with laceration of the internal lateral ligament of the ankle accompanied by a marked abduction deformity. For a long period it was believed to be the typical ankle fracture from abduction, but the great variety of ankle-joint fractures that the x-ray has revealed has altered this original conception and has demonstrated the inconstancy of the underlying lesion and that, with typical deformity, the fracture of the fibula may be anywhere within its lower half and not two or three inches from the malleolus. Likewise the internal malleolus is more often fractured than the internal lateral ligament is lacerated. The term Pott's fracture, like Colles's fracture had best be dropped from medical nomenclature as an inaccurate designation.

Diagnosis.—1. *Fractures with no Deformity.*—Fracture may be suspected from: (*a*) Pain and swelling of the ankle. (*b*) Inability to move the ankle without pain. (*c*) Swelling, ecchymosis, and local tenderness, especially about the affected malleoli. (*d*) Lateral movement away from the injured malleolus is most painful. (*e*) Tenderness over the margins of the tibia—anterior, lateral or posterior. (*f*) Very seldom a movable malleolar fragment can be detected with crepitus.

The actual fracture is ascertained and differential diagnosis between simple malleolus fracture and malleolar fracture with tibial fragments is only possible from the radiogram.

2. *Fractures with Abduction Deformity.*—The characteristic deformity is sufficient evidence of fracture but the actual underlying lesion is again difficult to determine without a roentgenogram. There is not only pain in and swelling of the ankle but swelling and pain along the fibula. Walking is impossible as body weight cannot be sustained.

Examination will show:

1. The foot is abducted and everted in the valgus position.
2. The normal bony prominences of the ankle are obliterated by the swelling.
3. Widening of the ankle.
4. There is marked prominence of the internal malleolus, or the margin of its base on the internal aspect of the ankle. The skin is drawn tense over it or may be punctured by it. The ankle displacement laterally may or may not be evident and the swelling may conceal a slight posterior dislocation.
5. With posterior dislocation the foot may be slightly flexed.
6. Marked tenderness over the internal malleolus and over the seat of fracture in the fibula.
7. The sharp edge of the stump of the broken malleolus may be palpable.
8. Abnormal lateral mobility of the ankle.
9. Crepitus is uncertain—in complete fracture of the malleolus and fibula it may be obtained.

3. *Adduction or Inversion Deformity.*—There may be but slight deformity—it is never as great as in abduction fracture. There is marked pain and swelling about both malleoli. On examination there is:

1. Inversion—adduction of the foot.
2. Widening of the ankle (slight).
3. Tenderness over both malleoli.
4. Marked lateral mobility of the ankle and crepitus—more marked at the internal malleolus.
5. Palpable fracture margins.

Posterior subluxation is very seldom observed with this deformity. The roentgenogram will confirm the diagnosis and determine accurately the fractures present.

4. *Fractures with Anterior Deformity at the Ankle.—Flexion Deformity.*—This deformity may occur with abduction deformity when posterior subluxation is present—the actual deformity depends upon whether flexion or abduction was the greater activating force. In frank posterior subluxation fracture of the posterior articular margin of the tibia may be suspected. The heel will be drawn up by the gastrocnemius muscle, the foot in partial flexion, with anterior prominence above the ankle of the lower end of the tibia. There will be shortening by measurement from the toes to the ankle. Any movement, but especially attempts to extend the foot, will be painful.

5. *Fractures with Anterior Prominence at the Ankle and Lengthening of the Foot.—Extension Fractures.*—The deformity of an extension fracture may be very slight. There is usually a slight prominence of the displaced fragment distal and anterior to the ankle. Except for excessive anterior joint swelling there may be but little indication of the lesion. With anterior subluxation there may be lengthening by measurement from the toes to the ankle. Upon the roentgenogram again must most reliance for diagnosis be placed.

Prognosis.—With simple malleolar fracture there should be return of normal function.

For fracture with displacement and deformity, especially an abduction deformity, complete reduction is an absolute requisite for the return of function. If careful roentgenographic observations are not made following reduction, subluxation or displacement of tibial fragments may be allowed to persist and mal-union with a stiff and deformed ankle will result, giving painful weight-bearing and real disability. In tibial articular surface fracture, especially with dislocation, some slight permanent loss of motion even with excellent reduction can be expected.

Treatment.—1. For fractures without deformity any slight displacement of the fragments should be corrected and a plaster cast from the toes to the knee used for immobilization. For separation of a fragment of the internal malleolus the cast should be applied with the foot in adduction. The roentgenogram should always be searched carefully for even slight subluxation of the ankle, correction promptly made and the foot fixed by a cast in adduction for external displacement, in full extension for posterior displacement and in full flexion for anterior displacement. If marked swelling is present or before a permanent dressing can be be applied, immobilization may be made by two well-padded boot splints bandaged in place. Application of a cast may be postponed until the swelling has subsided, *i. e.*, for two or three days.

2. With moderate abduction deformity temporary immobilization may be made with well-padded boot splints until a roentgenogram can be taken. Intelligent reduction is always facilitated by a roentgenogram. Reduction should be made as soon as the findings of the roentgenogram are known. With extreme deformity or open wound, immediate reduction is indicated to avoid infection or pressure necrosis of the tissues. If a fluoroscope is available, its assistance will be valuable, but the delay requisite for a roentgenogram is not justifiable. A general anesthetic should be administered. An assistant steadies and makes countertraction on the leg at the knee. The foot is then grasped by toes and heel, strong traction is made, while the heel is raised and the foot swung into alignment with the shaft of the tibia and finally overcorrected by adduction. It is important to raise the heel and keep the foot in flexion at least to a right angle to reduce any posterior subluxation that may have occurred; adduction not only overcorrects the deformity but brings the internal malleolus in closer apposition to the tibia and gives the greatest possible traction on the lower fibula and draws the fibular fragments into better apposition. A plaster-of-Paris cast from the toes to the knee maintaining the foot in adduction is most satisfactory. Reduction should be confirmed by the roentgenograph. Subluxation must be completely reduced—any slight remaining displacement demands another attempt at correction.

3. Fractures with inversion deformity are not common. Forced adduction of the foot produces, as a rule, first a fracture of the external, then of the internal malleolus and may fall short of producing deform-

ity. With greater adduction a fracture through the base or the entire inner end of the tibia is produced and internal subluxation of the ankle may follow—posterior subluxation is rare.

Reduction usually is easy and scarcely requires an anesthetic. The foot is grasped by one hand, the lower leg by the other. By traction and direct pressure on the inner end of the tibia the foot is brought into proper position at 90 degrees flexion with the leg. Overcorrection is not necessary; a plaster cast is applied from toes to knee.

4. Fractures with flexion deformity alone are rarely observed. Reduction of the posterior subluxation by traction, drawing the heel anteriorly and full extension, should likewise reduce any displaced fragment—a cast should be applied in full extension.

5. Fractures with definite deformity following an extension fracture are exceedingly rare. The anterior subluxation and displaced fragment are readily reduced by direct pressure and flexion and a cast may be applied in full flexion.

After-treatment.—The cast should be inspected daily. If it becomes loose as the leg atrophies from disuse or the swelling subsides it should be removed and a new cast applied. If at any time the toes become swollen or cyanotic, or there is excessive pain in leg, the cast should be cut and removed and another cast better padded applied. The cast may be definitely removed in three weeks. Massage and passive motion are begun and given twice daily and the cast rebandaged in place for one more week. A flannel bandage or an elastic ankle support may then be used for another week or two, depending upon the rapidity of the return of movement in the ankle and the disappearance of the swelling. Crutches may be used from the outset with simple malleolar fractures, but not until after the second week in abduction deformity and adduction fractures. Weight-bearing should be slowly tried after the sixth week. Good function should result in twelve weeks from the accident.

Complications.—Mal-union, as a result of the failure to recognize fracture or an accompanying subluxation, is not uncommon. Routine use of the *x*-ray before and after reduction will reduce the possibility of mal-union to a minimum.

When mal-union has occurred with poor alignment, painful weight-bearing and partial ankylosis, osteotomy, arthrotomy, arthrodesis or even astragalectomy may be indicated.

FRACTURES OF THE TARSUS

Fractures of the Astragalus.—Fracture of the astragalus is comparatively rare. Of tarsal fractures it is next in frequency to os calcis fracture.

Etiology.—1. Direct violence—crushing of the ankle region.

2. Indirect violence—a fall on the foot from a height or sudden weight-bearing with extreme dorsal flexion.

Pathology.—The lesion may be simply a sprain fracture or fissured fracture without displacement. The fracture may involve the neck, the body of the bone or the posterior process. With severe violence a splitting of the astragalus longitudinally into two parts or extreme comminution with flattening and impaction may be observed. Anterior dislocation of the astragalus with fracture may occur. An open fracture is not uncommon.

The usual break is a transverse fracture through the neck or where the body joins the neck; displacement is the rule. There may be displacement of the anterior fragment forward and upward or the posterior fragment may be displaced either forward, backward or rotated on its axis. Often the tibia is jammed down between the fragments—the anterior fragment driven forward and the posterior fragment backward against the tendo Achillis.

Fracture of the astragalus may be accompanied by fracture of the os calcis or malleoli, or dislocation of the ankle.

Diagnosis.—Without a roentgenogram, fracture of the astragalus can rarely be diagnosed. The great swelling of the ankle that rapidly follows the injury adds to the disability and pain in the ankle. Total disability and broadening of the ankle in the antero-posterior diameter is suggestive—the malleoli may seem lower and crepitus in the joint may be elicited. Every apparent sprain of the ankle that results from a fall or direct injury, especially those with much swelling, should be *x*-rayed. Fracture of the astragalus otherwise in many instances will be overlooked and permanent ankle disability result when early diagnosis and appropriate treatment might have given unimpaired joint function.

Fracture of the posterior process must be differentiated from a sesamoid bone occasionally found posterior to the astragalus—the os trigonum—a roentgenograph of both ankles will be required for diagnosis. If a separate fragment is found in both, a sesamoid is present; if in the injured foot only, a fracture.

Prognosis.—With proper reduction a good functional result is to be expected. There will probably be some slight limitation of flexion and extension. Even after resection the return of function is usually sufficient to assure a fairly useful joint.

Partial or complete ankylosis is certain if the displacement of the fragments is not corrected, also an impairment of earning capacity—estimated by von Bergmann as at least 15 to 20 per cent. (Roberts.)

In an open fracture infection may lead to necrosis of a fragment or arthritis of the ankle-joint or a general septicemia.

Treatment.—1. In fracture without displacement a plaster cast from the toes to the knee, with the foot at right angles to the leg, is sufficient. Immobilization should be continued for three weeks, then passive motion and massage are gradually begun.

2. In fractures with displacement simple manipulation may be of no avail, though traction and direct manipulation should be tried. Open reduction of the fragments is most satisfactory; the tendo Achillis

may be divided if necessary; if accurate reduction cannot be obtained, excision of the posterior fragment is indicated (Jones[1]). The entire astragalus has been resected with fairly good functional result. Such poor results are recorded from a "Laissez faire" policy that open operation and resection should be practised more frequently (Cabot-Binney[2]).

Old, neglected fractures, with deformity or impaired function, will require excision or arthroplasty. In resected cases massage and active motion should be begun in the second week, with very gradual passive motion.

FIG. 109.—Fracture of upper posterior portion of os calcis by avulsion. (Stimson.)

After open or closed reduction immobilization in a plaster cast with the foot at right angles with the leg should follow. The cast is removed in three weeks; active motion encouraged and massage and passive ankle motion carefully given. A bandage or adhesive-plaster straps are applied for support until joint function is almost normal. Weight-bearing should be most cautiously begun but not until ten to twelve weeks after the injury.

Fractures of the Os Calcis.—Fracture of the os calcis is the most frequent tarsal fracture.

Etiology.—1. Direct violence—crush of heel—falling on the foot from a height.

2. Indirect violence—forceful inversion of the foot.

[1] Am. Surg., 1902, xxv, 697.
[2] Ann. Surg., 1907, xlv, 51.

3. Muscular action—traction of the soleus and gastrocnemius through the Achilles tendon.

Pathology.—There are four types of fracture of the os calcis.

1. Heel fragment fracture, *i. e.*, that portion of the os calcis posterior to the middle line of the body of the astragalus. This will comprise:

(*a*) Fracture of the greater tuberosity or posterior process of the os calcis, which may be:

Fig. 110.—Epiphyseal separation of tip of posterior process of os calcis. (Roberts and Kelly.)

1. Fracture of posterior superior angle—an evulsion fracture from the pull of the Achilles tendon, which may also be ruptured. There may be wide separation of a tiny fragment or a large fragment with but slight separation (Fig. 109).

2. Epiphyseal separation (Fig. 110).

3. Transverse vertical fracture of the entire posterior process

4. The tuberosity or a portion of it may be bitten off by a machine.

(*b*) Fissured fractures.

(*c*) Splitting off of the external and internal tuberosities.

2. Fracture of the sustentaculum tali—quite rare. (Fig. 111).

3. Comminution of the anterior half of the os calcis (Fig. 112)

4. Massive comminution of the entire bone—the usual fracture following a fall. The heel is driven up and outward with radiating lines of comminution—the os calcis is compressed vertically and expanded laterally out under the external malleolus (Fig. 113).

FIG. 111.—Fracture of os calcis. (Cabot.)

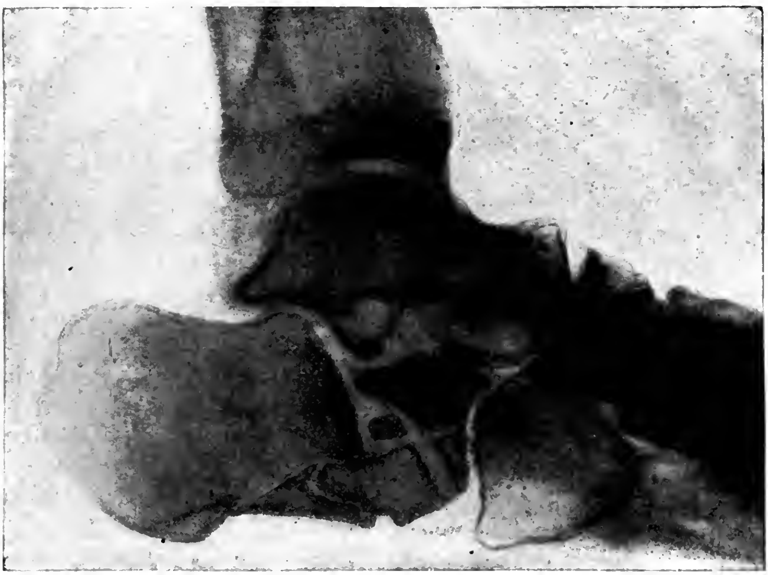


FIG. 112.—Fracture of os calcis. (Cabot).

There may be simultaneous fracture of both ossa calces.

Diagnosis.—With marked swelling after injury the fracture may be overlooked. The lesion may be suspected when a history of a fall on the feet is obtained, with pain and swelling about the heel.

Signs.—1. The internal or mesial arch of the foot is very low or obliterated.

2. Plantar flexion of the foot is painful, with limited dorsal flexion.

3. Absence of lateral motion of the foot at the ankle.

4. Swelling under the external malleolus and broadening of the foot below the ankle or a swelling at the junction of the Achilles tendon with the os calcis.

5. Tenderness of the os calcis on pressure—very rarely crepitus is obtainable.

6. Attempts to manipulate the os calcis are painful. With avulsion fracture of the superior angle of the greater tuberosity; the fracture margins may be palpable with a depression between them.

FIG. 113.—Fracture of os calcis.

7. The malleoli seem nearer the plantar surface than on the sound side.

The exact location and perhaps the first indication or suspicion of the fracture is revealed by the roentgenograph.

Prognosis.—In fractures with displacement much better function is obtained after attempts at reduction. Without reduction some permanent disability is certain and therefore diminution in earning capacity likewise. Even after reduction, because of the persistence of flat-foot, painful walking and weight-bearing, the return of complete function is not assured.

Treatment.—1. In fissured fracture a plaster cast from the toes to the knee will suffice. The foot may be flexed to relax the Achilles tendon.

2. In slight displacement the mere application of a cast with the foot in extreme flexion should give satisfactory reduction.

3. Avulsion fractures, such as fracture of the posterior superior angle, with separation of the fragments, can hardly be dealt with except by open operation, reduction and the direct suture of the fragments with kangaroo tendon. Tenotomy of the tendo Achillis may be necessary.

4. In fracture with obliteration of the arch or in fractures of the entire bone with displacement, Cotton's[1] advice has been too long neglected. An anesthetic is administered and the heel seized; the foot is flexed to its extreme limits to relax the pull of the Achilles tendon, and then traction is made to bring down the heel and to restore the arch. Rocking to release the impaction may facilitate this reduction or it may be necessary to thrust a steel spindle or pin in front of the tendo Achillis through and through from side to side and draw the os calcis back into position directly by it. Lateral movement of the foot is restored by manipulation. Reduction of the prominence beneath the external malleolus should be made with direct force and impaction by blows of a padded mallet laterally on the heel, beneath the external malleolus, and against a sand-bag beneath the internal malleolus, to drive the distorted bone back into position. A plaster cast is applied from the toes to the knee with a pad above the heel, a pad beneath the arch and the foot in plantar flexion.

After two weeks the cast may be cut to permit active motion and rebandaged in place; at three weeks it may be superseded by adhesive-plaster straps or a bandage and massage and passive motion given daily, but no weight-bearing should be allowed until six to eight weeks have elapsed.

Fracture of the Distal Tarsus.—*Isolated Fracture of the Cuboid, Scaphoid or Cuneiform Bones* is exceedingly rare. The entire tarsus is frequently involved in severe comminution or crush of the foot, for which amputation is frequently necessary; or the scaphoid and cuboid may be involved with fractures of the astragalus and os calcis.

An isolated fracture of the cuboid has been described by Goutermann;[2] a transverse fracture caused by direct violence, with the foot supinated. There was local swelling, tenderness on pressure, shortening of the inner margin of the foot; active supination was impossible. Abnormal mobility and crepitus could not be definitely detected.

Tarsal scaphoid fractures are quite rare. They may result from direct violence or from the twist of the foot following a misstep. The tubercle of the attachment of the tibialis posticus may be torn away. There is swelling and tenderness over the scaphoid, flat-foot and more abduction of the foot than usual. Immobilization should be made in plaster, the foot in adduction for three weeks and later correction of the flat-foot by an insole of cork or felt. Marked displacement may demand an open reduction.

Fracture of the scaphoid tubercle must not be confused with an occasional sesamoid bone in the tendon of the tibialis posticus. Bi-

[1] Ann. Surg., 1916, lxiv, 480.
[2] Archiv. klin. Chir., 1909, xci, 186.

lateral roentgenographs should be taken for differentiation; both will show a sesamoid, but if a fragment is observed only in the injured foot plate, fracture is present.

Fracture of the Metatarsal Bones.—Etiology.—Direct violence—two or more bones are usually involved and an open wound is common, due to a fall of a heavy weight or a crush.

Indirect violence—twisting of the toes, a fall on the outside of the foot or upon the outstretched toes—falling or tripping in a hole; jumping, dancing.

Pathology.—Transverse or oblique fracture of the body or an oblique fracture into the joint is the usual lesion. Comminution or an open wound is not infrequent. The first and fifth metatarsals are most commonly involved. There may be dorsal or plantar displacement or lateral deviation when two or three bones are implicated.

Fig. 114.—Fifth metatarsal fracture. Antero-posterior view.

Diagnosis.—There is pain and disability of the foot and swelling over the affected area—the swelling may be so marked that adequate palpation is very difficult.

The usual signs of fracture are commonly absent—abnormal mobility and crepitus are detected with difficulty. Besides swelling, local tenderness or palpable fracture margins may be the only indication of fracture. The x-ray is especially serviceable when symptoms and signs are obscure.

Treatment.—A plaster cast serves well when there is no displacement. If displacement is marked and traction and direct pressure will not suffice to reduce the fragments, and especially when two or three bones are involved, open incision and reduction and suture of the fragments into position are indicated. Dorsal or plantar displacement should especially be avoided.

Jones's fracture or fracture of the tuberosity of the fifth metatarsal bone at the phalangeal metatarsal joint occurs with the foot inverted, the heel off the ground and the weight of the body falling on the cross diameter of the foot, with sharp adduction of the metatarsals.

It is a split fracture; displacement is never detectable (Figs. 114 and 115).

Only local tenderness is present and x-rays of both feet should be taken to detect it. The bone of Vesalius, a separate ossicle, may be present at the proximal and external part of the tuberosity, and may readily be mistaken for fracture. Roentgenograms will show a unilateral lesion in the case of fracture—a bilateral fragment or separate ossicle when the Vesalian bone is present.

Immobilization in plaster for three weeks suffices.

Fig. 115.—Jones's fracture of the fifth metatarsal. Transverse fracture near the tarsometatarsal joint. Typical fracture is usually through the tuberosity and nearer the joint.

Fractures of the Phalanges.—Fractures of the phalanges of the foot are usually compound and comminuted and commonly require amputation. They are usually due to direct violence, and are transverse, oblique or involve the joint. Necrosis or osteomyelitis readily follows an open fracture and may necessitate amputation later.

Diagnosis.—Diagnosis is not difficult. In open fracture it is self-evident; in closed fracture, crepitus and abnormal mobility at the fracture site is significant.

Treatment.—Simple fracture may be reduced by traction and manipulation and immobilized by adhesive-plaster strips, plaster-of-Paris splints or a plantar splint, or by strapping to the neighboring toe.

Union should occur in two to three weeks.

FRACTURE OF THE SESAMOID BONES.

The sesamoid bones are formed in tendons where there is considerable friction and irritation as the tendons pass over a bony prominence or ridge. These bones are found most frequently in the hands and feet. Sesamoids constantly present are: 2 at the metacarpo-phalangeal joint of the thumb in the tendon of the flexor longus pollicis and 2 on the plantar surface of the first metatarsal near the phalangeal articulation in the tendon of the flexor brevis hallucus. Accessory or inconstant sesamoid bones may be found at the heads of all the metatarsals and metacarpals, especially on the radial side of the index finger and on the ulnar side of the fifth finger, at the interphalangeal joint of the thumb; in the flexor of the great toe, just proximal to the constant pair—simulating a fracture; and similarly there may be an extra sesamoid at the metacarpo-phalangeal joint of the thumb.

The confusing sesamoids of the tarsus have been mentioned elsewhere—a sesamoid in the peroneus longus should be added. The gastrocnemius sesamoid, an accessory os calcis and one between the internal and middle cuneiforms are also occasionally in evidence.

FIG. 116.—Fracture of sesamoid bone at the first metatarso-phalangeal joint. (Roberts and Kelly.)

Etiology.—Fracture of the sesamoids results from:

1. Direct injury—jumping or falling on the feet, or a blow upon the fingers or hand, as from catching a baseball.

2. Hyperextension may produce sesamoid fracture.

Pathology.—The fracture is a transverse separation of the sesamoid into fragments (Fig. 116). Rarely there is comminution.

Diagnosis.—Persistent plantar pain on walking and plantar tenderness of the first metatarso-phalangeal joint after injury, and pain and tenderness of the thumb or fingers at the head of the metacarpals should arouse suspicion.

Bilateral roentgenograms should be studied to rule out the possibility of an accessory sesamoid before the positive diagnosis is made.

Treatment.—If simple immobilization on a splint does not give sufficient relief, the fragments may be excised.

COMPOUND FRACTURES.

By DENNIS W. CRILE, B.S., M.D., Hon. Capt. R.A.M.C.

INTRODUCTION.

Comparison of Military and Civil Fractures.—A simple fracture occurring during a war is not different from a simple fracture in civil life.

A compound fracture caused by the protrusion of a fractured bone through the skin is not different in war or peace.

A bullet which fractures a bone in warfare performs its function according to the same rules as in peace.

Although civil practice seldom presents fractures caused by bomb, shell or shrapnel, these fractures as a group are merely extreme examples of what may happen with any compound fracture.

Wounds have been, are, and will be infected by the same organisms, when the same soil contaminates them whether the patient be a soldier or a civilian. However, the soldier generally has dirtier garments and skin than the civilian, his wound is not attended to so promptly, and he is exposed to cold, wet and rougher transport after receiving his inju y. Further, the soldier's dirt is a dirt rich in manure, garden soil, road dus and filth; while the civilian though ever so caked with dirt may be soiled with "clean dirt"—aseptic. Perhaps it is these factors which account for the difference in the operative treatment of fractures which exists in various parts of the world, country or even city. Any surgeon working on miners for instance—black with coal dust—or better still the dust of silver, copper or zinc ores—will find practically a surgically clean field; while another surgeon working on garbage collectors, though they be ever so white from their baths, will have to contend with countless swarms of microbes living in every one of the pores of this gentry. These elements make the soldier's wound more severe and its treatment more difficult.

These factors are offset in some degree by the excellent physical condition of the soldier and by the experience his surgeon has gained through seeing hundreds of similar cases.

For these reasons, the experience gained in the handling of fractures during three years of busy war surgery may be of some value in the treatment of compound fractures in civil life.

Definition and Scope.—Theoretically a compound fracture is any fracture which has come in contact with the outer side of the skin or with a foreign body.

Practically those fractures made by rifle or machine-gun bullets which have passed through, leaving a punctate entrance and a tiny exit wound, may, in the majority of cases, be considered as simple fractures, presenting only the ordinary mechanical problems. Civil compound fractures occurring in places and individuals surgically clean likewise belong in this category. Therefore these will occupy but little space in this chapter, which will deal especially with septic (infected) or potentially septic (inoculated) fractures.

Over 50 per cent. of the disabled soldiers are those who suffered compound fractures in their limbs.

Compound fractures of the skull and thorax are unimportant compared to the serious injuries of the soft parts which they accompany, and they are also less important than fractures of the locomotor system.

For these reasons the flat bones will not be intimately considered, and since non-lethal compound fractures of the spine are too rare to be of practical interest, they will not be discussed at length.

Bones are the only inflexible tissues in the body. As such they are subject to peculiar ruptures—fractures. These ruptures are produced by forces acting in abnormal direction or intensity—whether the force be direct violence, muscular action or a penetrating body.

They heal, as every ruptured tissue heals—by a proliferation of new tissue from the old—by primary union or granulation—and their healing follows definite laws and is modified by definite conditions.

When ruptured they bleed. The clot organizes—granulations appear and are transformed into fibrous tissue or cartilage in which are deposited bone elements, that in accord with Wolff's law then "assume the shape required by the strain put upon the part." The bone itself, or elements freed from the bone itself, seem necessary to the formation of new bone. Granulation tissue and fibrous tissue appear regardless, but bone seems to appear only in the presence of bone elements.

Broken bones when aseptic and without comminution, and when firm apposition is obtained between their ends, heal quickly by first intention, with a small sound callus.

When comminuted and when poor apposition is obtained between the fractured ends they heal by granulation, with larger callus formation and after a longer time.

When comminution is accompanied by good reduction and when infection is not virulent or chronic, union sometimes occurs surprisingly early.

When sepsis exists the appearance of granulations and callus is slower, and the callus is of inferior quality, being honeycombed and adulterated by sequestra.

When there has been early loss of considerable bone substance, by injury or operation, or when the opposing ends are widely separated by overzealous extension, union may never occur. Each fractured end produces some callus which fails to reach and unite with its opposing fellow. The result is sclerosis of the ununited ends and pseudarthrosis. When the soft tissues are interposed between the fractured ends union also fails.

When bone disease occurs union may be delayed or fail.

Fig. 117.—Showing the amount of gap which may be filled in by callus in septic wounds of the femur. This gap measured 7 inches and for over 5 inches of its length no bone chips remained which could be seen or felt; notwithstanding, the callus was firm and of good quality and this picture was taken eight months after the date of wound; the treatment consisted of dependent drainage for the first month and after that merely the continuance of extension in Thomas splint with knee flexing attachment—a diet rich in milk—daily massage; three small bits of sclerosed but sterile bone remain. Case treated in conjunction with Major John Beason, U.S.M.C.

When the blood supply to either end of the fractured bone is obstructed, from swelling and pressure consequent on osteomyelitis, or destruction of the medullary artery, or extensive stripping off of periosteum, or serious anemia and lowered vitality, union may fail or be delayed. The periosteal blood supply is very important in securing early union.

Neither space nor inclination permits an academic discussion of the various theories of bone regeneration. It seems more practical to accept the dicta that assert:

Periosteum is a vascularizing limiting membrane.

Bone and bone only precipitates bone.

And accept as facts that:

Bone without a blood supply dies.

Viable bone fragments hasten union.

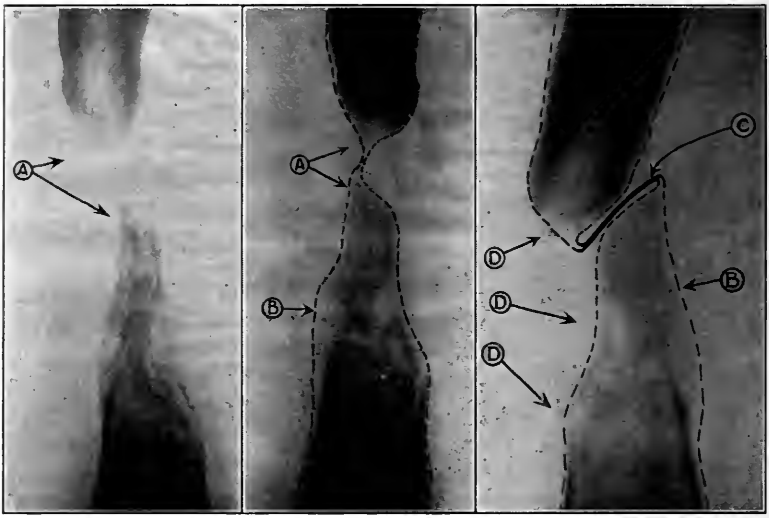


FIG. 118.—*X*-ray: Non-union and beginning pseudarthrosis. *A*, indicates the medullary callus which might have united if no gap had existed. Note the progressive rarefaction of both bone and callus. *B*, represents the periosteum. *C*, represents the adherent layers as shown at operation. The author's explanation of the cause of non-union in this case follows: There being no fragments left to hold the periosteal lumen open, the inward pressure of the surrounding soft parts occluded the periosteal tube. After three or four months the periosteum grew together obliterating its lumen. Periosteum being a limiting membrane, prevented the new calluses from joining together. Shortening was permitted too late. This new double layer of collapsed periosteum devoid of lumen folded upon itself leaving two semi-closed synovial cavities. This explanation uses the only positive function attributed to periosteum, *i. e.*, the limitation of bone-growth. The fact that the medullary callus had grown two inches from the lower fragment shows that bone formation itself was unimpaired. The stream-line taper of the ends of the callus indicates the natural line that a flexible tube assumes when subjected to uniform peripheral compression. Note the progressive atrophy of disuse.

Mobility at the seat of fracture causes overgrowth of callus:

Cortical (so-called periosteal callus) appears earlier than medullary callus.

Union occurs more quickly in small young bones and in well-immobilized, accurately apposed fractures.

Union occurs earlier in the presence of a vigorous circulation.

Anything tending to oppose these principles hinders union and anything favoring them advances union.

Therefore the ideal treatment for a compound fracture includes:

1. Sterilization.
2. Apposition of the fractured ends.
3. Absolute immobility.
4. Retention of *viable* fragments.
5. Maintenance of good circulation.

While the main purpose is to secure solid union of a fracture and the restoration of the bone to full function, there is one other consideration which must be incorporated in our ideal treatment, namely, the preservation of the function of adjoining muscles, joints, tendons and nerves.

This makes it necessary to add:

6. Freedom of movement of all joints possible.
7. Exercise of muscles and tendons.
8. Freedom from pressure on nerves.

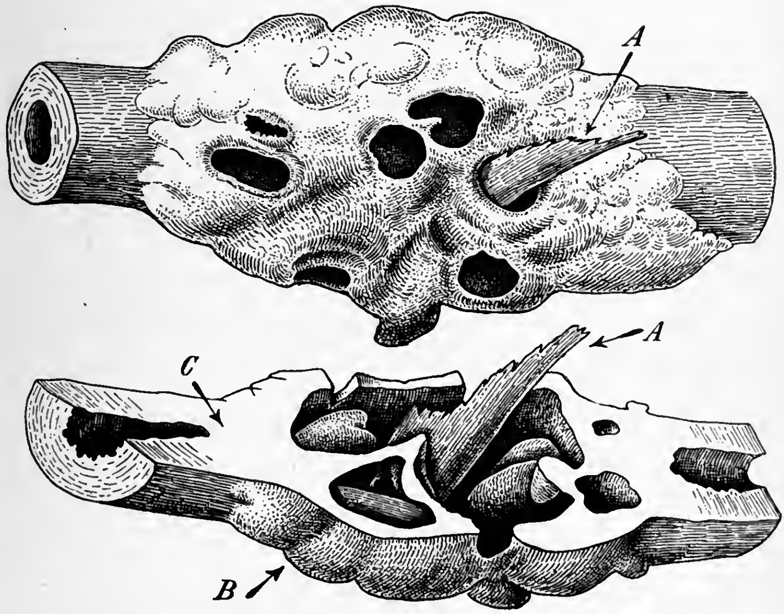


Fig. 119.—Sequestra, involucrum and cloacæ. *A*, sequestrum; *B*, involucrum with many cloacæ. *C*, hard eburnated bone closing medullary cavity, the cavities are lined with a glaring fibrous membrane—pseudoperiosteum.

With this ideal treatment always in view supplemented by the paramount condition that the patient must be free from pain and comfortable, one attempts to meet as many of its requirements as possible.

The Influence of Sepsis on Bone (Formation).—The tiny rigid canals in bone which enclose the bloodvessels admit of no swelling. Thus when the slightest pressure develops, as results when swelling follows inflammation, the blood supply is strangled. If the anemia persists the bone dies. The bone cells having been killed by sepsis the bone so involved is then a foreign body—dead tissue. If it is a fragment it soon becomes detached from its periosteum and may work its way out through a draining wound or may become encased by newly formed callus growing from live bone. If it is the end of a fractured bone still continuous with the living bone it gradually demarcates and is separated by the osteoclasts, when it may follow the same fate as the fragment. Meanwhile, acting as a foreign body, it excites a leukocytosis with pus which must find outlet. Thus cloacæ in the enshrouding callus are developed. The pus lying in contact with the bone-forming osteoblasts hinders their activities by the toxins the pus contains. The result then is a poor, thin shell of pitted, honeycombed callus with sinuses leading from it.

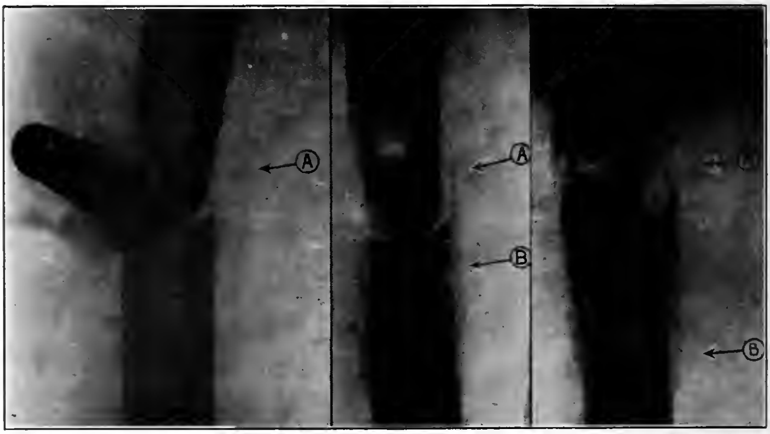


Fig. 120.—*X*-ray: Formation of an end sequestrum, the result of sepsis in the medulla destroying the blood supply to the end of the bone. The soft tissues are perfectly drained but the medullary cavity had poor drainage. *A*, follows the course of sequestrum over five months; *A* indicates the sequestrum; the first picture shows a drainage tube of good size and situation but demonstrates the fact that too close apposition of the fractured ends obstructs medullary drainage. *B*, indicates circumferential callus. Note cloaca and poor honeycombed callus; note the progressive rarefaction of the entire bone, due to disuse

The cavity of the involucrum is lined in time by a dense adherent layer of glaring membrane and the bone ends become plugged with sclerosed ivory-like bone, effectively preven ng the liberation of fresh, healthy osteoblasts and necessitating radical operation to secure fresh bone-forming elements. These statements are practical facts, not theories, and the prevention of these faults lies in the early free dependent drainage of the actual seat of an infected fracture and the removal of non-viable fragments at the moment they are first determined to be non-viable.

Rate.—Aseptic fractures in good apposition and without loss of bone substance consolidate at the same rate as simple fractures.

Bone gaps increase the time necessary for solid union at about the rate of three weeks per first inch of gap, being less in small bones and more in the femur. Two inch gaps take greater proportional time, and gaps of three to four inches in small, thin bones almost certainly fail to unite. In large bones consolidation may require even as long as twelve months and often fails entirely unless active interference is resorted to.

FIG. 121.—*X*-ray: Showing formation and removal of sequestra. *A* points to sequestrum; note the rarefying osteitis; note the better position secured after operation and the formation of sound callus, in three weeks between plates. The wound showed no signs of healing for three months, but after removal of sequestrum healed in three weeks. Union occurred and the femur was solid six weeks later.

In the presence of hindering factors, especially chronic sepsis, solid union may be much delayed, even as long as a year in the femur.

Union generally may be considered firm when the limb distal to the fracture can be actively supported by muscular action alone. It is not safe to permit any work to be done by the fractured limb for at least another month and in the case of the femur the body weight must not be borne for at least two and often three months after union is firm, as the new callus is not unyielding, and shortening, angulation or refracture may occur.

Milk.—Sir Anthony Bowlby has evolved the rationale for heavy milk diet in the simple words: "The one time of life when bones grow quickest and most is infancy when the diet is solely milk. Therefore, milk contains all the elements necessary for bone growth. Therefore in delayed union give a heavy milk diet."

Fig. 122.—The ambulatory Thomas splint, showing application. *A*, the threaded ends of the lateral bars and lock nuts; the length of either bar can be adjusted to a nicety so that the splint fits perfectly; by making the outer bar a little longer than the inner one, the weight can be put on the peroneal side of the foot and thus correct flat foot or genu valgus; the sole of the boot for the normal side is raised to allow the fractured leg to swing through in walking since the knee cannot be bent. This is the model supplied at the Kensington War Supply Depot (London) gratis to the author in large numbers by Mr. Browne of London.

The author heartily concurs in this principle and has seen many instances of quickly accomplished union which has been chiefly attributable to an excessive raw milk diet.

Blood Supply.—Constriction by loosely applied tourniquets above and below the fracture (Thomas's or Bier's hyperemia) seems to augment bone growth. It is not advisable in acute virulent sepsis.

Massage.—Vigorous tapping and heavy kneading near the site of fractures helps bone growth. It is contra-indicated in acute sepsis. (See Immobilization.)

Function of the Part.—Use of the muscles overlying the fracture hastens bone growth by increasing the circulation. It is contra-indicated in acute sepsis.

Shortening.—Allowing the fractured ends to touch each other at the expense of full length (when bone gaps exist) hastens union. Overlapping, on the contrary, delays union.

FIG. 123.—*A*, points to gap in callus, probably indicating the place where muscle interposed between the fragments. *B*, points to callus growing at a distance from the bone in the muscles and about bits of metal probably because bits of bone had been carried into the muscle by these missiles. This case was aseptic but there was no union after five months. In the fifth month the patient was given a diet composed mostly of raw milk and was also allowed to walk in an ambulatory splint. Union was firm at the end of the sixth month. Patient aged nineteen years.

Operative Measures.—Operative measures, such as removing eburnated bone from the ends of the fractures, freshening the surfaces by saw cuts, scraping and drilling and vigorous pounding of the ends of the fracture by a padded mallet percutaneously, all hasten callus formation. These cannot be done in the presence of acute sepsis.

Drugs and Glandular Secretions.—No drug, mixture of drugs, or glandular secretions has been proved to be of definite value in promoting bone production in fractures. Many workers have tried various secretions such as pituitrin and hypophysin, thyroid extract, adrenalin, marrow juice and pancreas extract as medicines, subcutaneous injections and local applications without arriving at any definite results. The author thought that hyperthyroidism had some stimulating effect on one case of subtrochanteric fracture of the femur which united in three weeks, but in two subsequent cases of fracture of the femur in patients showing signs of thyrotoxicosis there was no hastening of union.

My good friend and collaborator Major Rashbrooke of London has concocted a "bone grower" which contains calcium lactate and a few drops of pituitrin mixed with beef marrow which he claims is an excellent dose for fracture patients as it keeps them contented and reminds them that they are being cared for.

FUNCTIONS AND DEFORMITY.

The locomotor system is only as good as its function. In order to restore a fractured bone to function one should understand the principles upon which function depends and the causes of loss of function.

Hey Groves makes the following statement: "To what extent is the restoration of form in a broken bone an index of the future recovery of perfect function in a limb? Upon the answer to this depends the whole question of the modern treatment of fractures."

The data of this problem have been more thoroughly provided by the Fracture Committee of the British Medical Association than by any other source of information with which I am acquainted, and I cannot do better than quote their main facts in this connection:

They say:[1]

"An analysis of all the results, non-operative and operative, clearly shows the interdependence of the anatomical and functional result. The total number of cases in which a good anatomical result was obtained is 1736, and in no less than 1576 of these the functional result was also good. In other words, if the anatomical result be good the functional result is good in 90.7 per cent. If the anatomical result be bad the functional result is good (despite) in 29.7 per cent."

And from these facts they conclude (p. 1505):

"Although the functional result may be good with an indifferent anatomical result the most certain way to obtain a good functional result is to secure a good anatomical result."

Thus we see that one of the most potent causes of poor functional results is malunion (deformity, shortening or malposition).

Cases correctly judged suitable for conservative treatment should not result in malunion.

[1] British Med. Jour., 1912, ii, 1525.

Sir Robert Jones says: "The causes of malunion may be found (1) in errors in the initial treatment or of the setting of the bone; (2) in errors in the method of maintaining the fracture in position, or (3) in errors of after-treatment."

The writer has found that reduction of a compound fracture at primary operation, while often beset with great difficulty, is indeed a simple matter compared to the maintenance of that reduction until union is solid. This, Sir. Robert's second point, is the more difficult problem and one demanding constant attention from the surgeon and frequent x-ray photographs to assure him that malposition has not recurred or to demonstrate the deformity. The means of maintaining reduction will be discussed under the head of Intermediary Treatment (see p. 251).

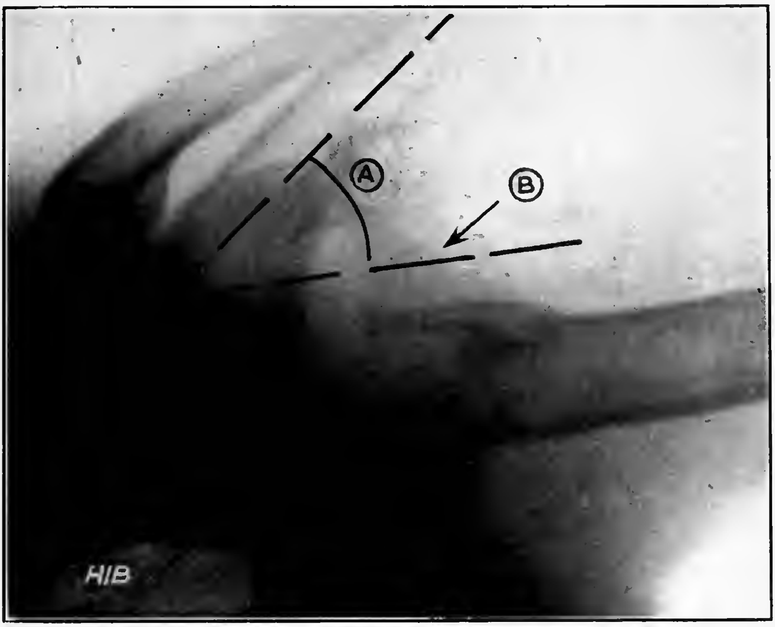


FIG. 124.—*X*-ray of excised shoulder-joint, showing proper position of abduction after treatment. *A*, points to callus which ultimately united the humerus to the glenoid, resulting in a useful ankylosed shoulder. *B*, indicates proper angle of humerus with acromion process.

Deformities.—Humerus.—The commonest defect is an inability to abduct the arm at the shoulder. This follows high fractures. The deformity in low fractures in limitation of flexion due to callus overgrowth about the elbow. Prevention consists of early movement of the joints and fixing the arm in abduction in high fractures and in flexion in low fractures, thus maintaining good line and preventing excess callus formation in the coronoid fossa.

Forearm.—The common deformity is loss of supination, due to synostosis or malposition resulting in some defect of the radio-ulnar articulation. The radius being an arc-shaped bone rotates about the ulna as a bucket handle about its two joints. There ore, any alteration in the longitudinal axis of the ulna or in the arch of the radius vitiates this movement. The deformity is prevented by fixing the forearm in supination always, avoiding lateral pressure on the radius and commencing passive rotation movements at an early date (about the third or fourth week.)

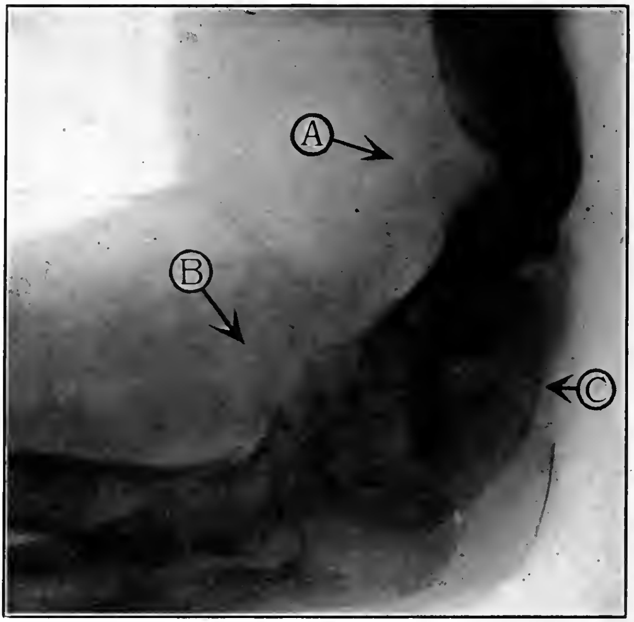


FIG. 125.—*X*-ray of elbow. *A*, points to refracture of supracondylar fracture humerus which occurred while patient was playing billiards (muscular action). *B*, points to solidly ankylosed elbow-joint resulting from fixation in a splint for six months. *C*, points to callus overgrowth in olecranon fossa which might have been prevented by early movement; the cause in this case of ankylosis, poor callus and refracture may be attributed to long-continued sepsis, which might have been eliminated early had all non-viable fragments been removed; thus the elbow could have had passive movement and ankylosis might have been avoided. (Case seen in consultation—not treated by author.)

Elbow.—The common deformity is loss of flexion. It is due to prolonged fixation in the extended position, coupled with callus excess about the joint. It is prevented by fixation in the flexed position, early movement and massage. Ankylosis of the head of the radius to the capitellum results from excessive immobilization and may be prevented by early rotation movements.

Wrist.—The wrist should always be fixed in hyperextension. A flexion deformity is common, and after the forearm muscles shorten and sclerose it is very difficult to correct.

Phalanges.—Sometimes fixed in flexion by scars in the forearm adherent to bone. It is very difficult to correct flexion deformity. Prevention lies in full extension of phalanges and early motion.

FIG. 126.—*X*-ray, elbow. Complete bony ankylosis in good position compound fracture of olecranon in which the elbow-joint was septic and was drained, necessitating prolonged fixation; good function of arm and hand; the patient is able to put his hand on top of his head, write, feed himself and suffers very little disability, while excision might have resulted in a flail elbow it could not have yielded a better functional result. In this case early motion was not practical as it would have caused a flare-up of infection or detachment of the olecranon. (Lieutenant Bolton's case.)

FIG. 127.—*X*-ray, elbow. Fibrous ankylosis which yielded to massage and resulted in motion of 30 degrees; the joint was mildly septic as a result of infection through a split in the trochlea; treated by immobilization without drainage, and passive motion so soon as sepsis disappeared and before the fibrous tissue became ossified. (Contrast with Figs. 125 and 126. The elbow shown in Fig. 125 could have yielded the same result and also the elbow shown in Fig. 126 had the primary operation been well and thoroughly done. Lieut. Bolton did not do the primary operation and when seen by him at a late date no better result could have been obtained. In fact his treatment saved the arm from amputation.

Fig. 128.—*X*-ray hand. Arrow points to split compound fracture of head of first metacarpal which has united to the second metacarpal head and trapezium ankylosing the thumb in abduction and preventing apposition, due to long immobilization which was necessary because of severe palmar sepsis; it might have been better to fix the thumb in adduction. (Major Hughes's case.)

Hip.—The deformity is limitation of abduction. The prevention is to fix the hip in abduction always.

Femur.—Shortening is due to insufficient extension. Often the fault lies in the apparatus. Often the patient refuses to bear the discomfort which heavy extension from the skin causes. Often the surgeon, through not having *x*-ray pictures taken and through not measuring accurately, does not know there is shortening until his patient limps. "Laissez Faire" is the commonest cause of shortening, and when combined with the pride which some oldtimers take in their thorough familiarity with classical methods of diagnosis—rough palpation, estimation and sonorous questions, the elucidation of crepitus, etc.—when combined with these, limps are the natural result.

Prevention is accomplished by efficient extension and constant supervision and the insistence that an ambulatory splint be worn for several months after union is established.

Angulation is due to inefficient extension and the uncorrected muscle-pulls. External angulation in fractures of the upper third with bow-leggedness, internal angulation in fractures of the middle with valgus deformity and posterior sagging, especially in low fractures, are the common errors of alignment.

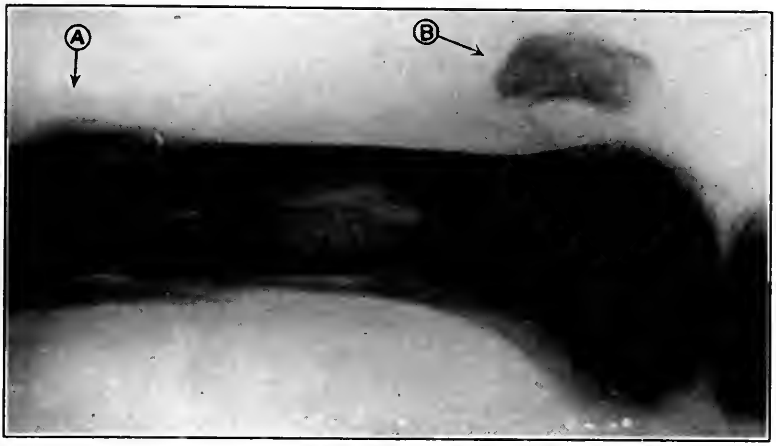


FIG. 129.—Lateral view of end-result in which knee flexion was limited by an adherent quadriceps muscle; arrow *A*, points to callus outgrowth into crureus muscle at adherent point; arrow *B* points to atrophied patella due to disuse. Excision of the scar at *A* resulted in a fair degree of motion.

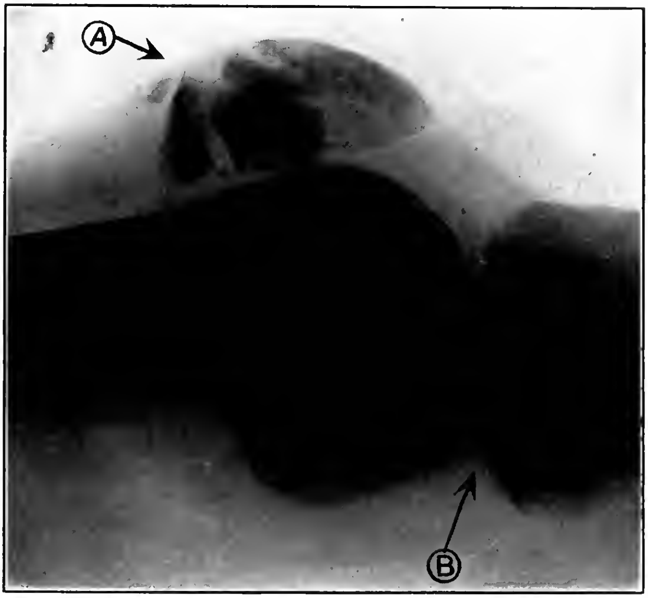


FIG. 130.—*X*-ray of knee-joint, showing *A*, comminuted fracture of patella caused by a bullet, treated by simple immobilization on a Thomas splint, *B*, points to bony overgrowth of the articular surface of the condyles; however, with vigorous massage and usage, ankylosis was avoided and there was motion of 45 degrees as an end-result, with solid union of patella. This is an exceptional case and the difficulty here was to overcome the secondary changes resulting from prolonged immobilization which had occurred before the case fell into the author's hands. The ordinary case of bullet fracture of the patella should not be immobilized longer than a month. Although no set rule can be laid down, active flexion and passive extension should be instituted early.

FIG. 131.—Compound fracture of femur, showing long split and small foreign body. The wound healed by first intention; extension by calipers.

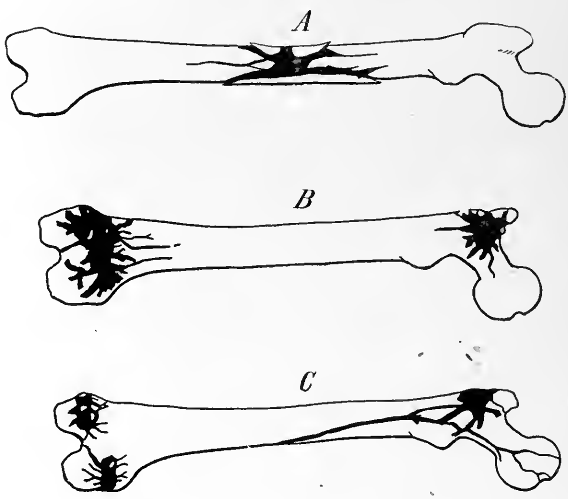


FIG. 132.—Types of fracture. *A*, of shaft; *B*, of cancellous ends (note joint fissures) *C*, of ends by shrapnel balls (note buried balls in condyles).

Prevention consists of efficient extension and correction by abduction or lateral pressure pads. A full normal anterior bowing of the thigh should at all times be insisted on.

Rotation results in flat-foot or a pigeon-toed gait. Flat-foot follows an outward rotation deformity.

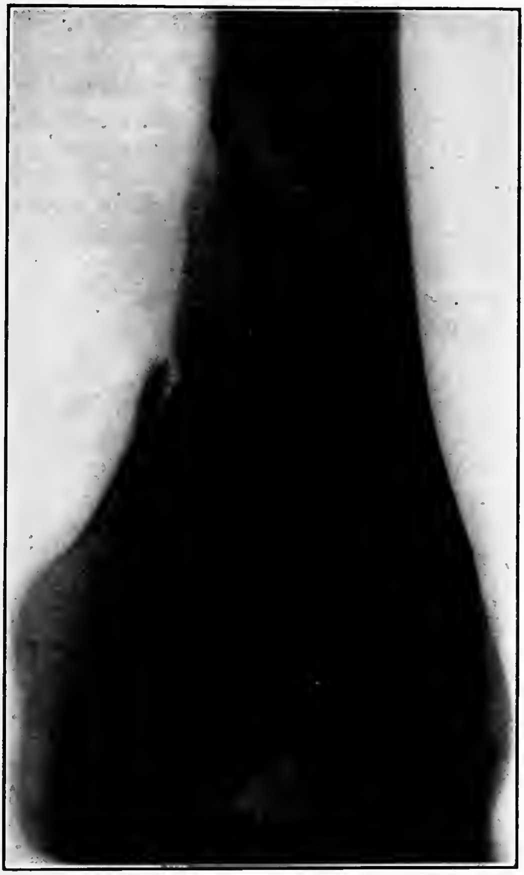


FIG. 133.—Compound fractures of femur incomplete, showing split running into knee-joint. Treated by immobilization only; the subcrural pouch was open and drained through the wound, full flexion and extension of knee as end-result.

The lesser trochanter is an index of the degree of rotation at the hip, and when its maximum shadow shows on the x-ray, the foot should point vertically to be in proper rotation relation.

Prevention consists in correcting the external rotation of the upper fragment by supporting the great trochanter from below, as with a suspended Thomas splint ring, and in seeing that the foot is held pointing vertically. Where there is no support for the trochanter, the toe must point markedly outward.

The Knee.—Ankylosis of the knee is the most frequent deformity seen. Often it is the best result possible, but generally some motion could have been gotten by early movement. Limitation of flexion is caused by sclerosis of the capsule, fibrous adhesion of the joint surfaces or patella, by adherent scars in the quadriceps and by callus outgrowth interfering with free gliding of the quadriceps muscle. Limitation of extension is caused by shortening of the posterior crucial ligament and the posterior capsular ligament of Winslow or by callus excess locking the upward movement of the patella. This deformity greatly hinders the descent of stairs and often is the cause of falling (the knee gives way, since it does not lock in extension, *i. e.*, the center of the joint is not posterior to the line supporting the body weight). It follows along immobilization in the flexed position.

Sometimes full extension cannot be obtained because during aseptic convalescence the pad of fat beneath the ligamentum patellæ increases in size, unless the knee is frequently fully extended. This fat disappears after the patient walks about for a time.

Prevention consists of early movement, massage and full extension of the knee during movement.

Tibia and Fibula.—Shortening is the common deformity when both bones are fractured. Combined with it one often sees valgoid deformity, with resulting flat-foot. When there is posterior sagging as well the ankle-joint cannot be fully extended. A varus deformity is least serious. Prevention includes correct alignment and correction of sagging on the splint. Knee flexion aids in overcoming shortening.

Ankle.—Ankylosis in the equinus position is bad and common. Flatfoot follows shortening of the fibula. The ankle should be immobilized at right angles and slightly in the varus position. The inability to raise the toes when walking may be due to excessive callus in front of the joint. This may be prevented by the right-angle position.

THE WOUND.

Bone Wound.—The type of fracture depends upon the speed and shape of the missile and the hardness, grain and shape of the bone. Thus high-velocity missiles tend to cause splitting fractures with long fissures and large fragments when the shaft of a bone is hit and penetrating or shattering fractures when the cancellous ends are hit.

The lower ends of the femur and humerus weakened by their notches often show a split running into the respective joints.

The flat, thin bones lend themselves to puncture.

The delicate medullary tissue is always contused for several inches above and below the seat of fracture. The medullary artery is always ruptured. One must remember that the devitalized and anemic pulp of the medulla is an ideal culture medium for bacterial growth. This holds true for the crushing fractures seen in civil practice.

The Flesh Wound.—The flesh wound may be unimportant in its length from the entrance to the bone. Usually its length from the bone to its exit is large, lacerated by bits of blown-out bone and the deformed missile; vessels and nerves may be torn and there is a skin defect. It is the exit wound that harbors infection and into which dirt is rubbed by clothing and by helping hands. The presence of foreign bodies, particularly clothing and dirt, devitalized and dead tissues, laceration and arterial lesions tend to increase the degree of sepsis. Wounds received in wet, muddy weather are more foul than those received in dry, sunshiny days. Wounds in Flanders were universally infected, those in the deserts of Egypt and the Holy Land were in general aseptic. During retreats when the wounded lie unattended, the wounds are more frequently infected than they are during an advance.

Arteries and nerves may be completely torn across, nicked or only bruised.

Fig. 134.—Showing two deformed bullets. This fracture healed by primary union without operation and without once causing a rise of temperature above 98 degrees. The bullets remain in place.

Arterial Lesions.—The femoral, posterior tibial and interosseous arteries are most frequently torn in connection with fractures. The brachial, while frequently torn, seems to slip easier to one side and escape with only bruising. When arterial lesion accompanies compound fracture the vessel should be tied at the first opportunity both proximally and distally. Arterial lesions *per se* are not sufficient reason for amputation.

Nerve Lesions.—The musculospiral nerve in the arm, the ulnar nerve in the forearm and the post-tibial nerve in the leg are most frequent concomitant nerve lesions. The sciatic nerve when divided and accompanying a fracture of the femur presents a grave state of shock. Lesions of the peroneal nerve result in drop-foot and therefore are more serious than post-tibial lesions. Many lesions of the posterior tibial nerve are accompanied by injuries of the same artery and for this reason primary amputation disposes of this very troublesome condition more often than it eliminates peroneal nerve lesions which are generally not accompanied by serious arterial lesions. Nerve lesions should be treated by immediate suture of the sheaths only. The suture should not include the fibrils. Occasionally regeneration follows immediate suture but at all events the cut ends of the nerve are kept in fair apposition so that secondary repair is easy after wound healing has occurred.

The wounds of the soft parts, brain, lung and pelvic contents, are more serious than the fractures of the flat bones overlying them.

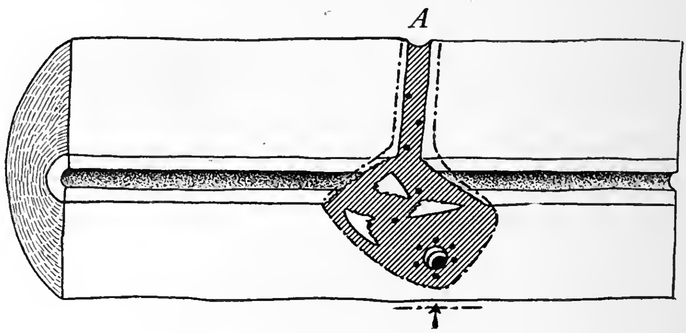


FIG. 135.—Inoculation about a foreign body and outline of revision operation leaving an uninfected wound suitable for B. I. P. P. Arrow indicates point best suited for drainage.

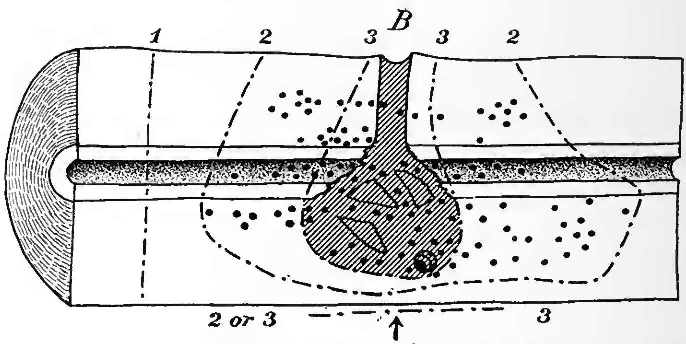


FIG. 136.—Inoculation has developed into infection; outlines of operation then possible. *1*, amputation; *2*, radical excision leaving an uninfected wound suitable for B. I. P. P. or flavine; this is seldom possible, because essential structures would have to be sacrificed; *3*, revision with Carrel's after-treatment. Arrow indicates point for dependent drainage.

Foreign Bodies.—Foreign bodies if sterile become encapsulated and firmly embedded in connective tissue. They do no harm even if situated in the medullary cavity.

A foreign body if infected is the center from which sepsis spreads. An abscess develops about it rapidly dissecting its way through the fascial planes in every direction and back through the track of entry. As a rule the track also becomes an abscess center, but sometimes the

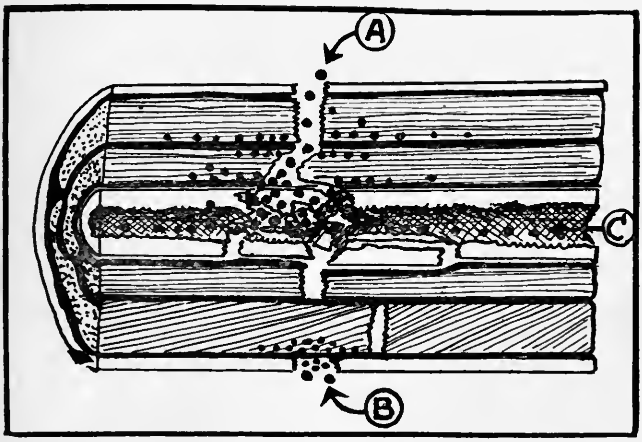


FIG. 137.—Muscle valve action. *A*, skin infection spread along medullary canal, *C*. *B*, skin infection blocked by sliding of muscle over entrance wound.

track may have been so lightly inoculated that the body resistance is able to overcome the inoculation, and but for the presence of the foreign body the fracture would have run an aseptic course. This constitutes the difference between the comparative innocuousness of through-and-through wounds compared to lodging wounds. For this reason every foreign body should be removed at primary operation before this unhappy sepsis develops.

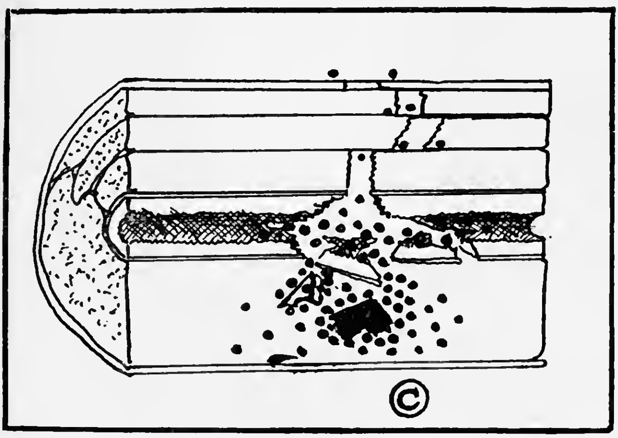


FIG. 138.—Muscle sliding valve action; infection about shell fragment invading medulla.

Types of Foreign Bodies and Their Characteristics.—Bullets entering nose first carry little or no dirt with them, never carry bits of clothing with them, and may pass through so hard a bone as the shaft of the femur without deviation, coming out through the skin again without tearing it. They generally pass entirely through the limb but may lodge near the skin opposite their entrance and rarely in the seat of fractures, since if their force is sufficient to fracture a bone, it is sufficient to carry them through and out again. Lodging bullets commonly only groove or scratch a bone.

FIG. 139.—Long oblique fracture caused by glancing missile; demonstrating position which can be obtained by operative reduction without mechanical fixation at site of fracture. Treated on Thomas splint with extension by stockinette glued to the leg. (See Fig. 178, p. 266.)

The bullet which has ricocheted or entered sidewise, or been turned sidewise on impact with a bone or broken into many fragments, or has has driven the shattered bits of bone before it, and results in the so-called explosive exit wound, must be regarded as having caused a severe compound, potentially septic fracture.

Shrapnel balls are not heavily infective and fracture hard bones with difficulty owing to their low speed of impact. The smaller bones are often fractured by balls, and the great trochanter, condyles, and tibial head commonly are incompletely fractured by balls which one finds buried in their cancellous substance.

Shrapnel balls often lodge just under the skin opposite their entrance and can be felt. The skin is tough enough to stop the slow moving ball after it has expended most of its energy on a bone.

Bomb fragments are generally multiple, and together with the mud accompanying them one of the most dangerous missiles from the standpoint of infection.

Shell fragments are highly infective, but, as a rule, less so than bomb fragments; and they are less often multiple.

Secondary missiles such as stones, or parts of machinery, or buildings seldom cause fractures. They are highly infective.

Any cloth that has been carried in with a lodging missile is generally carried through the fracture to lodge near the missile, though the cloth is often caught by the fracture itself, and held hidden among the ragged spikes of bone.

Cloth carries the greatest amount of infection. Cloth is generally carried into a wound caused by shell fragments, and the larger the fragment and the more angular it is, the greater the likelihood of its having carried clothing in with it. Bullets and shrapnel balls seldom carry cloth with them. Cloth is a frequent cause of persistent sinus.

Difficulties of Finding Cloth.—*Sight.*—Owing to its soft smooth character cloth is difficult to find at primary operation if the surgeon relies on touch only and this fact is an argument in favor of thorough wound revision by sight made possible by a large incision.

Contents of pockets are likewise highly infective and include such things as bits of paper, cigarette cases and tins, coins, nails and screws, clasp knives, keys and pipes, luminous and non-luminous watches, etc. They may be blown into the tissues by bullets or other missiles.

BACTERIOLOGY AND ANTISEPTICS.

Sepsis is the most important and serious element encountered in dealing with compound fractures. It is the cause, either direct, indirect or contributory, of almost all deaths after the first forty-eight hours; and of many deaths within forty-eight hours: the direct cause of toxemia, osteomyelitis, septicemia, and septic infarction; the indirect cause of secondary hemorrhage, and the contributory cause of prolonged shock. It is the cause of sequestra, sinuses, much delayed union, chronic osteomyelitis, faulty callus, sclerosis of muscles, large adherent scars, emaciation and the myriad complications of kidney, lung, joint, etc.

Thus sepsis should be eliminated at the earliest possible moment.

Bacteria can be found in two places:

1. On the surface of a wound—inoculated compound fracture.
2. Beneath the surface of a wound and mechanically or anatomically impossible of surgical removal—infected compound fracture.

The bacteria may belong to any family or type. The common ones are:

Anaërobes.	Inoculation stage.
B. tetanus	10 hours to 6 months.
B. aërogenes capsulatus	8 hours to 24 hours.
Aërobes.	
Streptococcus	12 hours to 24 hours.
B. staphylococcus	15 hours to 48 hours.
B. pneumococcus	
B. fecalis	

The latent stage (inoculated stage) is that time during which the bacteria lie on the wound surface multiplying and preparing the way to penetrate the tissue defence. It is during this time that it is possible to sterilize a wound by operation.

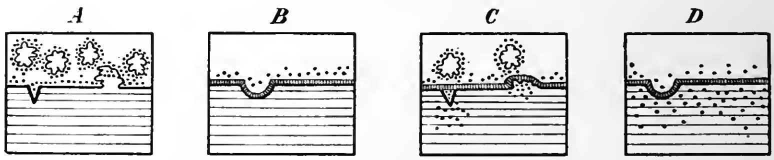


Fig. 140.—Inoculation, infection and antiseptics. *A*, an inoculated wound showing debris and bacteria on the surface. *B*, an inoculated wound after good operation for tevision and the application of an antiseptic barrier against bacterial invasion of sterile rissues; all debris has been removed and only a few bacteria remain which the antiseptic should destroy. The vertical lines represent a thin layer of antiseptic. If the bacteria are not numerous and not virulent, this wound could be closed by primary suture. *C*, an inoculated wound after poor operation and the application of an antiseptic; an inoculated crevice has been overlooked which harbored bacteria. They are now proximal to the antiseptic and are shown penetrating the tissues; a lump of devitalized tissue has also been left containing bacteria which are also proximal to the antiseptic and are shown penetrating the tissue. *D*, an infected wound after good operation leaving no crevices or devitalized tissue; the tissues are already infected so that the antiseptic which has been applied is worthless except for surface disinfection. This wound could not be closed by suture.

A poor surgical operation will not be made good by the use of all known antiseptics, while a good surgical operation will produce results with any or no antiseptic.

Therefore, one does not think of antiseptics until all damaged tissue has been cleared away from the wound and often only after dependent drainage has been provided.

Antiseptics.[1]—Most antiseptics (if not all) which kill bacteria also kill tissue cells, and those which inhibit bacterial growth also inhibit

[1] B. I. P. P. is bismuth iodoform paraffin paste, and consists of:

Bismuth subcarbonate, iodoform	āā	℥ij
Liquid paraffin	q. s. ad	a paste.

Flavin is a solution of the anilin dye acriflavin, $\frac{1}{5000}$ in water or alcohol.

Dakin's solution is a solution containing free hypochlorous acid and is a 0.48 per cent. solution of hypochlorite of soda neutralized with boric acid.

Eusol, which can be used instead of Dakin's solution, is made by mixing equal parts of dry chlorinated lime (bleaching powder) and boric acid. This mixture is kept in a tightly stoppered bottle. When needed 25 grams of this mixture is added to 1 liter of water, and after standing for several hours the filtrate is ready for use as eusol.

tissue activity. Phenol and its derivatives, mercury bichloride and the corrosives, the caustics and others belong to the first group. Tincture of iodine, alcohol, ether, the gaudy aniline dyes, hypochlorous solutions, strong NaCl solutions and B. I. P. P. belong to the second group. The latter group may be further divided into long-lived and short-lived groups. B. I. P. P. is a long-lived antiseptic, exerting its antiseptic effect until it disappears. A thin layer (proper use) will persist for about ten days. A large lump may lie in the tissues for months before being absorbed (see Fig. 141).

Fig. 141.—A large lump of B. I. P. P. lying unabsorbed in the great trochanter six weeks after it was applied. B. I. P. P. should never be used in lumps like this since such lumps often cause persistent sinuses and act as foreign bodies. In large amounts it has a toxic effect at times. Complete fracture through neck of trochanter, treated on author's abduction splint without shortening and with perfect anatomical and functional results; union in six weeks.

The fluid antiseptics are short-lived and are absorbed or washed away within a few hours. Thus, Dakin's solution must be renewed every two hours, flavine every twenty-four hours, ether and alcohol every fifteen minutes, etc. On the other hand the fluid antiseptics more readily reach every crack and crevice than does the more solid B. I. P. P., which will not spread beyond the actual place where the surgeon's finger rubs it. This diffusing property of fluids explains the *rationale* for the use of alcohol (or sometimes carbolic 5 per cent. followed by alcohol) before the application of B. I. P. P. Alcohol has the further property of absorbing moisture from the wound surface and thus preparing the surface physically for the intimate reception of its coating of B. I. P. P., which adheres poorly to a damp surface. For this reason it is well to apply B. I. P. P. while the tourniquet is in place or else after perfect hemostasis.

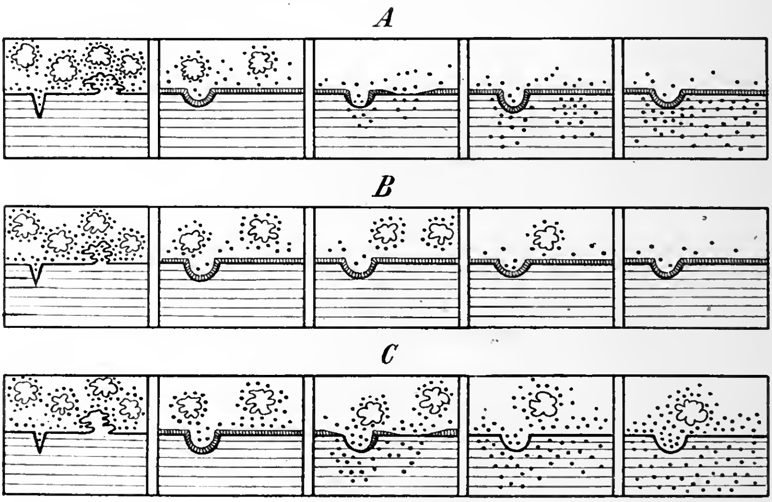


Fig. 142.—*A*, shows what may happen when intermittent antiseptics (such as Carrel's) are used; the antiseptic loses its power and if one instillation be delayed or omitted, the barrier is broken and bacteria enter healthy tissue where they grow; the antiseptic is then renewed but does not reach the buried infection. *B* shows what happens when an inoculated wound is thoroughly revised and a long-lived antiseptic B. I. P. P. is used as a barrier between healthy tissue and the debris of operation; the healthy tissue remains sterile. Faultless Carrel's treatment accomplishes the same result. *C* shows what may happen after revision operation if a short-lived antiseptic is used; the debris harbors bacteria which when the antiseptic loses its power, penetrate the healthy tissues and infection results. Each type of antiseptic has its useful sphere. All can be misapplied and when misapplied are often not only useless but harmful.

Salt solutions depend for their action on a mechanical washing of the surfaces, either directly by the actual solutions or indirectly, when concentrated, by the serum and leukocytes they call forth from the tissues.

Antiseptics and Bacteriology of Inoculated Wounds.—Bacteria on the surface will be killed by any antiseptic powerful enough, even if it does not penetrate the tissues, and unless the surface is reinoculated by the debris of operation it will remain sterile. However, it is seldom possible to leave revision wounds so clean that no reinoculation is possible. Some tiny corner, inaccessible or unnoticed, may still harbor bacteria ready to replant the entire wound. Therefore, the antiseptic used to prevent surface infection must not lose its bactercidal power for several days or must be renewed frequently and regularly. (Fig. 142, *B*.)

Attention to this principle of a continuous antiseptic barrier between infected and sound tissue explains the success of the various antiseptics in the treatment of inoculated fractures, and the continuous maintenance of this barrier is absolutely essential to the success of Carrel's treatment.

Dry gauze without any antiseptic or in conjunction with B. I. P. P. is the best dressing after a thorough revision of an inoculated wound has been well done, since when it is removed it leaves a wound free from blood clot. Blood clots and anemic tissue are culture media *par excellence* and should never be tolerated by a careful operator. However, if one is not confident that all bacteria have been eliminated, it is wise to use some antiseptic. (Fig. 140, *B*.) An anesthetic is generally required for the first dressing.

Bacteriology and Antiseptics in Infected Wounds.—The treatment of infection is based upon the resistance of living tissue to bacterial growth by antitoxin formation, leukocytosis and phagocytosis, surgery and antiseptics being employed only to augment this resistance by decreasing the dose of toxins and the culture media (dead tissue).

Any antiseptic is misused and abused when it is used in the hope of killing bacteria already buried in the tissue depths (Fig. 140, *C* and *D*). One so often sees failure and disaster follow the attempt to accomplish sterilization of tissues beneath the surface that no other term save abuse of antiseptics can be used to describe this futile hope; for, if antiseptics strong enough to penetrate tissues are used, they kill the penetrated tissue, which then becomes a medium for the microbes. Thus the antiseptic begets sepsis and destroys at one stroke the painstaking removal of dead tissue, the object of primary wound revision.

It is this misapplication of antiseptics and the expectation of panaceal properties which lead some surgeons to condemn as useless all antiseptics when used in the wound. They have one prime virtue, namely, surface sterilization, although they may depress the defence of the tissues against infection.

Therefore, antiseptics play only a small part in the treatment of *infected* wounds as distinguished from inoculated wounds. B. I. P. P. is worthless in infected wounds (Fig. 140, *C* and *D*). Flavine is of little value except that it suspends infection for a certain period in fresh wounds and tends to discourage granulation growth in healing wounds and thus may be used to prevent the premature closure of drainage wounds. Carrel's treatment is very useful in the early treatment of infected wounds and particularly poorly drained wounds, since it washes away surface organisms and may kill some of them (Fig. 140, *C*). It is the author's habit to use Carrel's treatment for all virulently infected wounds during the first ten days, but the treatment *in compound fractures* is modified always by rigid insistence on free dependent drainage and the relief of all tension by free incision. No pooling of pus is tolerated at any stage. (See Drainage, p. 242.)

Well-drained wounds after granulation tissue appears, have no need of antiseptics whatever, since no discharge accumulates which may be absorbed or may re-infect, and since the granulation barrier against infection is better than an artificial barrier.

Serums and antitoxins have not been found to be of much value in the treatment of infections, with the one great exception of tetanus antitoxin.

Tetanus.—The administration of tetanus antitoxin 500 or 1000 units, depending upon the anaërobic conditions of the wound, given subcutaneously at the earliest moment and repeated at weekly intervals for the first month, has banished generalized tetanus from the bacterial complications of compound fractures. Five hundred units given at once are worth 5000 given after twelve hours and worth 100,000 given after tetanus manifests itself. Local tetanus is still infrequently diagnosed by twitchings of a limb near the wound and the presence of trismus of slight degree. The author has generally been able to find some other cause for these symptoms: Once an abscess in the auditory canal, many times the pricking of a nerve by a movable spicule of bone, the pressure of a fragment in malposition, an abscess about a foreign body, osteomyelitis with toxic meningismus, myosites ossificans of a muscle, pressure of splints on the ulnar or peroneal nerve, an alveolar abscess and pyelitis and hematogenous meningitis.

When any sign of tetanus appears the wound, without hesitation over differential diagnosis, should be widely laid open, every corner cleaned and drained, peroxide of hydrogen used freely for dressings every few hours and enormous doses of antitetanic serum injected, subcutaneously, intramuscularly near the wound and intrathecally. The dose should be not less than 50,000 units without delay, and within a day up to 300,000 units should be given.

DIAGNOSIS OF COMPOUND FRACTURES.

The diagnosis of compound fractures presents little difficulty and can usually be made by sight alone. The skin is freshly broken; the limb abnormal in shape; powerless; a broken bone may be visible; light, gentle palpation may disclose irregular contour. One need know no more at the moment.

Further efforts at diagnosis are not only useless but harmful. The manipulation of the bone to elicit crepitus further lacerates the surrounding muscles, jabs them into painful spasms and implants infection in fresh tissues. Manipulation may be the last straw required to establish profound, hopeless shock. No attempt to refine diagnosis should be made at this time. *X*-ray plates may be taken to be developed and examined later if there is not much shock. Immobilize the fracture and get the patient into a warm, dry bed.

After he has become operable, refine the diagnosis but do so without again rendering him inoperable, *i. e.*, painlessly so.

X-ray.—The case should be *x*-rayed if it can be accomplished without delay, pain or further manipulation of the fracture and two plates should be taken, one anteroposterior and the other from a lateral direction. These plates then will show the exact position and the type of fracture and the displacement and the exact localization of the foreign body. It is folly to gainsay this, no matter how incorrectly one may interpret these plates. It is well to have every fracture x-rayed with the patient in a certain anatomical position, so that at operation that same position can be duplicated, thus obviating the errors which muscle sliding may introduce. One must then study the plates carefully before operating that he may know exactly what sort of fragments to expect,

Fig. 143.—X-ray showing little evidence of fracture.

Fig. 144.—Same case one month later, showing definite fracture. This illustrates the necessity for having two plates taken from different directions.

whether he can explore the medullary cavity without excessive removal of fragments, whether there are many powdered fragments (which are generally detached), whether there are long fissures extending into joints, whether there is a possibility of bone endangering the vessels, whether the limb is anatomically not worth saving. Knowing these things, the incision may be made intelligently, time will be economized and a good operation will be done.

The x-ray has so many advantages over the old classical methods of diagnosis that comparison with each of them, or with all other combined methods, would consume more space than they merit.

The x-ray will show sequestra and callus, and after one is familiar with the shadows, it supplies sufficient evidence on which to make a diagnosis of sequestra.

A portable x-ray outfit has become a necessity in the diagnosis of position in fractures of the femur. Some may criticise this statement as overemphatic. It is based on the treatment of a series of compound fractures of the femur under the supervision of my superior officer, Major M. Pearson, in which only the exceptional case was discharged with a limp and in which the average shortening was 0.5 cm. The portable x-ray apparatus gives a true picture of the position of the bones as they really lie all day and all night.

Moving the patient out of his apparatus upsets the whole arrangement, allows the possibility of movement or refracture of delicate precallus, stirs up quiescent sepsis and after all results in the picture of the femur as it is in the x-ray room but not resembling its position all day and all night.

Portable x-ray outfits are not required in the treatment of other limb fractures.

Palpation and Inspection.—Palpation and inspection are always valuable, easily accomplished and fairly accurate where the fracture is exposed or subcutaneous as when the phalanges, tibia, fibula, ulna, clavicle or any bony prominence is involved. Rough manipulation is never necessary or justifiable.

Measurement.—Measurement is worthless unless the two limbs are in precisely similar position and relations to the body. One can prove this easily on his own thigh. By changing the position of a normal thigh a difference of 8 cm. can be shown. It is obvious that careless measurements of fractured thighs are useless.

However, if one first assures himself that both limbs are in precisely the same position, measurement can be done so that repeated trials will not vary more than $\frac{1}{2}$ cm. ($\frac{1}{5}$ inch).

The points to be used for measuring the femur are the anterior superior spine of the ilium and the superior border of the patella. These points are available without disturbing the fracture. A measuring stick, such as bootmakers use is employed, as with it the bony points can be accurately engaged. A tape measure is unsatisfactory, as it cannot be accurately fitted against the landmarks. The pelvis must be flat in bed and the abduction angle the same for both legs. Hip and knee must be flexed to the same degree.

The anterior superior spine and the internal malleolus are used in fractures of the leg when the leg cannot be put to the ground. There is no satisfactory bony point in the upper end of the tibia, although the internal semilunar cartilage can be used when the knee is flexed.

The length of arm bones cannot be satisfactorily measured and, fortunately, their length is relatively unimportant, as simple shortening generally results in no disability and little deformity.

The Probe.—The probe poked querulously into the skin puncture generally gives no information and usually results in the heavy inoculation of the deep tissues that may have been lightly inoculated beforehand. It has no place in the diagnosis or treatment of fractures until granulation tissue has appeared. In this connection the following quotation from the *Medical Record,* November 26, 1881, at which time torrents of suggestion and criticism were poured into the medical literature regarding the treatment of President Garfield's fatal bullet wound, is interesting. Dr. E. B. Turnipseed, of Columbia, S. C., in a lengthy tirade, quotes a report of Dr. Bliss as follows: '"*After withdrawing my finger* (*from the entrance wound*) *I made an exploration with*

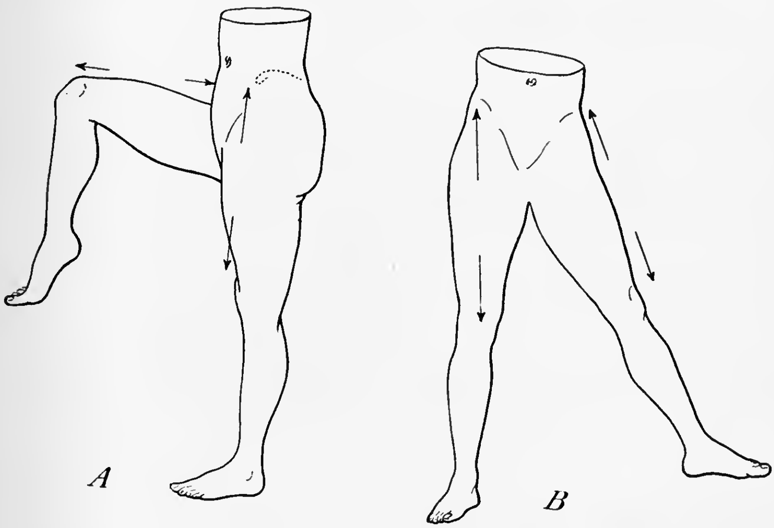


Fig. 145.—*A*, hip flexion brings the patella nearer to the anterior superior iliac spine by from 3 to 5 cm. *B*, abduction brings the patella nearer to the iliac spine by from 1 to 3 cm. Thus measuring one's thigh in the position of abduction and hip flexion may show it from 4 to 8 cm. shorter than when held in the ordinary standing position. This illustrates the possible discrepancies which may appear in measurements and demonstrates that neutralization of postural elements is necessary to accurate measurements.

a long flexible probe which I suitably curved before entering, and gently passed it downward and forward, and downward and backward and in several directions."' Dr. Turnipseed then comments: "He does not say how far he introduced the probe, but the resistance to the small silver probe once entered between the muscles, or fascia and muscle, is so little that I know full well, by experience, very slight pressure will force them to their full length. It appears, however, whether the probing did it or not, the pus burrowed just in the direction in which he probed." The probe did not find the bullet, but President Garfield had no fever at the time nor for eighteen hours afterward. Thereafter his wound was septic until he died. And autopsy disclosed the ball *encapsulated* and free from suppuration while the probed wound and the *probe wounds* were septic. Probing for the bullet is one of the worst things that can be done to a compound fracture. It is a useless waste of time, conveys no new information, since if there is only one hole something is inside—if two holes on opposite sides it has probably gone through, and even if one probes he cannot follow the track of a missile because the muscle planes act as valves, sliding one part of the track over another and blocking it. The probe makes its own track guided by force and ignorance and implants its load of microbes throughout the tissues. The missile generally passes through the fracture and lodges in the tissues opposite its entrance, so that the probe, if it should follow the bullet, passes through the fracture and infects it.

The probe is useful after granulation tissue appears. One can easily probe a sinus. Its walls are firm and smooth. At the bottom one may be able to feel bone and to tell whether that bone is covered with periosteum or whether it is a sequestrum. The probe properly used cannot infect a sinus with its highly resistant granulations and thick walls.

Infection.—Equally important is diagnosis of the degree of inoculation or the degree of infection present. One judges inoculation by the sort of wound and its dirtiness. One judges infection by the inflammation and tension of the part, the character and amount of discharge, the odor, the patient's temperature, pulse and facies and by direct bacterial examination.

Operability.—One judges operability by the patient's facies, his pulse, blood-pressure, respiration (especially its character), his color, the warmth of his nose and hands and the risk of the operation advisable or demanded. Only experience can properly evaluate these signs.

TREATMENT OF COMPOUND FRACTURES.

The first object of treatment is the saving of life regardless of the function of the fractured bone.

The second object is the restoration to function of the fractured bone.

Immediate Treatment.

Immediate treatment should aim to prevent further injury, both by mechanical means and through infection.

Further physical injury is prevented by the immediate immobilization of the fracture by any available means. It is best accomplished in the case of limbs by applying lateral fixation supplemented by improvised extension, a Thomas splint for fractures of the thigh, leg or humerus, an internal right-angle splint for the forearm and hand and a back splint with rigid footpiece for the ankle and foot. In the absence of these, any stick, board, rifle, sling or stretcher bar may be made to immobilize a limb.

The patient should not be moved until his fracture is immobilized, as movement will cause the surrounding muscle to be jabbed into contraction, with resultant pain, shock and the extension of inoculation.

Further bacterial injury is prevented by the application of an aseptic or antiseptic dressing to the skin wounds. It is best to paint them with iodine all around. The actual wound should not be touched except by a surgeon.

Scrupulous care must be taken not to rub dirt and bacteria into the wound.

If it is large and full of dirt, operation under anesthesia is necessary to cleanse it. Any attempt to cleanse the actual wound only aggravates the attendant shock and thus inflicts additional physical injury, which is precisely what one should not do.

No antiseptic should be injected into the wound track, since generally it cannot be done, and if it can be done would only cork up drainage. (See Muscle Sliding and Antiseptics.) (Fig. 138, p. 215 and p. 217.)

Morphin.—Morphin is a most valuable drug. It should be given in full doses (often gr. $\frac{1}{2}$ will be necessary to quiet a patient with a severe fracture). It allows the torn spastic muscles to relax, relieves the terrible pain of fresh compound fractures and allows the patient to be transported in comparative comfort, while without it transport might be utmost torture.

Shock, etc.—These things done, the quicker and the more gently the patient is placed in a solid warm bed the better. The patient should *not be washed* or disturbed in any way, particularly if there is any degree of shock present.

However, no two wounds are precisely the same, and one must always remember the fact that a patient still breathes is not sufficient evidence that his life can be saved, although apparently the most desperate case may recover under intelligent treatment.

After the patient is safely in bed one watches for the effect of the immediate treatment he has received.

When he arrives at the hospital his condition will depend upon his previous treatment and the seriousness of his wound.

Those cases poorly immobilized, exposed to cold, wet, brought long distances over rough roads and left lying out for many hours are in profound shock. Their blood-pressures may be 50 to 80, etc. Those well immobilized, etc., may have normal blood-pressure.

In the author's opinion shock is divisible into two phases: (1) the primary wound shock which is physiological (or, rather, biological) and the function of which is to lower blood-pressure and prevent hemorrhage; and (2) the second phase instigated by lowered blood-pressure in the presence of toxemia.

One can easily see that a fracture which is not immobilized is a constant source of continued muscle laceration. Surgeons have come to know that it is utterly impossible to improve a patient's general condition so long as his fracture is not properly splinted, and that in a case impossible of proper splinting the optimum operative moment is at once. Delay means that the patient's condition will be the worse for it. On the other hand, if a compound fracture is immobile one may expect resuscitation treatment to improve the patient's condition, other things being equal. Thus, intelligent primary splinting has saved many lives, to say nothing of countless limbs. We have come to know that these cases respond to resuscitation treatment to a certain degree and, passing this optimum point, retrogress. They must be operated upon then or not at all. It is important, too, that the moment chosen be on the ascending curve and not just after the optimum, for then the operation gives a shove down hill to the person already on the grade, which spells disaster. (See diagram, Fig. 146, p. 229.)

Only by close observation of many cases can one judge this point, and the best index for it, better than any sphygmomanometer, stethoscope, pulse-rate, blood volume or respiratory rate, is the man's face. Description is impossible, but nothing so tells the story of hope or so reveals despair as the patient's face. The blood-pressure, respirations, pulse-rate, and heart action are valuable, of course.

However, having decided upon operation—what operation? This, of course, will have been pondered over during the decision for operation and the type of operation necessary will bear great weight in the decision for operation.

Mortally Wounded Cases.—It is well to remember that there is such a thing as a mortal wound.

It is useless to attempt anesthesia of any sort on a patient whose systolic blood-pressure is lower than 70 mm. Hg, whose face is drawn, eyes sunken, breath shallow, etc. It is harmful to attempt any painful treatment such as forcible reduction of a fracture, incision for drainage, the application of a splint which requires movement of the fracture or gross manipulation, or even of examination (except by sight, x-rays or light touch). These measures hasten death. These cases must be left without movement of any sort and resuscitation treatment employed.

This group of cases includes mainly fractures of the femur and leg bones, where there has been terrible shattering, together with extreme laceration of the soft parts, arterial lesions and hemorrhage, gas gangrene and exposure.

Most of these patients are suffering from other wounds in addition to the ones causing the fractures, and the wonder is that death has been cheated so long.

Inoperable on Admission.—Cases poorly immobilized whose fragments have been constantly grating about piercing and lacerating soft parts and planting infection in every fresh laceration, bleeding from torn arteries, suffering from exposure, infection and shock, but which have a palpable pulse at the wrist, and whose systolic blood-pressure is over 70, will respond to immobilization and resuscitation treatment and become operable, as a rule. At the risk of repetition, resuscitation treatment will be useless unless the fracture is immobile. No matter what splint the patient is wearing (these cases sometimes owe their condition to the absence of any splint or of any efficient splint) it should not be changed unless this can be accomplished painlessly. The existing splint must be patched up and supplemented until it immobilizes the fracture. Not until this is done will resuscitation treatment avail, and if it cannot be done the case is hopeless.

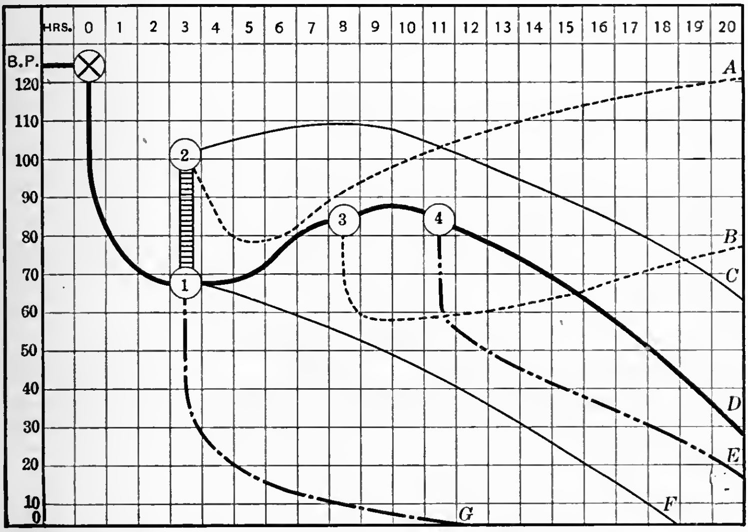


FIG. 146.—Blood-pressure charts (schematic), showing wound shock, transfusion, resuscitation, secondary shock, the shock of sepsis and operative shock, death and recovery. At the point marked *X* the patient sustains compound fracture of the femur or other grave injury. His blood-pressure falls rapidly at once and continues to fall during the period of transport. In the third hour (or after the lapse of any unit of time) at the point marked 1 it is 65 mm. of mercury. If he is operated upon then or subjected to rough manipulation his blood-pressure continues as the interrupted dash-dot line *G*. If his fracture is well immobilized but virulently septic and if supportive measures are employed the blood-pressure will likely follow the heavy line *D*. If transfusion of blood can be done at the point 1, the point 2 may be reached. If at the point 2 he is left with virulent sepsis unchecked by operation his blood-pressure generally follows the thin black line *C*. At any point on this line operation can be performed, after which his blood-pressure will probably follow the dotted course *A*. If no transfusion is necessary, operation may be performed at the point 3. This is the "optimum operative moment," and the blood-pressure after operation might follow the line *B*. If operation be delayed until the curve passes its zenith, as at 4, the prognostication is poor, as the double-dot-dash line *E* indicates. Transfusion should precede operation at this time but must be done cautiously as dilatation of the heart is readily produced in this weakened condition. Thus one can trace the best course as *X*—1—2—*A*, and the worst course *X*—1—*G*. The courses ending as *A* or *B* are good courses. Those ending *C*, *D*, *E*, *F* or *G* are bad courses. This, of course, is only a composite schematic arrangement, based on the author's observations, but it seems to condense the question of operability and the moment for operation into its most compact form.

Resuscitation treatment consists of rest, morphin, the application of external heat, blood transfusion, saline infusions, water or hot weak tea by mouth, the head lower than the feet, etc. (as per Dr. Percy.)

Those few who become operable after resuscitation treatment justify the effort which has been made and failed so often, and these then belong with the next group.

Operable on Admission.—Cases without profound shock, with good or fair pulse at the wrist, without the facies of shock, whose fractures have been well immobilized, no matter whether reduced or whether in malposition, but immobile, are operable.

Every operable patient is given morphin gr. $\frac{1}{4}$ and atropin gr. $\frac{1}{150}$ One of the best single indices of operability is the decision that an adult patient may be given $\frac{1}{4}$ gr. morphin. When there is a feeling that perhaps $\frac{1}{6}$ gr. would be safer, then patient is not safely operable and his recovery from an anesthetic and an operation is questionable. Therefore, when possible and within reasonable limits, he had better be let alone a little longer, so that he may further recover his strength or slide definitely into the moribund class in peace (Fig. 146).

The Primary Operation.

Only two radical operations need be done:

1. Amputation.
2. Excision of joints.

Only six early conservative operations need be done on compound fractures:

1. Reduction.
2. The removal of foreign bodies.
3. Wound revision (vessels, nerves, muscles, bones).
4. Drainage.
5. Suture.
6. The application of apparatus (calipers, etc.).

Suture should only be done in the stage of inoculation and not in infected fracture.

Only four late operations should ever be done on *open* fractures:

1. Sequestrectomy.
2. Drainage.
3. Ligaturing of bleeding vessels.
4. The correction of position and the application of apparatus.

When a compound fracture has become a simple fracture, either by primary suture, delayed primary suture or healing by granulation, any operation applicable to simple fracture may be done, and any corrective measure, such as excision of scars, nerve sutures, tendon transplanting, osteotomy, bone transplant, bone plating, etc., peculiar to old healed compound fractures may then be done.

General Principles of Radical Operations.—1. **Amputation.**—A limb anatomically hopeless should be amputated at the earliest moment possible. This class includes the various combinations of fracture with great vessel lesions, nerve lesions, sepsis and tissue destruction, joint complications. Any one of these complications alone does not indicate amputation, but in general any two combined with fracture are best treated by primary amputation. It is not always possible, in view of the low state of the patient, to amputate at once. Temporizing measures must sometimes be employed until such time as the amputation can be done without unreasonable risk of life.

Thus a vessel may be ligated, septic tissue drained, joints immobilized, the fracture extended and splinted and the patient given every opportunity to improve his condition. One must feel sure when adopting this course that his treatment will stay the nocuous process and not leave it to progress, since the object is to relieve the patient of the cause of his shock without inflicting more.

If it seems impossible to prevent progressive changes for the worse, amputation must be done at once, even at great risk. It is in dealing with this class of cases that the surgeon's judgment, experience and boldness in carrying out his convictions reap their great reward in the actual saving of life, and in the saving of his patients from long sufferings from a worthless limb that must be amputated after all at some later date. Only a man who knows what limbs will be useless can save this futile suffering, since any other feels compelled to save the wrecked limb on the chance that it might prove useful.

A limb with gross destruction of a joint, particularly when the head of the tibia, the ankle-joint, the wrist, or the elbow are so extensively injured that ankylosis is despaired of, and all function will be lost, should be amputated. The condition of the nerve or vessel will decide the question.

The sort of artificial limb possible will have great weight. The leg should be amputated more readily than the arm or hand since no entirely satisfactory artificial arm has yet been devised. Severe infection or a multiplicity of accompanying wounds argue against conservatism, since conservatism exposes the patient to more severe subsequent risks.

Seat of Amputation.—If the fracture is near the trunk it may be best to amputate through the fracture, and certainly in very grave cases recovery is unlikely if it is necessary to saw bones. An elective amputation should avoid all damaged tissue and be proximal to the fracture.

The technic of amputation is described elsewhere.

2. **Excisions of Joints.**—If the bones are too badly damaged to be of mechanical utility, even to preclude the possibility of ankylosis, and yet the limb below the fracture is a good limb, the joint should be excised. Joints tend to result in flail joints when an excess of bone has been removed. This fault seems to be more grave when the proximal component of the joint has been sacrificed. Excision of a joint is only a little better than amputation, when one considers the complications which may follow, the flail-joints likely to result and the long dangerous convalescence.

The knee should be excised with the idea of obtaining ankylosis always. Only a thin slice of tibial surface should be removed, but the entire condyles should be removed. The operation should be planned to result in a short stiff leg flexed 10 degrees at the knee.

Excision of the elbow-joint should be done with the utmost conservativeness. Every tiny bit of viable bone should be left in place and the excision done in the hope of obtaining a movable strong joint. Whole epicondyles, elecranon processes and trochleæ regenerate.

On the other hand, flail-joints following radical excision of the elbow are common.

One seldom has to deal with early cases of fracture into the hip-joint with the joint infected or shattered beyond hope of functioning. These wounds are often mortal. Whenever there is active infection with intracapsular fracture, the head of the femur should be removed and the acetabulum drained. Very mild degrees of hip-joint infection may be drained but drainage without excision of the head is unsatisfactory and dangerous. Ankylosis should be aimed for in the abducted position.

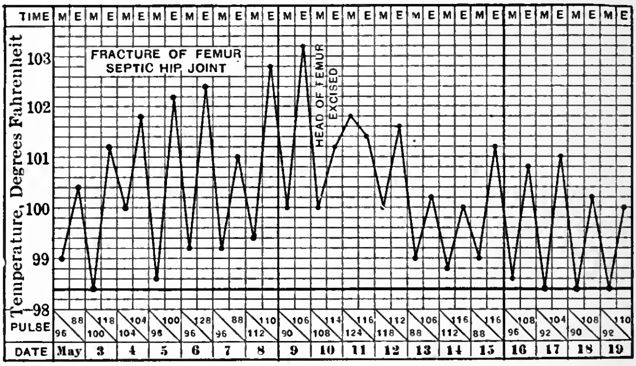


FIG. 147.—Chart showing septic hip-joint and result of excision of head of femur. Case treated in abduction from beginning to end. Good functional result with ankylosis.

The shoulder-joint when shattered and infected virulently should be excised. When severely infected through a split fracture and not shattered, attempts to drain the joint may be successful. It is very difficult to drain all the ramifications, however, and secondary excision must frequently be done.

The ankle-joint when shattered and infected is best treated by removal of the astragalus, with drainage. This allows all the joints to drain into the common cavity.

The carpus when infected should be treated radically.

Phalangeal joints infected are best amputated, except the thumb and the great toe-joints. These may be excised and heal kindly with drainage. The other digits individually are not worth the risk of conservative treatment in the presence of virulent sepsis.

General Principles of Conservative Operation.—It is difficult to lay down rules or schemes of operation in emergency surgery because none are operations of election. The wound and its condition must dictate the policy to be followed. There are some general things which ought to be noted.

Preparation.—The skin is scrubbed with the splint in place and without inflicting trauma. A careless, rough orderly can convert an operable case into a moribund case before the surgeon touches it. One must teach his staff that anesthesia does not excuse roughness or unnecessary movement, that it merely cuts off consciousness, but that injury still hurts the unconscious patient.

Conservative operation on the thigh is done with the Thomas splint in place by having the foot end slung up so that access is given to the posterior parts.

The arm and leg may be operated upon without the splint, since manipulation of these is easier and the consequent shock insignificant compared to that following manipulation of the fractured thigh. However, no avoidable trauma is permitted.

The Anesthetic.—Half an hour after morphin and atropin have been given the anesthetic should be begun. Nitrous oxide and oxygen by preference, or chloroform for a short operation, or chloroform changing to ether for long operations, which should seldom be done at this stage, may be used. Stovain or novocain intrathecally for cases of the leg and thigh which are in profound shock, *but are not anemic,* are very good anesthetics and seems to reduce operative shock to a marked degree. If there is anemia, however, spinal anesthesia is contra-indicated. Many fractures of the skull require no anesthesia, or, at most only a local novocain anesthesia.

Stimulants.—In fractures of the femur it is wise to give during operation hypodermoclysis of normal salt solution at a distance from the operative field.

Strychnin should never be used.

Adrenalin should not be used as a stimulant so long as the heart beats, as its late action is worse than the immediate benefit. It is a powerful stimulant when injected directly into the stilled heart—sometimes reviving it. Digitalin may be useful to help an exhausted heart over its crisis.

Transfusion with blood is the best remedy for operative shock, but the previous administration of adrenalin or pituitrin contra-indicates transfusion, as cardiac dilatation has often resulted.

The Incision.—It is nearly always possible to leave the wound of entrance untouched, unless one hopes to render an inoculated wound aseptic, or to attempt primary closure, when it is best to excise both entrance and exit wounds as well as the deep track.

The exit wound, being nearly always torn and large, affords best access to the fracture and demands revision.

The skin edges should be trimmed and every possible scrap of viable skin preserved. Little infection lurks in the actual skin, it being naturally resistant to infection, and by its dense structure does not allow much spread of infection. Thus, only the merest edge of devitalized skin should be excised, bearing in mind the possibility of secondary closure. If either entrance or exit wound are in a dependent position they may be used for drainage wounds. If neither are dependent a drainage wound should be made in a longitudinal direction through the skin. The deep fascia may be cut transversely, as then the wound gapes open and does not tend to close itself.

Muscle.—Damaged muscle is worse than useless and may be held as one of the cheapest tissues. In the presence of a compound fracture the more muscle removed the less the tension, the better the drainage, the less culture media for bacteria, the greater the ease of skin approximation, the less the scar. Damaged muscle becomes fibrous and adherent to any bone with which it makes contact.

One should consider muscles in groups rather than as individuals in the lower limb, trunk and upper arm. Excising a muscle from a group whose actions are similar does not leave any disability. The muscles of the forearm must be more delicately and more conservatively dealt with. It is well when doing the primary operation on any compound fracture to remember that to save a muscle is poor surgery if the limb is amputated three days afterward.

The free sacrifice of muscle will save many limbs and result in slight disability.

Skin, on the other hand, should be most jealously preserved, as well as nerves, vessels and bone.

Nerves.—Nerves are injured or severed sometimes by the ends of the fractured bone, *e. g.* the musculospiral in the arm; the peroneal in high fractures of the fibula; the dorsal roots in fractures of the vertebræ.

They are often caught in exuberant callus or between the fragments during reduction.

If severed there is loss of function and atrophy of the muscles they enervate and anesthesia over their cutaneous distribution. When pressed upon by callus or fragments, pain may result which is referred. When severed there is generally no pain. Tapping over the distal end of the proximal segment of a severed or compressed nerve elicits tingling, etc., over its cutaneous distribution. (Tinne 's sign.)

The peroneal nerve is often paralyzed by external pressure from splints, slings and bandages (particularly glue or adhesive plaster extension on the leg). The patient complains of burning or mysterious sensations on the side of his leg. If his physician is wise, it goes no further. If he is not, in twenty-four hours the peroneal nerve may be paralyzed and will degenerate and regenerate. Meanwhile the extensors and evertors of the foot atrophy and sclerose. This happens far too often and is the result of carelessness.

The tone and circulation of the affected muscles must be maintained meanwhile by daily massage and deformity prevented from developing, while the nerve regenerates.

Bloodvessels. — *Hemostasis.*—When an artery is torn hemorrhage results. If free the blood-pressure falls until either death results or until a clot plugs the bleeding vessel. At operation the wound surface must be searched minutely for these plugged vessels (vigorous rubbing may dislodge clots and demonstrate vessel lesion by bleeding) and they must be ligated, else secondary hemorrhage may occur after a week or ten days from softening of the clot.

Gangrene is most likely to follow ligation of the posterior tibial artery, especially if ligated between the branching of the anterior tibial and the peroneal; since then very scanty collateral circulation is left.

Ligation of the popliteal is also frequently followed by gangrene. It is sometimes advisable to insert a Tuffier tube for forty-eight hours when ligaturing the popliteal.

The superficial or deep femorals, the brachial, radial, ulnar or anterior tibials may be ligated with comparatively few misgivings, especially if the ligation be done after there has been inflammation in the limb, since then the collaterals are dilated and readily assume the burden of the circulation.

Rarely is one called upon to ligate other vessels, such as the iliacs, the carotids, axillaries, subclavians or vertebrals. The author has done each of these ligations several times, generally with recovery.

The tourniquet is a most valuable instrument during operation on compound fracture of the limb bones. By using a tourniquet whenever possible and applying it before beginning the operation no blood is lost. This is of prime importance to a patient in shock or who may emerge from his anesthetic in shock. No savable drop of blood should ever be lost. The tourniquet allows one to work in a dry field, the tissues unobscured by blood or an assistant's swabbing hands, the time of operation is cut down and often by having a dry, clean field the holes in arteries and large veins can be seen and secured, while in the presence of a continuous flow of blood a long tedious task would be often poorly accomplished. Nothing is more trying than to attempt arterial ligature when the concomitant veins steadily pour out blood, clouding the field.

To use a tourniquet during operation one must know anatomy thoroughly, so that he does not cut rashly into forbidden arterial regions. The principle of not cutting into arterial regions until the vessel is seen must be adopted. The tourniquet should always be removed before the wound is packed or dressed and a final scrutiny made, else delayed hemorrhage may result.

The tourniquet should never be used to stanch the bleeding at the time of the wound, nor should a patient ever be allowed to travel with a tourniquet in place. Gas gangrene may result. Someone should ride with him, stanching the flow of blood by digital compression of the artery at some proximal point.

Bone.—All non-viable fragments should be removed whenever they can be definitely diagnosed as non-viable. This applies to early, intermediary and late operations. No direct evidence has yet been produced that dead bone produces bone, while common universal experience teaches that dead bone does harm. (See Sequestra and Bone Repair, p. 199.)

Whenever doubt exists as to whether a fragment is viable it should be left in place. Every tiny chip of living bone is a center for osteogenesis and especially in greatly comminuted areas one should leave the tiniest chips of viable bone undisturbed. Remember that operation, incision and dissection may do as much harm as the original wound in cutting off the blood supply to bone fragments.

One must realize that the removal of bone from its osteogenetic layer of periosteum (if such layer exists) is impractical in the absence of inflammation. Inflammation seems to have the power of loosening the bone-forming elements from the osteoperiosteal region, so that infected fragments when removed leave osteogenetic elements behind. Conversely, uninflamed fragments when removed, no matter how carefully and painstakingly, by sharp rugine dissection, tend to carry their osteoblasts with them. It is the recognition of this principle which correlates the ultraconservative British School with the ultra-radical French school. Both schools have facts and sound principles as bases, but the British carry their conservative principles mistakenly into the infected group of fractures while the French carry their radical methods mistakenly into the uninfected (inoculated) group of fractures. Thus there is no reason for removing the viable fragment from A.'s clean aseptic fracture, and exposing him to the risk of non-union or delayed union because B.'s leg which was foully septic was saved by total esquillectomy. Nor is there any reason for allowing B. to be exposed to death, amputation, repeated late sequestrectomy and delayed union because A. healed without incident. It would be equally fallacious for a surgeon to drain A.'s interval appendix because B.'s gangrenous appendix developed peritonitis, or, conversely, to close B.'s ruptured appendix incision because A.'s clean appendix wound healed by first intention. Both methods are good and rational, but they should not be misapplied. One should attempt to leave enough bony defect in a dependent position to ensure free drainage of the medulla. This saves many fragments from intercanalicular pressure, anemia and consequent necrosis.

When removing bone fragments, avoid tugging and pulling to strip off the periosteum. Do not grasp the fragment in a huge lion forceps and twist it out. These firmly adherent fragments are ninety times out of a hundred viable fragments and should be left in place. When it is necessary to remove such a fragment, do so by painstakingly freeing it from its periosteum with a sharp rugine, always scraping heavily on the bone so as to leave the outermost layer of the bone scales with the periosteum. Total esquillectomy is never justified in cases where infection has not manifested itself.

It is in these cases that the Lyons School do most harm.[1] By adopting the maxim that, if radical removal of infected worthless fragments (doomed to form sequestra) from virulently septic cases saves both lives and limbs, it should be performed routinely even when unnecessary, they carry the theory of drainage and débridement too far.

Detached Fragments.—All sequestra owe their origin to loss of blood supply. This comes about by detachment from periosteum and continuity at the time of fracture, during rough operation or by strangu-

[1] Leriche: Treatment of Fractures.

lation of the blood supply by pressure consequent on inflammation. Therefore, at open operation all detached and non-viable fragments should be removed. Hey-Groves thinks that sometimes these dead bits give off viable osteogenetic cells. This may be true, but their disadvantages and the harm they do more than outweigh this slight advantage, particularly if there are sufficient viable fragments left. No viable fragment should be removed, counting them as fragments

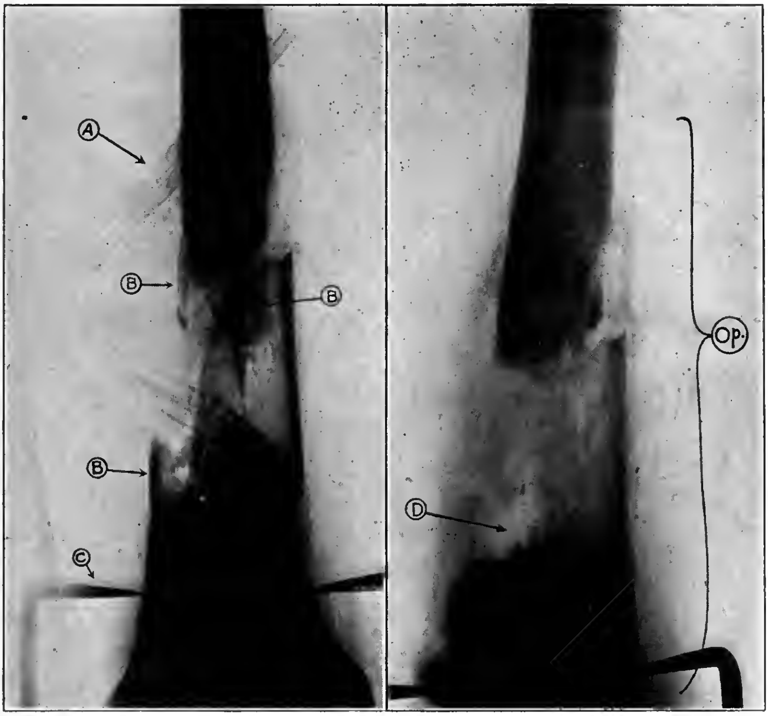


FIG. 148.—*X*-rays of chronic osteomyelitis and multiple sequestra. When first seen four months after the wound there was only anterior drainage so that each day pus pooled in the fracture cavity. The case had been treated by Carrel's tubes (*A*). The arrows marked *B* indicate sequestra. *C* indicates caliper points embedded in periosteal callus. After radical operation the entire cancellous tissue within the condyles was found full of pus and necrosed trabecular tissue and chronic osteomyelitis extended three inches up the shaft. All this necrosed bone was removed and posterior dependent drainage was established. The wounds healed within a month and the second *x*-ray shows the bone condition at that time. Note the homogeneous character of the callus. The light area marked *D* was the seat of dependent drainage. Two large tubes were used as in Fig. 160.

with a blood supply and without infection sufficient to strangle their blood supply within forty-eight hours, since in that time they may give off osteoblasts. A fragment heavily infected or one interfering with drainage is not a viable fragment.

Comminution of a bone presents a difficult mechanical problem, and in the presence of infection must be provided with efficient drainage, or else the fragments will necrose through osteomyelitic processes,

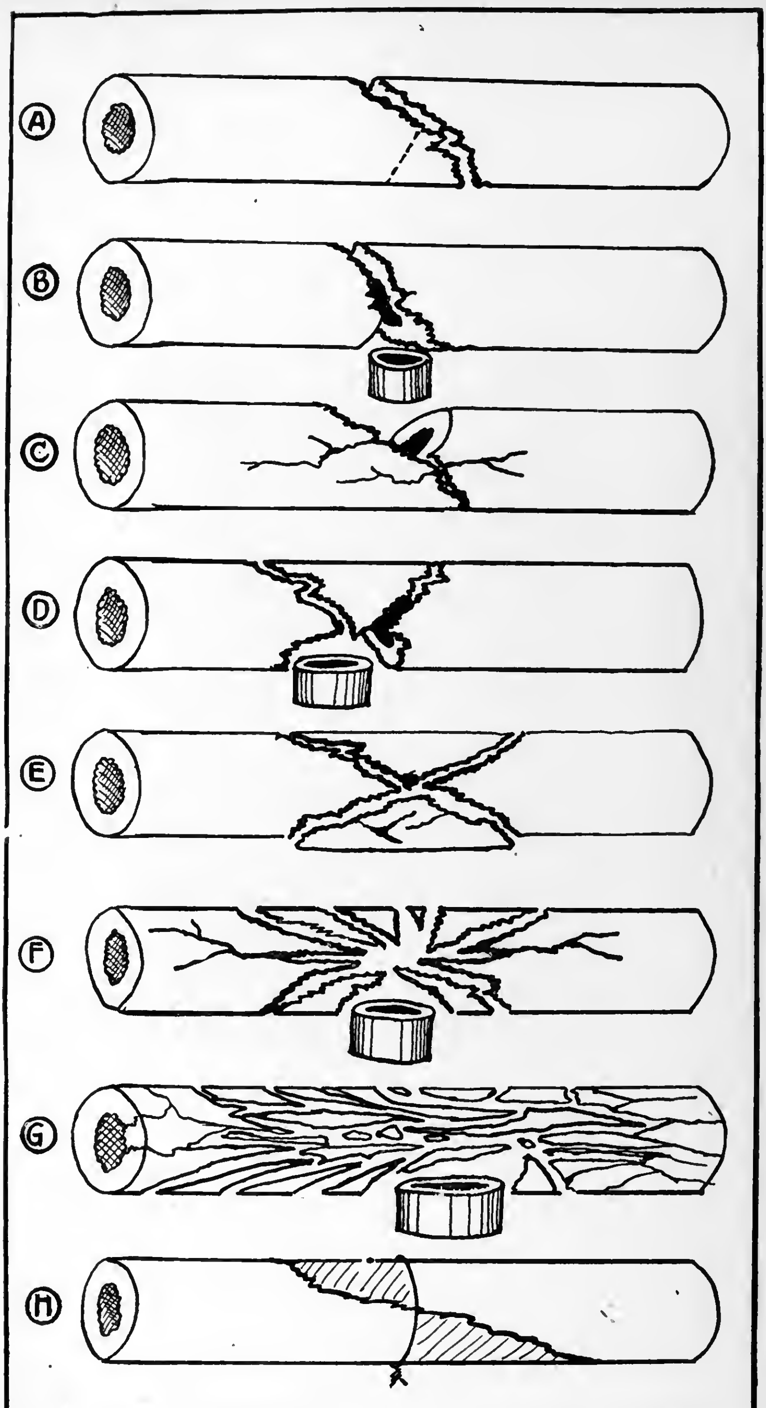


Fig. 149.—Types of fracture and drainage. *A*, oblique. *B*, oblique, with bit removed to provide drainage of medulla. *C*, fissured; these fissures are very difficult to sterilize; the defect is on the superior side in this case and therefore drainage of the medulla is inadequate if infection develops; this case would then cause endless trouble, the fissured point of bone finally separating as a sequestrum. *D*, good drainage. *E*, butterfly fracture. *F* and *G*, comminuted fractures well drained. *H*, oblique fracture accurately fitted together; if there is medullary infection it will be tightly corked up and virulent acute osteomyelitis will result; an encircling wire will augment the formation of sequestra.

leaving a wide bone defect, to heal by granulation and bone growth (Fig. 117, p. 197.) (Figs. 150 and 151.)

FIG. 150.—Bone gap, fragments, refracture and caliper extension. While adhesive plaster extension was on legs with ten pounds extension the lower fragment was displaced backward; 3 cm. shortening. Calipers were then applied with ten pounds extension; no shortening; note osteogenesis about small fragment marked by arrow *A;* if this fragment had been removed at the first operation, union might have been delayed.

Sequestra.—When operating after three weeks or so, one often finds that some callus must be cut away to free a sequestrum. This new callus is very vascular and the arterioles are devoid of constrictor muscles, so that when cut they do not close. Packing must be left which compresses their ends, or delayed hemorrhage may occur.

One should always establish free dependent drainage after sequestrectomy. It is the author's custom when removing sequestra at an advanced stage of union to scrape the walls of the sequestral cavity with a sharp spoon removing all fungosities and pseudo-periosteum so as to freshen them and facilitate bone formation. One often brings out small unnoticed sequestra in the spoon and sometimes finds bits of cloth even after six months have elapsed.

Fig. 151.—Note homogeneous callus. *B*, refracture of callus; occurred in sleep while all apparatus was still in place; the patient did not know he had refractured his femur until he noticed the queer shape of his leg after awakening the next morning. Reunited in three weeks. Note pressure pad exerting lateral pressure. The spike on the proximal fragment was embedded in muscle.

Reduction and Operative Fixation (Early).—No good will come of attempting mechanical fixation at the seat of fracture in compound fractures within the first week after injury. The opportunity which the exposed bone presents is often too tempting for the surgeon to abstain from applying some fancy operative fixation. It will be doomed to failure in 90 per cent. of the cases. It will fail in 100 per cent. if there is a drop of pus present. One must remember that every compound fracture is inoculated and that any foreign body fixed in an inoculated field may form an abscess.

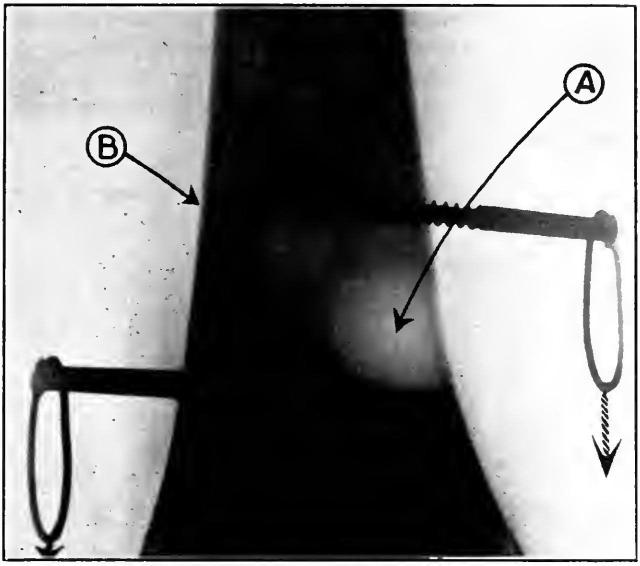


Fig. 152.—Screws in condyles as used by Capt. Davies, R.A.M.C. This method of extension is very comfortable and efficient, but there is a possibility of sinuses resulting as with the Steinman pin. The screw must engage the opposite cortex. Nails will not act as well as screws in this capacity.

A *B*

Fig. 153.—*X*-ray showing the effects of an encircling wire in the presence of chronic sepsis. *A*, silver wire encircling the lower end of the upper fragment and the upper end of a spike from the lower fragment. *B*, the arrow indicates a sequestrum separated by the encircling wire, which had cut off its blood supply; shows excessive callus formed in the presence of sepsis when the periosteum has been loosened and a gap left between the bony cortex and the periosteal surface. Encircling wires should not be used in open fractures.

No plates, screws or wires should be inserted within the first week in any compound fracture. Sometimes when there is no evidence of inoculation whatever, a heavy strand of gut may be fastened around an oblique fracture or around a large split-off fragment, care being taken not to detach the fragment from its periosteum in so doing.

Primary reduction should always be attempted at operation, an effort being made to lock the fragments so that their ends resist the shortening action of the muscles.

Closure of the Medullary Cavity. — If severe infection exists, the medullary cavity should be left exposed and free to drain, if needs be, by chipping away a bit of cortex in a dependent position.

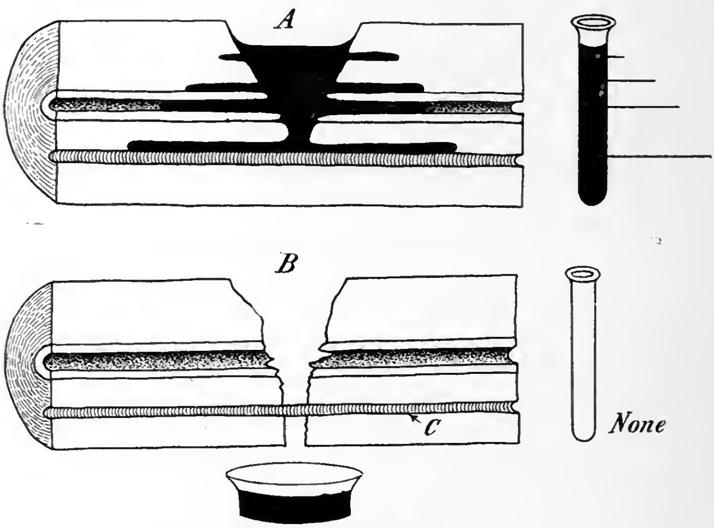


Fig. 154.—Pus pockets and tracking. *A*, shows a pool of pus; the horizontal black tracks represent the burrowing power of pus, which increases both with the age of the pus and its height of head or pressure; the medulla of a fractured bone is shown and below an artery bathed in pus. *B*, shows the same wound drained dependently. *C*, the artery which should not ulcerate in this type of wound. The test-tubes show the trypsin content of the pus at the various levels (depending upon age).

Aside from the futility of early mechanical fixation at the site of fracture, definite harm may result. If the medullary cavity is infected its free drainage will be obstructed by the exact refitting of the fragments, and certainly necrosis of what would have been a valuable viable fragment will result. The author has seen several deaths and many amputations attributable to this closure of infected medullary cavities.

Drainage. — Drainage is a mechanical proposition, depending on physical laws, which are:

1. Fluids run downhill.
2. A column of fluid exerts a pressure depending upon its height of head.

Pus has, in addition to its physical properties, the ability to dissolve tissues by virtue of the trypsin it contains, and this power seems to increase with the age of the pus. Therefore, pus should not be allowed to lie in pools, and pus will not lie in pools if there is a hole in the

Fig. 155.—*X*-ray of supracondylar fracture of femur, fifth month; at the end of four months there was no union; during this time drainage was not dependent so that an infinitesimal amount of pus continually bathed the seat of fracture; dependent drainage was established between the hamstring muscles three weeks before this *x*-ray was taken; note good homogeneous callus filling the gap between the fragments where none existed three weeks before. Union was complete two months later.

bottom of the pool basin. Further, pus which is under pressure, whether from enclosure or from height of head, will burrow. Pus not under pressure does not burrow.

Where dependent, unobstructed drainage is employed pus does not pocket nor track.

Drainage of Bone.—Too great emphasis cannot be laid upon this principle in the treatment of compound fractures. The lack of dependent drainage is the cause of most secondary hemorrhage, bone necrosis, pus pocketing, delayed union and pain. With these things in mind one strives to establish dependent drainage in infected fractures at the earliest moment, so that not a single drop of pus can exist under pressure. A dram of pus under pressure is more harmful than a pint of pus drained away into the dressing outside the skin.

Every infected fracture of the femur should have a drainage incision made either between the hamstring muscles or just external to the biceps muscle (the latter being better), and this incision should admit at least one rubber tube an inch or more in diameter and the tube should reach to the actual fracture. It is more difficult to establish dependent drainage in the case of the tibia and foot. Large sections of the ham muscles must be excised in the leg, and often only astragalectomy solves the problem in the foot. It is easy to arrange dependent drainage for the humerus or forearm or hand, because the position of the arm can be altered while the leg must rest in one position. Large rubber tubes leading from the seat of fracture downward are best for drainage, and two are better than one. The best size is one-inch diameter.

If two tubes are used they can more easily be cleansed and are more efficient (Fig. 160).

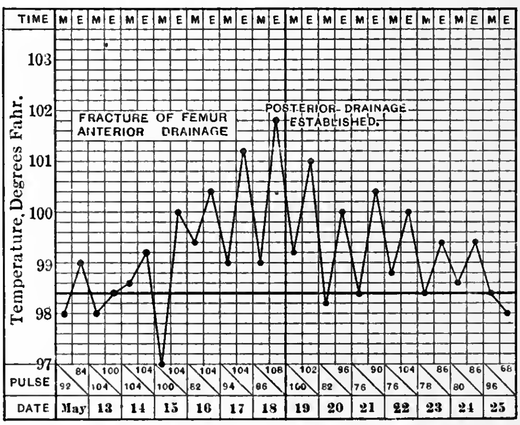


FIG. 156.—Chart showing pocketing of pus and result of dependent drainage.

Drainage of Soft Parts.—When infected and tense the soft tissues surrounding the fracture should be freely incised so that all tension is relieved. Especially is this necessary when gas gangrene is spreading. If muscle bellies interfer with the drainage of the bone the complete muscle may be cross-cut and allowed to retract or a segment of it excised. It is particularly advantageous to excise three or four inches of the biceps femoris when there is great edema of the thigh complicating infection of a fractured femur. This ensures long-lived dependent drainage of the fracture, relieves the tenseness of the thigh, allows the skin to meet at an early date and does not impair function after the fracture is healed, since the other hamstring muscles are intact. The gap fills with firm connective tissue and the biceps resumes its function.

Similarly, in the fracture of the humerus, large pieces can be removed from the biceps or triceps muscles without impairing their function, so long as the complete muscles are not divided. The gastrocnemius and soleus may be similarly dealt with, but more cautiously. The muscles of the forearm must be conserved more carefully, although excision of the extensor carpi ulnaris or flexor carpi ulnaris may sometimes be justified.

These excisions of muscle are excisions of healthy muscle for the sole purpose of providing long-lived free drainage of a fracture. If there is muscle infection as well the indication for excision is more plain.

The heavy muscles of the buttock may be sacrificed freely for this purpose without loss of function. In reality these excisions of coarse muscles leave much less disability than is often caused by the extensive adherent scars which follow myositis.

Technic of Conservative Operations.—Inoculated Fractures.—The wounds of entrance and exit should be excised, saving the skin most scrupulously. Muscle, fat, fascia which are damaged, should be radically excised, in an attempt to avoid reinoculation of the freshly cut surfaces. Remove foreign bodies and cloth and dirt. All loose and utterly detached bits of bone should be removed. No adherent bone should be excised if thought viable. If comminuted, avoid interfering with the blood supply of the fragments and leave the bone defect, if there is any election of its position, on the dependent aspect of the bone (see Fig. 149).

The fracture should be reduced and if opportunity exists the fragments locked so that subsequent displacement will not occur. In the case of transverse or oblique fractures it is wise to secure either a slight degree of overextension, so that there is a gap between the ends, or to allow slight lateral displacement, so that medullary drainage is ensured.

It is the author's custom always to leave dependent drainage in the thigh and leg, closing all other wounds, in favorable cases. Sometimes it is best, if any tension exists, to leave all wounds packed open with dry gauze for twenty-four to forty-eight hours after operation, and then after all edema has disappeared to suture all except the dependent drainage stab wound.

The Conversion of Compound Fractures into Simple Fractures.—Inoculated compound fractures may be closed at the primary operation if the fracture has been caused by a clean bullet or if only a spicule of bone has pierced the skin and has not been heavily inoculated.

Shrapnel-ball fractures may often be closed. Infrequently a shell fracture may be closed.

Bomb fractures and fractures about the ankle and feet should seldom be closed, as they are nearly always heavily inoculated. A compound fracture which has been closed at primary operation must be watched with extreme care for the ensuing forty-eight hours, so that at the first sign of tension or inflammation the sutures may be removed. These cases, when a mistake is made in closing a wound still inoculated with a gas-forming organism, flare up with remarkable virulence in a few hours, and unless tension is relieved immediately the most serious sepsis ensues. If no reaction occurs within forty-eight hours, the wound will heal by primary union and the fracture then is a simple fracture and outside the scope of this article, presenting only the mechanical problems of simple fractures, seldom developing sequestrum, abscess or callus disease. However, sequestra do sometimes give trouble in these cases at late dates.

Time.—The success of primary closure depends paramountly upon the time which has elapsed since the wound was received. It is seldom possible to close an inoculated fracture after thirty-six hours, for the simple reason that the fracture is then an infected fracture impossible of surgical sterilization. It is bad practice to attempt to close a compound fracture in the presence of edema and swelling, or when the patient has any fever, or in the presence of gross pus.

Colonel Hugh Cabot has tabulated a series of compound fractures which he and the surgeons of the Harvard Surgical Unit closed. It is the best series yet brought to the author's notice, and since the majority of the closures were done without bacterial examination, it demonstrates the point that while bacterial examination may be of extreme academic interest, the surgeon experienced in dealing with compound fractures has little need of it.

REPORT ON WOUNDS TREATED BY SUTURE AT B. E. F. GENERAL HOSPITAL, NO. 22.

August 8, 1918, to September 19, 1918) (6 weeks).

PRIMARY SUTURE

TABLE III.—CASES INVOLVING BONES AND JOINTS.

Total No. cases.	Success.	Partial success.	Failure.	Per cent. complete success.	Per cent. complete plus partial success.	Per cent. failure.
184	146	11	27	79	85	15

TABLE VII.—CASES INVOLVING BONES AND JOINT.

30	26	2	2	87	93	7

TABLE IV.—ANALYSIS OF BONE CASES (PRIMARY SUTURE).

	Total No. cases.	Success.	Partial success.	Failure.
Humerus	16	14	1	1
Radius or ulna	60	50	3	7
Metacarpals	40	31	2	7
Elbow-joint	13	8	2	3
Wrist-joint	13	10	1	2
Knee-joint	2	2		
Miscellaneous	40	31	2	7

Late Closure of Infected Fractures.—No infected fracture should be closed primarily, but sometimes it may be closed by delayed primary suture, *i. e.*, the primary operative wound is left open for one to ten days until all swelling and inflammation disappear and then the edges are sutured, perhaps leaving a drain in place for forty-eight hours.

It is sometimes possible, after a few weeks, or even months, when good healthy granulation tissue has appeared, to close the wounds by secondary suture. It is good practice to plan to do this whenever a large, gaping wound threatens to result in an extensive inelastic scar, adherent at the site of fracture and involving some extremely useful muscle, such as the quadriceps femoris or the triceps or the flexors of the forearm. It is wise to wait until the discharge from the wound is negligible, and when closing any wound which has allowed pus to pool to establish a small efficient dependent drainage wound, so that the sutures will not be bathed in pus, no matter how low grade or laudable that pus may be. Care must be taken that the sutures (which must be deep ones) do not interfere with the blood supply to the skin edges and that no individual suture bears much tension. One must be assured that no osteomyelitis or sequestra are present.

The wound, the fracture and the patient are the most important guides to wound closure. However, it seems a general rule that compound fractures in which the wound at its depth shows less than two organisms per field from direct smear examination can generally be closed, provided none of the contra-indications mentioned above are present. Personally the author has closed compound fractures which showed over ten organisms per field, with success, and has failed where no bacteria at all could be discovered.

Conservative Operations of Inoculated Joints.—If a joint has sufficient bony support left (or promise of sufficient regeneration) and is only inoculated or mildly infected it can be saved.

The joint should be freely exposed, thoroughly washed out and all soiled tissue removed, both bony and soft. When there is a defect in the synovial membrane a plastic operation may be necessary to close it. The author prefers to leave a small amount of B. I. P. P. (℥ss) inside and after closure to move the joint for some time, so as to rub the B. I. P. P. into every crack and cranny of the joint. No harm is done by moving a thoroughly clean joint. The joint is then immobilized and kept immobile for at least ten days after the patient's temperature is normal. The skin may be closed primarily if there is no inflammation or tension, but if either of these exist it is best to leave the skin open for a few days and close it by delayed suture. The synovial membrane has been found one of the most resistant tissues of the body to infection. One rarely has need to drain a joint within the first forty-eight hours. Either the closing operation can be attempted or the joint excised or amputated. Early motion is important in dealing with all joint wounds, but in this class of cases the pain of too early forced motion is unnecessary. These *inoculated* joints treated as outlined here practically all result in full function; and while Willems of Ghent and others have had good results by immediate active motion, the author does not favor this procedure as it is painful and he has seen cases in which too early movement apparently caused the spread of inoculation. Immobilization may be discarded on about the tenth day. (For excision of joints, see p. 231.)

Infected Joints—Drainage.—Infected joint fractures result in great tenseness, inflammation, tenderness and pain on motion of the joint, and a muscular fixation in the position which gives the greatest cubic content of the synovia should be selected. When there is concomitant gross defect of the synovial membrane, little or no swelling results, but serous pus and synovial fluid exudes.

If a joint contains pus and its articular cartilages are eroded and pitted but its bones are mechanically functional, it should be drained.

It is almost impossible to perform satisfactory drainage of the elbow. It is best drained through the triceps by longitudinal or horseshoe incision depending upon the bony injury. Generally one must do a modest partial excision of the trochlea or olecranon, and often the head of the radius must be excised.

The knee-joint can be drained either by horseshoe incision or by long lateral incisions on either side of the patella. Both methods should nearly always be combined with posterior incisions from the most dependent points of both lateral extensions of the synovial membrane. These incisions are best made after the anterior incisions since then one can insert a long artery forceps into the lateral extension and poke it through the membrane; and thus by spreading its points dissect down to the skin of the sides of the popliteal space. The knife then needs to cut only the skin so that there is no fear of cutting the artery or the external popliteal nerve. Multiple tubes are then inserted throughout the joint and Carrel's treatment carried out. The joint should be immobilized on a Thomas splint—not in plaster—since occasionally pus burrows into the calf along the tendon of the popliteus muscle—and if plaster obscures the calf one cannot note this fact until too late to save the limb. By attaching a hinged knee flexion piece to the Thomas splint early motion can be instituted after sepsis is overcome (see Fig. 176). Knees treated in this fashion generally recover motion, although many result in ankylosis. It may be that the treatment by immediate active motion gives better results in this class of cases, but it is the author's feeling that the cases reported by Wilkins could not have belonged in this class but rather were the wounds classified here as inoculated fractures.

Attempts to drain the shoulder- and hip-joints have not been satisfactory, so that it is our custom to excise the heads of the humerus or femur when these joints are virulently septic. The wrist and ankle and phalangeal joints require radical treatment when virulently septic.

Infected Fractures.—Total Esquillectomy.—This is the most radical conservative operation which may be performed. It is justifiable only in the presence of very severe infection of the medullary cavity and the bone fragments themselves. The Lyons school, bespoken by Leriche, are its chief advocates. It is the paramount cause of non-union and should not be done except necessity demand. If there is pus in the fracture which will not drain freely unless the fragments are removed the operation is sound. All infected bone should be removed and the medulla cleaned until healthy tissue is found—and dependent drainage established.

The tendency to remove an excess of bone fragments from the humerus is almost universal and depends upon the fact that a short humerus is not a functional deformity. This is true, but non-union occurs very readily in the humerus. The ends of the bone should be allowed to meet at the earliest possible moment after infection clears up.

Total esquillectomy of the femur should seldom be done. In the presence of acute medullary osteomyelitis enough bone should be removed to allow of free dependent drainage and no more, since non-union occurring in this bone is very serious.

The posterior fragments only should be removed at the early operation.

Total esquillectomy may be done within greater limits when only one of the leg or forearm bones is broken, and should always be done when the astragulus or the carpal bones are fractured—in the presence of active infection. The metacarpals and metatarsals may be freely cleaned away. The phalanges, if no joint is involved, may be treated radically, if septic. They heal very well with slight operative interference when not excessively septic.

Transport from the Operating Room.—The patient should be received for operation lying on his original stretcher. He should not be removed from it. He should be carried away from the operating room on it and should not leave it until he is placed in a solid bed, where he can remain until consolidation occurs.

In the case of fractures splinted in Thomas's knee splint, two transverse suspension bars should have been attached to the stretcher immediately, the ring of the splint suspended from the bar over the pelvis and the foot of the splint suspended from the bar over the feet. This suspension assures the surgeon that the ring of the splint will not slip over the ischial tuberosity and press upon the perineum, causing pain, retention of urine by pressure on the urethra and slackening of the extension.

He should be sent from the operating table with this suspension in place, and it should be maintained continuously until the femur or tibia is solid.

When transferring the patient from his stretcher to his bed an intelligent orderly must confine his entire attention to this important point, else all the skill spent in primary reduction of the fracture will be wasted in one moment.

Intermediate Treatment.—Treatment After the First Week.

The problem of acute infection should be settled during the first week.

The clean through-and-through bullet wounds should be aseptic and the punctate wounds sealed with dry serum.

The wounds which have been revised and sutured, if well done on cases seen before inoculation had become infection, should be healed and all drainage removed.

Some of the cases still retaining foreign bodies, but which were not operated upon early, will have become afebrile.

These cases then present only the problem of simple fractures and are therefore removed from the considerations of this chapter.

The cases still containing foreign bodies which have developed abscesses about them should have the foreign body removed and the abscesses drained dependently.

The cases of well-drained mild sepsis will require little except supervision and the maintenance of drainage. They should be afebrile.

Gas gangrene will either have been conquered or the patient killed by the infection, but those who have overcome the gas infection will present multiple wounds septic from other infections, streptococcus, staphylococcus and pneumococcus.

These are the particular cases that must be watched very carefully for signs of osteomyelitis or pocketing.

These are the ones whose arteries may be bathed in pus in some remote pocket, who may be concealing some arterial rupture closed for the moment by a softening clot. These wounds are covered with fascial sloughs and decomposing muscle and here Carrel's treatment is the treatment *par excellence*. Every part of each wound must be kept open and free from pocketing.

If any bit of bone obstructs drainage it should be excised. If the case has been diagnosed aright when first operated upon the surgeon will have ensured free drainage of the medullary cavity. If it does not exist it should be provided at once or else widespread osteomyelitis involving the entire medulla may develop; some near or remote joint may develop a virulent arthritis; septicemia with pneumonia may set in or renal infarct or endocarditis occur.

Secondary Hemorrhage.—Secondary hemorrhage has two causes. The most frequent is traumatic rupture of a large artery, which has been plugged by a clot and overlooked at initial operation. When the clot softens, hemorrhage occurs. The most frequent time for this to happen is on the tenth day after injury. The second cause of hemorrhage is sepsis developing in the arterial wall and often predisposed by a bruising of the artery without actual initial rupture, or by the pressure of a displaced fragment upon it.

The cause of arterial sepsis aside from that following traumatic devitalization of the walls is the pooling of pus and its stagnation about the artery—the lack of free dependent drainage (Fig. 154). Thus the author has repeatedly seen large pulsating arteries which had been carefully dissected away from devitalized tissue crossing well-drained cavities without the occurrrence of secondary hemorrhage. The artery must be kept from contact with stagnant (or any sort of) pus by dependent drainage. It then becomes surrounded by healthy granulation tissue, which protects it until it is incorporated into the mass of new tissue as healing occurs.

Conversely the author has repeatedly had to operate on exsanguinated patients for the arrest of secondary hemorrhage, and practically always when there had been no primary injury to the bleeding vessel it has been found surrounded with pus which could not escape except through an incision higher then the level of the artery. These arteries show erosion and ulceration along the whole length which has been submerged in pus, so that it is useless to ligate immediately proximal to the bleeding-point, or recurrence will follow from one of the remaining ulcers (Fig. 157). In the presence of a pus bath the artery must be followed proximally and distally until healthy vessel wall is found if recurrence is to be avoided. And, further, the cause must be removed *i. e.*, free dependent drainage be established.

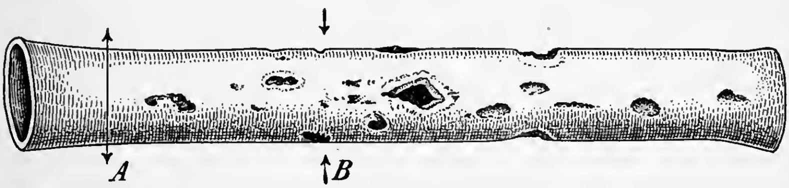


Fig. 157.—A segment of an artery which has been bathed in pus and which ulcerated; it shows one large hole and many secondary septic ulcers any one of which might have eroded through within another ten days; the arrow, *A*, shows where ligature could be done safely; the two arrows, *B*, indicate an insecure seat of ligature.

If ever one anticipates the possibility of secondary hemorrhage occurring, a tourniquet should be kept looped about the head of the patient's bed, and if the hemorrhage occurs it must be fearlessly and resolutely fastened about the limb. Instruct the nurse beforehand in the application of a tourniquet and impress upon her the futility and harm of applying a tourniquet only fairly well—the damming of venous blood and the incomplete arterial occlusion resultant.

The ligation of large arteries after active inflammation of a limb has subsided, so that no tenseness remains, need not be greatly feared, since inflammation seems to develop the collateral circulation quickly. If there is tension in the limb one must incise the skin longitudinally until no tension remains.

The Maintenance of Reduction.—The maintenance of reduction is not automatic. However well a compound fracture may have been reduced at primary operation it will not maintain its reduction without retaining apparatus. The old myth of initial bone-setting, a plaster case and forgetfulness is not applicable to the modern treatment of compound fractures, for nowadays the results of pre-war treatment will not bear comparison with the results which the army surgeons have produced.

Plaster of Paris.—Plaster casts should never be used in the treatment of open fractures. Plaster hides the skin. Infection may burrow or hide itself beneath the plaster and be unrecognized until the limb is hopelessly septic.

For this reason alone—not to mention the possibility of the strangulation of a limb which may swell—plaster should not be used in the treatment of open fractures.

At times, but rarely, a plaster cuff may be used as a base for fixation rods, as Pierre Delbet advocates for the ambulatory treatment of special fractures.

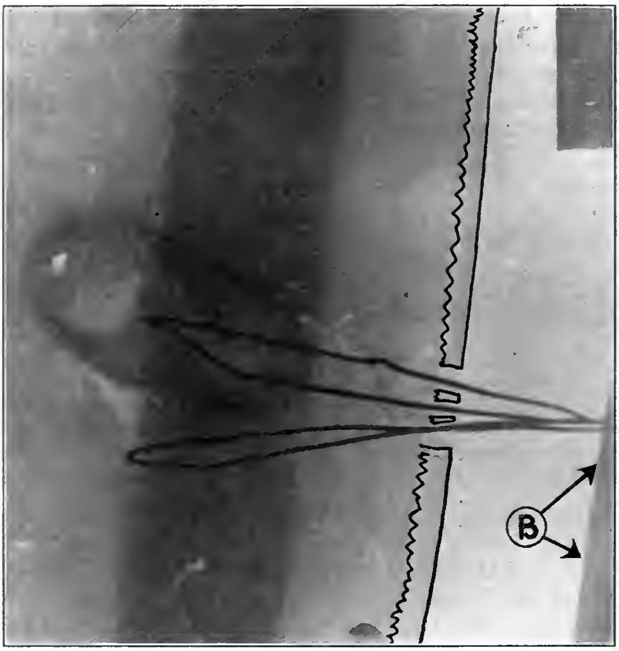


FIG. 158.—*X*-ray, showing two strands of wire passing one around each fragment, appearing through the skin and being fixed to the bar of a Thomas splint, *B*, these wires did not entirely encircle the bone and therefore did not cause end sequestra as in Fig. 153; note the large drain tube. The skin has been outlined for better illustrative purposes.

Lane's Plates, etc.—Neither is mechanical fixation by plates, bolts, screws or wire practical in open fractures. Very infrequently one sees a gratifying result follow the use of wire at the seat of fracture while necrosis of bone, osteomyelitis, delayed and non-union, amputation and death, attributable to no other cause than mechanical fixation by the use of foreign bodies at the seat of fracture, is often seen.

These means have a definite and gratifying use in closed aseptic fractures, but should never be used in open fractures.

To supply the need for mechanical fixation the author has devised and used the following instrument, which is applicable to the femur, the tibia or the humerus. It secures absolute rigid fixation of the fracture in perfect anatomical position—allows early motion in all joints, is comfortable and no foreign body is inserted at the seat of fracture.

Author's Prosthetic Splint; "Minimax Major."—To Codevilla, Lambret and Hey-Groves belongs the credit for first having demonstrated the possibility of obtaining positive extension of fractures by securing mechanical apparatus to the fractured bone at a distance from the seat of fracture. Neither method has come into general usage, because, by Lambret's appliance, it is impossible to reduce a fracture after the apparatus has been applied. Reduction has first to be accomplished.

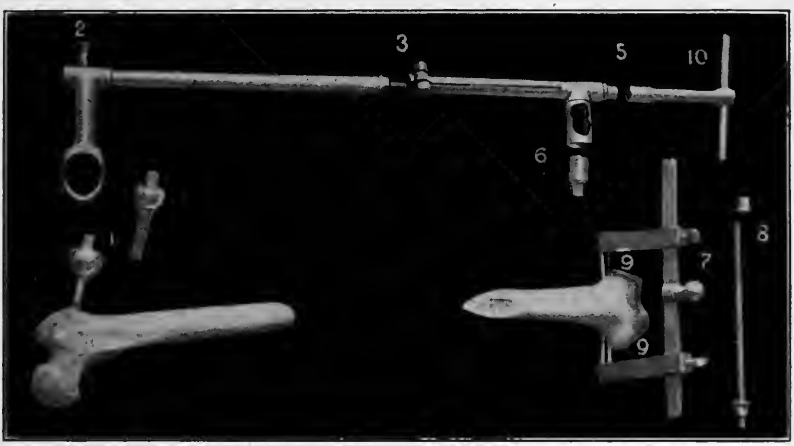


Fig. 159.—The minimax major dismantled. *1*, peg in great trochanter; *2*, lock nut, for trochanteric ball and socket; *3* length screw and locking collar; *5*, nut for length screw; *6*, lock nut for condylar ball and socket; *7*, condylar ball; *8*, condylar tightening screw; *9*, double points; *10*, key; it will be seen that the trochanteric ball is mechanically a part of the upper fragment and that the condylar ball is mechanically a part of the lower fragment.

Further, the screws work loose and must be multiple.

Hey-Groves's apparatus has the same objections in not thoroughly immobilizing and both methods demand extensive operation involving the medullary cavities.

The author's apparatus secures absolutely rigid immobility, not only extension. Reduction is accomplished by the apparatus, and complicated operation is not demanded.

The caliper ends grasp the condyles without penetrating the cortex.

The proximal end is fastened to the bone by driving the square nail into the trochanter at its subcutaneous part until the calcar femorale is reached by the point of the nail.

Incision through the skin an inch long is made at the three points mentioned.

The balls are fitted to their respective sockets, reduction accomplished and the apparatus locked at all joints.

The machine then assumes the functions of the femur, which is held immobile and left to solidify, unhindered by plates, screws, wires or pins.

It gives comfort and results in selected cases.

The minimax minor is designed for the humerus or tibia.

FIG. 160.—Lateral view of femur with minimax in place; arrow points to pus pocket; note two large drain tubes opening into cavity and also note that any discharge from the medulla may drain freely into the tubes; note multiple bits of metal which are fragments of a cigarette case. Case treated by author's fixation apparatus "minimax major." A glance shows that bone plates or any internal fixation would be impossible in the presence of the abscess.

Extension of Fracture.—If absolute fixation cannot be applied to a limb bone some one (or combination) of the various methods of extension must be used. Extension has as its object three definite results, *i. e.*, the correction or prevention of shortening, the restoration of muscle and fascia to their proper functions and the lessening of pain and shock.

Extension must always pull on the distal fragment and the term implies that counterextension exists, pulling on the proximal frag-

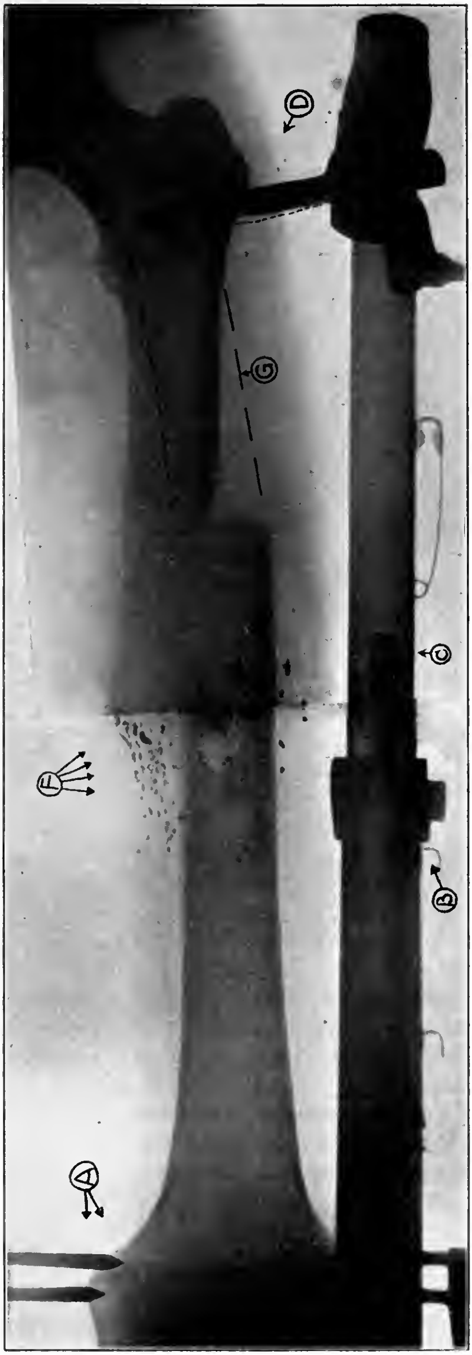


FIG. 161.—Author's prosthetic splint. The minimax in place. *X*-ray (this illustration was made by joining together two plates taken simultaneously and therefore there is considerable distortion). It shows some lack of abduction of the upper fragment which was entirely corrected after this *x*-ray showed the malposition. *A*, the double pins grasping the condyles. *B*, the locking collar for rotation. *C*, the length screw. *D*, the trochanteric peg (note that its point is firmly seated in the calcar). *E*, the condylar ball and socket. *F*, bits of cigarrette case which were blown into the thigh. *G*, the dotted lines indicate the final position shown shown on subsequent *x*-rays, none of which showed the entire length of bone and are not used for that reason. Same case as Fig. 160.

ment. Counterextension may be procured by any means exerting opposing traction.

Gravity may be used to exert counterextension by placing the body on an inclined plane and thus exerting traction on the proximal fragment through muscles and ligaments.

No matter what form of counterextension is employed, its force exactly neutralizes the opposing force of extension.

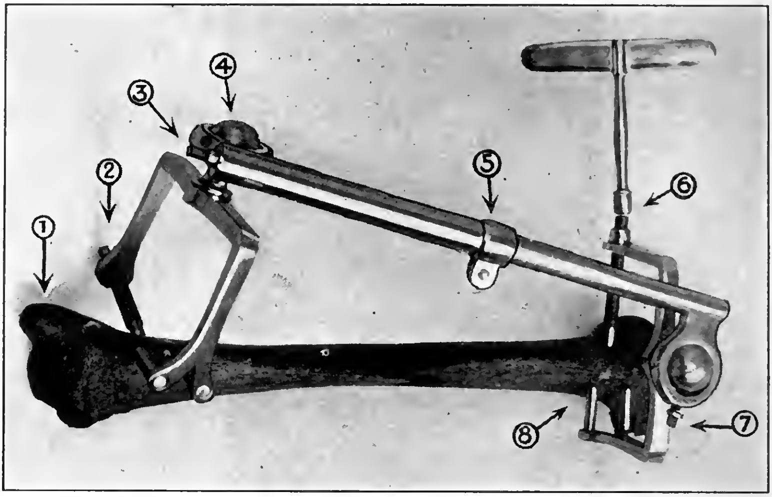


FIG. 162.—Minimax minor applied to the tibia. *1*, internal malleolus; *2*, screw pin gripping bone and opposing double pins on the opposite side, thus making a three point suspension or grip; *3*, nut for length screw; *4*, ball and socket; *5*, rotation; *6*, key (which fits all nuts) on screw point, which grips the tibial tubercle); *7*, lock nut for ball and socket *8*, double points; the points of application are in each instance subcutaneous.

Direct extension applied to the bone is best in compound fractures of both bones of the leg or the femur. It is best applied by means of calipers. The older appliances, such as percutaneous nails, Finochietti and Chutros stirrup, Steinman pins and Sinclair screws, all have the disadvantage of penetrating the medullary cavity and there they often set up a low-grade osteomyelitis rarificans, which results in a chronic sinus after the appliance is removed. It seems that the more immobile the apparatus is in relation to the bone it takes its purchase from, the less disturbance it causes.

However, Major Hey-Groves uses transfixion pins, with good results, and Sinclair uses screws extensively. The pin has the objection of occasionally setting up medullary osteomyelitis resulting in chronic sinuses, and in the author's experience is not so comfortable. The screw driven through one cortex, the medulla and into but not through the opposite cortex seldom produces osteomyelitis and is very comfortable, but for fractured femurs it must be driven into the tibia and thus pulls through the knee-joint, which suffers subsequently from stretching of its ligaments often to an astonishing degree and results in lateral mobility in that joint, which persists for a long time and in some cases seen a year afterward promised to be permanent. This fact also prevents early motion of the knee, and consequently flexion is often lost through adherent scars incorporating the quadriceps into the callus at the fracture, with consequent fixation in full extension of the knee-joint.

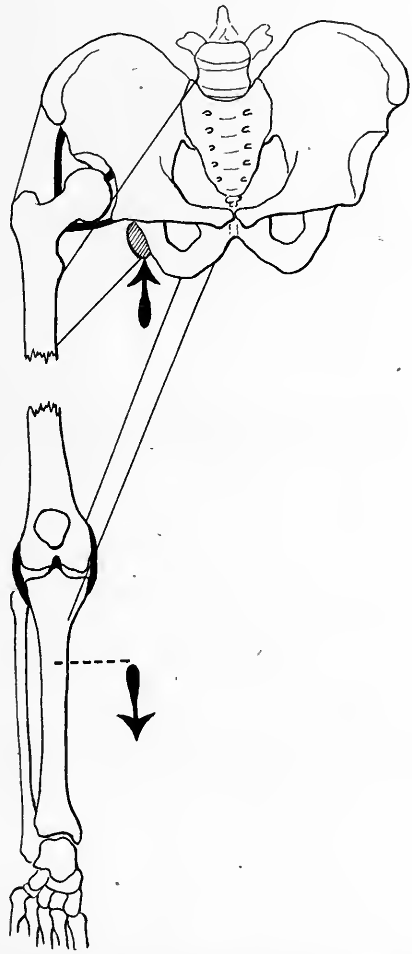


FIG. 163.—Schematic extension and counterextension, with interposed joints and muscles. The thin lines represent muscles which tend to detract from the force; the heavy lines represent ligaments about the hip and knee which may be stretched.

For this reason alone the calipers are infinitely the better instrument, but they should not penetrate bone.

Calipers.—To Colonel Frederich Besley belongs the credit for having introduced the "calipers" into their widespread usefulness.

They have replaced all older methods of obtaining extension for the femur and are equally efficient for extension of the leg bones. The photographs show the action better than words can describe. The modification has the advantage of permitting full extension of the knee while the old model impinged on the tibial crest with the knee bent 10 degrees.

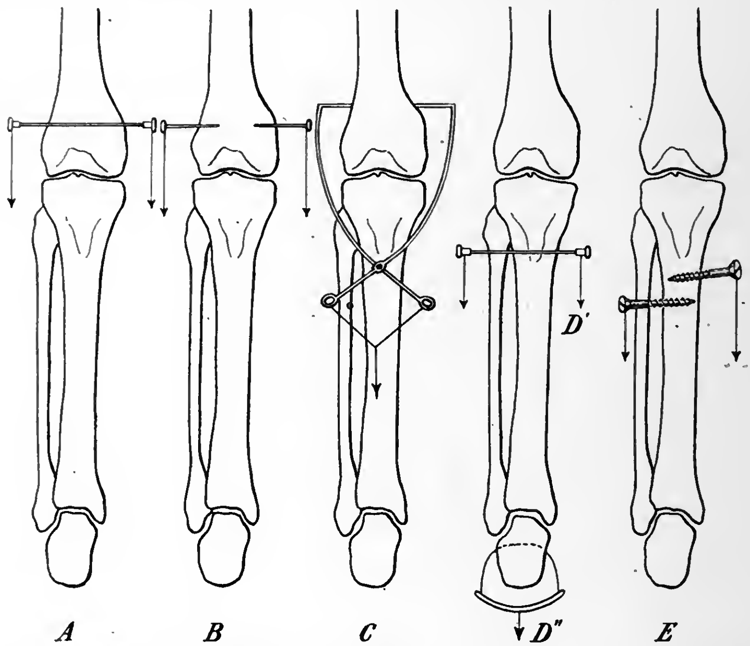


Fig. 164.—Method of direct bone extension. *A*, Steinman's pin. *B*, Murphy's percutaneous nails. *C*, Calipers. *D*, Hey-Groves' pin. *D*, Finochetti's or Chutros, stirrup. *E*, Sinclair's screws, or, when used supracondylarly, Davies' method,

Further, the new model has blunt points which do not penetrate the cortex so readily, and it locks so that it can neither slip nor jiggle, nor can the points come closer together, thus checking penetrating tendency.

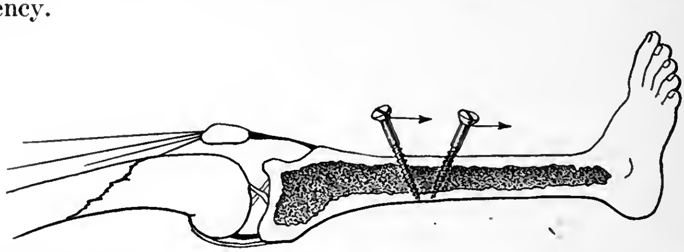


Fig. 165.—Sinclair screws, showing their anchorage and how lower leg extension prevents early knee flexion and consequently allow the quadriceps to become adherent.

If calipers be permitted to penetrate the cortex, pain and leukocytosis ensue and a sinus may result which is very chronic. The author has applied calipers to over two hundred patients without a sinus

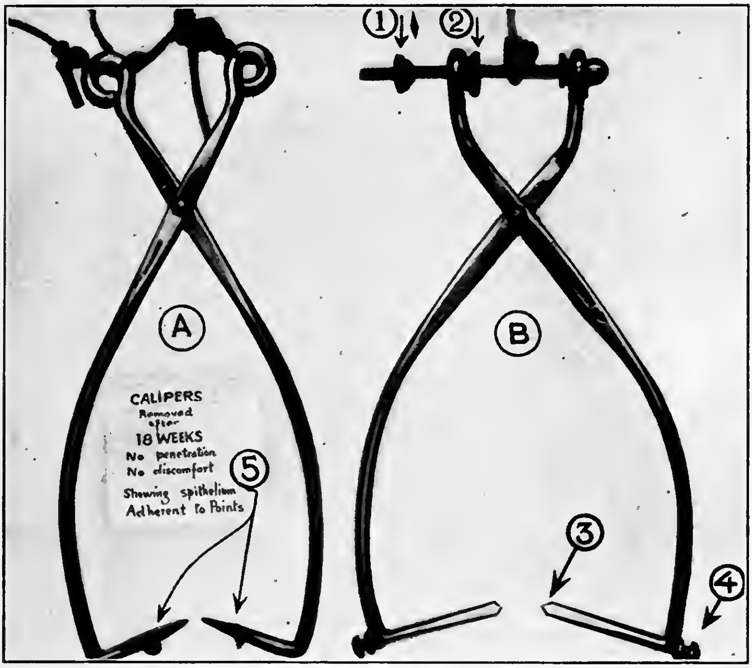


FIG. 166.—*A*, Besley's calipers, which were in place for eighteen weeks with perfect comfort and efficiency. *B*, author's upright calipers. *1*, nut locking against opening; *2*, nut locking against closing; *3*, eccentric blunt non-rustable points; *4*, button for fastening of extension cord; *5*, epithelium adherent to points.

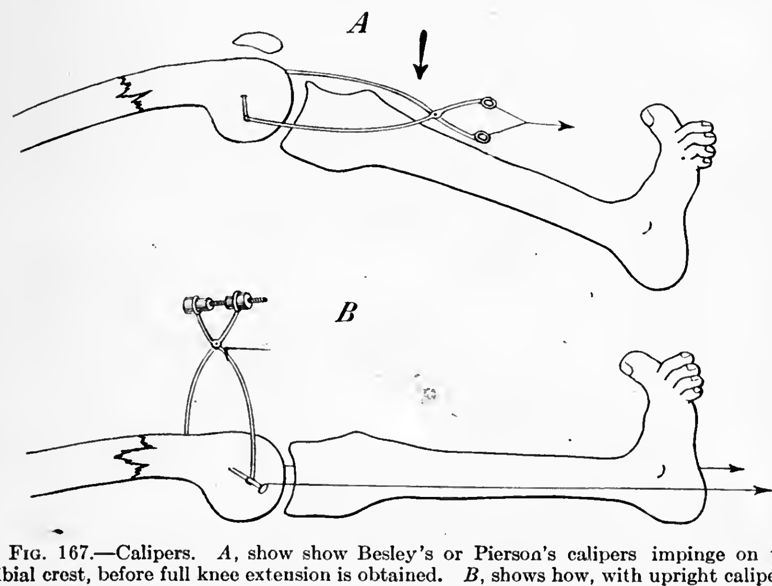


FIG. 167.—Calipers. *A*, show show Besley's or Pierson's calipers impinge on the tibial crest, before full knee extension is obtained. *B*, shows how, with upright calipers, and side cords, the knee can be fully extended.

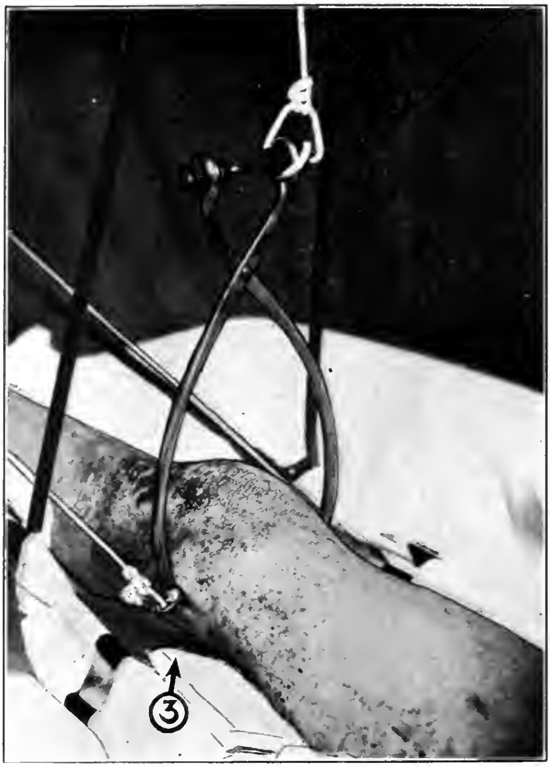


FIG. 168.—The author's upright calipers, which permit full extension of the knee and are more comfortable than the old model. They do not slip nor penetrate so easily. *3*, extension cord passing alongside the leg to the pulley and weights. The calipers are supported by a cord dropped from an upright bent rod fixed to the splint bars.

FIG. 169.—Edmonton model calipers in place just above the malleoli for extension of fracture of both bones three inches above ankle; note open incision from ankle to tibial tubercle exposing whole length of tibia. This was made for drainage purposes and if it had been posterior would have needed to be only a few inches in length; the ankle should be flexed to a right angle.

developing,[1] but has seen a case who wore calipers during transport, which penetrated the cancellous bone and resulted in a sinus, still unhealed after a year.

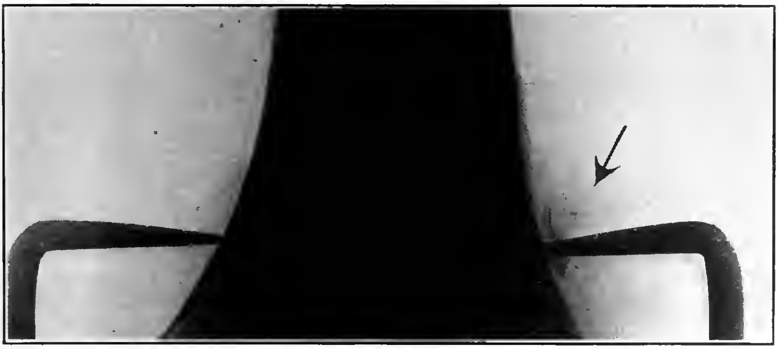


FIG. 170.—Periostitis about the caliper point. There was a dull, aching pain in the region so that the calipers had to be removed; wound healed at once; no further trouble.

Application.—*General Anesthesia.*—Make an inch-long incision over and proximal to the adductor tubercle down to the deep fascia, and another of equal size above the external condyle directly opposite

FIG. 171.—Showing healed caliper wounds and end-results of fractured femur. (Major M. Pierson's case.)

the first. Rub with B. I. P. P., push the calipers' points down to the bone and set the lock nuts. Do not penetrate the synovial membrane of the knee. Apply dressings to the wounds and fix the extending weights by cords.

When calipers are contra-indicated or unnecessary, skin extensions

[1] Fracture of the Femur—on Caliper Extension, Jour. Am. Med. Assn., March 15, 1919.

may be employed by means of adhesive plaster, gauze and glue or stockinette and glue.

Splints.—The ideal splint would be one which was comfortable, maintained absolute immobility, full extension, perfect alignment, left al' joints free for full mobility, allowed the patient freedom of movement in bed and involved no further damage to any structure than existed *a priori*, and which left the entire limb bare for inspection and the dressing of wounds There is no splint which fulfils all these requirements

Fig. 172.—Calipers used to compress long fragments into a solid shaft by exerting lateral pressure. It is not advisable to compress such fissures while acute infection exists as this would obstruct medullary drainage. Compression may be done after the acute condition is overcome and in simple fractures at the beginning of treatment.

Lower Limbs.—If all other external splints for the lower limb were lost and the Thomas alone remained, little suffering would result. It is the universal lower limb splint, and will, with accessories, efficiently and comfortably splint any bone condition.

Extension straps are applied to the leg or thigh or direct bone extension is used. The extension apparatus is tied to the notch in the distal end of the splint. This pushes, through the rigid splint, the ring against the tuber ischii. The tauter the extension is made, the greater the pressure against the ischium becomes. Slings of flannel support the limb from the side bars. The extension and counter-pressure tend to pull the fragments apart.

Practically there are several things which may vitiate this result. The pressure of the ring may make the skin over the ischium sore. The reasons are that the pressure is too great (more than twenty pounds), the skin is moist from poor nursing, the ring is improperly padded, the skin is naturally soft from inflammation of surrounding parts, from old age, from general debility. The skin under the ring should be treated daily by drying, rubbing with alcohol and powdering; the

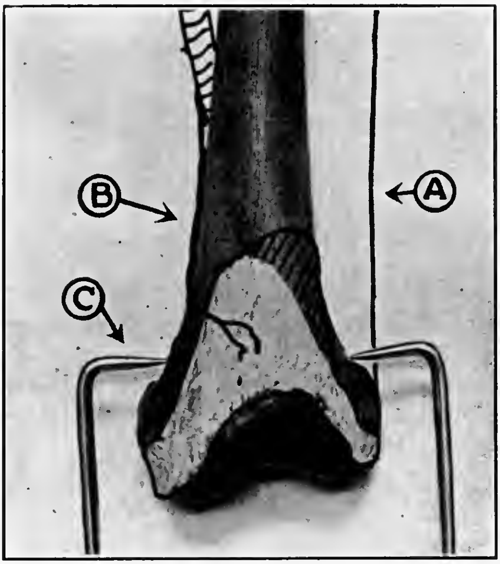


Fig. 173.—Calipers applied to the femoral condyles. *A*, represents the iliotibial band *B*, represents the anastomotica magna artery. The synovial membrane is outlined and the white area is constant in all cases, the shaded area is generally present, that is the subcrural pouch generally hangs over the side like a tamoshanter cap; the actual points of these calipers are too sharp and too thin (see Fig. 166, *B*); the point (*C*) is applied in a proper position; note that the outer point is not directly transverse to the line of the femur; this is correct as the weight bearing of the thigh is the line of the tibia (which passes through the hip-joint). Therefore, calipers should be applied transverse to the line of the tibia as the illustration shows.

ring should be rubbed daily with green soap, the skin should be moved about so that no one point continually bears the pressure. Needless to say the skin should never be allowed to remain moist for a moment. The ring should be firmly and evenly padded and covered with smooth leather. An old ring which is not torn or utterly worn out is better than a new one. Washing with soap and water does not harm a ring but it should be thoroughly dried before it is applied. By strict adherence to these principles the skin should bear a pressure of twenty pounds indefinitely. It is well, if the individual has a tendency toward a delicate skin, to start off with less pressure, for often it is found that

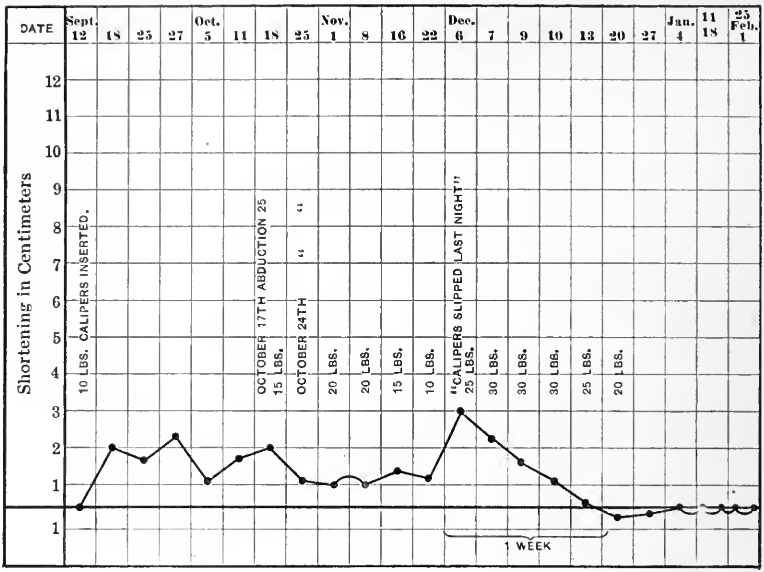


Fig. 174.—Chart showing length of femur. The case was a compound fracture at the lesser trochanter and was treated by caliper extension from the condyles. In the fourth month the caliper points rusted off and slipped during the night, resulting in 3 cm. of shortening. There was heavy callus and the patient could lift his leg actively; nevertheless by applying very heavy weights as shown on the chart full length was obtained within a week.

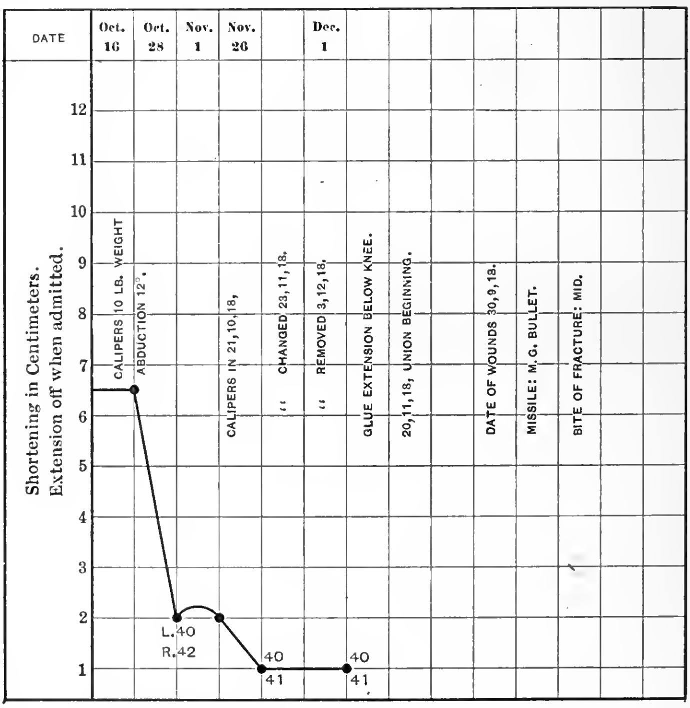


Fig. 175.—A length chart, showing the use of calipers on the condyles. Note that there is an apparent discrepancy in the length of the right leg which, of course, being uninjured does not vary in length. This is due to the fact that at the time of the fourth measurement the abduction was greater, hence the leg appeared shorter to measurement.

ten pounds is sufficient to overcome muscle pull, provided it is steadily applied and the slack constantly taken up.

Another reason for failure is that the ring may slip over the tuber ischii and press against the pubes, where the bone is subcutaneous and the skin thin and soft. This region will not tolerate pressure without pain. If the ring is suspended so that the patients' weight lies on it, it will not slip over the tuber, no matter how large the ring is. This should always be done, and it is important in correcting outward rotation of the upper fragment in fractures of the femur.

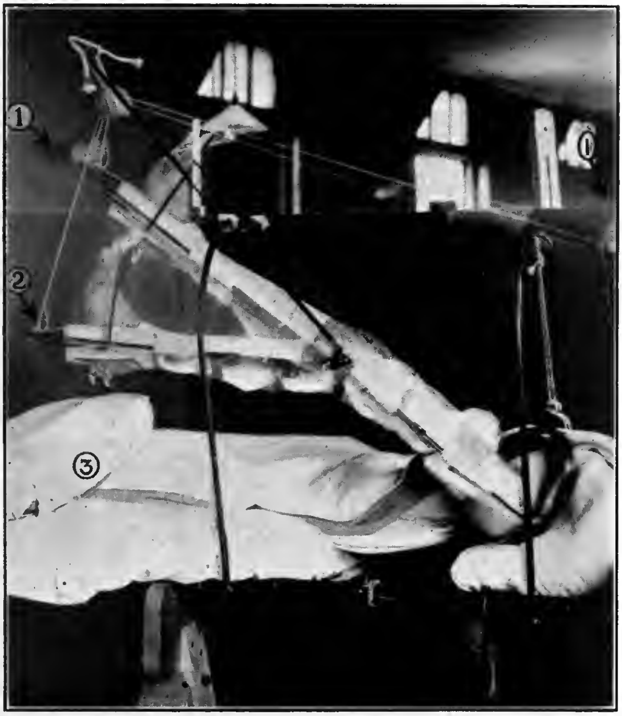


Fig. 176.—The "anti-aircraft" position. The splint is cocked up 45 degrees after union is solid, so that the knee can be flexed to greater degree; this picture was taken by a single exposure, during the first half of which the knee was flexed (*2*) and during the last half it was extended (*1*); the extending was accomplished by pulling the cord as the fingers marked (*1*) show; it is meant to show the action of the hinged knee flexion piece when grafted on to a Thomas splint; (*3*) is the removable section of the Pierson bed. Note the suspension of the Thomas ring. By this means the ring is kept snugly at the tuber ischii and cannot slip against the perineum no matter how large it is.

Fixed extension as described above may be superseded by weight-and-pulley extension, which requires less constant watching, and which simplifies the problem of ring pressure, since then the splint does not press so firmly against the ischium, and when the foot of the bed is raised and the body weight pulls against the extension the ring exerts no counterpressure whatever.

Weights and pulleys need only be used for thigh and leg fractures. Ten pounds is sufficient pull to stretch the leg full length.

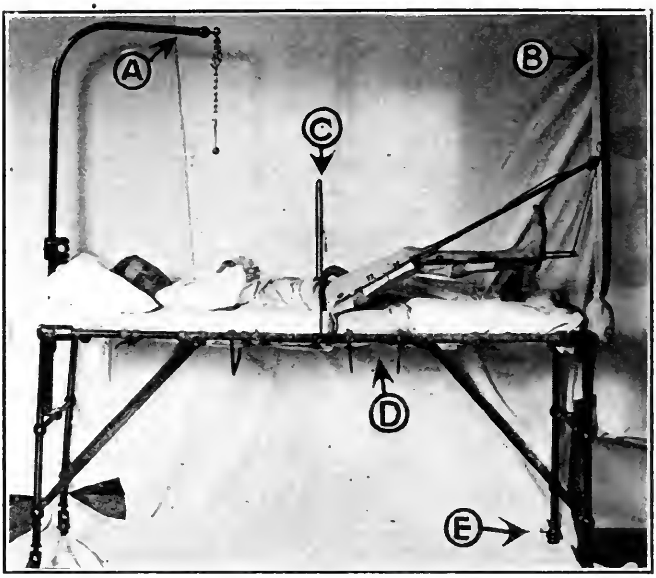


FIG. 177.—Pierson bed. *A*, gallows for slinging fractured arm or for patient to use in raising his body. *B*, foot bar to which the distal end of the splint is secured. *C*, transverse bar from which the ring of the splint is suspended; the splint then becomes a part of the bed. *D*, small section of mattress which can be dropped for dressing and use of bed-pan. *E*, telescopic legs raising the foot of the bed. Note absence of springs, which are replaced by canvas slings.

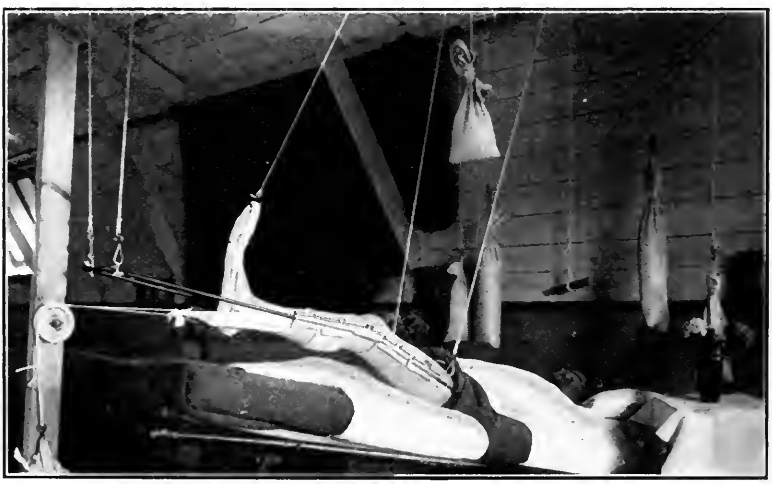


FIG. 178.—The Camier's method of suspension by counterweights. The weight balancing the ring of the splint must be at least ten pounds, so that the ring is kept snugly in the gluteal fold; this both corrects outward rotation of the upper fragment by exerting upward pressure on the great trochanter and also keeps the ring from slipping over the tuber ischii; the splint is merely a cradle for the limb.

Ten pounds applied within the first week will probably suffice to obtain full length of the thigh if it is applied directly to the bone. Between the first week and the sixth week fifteen pounds generally suffice. After callus has formed, up to thirty pounds may be required.

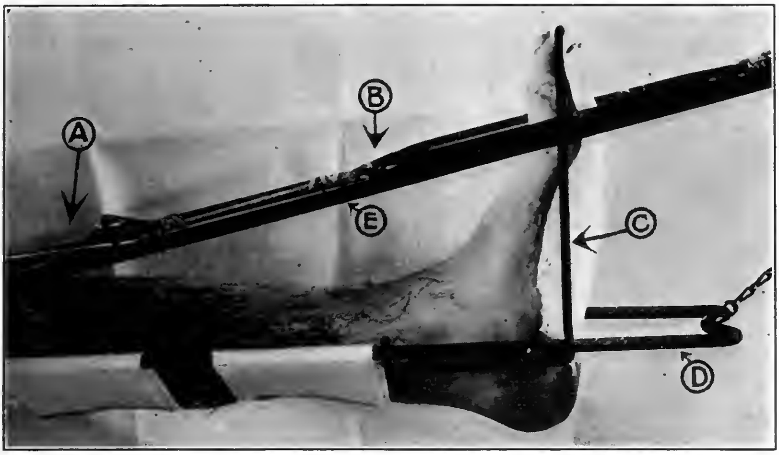


Fig. 179.—Small wire footpiece. *A*, calipers. *B*, hexagon to allow foot to come up through. *C*, gauze strip supporting foot. *D*, bar of hinged knee flexion splint. *E*, bar of Thomas's splint.

Fig. 180.—*X*-ray, femur showing pressure pad in action.

No skin extension will hold thirty pounds without causing blisters, and therefore calipers should be used when heavy weights are required.

Do not believe that because some author has said that ten pounds is enough it always suffices.

The only way to tell if enough weight is being used is to measure the leg. If it is short, apply more weight.

Pulleys may be blocked by knots in the cord or by poor axles or by pressure against their wheels. Knots near pulleys are sure indices of slipshod methods.

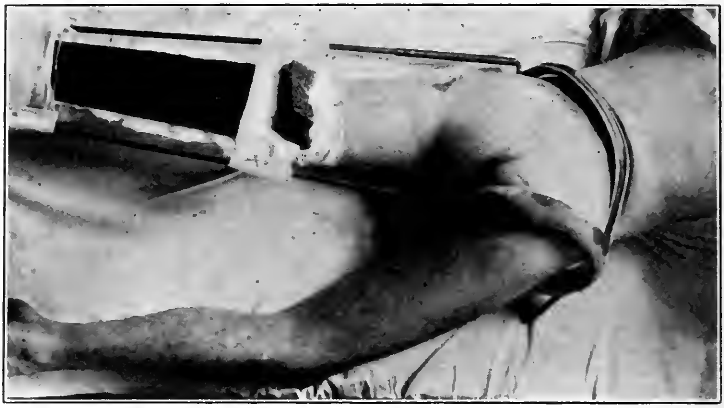


Fig. 181.—Author's abduction splint; the pelvis is tilted by counterpressure on the opposite tuberosity of the ischium.

Suspension arrangements of many sorts are valuable in that they allow the patient to move about in bed. They aim to counterbalance the weight of limb and splint by weights hung over pulleys overhead. The type of bed and room must decide the type of suspension employed.

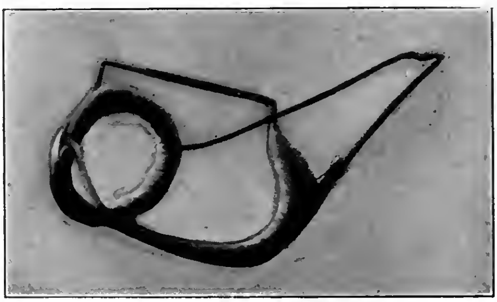


Fig. 182.—Author's abduction splint; note ring on opposite thigh pushing against the tuber ischii thus tilting the pelvis; note that the upper thigh and buttock on the fractured side are bare and unincumbered.

Accessories.—A footpiece should be applied always, and there are several types of wire footpieces to meet any demand.

The knee-flexion piece[1] that has become popular during the last year is very valuable and admits of obtaining any degree of knee flexion and movement. It is simply clamped in place at the knee region

[1] Designed by Capt. Walkin Williams.

and takes the support slings from there distally instead of the original Thomas bars. The patient operates it by a pulley and cord. (See Fig. 176.)

Abduction.—Abduction is necessary in treating high fractures of the humerus or femur.

The arm may be abducted by slinging it above the head while the patient lies in bed or by using an abduction splint when he is up.

Abduction of the thigh may be obtained by fixing both legs to the foot of the bed in the abducted position. This is unnecessary and very uncomfortable. It can be obtained by slinging the affected leg only in the abducted position if counterpressure is maintained on the ischial tuberosity, as in the Pearson method, or, not having the Pearson bed, or when the patient must be transported, by using the author's abduction splint. (Figs. 181 and 182.)

Fig. 183.—Arm splints. (*A*) Straight Thomas, affords easy access to arm wounds but is difficult for transport. (*B*) Bent Thomas, allows elbow flexion and gives access to shoulder wounds. (*C*) Straight Thomas, with hinged ring, good for transport and treatment of compound humerus. One must not keep an arm in a straight Thomas too long or a stiff elbow will result. (*D*) Cock-up wrist splint. (*E*) Arm abduction splints. (*F*) Mittledorff's triangle. (*G*) Jones's posterior elbow splint is an excellent splint for excised or draining elbow-joints, as it immobilizes in the correct position and allows access for dressing. (*H*) Jones's ankle splint.

This modification of the Thomas splint produces abduction automatically by transferring the ring to the opposite thigh and obtaining counterpressure against the opposite tuber ischii, thus tilting the pelvis. The splint is adjustable. It may prove useful in the treatment of simple fracture of the femoral neck.

Arm.—Thomas's arm splint is similar in principle and construction to the knee splint. Side bars are fastened to a padded ring, giving counterpressure against the muscles of the axilla and chest walls. Extension is obtained by adhesive strips from the skin. Clark's modification flexes the elbow and allows the arm to come to the side.

One must take care that the straight Thomas splint is not kept on the arm long enough to result in ankylosis of the elbow in the fully extended position. It is the author's custom to change the straight splint to one which allows the elbow to flex to a right angle at the earliest opportunity. Often the elbow can be flexed by bending the straight splint *in situ* if it is thought that changing the splint would perhaps refracture delicate callus or allow malposition to occur. Never allow the elbow to remain straightened for more than one month at most.

Both these models, especially the original straight splint (modified by a hinge at the junction of bars and ring) are excellent for early treatment of fractures of the humerus. They afford ready access to wounds for dressing.

The internal angular splint is a good splint for later treatment when wounds are healed and when motion is being returned to a stiff elbow.

The right angle, or acute angle splint, is also useful when it can be removed from time to time without disturbing bony position.

The posterior splints of Jones are excellent for fractures about the elbow-joint, which necessitate immobilization, and the twisted splint of Hey-Groves being posterior on the arm and anterior on the forearm, has special advantage when wounds interfere with other splints.

An essential feature of all splints for the arm is that they allow of supination of the forearm.

Forearm.—All splints for forearm and wrist fractures should hold the wrist in hyperextension (dorsiflexion).

The flat bones seldom require splinting.

A bed is probably the best splint for fractures of the pelvis and spine. The two legs may be fixed to the foot of the bed by adhesive plaster extension strips and body weight made to act as counterextension by raising the foot of the bed.

Treatment.

Late.—If the early and intermediate treatment has been successful the late treatment presents no problems. After union occurs one must occasionally remove sequestra and the more conservative the initial operation has been the more frequently this late operation is necessary.

Sequestra cause persistent chronic sinuses which heal and break down intermittently and which will not heal permanently until the sequestrum at the bottom is removed, which often means an extensive operation.

One sometimes sees cases of malunion which require corrective treatment, such as osteotomy and refracture; and this can be done at any time—even before the wound is healed; or cases of non-union, as those requiring shortening of one of the forearm bones, so that the eburnated ends of its fellow may come together and thus unite.

Non-union sometimes yields to excessive milk diet combined with apposition of the ends, operative freshening of the ends and use of the limb supported by apparatus.

Stiff joints, particularly the elbow and knee, if there is not actual ankylosis, yield to massage and movement. The treatment for stiff joints is a preventive one—namely, early and frequent movement.

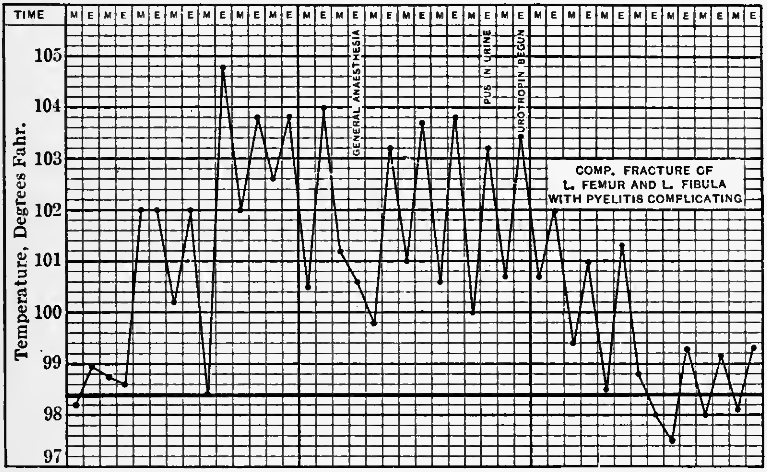


FIG. 184.—Chart showing rise of temperature due to pyelitis. There was marked edema of the wounded ankle and leg (and none on the sound leg) so that exploratory operation was done in the hope of finding an undrained pus pocket, but without success; for several days no explanation could be found for the condition of the leg and the temperature; pus found in the urine established the diagnosis and urotropin dispelled the symptoms; the pyelitis may have resulted from the excretory action of the kidney on bacteria from the wound.

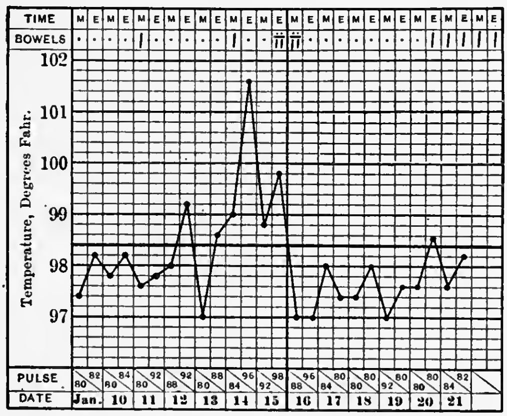


FIG. 185.—Chart showing rise of temperature due to removal of splint. The hip had been immobilized in abduction for four months; when abduction was discontinued, tenderness and pain developed in hip-joint. The arthritis quieted down after fomentation and purging. Result, freely movable joint. Compare pulse-rate with that of Fig. 147 where serious arthritis existed. This is an important differential point between virulently septic joints and joints which are not seriously involved.

Scars.—Scars cause limitation of motion when adherent to bone and therefore loss of function. All granulating wounds leave scars proportional to their area, and to the degree of sepsis present. Therefore one must attempt to render any wound aseptic at the earliest moment. Early passive movement tends to make a scar elastic and pliable. Movement, however, tends to retard the clearing up of sepsis so that skill and experience are required, to judge the best moment for the instigation of movement.

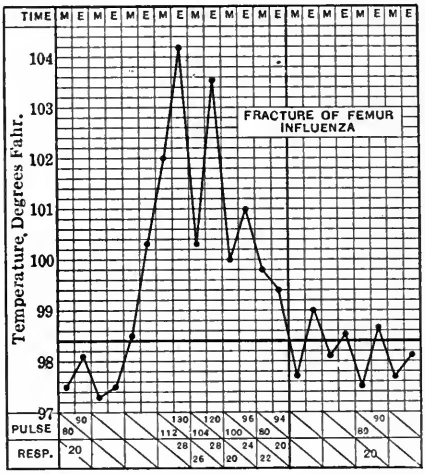


Fig. 186.—Chart showing influenza complicating compound fracture of the femur.

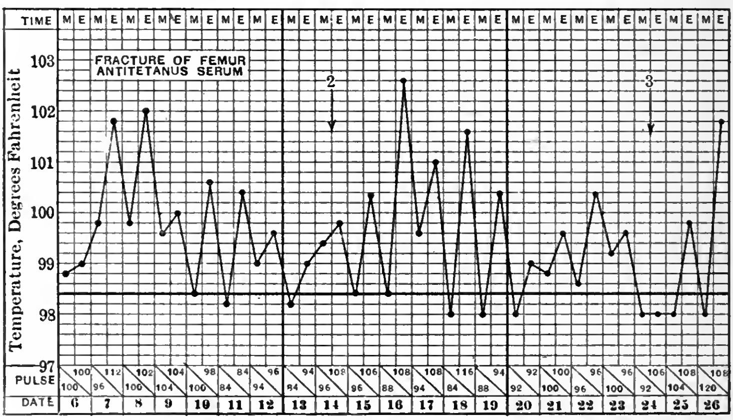


Fig. 187 —Chart showing rise of temperature due to routine injection of A. T. S. at ten-day intervals. The rise of temperature occurs on the third day generally. One whole day intervenes between injection and rise.

Secondary wound suture is the best late means of preventing adherent scars. When a scar greatly interferes with function, as do extensive scars in the quadriceps femoris regions or in the triceps and forearm, they may be excised.

Care must be taken that sufficient time has elapsed since healing took place for all latent bacteria to have been destroyed. Very dangerous and disheartening recrudescence of infection may occur unless four months have elapsed, and even after a year it seems possible for latent infection to spring into activity. Small cysts containing a small amount of milky fluid are often seen in old scar tissue, and it is in these that spores lurk, so that it is best to excise scar tissue *en masse*, carrying the knife through healthy tissue. It is well to rub the edges of the clean tissue thoroughly but sparingly with B. I. P. P. (See Antiseptics.)

Scars often enshroud nerve filaments and cause pain. It seems that scars on the extensor areas are greater hindrances to full function than flexor scars. For this reason incision for drainage should be made in the flexor regions.

Massage; Electricity.—Massage may be begun as soon as there is no active infection in the part. Indeed, massage should commence as soon as the first acute stage has passed. It should be gentle and light stroking at first, and, later, if muscles are hard or adherent to the callus it can be more vigorous.

Massage is invaluable in preventing stiff joints, wasted muscles and poor circulation. Do not massage acute sepsis, as movement merely pumps infection into fresh places.

Aside from this single contra-indication, the sooner massage is begun the better for bone growth, muscle preservation and joint mobility.[1]

Electrical Stimulation (Faradism) is useful to preserve muscle from wasting. It is helpful when the vastus internus tends to waste, since by preserving this muscle the function of obtaining complete extension of the knee is preserved. The vastus internus is the chief muscle used to extend the knee the last 10 degrees.

DIFFERENTIAL DIAGNOSIS AND COMPLICATIONS OF COMPOUND FRACTURE.

There should be no elevation of the temperature whatever after the first week and whenever an elevation of the temperature occurs the cause should be ascertained at once and the condition corrected. Entire wards of 60 patients with compound fractures have been free from temperatures over 100° for weeks.

A patient suffering from a compound fracture may develop fever from any other cause, *e. g.*, arthritis, appendicitis, bronchitis, malaria, phthisis, rheumatism, influenza, pyelitis, constipation, serum reactions or erysipelas.

Toxemia.—Toxemia is the commonest complication of compound fracture and indicates uncontrolled sepsis at the fracture with probable pocketing of pus so that the poisons of decay are being absorbed. Whenever the patient becomes toxic the wound should be investigated under an anesthetic or septicemia may supervene.

[1] J. B. Mennell: Massage: Its Principles and Practice.

Septicemia.—Septicemia causes rise of temperature to 103°, 104° or 105° and even higher with chills, flushing of the skin, rapid respirations restlessness, delirium, high pulse-rate and sometimes hematuria and jaundice. The wound must be investigated and drained at once; and it is the author's custom when called to see such cases to give Ol. ricini ℥ij at once; Urotropin gr. xxx per day and all the water that the patient can possibly drink, even as much as six quarts. Morphin in quarter grain doses may be given to spare the patient's energy and make him lie still, so that all his powers may be used to combat the microbes. If the patient's condition will permit, amputation should be done, leaving the stump wide open. This is the only certain means of removing the focus from which the septicemia emanates and will save many lives.

Septic Arthritis.—This occurs by extension of sepsis along fissures into contiguous joints, and occasionally as an evidence of pyemia.

The affected joint should be drained if proximal to the fracture but if distal to the fracture it is safest to amputate at once. Often this procedure should be employed when proximal joints are involved particularly when the patient is exhausted from a long chronic course of sepsis.

The author has seen several cases of acute arthritis coming on in the uninjured hip-joint the day after extension ceased. These cases subside without operative interference, and are best treated by immobilization and administration of sodium salicylate (Fig. 185).

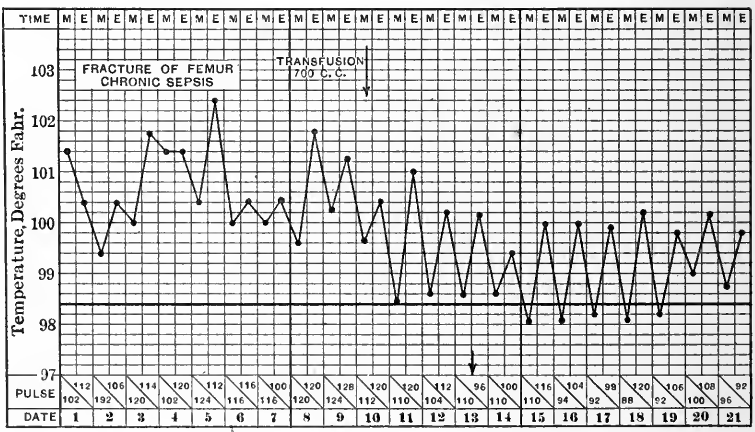


Fig. 188.—Chart showing influence of blood transfusion on chronic sepsis (note pulse-rate); the first half of the chart is typical for the preceding month.

Pyemia.—Septic infarcts frequently follow septic medullary osteomyelitis and are the cause of many deaths during the first two weeks. The common seat is the lung. The kidney, liver and joints, particularly the knee- and shoulder-joints, are common seats of hematogenous infection. When a joint distal to the fracture is involved the limb should be amputated, for while drainage has occasionally saved the limb it has often failed and death resulted.

It is sometimes difficult to distinguish between hematogenous meningitis and toxic meningismus.

At all events septic infarction means undrained sepsis at the fracture and demands surgical interference at the fracture.

Fat embolism following gunshot wounds occurs, but is an infrequent cause of death. It does not occur often enough to argue against forcible reduction.

Water.—If an excess of water is given to patients suffering from severe infections the toxins formed in the wound are washed away through the excretory organs and toxemia is decreased.

Purging.—Purging eliminates toxins, both the normal toxins (which in constipation are added to the wound toxins) and the bacterial toxins.

Transfusion.—Transfusion seems to have little antiseptic effect on acute sepsis or septicemia. Its effect is marked on acute shock or chronic infection, accompanied by emaciation and protein depletion. It acts by rebuilding the wasted body tissues and not by direct attack on bacteria.

CAUSES OF DEATH IN COMPOUND FRACTURES.

1. Mortal wound, lethally infected.
2. Operative or manipulative shock.
3. Undrained sepsis.
    A. Soft parts.
    B Medullary cavity.
        (*a*) Septicemia.
        (*b*) Infarction and pneumonia.
        (*c*) Septic metastasis.
4. Hemorrhage.
5. Chronic sepsis.

CAUSES OF DELAYED UNION.

1. Undrained sepsis.
2. Bone gap.
3. Constitutional debility.
4. Poor blood supply to fracture area.

CAUSES OF NON-UNION.

1. Bone gap (generally operative.)
2. Occlusion of periosteal lumen by constricting pressure of soft parts.
3. Intervention of soft tissues between the fragments.
4. Sepsis.
5. Constitutional or local disease.

CAUSES OF REFRACTURE AND WEAK CALLUS.

1. Same as causes of delayed and non-union.
2. Premature function of the part.

MISTAKES.

1. **Shock.**—Those cases which died of shock following extensive primary operation (the attempt to do a single big operation rather than two lesser ones) would have been better treated by temporizing measures.

2. **Amputation.**—The cases that die during the first week which might have been saved by amputation include those with great shattering, those with severe sepsis in the shattered knee-joint or femur or humerus, and especially those with streptococcic infections or gas infections near the trunk; those with severe infection, shattering wounds and arterial injury, particularly those with lesions of the posterior tibial artery complicating fracture of both leg bones.

Those which survive and endure long sufferings and find that the saved limb is worthless, include those fractures of the leg where much bone has been destroyed and where severe infection has existed, and those who have lost the mechanical bony support necessary for function of the knee or elbow, especially if complicated by nerve lesions.

This class represents, as a rule, the flail-joint folk and the non-union folk, and their surgeon made one of two mistakes: either he excised too much bone in the effort to provide free drainage, or else he refused to amputate when too much damage had been done ever to hope for compensatory function to return. These limbs should have been amputated.

3. **Resection and Radical Esquillectomy.**—The cases which might have lived with resection but who died with joint drainage include those whose joints were severely damaged with radiating fissures leading into the cancellous tissue which were inaccessible to surgical cleansing and which consequently developed acute osteomyelitis, septic infarction and septicemia; or those whose synovial membranes had such a degree of laceration as to make them inadequate for closure; or thosewhose femoral condyles or tibial head were grossly comminuted, so that infection was provided with multiple hiding-places; or those with severe infection of the elbow, etc. Resection might have saved these lives or limbs.

It is well to know that an erysipeloid condition of the skin often accompanies acute paroxysms of osteomyelitis, and that serious consequences may follow medicinal treatment of this condition.

4. **Esquillectomy.**—The cases whose medulla and fragments were heavily infected, and whose medullary cavity was left with insufficient free drainage and with infected cracks and medulla; or those whose medullary cavities were corked up by a too accurate primary reduction in the presence of severe infection, and who then developed an acute

medullary osteomyelitis, with its sequelæ of septic infarction, hematogenous infection of joints, septicemia and the formation of sequestra, would have been better treated by radical esquillectomy.

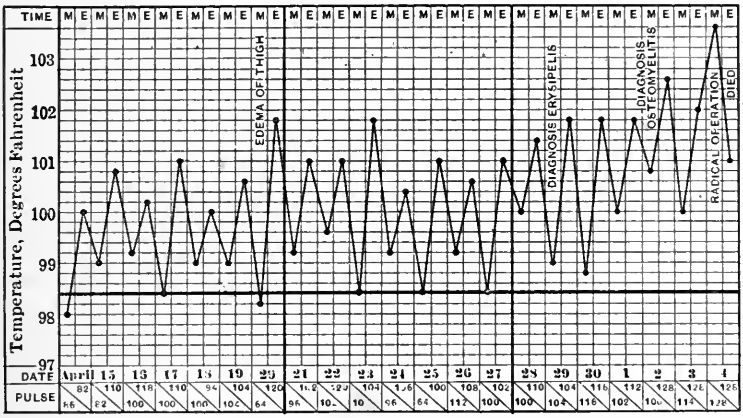


FIG. 189.—Chart showing a mistake in diagnosis; erysipelas *vs.* osteomyelitis.

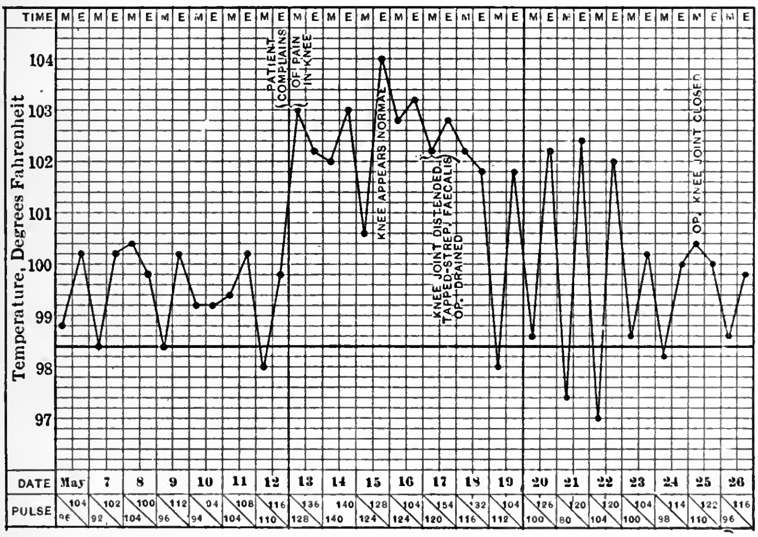


FIG. 190.—Chart showing onset of hematogenous infection of knee-joint, and result of operation by radical drainage and later closure of knee. Note similarity of onset in this grave condition with that of influenza onset; Fig. 186.

5. **Hemorrhage.**—Those cases which died from secondary hemorrhage might have survived if the surgeon had made larger incision and had searched more diligently for contused or torn vessels, or if good dependent drainage had been established.

6. **Sequestra.**—Cases of late refracture and which contain sequestra might have been uneventful if dependent drainage had been employed.

7. **Scars.**—Cases of poor function resulting from adherent scars might have been cases with good function had sepsis been overcome early and had secondary wound closure been done, so that early motion could have been practised.

8. **Movement.**—Cases with stiff joints might have had sound joints if early movement had been practised and if extension had been obtained from the limb proximal to the joint rather than distal to it.

I wish to acknowledge my indebtedness to General Sir Robert Jones, R.A.M.C., Colonel Sir Harold Stiles, R.A.M.C., and Lieut.-Col. Hugh Cabot, Harvard Surgical Unit, for the opportunities they have given me for the study of compound fractures and kindness in reading my manuscript.

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DISLOCATIONS AND SPRAINS.

By DENNIS W. CRILE, B.S., M.D., Hon. Capt. R.A.M.C.

GENERAL PRINCIPLES.

A dislocation is a condition in which a joint has suffered abnormal mobility so that its joint surfaces assume extraordinary positions. Commonly the term signifies that the abnormal position still exists when first seen by the surgeon. As a matter of fact many dislocations are spontaneously replaced and when first noted the parts are not in dislocation. These constitute sprains and the differential diagnosis, between sprains and true dislocations is very difficult at times, *e. g.*, certain spontaneously reduced or incomplete dislocations of the clavicle, the semilunar cartilages of the knee, and especially conditions of the carpus, when swelling is present.

Causes and Predispositions.—Trauma is the common cause and is usually indirect, the force, as a rule, being transmitted to the joint through the distal bone, which is generally the bone dislocated; thus the phalanges are dislocated at the first metacarpophalangeal joint, the posterior dislocation of the ulna occurs at the elbow and dislocation of the humerus at the shoulder.

Muscular action may be the exciting factor, as in dislocation of the jaw during yawning or as in recurrent dislocation of the shoulder or patella. Cases of primary dislocation by muscular action are rare (except of the jaw) and often are associated with a predisposition—as the deficiency of the acetabular, the flatness of the glenoid or condylar cavity, previous arthrites or fracture of the articular surfaces or previous rupture of the capsular ligaments.

Wasting of the muscles which act upon the articulation and the consequent slacking of the ligaments supporting the joint predispose to traumatic dislocation as do congenital deficiencies and maldevelopments as in the imperfect acetabulum or poorly formed femoral head. Intrauterine dislocations form another group of predispositions and causes.

Tuberculosis of the epiphyses with resultant deficiency of joint surfaces may predispose to dislocation and this fact should not be overlooked as tuberculosis is sometimes discovered after a dislocation has been treated and may be falsely thought to have been the result rather than the remote cause of the dislocation.

Early Charcot's disease is sometimes responsible for dislocations.

Hypertrophic arthritis is seldom seen in dislocated joints because the nature of the disease increases the depth and stability of the joint. The fact that hypertrophic arthritis results in a limited range of motion, invites spraining of the ligaments and sprains of hypertrophic joints are frequent and the cause of a good measure of discomfort to these patients.

Distention of the synovial membrane by effusions predisposes to dislocation.

Frequency.—Dislocations occur with greatest frequency in adult males, because of their greater activity and liability to misadventure, and because their bones are less liable to fracture than are the bones of children or the aged.

The shoulder-joint is particularly liable to dislocation because of the absence of supporting ligaments, the shallowness of the glenoid and the absence of bony guides or grooves. Nearly one-half of all major dislocations occur at the shoulder (Brewer). The finger-joints are frequently dislocated because they are exposed to trauma and because their joint surfaces present practically no restraining margins.

The elbow-joint is next in frequency (posterior dislocation); then the hip, jaw, carpus, tarsus and patella. Dislocations of the vertebræ without fracture are rare and are practically limited to the cervical region. Dislocation of the knee is very rare but the semilunar cartilages are often dislocated. The fibula is seldom dislocated.

Pathology.—When incomplete dislocation has occurred with spontaneous reduction the capsule is not generally torn. The external ligaments are often ruptured, the joint cartilages may be contused, the tendons about the joint may be torn from their sheaths and displaced, or they may be actually ruptured.

When complete dislocation occurs, the joint capsule is nearly always torn through. There is hemorrhage into the joint cavity, the external ligaments are generally torn, surrounding tendons displaced or ruptured, muscles often ruptured and bruised, nerves and bloodvessels may be displaced or looped about the end of the dislocated bone, or the displaced bone may injure some viscus. These are called complicated dislocations. In extreme cases the nerves may be ruptured or the spinal roots may be avulsed.

Occasionally, dislocations are compound, the articular surface protruding through the skin. Compound dislocations are rare and most commonly occur at the basal thumb-joint.

Hematomas may form about the dislocations and are quite often subcutaneous. The articular cartilages may be torn from the surfaces or may be split. Small bony protuberances from the joint surfaces, as the acetabular rim, the edge of the glenoid or the edge of the metacarpal or phalangeal joints or the coronoid process of the ulna may be fractured.

If dislocation is allowed to persist, secondary changes occur which result from the transformation of the synovial exudate or hemorrhage into fibrous tissue which may fill the articular cavity more or less completely. If the joint be allowed to remain immobile, fibrous or bony ankylosis may occur. If motion has been allowed, a new articulation may result from the atrophy of the bone on which the dislocated articular surface rests. In this case the central absorption of bone is combined with a peripheral deposition of new bone and gradually an entire aberrant joint is developed. After three or four months, as a rule, it becomes impossible to reduce the dislocation.

Diagnosis.—In typical cases the diagnosis is evident by inspection. There is deformity, loss of function, the head of the bone may cause an abnormal prominence beneath the skin which prominence moves with the bone. There is pain which increases with any motion, there may be shortening or lengthening of the limb but the length of the bone is unchanged. The position of the limb, distal to the dislocation may be abnormal or typical. The head of the bone may be absent from its normal position but still not palpable. There may be considerable swelling in the joint and about the joint and after a few days discoloration appears. At times it is very difficult to distinguish between sprain and dislocation. The presence of a single circumscribed tender point indicates sprain, but the absence of deformity does not contra-indicate dislocation. Whenever one is in doubt, it is well to make a correction test by attempting proper reduction and in this way be assured that dislocation is not overlooked. The differential diagnosis between fracture and dislocation may be confusing when the suspected fracture is of the head of the femur or of the surgical neck of the humerus. If true crepitus is found—fracture exists. A tendency to recurrence after reduction combined with abnormal mobility suggest fracture while restriction of motion and easily maintained reduction indicate dislocation. One should always bear in mind the fact that dislocation and fracture often coexist. Every dislocation which tends to recur should be examined by the *x*-ray for the presence of joint fractures, and where ready facility exists *x*-ray photographs of all dislocations should be made routinely.

General Principles of Treatment.—*Sprains.*—The ligaments which have been torn, stretched or bruised, should be allowed to rest in the relaxed position for at least a week so that repair can take place without permanent lengthening or laxity of the ligament.

This can be accomplished by immobilization of the joint by plaster-of-Paris cast, splint, adhesive strapping, bandaging or by use of a sling (to support the weight of an arm). In the case of sprains of the knee-joint, rest in bed with pillows to support the limb may be sufficient. Often, strenuous measures may be discarded, particularly if the patient be an intelligent person upon whom one can depend to obey orders. No strain whatever should be put upon the strained tissues.

Repair and Healing.—The torn capsule or ligaments should be allowed to repair by immobilization, and it is very important that this repair take place with the ligament in its normal condition, especially as regards length, for if lengthening occurs after ligamentous healing, the dislocation of the bone may recur. This is the commonest cause of "habitual dislocation." During the period of immobilization, contiguous joints should be moved. In fact, the involved joint should be moved if no great effusion is present, but the motion used should be one that does not put strain upon the tender healing ligaments. Thus in dislocation of the outer end of the clavicle, shoulder motion should be encouraged in all directions except abduction and extreme adduction, which movements would cause the coracoclavicular ligament to stretch. The straining of a ruptured or sprained ligament or capsule causes pain—a most valuable warning signal. It is always safe and wise to allow whatever motion is painless. Nature has arranged her plan so that pain will tend to prevent harmful motion and this arrangement is ideal for the purpose of the after-treatment of dislocations.

Time for Reduction.—Dislocations proper should be reduced at the earliest moment possible—the part should be immobilized for at least a week and often two weeks. It is unwise to delay reduction of a dislocation, because even after a few hours, the muscular tension increases and a certain amount of stiffness develops in the fibrous tissues and muscles which hinders reduction. The difficulties of reduction increase in direct geometrical proportion to the time which has passed since the dislocation has occurred, due in a large measure to the effusion which takes place into the tissues—and after several days to the organization of the effusion which is part of the normal process of repair.

In the presence of very severe contusions and marked local reactions, about the joint, one must not be led to delay reduction by the hope that after a few days the local congestion will have diminished. While this is true, the congestion will disappear more rapidly after reduction has been accomplished and reduction will more easily be accomplished in the presence of congestion than it will be in the presence of sclerosis and stiffening. Furthermore, the manipulation necessary to accomplish reduction after three or four days will in all probability excite a second reaction about the joint which will equal the primary reaction in intensity. Hence, the patient will have two spells of discomfort instead of one.

After a month has passed, reduction will sometimes be found impossible without resort to open operation. This is particularly true of the carpus, tarsus and clavicle. In the shoulder- and hip-joints, reduction can in many instances be accomplished in a month or even two months or more. The manipulation of a dislocation which has persisted for several months is a major undertaking and one which experience teaches had best be left to the specialist. These cases present no urgency whatever and are the ones in which fractures occur during strenuous, but clumsy efforts to obtain reduction. There are many cases on record in which the neck of the humerus or the neck of the femur has been fractured by the indirect violence of skilled surgeons who were attempting to reduce dislocations of long standing. If gentle efforts do not readily accomplish reduction in an old case, it is considered wise to undertake an open operation. In this way the dangers of fracture, the laceration of bloodvessels, the tearing or stretching of nerve trunks, the rupture of muscles or ligaments, may be avoided. Reduction by open operation entails considerable risk, since the joint cavities are subject to septic complications. These operations demand aseptic precautions of the utmost rigidity.

Dr. Charles Edwin Briggs, of Cleveland, has summed this matter up in the words: "It must be recognized that the favorable opportunity (for reduction) of the first few hours cannot be recalled."

In general it may be said that dislocations in which there is rigidity, are those in which only a small opening has been made in the capsule, through which the head of the bone has escaped. Those dislocations which present free mobility are often ones in which the capsule has been extensively lacerated so that its supporting function has been lost. These are easily reduced but reduction is maintained with comparative difficulty and it is in this class of cases that plaster-of-Paris or retaining splints should be employed at times.

The dislocation in which the capsule is slightly torn presents greater difficulty in reduction, but once truly reduced is easily held and this class of cases requires little or no retaining apparatus. The act of reduction should be done gently. In general it may be said that the surgeon's skill varies inversely as the amount of force he exerts in effecting a reduction.

This statement does not apply to congenital dislocations of the hip and certain rare cases of traumatic dislocations. A thorough knowledge of anatomy and the mechanism of each dislocation is essential to their intelligent reduction, although a great many cases of dislocated phalanges, clavicles, patellæ and so-called subluxations of the spine, are readily reduced by unskilled persons.

General anesthesia is a great help in accomplishing reductions of the larger joints because it relaxes all the muscles and abolishes all voluntary or protective contractions of these muscles. Under general anesthesia one can often feel the head of the bone and find the rent in the capsule through which it became dislocated.

Surprise Manipulations.—It is unwise to make surprise movements or to make attempts to divert the patient's attention while a sudden twist is engineered. It is impossible to surprise a muscle for its reflex contraction is instantaneous and quite beyond the control of the patient. Surprise reductions are often responsible for fractures. The pain of the outraged muscle may surprise the patient—and the surgeon—but the dislocation will not be surprised.

Steady traction, either by direct extension or by gentle prolonged leverage (as in Kocher's method) is far superior to any trick jerks and will accomplish results more readily.

One can often feel the resistance which tendons or nerves give to reduction when they are looped about a bone or stretched across the path which a bone must follow during the course of reduction. This resistance should never be disregarded but manipulation continue until they are gently pushed aside or evaded.

Signs of Reduction.—Reduction is generally accompanied by a snap or click as the two joint surfaces come together or as one joint surface slides over the rim of its fellow. Motion is at once restored in all normal directions at times without any pain whatever, at other times with pain accompanying certain motions only, but most commonly accompanied by pain with any motion.

The normal outlines of the part are at once restored, except for general swelling. A great sense of relief is experienced by the patient. Rarely one may feel crepitus which may be due to the articular surfaces scraping over a torn shred of ligament and one must bear this in mind when making a differential diagnosis between joint fracture and dislocation. This crepitus is of a soft character and should not be confused with hard true crepitus. Occasionally one feels a velvety softness after reduction has been accomplished which may be due to the interposition of a tag of capsule or muscle. A little passive motion of the joint after reduction may result in freeing it from this soft tissue and only in very rare instances is one justified in performing extensive manipulation for the purpose of clearing the joint. A small amount of soft tissue will be absorbed in time.

Nerve Injury.—Continued pain referred to the limb distal to the dislocation may indicate that a nerve-trunk has been displaced and caught in abnormal relation. The pain will follow the cutaneous distribution of the nerve and is most often seen in the ulnar and sciatic regions. The crural nerve may be pressed upon in forward dislocations of the hip while the dislocation persists.

Synovitis.—The synovitis which occurs after all dislocations may be treated by pressure bandage, the application of ice-bags or cold compresses and by very gentle friction massage. Care must be exercised that the pressure bandage does not obstruct circulation to the distal parts. The synovitis is often accompanied by hemarthritis and when the tension is very great, the joint should be perfectly immobilized for about eight to ten days. The knee-joint may be tapped in selected cases. After two or three days cold compresses may be replaced by hot fomentations or the use of a therapeutic light coupled with massage, the purpose of these measures being to dilate the lymph- and bloodvessels so that absorption of the fluid will occur more readily.

Movement.—During the entire convalescence from dislocation, active motion *which is painless* should be allowed and encouraged. After ten days exercises should be designed to restore full active function to the joint and certainly after three weeks, strenuous measures should be adopted to secure vigorous motion in the joint. At this time the pain factor should be disregarded, as it no longer represents a protective agency but merely indicates a commencing sclerosis and atrophy of disuse. Pain at first is acute but when due to beginning sclerosis assumes the character of a soreness or a "bruised feeling." This should be disregarded. This is especially true in elderly patients in whose cases massage should be done daily unless there is a large effusion into the joint which gives signs of becoming infected as when the temperature is elevated or local inflammation manifests itself. These parts should be immobilized and treated with hot fomentations of boric-acid solution or the use of the therapeutic light. It is a rare condition.

In the knee-joint, effusions may be reduced by the use of adhesive strapping applied in a basket fashion so that it makes uniform pressure over the front and sides of the joints. It is not wise to make pressure over the popliteal space as this may tend to produce edema of the lower leg.

The synovitis which accompanies dislocation of the finger-joints may also be treated by firm adhesive strapping and many cases of ankle-joint effusion are made comfortable by the use of strapping.

Open operation should only be resorted to after all other means have failed and after consultation, since it is often surprisingly easy for a specialist of large experience to reduce dislocations which completely baffle the well-trained practitioner. When open operation is resorted to, dislocations of long standing will require thorough exposure of the joint and the removal of newly formed tissue from the joint cavity. It is often necessary to divide the tendons of contracted muscles and generally the slackness must be taken out of the capsule of the joint by taking a pleat or a tuck in it and for this chromic catgut or silk should be used.

In extreme cases of long-standing dislocations, particularly at the hip-joint in old people, it is sometimes necessary to excise the head of the bone, in which event one generally aims to secure ankylosis with the thigh in abduction and flexion. Excision of the shoulder or elbow is generally done for the relief of restricted motion or ankylosis and one aims to secure a movable joint. In the case of the shoulder, the head of the humerus is most often excised while at the elbow the head of the radius or a portion of the condyles of the humerus are generally removed. A flap of fascia preferably pediculated (although it may be used as a free transplant) is interposed between the surfaces.

Open operation should be done with special regard to anatomical relation, so that no hemorrhage will occur during the operation. This dispenses with the necessity for using a large amount of catgut and with the possibility of a large blood clot forming in the wound. Either of these conditions predisposes to infection which must be rigidly guarded against. No drainage should be used as a rule. The muscles should not be sutured. Rarely will it be necessary to suture the fascia. The skin is closed with horse-hair in adults or catgut in children, as the use of catgut makes it unnecessary to remove stitches. Open operation should not be done unless special indication exists; such as serious loss of function or pain on motion or the insecurity of the limb in certain positions. The operation for the reduction of a dislocation after three months or more is more difficult than bone plating and is wisely left to the specialist.

DISLOCATIONS OF THE JAW.

In rare instances the condyle may be dislocated upward when fracture of the base of the skull occurs. The condyle then enters the middle cranial fossa and reduction is done by bringing the front teeth together, using the molars as a fulcrum. This injury is usually fatal, due to intracranial basal hemorrhage. Rarely a backward dislocation may occur but the strong buttress of the temporal bone usually prevents this. When seen there is often a fracture of the anterior wall of the bony auditory meatus. Reduction is accomplished by pressure forward against the ramus of the dislocated side.

Forward dislocation is the common type in which the condyle or both condyles slip forward with a click and settle into the zygomatic fossæ. The anterior ridge of the mandibular fossa—the eminentia articularis—prevents reduction. The dislocation follows voluntary attempts to open the mouth widely, blows upon the chin, generally a little to the side of midline, or the spasmodic contraction of the external pterygoid muscles during yawning.

Symptoms.—The mouth cannot be closed and the lower jaw appears thrust forward. Swallowing is difficult and saliva drools from the open lips. Pain is not generally severe but discomfort is great as no food can be masticated and drinking is difficult. When only one condyle is dislocated the chin deviates toward the opposite side. A depression which resembles a dimple in some cases is seen just in front of the tragus of the ear and the condyle can be felt in its abnormal position.

Treatment.—Reduction should be accomplished immediately. Both thumbs of the operator are placed inside the mouth on the last molar teeth and downward pressure is made. Simultaneously the chin is elevated and backward pressure is made with the fingers and thumbs. The condyles will be felt slipping into their sockets with a click. The jaw should be kept closed for about ten days by bandaging and thereafter the patient should be told not to open the mouth widely at any time. It is wise to protect one's thumbs with bandage or adhesive plaster pads when doing this reduction, especially if the patient be excitable, otherwise the physician's thumbs may be bitten.

Scudder recommends the use of general anesthesia but this is rarely necessary. He also states that many cases will require that the mouth be opened further than it is by downward pressure on the chin and this having relaxed the lateral ligament allows easy reduction by direct backward pressure.

Old irreducible dislocations may require open operation with excision of the condyles. McGraw recommended a tiny incision through which he inserted a steel hook grasping the condyle. Traction on this hook reduces the dislocation.

Recurrent dislocation may be treated by open operation during which the meniscus is fastened to the periosteum.

DISLOCATIONS OF THE CLAVICLE.

Sprains of the acromioclavicular joint are more frequent than dislocations and often the distinction between sprain and dislocation here is impossible. In typical dislocation the outer end of the clavicle is displaced upward and outward. The acromioclavicular ligaments are ruptured, the conoid ligament and the trapezoid ligament are generally torn.

The dislocation is associated with accidents during which twisting has occurred and may be unsuspected until swelling disappears when the end of the clavicle is found protruding beneath the skin and separate from the acromion or resting upon it. A depression is seen in which the finger may be laid and an irregular multiangular appearance is given to the shoulder.

Reduction is simple in most cases but the maintance of reduction is very difficult. An adhesive plaster bandage well padded over the bony points of contact retains many of these reductions. It is best applied over the outer third of the clavicle and, passing downward, includes the tip of the elbow, which is pulled firmly upward. There should be a hole in the adhesive plaster where it passes over the tip of

Fig. 191.—Dislocation of the clavicle; outer end.

the elbow and very plentiful padding must be provided, else decubitus may result over the bony points. Authorities differ as to whether an anterior hollowing of the shoulders or an erect dorsal position of the shoulders favors reduction. It seems that if reduction is accomplished the anterior sloping shoulders favor the retention of the reduction, while if reduction is not complete the erect position favors gradual reduction.

In cases where soft parts are interposed it is necessary to do an open operation, clearing the joint and suturing the clavicle to the acromion with wire or chromic catgut.

Some cases may be retained in reduction by keeping the patient in bed and flat on the back, thus removing the downward drag of the weight of the arm.

Dislocation of the inner end of the clavicle may be forward, backward or upward. All forms are very rare and the result of violence to the shoulder.

The forward and backward dislocations may be reduced by pulling the shoulders backward against the knee placed between the scapulæ behind. Meanwhile pressure is made on the clavicle.

The upward variety is reduced by levering the shoulder outward by means of the humerus. A pad is placed in the axilla and the elbow forced against the chest. Manipulation of the clavicle is made simultaneously by a second person. Care must be exercised that the humerus is not broken.

Reduction is maintained with difficulty and it is sometimes best to fix the shoulder in the anterior sloping position with elevation of the shoulder on the affected side, combined with downward pressure over the clavicle.

Occasionally either the dislocation of the outer or inner end requires open operation with suture. This is only recommended where persistent pain in the back or arm indicates radical measures.

DISLOCATION OF THE RIBS.

This is a condition seldom seen but one which has been reported. The dislocation occurs between the head of the rib and the spinal column and is said generally to be accompanied by fractures of the spine, occasionally the rib is dislocated from its costal cartilage.

Treatment.—Treatment consists in the application of a strip of adhesive plaster, three and one-half inches wide around the entire chest at the level of the dislocated rib. It is of practically no advantage to apply the plaster around one-half of the chest only as this usually does not relieve the pain while the complete strapping makes the patient comfortable at once.

DISLOCATIONS OF THE COCCYX.

Dislocations of the coccyx may be caused by persons sitting down abruptly upon some unexpected projection. The diagnosis is made by palpation of an irregularity with tenderness on moving the coccyx. Rectal examination with the finger should be made in all suspected cases, as the dislocation is readily detected in this manner.

Treatment.—The finger is passed into the rectum and the coccyx is pushed backward into place. No further treatment is necessary except to make repeated examinations during the following week to see that the deformity has not recurred.

DISLOCATION OF THE SHOULDER.

Causes.—There is often a shallowness of the glenoid cavity with deficiency of the glenoid rim. There may be a lax capsule. This is the most frequent abnormality found in cases of habitual dislocation of the shoulder. Shoulder dislocation is most apt to occur in persons over twenty-one years of age and it is extremely rare in younger people.

Dr. Briggs, of Cleveland, states that only 1 per cent. of shoulder dislocations occur before twenty-one years of age while the largest number occur between the ages of fifty and seventy. The direct cause generally is a fall; the weight being caught on the hand or elbow which is often extended backward. Thus the weight of the body is suddenly transmitted to the head of the humerus in an anterior direction.

Pathology.—By far the largest number of dislocations at the shoulder are forward and inward dislocations of the head and many are subcoracoid in type. Dr. Briggs states that 98 per cent. of shoulder dislocations are of this variety. This has held true in our experience.

Fig. 192.—Subcoracoid dislocation of the humerus. Note the prominence of the acromion, the flatness of the shoulder, the line of the shaft of the humerus and the empty glenoid cavity.

Hey Groves classifies dislocations of the shoulder as:

1. Subcoracoid, in which the head is below the coracoid process upon the neck of the scapula.

2. Subclavicular, which is an exaggeration of the subcoracoid variety, and in which variety he states that the greater tuberosity and coracoid process are fractured or their muscles are torn. It is a rare condition.

3. Subglenoid, in which the head of the humerus rests beneath the glenoid process and the axillary vessels are compressed.

4. Subspinous, in which the head rests behind the glenoid process on the scapula below the spine.

5. The supracoracoid which is very rare and in which the acromion process is fractured, allowing the humeral head to rest above the glenoid and in contact with the coracoid process.

6. Luxatis erecta, in which the arm is stiffly extended above the head, and the head of the humerus rests below the glenoid cavity. In this dislocation (which the author has never seen), it is said that little damage occurs to the muscles or capsule.

Diagnosis.—In the common anterior variety the usual signs of dislocation are present with loss of function, spasticity of the shoulder muscles, restriction of mobility, active and passive; abnormal contour of the shoulder; the elbow is held away from the side and cannot be made to touch the side of the body when the hand is on the opposite shoulder; measurement around the shoulder is greater than normal and measurements from the acromion to the external condyle may be decreased. In the subglenoid type there may be lengthening of this measurement. In the ordinary types the soft parts fall away from the acromion in a sagging manner so that a straight edge placed along the outer side of the arm may touch the acromion process and the external condyle. The deltoid fulness disappears. By determining the direction of the humeral shaft and bearing in mind the position of the glenoid, it can often be noted that it is impossible for the humeral head to rest in the glenoid cavity. In fact, the humeral head is generally readily palpable beneath the pectoral muscle when the common anterior dislocation exists. Slight rotation of the humerus often helps in discovering the abnormal position of its head. In fracture of the surgical neck without impaction, rotation of the humeral shaft does not produce rotation of the head, so that when one is able to feel the head rotate with the shaft, there must be either a normal joint, a dislocation or an impacted fracture. Some cases of impacted fracture of the surgical neck cannot be differentiated from dislocations except by *x*-ray plates, but this condition is rare and as a rule dislocation is evident to the layman.

It may be difficult to diagnose the double condition of fracture with dislocation. Exact knowledge of normal joints and comparison of the doubtful joint with the opposite normal joint is of the utmost value.

At times a sort of vague crepitus may be felt in a dislocated joint where no fracture exists. This may be due to the fact that a torn piece of capsule is caught between the bones. The crepitus in such a case resembles a creaking more than a true crepitus.

Vigorous or rough "strong arm" examination should never be done, as such unskilled examinations may cause further and at times extensive damage to soft parts. In this way convalescence will be greatly lengthened and permanent loss of function may at times be attributed to rough examination.

Treatment.—The method of reduction by scientific manipulation as introduced by Kocher, of Berne, is so superior to all other methods that we do not use another. The method called "foot in axilla" is not only rough, but is not efficient and in strong hands is dangerous, for many surgeons have fractured the surgical neck of the humerus by using this method.

The method introduced by Stimson is valuable, but only after failure by Kocher's, as exact knowledge is not so necessary in Stimson's method. It is doubtful whether one skilled in reduction by Kocher's method would ever find occasion to use Stimson's method with success, although in difficult cases it might be tried. Reduction by sheer strength or force should never be attempted, as grave damage may result, such as rupture of nerves or vessels or fracture of the humerus or laceration of muscles.

Kocher's Method of Reduction.—General anesthesia is not necessary but it is a great help as it relaxes spastic muscles. The patient lies upon his back with the dislocated shoulder protruding over the edge of the bed. The operator stands on the side of the dislocation and with one hand grasps the dislocated humerus gently and firmly at the condyles just above the elbow. He grasps the wrist with the other hand, thumb uppermost. The patient's elbow is flexed to a right angle and the elbow is brought close to the side at the axillary line. The elbow is held thus while the humerus is made to rotate outward by carrying the patient's wrist outward, the elbow remaining flexed to a right angle. Outward rotation is made until considerable resistance is felt, thus relaxing the rent in the capsule. This outward rotation is maintained while the elbow is brought toward the nipple keeping close to the chest-wall. This position of the elbow is maintained while the humerus is rotated inward by placing the patient's hand on his opposite shoulder with a sweeping motion. Traction must have been made by pulling the condyles downward during all manipulations. A definite thud or click signals reduction. Care must be exercised that the surgical neck is not fractured. This may occur if the head of the bone has been entangled in ligaments or muscle.

Of course, the reduction is described in stages; but in actual practice the successive positions follow one another in a gradual and slow sweep.

After-treatment.—The forearm is supported by a sling which includes the hand. It is wise to apply cold compresses to the shoulder region for the first twenty-four hours to prevent great edema developing. As soon as it is possible passive motion is begun. In average cases this passive motion will be begun during the first week. In fact in cases where no great damage has been done to the soft tissues active movement is permitted at once.

Motion in abduction is to be encouraged and practised at the earliest possible moment, as this motion—*i. e.*, abduction of the arm—is the most difficult function to preserve fully.

A good plan is to have the patient stand beside a bookcase or victrola (or a piano later) and have him rest the elbow upon that object. He is then made to bend at the knees. The lower he bends the higher the arm is raised and abducted. When he has done the exercise 10 times he may be able to add the thickness of a book to the height of the victrola and next time he begins on the book and at the end of the 10 or 20 movements another book may be added. He then begins the next series on the two books and continues in this way. A great many old cases have increased the usefulness of their arms 50 per cent. by this simple exercise.

DISLOCATIONS OF THE ELBOW-JOINT.

Dislocations of the elbow-joint are frequently seen in children, resulting from the same injury that in adults results in dislocation of the shoulder, *i. e.*, a fall on the hand with the arm in the extended position. The usual condition is a backward displacement of both bones in which the coracoid process of the ulna comes to lie in the olecranon fossa of the humerus with the head of the radius behind

Fig. 193.—Fracture-dislocation of the elbow.

the external condyle. In adults the coracoid process is often fractured but in children it tends to remain intact. There is usually considerable laceration of the ligaments—the arm is flexed as a rule, although in the extreme backward dislocations the position of slight flexion is presented. The pull of the biceps muscle on the radial tuberosity generally produces supination although in an illustration of Ashhurst's reproduced in Brewer's *Text-book of Surgery*, p. 890, the forearm is held in pronation. This is an unusual position. The bony points about the elbow are abnormal, the tip of the olecranon being considerably posterior to its normal position and it is abnormally prominent. The head of the radius may be felt behind the external condyle. There is apparent shortening of the forearm; all motions are painful and restricted by a muscular spasm.

Treatment.—The backward dislocation is reduced readily by traction on the wrist, the forearm in supination and the elbow flexed. The operator's knee is placed in the fold of the elbow to secure countertraction. There is seldom any difficulty in accomplishing this reduction except in rare cases where the head of the radius and the coracoid process resist passage across the condyles. In these cases the forearm should be used as a lever to overcome the spasm of the brachial muscles. The treatment of the rare forward dislocation which is usually a complication of fracture of the olecranon is secondary to treatment of the fracture. If no fracture exists, flexion of the elbow over the operator's knee, combined with backward pressure applied to the forearm, accomplishes reduction with ease. Lateral dislocations are extremely rare and are treated in the same manner. General anesthesia assists materially in effecting these reductions. A plaster cast with the part in the fully flexed and supinated position is advisable in difficult cases, while simple cases will require nothing more than a sling to support the forearm.

DISLOCATIONS OF THE HEAD OF THE RADIUS.

The head of the radius is commonly dislocated forward; rarely it is dislocated backward or outward and in young children who have been lifted by the arm there may be a subluxation. Dislocations of the head of the radius are frequently associated with fracture of the ulna. In the forward dislocation the head or the radius is palpable in the antecubital space. There is a hollow just behind the belly of the extensors of the forearm where normally the head of the bone can be felt. Supination and flexion are impaired.

Treatment.—The dislocation is easily reduced by traction and manipulation but there is great difficulty in maintaining reduction. It is best retained by keeping the elbow in extreme flexion with a large pad in the crook of the elbow against which leverage is made on the proximal end of the radius. The forearm should be kept in supination and immobilized for ten days, at which time rotary movements should be begun, but full flexion should be maintained. After two or two and a half weeks, slight extension may be begun cautiously, as full extension tends to produce recurrence. When the dislocation is accompanied by fracture of the ulnar shaft, it is advisable to treat the ulna by internal fixation of some sort, since otherwise the dislocation of the radial head will recur and deformity of the ulna will result.

DISLOCATIONS OF THE WRIST.

Dislocations of the wrist are rare. They may be backward or forward and are generally caused by falls upon the hand and are often associated with Colles's fracture. The backward variety without fracture presents an appearance almost identical to the typical Colles's deformity and may require the x-ray for differential diagnosis. The forward dislocation is extremely rare but easily diagnosed by the prominence of the radius and ulna on the back of the hand.

Treatment.—Dislocation is reduced by direct pressure and traction and general manipulation of the wrist. The wrist should be immobilized by a splint of plaster of Paris in the position of dorsiflexion.

Fig. 194.—Fracture of the neck of the scaphoid bones. The upper fragment replaced after palmar dislocation.

DISLOCATION OF THE SEMILUNAR BONE.

Dislocation of the semilunar bone is a serious condition and often associated with fracture of the tip of the styloid process or with fracture of the neck of the scaphoid bone. The displacement is practically always forward. A prominence can be felt beneath the flexor tendons at the wrist and there may be tingling in the tips of the fingers over the median nerve distribution. An x-ray is necessary for the diagnosis which is often overlooked by the general surgeon even when clearly demonstrated by an x-ray plate.

Treatment.—Reduction of carpal dislocations is exceedingly difficult. The dislocation of the semilunar bone is best reduced by first making marked hyperextension of the wrist, combined with traction. Direction pressure is then applied to the dislocated bone while the wrist is gradually flexed. At times supination and pronation will assist and quite vigorous movements of the wrist may be necessary. Some carpal dislocations are quite irreducible. These should be treated by open operation and even with highly skilled operators, reduction is impossible at times. In these cases the offending bone should be excised and the wrist immobilized in the hyperextended position for about a week when active massage should be employed. Dislocations of the carpal bones should never be allowed to go unreduced longer than three weeks because after this time their normal site becomes filled with connective tissue, rendering reduction impossible. Cases of dislocation of old unreduced carpal bones must be dealt with by open operation with excision of the offending bone. It is our custom to leave a very small piece of rubber tissue at one end of the small incision for twenty-four hours so as to permit the escape of excess synovial fluid which would otherwise cause great pain. The wrist should be dorsiflexed and fixed in a loose plaster-of-Paris cast.

DISLOCATIONS OF THE HAND.

Dislocations of the hand at the metacarpophalangeal joint are fairly common and usually a single bone is dislocated. The basal phalanx of the thumb is most frequently dislocated backward. The primary condition is one in which the capsule is not ruptured but the thumb has merely been hyperextended and locked. The complex dislocation of the thumb is produced when the proximal end of the phalanx passes through the capsular ligament. This allows the thumb to lie in a parallel plane to its metacarpal bone. In reducing any backward dislocation of the thumb it is essential to maintain hyperextension until the proximal end of the phalanx is brought end-to-end with the distal end of the metacarpal at which time (and not before) flexion may be made. If the primary or so-called complete dislocation is treated by traction, it may be converted into the complex variety and as such presents greater difficulty in reduction. It is rarely necessary to make open reduction of this dislocation. Forward dislocations of the thumb-joint are rare and are reduced by direct pressure with traction, flexion and extension.

Dislocations at the Carpometacarpal Joints.—Dislocations at the carpometacarpal joints are seldom seen. They are easily diagnosed because of their subcutaneous position and are reduced by direct pressure and extension.

Interphalangeal Dislocations.—These are quite common, particularly of the terminal phalanx. This injury is commonly known as a "baseball finger." There is often splitting of the joint surfaces and it is due to this cause that the deformity results. They are reduced by direct manipulation and should be immobilized for about a week or ten days.

DISLOCATION OF THE HIP.

Anatomy.—Dr. Wm. W. Reid, of Rochester, N. Y., published a paper in 1851 in which he concluded that a dislocation of the femur on the dorsum ilii is reduced with the greatest ease in a few seconds or minutes without much pain, without an assistant, without pulleys, or any other mechanical means, simply by flexing the leg on the thigh, carrying the thigh over the sound one, upward over the pelvis as high as the umbilicus and then by abducting and rotating it.

In 1853 Dr. Moses Gunn, of Chicago, concluded that "The untorn portion of the capsular ligament . . . prevents its ready return over the edge of the cavity to its place in the socket."

Eight years later, Dr. Henry J. Bigelow, Professor of Surgery in Harvard College, did his classical dissection demonstrating the Y ligament which bears his name. He recognized "That the anterior portion of the capsular ligament . . . is so identified with the phenomena of luxation that reduction must be accomplished almost wholly with reference to it."[1]

The ligament of Bigelow (the iliofemoral, or Y ligament) is a strong, thick band of dense fibrous tissue, extending from the inferior-anterior spine of the ilium downward across the front of the joint and splitting about its middle into two bands, one of which is attached to the great trochanter and the other to the lesser trochanter. This ligament is really part of the capsular ligament, from which it cannot be separated. For this reason its demonstration is artificial. Its length is about five inches and in the average adult it will stand a strain of 500 pounds (250-750, Bigelow). The function of the ligament is to prevent hyperextension of the hip. The capsular ligament of the hip has several other thickened bands in it, one below, the pubofemoral, and another behind, the ischiofemoral, are worthy of mention, but have little bearing on dislocations.

The ligamentum teres is short and extends from the center of the head to the center of the acetabulum; it is very strong but is practically always ruptured in dislocations of the hip. It is of no importance in the mechanism of reduction, but undoubtedly prevents dislocation in many cases. The cavity of the acetabulum—the socket—is nearly a hemisphere. The acetabulum is rugged and overhanging above and behind. The weakest part in the rim is the lowest part where the bone is thin and the cotyloid notch is present. The head of the femur fits into the acetabular cavity so nicely and the soft parts make such competent valves that it is impossible for soft tissue to enter the cavity until the femoral head is removed. This fact tends to prevent dislocation of the joint since atmospheric pressure must first be overcome. The tendon of the obturator internus muscle passes over the neck of the femur posteriorly—if it remains untorn in backward dislocation, the femoral head does not, as a rule, pass up on to the dorsum ilii. When dislocation occurs the inferior posterior portion of the capsule is generally ruptured.

It is probable that the head of the bone leaves the socket at this point in most instances and is subsequently carried to one of the common positions by a continuance of the force causing the dislocation. Dislocation generally occurs when the thigh is flexed, abducted and rotated inward. Frequently dislocation results from a heavy weight falling on the back of a person in a stooping position.

[1] Quoted from Bryant and Buck—"American Practice of Surgery."

Incidence.—This dislocation generally occurs in individuals of early adult life and occurs eight times more frequently in men than in women (Brewer).

Classification.—The dislocation is termed forward or backward, depending upon whether the head is carried forward or backward in relation to the rim of the acetabulum. In either instance the primary mechanism of the dislocation is similar, *i. e.*, the capsule is torn below and behind (except in those rare cases in which the ligament of Bigelow itself is torn).

Backward dislocations are further divided into:

1. Iliac.
2. Sciatic.

The forward dislocations are:

1. Thyroid.
2. Pubic.

Occasionally the head of the bone comes to lie above the acetabulum or in the cotyloid notch or it may be carried as far as the perineum. These latter three locations are extremely rare.

Backward Dislocations.—1. *Iliac or Dorsal Dislocation.*—The head of the femur lies on the dorsum ilii and can be felt in the buttock. In order that it may come to rest in this position, the obturator internus must be stretched or ruptured. The small rotators of the hip are ruptured or contused—the trochanter is above Nélaton's line and is closer to the anterior superior iliac spine than usual. The iliotibial band is relaxed—the leg is shortened from two to three inches and is in flexion, adduction and inversion—the lower end of the dislocated thigh crosses over the lower end of the opposite thigh and its toes rest on the instep of the sound limb. The femoral head cannot be felt from the front.

2. *Sciatic Dislocation.*—The sciatic dislocation is merely the preceding stage of an iliac dislocation. The force has not been sufficient to rupture the obturator internus so that this muscle prevents complete displacement on to the ilium. The great toe rests on the dorsum of the opposite great toe rather than on the instep as it does in the complete dislocation. Shortening is not so great and rarely exceeds half an inch. In both of these backward dislocations shortening is always present. The foot is practically always inverted, the trochanter is practically above Nélaton's line.

Forward Dislocations.—Forward dislocation (thyroid and pubic) are distinguished from backward dislocations by eversion of the foot and abduction of the thigh. The head of the femur can be felt in Scarpa's triangle in front and in the pubic variety it lies just below Poupart's ligament and is easily palpable and generally visible as a rounded, hard swelling. It is felt with greater difficulty in the thyroid position and is about two to three inches below Poupart's ligament.

1. *Thyroid Dislocation.*—There is always lengthening and this is the only dislocation of the hips in which lengthening is found. The increase may be as much as two inches. The trochanter is below

Nélaton's line, the prominence of the trochanter is replaced by depression, the knees cannot be brought together without great pain and the limb cannot be fully extended.

2. *Pubic Dislocation.*—There is shortening, abduction and marked eversion so that the foot lies in the horizontal position on the bed, resting on the peroneal side. The prominence of the trochanter is missing, internal rotation is very painful, the knees cannot be brought together.

Irregular Varieties.—Great force may rupture the ligament of Bigelow and bring the head of the bone to lie near the anterior-superior spine of the ilium beneath the gluteus muscle. This is the extreme degree of iliac dislocation and in some cases is compound. The shortening is very great, as much as five inches being possible. The foot may be everted, the dislocated head is readily palpated, the diagnosis is self-evident.

Perineal dislocation may result after rupture of the ligament of Bigelow, the head of the bone being in the perineum where it is readily felt. There is often marked ecchymosis and there may be rupture of the urethra with extravasation of urine. The indefinite variety sometimes called infracotyloid dislocation is the initial stage of practically all dislocations in which the head of the bone escapes from the acetabulum and is not carried to a typical location. Central dislocation is very rare and is always accompanied by fracture of the acetabulum.

Complications.—The pelvis or the neck of the femur may be fractured by the initial force, or the neck of the bone or rim of the acetabulum may be fractured in attempts at reduction. In very rare instances the dislocation is compound and in these cases the dislocation is almost always the extreme iliac type, the perineal type or the pubic type.

In the pubic dislocation the femoral vessels may be ruptured; in the posterior dislocation the sciatic nerve may be stretched, ruptured or contused or looped around the bone.

Prognosis.—When the ligament of Bigelow is intact and when otherwise uncomplicated, prognosis should be good for complete functional recovery in a short time. When compound, the prognosis is doubtful, depending entirely upon the degree of infection incurred. Rupture of the femoral vessels is a serious complication but one should not expect gangrene of the leg after ligation of the vessels except in an infrequent case or in the aged or those with constitutional disease. If the patient is aged this lesion is far more dangerous than in the young adult. With rupture of the sciatic nerve, prognosis of functional recovery cannot be given, but with nerve suture it may be hoped for. With rupture of the urethra and extravasation of urine, prognosis is guarded and the bladder must be drained either by an inlying catheter or suprapubic cystostomy. Prognosis in old unreduced cases must depend upon the individual. Reduction is attended with considerable risk of fracture and often cannot be accomplished at all. In old thyroid dislocations a functioning joint is sometimes developed which permits considerable motion and no shortening. All the other dislocations yield very unsatisfactory results if unreduced.

Treatment.—Treatment consists in causing the head of the bone to retrace the path which it followed since leaving the acetabulum. In doing this one must beware of fracturing the neck of the bone and of entangling the obturator internus muscle or sciatic nerve. An anesthetic is practically always necessary and is always advisable unless definite contrary indications exist. It is unwise to make indefinite preliminary manipulations or to employ haphazard jerks and tricks since these efforts tend to increase the spasm of the muscles which is already present. If it is impossible to give a general anesthetic, morphin should be administered. The patient is placed upon his back and an assistant holds the pelvis so that it is immovable.

In the backward dislocations, i. e., those with inversion of the foot, the knee is flexed, the thigh is flexed in the position of adduction. The knee is brought well up toward the umbilicus and is then swung out so that the leg is in abduction and at the same time the leg is everted. At this point the head of the bone often snaps back into the acetabulum. The leg is then brought down straight in extension, abduction and eversion. During all these motions the resistance of the muscles must be overcome by a steady, strong pull, at all times in the long axis of the thigh.

The anterior dislocations, i. e., those in which there is eversion of the foot, the knee is flexed, the hip is flexed in the position of abduction and then is brought with a sweeping motion into a position of adduction. Simultaneously the limb is inverted and is then brought down straight in a position of adduction and inversion. At some point in this maneuver the head of the bone will be felt to snap back into the acetabulum. Steady, strong traction must be constantly made in the long axis of the thigh. These maneuvers may be employed in the irregular dislocations as well as in the orthodox varieties.

In the case of an *irregular dislocation* it is first reduced to one of the forward or backward varieties. The external iliac dislocation should be reduced as though it were a backward dislocation, the perineal as though it were a forward dislocation. Compound dislocations should be treated by operative cleansing of the wound and replacing of the bone. When fracture of the neck is present, it is generally necessary to do an open operation, replacing the head in young people and excising it in old people, after which treatment of the fracture assumes paramount importance. After the uncomplicated dislocations have been reduced, it is unnecessary to employ any retaining apparatus but the patient should be kept quietly in bed for a week or thereabouts when he may be allowed to walk about with crutches. It is wise to keep the limb reasonably quiet for a few days so as to obviate any possibility of an embolus originating from a possible thrombus which may have formed in the vein from injury or pressure. Passive motion should then be begun gently and gradually increased until active movements are possible. It is unwise to fix the hip overlong or to allow the patient to become lazy, in which event lameness may persist for months. It is wise to have old people ambulant as soon as they have recovered from the shock of their misfortune, so that they will not contract static pneumonia.

Congenital Dislocation of the Hip.—Congenital dislocation of the hip differs from acquired dislocation in that the joint is insufficiently developed. The acetabular cavity is very shallow, particularly in its iliac segment so that there is very little superior rim. This makes it impossible to hold the head of the bone in the cavity by ordinary means. In addition to this, the head of the bone is poorly formed and in many cases is entirely absent. The angle of the neck of the femur is greater than normal (coxa valga). In some cases the superior rim of the acetabulum is not only deficient but is developed in an abnormal position on the ilium. The acetabulum is often filled with fat or connective tissue. The capsule is stretched and thickened and is attached to the false joint which is generally above and behind the true acetabulum but which is occasionally in front.

Incidence.—It is the most important of all congenital dislocations. Eighty per cent. of cases occur in girls. Both joints are involved in about 30 per cent. of the cases.

Diagnosis.—The child begins to walk late and deformity is seldom evident before walking begins. The gait is waddling, the child rolls from hip to hip as it walks. There is marked lordosis and prominence of the buttocks. The hips are very broad and the perineum is widened. The belly becomes prominent, even protuberant, due chiefly to the lordosis, which is almost entirely confined to the lumbar spine. In unilateral cases scoliosis is also present and the heel of the affected side is not habitually allowed to touch the ground. There is no pain, as a rule, but after walking there may be lameness and aching which sometimes is referred to the back. The thigh is kept in slight flexion and adduction and is slightly inverted. All motions except abduction are usually well performed. There is shortening of from one to three inches. The trochanter is above Nélaton's line and it is farther from the midline than the normal trochanter, *i. e.*, the hip is broadened. There is generally a sort of hollow near the origin of the adductors. The hip is freely movable except in adduction, which is limited. In early cases the shortening is easily overcome by traction on the limb but in older cases where the abnormal joint has become well organized, traction has little effect on the length of the limb. The head of the bone may sometimes be felt on the dorsum of the ilium and is always absent from its normal location. There may be attacks of recurrent synovitis in older children or in adults. An *x*-ray of the pelvis which includes both hip-joints should always be taken and this will demonstrate the lesion nicely. The condition is easily differentiated from tuberculosis of the hip-joint by the absence of night cries, the absence of fever, the painless motion of the joint and the prominence and breadth of the buttocks.

Treatment.—Treatment is rarely undertaken in children under two years of age, and there is no advantage in earlier treatment. Between the age of two and eight it is wise to practise the method of Lorenz, the so-called "bloodless operation." The child is anesthetized, reduction is accomplished by manipulation which often requires great strength on the part of the surgeon. The adductor muscles are ruptured near their origin by heavy kneading or striking the tense tendons with the edge of one's hand—other muscles which prevent the abduction, extension, flexion or rotation are likewise ruptured by stretching or kneading. Many surgeons prefer to make subcutaneous tenotomy rather than forcible rupture of the muscles. Reduction is accomplished by traction in the axis of the thigh and manipulation, and the limb is then fixed in extreme abduction by a plaster spica and the abduction is maintained for from six to eight months. It is a good plan to fix both thighs in extreme abduction (by plaster casts) even when only one hip is deformed and to keep this position for at least three weeks. At this time in unilateral cases the double cast may be removed and a single abducting spica applied. The child is allowed to run about and play as much as it will, in fact the more the child uses the leg the better and more quickly does the proper joint develop. An *x*-ray must be taken of the hip shortly after reduction with the cast in place to prove that the head of the bone is in proper relation to the pelvis and if good reduction has not been accomplished the cast must be removed and reapplied after further manipulations. This is very important. Abducting casts must be worn for from eight to eighteen months or else relapse may occur—or even if no relapse is suffered the functional result may not be satisfactory. If these measures fail the open method of Hoffa should be employed. This consists in making an incision from the anterior superior spine downward and backward passing behind the great trochanter. The capsule is exposed and opened, the soft tissue which may fill the acetabulum is removed, the head of the dislocated bone is examined and shaped if necessary and is placed in the prepared acetabulum. In case of an extremely shallow acetabulum the superior margin may be turned down with a chisel, making a rather substantial rim of bone. Transplantation of bone may be done in order to deepen the acetabulum. A transplant from the tibia is usually used as a wedge to turn down a superior rim from the ilium. It may be necessary to do osteotomy of the femur in order to correct the coxa valga. The wound is closed and the limb fixed in a fully abducted position with a slight amount of flexion. The abduction should be maintained by a plaster cast for six months at least.

DISLOCATIONS OF THE KNEE.

The knee is rarely dislocated and only as the result of a severe injury. Many of the dislocations are compound and the injury is very serious. The tibia is dislocated either forward, backward or laterally and in rare cases in a rotary fashion. The deformity is gross and the diagnosis evident from inspection. In all varieties the popliteal vessels and nerves are always tensely stretched and may be ruptured. Gangrene of the leg may result from occlusion of its blood supply or paralysis may follow injury of the nerve supply. The crucial ligaments are always ruptured. Prognosis is grave, the joint seldom recovering perfect function and practically never recovering good function when the dislocation has been complete. Twenty to 25 per cent. are compound and in these there is danger to life and many amputations follow ordinary treatment.

Treatment.—Reduction is simple, by traction and direct pressure. The leg should be immobilized for several weeks in the slightly flexed position. When ruptured, and when the condition is uncomplicated, the crucial ligaments should be sutured by opening the joint. They can be reached either by splitting the patella or by an anterior horseshoe incision, dividing the patellar tendon or making a jig-saw entrance through the patella. Compound dislocations of the knee should be treated by primary cleansing, revision and immediate suture of damaged structures. Active motion should be encouraged from the first, provided no tension exists in the joint. No tension must be allowed to exist in the joint and if tenesmus develops the joint should be opened. When sepsis supervenes the joint should be immobilized. The circulation of the leg must be watched very carefully and if the pulse in the dorsalis pedis or posterior tibial arteries cannot be felt, external heat should be supplied to the leg below the knee. The entire leg should be slightly elevated to allow venous drainage; massage should be used (except where joint sepsis exists) with the purpose of maintaining viability while a collateral circulation is developing—gangrene seems to follow obstruction of the popliteal more frequently than it does obstruction of the femoral artery. Special attention must be paid to this feature in the aged.

DISLOCATION OF THE PATELLA.

Dislocations of the patella are rare and the patient is not usually seen while the dislocation persists. Spontaneous reduction or reduction by the patient or a friend is usually accomplished before the surgeon arrives.

The common type is a recurrent lateral dislocation in which the patella slips over the ridge on the lateral condyle and comes to lie at the outer side of the knee. It occurs during unusual muscular effort, as in catching one's self while slipping.

Pathology.—The lateral parts of the anterior capsule are sometimes torn and always placed under undue tension. The stretching or tearing of the capsule engenders a synovitis which is noticed early (within a few hours). The synovial fluid may amount to more than 60 c.c. excess of and if tearing of ligaments has occurred it may be bloody. There is often a discoloration of the skin over the side of the knee, generally over the inner anterior aspect resulting from subcutaneous hemorrhage. It may not appear for two days or thereabouts. If the synovitis is not interfered with, the effusion is absorbed after fifteen to twenty-one days, leaving a lax capsule. This is due to the fact that repair of the capsule takes place while it is under tension and consequently its normal tone is lost. It is this fact that tends to produce habitual dislocation. In cases of slight effusion into the joint, or where a large excess of fluid has been removed by aspiration, the capsule undergoes repair in its undistended condition and recurrence is not so likely.

Symptoms and Signs.—There is a history of sudden pain, loss of function, a click or a jar in the knee and the appearance of a lump (or the knee-cap) on the side of the knee. Shortly afterward the lump snaps back into place or the knee-cap is pushed back. There is pain on active and passive motion and the joint swells. It becomes inflamed and painful. Palpation reveals tenderness about the capsule in front and laterally and if seen after effusion has appeared the patella floats.

The *x*-ray shows the condyles separated from the tibial head and the patella held away from the condyles.

Treatment.—If seen in the primary attack the joint should be aspirated amid strictly aseptic surroundings, bearing in mind the fact that an infected knee-joint is a very serious condition. A large caliber needle such as used for spinal tapping and a glass syringe will serve very well. It is a good plan to incise the skin with the point of a scalpel before inserting the needle as this lessens the possibility of introducing organisms into the synovial cavity. This is not necessary but it is a wise precaution. A preliminary infiltration with local anesthesia is the custom although this causes more discomfort to some sturdy individuals than does the single stroke of the large needle.

The author performed in a period of two weeks aspiration of 60 consecutive knee-joints without infection or untoward effect and, in all, has performed aspiration in upward of 250 cases without infection. The majority of these were cases of synovitis secondary to dislocated semilunar cartilages (*vide infra*).

If the case is not seen until after the second or third recurrence aspiration is not advisable because the ligaments in these cases are hopelessly stretched, and only open operation with pleating of the capsule will do any good. It is a good plan to defer operation until the seventh to fourteenth day after the accident as then the tissues will have regained their normal blood supply and resistance. Meanwhile the knee should be immobilized, preferably in plaster of Paris.

DISLOCATION OF CARTILAGES OF THE KNEE.

The cartilages of the knee are semifixed to the tibia—the internal being the more stable of the two. Each cartilage is attached to the tibial tuberosities at its ends and by small vertical ligaments. The internal semilunar cartilage is semicircular and moves only slightly on rotation at the knee-joint while the external cartilage is almost circular and tends to follow the external femoral condyle in rotatory movements. The internal cartilage has attachment to the internal lateral ligament and the capsule, while the external cartilage is more separate from the capsule—the tendon of the popliteus muscle passing between. There is an extension of the true joint synovia beneath both ligaments.

The function of the ligaments is to present a slightly flexible socket for the condyles and to serve as an elastic brake in rotation which comes into action before the crucial ligaments actually check rotatory motion.

Thus in strenuous twisting of the leg or in kicks which have been misjudged, the internal ligament is likely to be torn away from its moorings. This happens far more frequently than does dislocation of the external cartilage since the latter has a greater normal range of motion. The twist of the slightly bent knee causes most of these dislocations.

Hey Groves states that dislocation of the internal cartilage is twice as common as that of the external. In our experience the percentage is even larger.

Pathology.—In recent cases there is effusion into the joint, often of a hemorrhagic character but sometimes the fluid is clear. All degrees of dislocations may be found from simple rupture of the vertical ligaments to complete detachment of the cartilage. In some cases the cartilage is rolled or doubled back on itself or a fragment may be detached and loose or a strip may be torn from the edge. After a while the capsule of the joint becomes somewhat thickened and the dislocated cartilage may become frayed or tags may be thrown off.

Diagnosis.—There is sudden pain in the knee-joint, generally on the inner side near the lateral ligament. The knee may be locked in slight flexion or there may be a grating in the joint on motion or the patient and surgeon may feel a click on motion—sometimes the joint is not locked when seen but if the knee is moved locking may be produced. Locking is a common symptom in recurrent attacks. These patients may learn how to unlock their joints but locking can seldom be produced voluntarily. Synovitis occurs after a few hours and may be demonstrated by the floating patella and the visible outline of the subcrural pouch above the patella—occasionally one can feel a defect over the normal site of the displaced cartilage. In other cases the cartilage can be picked up between the fingers and moved in abnormal degree on the tibia.

In a great many cases no physical sign can be noted except the effusion and tenderness to palpation and occasionally the tenderness may be absent. The *x*-ray is not of great value in demonstrating the lesion although a folded or rolled cartilage may be demonstrated.

Treatment.—Reduction is easily accomplished in practically all cases by manipulation. The thigh and knee should be flexed to a right angle, the patient lying on his back. The operator stands beside the bed on the side of the dislocation; one elbow is hooked underneath the popliteal region, the other hand grasps the dorsum of the foot—upper traction is exerted by the arm under the knee—at the same time in the case of the internal cartilage the leg is abducted at the knee (not at the thigh). This causes some separation between the internal condyle and the internal articular surface of the tibia. The foot and leg are everted. This relaxes the anterior crucial ligament which often holds the dislocated cartilage in the intercondylar notch. In *resume* the knee will be flexed while knock-knee is produced together with eversion of the tibia. The hand which grasped the dorsum of the foot is now replaced by the ulnar side of the elbow which maintains the eversion and the fingers of this hand manipulate the region of the internal cartilage while the knee is passively extended. When fully extended the pressure producing the knock-knee is relaxed, the internal condyle of the femur is allowed to rest on the internal articular surface of the tibia and the internal semilunar cartilage and active flexion and extension are allowed.

In this way practically all dislocations may be reduced easily, without inflicting further damage on the cartilage. A posterior splint should then be applied and ice-bags placed about the joint so that effusion will tend to be minimized. On the second or third day if the effusion is great and the joint is tensely distended, it is our custom to tap the joint, withdrawing from 15 to 60 c.c. of fluid. By this means the ligaments are allowed to relax and the process of repair occurs without stretching. When repair occurs in a tense distended joint the cartilage does not become firmly anchored in its normal position and recurrence is the rule, while if repair occurs with the femoral condyles pressing the cartilage against the tibia, recurrence is not so likely. We do not recommend tapping the knee-joint by any one but a practised surgeon under the strictest antiseptic conditions.

A splint should be worn six weeks and the joint firmly bandaged with adhesive plaster. Aspiration of the joint is of no value in recurrent cases since the ligaments are already stretched.

In recurrent dislocations where two or more definite attacks have been suffered, and where a definite diagnosis of detached or split cartilage has been made, it is best to open the joint by a transverse incision directly over the detached cartilage. The knee should hang over the edge of the table in the flexed position, since the cartilage can be easily felt. The incision need be only one inch or one and one-half inches long and the knife which cuts the skin should be discarded before opening the joint. If a perfect cartilage is simply displaced it may be sutured in place but if the cartilage is grossly damaged or disorganized, it should be excised and if there is any defect in the cartilage the joint should be carefully searched for any loose bodies. The synovia should be closed with fine catgut and one or two stitches of silkworm gut or horsehair placed in the skin. A posterior splint should be worn for a few weeks afterward, when the patient should be allowed to use the limb.

DISLOCATIONS OF THE FIBULA.

This condition is very rare and practically always occurs at the upper end, only a few cases being on record of dislocations occurring at the lower extremity. The upper end of the fibula may be dislocated forward, backward or upward, usually as the result of direct violence in the first variety, the pull of the biceps muscle in the second variety and indirect violence in the upward type. The diagnosis is evident by inspection and palpation, there being deformity and often ecchymosis with pain.

Treatment.—Treatment consists of reduction by direct pressure combined with inversion of the foot and in stubborn cases the foot should be kept in inversion by the use of a splint. Flexion of the knee tends to relax the biceps muscle and the maintenance of this position may be of material assistance in retaining reduction.

DISLOCATIONS AT THE ANKLE.

Anatomy.—The ankle-joint is a very strong joint due to its definite mortise arrangement and to the many strong inelastic ligaments surrounding it. The strong tendons of the leg muscles surround it on all sides and assist in providing stability. The lateral ligaments are thin and rather insignificant. The posterior tendon of the flexor longus hallucis crosses it. The relative strength of the ligaments is shown by the position of the bulging which is seen in synovitis. This bulging appears first in front beneath the extensor tendons and in front of the lateral ligaments, since here the capsule is weakest. In more extensive effusions the bulging is noted on either side of the tendo Achillis. Bulging is practically never seen beneath the lateral ligaments, thus demonstrating their strength. The ankle-joint proper allows only of extension and flexion and no lateral mobility except in extreme extension when lateral mobility is barely perceptible.

Dislocation at the ankle-joint is nearly always associated with fracture of the lower end of the tibia or fibula or both bones. The astragalus may be dislocated backward, forward, outward and upward. The dislocation is rarely of a pure type and the most common form is due to a sudden twisting of the foot; either eversion when the luxation is outward or inversion when the luxation is inward. In simple dislocation without fracture, one or other of the lateral ligaments and sometimes both are ruptured. In the outward type following eversion the internal lateral ligament is ruptured, and *vice versa* in the inversion type. In complicated cases the fracture of the fibula is generally two or three inches above the joint. This occurs with either outward or inward luxation when the external lateral ligament remains intact. The outward luxation with fibular fracture is Pott's fracture. In Pott's fracture the fibula is fractured two or three inches above the malleolus, the deltoid ligament is torn and the tip of the internal malleolus may be torn off. The tendon sheaths are injured, sometimes torn, the astragalus is rotated outward so that the foot is in marked outward eversion, the inferior tibiofibular ligaments remain intact. When the tibiofibular ligaments rupture with consequent separation of the lower ends of the tibia and fibula, the injury is known as Dupuytren's fracture. In this case there is widening of the ankle-joint and considerable lateral mobility results.

Inward dislocation is accompanied by rupture of the external lateral ligament or by fracture of the tips of the external malleolus, in which case the lateral ligament remains intact, the internal lateral ligament or deltoid ligament is generally intact but often the tip of the internal malleolus is fractured. The inferior tibiofibular ligament remains intact practically always. The foot is found in a position of eversion.

The *upward dislccation,* which is very rare, is usually associated with Dupuytren's fracture in which extreme separation of the tibia and fibula occurs. The anterior and posterior ligaments are ruptured but the lateral ligaments remain intact as a general rule. Obviously the inferior tibiofibular ligaments are ruptured and there is actual shortening of the leg and great increase in the width of the ankle-joint. This injury occurs in falls from a great height, in which the individual alights flat upon the soles of the feet.

In the *backward and forward* dislocations the astragulus is replaced either behind or in front of the tibia. The anterior and posterior ligaments are both torn and very often the lateral ligaments as well. These two forms are often associated with fracture of the fibula two or three inches above the malleolus and usually there is fracture of the inner malleolus as well. It commonly happens following a jump from a moving vehicle. In *backward dislocation,* which is the most common, the foot appears shortened, the heel unusually prominent, the tendo Achillis is tense, the malleoli are in an anterior position. In *forward dislocations* the opposite conditions exist, *i. e.,* the foot is lengthened, the heel is less prominent and the malleoli are displaced backward. The astragulus can be felt in front of the tibia.

Treatment.—Normal relations of the foot are restored easily. In lateral dislocations the treatment is exactly the same as for Pott's fracture. The upward dislocation is a very difficult one to treat efficiently after reduction, particularly if it is complicated by fracture. It is very important to reëstablish the lateral stability of the joint by compression of the malleoli. Very heavy pads of saddler's felt should be placed on each malleolus and great care must be taken to adjust lateral compression so that necrosis of the skin over the malleoli shall not occur. In anterior-posterior dislocations the knee should be flexed to relax the tendo Achillis, and in this way reduction will be facilitated. Sometimes extreme extension of the ankle allows reduction, particularly in the backward variety where the edge of the tibia rests in the notch over the neck of the astragalus. In dislocations where no fracture has occurred, immobilization need not be retained more than ten days, when massage should be begun as recommended by J. B. Mennell, of London. The ankle should invariably be immobilized, when necessary, in a position of dorsiflexion, making an angle a little less than a right angle with the leg. This is the most inflexible rule of position.

Dislocations of the Astragalus.—The astragalus alone may be dislocated by falls from a height or a twisting of the ankle. The dislocations are: (1) Forward and outward; (2) forward and inward; (3) backward; (4) rotatory. Of these types, the forward type is the most generally seen and is differentiated into the outward and inward type by the position of the foot. In the forward and inward type the foot is generally everted, the astragalus being palpable just in front of the internal malleolus; in the forward and outward type, the foot is inverted and the astragalus is palpable just in front of the external malleolus. In the backward type the bone is generally felt on either side of the tendo Achillis and the tendon is tense. In all of the simple dislocations of the astragalus the foot itself is not markedly deformed. This is particularly true in the rotary displacements.

Treatment.—Generally the dislocation can be reduced by direct pressure over the bone combined with traction on the foot and countertraction at the flexed knee. Frequently cases are seen, however, which defy closed reduction even under anesthesia and in these, open reduction must be done, using a curved incision. If open reduction cannot be accomplished—which rarely happens—the astragalus must be excised completely. We have never found it necessary to make the excision in the simple condition, but following compound dislocations one should have little hesitation in excising this bone in its entirety.

Subastragaloid Dislocations.—The astragalus remains with the tibia and fibula; the scaphoid and os calcis are abnormally separated from the astragalus, the foot is generally displaced obliquely backward and inward or backward and outward. The forward subastragaloid dislocation is described but very rarely seen. Fracture of the malleoli quite often accompanies the dislocation which frequently follows twists of the foot.

Diagnosis.—Flexion and extension of the ankle are little impaired but active inversion and eversion are very painful and limited. The foot seems to be shortened and the malleoli are extra prominent. Sometimes it is associated with fracture of the astragalus.

Treatment.—The knee is flexed, strong traction is made on the foot and countertraction made on the end of the fibula.

Other Dislocations of the Tarsus.—The medio-tarsal joint may be dislocated, the cuboid and the scaphoid being separated from the astragalus and os calcis. The cuneiform bones may be dislocated individually or as a group. The tarso-metatarsal joint may be dislocated in any direction or the individual bones may be dislocated.

Phalanges.—The phalanges are very rarely dislocated owing to the protection they are normally afforded by shoes. Diagnosis in all these small bone dislocations which are subcutaneous is very simple by palpation and inspection.

Treatment.—They are replaced by direct pressure and traction and are held in place by splints.

DEFORMITIES OF THE UPPER AND LOWER EXTREMITIES.

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DEFORMITIES OF THE LOWER EXTREMITY.

DEFORMITIES OF THE HIP.

Congenital Dislocation of the Hip.—This, although comparatively infrequent, is the most important of the congenital deformities of the hip, and unless corrected, occasions a life-long disability which may be grave. It is more common among females than males, although it occurs among males in the proportion of 1 to 20 cases. The cause is unknown, but it is prenatal. Originally it consists of a laxity at the joint due to a defect in the cartilage and periarticular ligaments so that the head of the femur is not held firmly in place, slipping out easily. This is not noticed in early infancy, but when the patient begins to stand and the pelvis slips down, not being supported by the femoral head and its support in the acetabular socket, strain falls in consequence upon the ligaments attaching the pelvis to the femur, which become altered, the capsule becomes stretched covering the acetabulum and by alteration in growth eventually checks the entrance of the head into the socket. Alteration in the inclination of the neck of the femur, and the shape of the head and of the acetabular rim all follow, as well as a twist in the upper part of the femur, the head pointing forward, while the great trochanter falls back of its normal position.

Two most important changes take place, first, abnormally strong and short ligamentous attachment between the lesser trochanter and the acetabulum so that the femoral head cannot be pulled down to the socket; secondly, a contracture of the neck of the capsule through which the femoral head cannot be pushed. When an attempt is made to do this, the capsule and not the head fills the acetabulum (Fig. 195.)

The affection is easily recognized when the patient begins to walk, from a peculiarity in gait, especially marked in double deformity. There is a marked hollow back. When the patient stands on the affected leg, lifting the other, the pelvis drops on the other side, the cleft of the buttock is not held vertical but is inclined pointing toward the affected side. The vulva also on the opposite side drops when the patient stands on the affected limb. These characteristics are naturally more noticeable in the heavier child and may not be as recognizable in infants beginning to walk. In these later cases, there is little difficulty in recognizing an undue laxity in an attempt to pull the leg down. On palpation, the femur can be felt out of its normal position and above it.

Fig. 195.—Lordosis accompanying double congenital dislocation of the hip untreated.

The motions of the limb in the joint are normal; there is no pain and the patients are active. The diagnosis can be confirmed by an x-ray picture (Fig. 196), but the sign of the femoral head and the shape of the acetabulum are not accurately defined as there is usually an abnormal amount of cartilage and a delayed ossification in these structures.

The adductor muscles become shortened as well as the fascia lata, especially the iliotibial band.

Treatment.—The method to be employed varies with the age of the child and the resistance of the abnormal tissue.

In the rare instances where the affection is recognized in infancy, recovery may sometimes take place if the hip is reduced and the femoral head kept in place until the tissues have reformed normally around the reduced head. This is only possible when the capsular opening in front of the dislocated head is sufficiently large to permit a normal reduction without folding in the capsule.

For the purpose of holding the head in position, a fixation traction splint of service in the treatment of hip disease is preferable to a plaster-of-Paris fixation as much more effective, less cumbersome and more cleanly in a young infant.

FIG. 196.—*X*-ray of congenital dislocation of the hip.

In young children able to walk but not old enough for the development of great resistance of obstructing tissue, reduction by skilful manipulation is usually easily accomplished.

Various methods of manipulation are of service, the underlying principles of all being to stretch the resisting tissues, the adductor muscles, the shortened iliofemoral and capsular ligaments, while the latter are stretched to prevent crumpling of the capsule in front of the entering head to push the head through the capsule neck into the acetabulum.

The limb should be forcibly abducted (after a strong pull downward during the abduction). One of the surgeon's hands should be placed above the great trochanter with the thumb pressing on the tissues above the femoral head. The trochanter should be pressed downward to prevent any riding upward during the manipulation. After the tissues are thoroughly stretched, the limb should be held at the lower part of the thigh by the operating hand and the head pressed forward and downward by pressure upon the trochanter from the surgeon's other hand. This, combined with a slight twisting motion given to the limb, will cause the head to slip into place easily in the less difficult cases.

A convenient method is as follows: The patient lies face downward upon the operating table, with the affected limb hanging loosely over the edge. The limb is grasped above the knee by the surgeon, who places one hand on the patient's trochanter and sacrum. Suitable manipulation can in this way be carried out with the pelvis held well fixed, not always easily secured if the patient lies upon his back.

In more resistant cases, a mechanical aid will be found to give greater precision and better applied force.

Of the various mechanical devices, one thoroughly tested at the Boston Children's Hospital, Boston, will be found to be of use because of its portability and effectiveness.

In the most resistant cases, more radical measures are needed: (1) To divide the capsular neck which prevents the entrance of the head into the acetabulum and is too strong to be stretched by the entering head. (2) To correct any bone deformity which prevents cure.

The first can be accomplished by cutting down upon the neck near the dislocated head, which opens the capsule, dividing the capsular construction with a herniotome, holding the enlarged capsule open, passing the head through this into the socket and finally stretching the redundant part of the capsule around the neck of the reduced head, to form a firmer collar to hold it in place.

If occasionally the head is misshapen and cannot fit into any acetabulum from a conical shape or undue flattening, in very rare instances the acetabulum itself is distorted and in many cases the acetabulum is more shallow than normal from imperfect ossification, but as a cartilaginous rim remains after reduction and the pressure of the head in the joint, a more normal acetabulum may be expected to develop in time.

In many instances after the reduction it is found that there remains a slight distortion due to a flattening or a twist of the femoral neck, leaving what is known as coxa vara or coxa valga. In a majority of these cases in young children this condition rectifies itself in time by growth after reduction and restoration of normal joint function.

In older and exceptional cases, operative interference as is indicated in rachitic distortions to be described later, may be needed to establish a normal condition.

It has been thought that a marked twist of the femur when the trochanter falls back of its normal position as the individual stands with the foot pointing straight forward is incompatible with a proper reduction of the hip and favors relapse.

In view of the fact that the twist has been found to be present in many normally functioning hip-joints, the difficulty can be remedied by high osteotomy after reduction and before the patient attempts to walk.

The after-treatment following reduction demands care and attention for a period varying from twelve to eighteen months in order to secure the best results.

The most important fact in establishing a permanent cure is the position in which the limb is placed for several months after reduction. The limb should be held so that the muscles on regaining power will not pull the head out of the socket and also that it be so held that no contraction shall remain of a character to dislocate the head as the limb is brought to its normal position for normal walking. This position will vary to a degree according to the nature of the twist of the neck, the shape of the head and of the acetabulum, but in the main it may be said that the best position will be with the femoral head pressed well forward in the socket with the thigh strongly flexed and strongly abducted, and with the knee flexed. The patella should not face upward as the child lies on its back, but forward. This is more awkward but it is superior to the latter in that it does not require any twisting of the femur when the leg is brought down to the normal vertical position needed in standing and walking, and for this reason does not pull on the ligaments (torn in reduction), around the capsule, shortened by cicatrization in a way to throw the head out of the socket.

The length of time the limb remains in a plaster bandage naturally varies; from three to six months being usually needed. The bandage at the end of a few weeks should be bivalved to provide for inspection of the limb without disarrangement of the position of the limb which needs to be held well fixed in the desired position. Massage and some careful voluntary movements may be allowed at the end of six weeks or two months.

Stiffness at the joint gradually diminishes after the unconfined use of the limb is allowed and as the limb by its own weight drops under the drag of locomotion to the normal vertical position, although several months may be needed for the restoration of free motion.

Soutter, of Boston, in the after-treatment of his and many of Dr. Bradford's cases, recommends removing the anterior half of the cast after two months in increasing amounts, to allow flexion but not adduction of the hip but retaining the abducted plaster for crawling. Finally after the leg is strong and crawling is easy with the plaster and practiced six to eight hours daily, the plaster is removed and the patient crawls without the plaster one-half an hour twice daily. Crawling is a safe position as there are at least three points on the floor. The crawling is increased gradually to eight hours daily. In about ten months after the operation the patient stands for the first time. The legs then will be found equally strong and able to resist dislocation; since using this method very few relaxations have occurred. There has been no stiffness and progress is practically uneventful.

Rachitic and Structural Deformities of the Femoral Head and Neck.—These deformities are as a rule the result of the yielding of growing bone to the unusual strains incident to various conditions surrounding the life and conditions of infant activity (Fig. 197).

These can be classed as rachitic deformities although they may occur in individuals showing no other signs of rachitis. They are of two types, known as coxa vara and coxa valga.

Fig. 197.—Rachitic deformities with fractures.

Coxa Vara.—This not uncommon deformity may be bi- or unilateral and in the marked cases is characterized by a slight peculiarity in gait; a slight limp if the affection is unilateral or a roll in gait in bilateral cases. There may in severe cases be occasional pain, but as a rule, the affection is painless (Fig. 198).

In young and growing children, mild grades of this deformity can be expected to be corrected by healthy tendency of growth to a normal type but the severe forms can only be corrected by operative interference.

Not infrequently the flattening of the neck is accomplished by a twist in the neck recognized by the fact that the trochanter falls back of the normal line of the transverse axis of the pelvis when the patella faces forward or the foot is pointed straight to the front; also when the thigh is flexed to right angles, the femur, if a twist of the femoral neck is present, is twisted and the knee is turned to one side. There may also be limitation to inward inversion of the limb.

Fig. 198.—Coxa vara.

In coxa vara the trochanter is higher than normal as is recognized by marking a line from the anterior superior spine to the middle of the tuberosity of the ischium (Nélaton's line), the thigh being flexed at right angles, normally the top of the great trochanter is below this line; in coxa vara, it is above it. In unilateral cases there is shortening of the limb. The affection may on a superficial examination be confused with a congenitally dislocated hip but the mistake is impossible if an x-ray picture is made. Furthermore, in a coxa vara the pelvis does not drop on the opposite side if the patient stands on the affected limb.

Treatment.—Where the coxa vara interferes with abduction of the hip, it is treated by an oblique ostectomy through the lower part of the trochanter, done on an operating table with traction, the leg is then abducted 55 degrees and put up in plaster with forcible traction, holding the leg until the plaster is dry. The patient is allowed up in five weeks and walks on the leg with apparatus in six weeks. After that the apparatus is gradually removed.

Coxa Valga.—This is a deformity more rarely met than coxa vara, which it resembles in being of a rachitic nature and from which it differs in that instead of a flattening of the neck, the angle of the neck to the femoral axis is increased. There is usually also a twist of the neck.

There is slight peculiarity in gait, which is awkward. Palpation in marked cases would show that the trochanter is lower than normal, but ordinarily a skiagram would be required to detect the increased obliquity.

In most of the cases of young children correction may be expected to take place from the effect of growth, but in advanced cases, operative interference will be needed to overcome the deformity.

Hip Flexion Due to Contracture of the Soft Tissues in Poliomyelitis and Other Conditions.—Transplantation of the Hip Flexors, Origin Downward.—When deformity at the hip is due to the soft tissues an operation should be done for this. When it is due to bone, an osteotomy is indicated as described under Ankylosis of the Hip.

Hip flexion due to contracture of the soft tissues comes from habit of position, from contracture of the muscles, from lack of growth, from scar contracture or from injury. Instead of cutting the muscle and resisting fascial bands that maintain the deformity, transplantation of the hip flexors was devised by Dr. Soutter and is done as follows:[1]

The patient lies on his back. *First Step:* An incision is made one and one-half inches posterior to the anterior superior spine and extends vertically upward one and one-half inches and downward three inches. In a small patient the incision would be proportionately smaller. This incision goes through the fat down to the layer of fascia which in paralytic cases is usually quite deep. The fat is dissected off the fascia posteriorly allowing the operator to feel the trochanter through the fascia. The tissues are next dissected forward and retracted exposing the anterior superior spine. *Second Step:* The fascia is incised from the anterior superior spine backward to just off the top of the trochanter. These tough fibers being relieved, much of the flexion can be overcome but not enough without relieving the tension of the tendons attached to the anterior superior and inferior spines. *Third Step:* An osteotome is used to remove a very slight amount of bone from the anterior superior spine. The periosteum is now removed with an osteotome from the outer side of the crest and from the inner side of the crest of the ilium back about two inches. The osteotome is used as an elevator to clear the periosteum from the anterior spine and below it, including the inferior spine. A large sponge is used to push the periosteum and the muscles down as far as they will go. The crest of the ilium will now stand out. Any extremely sharp points may be removed. The operator turns the patient slightly on the opposite hip, places a towel over the buttock and stretches the leg backward. As he does this he may feel through the wound for any resisting fibers. The fat is sutured with interrupted chromic catgut and the skin with continuous chromic catgut. When the dressing has been applied, further stretching and hyperextension will often be necessary in extreme cases. A plaster-of-Paris spica bandage is now applied over a generous amount of sheet wadding with felt pads

[1] Soutter operation.

over the sacrum and over each anterior spine. The plaster reaches in front from the nipple line to the toes, behind from just above the top of the sacrum to the heel. The plaster should be reënforced over the side and front of the hip and over the sides of the abdomen so that a large round window may be cut exposing the whole of the abdomen from the pubic bone to the sternum. The patient lies on a Bradford frame which is covered one-half way with canvas. The canvas supports the buttocks and the chest and head. The legs drop through the Bradford frame to the bed and the frame is supported at each end off the bed. The hip should be adducted slightly and hyperextended about 30 degrees; after six weeks in this position the patient is gradually allowed to get up with whatever braces are necessary to hold any deformities below the hip. Two hours each day the patient should be put in this hyperextended position for about one year.

Fig. 199.—*X*-ray of tuberculosis of the hip untreated, with dislocation and destruction of the head and neck.

Deformity of the Hip with Ankylosis.—In hip disease, after carious destruction which consumes the affected head and a portion of the acetabulum combined with chronic muscular spasm which crowds the femur upward, a subluxation of the hip-joint takes place, with the limb in a position of greatest protection from jar, viz., flexion and adduction. In cases where recovery from the osteomyelitis progress takes place, bone cicatrization takes place, with ankylosis of the hip-joint and the limb in a deformed position sometimes subluxated.

The only relief for this condition is by osteotomy of the femur in the lower part of the great trochanter (Fig. 199).

Treatment.—Operative interference in these cases when needed consists of the division of bone by a subcutaneous slightly oblique osteotomy. For the best results in these cases the patient should be free from disease at least two years. A traction operating table should be used. Traction is applied, the osteotomy performed obliquely through the lower portion of the great trochanter. After cutting the bone the traction is increased, the leg put in a position of 35 degrees of abduction and in slight hyperextension. While the traction is still applied a plaster-of-Paris spica bandage is applied from the nipples to the toes with a few turns above the thigh of the good leg. The plaster should be well reënforced over the groin and side of the leg and front of the chest. A large abdominal window is cut to remove all pressure over the abdomen, the back of the plaster is removed above the pelvis. Large felt pads over the sacrum, anterior spines and front of the chest, and about the knee will make the plaster more comfortable; opiates are necessary for one or two days. In bed the plaster below the hip rests on a chair and the leg is slightly hyperextended. In five weeks the patient is stood up, and the plaster is cut away below the knee. After learning to walk with crutches a smaller plaster is applied and later a leather for part of each day for at least a year.

The writer prefers linear osteotomy done subcutaneously in a direction and in a location varying with the deformity, as being more simple and causing less shock than the more complicated operation requiring a removal of a section of bone.

There is little difficulty for any one familiar with the use of an osteotome to make a complete section subcutaneously. The osteotome should be drawn directly through the skin down to the bone and entered through the cortex, and then by changing its inclination sideways with each blow of the mallet, a wide division of the inside of the shaft is made. After this is done, the osteotome can be withdrawn slightly and the cortex divided on its outer surface.

If the osteotomized limb is placed in a corrected position there will be left a wedge-shaped gap between the fragments at a certain part in proportion to the amount of correction; this will be filled with blood clot which will favor organization and the development of new bone filling the gap and giving in time a strong bone with a corrected position of the limb. Under proper aseptic precautions this procedure is devoid of danger.

The site and direction of the osteotomy varies with the case; it should be done as high up as possible. If the operation is carefully done there is no danger of increasing any stiffness of the joint.

When an ankylosis is present, no motion can be expected to follow a linear osteotomy, but the limb may be brought down nearly to its normal length, and if placed in a slightly abducted position with an ankylosed hip, the normal practical length may be secured through the tilting of the pelvis.

Deformity Following Arthritis Deformans (Morbus Coxa Senilis).—Albee Operation.—When there is much deformity and pain following bony proliferation about the hip the pain often is incessant night and day, as the condition occurs in those past middle age, and extensive operation is undesirable. The limited usefulness of the hip and the pain is relieved by removing a quadrilateral piece of bone from the acetabulum and upper part of the head of the femur. The osteotome is driven inward and slightly upward; in chiselling the acetabulum while in going through the head of the femur the slant is increased upward, this prevents the head from slipping out in weight-bearing and assures ankylosis in an abducted position. A plaster cast is worn for six weeks, the patient being allowed to get up in two weeks, the pain disappears entirely but the hip is stiff.

FIG. 200.—Bowing of the femur.

Curved Femora.—This condition is seen not infrequently in rickets. In young children, in mild cases this can be expected to be corrected by normal growth but in the severer type, osteotomy is necessary to correct the curve. This is true also of curved femora from union in faulty positions after fracture (Fig. 200).

Treatment.—A linear osteotomy is done and faulty alignment corrected, the leg being held in plaster. For the consideration of overlapping fractures, see Section on Fractures.

DEFORMITIES AT THE KNEE-JOINT.

Knock-knee.—A rachitic change at the lower end of the femur and upper part of the tibia, one or both, gives rise to an awkwardness in gait and a disfiguring deformity. The inner condyle is lower than the outer condyle, which gives an obliquity to the plane of the joint which, in standing, throws the knee-joint to the inner side of the normal vertical line of the leg and thigh (Figs. 201 and 202).

Fig. 201.—Rachitis. Knock-knees.

Fig. 202.—Knock-knee.

When the leg is flexed at right angles with the thigh, the leg falls into normal anteroposterior plane of the thigh axis, but when the leg is straightened it is deflected obliquely outward. When the limb is flexed on palpation the inner condyle will be found to project beyond the outer. A slight femoral twist is sometimes added and the condition may be associated with coxa vara and curved femora or with coxa valga.

Treatment.—The conservative treatment, which in very young children can be carried out with success, consists of the use for six months or a year of an apparatus which permits correcting outward pressure upon the inner condyle with counterpressure on the trochanter and ankle. This pressure, if continued for a sufficiently long period, aids the normal tendency and growth to normal type.

This treatment is valueless in older children about four to six. The apparatus used should be light and simple, permitting locomotion. These conditions are met by the type of an ordinary Thomas knee splint, secured to a shoe socket and furnished with straps, connecting the outer upright with a pressure pad to press the inner condyle outward.

An application with a single outside upright can also be used. It is necessary to arrange semicircular steel bands above and below the knee in the Thomas splint to provide for proper pressure. This application if worn continuously night and day would bring about more speedy correction than if used only a part of the time, but as there are manifest disadvantages in the constant use of the appliance, and as reliance for correction is to be placed chiefly in directing the growth of the bone rather than direct correction of an existing deformity, the use of the appliance a part of the time daily is more practical than its constant use.

The continued use of corrective plaster-of-Paris bandages is often used but, as it prevents locomotion or makes it difficult, the method is inadvisable in a very young child.

Operative Treatment.—Linear osteotomy is a simple, safe, and effective surgical procedure for the correction of knock knees. The osteotome should be entered on the inner side of the lower end of the femur just below the tubercle of the adductor tendon insertion. The bone is divided through three-fourths of its width and there broken.

Some surgeons prefer inserting the osteotome on the outer side and there is little choice in the two methods. The operation should be done without dissection. The leg is held in a well fitting plaster-of-Paris dressing from the toes to the thigh on the femur and, if desired, may include the pelvis. The bone should be held overcorrected, a bow-leg should be made a slight knock-knee, and *vice versa*. The plaster is changed the fifth week and a lighter plaster applied. Walking is then allowed with the plaster on or with corrective apparatus for six months, during which time the patient is to have proper diet for his age with orange juice, and periods of rest during the day.

Genu Varum (Bow-legs).—This condition is the reverse of genu valgus and is usually associated with curvature of the tibia in the condition commonly known as bow-legs to be described later. In pure genu valgum, *i. e.*, when the condition is confined to the vicinity of the knee what has been said above as to the treatment of genu valgum is equally applicable to genu varum if it be borne in mind that the correction desired is in a reversed direction (Fig. 200).

Giving these children an ordinary boy's tricycle to ride during play hours will in many cases produce an almost perfect correction of this deformity in a few months in connection with proper feeding, putting the child to bed early each day and providing hygienic conditions without the use of orthopedic treatment, the correction being brought about by the use of the muscles in running the tricycle.

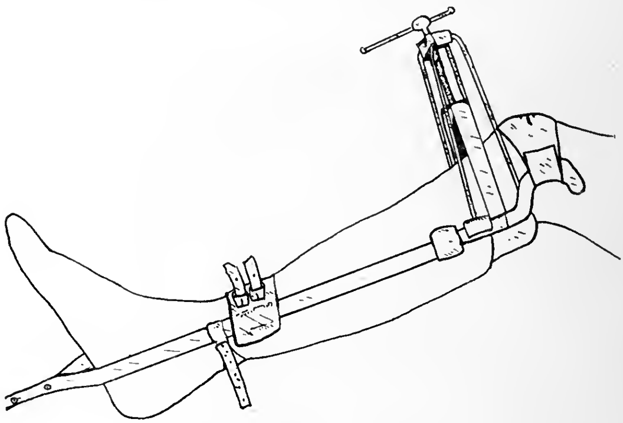

Fig. 203.—Genuclast. (Goldthwait.)

Flexed and Ankylosed Knee.—Following osteomyelitis of the knee, unsuccessfully treated, an ankylosed and flexed knee may result.

The correction of the deformity in young children may be made by manual forcible straightening followed by fixation in a plaster-of-Paris bandage, followed for a long period by the use of the Thomas caliper splint to prevent relapse after locomotion.

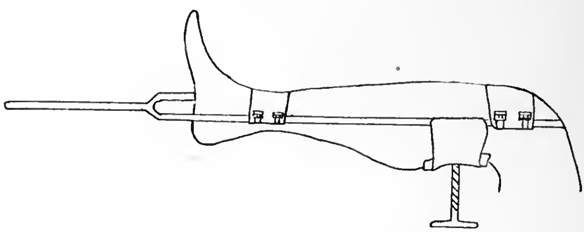

Fig. 204.—Genuclast.

There is little danger that the manipulation if carefully done, will reawake a latent osteomyelitis of any importance.

In some cases the condition is accompanied by a subluxation of the tibia, which must be corrected before straightening the limb. This can be done manually in the lighter cases or in the more resistant cases by the aid of a mechanical device depicted in Figs. 203 and 204. The procedure for the correction of flexed knee is more readily done with the patient lying upon the face with the table serving as a point of resistance for the knee and the leg as a lever. In this way any amount of power can be applied to stretch or tear adhesions.

Treatment.—In case of bone ankylosis a linear osteotomy close to the line of the joint is simpler and fully as effective as more complicated procedures.

Plastic operations to give motion at the knee have given less satisfactory functional results than those obtained in other joints.

Fig. 205.—Congenital hyperextension of knee and contracture of hip.

Genu Recurvatum (Hyperextension of the Knee).—A rare congenital deformity of the class occasioned probably by malposition *in utero* (Fig. 205).

The lower extremity, instead of being straight and capable of flexion, is bent upward at the knee and is incapable of flexion.

In infancy the deformity is easily corrected under ether. The limb should be fixed in a slightly bent position and held so for a few months.

In older cases where malformations in the shape of the bone have been developed, osteotomy may be needed to bring the plane of articulation to its normal place.

In these cases the patella usually is misplaced; the quadriceps is shortened and the posterior capsular ligaments lengthened.

Slipping Patella.—Owing to a laxity of the ligament which connects the patella with the tibia and to the undue length in some cases of the ligamentum patellæ the patella is less firmly held in position than normal and liable to be dislocated, slipping to the outside. The accident occurs when the limb is slightly bent and with the knee in a knock-knee position. The sudden contracture of the quadriceps would tend to pull the patella to the outer side. It slips with a snap, the limb becomes useless until the patella is pushed back into its normal position, which is easily done.

Where these attacks are frequent, surgical intervention is necessary. The affection is seen chiefly among young women or girls.

Treatment.—In mild cases under systematic gymnastic exercises, a normal condition in growing girls can be brought about, but in the severer cases, the use of the knife is necessary for a cure.

If the ligamentum patellæ is long, a reef can be taken in it. It is desirable also to broaden its attachment on the tibia. This can be done by splitting the ligamentum patellæ, the outer half is detached subperiosteally from its attachment to the tibia. It is then passed under the inner half which is still fixed to the bone. The patella is displaced slightly inward while the lower end of the outer half of the tendon is attached to the inner side of the tibia by means of silk suture if necessary. The operation is done without opening the joint. A reef may be taken in the inner capsule of the knee-joint below and to the inner side of the patella. Plaster is applied and the knee immobilized for four weeks. Walking is then encouraged and slight flexion of the knee several times a day. Exercises are increased daily until the leg is strong. The results are very gratifying.

Poliomyelitis, Muscle and Tendon Transplantation. (See Hip Deformities, Knee Deformities, Feet Deformities and Deformities of the Upper Extremity).—Transplantation of muscles and tendons is done in paralytic conditions, when unparalyzed muscles causing deformity may be transferred to take the place of paralyzed muscles and so improve locomotion.

Unopposed unparalyzed muscles may often be spared and transferred to perform the function of paralyzed muscles or partially paralyzed muscles that cannot perform their function on account of lack of strength. No muscle or tendon transplantation should be done until the patient has had a thorough chance to recover function. Muscle training ought to be used and at least two years should elapse from the time of the paralysis before any such operation. Also any deformity or contracture should be corrected and the muscles thus hampered should be given a chance to return before any transplantation is done. No one who is unskilled in operating or unconversant with the mechanical action of the muscles should undertake these operations. The selection of the muscle to transplant and the position for insertion must be chosen with care.

The general principle in muscle transplantation is to get as straight a pull as possible in a direct line. For this purpose, the tendon to be transplanted is freed below and the muscle dissected up one-half of its length. The position for insertion is chosen in a direct line above it, and an incision is made.

A subcutaneous tunnel is made from this point to the position of insertion. This tunnel is made large enough to hold the transplanted muscle. A subcutaneous tunnel is made from the incision in line with the insertion to the muscles to be transplanted. This muscle is brought forward, a number fourteen or number eighteen braided silk is quilted up one side of the tendon and down the other, being careful not to split the tendon in the process of applying about six quilted sutures on each side of the tendon. The two silk strands now reach below the tendon and serve not only as a method of inserting it to the periosteum below, but also make it long enough to reach to wherever it is intended to go. The tendon and its silk prolongation is pulled through the tunnel down to the position selected for its insertion. It is here quilted into the periosteum, using a short heavy periosteal needle. Before doing a transplantation, all deformities should be corrected.

Fig. 206.—Poliomyelitis equinus.

Fig. 207.—Poliomyelitis apparatus to aid in locomotion, with complete paralysis of both legs.

Muscle and Tendon Transplantation. After-treatment.—Plenty of padding is applied about the leg or arm. A well fitting plaster-of-Paris bandage is applied and split on the two sides so that the front or back half may be removed for inspection of the dressing on the fifth and tenth days. A plaster is worn continuously for six weeks after operation. A brace is used to immobilize the joint after the sixth week and the plaster reapplied at night. After six months the plaster is omitted but the brace used for from nine to fourteen months, depending on the strength of the muscle. The muscle transplanted should be trained for its new function. This may be begun at the fifth week after operation, the plaster being removed for this purpose and replaced after each lesson. The arc of motion should be small and the strain slight with the muscle training at first. As the muscle acquires strength the brace is omitted more and more. Following the above directions, one or two hamstrings may be transplanted to act as a quadriceps. To reënforce a weak or paralyzed quadriceps the sartorius may be transplanted. The insertion of any of these muscles is made into the patella and tied; the silk is next made into the tibia below. The long flexor of the toes or the peroneus may be transplanted for toe-drop and inserted into the middle of the tarsus in front or slightly to the inner or outer side as the case requires. The peroneii may be transplanted to reënforce a weak or paralyzed tendo Achillis.

Paralyses of the Quadriceps. Transplantation of the Hamstrings for Partial or Total Paralysis of the Quadriceps Extensors of the Knee.—Transplantation of the hamstring is made as described for transplantation of the peroneii excepting that the insertion of the silk is made into the patella and tied and then again into the tibia and tied. When the sartorius is transplanted it will of itself reach to the patella. The quadriceps extensor is sutured to it and may be made to overlap at the patella.

Bartow Silk Ligaments at the Knee.—For a flail-knee or a paralytic case, with a very weak quadriceps, Bartow silk ligaments may be inserted as follows: A drill is passed through the femur one-half inch or one inch outside of the patella through the joint and out through the tibia and skin over it; the knee is held straight for the purpose. A number fourteen or eighteen silk doubled is now passed into the drill hole and the drill withdrawn. The drill is now passed with the silk from the upper skin hole subcutaneously to the lower skin hole. The two silk ends now protrude together. They are now tied firmly, their ends cut and then allowed to slip under the skin. A plaster is applied for six weeks. After that a protective splint is used for two to four months, allowing a little motion at the knee. With these ligaments the knee is more useful for weight bearing. A little motion is allowed by the ligaments but not enough to a'low the knee to bend and give way under the patient.

Anterior Bowed-legs.—This rachitic deformity consists of a curvature of the tibia and fibula according to certain well defined types. The most common is a gradual outward curve most marked at the junction of the middle and lower third of the leg, or at the middle. In some instances the femur is also involved and there may be in addition a genu varum. The curve may be complicated by a forward bending of the tibia. This latter condition may be the chief curve and the deformity is not a bow-leg, but the so-called saber leg (Fig. 208).

Treatment.—The condition of bow-legs is very common in infants and should give no cause for anxiety, as under normal conditions growth tends to a normal type. The same is true of slight curves in young healthy children. When the curvature is marked it interferes with normal locomotion and is disfiguring; surgical treatment is demanded. Treatment by apparatus in these cases is as a rule ineffective.

Curves can be corrected by repeated plaster-of-Paris bandages, but at the imminence of impaired locomotion and weakening of the tissues.

Fig. 208.—Anterior and lateral bowing of tibia.

The Thomas caliper splint can be adjusted with proper pressure straps or an apparatus effective only below the knee extending inward and if necessary backward; pressure over the part of greater curvature with counterresistance at the inner condyle and inner malleolus.

The simplest and best method for correction is by operative interference. This can be effected either by osteoclasis or osteotomy. This is so readily done in young children that it is preferable in such cases. After the fracture the limb is pulled straight and put up in a plaster-of-Paris bandage which should extend to the hip.

In all of the more resistant cases, osteotomy is to be employed, the bones being partly divided three-fourths of its diameter by a linear osteotomy and broken manually as the limb is straightened.

There is no danger of splintering or shearing in the bone and the procedure may be regarded as devoid of danger.

There is no need of dissection down to the bone as an osteotome which will divide bone can easily penetrate the soft overlying tissues and there are no anatomical hindrances to the entrance of the osteotome.

In case of anterior curves, the bone should be divided in the concave position and the limb pulled straight, some force being needed in some cases to correct the curve. In larger children, or adults, a small wedge of bone is removed, enough to allow correction of the anterior curve. If the gastrocnemius is shortened, a tenotomy of the tendo Achillis will correct this.

Paget's Disease.—This affection, which may be regarded as the rickets of old age, gives rise as a prominent symptom to curved tibia with some forward bending. Other bones are affected with a combination of rarefaction and condensing osteitis. The bones bend under the superimposed weight of the erect attitude. The spine is bent and the figure shortened.

In extreme cases the curve may be so great as to impede locomotion and threaten fracture, which rarely occurs. Union after fracture takes place as in normal bone. The affection is painless as a rule. No satisfactory treatment has been suggested. Apparatus is of little value and operative interference is inadvisable.

Chondrodystrophy.—A congenital defect occurs by which there is a defect in the development of bone *in utero*. The nature of this is unknown. The trunk grows normally but there is an abnormal shortening of the long bones, particularly of the femur. The humeri are also shortened in typical cases. The affection is more commonly bilateral, but unilateral cases are seen.

Congenital Absence of the Tibia.—This is a rare affection. It is usually associated with a curved condition of the lower extremity, the foot articulating only with the fibula turned to the inside.

Treatment.—The remedy which has been usually recommended for this condition is the insertion of the astragalus between the fragments of the fibula after splitting the lower end of the latter. But a more satisfactory method has been recently employed by Dr. Soutter who replaced the absent tibia by the insertion of a longer graft of bone removed from the tibia of an older sister.

Congenital Constriction.—Rarely, a congenital deformity is seen due to the constriction *in utero* of abnormal amniotic bands. The corion is altered and appears as a string partly around the leg. Linear deep division of the constricted bands will make a more normal growth of the limb possible. Wolf skin grafts are sometimes necessary to fill in the gaps in the skin and fat.

DEFORMITIES OF THE FOOT.

Congenital Deformities.—The most important of these is the well-known club-foot, talipes equinovarus, which is a prenatal displacement of the tarsal bones forming the midtarsal joint, the front of the foot being turned inward and upward at the astragalus, scaphoid and calcaneo-cuboid articulations. There are changes in the shape of the bones and alterations in the length of the ligaments and muscles giving the movement of the front of the foot (Figs. 209 and 210).

Fig. 209.—Equinovarus.

Treatment.—The important question in regard to club-foot is that of treatment, which varies according to the age and extent of the deformity. The simplest and most practical treatment in early infancy is correction by the repeated application of plaster bandages with manual foot correction while the plaster bandages are hardening. Correction should be made first from the varus position to that of equinus, then to the equinovalgus position and finally the raising of the front of the foot to a position of calcaneus.

Much care and patience and some technical skill is needed in the application of suitable plaster bandages, with proper protection of the skin from chafes and undue pressure.

The process of correction and overcorrection can be aided by subcutaneous tenotomy of the tendo Achillis, and in some cases of the plantar fascia as well as the internal lateral ligament and the abnormal intertarsal ligament connecting the displaced scaphoid on the inner side with the astragalus or internal condyle.

If these resistant tissues are divided, manual correction and overcorrection of the deformity are easily made by stretching forcibly the remaining resisting tissues. By manipulation, the foot should be brought to a nearly flaccid condition in which it can be placed with the exercise of but little force, in an overcorrected position, that is, with

Fig. 210.—Club-foot.

the outer edge raised, the toes pointing out and the front of foot raised. Plaster-of-Paris bandages should be worn constantly until the bones have adjusted themselves and there is no danger of relapse. This is indicated by a normal gait and normal tread. The heel should strike the ground normally as well as the ball of the great toe and there should be no undue pressure in walking, on the outer border of the sole of the foot.

To prevent the rolling of the leg inside of the plaster bandage, it is necessary to apply it above the knee with the leg flexed at the knee.

During a later stage of convalescence carefully adjusted apparatus can be used in place of plaster-of-Paris bandages.

In adjustment of the sole of the boot, a wedge on the outer part of the sole is serviceable in securing a normal tread while the muscles have not yet recovered the normal balance.

In older and more resistant cases it is a waste of time to attempt correction of talipes equinovarus without some form of operative intervention (Fig. 211).

The simplest of these is forcible wrenching of the foot into an over-corrected position after division of the retracted and contracted soft parts either subcutaneously or by open incisions.

Fig. 211.—Equinovarus. Club-foot.

Manifestly where this division can be thoroughly done subcutaneously (as this involves no dissection and incisions of innocent soft tissue) this is to be preferred to a method of open incision. Subcutaneous tenotomy of the tendo Achillis is, as has been demonstrated by the teaching of several generations of surgeons, done simply and effectively and is much to be preferred, when no reefing of the tendo Achillis is needed to divide the tendons after open incision. The same is true of divisions of the superficial plantar fascia.

When the os calcis is tilted, as it usually is in club-foot, Dr. Obers' operation is of great value in older children and in adults. (see p. 334.)

No matter how thoroughly the shortened fascia ligaments and tendons may be divided, a certain amount of stretching force is also needed to correct the deformity. This in the more resistant cases is more than can be applied manually, though manual stretching is needed also.

The best way to employ correcting manipulation is to place the anesthetized patient upon his face on the operating table with the limb flexed at the knee. The leg is to be grasped below the ankle with one hand, and with the other, the front of the distorted foot is held. Pressure can be exerted by the palm of the manipulating hand aided by the thumb and fingers, whereby correcting pressure can be exerted downward upon the front of the foot and the displaced cuboid while the foot is held twisted outward. The knee resting upon the table gives resistance while the surgeon's weight can be thrown as a correcting force. When the os calcis is twisted and held in a faulty position, this can be relieved as well as the correction of the varus deformity helped by detaching the ligamentum attachment at the internal condyle.

Various forms of wrenches have been used to aid in correcting club-foot. The one depicted in the accompanying illustration will be found of use in the more resistant cases (Fig. 212).

Fig. 212.—Thomas's club-foot wrench.

In older cases, changes in the shape of the bones take place of a character to interfere with correction. This is chiefly in the os calcis and astragalus; the facet of the scaphoid articulation of the latter is more on the inner side than normal and faces somewhat downward with a corresponding distortion of the neck. In addition the plane of articulation of the cuboid with the os calcis is changed so that if the cuboid is placed in its normal position, anterior to the os calcis, the bony irregularity of the os calcis is such that it would tend to slip back into the position of distortion. This can be obviated by removing a small wedge-shaped piece of bone from the anterior part of the os calcis and also by an osteotomy of the neck of the astragalus. If this is properly done, correction can be made complete.

The deformity of club-foot, talipes equinovarus, is an eminently curable one, *i. e.*, correction with a permanent restoration of function, but few procedures demand for success more careful attention and detail in the after-treatment.

Operations for Club-foot.—In the infant, when manipulation performed daily does not gradually stretch out the deformity, a tenotomy of the plantar fascia and of the tendo Achillis is done as follows: The skin of the left foot is prepared for operation in the usual way. The patient is anesthetized. The operator manipulates the foot with the hand or with a foot wrench or both. After this a tenotome is inserted through the skin just to the inner side of the plantar fascia. The tenotome is slid across the plantar surface of the foot between the skin and the plantar fascia. When the tenotome has reached well across the foot the blade is turned toward the plantar fascia. By a sawing motion the fascia is cut fiber by fiber without cutting the structures under this fascia. The sensation is like that of cutting celery. When all of the fascia fibers are cut the foot is stretched again correcting the adduction of the foot and the equinus. After the deformity is well stretched the tendo Achillis is cut subcutaneously by a tenotome. The operator grasps the ball of the foot in the left hand. This allows him to stretch or relax the tendon. The tenotome is passed through the skin just forward of the tendon on either the outside or the inside of the foot. When it has entered the tissues under the skin, the tendo Achillis is relaxed by the surgeon. The tenotome is next passed under the skin posterior to the tendo Achillis. When it has reached the other side, the tendon is tightened by the surgeon and the blade of the tenotome is pressed against the tendon and by a sawing motion the fibers of the tendon are gradually cut through. The last few fibers are torn, for the operator is constantly pressing on the ball of the foot, while he is cutting the tendon.

Zigzag Tenotomy.—The operator may cut the tendo Achillis as above described with the following modification:

When the tenotome has reached the opposite side of the tendon it is cut half through. The tenotome is next withdrawn partly so that the tendon may be cut on the proximal side half way through. The tendon is stretched and tears between the two cuts. The operator is careful to cut the tendon at one level on one side and from one-fourth of an inch to one-half of an inch higher or lower on the opposite side. A plaster-of-Paris dressing from the thigh to the toes, well padded especially about the os calcis, is applied, holding the foot in a valgus position with dorsal flexion. The foot should be abducted about 25 degrees, dorsally flexed 30 degrees and the cuboid raised. In four weeks the patient is allowed to walk.

Tenotomy of the Plantar Fascia.—The foot having been prepared for operation, the operator takes a small tenotome and with the finger easily passes it through a puncture to the inner side of the plantar fascia about the middle of the foot or a little posterior to the plantar fascia.

The operator grasps the ball of the foot in one hand, which enables him to tighten or loosen the plantar fascia at will. As he slides the tenotome between the skin and the plantar fascia he relaxes the fascia until the tenotome reaches the outer side of the foot. He then turns the blade downward and by a gentle sawing motion cuts the fibers of the plantar fascia with the tenotome. The fibers of the plantar fascia are made tight by pressing on the ball of the foot. When all of the fibers have been cut, which can be felt through the sole of the foot, the operator repeats the above-described manipulation, gaining as much as possible.

In order to walk with the foot in this position, a wedge of wood or plaster is applied under the foot. Six weeks after the operation the plaster is removed and the foot manipulated daily to maintain the overcorrection. The plaster is continued for nine months, being changed as often as necessary. After nine months the shoe is used with a wedge under the sole, tilting up the outside of the foot especially at the cuboid.

Bone Operation for Equinovarus.—When there is much bony deformity resisting correction, a small wedge is removed from the astragalus to allow the dorsal motion of the foot and from the forward end of the os calcis when more eversion is necessary. These bone wedges should be removed only when sufficient correction is not possible by tenotomies and manipulation as above described.

Patients under five rarely need bone operations. When the os calcis is tilted outward maintaining the varus position, the deformity is apt to recur unless this is corrected and maintained overcorrected.

Ober Operation for Club-foot.—When the os calcis is tilted the ligaments and fasciæ at the inner malleolus are lengthened as follows: An incision is made two inches above the internal malleolus downward to the tip and curving slightly forward two inches. The tissues are dissected up exposing the internal malleolus. The periosteum is incised along the anterior border of the malleolus upward one or one and one-half inches from its tip. The periosteum is likewise incised along the posterior border of the internal malleolus upward for one or one and one-half inches. These incisions are connected at the top. The periosteum is now raised carefully with an osteotome from above downward; when the tip of the malleolus is reached the osteotome tips down under the malleolus, lifting the ligaments with the periosteum from the malleolus and from the tarsus below, for one or one and one-half inches. The osteotome is now used to raise the periosteum along the anterior periosteum incision. The periosteum is here raised from the tibia continuously with the ligaments. The cut edge of the periosteum sticks to the bone, gently raising the anterior end of the malleolus and from the contiguous portions of the tarsus. In like manner the periosteum is raised from the posterior periosteal incision and the os calcis, the surgeon being careful to stick to the bone not uncovering the tendons from their sheaths behind the malleolus. When the periosteum is raised from the malleolus and the contiguous portions of the astragalus, os calcis and scaphoid, as above described, the deformity may be stretched and overcorrected manually. The incision is closed by stitching the subcutaneous fat and then the skin by chromic catgut sutures number 00. After stretching the foot and overcorrecting the deformity, the tendo Achillis is tenotomized as described above. The after-treatment has already been described. In paralytic equinovarus the deformity is corrected by tenotomies or bone operation as the case requires. In these cases the deformity is only slightly overcorrected. When the tibialis anticus is very strong and the cause of the deformity, it may be transplanted to the middle of the tarsus and inserted here by heavy quilted silk sutures. When the ankle has good lateral stability, this transplantation is usually sufficient to maintain the corrected position of the foot.

Club-foot Paralytic.—When however there is an equinovarus deformity and the ankle is laterally flail, an astragalectomy with displacement of the foot backward (Whitman operation) is to be recommended.

Fig. 213.—Paralytic club-foot.

For a flail-ankle or a weak ankle or extreme calcaneus, a brace is necessary to prevent strain. An astragalectomy with displacement of the foot backward would give good lateral stability, and usually one-third to two-thirds of the normal upward and downward motion of the foot and a brace will not be necessary (Fig. 213).

Congenital Equinovalgus Calcaneus.—These congenital forms of the malposition of the front of the foot are rarely of sufficient importance to demand the surgeon's attention. They are not uncommonly seen in newly born infants and can be expected to correct spontaneously with the natural growth of the infant. In cases where this is delayed, plaster-of-Paris bandages can be used to hasten the process.

A congenital equinus deformity is rarely seen. What has been said of the other deformities is equally true of this.

Older, uncorrected cases of these deformities if met can be treated by operative measures, tenotomy and forcible correction, or removal of a wedge of bone from the scaphoid.

Fig. 214.—*X*-ray of extreme valgus.

Valgus; Calcaneovalgus.—When a paralytic calcaneovalgus exists, the deformity should be corrected by stretching or by the removal of a small wedge of bone from the scaphoid or astragalus or by a transplantation of the peronei to the inner side of the foot, depending on the cause of the valgus (Figs. 214 and 215).

Operation.—In valgus, due to a congenital condition, an incision is made on the inner side of the foot, and a small wedge of bone removed from the astragalus or scaphoid. The foot is adducted with the knee bent at right angles, closing the gap of the wound. In adducting the foot, the plane of the ball of the foot should be kept on the same plane as the heel but the foot may be dorsally flexed slightly. A tenotomy of the tendo Achillis and of the peronei may be necessary in some of these cases. The foot is held in an adducted position of about 60 degrees or more for about six weeks, by a plaster-of-Paris case extending from the toes to the groin with the knee flexed at right angles.

In small children it will not be necessary to remove a wedge but the foot may be stretched and a tenotomy of the tendo Achillis and peronei will often suffice to allow the foot to be adducted and held in plaster. These plasters may be changed once in six weeks and should be kept on from eight to ten months. After that the mother is taught to manipulate the foot to correct the deformity.

FIG. 215.—Extreme valgus deformity of both feet.

Acquired Deformities of the Feet.—The acquired deformities of the foot, ordinarily seen by surgeons, are the results of footwear and vary to a degree with the shape and fashion of the shoe or boot worn.

Acquired variations from the normal type in the shape of the foot in bare-footed races consists chiefly in enlargement of the foot from excessive use similar to that seen in the hands of handworkers. An exaggerated development of the muscles of the feet proper in comparison with that of the muscles of the leg and calf is seen in bare-footed races who use the flap of the foot and the flexor toe muscles in active locomotion, then the whole of the foot, with the heel raised, that is, they are bent-knee rather than straight-leg walkers. In other instances, there is a marked development of the adductor muscles of the great toe and an increase of the flexor muscles of the great toe. There is a increased flexibility in the mobility at the first metatarsal cuneiform articulation whereby the great toe can be adducted, *i. e.*, turned inward more than is usually seen.

The chief acquired deformities present the reverse of an increase of function but come from impaired or restricted use with the resulting changes.

With stiff soles and cramping uppers, with pointed toes and high heels, the toes are crowded, the action of the muscles moving the toes is hampered and limited. The stiffening of the muscles and ligaments results in the displacement of the digits, crumpled toes, that is, a position of fixed flexion of the joints, between the first and second digits.

Hallux Valgus.—The most common acquired deformity of the great toe is that known as hallux valgus, in which the great toe deviates to the outer side; there is a corresponding inward deviation of the first metatarsal. The projection of the metatarso-phalangeal articulation which results exposes the head of the metatarsal to the injury from the rubbing of shoes. This may cause an inflammation of the small bursa at this place, a condition familiarly known as a bunion, or to the development of exostosis and alteration of the bone tissues of the joints,

Fig. 216.—*X*-ray of hallux valgus.

ossification of a portion of the exposed joint cartilage with an abducted side position with articulations (Fig. 216).

Treatment.—When an operation is needed, an osteotomy may be done just back of the joint, any large exostosis removed; the bursa dissected out and the foot put on a plantar splint, made and fitted before the operation with a great toe part, extending beyond the toe and adducting it, overcorrecting the valgus. The foot is fastened to the splint by means of adhesive plaster, under which is placed felt or several layers of sheet wadding. The toe is now adducted and held in a similar way. A light plaster-of-Paris bandage is applied over this to fix the ankle and foot. An *x*-ray is taken on the fifth or the seventh day if necessary. After four weeks the patient bears weight and motion of the toe is allowed a little at a time, several times a day, in addition to the walking which is done with the splint; as soon as the toe is not sensitive, walking is allowed without the splint. Shoes must be used after this that will not cramp the toes.

Policeman's Heel. Stone Bruise.—Heavy individuals who are obliged to stand daily for long periods on a hard or uneven surface without the activity of walking, obliging them to use the front of the foot and thus relieve the under part of the os calcis from body weight pressure, may suffer from a dull pain in the bottom of the heel following periods of long standing.

This condition may be due to a strain and consequent congestion of the plantar fascia or flexor brevis muscle at its attachment to the os calcis or to the congestion of the tissues of the heel under the bruising pressure of the projection in the weight-bearing portion of the os calcis.

Projecting rheumatic spurs or, enlargement due to prolonged strains that is exostoses, may be developed here or as a result of planovalgus and a resulting tipping of the os calcis and weight bearing upon a limited portion of the os calcis, bruising of the tissues may follow. This condition is characterized by localized tenderness on deep pressure at the heel.

Treatment.—Rest, the use of crutches, shoes with an advanced heel, heel cushions cut to readjust the heel pressure, correction of the flat-foot and throwing more weight on the outer edge of the foot accompanied by methods to improve the circulation of the foot may be relied upon to effect a cure.

Humped Foot. Pes Cavus.—This condition more commonly seen in feet which have been weakened by a previous attack of infantile paralysis, is also seen in feet which have been unduly exposed to a constant injurious pressure.

Boots and shoes are made on lasts of conventional shape, the last is flattened on the inner and upper border more than the normal shape of the foot demands. If the foot is looked at in profile, it will be seen that the line of the first metatarsal is on a much higher level than that of the fifth metatarsal and if a cross-section of the foot were made, it would appear that the base of the first metatarsal was higher than that of the other. This is not considered by the bootmaker, who desires to furnish as closely fitting a shoe as possible. The front of the foot slightly everted can be made to bring the metatarsals upon the same level. Where the leather of the shoe upper is soft it is stretched in use, but if there is a low vamp and a high heel, the foot at every step slides forward against an unyielding welt, which exerts a backward pressure which eventually depresses the first metatarsal and finally the second and third so that they are inclined downward unduly and in some instances this gives undue prominence to the first cuneiform which may appear as a projection; in some rare cases an exostosis is developed from the irritation.

Pes Cavus in Poliomyelitis.—Pes cavus in poliomyelitis cases can be much benefited by an astragalectomy and displacement of the foot backward. When the ankle is flail, when the foot cannot dorsally flex, there is pain here and pain due to the cramped condition of the toes seen more commonly in the spastic paralytic cases with pes cavus. In these cases a wedge should be removed from the astragalus to allow the foot to dorsally flex and the hammer toe corrected as follows: A small incision is made over the metatarso-phalangeal joint between the fourth and fifth tendons; these are tenotomized and the toes stretched down and the interphalangeal joint stretched up. A tenotomy of the capsules of these joints is often necessary; for this purpose longitudinal incisions are made between the tendon and the artery down to the bone, the tenotome or a small sharp osteotome used to relieve the tight capsule; as it is kept close to the bone the osteotome will release the capsule on the side of the incision over the middle and over the other side of the bone. Enough should be done to allow the joints to flex and to extend easily. If the deformity is bone and of long standing the head of the metatarsal should not be removed but a small portion of bone, enough to make the joint loose, may be removed from the proximal end of the phalanx. The foot is held on a plantar splint with the toes overcorrected stretching out the deformity. After three weeks' stretching exercises are used. For a total flail ankle due to paralytic conditions, astragalectomy and displacement of the foot backward gives excellent results.

Paralytic Deformities of the Feet. Pes Equinus.—Pes equinus may occur from the position of the foot lying in bed causing a shortening of the calf muscles and the tissues posterior to the joint. It may be due to weakness or paralysis of the muscles, anteriorly, or to the pull of the strong muscles behind (see Figs. 206 and 213).

Where the position is due to an injury or to a fracture, the position may be more or less permanent on account of the bony changes about the joint. Whenever the condition has persisted for any length of time, there is a more or less change in the soft tissues, preventing the correction of the deformity. When the condition is slight, the patient may stretch up the ball of the foot with the good muscles, if there are any, the ball of the foot may be pressed up passively, the patient passing a strap under the ball of the foot and pulling on it with the hands, or this may be done by a masseur.

When the equinus condition is considerable, other means are often necessary. A plaster cast may be applied in the position in which the foot is placed. The plaster is cut away over the dorsum of the foot and over the sides of the ankle, leaving the posterior part of the plaster only. A strap is then placed around the upper end of the plaster below the knee and another strap placed around the plaster over the ball of the foot. These two straps are connected by a third strap which pulls them together, closing the cut out portion of the plaster and correcting the equinus. The same effect may be produced by attaching one pulley at the upper strap, the other at the lower strap. The cord connecting the pulleys is pulled on by the patient and tightened to correct the equinus. The foot is held this way for ten or fifteen minutes several times a day, the time being increased to several hours daily.

Sometimes it is necessary to do a tenotomy of the tendo Achillis under ether and stretch the foot upward forcibly. This may be done as follows:

FIG. 217.—*X*-ray of tenosynovitis of tendo Achillis, with calcaneous deposits.

Tenotomy of the Tendo Achillis.—A tenotome is introduced at the side of the foot about one-fourth of an inch anterior to the tendo Achillis. The skin is raised on the tenotome and the tenotome passed posterior to the tendo Achillis. The foot is held to relax this tendon. By a gentle sawing motion, the tendon is cut across about half way through on one side. The tenotome is next placed on the other side of the tendo Achillis and by a gentle sawing motion the tendon is cut half way through on this side. The two cuts in the tendo Achillis are made about three-eighths or one-half inch apart. The tenotome is now withdrawn from its original point of incision. The foot is now stretched upward. The tendo Achillis will give way allowing the equinus to be corrected. The foot is placed in a position of 30 to 40 degrees of dorsal flexion. In doing this the shortened tissues posteriorly will be very much stretched out. A plaster-of-Paris bandage applied from just below the knee to the toes will hold the foot in the overcorrected position for about four weeks. After this the foot is brought down to a right-angled position and held there by means of a plaster-of-Paris bandage and the patient encouraged to walk on the foot. At the end of ten days or two weeks this plaster is removed part of the day and finally removed entirely. Occasionally, when the position of equinus is due to an injury or to an old fracture or has persisted for several years, there will be a bony impediment to the dorsal motion of the foot. In these cases, it is often necessary to remove a small wedge from the astragalus. This wedge should be removed at some distance from the tibia in order not to have any bony repair too near the joint which might interfere with its action.

Equinus Deformity. Operation for Removing a Wedge from the Tarsus to Allow Dorsal Motion of the Foot.—When this operation is necessary, a longitudinal incision is made over the front of the foot just below the tibial joint and parallel to the extensor tendons. The layers are not separated but the dissection is made carefully down to the bone with a knife. An osteotome is used to lift the periosteum from the astragalus; a small wedge of bone is removed from the astragalus. When this gap is closed, a tenotomy of the tendo Achillis may be required. The combined operations should give a dorsal position of 30 to 40 degrees from right angles. A plaster is applied holding the foot in this position for five weeks. After this the foot is brought down to a right angle and held in this position with a plaster-of-Paris bandage and the patient encouraged to walk on the foot. When walking becomes a simple matter, the plaster is removed a little each day, and finally dispensed with.

Equinus Due to Paralyzed Muscles.—When the equinus is due not to a shortness of the posterior muscles but to a weakness or paralysis of the anterior muscles, these should be vitalized as much as possible by means of gentle massage and muscle training.

If the posterior muscles are good, the peronei or the tibialis anticus or the long flexors of the toes may be transplanted forward to be used as muscles to elevate the foot. The parts of the tendons to be used should not be clamped or injured by instruments.

An incision is made over the front and middle of the tibia down to the bone. A tunnel is made from this incision posteriorly to the dissected up muscles. The muscle is brought out forward through this incision and another tunnel is made just in or below the subcutaneous fat from the anterior incision to the dorsum of the foot. Here a curved incision is made over the dorsum of the foot, the incision being made through the skin and the superficial fascia. These are turned back if possible in one piece. The extensor tendons and muscles are retracted exposing the periosteum over the dorsum of the foot. A strong number eighteen silk is now inserted through the lower end of the peroneal tendons by quilted sutures up one side and down the other.

The tip of the silk is passed through a long ligature carrier down through the anterior tunnel made in or posterior to the fat and reaches the anterior portion of the foot. By means of a heavy round curved periosteum needle, resembling a cervix needle with a short curve, this silk is quilted in the periosteum over the front of the foot and tied there (Fig. 218). Before tying the suture the silk is pulled tight.

The surgeon should be careful that there is no constriction in the tunnel which may give way later and let the foot down. The position of insertion of the silk on the dorsum of the foot will vary according to whether there is a valgus or varus deformity accompanying equinus.

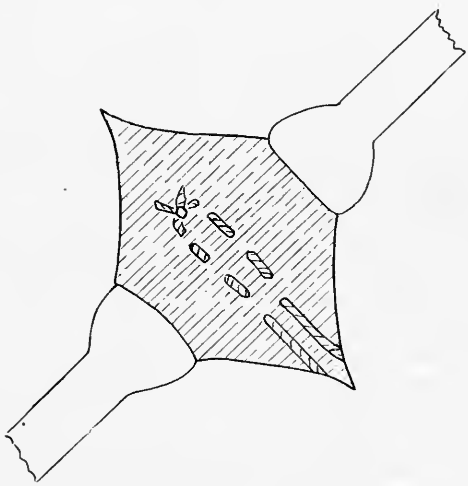

Fig. 218.—Silk quilted in periosteum.

If there is a tendency to valgus, the insertion will be more to the inner side; if there is a tendency to varus, the insertion will be more to the outer side. When the silk is drawn tight and tied, the ends are cut and the knot pressed down into the periosteum and bone. By flattening the knot there is less likelihood of irritation later on. The deep fascia is brought together over this with interrupted chromic catgut sutures number 00, the subcutaneous fat with interrupted chromic catgut sutures number 00 and the skin with continuous chromic catgut. The foot is now enveloped in sterile sheet wadding and a plaster applied from the toes to the groin holding the foot slightly overcorrected so that there will be no tension on the silk. This plaster is removed at the end of six weeks and a second one applied allowing the patient to walk with it. At the end of two weeks more a caliper brace is applied a part of each day and finally replaces the plaster. At the end of ten months or a year the patient is allowed to walk a little without the brace and finally as the leg becomes strong, no protection will be necessary excepting when prolonged walks are undertaken.

If the peronei muscles are paralyzed or for any reason it does not seem wise to use them for transplantation, the long flexor of the toes or the tibialis posticus may be used in the same way.

When there are no muscles that can be spared for transplantation and the muscles that control the ankle are very much lacking in tone and the equinus position is due entirely to a laxity in the muscles anteriorly, silk ligaments may be used to hold the foot at right angles. These may be inserted from the middle of the tibia, four strands of number eighteen silk being inserted there, two going to the outer and two to the inner side of the midtarsus. These strands are carried posterior to the fat in small tunnels down to the point of insertion. At the point of insertion two strands are quilted to the periosteum on the outer side of the fat and then tied and two to the inner side in the same way. Before tying these ligaments, the position of the foot should be carefully noted and the foot should be held flexed about 5 degrees beyond right angle. These ligaments will allow the upward motion of the foot but will prevent the foot from dropping down beyond a right angle. In this way much of the difficulty and lameness in walking will be obviated. A curved incision should be used over the insertion of this silk in order that the line of suture of the skin and subcutaneous tissue will not fall directly over the insertion of the silk into the periosteum. The foot is held in a plaster-of-Paris bandage for four weeks. At the end of that time the patient is allowed to bear a little weight on the foot with the plaster. At the end of eight weeks, a caliper brace preventing toe drop and preventing lateral strain on the ankle is used for about a year instead of a plaster. A night brace or plaster is used to prevent toe drop while in bed.

Calcaneus Deformity. — When there is a marked calcaneus deformity, if the lateral stability of the joint is good, one of the peronei or the long flexor of the toes may be used to reënforce the tendo Achillis.

Operation for Transplantation of the Peroneus Longus to the Tendo Achillis.—An incision is made half way to the outer side of the tendo Achillis. Through this incision the peroneus longus is isolated, dissected upward from the bone about six inches, its tendon inserted through a slit in the tendon of the tendo Achillis, and then through a second slit in this tendon. The foot is put in a slight equinus position, the tendon of the peroneus is pulled tight and silk sutures are placed holding these tendons together but not placed in such a way as to interfere with the circulation of the tendon. The deep tissues are brought together with interrupted chromic catgut sutures number 00, the subcutaneous fat with interrupted chromic catgut sutures number 00 and the skin with continuous chromic catgut. The foot is held at right angles by plaster-of-Paris bands extending from the toes to just below the knee. This is used for about four weeks. The patient is then allowed to walk on the foot in the plaster for two weeks more. After that caliper is used with a reverse stop preventing calcaneus. The patient uses this for about one year; as the leg becomes strong the brace is discarded.

Extreme Calcaneus. (Dangle-foot, Flail Ankle). — When there exists an extreme condition of calcaneus or when there is a flail condition of the ankle with no stability so that the foot can turn one way or another without control, or when the muscles are very weak and a semiflail condition exists, an astragalectomy as described below is distinctly advisable and will give in the course of time a very useful foot. This operation will make a brace unnecessary, even in very extreme paralytic conditions.

Astragalectomy Operation.—An incision is made two and one-half inches long parallel to the lower end of the fibula and anterior to its lower tip. The incision is carried down to the bone and the external lateral ligament is chiselled from the external malleolus. The astragalus is removed completely in two parts and the foot displaced backward and placed in a slight equinus position. The periosteum and deep fascia are brought together with interrupted chromic catgut sutures; the subcutaneous tissue with interrupted chromic catgut sutures and the skin with continuous chromic catgut sutures. Plaster is applied from the toes to the midthigh.

Paralytic Deformities of the Feet.—The correction of these deformities is ordinarily not difficult, requiring only tenotomies if any operative procedure is necessary followed by forcible correction. To give more permanent relief, muscle transplantation or astragalectomy with displacement of the foot backward is of great benefit.

Paralytic Valgus and Equinovalgus also Calcaneovalgus.—When a valgus and equinovalgus are due to paralysis, where the paralysis is complete below the knee and there is no hope of gaining power by muscle training, if the patient is seven years old or over an astragalectomy with displacement of the foot backward may be done with advantage as this does not involve stiffening of the ankle but gives stability to the ankle at that joint.

Where the valgus is due to paralysis of the muscles at the inner side of the foot and to strong peronei pulling the foot into a valgus position, these muscles may be transplanted forward and used to give dorsal motion of the foot. Where the ankle is fairly stable this alone will suffice. When there is a weak flail ankle this may be done in connection with an astragalectomy.

Paralytic Varus and Equinovarus.—When the varus is due to a total paralysis below the knee, an astragalectomy with displacement of the foot backward will give a stable ankle without stiffening it. When the muscles are spared on the inner side of the foot and totally paralyzed on the outer side a restoration of the balance of the foot may be obtained by transplanting the long extensors of the toes to the outer side of the tarsus with or without transplanting the tibialis anticus to the middle of the foot. When, however, there is a "dangle-foot" or flail condition of the ankle it will be necessary to do an astragalectomy and displacement of the foot backward in addition to transplanting the muscles.

Muscle Transplantation.—In transplanting a muscle from one part of the leg to another it is necessary to obtain as straight a line as possible for the pull of the transplanted muscle. For this reason the muscle is dissected up about two-thirds of an inch from its insertion, carried forward or backward as the case may be, and then placed in a tunnel under the skin in the foot in as straight a line as possible to where it is to be attached to give the desired motion.

In describing transplantation of the peroneii forward to give dorsal motion to the foot it will be possible to transplant the muscles on the inner side of the leg forward and backward, using the same general principles. Above the knee the hamstrings are transplanted forward in a similar way.

Transplantation of the Peronei Forward with Paralysis of the Tibialis Anticus.—An incision is made posterior to the external malleolus, extending directly upward to just about the middle of the leg, the peroneii tendons are isolated, cut away below, held with a sponge while the muscle is being dissected from the bone to the middle of the leg. Silk number eighteen, very strong and tested by the operator before inserting it, is applied, up one side and down the other of the tendon, about eight quilted sutures on either side of the tendons. An incision is now made on the front and middle of the leg about two inches long. A blunt instrument is used to connect this incision with the upper end of the first incision. The silk, tendon and muscle are now carried forward and out of the anterior incision. A tunnel is made with a blunt instrument in the subcutaneous fat along the front of the leg down to the middle of the tarsus. A curved incision is made over the middle of the tarsus. The fat, skin and fascia, all in one layer are folded back, allowing the blunt instrument to be withdrawn. A long tendon carrier or clamp is passed upward from the tarsal incision through the tunnel, it grasps the end of the silk which is now pulled through the tunnel. The tunnel should be made large enough so that there will be no constriction of the tendon and muscle. Heavy curved periosteal needles about three-fourths of an inch long are now threaded on the ends of the silk. This is quilted into the tarsus at about its middle if the desired pull is to be straight. If there is a tendency to varus the position of insertion should be further in. Three or four quilted sutures are made in a direct line through the periosteum on the dorsum of the foot with each needle. The silk is pulled down and with it the tendon and muscle and the foot is put up in slight dorsal position and held there by the silk before tying. The silk is then tied three times and the ends cut. The blunt flat end of dissecting forceps is now used to flatten the knot into the foot. The deep fascia and fat are now brought together with interrupted chromic catgut sutures number 00 and the skin with continuous chromic catgut sutures number 00.

The other incisions are closed in a like manner. A very small dressing is applied over each incision, one-half an inch longer than each incision and about one or one and one-half inches wide, and eight thickness only. Sterile sheet wadding is placed over this and should fit the leg and foot. This will enable the surgeon to judge the position of the foot in correcting the deformity. The plaster is applied holding the foot without tension on the transplanted muscles. This operation may be done in connection with an astragalectomy.

Transplantation of the Long Extensor of the Toes to the Dorsum of the Foot.—A curved incision is made over the dorsum of the foot about three inches long. The extensor tendons are cut away below, quilted up one side and down the other with silk. A groove may be made in the bone and the tendons inserted here and then fastened to the periosteum by quilted sutures. Enough tension should be put on the tendons to hold the foot in a slight dorsal flexion. The incisions are made and closed as described for transplantation of the peroneii to the dorsum of the foot.

Weak Foot, Flat-foot (Planovalgus).—That this condition is chiefly an acquired deformity and in a majority of cases the result of foot wear would seem to be demonstrated because it is rarely seen in the barefooted or moccasin-wearing races. Although the contrary was formerly believed to be true, later investigations show that pes plano is rarely found among healthy barefooted adults. It is, however, true that owing to the development and large size of the plantar muscles among the barefooted an apparent low arch is to be noticed not to be verified by accurate footprint evidence. Flexible feet in the barefooted enable the individual to stand occasionally in a plano valgus or knock ankle attitude; this, however, is to be distinguished from the constant assumption of the position of the foot (see Figs. 214 and 215).

When the body weight falls upon the normal foot it is supported on the heel, the outer border of the foot and the ball of the great toe; that is, the head of the first metatarsal, the toes may be or may not be brought into action according to the heel of balance or whether the body weight is thrown forward or backward. In normal shoe walking the weight is thrown first upon the heel as the leg is thrust forward and then as the body is pushed forward the outer part of the sole strikes the ground and again as the body weight is borne on the other limit and the foot formerly in front falls behind all the heads of the metatarsals and the toes are used to push the body forward the heel being raised and the foot lifted and again brought forward. In more rapid walking and in running the front of the foot is used more and more and the heel less as the front of the foot is used in the backward push needed for progression. The bared foot is spread through what may be called the thumb action of the great toe which diverts the first metatarsal inward. In shoe-wearing people, especially those wearing shoes narrowed at the toes, this thumb action is prevented and the foot and toe are pointed outward as it pushes backward. This tends to favor the toeing-out attitude in walking and standing so common in shoe-wearing people where the shoe prevents proper spreading of the front of the foot or actually constricts the front of the foot. Boots restricting proper toe action cause atrophy or weakening of the toes. There is still further weakening of the foot muscles from tightly laced and tightly fitting boots with stiff counters and soles, practically constricting boxes into which the foot is crowded, interfering with proper foot muscular action, more than the glove interferes with the hand muscles in writing or any occupation needing the play of the thumb or fingers.

The result of this is that individuals tend to stand faultily with the body weight falling to the inner side of the midtarsal joint instead of to the outer side, Nature's position of greater weight-bearing strength in the foot. In individuals standing many hours on their feet, carrying loads or with weakened muscles faulty foot attitudes with constant pain and discomfort from irritation of the overstrained ligaments may develop. If degenerative changes take place the faulty attitude may become fixed, the normal midtarsal joint mobility and inversion lost and a fixed flat-foot pes planovalgus result. This in heavy individuals may become in time a serious disability.

Treatment.—In light cases with flexible midtarsal articulation the treatment is simple and a complete cure can be expected. It is essential, however, that the constant wearing of shoes or boots which cramp or impede the foot muscles, especially the muscles of the first metatarsal and great toe, must be avoided. The occasional use of fashionable shoes may be permitted but for constant wear a boot permitting freer foot action is essential.

Special exercises persistently carried out and designed to develop the weakened muscles, especially the sole and great toe muscles, as well as the tibialis can be used. The wearing of moccasins in lieu of bare feet is of more practical value than daily exercises, but the latter is often necessary as a substitute. A cure is established only when a relating normal muscle tone has been established. Experience has shown that this can be accomplished in all healthy individuals provided a reasonable amount of persistency is employed under proper direction and guidance.

The situation is more complicated when midtarsal stiffness is present. This must be overcome by proper treatment. In the lighter cases the daily use of an effective correcting force exerted to furnish midtarsal inversion is sufficient to bring back to normal, play at the midtarsal joint. In addition to this, muscular exercises are needed to promote normal muscular strength and to give normal gait and attitude. Proper shoes are also needed to prevent undue muscle cramping and allow normal front foot and toe action.

In the more rigid cases, some form of operative interference is needed.

Wrenching.—The simplest form of operation is forcible correction under an anesthetic, either manually or with the aid of a wrench. While the os calcis is held firmly, the front of the foot is forced into a varus position, it being borne in mind that the correction must be in the midtarsal articulation and not merely of the metatarsals. The scaphoid and cuboid in these cases are placed too far to the outside and the cuboid on a slightly higher plane than normal, and this should be corrected or overcorrected.

In the more resistant cases, where the articular ligaments have lost their elasticity by fibrous degeneration, mechanical aids are a help in correction. The foot can be manipulated over a wedge-shaped block or a wrench can be used. The well known Thomas wrench or its modifications are of service for this purpose.

Tenotomy of the Tendo Achillis.—In doing a tenotomy of the tendo Achillis, an incision may be made to the outer or inner side of the tendon and the tendon lengthened by cutting it obliquely and then sutured or not. As this tendon unites very readily and is very easy to tenotomize subcutaneously, it saves time and there is less danger to adhesions to the skin by a subcutaneous tenotomy. Whenever other operations are being done on the patient a subcutaneous tenotomy is preferable.

Operation for Subcutaneous Tenotomy of the Tendo Achillis.—The operator grasps the ball of the foot with the left hand, a very small tenotome is passed through the skin and foot just forward of the tendo Achillis. The tendo Achillis is now relaxed by lowering the ball of the foot. The tenotome is passed between the skin and the tendon until it reaches the other side of the tendon. The blade of the tenotome is now pressed against the tendon, the operator presses on the ball of the foot, tightening the tendo Achillis. By a gentle sawing motion, the tendon is cut across and the last few fibers torn by pressing on the ball of the foot. The tenotome is then withdrawn leaving a small puncture wound in the skin.

Osteotomy.—Linear osteotomy through the neck of the astragalus and os calcis, accompanied by corrective wrenching.

Ostectomy.—Removal of a wedge of bone from the inner side of the neck of the astragalus with an osteotomy of the os calcis, followed by wrenching, is necessary only in the more resistant cases. The foot is put up in plaster with the scaphoid pressed high, the front of the foot is adducted and the foot is placed in dorsal flexion. The plaster is worn five weeks after that. Walking is encouraged with the plaster on and it is removed a part of the time for exercises and manipulation. When the foot is strong it is discarded.

Tenotomy of the Peronei.—Correction is aided by tenotomy of the peronei which if strong and shortened not only offer resistance to correction but favor relapse after correction.

DEFORMITIES OF THE TOES.

Duplicative fusions are seen in toes as in the fingers as congenital defects. The fusions need no treatment, the reduplications may require amputation. Gigantism of the toes or the foot may be seen. Amputation is the only treatment to be considered.

Anomalous bones of the foot occur, consisting chiefly of small supernumerary separate developments of bone on the surface of the os calcis or astragalus. They do not interfere with function and are only of importance for the reason that they be mistaken for a small fracture on an x-ray examination.

Irritative Exostosis of the Os Calcis, Heel Spurs.—Policeman's heel, spurs, heel bursitis exostosis are sometimes seen in either of two parts of the os calcis: (1) At the attachment of the tendo Achillis, (2) at the attachment of the shorter plantar muscles and fasciæ. Under the strain of use and toxic conditions as yet not clearly understood, bone deposits take place in the periosteum at the joint where the muscles are fastened to the bone for functional action. After severe injuries, the exostoses are sometimes very large, measuring in one instance over two inches.

Fig. 219.—Congenital absence of metatarsals and toes.

In the upper and posterior corner, the condition is complicated by the fact that the edge of the counter of the boot often presses unduly upon the tissues which at that point is little protected by fatty tissue. A small bursa is present normally between the upper edge of the os calcis and the tendo Achillis. Under shoe irritation this may become inflamed. The condition is easily relieved by removing the counter of the boot and in the more severe cases, such an adjustment of the boot as will prevent any pressure on the affected portion of the foot.

In the advanced cases, if an exostosis has developed, it can be removed with an osteotome.

Spastic Deformities of the Lower Extremities.—These consist in contracted hip flexors, in contracted hamstrings and contracture of the gastrocnemius and in some cases also in contracture of the adductors with or without contracture of the tensor vaginæ femoris. The condition is relieved by a myotomy and in some cases muscle transference is needed. At the hip the same operation for transfer of the thigh flexors (the Soutter operation) will relieve the tension here and make locomotion easier.

Fig. 220.—Supernumerary foot.

When the adductors and inner hamstrings are spastic and act constantly to cause a cross-legged progression with the knees flexed and interfering in extreme cases, it is better to make an incision over the adductors in the upper third of the thigh and remove a piece from the muscle. The inner hamstrings are treated similarly by cutting a piece from the tendons. This allows the good muscles of the leg to come into play without the constant incoördinate action of the spastic (Fig. 221).

Braces are often necessary a part of the time to stretch the knee straight. In some cases they are necessary for locomotion. A plain caliper splint is sufficient. The caliper has a posterior thigh pad high up, a band over the knee-cap and a socket in the shoe. Muscle stretching and training in coördination is very helpful in these cases.

Fig. 221.—Spastic equinovarus deformity.

Arthritis Deformans.—The deformities of the lower extremity following arthritis deformans, Charcot's disease, are not considered here as they belong more properly to the consideration of these affections.

DEFORMITIES OF THE UPPER EXTREMITIES.

ELEVATION OF THE SCAPULA (SPRENGEL'S DEFORMITY).

This deformity is a congenital defect, affecting usually one side only, though in rare instances it is double. It is due to an arrest of the descent of the scapula from the elevated process found in the fetal state (Figs. 222 and 223).

This causes an alteration in the shape of the bones forming the shoulder-joint, *i. e.*, acromion and the coracoid process and the periarticular tissue ligaments, but more especially the length of the muscles moving the scapula. There is usually a fibrous or cartilaginous band

FIG. 222.—Congenital elevation of the scapula. Sprengel's deformity. (Front view.)

FIG. 223.—Congenital elevation of the scapula. Sprengel's deformity. (Side view.)

connecting the scapula with one or more vertebræ. Usually it can be felt; sometimes it is found if the case is operated upon (Fig. 223).

Operative attempts to correct this deformity limited to division of the shortened muscles or the removal of the projecting corner of the shoulder blade have been only partially successful, largely for the reason that the joint proper has been shaped for motions in a deformed position and the scapula itself, independent of its attachment, tends to resume a faulty position.

Attempts have been made to correct this by the division of the scapula near the shoulder-joint after freeing the attachments of the muscles at the elevated corner of the scapula. This can be done by means of an osteotome. When an operation is indicated, the upper muscles, the short muscles and the cartilaginous fibrous band should be removed subperiosteally with an osteotome, the scapula slid down and sutured to the muscles or fascia below by chromic catgut sutures or other absorbable material. It is sometimes necessary to cut the

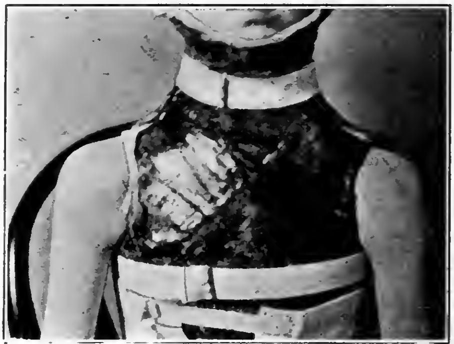

Fig. 224.—Molded collar to support the head.

subscapularis tendon near its attachment to the humerus and the pectoralis major to allow the full correction of the shoulder blade. The upper arm should be fixed in a strongly adducted position until the divided scapula is healed, while the rest of the scapula, freed from shortened muscles, is pressed by bandaging down as far as possible when the use of the arm is resumed. Systematic muscular exercises, the use of the dumb-bells and clubs are of service in preventing an increase of the resulting deformity. Spinal curvature and projection of the shoulder blade are benefited by exercises, stretching and shoulder braces worn part of each day.

Other variations from the normal type in the shape of the scapula are observed, but these do not affect the function of the upper extremity.

BOWING DUE TO RICKETS.

Rachitic bowing of the upper arm, is observed occasionally but rarely to an extent to deserve operative correction. When the deformity requires correction a linear osteotomy is done and fixation in plaster in a corrected position. The same may be said of a deformity due to a fracture healed with faulty alignment.

DEFORMITIES OF THE SHOULDER.

Relaxation of the Shoulder-joint.—This condition sometimes follows repeated dislocations of the shoulder-joint and sometimes it appears to be a condition of the periarticular ligaments which favors the frequent slipping of the head of the humerus out of its normal position.

Treatment.—This condition can be relieved by cutting down upon the joint and shortening the periarticular ligaments and taking a fold in the capsule.

An incision is made one-half inch below the acromion extending outward parallel to the deltoid fibers between the deltoid and the pectoral. The incision is carried inward three-fourths of an inch below the clavicle and parallel to it. The muscles are retracted exposing the capsule and the head of the bone placed in position. Its free action assured, the capsule is closed and if necessary shortened by purse-string or quilted sutures. The tissues are closed in layers by interrupted chromic catgut sutures number 00. The arm is held at the side and the elbow supported by straps and a swathe, the straps from the opposite shoulder. The elbow is well padded under the supporting straps and a hole cut over the tip of the elbow and ulnar nerve prevents sloughing and allows inspection at this point. This dressing is worn for about six weeks. After that the arm is gradually put into use. Massage and exercises are of advantage.

Bartow Silk Ligaments at the Shoulder.—Where the muscles at the shoulder are entirely paralyzed, the head of the humerus may be fixed to the scapula by silk ligaments. The scapula muscles will then control the humerus and make the arm more useful.

The Bartow drill passes without incisions through the acromion and the great tuberosity, the arm being held abducted 50 degrees before the drill is inserted. Heavy silk, number fourteen or eighteen, is pulled through the drill holes. The silk now passes out of the skin above and the skin at the side of the shoulder. The drill is now passed subcutaneously from the skin hole above to the one below. The silk is threaded through the eye of the drill. As the drill is withdrawn, both silk strands protrude together and are ready to be tied. The humerus is placed in position and the silk tied tightly. The ends are cut and allowed to slip under the skin.

Ankylosed Shoulder-joint.—Bony ankylosis of the shoulder-joint rarely occurs but fibrous ankylosis or functional stiffness from fibrous degeneration of the ligaments and capsule are common results from chronic inflammatory processes attacking the joint, epiphyseal osteitis juxta, epiphyseal osteomyelitis, toxic arthritis or synovitis. As the head of the humerus cannot move in its socket, the use of the upper extremity is limited to the movements of the scapula which with the arm fixed on its usual position relative to the scapula, checks raising the arm above the level of the shoulder.

Treatment.—There are two surgical procedures which are employed to relieve this disability: (1) an arthroplastic operation; (2) forcible alteration of the position of the arm and the placing of it in an ankylosed position more favorable for the use of the arm, or an arthroplasty may be done.

When an arthroplasty is undesirable, an osteotomy is done below the tuberosity and the arm abducted and allowed to heal with the elbow abducted 60 degrees in a neutral position as to rotation. The use of the shoulder will now come from the scapula muscles.

Arthroplasty.—An anterior incision is made through the deltoid fibers extending from the acromion. The deltoid is divided one-half inch from the anterior border. This incision may be extended backward over the shoulder and dividing the deltoid behind (Codman incision), separating the acromion, with an osteotome, with the attached deltoid. The shoulder-joint is exposed, the head chiselled away from the scapula and made round but smaller than normal. An incision is made over the outer side of the thigh, and a piece of fascia lata removed at least four by four inches placed over the head of the bone. The capsule which was carefully removed from the neck of the bone with an osteotome is now replaced and sutured in position and the wound closed in layers. The shoulder is abducted about 60 degrees in plaster or a firm apparatus for five weeks. After that time, motion is allowed and gradually increased.

Forcible Correction.—If the humerus is forcibly placed in a strongly abducted position and allowed to become fixed in this position, the resulting functional arc of upper limb abduction made by the movements of the scapula will be increased. After breaking up adhesions, the arm should be held extended straight upward in a plaster-of-Paris bandage extended well down around the thorax. This method of manipulation is desirable only in cases of slight adhesions where there is no inflammation and no disease, for at least a year. The surgeon should remember the normal motions of the shoulder. It will abduct to about 90 degrees and then if outwardly rotated it will abduct 80 to 90 degrees more, varying in individuals. Outward rotation varies and averages about 50 degrees; inward rotation about 110 degrees, or more. Hyperextension or backward motion of the shoulder may be limited at 45 degrees. The extent of motion in the well arm may be used as a guide in stretching and manipulating the affected arm under anesthesia, remembering that a bone unused for a long time is brittle and easily fractured so that force must be used with a good deal of care. After the use of a plaster bandage for two or three weeks, the arm can be lowered gradually and held on a wire arm rest and the scapular muscles exercised until the raising of the arm to the head is easily done. As the arm grows strong on the wire shelf, the shelf is lowered until the elbow reaches the side. After that the shelf is worn a little each day.

Paralytic Deformities of the Upper Extremity.—Poliomyelitis cripples the upper extremity less frequently than the lower to the extent of developing a permanent paralysis. In the upper extremity the deltoid is more apt to be partially or totally paralyzed than the rest of the arm. The arm and forearm may be paralyzed.

The surgical problem in the shoulder disability following infantile paralysis consists in an attempt to restore function as far as is possible. There are no muscular contractures to be overcome and in most instances several of the muscles of the limb are weakened from disuse in part and not totally. Scapular muscles are as a rule unaffected and are available for muscle transplantation. The muscle available for transplantation is the trapezius. An incision is made over the upper border of the muscle as it is attached on the acromion. The incision should be extended downward over the region of the deltoid. A portion of the belly of the muscle is detached and the end separated from the acromion. It is quilted with silk number eighteen and carried to the anterior portion of the deltoid and sutured to it by freeing the deltoid and uniting the ends as well as by uniting quilted sutures attached to each muscle. The arm is held extended above the head to free the muscle from strain. After six weeks the arm is put on a wire shelf in the same position and gradually lowered until the arm is held at right angles from the side of the body. The arm is exercised on this shelf until the muscles are strong and kept in abduction for six months, a longer time if necessary. The muscles of the arm and hand are exercised continuously until it is time to allow the arm to hang at the side. The shelf should then be used two hours a day to enable the transplanted muscle to be relaxed.

Transplantation of one-half of the pectoralis insertion to the trapezius may be done. The latter is freed as above described. A second incision is made over the pectoralis major insertion, inward to the nipple. One-half of the pectoralis insertion is separated with its fibers without disturbing the insertion. Enough of the muscle is cut in its belly to allow it to reach from the humeral insertion to the trapezius. The two muscles are sutured together and quilted silk sutures are placed separately in each muscle and then tied. The arm is put up as described above for transplantation of the trapezius. The after-treatment is the same.

Arthrodesis of the shoulder-joint is a measure to be reserved in paralysis of the shoulder for cases where the paralysis is so extensive that there is little or no chance of benefit from muscle transplantation. The arm, after the erasion of the cartilage, should be placed in an abduction position of 60 degrees to give the scapular muscles an opportunity for a freer control of the movements of the arm. Silk ligaments may be placed as described by Bartow from the acromion through the tuberosity fixing the shoulder to scapula, the arm held by plaster abducted 60 degrees. This allows the scapular muscles to control the totally paralyzed shoulder.

Chronic Spasm of the Shoulder Muscles.—Following injuries to the cortex or spinal roots of the cervical plexus, a condition of disarranged muscular tonicity in the upper extremity may be seen. This more commonly involves also the forearm and hand, one or both; or both also of the lower extremities, if the cortex has been injured at birth (Little's disease) but occasionally the shoulder muscles are the ones chiefly affected. An exaggerated stiffness of certain muscles, more commonly the pectoralis, is constant, which overcomes and weakens the opposing muscles. This is followed by a permanent contracture of these overcharged muscles and a disability different in kind but equal in lack of usefulness to that seen in a true paralysis.

This muscle-bound condition is to be overcome in the earlier stages by muscle training, *i. e.*, by isolating the group of faulty muscles and instituting exercises which will exercise those muscles without exciting too great nervous effort. Daily systematic stretching of the contracted muscles is also necessary.

Treatment.—In later cases, operative interference is needed. This consists in division of the contracted muscles or the resistant portions and overstretching the rest, by muscle transference. After the procedure the limb should be kept in an overcorrected position until the tissues are healed and later systematic exercises prescribed. The ultimate results of nerve transplantation have hitherto not been as satisfactory as those following myotomy thoroughly done. If at the initial stage of nerve lesion the condition at the cervical roots could be recognized, operation upon the nerves could be performed with better results. After abnormal conditions of the muscles have been established, there is less hope in attempting to remove its disability by an operation on the nerves. The synovial difficulties of early exact diagnosis are so great as to limit the usefulness of this procedure.

Slipping of the Long Head of the Biceps.—A loose position of this tendinous part of the biceps occasionally causes disability and can be remedied by severing the attachment near the head of the humerus and thus throwing it out of action.

DEFORMITIES OF THE ELBOW.

Cubitus Valgus (Bowing of the Elbow or Bowing of the Humerus).—Under certain conditions of growth which may be classed as rachitic, the growth at the lower end of the humerus may be such that the inner condyle may be longer than the outer, with the result that the extended arm is not straight but presents a line bending inward at the elbow as is seen in knock-knee. This condition may also follow injuries at the elbow-joint affecting the shape of the condyles, *i. e.*, epiphyseal strain or fissure fractures.

Treatment.—Mechanical treatment of this condition is inadvisable because clumsy and rarely beneficial. Repeated application of correcting plaster-of-Paris bandages or similar appliances made of leather or celluloid is advisable but the most serviceable method is by correction after supracondyloid linear osteotomy. This if properly done involves no danger to the joint, or limitation of its strength or function.

Operation.—The arm is held straight by an assistant holding the forearm and another the shoulder; the arm rests on a sand bag. A small incision is made through the skin just above the condyles. A blunt dissector is used to reach the bone. The tissues are held retracted while the surgeon cuts the bone just above the condyles. When the bone is cut through the skin is sutured. Sterile sheet wadding is applied and then a plaster-of-Paris bandage. The assistant still holding the bone without allowing it to be jarred the surgeon applies gentle pressure overcorrecting the deformity. The plaster is removed in five weeks, the arm held fully extended all that time. After that time massage and exercises are indicated.

Stiffened Elbow-joints.—Any severe injury to this joint or chronic inflammatory process is followed by a stiffened elbow. While the disability of this condition is diminished by stiffness in a right-angled position, it constitutes a serious handicap. If the elbow is stiff with the arm nearly straight the patient is crippled with an almost useless arm.

Arthroplasty. — When necessary the removal of obstructing bone structure offers a valuable method of relief in this condition.

Arthroplastic Operations on the Elbow.—A posterior incision is made just to the outer side of the olecranon three inches upward and three inches downward from the center of the joint. The dissection is carried down to the bone without separating the tissues in layers. An osteotome is used to clear the periosteum from the outer condyle and then the head of the radius behind and laterally. Care should be taken not to cut the triceps nor to injure the ulnar nerve. The latter will not be seen if the surgeon sticks to the bone subperiosteally, removing the tissues from the inner condyle and then the ulnar. The olecranon is cut across, the joint divided, and enough bone removed from the humerus, leaving the tips of the condyles. The humerus is rounded to resemble the normal outlines. Some bone is removed from the ulna and also from the head of the radius, if this is involved in the ankylosed condition. The ulna is curved to receive the humerus. The lower end of the humerus is covered front and back and laterally by a piece of fascia folded over its end and sutured in place, fitting the bone like a sock. The periosteum is carefully fitted about the joint, the muscle over this, and then the arm is put up flexed at an acute angle. The joint is immobilized for four weeks. Gentle motion in extension is done after the third week. The right-angled position is used after the fourth week as long as the acute flexion is not difficult. As further extension is allowed, the acute flexion should be easy and painless. Excellent results follow this operation. Flexion is possible until the limb is able to touch the shoulder and almost complete extension. The elbow is firm, depending on the care in doing the operation subperiosteally.

Flail Elbow.—When the biceps and the triceps are paralyzed as a result of poliomyelitis, a useless condition of the joint follows. If the former alone is paralyzed, the condition is nearly the same as when a weakened condition of the triceps from disuse exists. Some benefit can be obtained by muscle transference of the pectoralis minor, freeing the pectoral attachment (leaving that at the coracoid process untouched) and attaching the cut end into the fascia of the paralyzed biceps. The triceps when spared may be totally (or one-half) brought forward as described for transplantation of the hamstrings. The triceps is inserted into the biceps and by quilted silk elongation into the bicipital fascia. Relief can also be given by holding the elbow at right angles, by silk strands, or by operation for ankylosis of the elbow at a right-angled position.

Contraction of the Biceps.—This condition occurs in spastic, obstetrical, cerebral paralysis, but not to a degree as to demand myotomy.

DEFORMITIES OF THE FOREARM.

A congenital defect is occasionally met, consisting in the absence of the radius. The forearm is somewhat shortened, the ulna curved with the convexity outward and the hand is turned sharply inward and upward. There is a prominence of the styloid and a prominence of the ulna. The forward and backward motions of the wrist and hand are normal but there is no movement in pronation or supination. While the hand is useful, it is unsightly. The deformity is usually single but a double deformity also occurs. The deformity is corrected only by operative measures. Formerly this was attempted by splitting the end of the ulna and placing the hand in a corrected position between the split ends. This corrected the deformity but left a stiff wrist-joint and seriously impaired the usefulness of the hand. More promising results are offered by the insertion of a long bone graft (taken from the tibia) into the place of the diaphysis of the radius, after correction of the position of the hand and a linear osteotomy to straighten the curved ulna. This operation can be done thus: The graft should be inserted in a long groove in the ulna and extend to the center of the bone and make good contact there. The graft must extend and be well buried at its lower end in the carpal bones. Failure to get good bony apposition will mean absorption of the graft.

Synostosis of the Forearm.—In rare instances, a congenital fusion of the radius and ulna is observed. The arm is fixed in a midposition between rotation and supination. The motion of the wrist and elbow is normal. The radius and ulna are fused at the upper end. It is possible to separate the united bones but it is more difficult to obtain a satisfactory restoration of normal muscular function and the benefit of operative interference on the usefulness of the limb is doubtful, excepting sometimes from removing bone from the radius.

Flexed Fingers.—Flexed fingers occur from congenital malformation of the skin on the flexor surface reaching across up to the back of the flexed finger instead of along its flexor surface. This condition is relieved by a V-shaped incision which is rarely sufficient. Wolf skin grafts must usually be used also, and in some cases, tendon elongation by means of silk quilted from the tendon to its other cut end.

Other flexed conditions of the fingers are more marked in cerebral paralysis where inequality in action of opposing muscles is more noticeable than after poliomyelitis, for the reason that stronger contractures are seen, as well as exaggerated pronation. The only surgical relief which can be offered in the paralytic deformities and disabilities of the hand is by muscle and tendon lengthening and by tendon transplantation, *i. e.*, the division of contracted flexors by tenotomy or the transference and insertion of a flexor into a useless extensor; or in the case of exaggerated pronation, the insertion of the pronator radii teres into the outer instead of the inner side of the radius.

Systematic muscle training is needed as an after-treatment.

The results hitherto observed from nerve transplantation have not yet been sufficiently good in hand palsies, to warrant the recommendation of the method.

Pronation of Forearm.—Tubby Operation.—When there is a loss of power of supination due to paralysis, flail or spastic, if the pronator radii teres is spared, Dr. Tubby has suggested taking this pronator and transplanting it so that it will supinate the forearm.

Operation. Transplantation of the Pronator Radii Teres to Obtain Power of Supination in the Forearm.—An incision is made three inches long in the outer and upper third of the forearm, extending down to the middle of the forearm. The superficial muscles are retracted, exposing the oblique fibers of the pronator radii teres. These fibers are inserted in the radius by fibrous bands continuous with the periosteum. The insertion of this muscle is removed from above downward, taking as much of the periosteum as possible. It is to be passed backward posterior to the radius to its inner side and up again on the outside from without, inward.

The insertion is made at a higher level than the original insertion. The details are as follows: A blunt dissector is used through the anterior incision and is passed backward between the radius and ulna. As it protrudes from the skin posteriorly, an incision one and one-half inches is made here. A clamp is introduced at this point and protrudes forward. The tip of the pronator radii teres is put in the clamp and the muscle pulled out backward. A heavy No. 18 silk is quilted into the tendon up one side and down the other; about four quilted sutures on each side. These two strands are used to make an insertion into the radius. A hole in the radius is drilled with the forearm in the position midway between pronation and supination. The drill hole should be from side to side when the forearm is supinated. The tendon of the pronator radii teres is now passed forward on the outer side of the radius and reaches around to the front of the radius. One silk strand from the tendon is passed into the hole of the radius entering the bone at its ulnar side. The silk then passes outward and backward around the posterior surface of the radius and up between the two sides. The tendon is pulled tight, the silk is tightened and the two strands of silk now tied together with the forearm held in extreme supination. The tissues are now closed layer by layer with interrupted chromic catgut sutures number 00, the skin with continuous chromic catgut sutures number 00. In drilling the bone to receive the silk the hole in the bone is made as described above. The drill should be large so that the silk will not be constricted in a small hole. A double silkworm-gut leader is passed through the drill hole in the bone, the loop being ready to receive the silk. The silk is drawn through the bone and passed around it as described above. The arm should be held in extreme supination in plaster of Paris. At the end of two months a splint may be substituted. The splint is removed for active and passive exercises and massage a month or six weeks after the operation.

At the end of six months the splint may be removed during a good deal of the day and at the end of a year it may be worn for only a few hours each day, depending upon the tendency of contracture to form.

Imperfect and Achondroplasial Growth.—Under a fetal condition, as yet not understood, a malformation is occasionally observed consisting of an arrested or imperfect growth of the diaphysis of the long bones, particularly of the humerus or femur. This is sometimes confined to one limb or all the extremities may be affected. The deformity varies considerably in degree. There is growth in bone after birth, but not to an extent to overcome the abnormality. The use of preparations of the ductless glands in the treatment of these cases was at first considered of some value. Unless there is a distinct myxedematous condition complicating the case, the use of thyroid is of very doubtful value. Exercise is beneficial and stretching prevents lordosis and knee flexion (Figs. 225) and 226).

Dupuytren's Contracture.—This condition consists in a contracture of a certain portion of the palmar fascia by which one or more fingers are drawn into a flexed position and can be imperfectly extended if at all. The affection is much more common in men than in women. It is more commonly unilateral but may not infrequently be bilateral. The progress of the deformity is not to spontaneous recovery. A gradual increase of the flexed position is the rule. A thickened condition of a part of the tissues in the palm of the hand is felt on palpation directly below the skin. This may be limited to a large nodular lump, or may be less sharply limited. The contracture is due to a fibrous degeneration in the fascial tissue which extends to the proximal portion of the finger. The cause of this degeneration is not known.

Treatment.—The only treatment of this condition is straightening, after division of the contracted tissue. This can be done through a free incision of the skin, followed by a number of subcutaneous incisions, by the tearing of the tissues, through the use of force, or by extension removal of the degenerated fascia. When the condition is slight, frequent daily stretching will be of benefit unless the condition is of such long standing that the joint capsule is contracted. Opening of the joint, or of the tendon sheaths, or division of the tendon is unnecessary and is to be avoided. It is important that the skin incisions should be made in such a way as not to develop scar tissue, which, on healing, would contract in the direction of the deformity and it is also necessary that during healing and for some time afterward, a retentive splint should be worn holding the finger straight.

The stretching of the skin and fascia should be performed daily when the splints are removed.

Fig. 225.—Achondroplasia.

Fig. 226.—Achondroplasia (*x*-ray).

Trigger Finger.—A peculiar disability is rarely met consisting in a jerky movement in extending or flexing a finger or thumb.

The motion is free at the beginning and at the end of the motion, but in the middle a check is felt which is only overcome by an increased effort by means of which the finger suddenly moves freely as if by means of a spring release.

The condition is due to a localized thickening of the tendon or to a narrowing of the sheath, or a combination of these; occasionally the tendon slips to the side at a given point in the motion.

In some instances this is a temporary condition, but in many cases it is necessary to cut down and divide the thickened portion of the tendon sheaths.

The tendon may be greased with sterile vaseline to prevent further adhesions or wiped in fascia or both. Slight motion of the tendon should begin three days after operations.

Tenosynovitis.—An increase in the tendon synovial fluid follows strain or injury, and may be expected to correct itself, but a chronic condition with congestive thickening of the synovial lining wall and an abnormal amount of gelatine fluid may occur. This may be diffused and seen in the palmar tendon at the wrist or localized in tendons on the dorsum, the so-called "weeping sinew;" in some cases synovial fringes are found and in rare instances rice bodies.

The symptoms are, besides enlargement of the tissues which is painless, a sense of weakness at the joint and sometimes a crepitation on palpation.

Where massage is not sufficient to improve the condition, evacuation of the excess of fluid or rice bodies through incision and in the extreme cases, removal of congested tissue is needed, and complete removal of the sheath as far up as the muscle tissue.

Ischemic Paralysis.—As a result of the ischemia, following bandaging or the pressure of bandaged apparatus in the flexion of the elbow, a peculiar disability of the forearm and hand may be developed (Fig. 227).

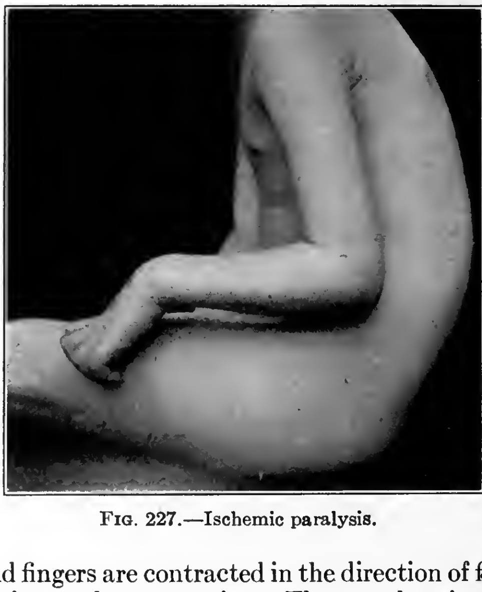

Fig. 227.—Ischemic paralysis.

The hand and fingers are contracted in the direction of flexion. There is atrophy and incomplete pronation. The muscles give evidence of a loss of elasticity and have undergone fibrous degeneration.

Treatment.—In the milder cases, relief can be afforded by gradual mechanical extension, but in the severe cases it is necessary to divide the contracted tissues followed by splint extension.

In some instances of extreme deformity, shortening of the bones has been necessary to correct in extreme contracture from shortened tissue.

This is more apt to be successful than muscle or tendon lengthening in these cases.

Fig. 228.—Club-hand.

Fig. 229.—Club-hand.

Silver Fork Deformity at the Wrist.—The deformity following fracture of the lower end of the radius is well known. A somewhat similar, but less marked condition occurs occasionally from a malformation, congenital or acquired (Madelung's deformity of the wrist-joint), chiefly at the articular surface of the lower end of the ulna. The carpus is articulated more than normally in the inner and palmar direction.

The styloid process of the ulna projects and the upper surface of the wrist seems to be more full than usual. There may in addition be a laxity at the stylocarpal ligaments.

Treatment.—Osteotomy will correct extreme deformity. The condition rarely demands energetic treatment. The impairment of function and the deformity are both slight.

Fig. 230.—Webbed fingers.

Paralysis of the Hand.—In the flaccid palsies following poliomyelitis, as a rule, there are little or no deforming contractures, in most instances slight power remains in flexion and extension of the fingers. In some cases adaption shortening of the carpal flexors is seen so that although the fingers may be extended, the hand remains useless. Where the extensors are paralyzed and the flexors spared, some of the flexors may be passed between the bones and attached to the paralyzed extensors. Where the extensors are paralyzed the flexors may be used.

The transplantation should be carefully planned so that the most useful fingers should be used and the wrist controlled to give as good function as possible. The action of the index finger and thumb should be looked after; next to this, power of flexion of the fingers.

Following the operation, the muscles transplanted are protected by splints and held in a relaxed position for three weeks. No great strain is allowed for at least two months. The muscle training is started after the fourth week and the splints are used off and on for six months. The tendons transplanted are quilted with number fourteen silk up one side and down the other. The silk is then used to attach the good tendon to the paralyzed or to the bone as the case requires. Where the tendon will reach the paralyzed tendon, the latter is split once or twice and the tendon passed through these slits and the tendons sutured together beside.

Congenital Deformity of the Fingers.—A union of the skin covering two or more fingers while the bones are separated is sometimes seen and in rare instances the union of the tips of the fingers. These conditions of congenital deformities can in a measure be relieved by the usual operation for fingers, *i. e.*, removal of a superfluous finger which should be done after *x*-ray examination in order to determine which bone is attached to the bone below; removing the wrong supernumerary means poor function later on. The operation is very simple (Figs. 228, 229 and 230).

EXCISION OF JOINTS.

By ASTLEY PASTON COOPER ASHHURST, M.D.

Excision of a joint implies the removal of the articulating ends of the bones forming the joint under consideration; if the articulating surface is removed only from one of the bones entering into the formation of the joint, the operation is termed a *partial excision,* as when the head of the femur is removed leaving the acetabulum intact. If only the soft tissues of the joint (synovia, cartilages, ligaments) are removed, without interference with the bone, the operation is termed *arthrectomy* or *erasion.* The term *resection* is limited to the removal of a portion of the shaft of a bone, involving its entire thickness. A very limited excision, with the object not of removing all diseased tissue but merely to secure ankylosis, is termed an *orthopædic excision* or an *arthrodesis.* It is employed especially in cases of flail joint following anterior poliomyelitis.

General Indications.—Excision was much employed in the latter half of the nineteenth century for tuberculous arthritis; but the further development of conservative measures, which at that time had enabled surgeons to substitute excision for amputation, has now rendered cure without any operation the general rule, at least in children; so that excision of joints is becoming one of the rare operations.

But in addition to tuberculosis, which sometimes (especially in adults) is still an indication, excision may be employed for various other forms of arthritis, as well as for ankylosis in bad position. Thus it has been employed in recent years in cases of hypertrophic and of atrophic arthritis, and in a few cases of neuropathic arthritis (Charcot joints). In the knee, ankle, wrist and sometimes in the hip, the object of the operation, no matter for what affection it is employed, is to secure ankylosis in good position. But in the elbow, shoulder, and sometimes in the hip, ankylosis is not desired, and is prevented by extensive removal of bone. As this wide removal of bone may result in marked loss of stability, surgeons are now endeavoring to prevent ankylosis without the sacrifice of so much bone by interposing between the bone ends flaps of fat, fascia and muscle, or of artificially prepared animal membrane. Such an operation is known as *arthroplasty,* and is discussed on pages 359, 639 and 688.

Instruments Required.—In addition to those such as scalpel, scissors, dissecting forceps, etc., needed in every operation, the usual *bone instruments* should be provided. These include *periosteal elevators,* various forms of *saws* (the ordinary amputating saw, chain saw, Gigli's wire saw, Adams's saw, Butcher's saw, Hey's saw, etc.) according to the joint attacked and the preference of the operator; *chisels* and *gouges*, with a *mallet; sequestrum forceps*, to remove loose fragments; a *resection knife*, which is a strong-backed, blunt-pointed,

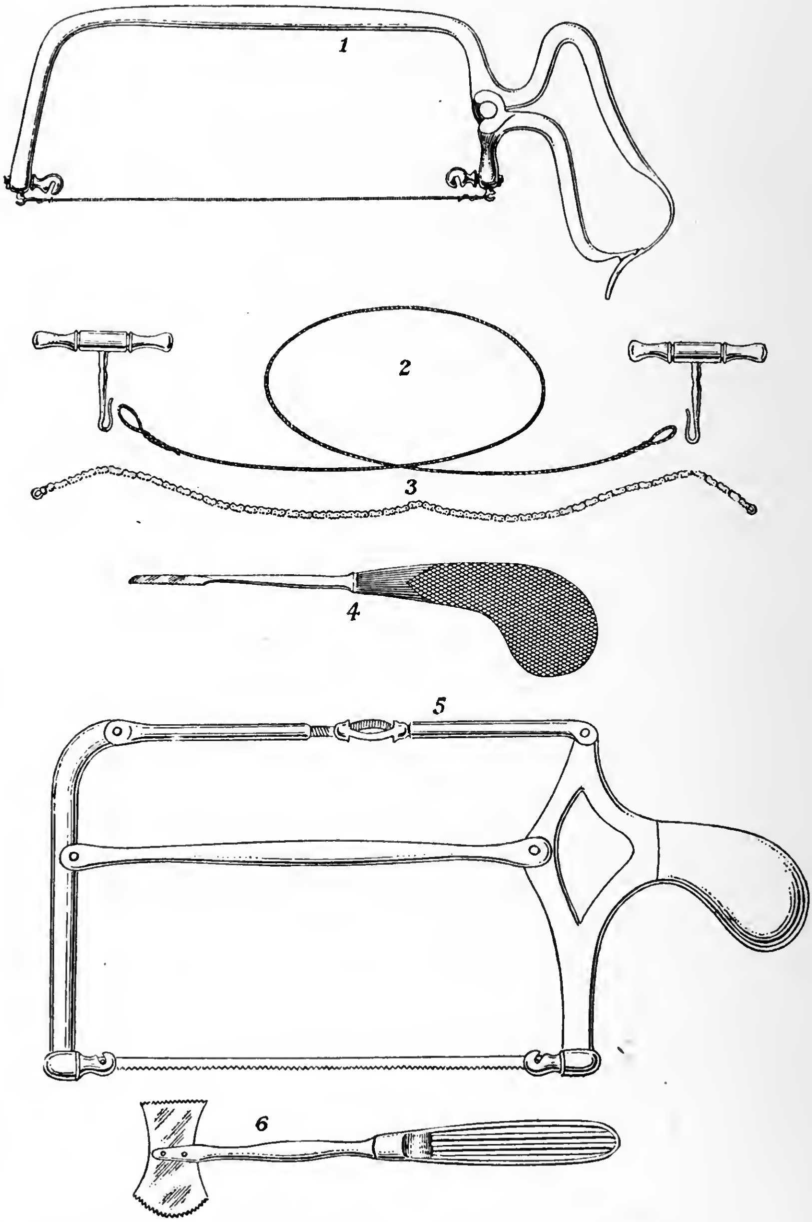

FIG. 231.—Saws: *1*, Mounted Gigli saw; *2*. Gigli saw and handles; *3*, Chain saw; *4*. Adams's saw; *5*, Butcher's saw; *6*. Hey's saw. (Ashhurst's Surgery.)

short-bladed instrument, useful for cutting strong ligaments, cartilage, etc.; *lion-jawed* or other form of *bone-holding forceps;* as well as *gouge forceps, bone nippers* and *Volkmann's sharp spoon* (Figs. 231, 232 and 233).

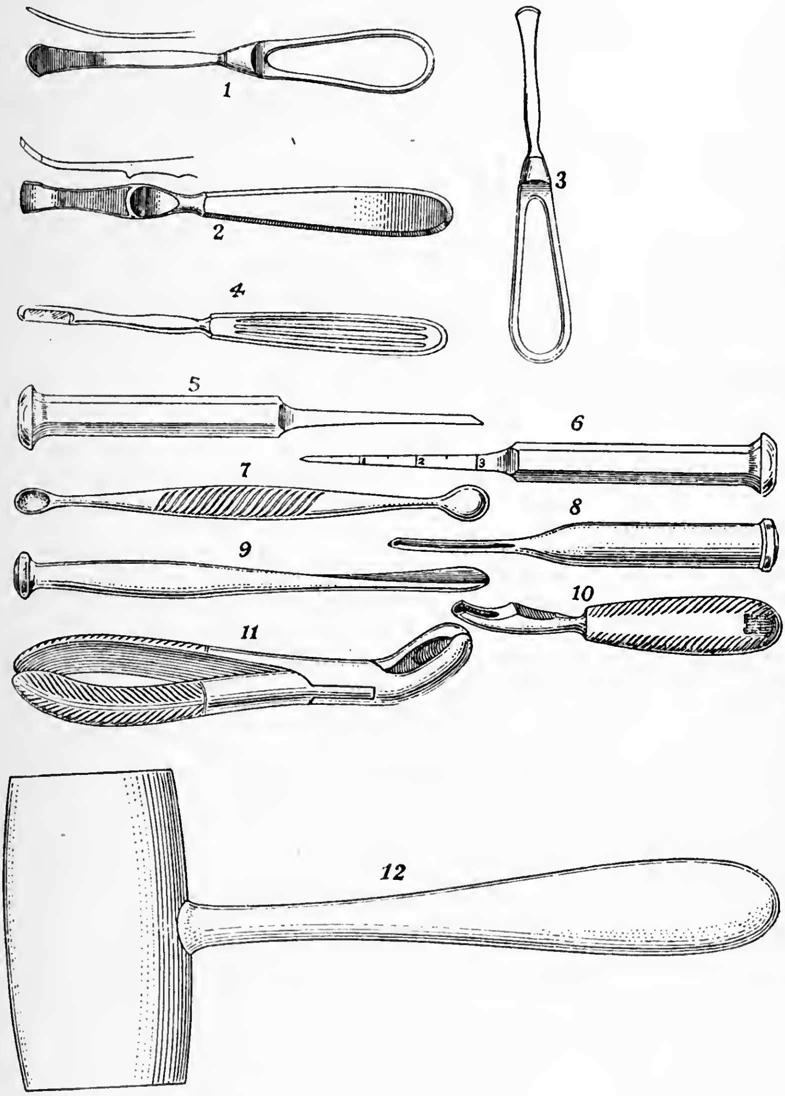

FIG. 232.—Joint instruments: *1, 2, 3.* Periosteal elevators; *4.* Resection knife; *5.* Chisel; *6.* Osteotome; *7.* Volkmann's sharp spoon; *8, 9, 10.* Gouges; *11.* Gouge forceps; *12.* Mallet. (Ashhurst's Surgery.)

General Operative Methods.—The joint is exposed with due regard to its vascular supply, and to possible damage to neighboring nerves, muscles and tendons. It is not advisable to employ an Esmarch band for temporary hemostasis, since this tends to increase post-operative oozing. Bleeding from the bones rarely is troublesome; if so, it may be controlled by hammering gently on the cancellous tissue, crushing in the bone trabeculæ, or better still by application of strips of muscular tissue cut from a muscle exposed during operation. Bleeding from the soft parts is controlled by clamping all bleeding-points as they are encountered, and subsequently ligating the vessels which spurted; the others cease to bleed after a few minutes of forcipressure.

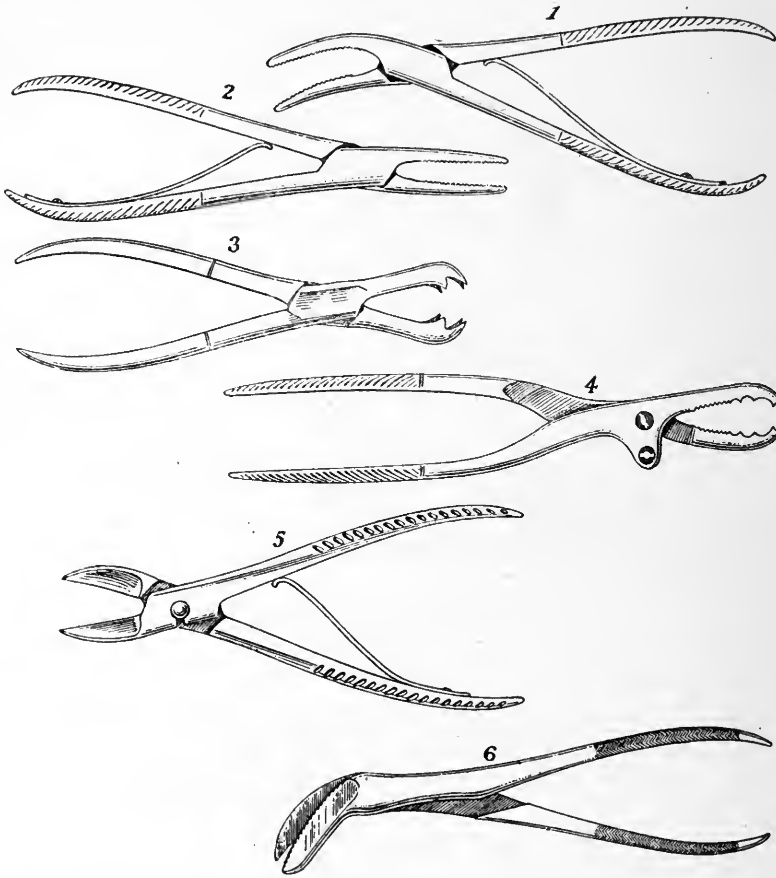

Fig. 233.—Bone forceps. 1, 2. Sequestrum forceps, straight and curved. 3. Fergusson's lion-jawed forceps. 4. Farabeuf's bone-holding forceps. 5. Liston's bone nippers. 6. Saw bladed forceps.

Whenever possible the joint cavity should be opened, and each bone end should be removed separately. Attempts to excise the joint in one mass, except by very experienced surgeons, are apt to result in the removal of too little or too much bone. The joint cavity, even in cases of bony ankylosis, seldom is completely obliterated, and after incising the capsule it usually is possible to rupture intra-articular adhesions by flexing or otherwise manipulating the joint until the bone ends become accessible. If bony ankylosis is present it usually is necessary to use chisel or gouge to separate the bones. When the bone ends are finally exposed, they are to be removed by saw or other instrument. The surgeon then places the limb in the most useful position in order to ascertain if enough bone has been removed for the purpose proposed, whether this be to secure ankylosis or a movable joint. If removal of more bone is required, the bone ends are made accessible again by partial dislocation, and the saw is again employed. When not contra-indicated, subperiosteal excision is to be preferred, especially if it is desirable (as at the shoulder and elbow) to retain the functions of muscles which are inserted into the portions of the bones excised.

When sufficient bone has been removed, the soft parts are closed, with provision for drainage by tube in almost all cases; and the limb is dressed in the desired position in plaster of Paris or splints. The drainage tube may be removed in from twenty-four to forty-eight hours. If a movable joint is desired, active motion should be encouraged as soon as the soft parts are healed. Painful passive motion never should be enforced, as it is prone to produce stiffness. If ankylosis is the end sought, the joint should not be disturbed for from six to eight weeks; and immobilization by orthopædic apparatus should be provided for some months longer, the patient being allowed to walk about.

EXCISION OF THE SHOULDER.

Excision of the shoulder is done oftenest to relieve ankylosis, but is also employed in adults with tuberculous arthritis. A partial excision (removal of the upper end of the humerus) is sometimes done in cases of irreducible luxation, to relieve pain and secure more motion. Two methods of operation will be described: (1) By an anterior incision (Langenbeck); and (2) by the posterosuperior route, with temporary resection of the acromion (Kocher).

Excision of the Shoulder by the Anterior Method.—This is the operation most often employed. It is especially adapted for cases of tuberculous disease, and for old irreducible anterior luxations.

A straight incision is made, from a point midway between the coracoid process and the greater tuberosity of the humerus, downward and outward for ten to twelve centimeters. The knife passes through the anterior fibers of the deltoid down to the humerus, exposing the long tendon of the biceps (Fig. 234). This is displaced from its sheath, either inward or outward, as may be more convenient, but is not divided. The arm being held close to the chest, the joint is then opened by cutting upward along the sheath of the biceps tendon. With the arm rotated inward, the muscles attached to the greater tuberosity (supraspinatus, infraspinatus and teres minor) are shelled off with their periosteal attachments, by means of a periosteal elevator. Then the arm is rotated externally as far as possible, and the subscapularis is similarly detached from the lesser tuberosity.

FIG. 234.—Excision of shoulder by anterior longitudinal incision; the fibers of the deltoid have been split exposing the long tendon of the biceps in its groove.

FIG. 235.—Excision of shoulder by anterior longitudinal incision. After division of the capsule and the muscles attached to the tuberosities the arm is allowed to hang over the edge of the table; this causes the head of the humerus to project from the wound.

Even when firm ankylosis is present, the line of the joint may be gradually defined by keeping the instruments close to the humerus. It may now become possible to luxate the upper end of the humerus into the wound, by carrying the arm downward toward the floor, and thrusting upward on it in its long axis (Fig. 235). If the operation is done for tuberculosis it may be sufficient to remove the carious bone by gouge and curette. The tuberosities of the humerus, if possible, or at any rate the periosteal insertions of the rotator muscles should be preserved, as already indicated. It is better to remove more bone from the glenoid than to convert the shoulder into a flail joint by depriving it of the power of rotation, unless removal of the tuberosities is absolutely necessary. When required the humerus may be sawed through the surgical neck, with a chain saw, or even an ordinary amputating saw. The wound is closed with a few buried sutures in the deltoid, and superficial skin sutures; the drainage tube emerges about the middle of the incision. The arm is bandaged to the side, with the elbow well forward, and the seat of operation is protected with a shouldercap of binder's board. As ankylosis is not desired, motion is encouraged after the end of the second week.

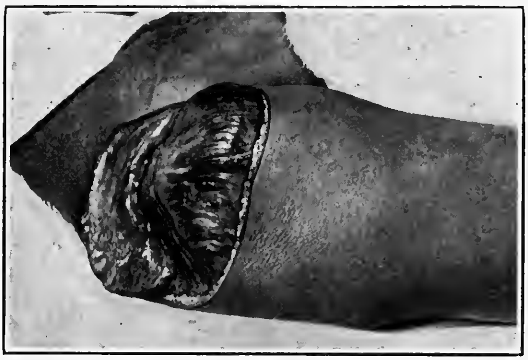

FIG. 236.—Curved incision around acromion, flap of skin turned up.

Excision of the Shoulder with Temporary Resection of the Acromion is especially applicable to cases of bony ankylosis, in which better exposure often is desirable than can be secured by an anterior approach. The best skin incision is that recommended by Nélaton: It commences below the anterior border of the clavicle, near the acromio-clavicular joint, and passes backward around the shoulder, below the greater tuberosity of the humerus, terminating at the middle of the lower border of the spine of the scapula. This incision is deepened until the fibers of the deltoid are bared, and the skin flap thus outlined is raised from the deltoid and reflected upward until the acromion and outer half of the spine of the scapula are exposed (Fig. 236). The trapezius is then detached subperiosteally from the upper border of the scapular spine, and the deltoid from its lower border, exposing the supraspinatus and infraspinatus muscles.

These are likewise separated from the spine until a blunt instrument can be passed beneath the root of the acromion (Fig. 237). This serves to protect the suprascapular nerve and artery while the acromion is detached by osteotome or saw by an oblique section. The acromio-

Fig. 237.—Spine of scapula exposed and retractor passed under base of acromion.

clavicular joint having been opened, the acromion is turned forward and downward, carrying with it the deltoid, and freely exposing the capsule of the shoulder-joint (Fig. 238). The bicipital groove being identified and the long tendon of the biceps drawn from its sheath, the capsule of the joint is to be opened by an incision parallel to the

Fig. 238.—Acromion divided at its base and turned forward. The long tendon of the biceps is clearly exposed; in front of it the subscapularis just comes to view, posteriorly the supraspinatus and infraspinatus muscles are seen.

biceps tendon, from the tuberosities to the glenoid. The margins of the glenoid may now be defined, and in cases of bony ankylosis the humerus may be separated from it by chisel or gouge under full control of the eye. The subsequent steps of a typical excision are then carried out as already described. Sufficient bone having been removed, and articular contours restored as far as possible, the acromion is replaced. It is convenient to secure it in place by one or two screws; the self-boring screws of Lambotte are excellent for this purpose. In very young children it is sufficient to suture the periosteal attachments of the trapezius and deltoid securely over the acromion. If drainage is employed, the tube should emerge posteriorly. The skin flap is then brought down and stitched in place.

This method of operation is well adapted also for cases in which it is desired to perform *arthroplasty*. An interposing flap is readily obtained from the pectoralis minor muscle, with its pedicle at the coracoid process, or from the deep surface of the deltoid. Excellent exposure is gained also in cases where *arthrodesis* is planned.

EXCISION OF THE ELBOW.

Two methods of excision of the elbow will be described: (1) By a posterior longitudinal incision (Langenbeck); and (2) by external incision with temporary resection of the external condyle (after Kocher).

Fig. 239.—Excision of the elbow-joint. A posterior longitudinal incision is made, beginning above over the ulna and terminating below over the humerus, where the triceps has been split.

Excision of the Elbow by a Posterior Longitudinal Incision.—A longitudinal incision, 10 to 12 cm. in length, is made over the posterior aspect of the elbow-joint, slightly to the ulnar side of the midline, splitting the fibers of the triceps and its fibrous expansion over the olecranon. This incision begins over the forearm and ends over the humerus (Fig. 239). It passes directly to the shaft of the humerus above the joint, and to the subcutaneous surface of the ulna below. Great care is exercised not to incise that portion of the triceps expansion on the radial side of this incision, as the subsequent power of active extension of the elbow depends very largely on its preservation. The triceps is now reflected from the humerus by means of periosteal elevators, keeping the instruments close to the bone. The ulnar nerve is in great danger of being wounded as it passes between the internal condyle and the olecranon; it is closest to the bone, and in greatest danger at the base of the olecranon, just where this joins the shaft of the ulna. Usually the joint is opened through the posterior part of the capsule, which is very thin, but the bones cannot be sep-

Fig. 240.—Excision of the elbow-joint. The joint has been opened posteriorly and the condyles of the humerus exposed. Above is seen the olecranon; just below it the trochlear surface of the humerus. The retractors pull aside the split triceps and the scissors are cutting the internal lateral ligament.

arated until the lateral ligaments have been divided. When the soft parts have been reflected far enough to expose fully the epicondyle and epitrochlea, the lateral ligaments may be divided *just below these prominences* by cutting *against the bone* (Fig. 240). Whenever possible it is best to separate the soft structures from these prominences by blunt dissection (subperiosteal) so as to preserve the muscular origins. The lower end of the humerus may then be luxated into the wound, and sawed off at the level of the epitrochlea and epicondyle. The radius and ulna are then displaced backward, and their articular extremities removed. The radial attachment of the biceps always should be preserved, and as much of the superficial surface of the olecranon as is not diseased. Another method of opening the joint is first to saw through the base of the olecranon process, and then, after its removal, to dislocate the lower extremity of the humerus into the wound. In any case, when enough bone has been removed to ensure subsequent mobility (at least 4 cm. should intervene between the humerus and the bones of the forearm) (Fig. 241), the wound is closed by buried sutures for the aponeurosis of the triceps, and superficial skin sutures. Tube drainage is provided for the first day or two, unless there has been remarkably little bleeding. The elbow is dressed on an internal angular splint, which is discontinued so soon as healing of the soft parts is complete. Active motions are then encouraged.

Fig. 241.—Excision of the elbow-joint. Above is seen the sawn surface of the ulna, below is that of the humerus. The space between the bone ends should measure at least 4 cm.

This method of operation is well adapted for cases of far-advanced tuberculous disease. In cases of bony ankylosis, however, exposure of the joint is difficult, and in these as well as in early cases of tuberculosis, I believe the following method of operation is to be preferred, especially as it preserves the lateral ligaments so necessary to ensure stability in the new joint.

Excision of the Elbow by External Incision, with Temporary Resection of the External Condyle.—An incision is made from a point about 5 cm. above the epicondyle, along the external supracondylar ridge to the joint level, and thence downward over the head of the radius, curving posteriorly to terminate near the subcutaneous surface of the ulna, about 5 cm. below the tip of the olecranon (Fig. 242). The upper part of this incision passes directly to the bone (supracondylar ridge), but below the joint level only the skin and superficial fascia are divided at first, exposing the aponeurosis covering the common tendon of origin of the extensor muscles. The soft parts are reflected from the humerus and joint, front and back, until free exposure is

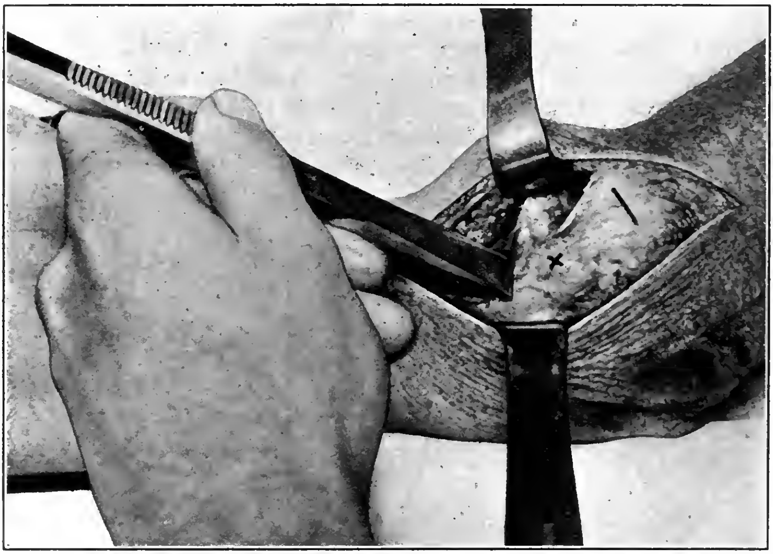

Fig. 242.—Excision of elbow, external condyle × and head of radius — exposed and osteotome applied to external condyle. (Ashhurst, in Annals of Surgery.)

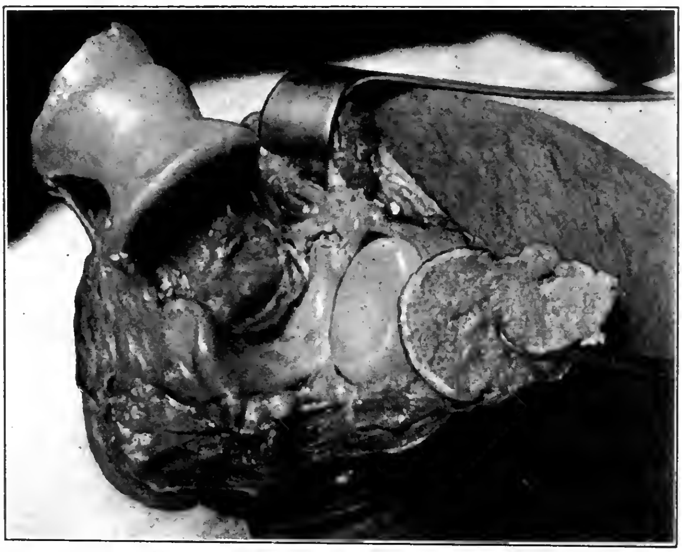

Fig. 243.—Excision of elbow, joint luxated around internal lateral ligament as a hinge. (Ashhurst, in Annals of Surgery.)

secured. The external condyle is then detached by chisel from the humerus, and is turned downward, exposing the joint. If ankylosis is present, the bones are readily separated by gouge and mallet. If there is danger of injuring the ulnar nerve, a small incision may be made on the inner side of the joint, between epitrochlea and olecranon, and the nerve drawn out of the danger zone. If ankylosis is not present, the elbow-joint can be exposed at once by adducting the forearm on the arm around the internal lateral ligament as a hinge. All parts of the joint are thus fully exposed to view (Fig. 243). If it is now desired to expose the lateral surface of the olecranon more fully, the skin incision should be deepened to the bone between the anconeus posteriorly and the extensor carpi ulnaris anteriorly. It is usually recommended to do this at the commencement of the operation, but it is not always necessary. Excision is then proceeded with, until a sufficient amount of bone has been removed. If no interposing fat and fascia flap is to be employed (arthroplasty), a space of 4 cm. at least should exist between the bone ends. If arthroplasty is to be done, a space only of 2 or 3 cm. is necessary; a flap is readily obtained from the superficial surface of the triceps, with its base at the olecranon. When the excision is completed, the external condyle is fixed in position by two Lambotte screws, and the soft parts closed in layers without drainage. If much bone has been removed from the humerus, it will be necessary to trim off the articular surface of the detached external condyle to a corresponding degree.

The great advantages of this operation are: (1) the facility with which the bones are divided in cases of bony ankylosis; (2) the ease with which the entire joint cavity is exposed, thus adapting this operation for exploratory purposes; and (3) the preservation intact of both lateral ligaments, which assures greater stability in the joint than when excision is done by the posterior incision.

EXCISION OF THE WRIST.

Very seldom is excision of the wrist required. A tuberculous lesion either can be cured by persistence in conservative treatment (almost always in children) or is so far advanced as to demand amputation of the forearm. When excision is attempted it is important to remove all the diseased bone, including the articular ends of the radius and ulna and of the metacarpals, as well as all the carpal bones; but whenever possible the trapezium should be preserved, as its removal impairs the usefulness of the thumb.

1. A *single dorsal incision* (Boeckel, Langenbeck) over the lower end of the radius, between the extensors of the thumb and the extensor indicis, gives fair exposure of the radial portion of the joint, and may be used in children where it is desired merely to remove some carious bone by the curette.

2. *Two dorsal incisions* (Ollier, 1888) give somewhat better exposure: The *radial incision* is on the dorsal surface midway between the two styloid processes; it passes obliquely downward and radially to the middle of the index metacarpal. After opening the wrist-

Fig. 244.—Excision of the wrist-joint. The web between the index and middle fingers is divided.

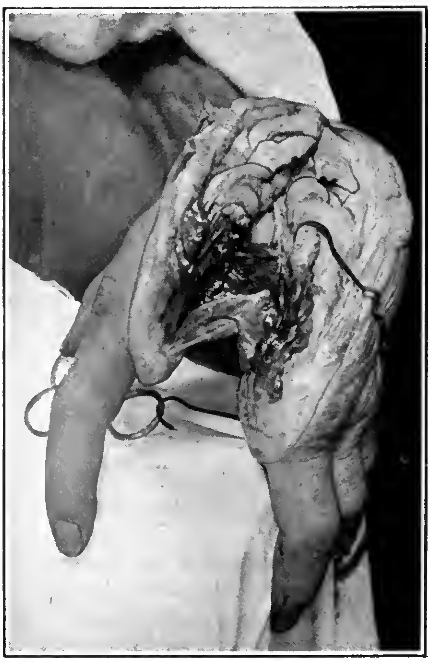

Fig. 245.—Excision of the wrist-joint. By rolling the metacarpal bones apart the carpal bones are fully exposed.

joint, an *ulnar incision* is made along the ulnar border of the extensor carpi ulnaris. The soft parts, including the periosteum with the tendinous insertions, are then stripped from the bones, and these are removed piecemeal, by saw, gouge or bone forceps.

3. The best exposure is obtained by *splitting the dorsum of the hand*, after the method of Studsgaard of Copenhagen (1891): As practised by Mynter (1894) the dorsum of the hand is split from the web between the index and middle finger up to the wrist. It is not necessary to

Fig. 246.—Result seven months after excision of the wrist for tuberculosis, in a patient, aged twenty-eight years. Episcopal Hospital of Philadelphia.

split the flexor surface further than the base of the thenar eminence. The incision passes between the extensor indicis and the extensor tendon to the middle finger (Fig. 244). The metacarpals are then rolled apart, and the wrist is entered between the trapezoid and os magnum (the lesser multangular and the capitate of the newer terminology) (Fig. 245).

After any of these operations the wrist should be immobilized in slight hyperextension for six or eight weeks or longer, as ankylosis is desired. In my own cases I have employed a suture of phosphor bronze wire to fix the bones (Fig. 246). The fingers should be left free, and their early active use encouraged. The hand seldom is very useful.

EXCISION OF THE HIP.

In most cases, especially in children, a partial excision, or removal of carious bone by the curette, is all that is desirable. If ankylosis follows, the limb will be more useful than when a luxation occurs as the result of a complete excision.

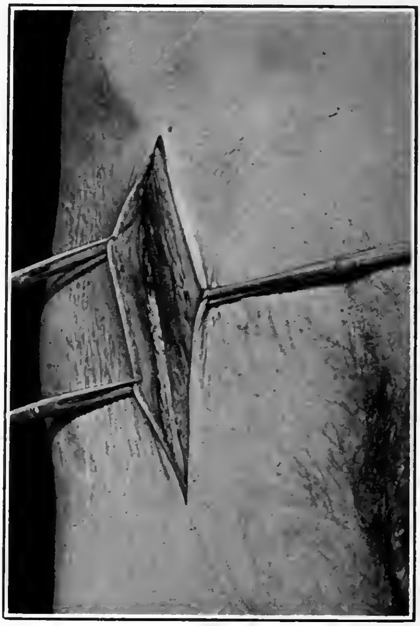

Fig. 247.—Excision of hip-joint by anterior longitudinal incision. The interspace between the sartorius and the tensor fasciæ femoris is exposed.

1. For atypical or partial excision the *anterior incision* (Hueter, 1878) is to be preferred. This begins at the anterior superior spine of the ilium and extends longitudinally downward about 10 cm. The interspace between the sartorius and tensor fasciæ femoris is found, and these muscles are separated (Fig. 247); beneath them will be found the rectus femoris on the medial and the gluteus medius on the lateral side of the wound. Between these latter muscles the capsule of the hip-joint is exposed and incised. Better exposure of the joint is secured by an incision on the medial side of the sartorius (Luecke), the capsule being opened between the rectus femoris and the iliopsoas muscles (Fig. 248). Carious bone is then removed with sequestrum or gouge forceps, or with Volkmann's sharp spoon. The acetabulum also may be gouged if diseased. If the head of the femur

is so diseased as to require complete removal, its neck may be divided by chisel or by Adams's saw.

2. The *posterior incision,* known during the nineteenth century by the name of Langenbeck (1867), is preferable to the anterior where an extensive operation is contemplated, and where free drainage is required. This incision is made in the axis of the femur, with its center over the great trochanter, and about 12 cm. in length; in the upper portion it splits the fibers of the gluteus maximus and in its lower it passes directly to the bone. The great trochanter is cleared of its muscular attachments (subperiosteally when possible), the capsule

FIG. 248.—Excision of hip-joint by anterior longitudinal incision. Instead of passing on the outer side of the sartorius the surgeon may pass between this muscle and the iliopsoas, as is shown here. Note the external circumflex artery and the nerves to the sartorius and rectus. These limit the exposure below.

of the joint is opened posteriorly between the pyriformis and gluteus medius and the cotyloid ligament is divided; this admits air to the joint, and after division of the ligamentum teres, the head of the femur can be luxated on to the dorsum of the ilium by adduction and flexion of the thigh. The femur is now divided with saw just above the lesser trochanter, and the head, neck and greater trochanter are removed. If the acetabulum is healthy, or if its diseased structures can be completely removed, the upper end of the femoral shaft is then placed in the acetabulum, the wound is closed with drainage, and the leg is immobilized in abduction and slight flexion (no external rotation), in the hope that ankylosis will occur. If the diseased tissues cannot be thoroughly removed, and particularly in cases where marked secondary infection exists, it is better to allow dorsal dislocation of the femur in order to facilitate drainage of the acetabulum. In such cases the operation is followed by greater disability (shortening, adduction, instability) than where the femoral end can be placed in the acetabulum. However, in some cases it is possible to correct this dislocation by a later operation (Figs. 249 and 250).

3. The *external incision* of Lambotte (1913) is less destructive to the soft parts than the posterior incision, and gives as free exposure

Fig. 249.—Skiagraph showing absorption of head and neck of femur from tuberculosis with pathological luxation and marked flexion-adduction deformity. Episcopal Hospital.

of the upper end of the femur and the acetabulum. This approach also is valuable for arthrodesis of the hip according to Albee's method, for operations for non-union of the neck and for the bloody reduction of congenital dislocations. The incision passes from the anterior-superior spine of the ilium directly to the external surface of the great trochanter, and is continued thence down the outer surface of the trochanter for 6 to 8 cm. The incision is deepened to the fascia lata, and this structure as well as the tensor fasciæ latæ is cut through in the lines of the skin incision. This exposes the capsule of the hip-joint just in front of the anterior border of the gluteus medius muscle (Fig. 251). The large flap is drawn well to the inner side of the thigh by retractors, which also protect the femoral vessels. The

FIG. 250.—Pathological dislocation of the hip. After exposure by Lambotte's incision the upper end of the femur has been replaced in the acetabulum. Episcopal Hospital.

FIG. 251.—Excision of the hip-joint, by Lambotte's incision. The large anterior retractor protects the great vessels and draws the iliopsoas and rectus muscles toward the midline.

capsule is then incised anteriorly, the cotyloid ligament and the ligamentum teres are divided, and the femoral head luxated forward by abduction and outward rotation of the thigh. After excision of diseased structures and reposition of the great trochanter or remaining portion of the femoral shaft in the acetabulum (if not contra-indicated), the fascia lata is accurately sutured throughout the wound, and the skin closed. In suspected cases drainage must be provided.

EXCISION OF THE KNEE.

This is the most frequently done of all the excisions. Every surgeon develops minor variations of his own, and it is sufficient here to describe one typical form of operation.

Fig. 252.—Excision of the knee-joint by simple transverse incision.

A transverse incision is made across the joint *below the patella,* from the posterior lower edge of one femoral condyle to a corresponding point on the other (Fig. 252). This incision passes only to the deep fascia, and the skin and subcutaneous tissues are dissected upward, until the tendon of the quadriceps is exposed. This is then divided *just above the patella,* exposing the femoral condyles. The lateral expansions of the quadriceps being divided and the patella turned downward toward the tibia, the knee is fully flexed, exposing the ligamentum mucosum (Fig. 253), or, when this is not present, bringing at once to view the crucial ligaments. The end of the femur is next cleared for the saw: The saw should be applied parallel to the articulating surface; that is, the internal condyle is to be left longer than the external, and the line of section is to emerge

Fig. 253.—Excision of the knee-joint. The joint has been entered by sectioning the quadriceps tendon just above the patella and the latter has been turned down, exposing the condyles. Note the ligamentum mucosum attached to the intercondylar notch.

lower (nearer the foot) on the posterior surface of the femur than anteriorly (Fig. 254). In children the section should pass well below

Fig. 254.—Excision of the knee-joint. The ligamentum mucosum has been divided, exposing the crucial ligaments. The saw is removing a section from the condyles.

the level of the epiphyseal line, which lies opposite the adductor tubercle; even in adults it is seldom necessary to remove more than the anterior surface of the condyles. Having completed the section of the lower end of the femur, the upper end of the tibia is next cleared, and with the patella still attached, is sawed off at right angles to its shaft, but with a slight anteroposterior obliquity, corresponding to that of the femur (Fig. 255). This tends to prevent posterior subluxation of the tibia. Care is exercised not to wound the popliteal artery; if the joint is kept fully flexed while the bone ends are being removed it is in little danger. The lateral ligaments are preserved when possible, as they give great stability to the joint until ankylosis is complete. If on attempting to straighten the limb it is found that enough bone has not been removed, another slice may be sawed from femur or tibia. The knee should come into *full extension;* the tendency of the bones is to undergo flexion later. If diseased foci exist in the bone ends beyond the plane of section they may be removed with gouge

Fig. 255.—Excision of the knee-joint. After section of the condyles of the femur, the articular surface of the tibia is removed along with the attached patella.

or curette, as it is very undesirable to shorten the limb by the removal of too much bone. In most cases it is sufficient to remove from 2 to 4 cm. of bone in all; such an amount of shortening is advantageous, since with a stiff knee a slight degree of shortening promotes ease in walking.

It is not necessary to fix the bone ends by wire or other suture except where the lateral ligaments have been divided or much bone has been removed. In such cases the insertion of a bone transplant is preferable to metal fixation. In all cases, however, the periosteum and tendinous structures should be united with buried sutures of chromicized catgut. Drainage for twenty-four or forty-eight hours is advisable in most cases. The limb is dressed in plaster of Paris, and is suspended vertically for twenty-four hours, to diminish the oozing of blood. The tube is removed through a small window cut in the gypsum case, without disturbing the deep dressings.

Immobilization should be continued for six or eight weeks or longer if ankylosis is not present when the gypsum case is removed. There is great tendency during convalescence and before ankylosis occurs, for the knee to bow outwardly, as well as for the tibia to be displaced backward, from the pull of the hamstring muscles. These tendencies should be guarded against when the dressing is first applied; and an orthopædic brace should be worn for a year at least after operation.

EXCISION OF THE ANKLE.

When excision of the ankle is done for tuberculosis, exposure is obtained by an incision about 7 cm. in length along the posterior border of the external malleolus, continued for 5 cm. or more beneath

FIG. 256.—Excision of the ankle-joint. A curved incision around the external malleolus exposes the peroneal tendons, which are to be divided. The extensor tendons are not cut.

the external malleolus and forward across the foot as far as the extensor tendons (Fig. 256). The peroneal tendons are divided, and their sheaths, which usually are involved in the tuberculous process, are excised. The external lateral ligament of the ankle is divided, and the ankle-joint is fully exposed by displacing the foot inward (Fig. 257). The external malleolus generally is diseased, and is removed by chisel or saw; this may be done as a preliminary to opening the joint, which then may be exposed by turning the malleolus downward. The internal malleolus is carefully cleared, and is removed along with the articular surface of the tibia. If the astragalus is much diseased the entire bone should be removed; and when this is done it is well, in order to encourage ankylosis, to remove the articulating surface of the calcaneus also. Then the foot is brought back into place, the ligaments and tendons are repaired, and the foot is dressed as described below.

When the operation is done for infantile paralysis (*arthrodesis*), to convert a flail joint into one possessing useful stability, the same exposure may be employed; but usually it is sufficient to make a small transverse incision across the front of the ankle-joint which is entered between the extensor muscles and the tibialis anticus. The articulating surfaces of the tibia, fibula and astragalus are then removed by gouge and mallet. Osteotomy of the fibula, just above the external malleolus, with inward displacement of this process as advised by Goldthwait (1909), is not necessary to obtain ankylosis.

Fig. 257.—Excision of the ankle-joint. After division of the peroneal tendons and the external lateral ligament the foot is dislocated inward exposing the articular surfaces of the tibia and fibula and those of the astragalus.

Arthrodesis of the *subastragalar joint* is conveniently done through an incision about 5 cm. long below the external malleolus, parallel with and just above the peroneal tendons, which are not injured. Through this incision the entire cartilaginous surfaces of the astragalo-calcanean joints (both in front of and behind the strong astragalo-calcanean ligament) are removed, and sometimes also the cartilages lining the astragalo-scaphoid joint (and which forms part of the sub-astragalar joint). If the latter joint is not easily accessible it is better to expose it by a second incision parallel with and on the fibular side of the tendon of the tibialis anticus.

After any of these operations the foot is dressed in plaster of Paris in slight dorsal flexion and adduction, so as to promote ease in locomotion and prevent the development of postoperative flat-foot. No drainage is necessary in cases of arthrodesis for flail-foot, and usually not after excision for tuberculous disease, unless secondary infection is present. Immobilization should be continued for two or three months, and supporting apparatus should be worn for a year. In cases of tuberculosis secondary amputation may be required.

AMPUTATIONS.

By NELSON M. PERCY, M.D.

In the performance of an amputation, the first indication is to conserve the safety of the patient, the second, to secure a stump which will most satisfactorily meet the demands to be made upon it by the artificial limb.

When infection is present or probable, flaps are contra-indicated, because of the lowered resistance following the impairment of circulation incident to their formation, and incisions cannot be closed with safety.

The flapless operation obtained considerable favor in the first year of the World War; as a life-saving measure it lessened shock by shortening the time of operation and permitting amputation at the lowest possible level; it was therefore well adapted only to periods of stress. When this method of amputation is chosen the whole consideration is naturally given to the saving of life, it being understood that reamputation will be performed later. With proper technic the stump obtained after the reamputation should be practically as long as that which would have been secured had the usual type of amputation been performed originally.

When the incision is left open, whether the circular method has been used or the one with short flaps, traction should be applied to the skin as soon as the acute inflammation has subsided, to overcome retraction and thus limit the size of the resulting scar. If it has been possible to make flaps of sufficient size, the skin may be pulled down sufficiently to approximate the edges and in some cases a secondary suture may be performed; if the tissues are not sufficient to cover the bone, they are kept from retraction until it is safe to perform a secondary removal of the projecting bone or a typical reamputation. The method of extension illustrated (Fig. 258) seems to meet all indications.

With the marked success that has recently been attending both the primary and the delayed closure of wounds, it seems reasonable to expect that in the future fewer amputations will have to be left unsutured and that it will be possible more nearly to approach the normal type of technic.

In amputation performed under more favorable conditions, the chief attention should be paid to the future requirements of the artificial appliance. The favorable sites for amputation to meet these requirements are shown in Figs. 259 and 260.

Whatever the method of amputation, proper attention must be paid particularly to three points: (1) The periosteum should be cut cleanly with a knife at or slightly above the level at which the bone is to be divided, thus avoiding shredding of the periosteum, and so diminishing the probability of spur formation; (2) the nerves should be drawn down strongly out of their sheaths and an inch or more removed in order to diminish the danger of their being caught in the scar and of overgrowth of the nerve ends; (3) a sufficient amount of soft tissue must be secured over the end of the bone.

Standardization.—Because of the lack of standardization in amputations and in order to obtain more uniform results among all of the different workers, the Interallied Surgical Conference adopted the following conclusions and recommendations:[1]

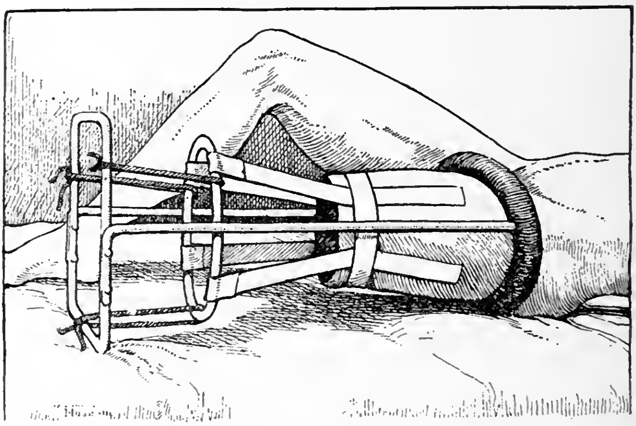

Fig. 258.—Stump extension with a modified Thomas knee splint. (Adapted from Sinclair.) "A Thomas knee splint is cut down and a 9-inch square riveted on to the side bars 12 inches beyond the end of stump. An 8-inch circle of aluminium is attached by gauze and glue to the skin of the stump so as to be 6 inches distal to the cut surface. Extension is made from the ring to the square either by tapes or rubber bands. The square acts as a pedestal and also for the attachment of the extensions."

Instead of the brace a weight and pulleys may be used; three cords are tied to the ring, each passed through a pulley and all fastened to the weight. (Courtesy of the Military Surgeon.)

1. Amputation is indicated only when conservation of the limb would lead to the death of the patient, or if eventual loss of the limb is inevitable.

2. The two chief indications for amputations are: (*a*) Extent of the injury, and (*b*) infection.

3. Amputations for infection are always the more dangerous. French statistics of 29,139 amputations show that the general mortality of 6 per cent. is elevated to 28 per cent. in case of infection. Again, a review of 3633 disarticulations furnishes the same result.

4. Amputations of the upper extremity are less frequently indicated than those of the lower. This depends upon the facts that in the

[1] Review of War Medicine and Surgery, 1918.

upper extremity serious infections are less frequent, resections are followed by more favorable results, and the prospects offered by prosthesis are unsatisfactory to both surgeon and patient.

5. The indications for primary amputation are found in the nature and extent of the injury—pulverization, crushing, partial avulsion of the limb, and especially rupture of the main bloodvessels.

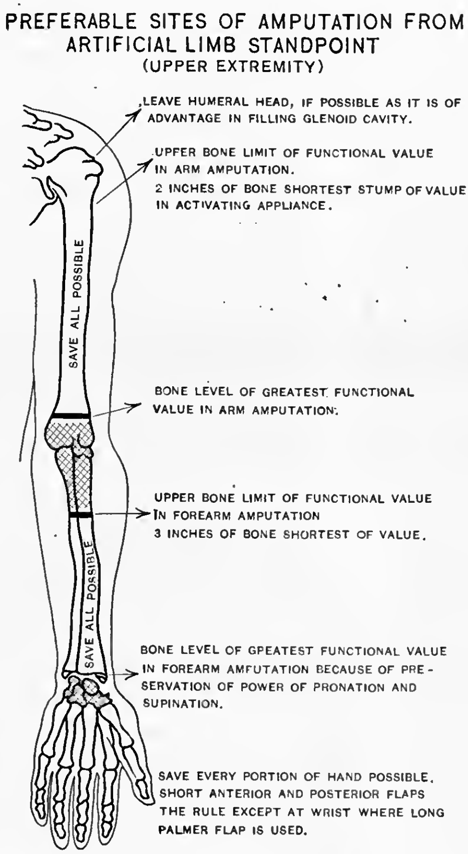

Fig. 259.—Amputation (bone division) in shaded area unsatisfactory from artificial limb standpoint.

6. The indications for secondary amputation are found in massive gangrene, either ischemic or infective. Other extending infections (superficial gangrene) may be treated by conservative measures.

7. Late amputations are most often indicated in cases of chronic infection with cachexia, which do not respond to any form of treatment. Primary amputations, or those delayed for twenty-four or forty-eight hours, should (having due regard to the gravity of the lesions), as far as possible, be made to correspond with the site of the fracture, the soft parts being simply divided and the bone trimmed

or rounded off, if necessary. In less serious injuries, the site of the amputation should be as near the seat of the fracture as possible. Amputation called for by infection should be performed by the "flush method," or with short everted flaps fixed by suture to the skin of the limb above. When the wound has become sterile and the soft parts have been drawn down as far as possible by extension methods, the amputation flaps may be refashioned, if it be required.

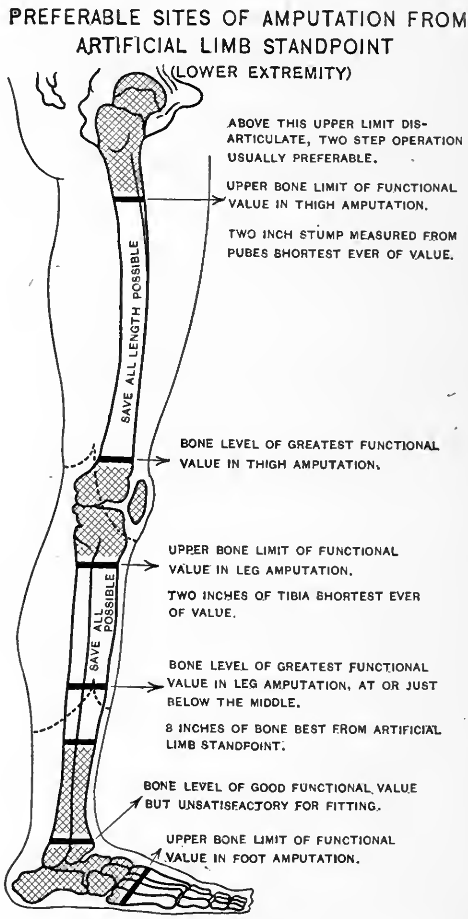

FIG. 260.—Amputation (bone division) in shaded area unsatisfactory from artificial limb standpoint.

The technic of late amputation should be guided by the method most likely to adapt itself to prosthetic necessities. When long fissures run upward from a fracture, the amputation may still be carried through the point of complete solution of continuity, and the fissured portion of the bone retained, due care being exercised in the disinfection of the wound.

1. When shock is severe, nitrous oxide combined with oxygen is the anesthetic of choice; if this cannot be obtained, ether should be substituted.
2. As a general rule, shock is not to be regarded as a contra-indication to amputation.
3. Provisional hemostasis (by a tourniquet or by preliminary ligature of the main vessel) is necessary and should be complete.
4. The periosteum should be divided at the exact seat of section of the bone, and periosteal flaps should not be raised.
5. In primary amputations, especially those indicated by infection, the wound should be left widely open. Care should be taken not to open up the intermuscular planes. With this object the vessels and nerves should not be followed into the intermuscular clefts, but should be cut long.
6. Post-operative measures are mainly directed (*a*) to disinfection of the field of operation, which should obviate the occurrence of osteomyelitis; and (*b*) to controlling cicatricial contraction of the flaps.
7. The length of the resulting stump is of more importance than perfection of its covering.

AMPUTATIONS OF THE LOWER EXTREMITY.

Disarticulation of the hip-joint is a more serious operation than amputation through the neck of the femur, even when performed by a racket incision and with preliminary ligature of the vessels.

For satisfactory fitting of an artificial limb an amputation through the thigh should leave a stump extending 12 to 14 cm. below the great trochanter.

Amputations through the upper fourth of the thigh are difficult to accommodate with an apparatus, in consequence of the abduction of the femur which takes place.

Amputations through the middle and lower thirds of the thigh give good results. The great sciatic nerve should be divided above the level of the flaps.

Gritti's method is only suitable to late amputations.

Disarticulation of the knee-joint is a useful provisional procedure.

Amputation through the tuberosities of the tibia gives a good result, as the patient can wear an apparatus fitted to the flexed knee.

Amputation of the leg should be performed at the lowest practicable level. A posterior flap appears to be preferable.

The fibula should be cut an inch shorter than the tibia.

Tibio-tarsal disarticulation with removal of the malleoli, subastragaloid amputation, Lisfranc, Syme and Pirogoff, all give excellent results.

Chopart's method is suitable only for secondary or late amputations.

Any resection of the bones of the foot which insures a perfect sole and preserves the normal axis of the leg should be preferred to any amputations.

AMPUTATIONS OF THE UPPER EXTREMITY.

In amputations at the shoulder, the head of the humerus should be preserved if possible.

Amputation of the arm should be performed at as low a level as is practicable. Either the circular or the flap method may be employed; 10 cm. of the humerus are necessary for a useful stump.

In the forearm every effort should be made to preserve a lever at least 10 cm. in length below the elbow-joint, and to maintain the movements of pronation and supination.

In the hand, whenever possible, trimming operations should be adopted, since every segment which can be preserved may prove of great service.

Movements of the joints above an amputation, and attention to the nutrition and mobility of the muscles, should be maintained during the whole course of cicatrization.

The application of artificial limbs should be prompt and a provisional apparatus should always be insisted upon, especially in the case of the lower limb.

ARTIFICIAL LIMBS.

The fact that there were about 500,000 amputated limbs resulting from the past war has brought the subject of artificial limbs to our most urgent attention.

Previous to the World War artificial limb construction had undeniably reached its highest development in the United States. This is shown through the preference still given the American type of artificial leg by our allies, and further through the purchase by Germany, before our entrance into the war, of the patent rights for an American artificial arm. Instead of our preëminence in this work being a cause for congratulation, however, it is indeed rather the opposite, since it was the result of the unusual number of amputations occurring in industry before the introduction of the "safety-first" movement. It must be admitted, also, that the credit for this advanced position in artificial-limb construction should be rightly given almost entirely to the manufacturers, the medical profession as a whole having paid little attention to this phase of treatment.

Despite the large amount of study that has been expended upon the subject, a review of European literature since 1914 seems to show little of any great value that has been added to our knowledge of artificial-limb construction. Yet it is evident that there has been a marked improvement as a whole in the results obtained with artificial appliances. This improvement has evidently been brought about largely through a better appreciation by the surgeon of the relation of the amputation to the fitting of the artificial limb, recognition of the great importance of the after-care of the stump, more intelligent coöperation between the surgeon and the artificial-limb maker, and more thorough and systematic training in the use of the artificial appliance.

PAINFUL NERVE STUMPS.

Corner[1] distinguishes at least five types of pain in amputation stumps, the first of which is universal and the last uncommon.

1. Early pain, coming on immediately after the amputation, dependent on an endoneuritis set up by the injuries inflicted on the nerves at that operation. When alone present this accession of pain dies away in a few days or weeks.

2. Compression pain, coming on about two months after the interval and sometimes steadily increasing.

3. Inflammatory pain. The early pain never passes off, or it may become paroxysmal and severe, or it may even be still more clearly defined.

Clinically these cases may be grouped in a series; pain immediately after the operation is due to the trauma of that operation and the inflammation of the repairing tissues; a little later, after from two to ten months, the pain is due to the compression of the nerve fibers by the contraction of scar tissue; later still, pain is due to active inflammatory changes in the nerve ends.

4. This clinical type is produced by the regeneration of nerve fibers. It is characterized clinically by more continuous pain and illusions as to the presence of the missing part; for instance, the amputated foot. The pain is acute and first appears within a few days of the amputation. At first it is not great, but increases in severity.

The fourth type has clinical features of both the second and the third type.

5. This type is only recognized clinically by the process of elimination; nerve trunk after nerve trunk is removed by operation and their consideration eliminated by trustworthy surgery. Still the pain and tenderness persist, and are not of neurotic origin. The pain may originate from the irritation and inflammation round a silk ligature or other foreign body. Or the skiagram may show that it is due to disease in the bone; terminal rarefaction of the bone is due to the injuries of operation and the healing of the wound, but when the bony changes are further afield they are partly due to nervous irritation—dystrophy. Such cases exhibit the usual signs of bone pain, night pain and pain in wet weather, and are very persistent. They are frequently called neurotic patients, but the fault is not theirs—but ours; we have not found out the cause of the patient's pain. We should bear the reproach. The stumps of patients of this type frequently twitch and twitter.

THE CARE OF THE STUMP.

Proper care of the stump is indicated broadly for two reasons: (1) To secure ultimately the maximum degree of usefulness, and (2) to minimize the difficulties associated with the first attempts at using an artificial limb and thus avoid discouragement of the maimed.

[1] Brit. Med. Jour. 1918, p. 1665.

Freedom from sensitiveness to pressure is the chief qualification of a good stump and is the measure of its capability for end-bearing. This is mainly dependent on the absence of swelling and congestion of the soft parts and above all of exostoses on the bearing surface of the bone. It is evident, therefore, that those measures must be used which will hasten absorption and prevent the formation of exostoses or limit their location to less harmful areas. In addition to the measures usually employed for such purposes, namely, elevation of the part, bandaging, massage, hydrotherapy, electric-light baths, and electricity, particular emphasis must be laid on the benefit derived from early functional use; carefully graduated pressure on the end of the bone helps to give it a smooth and rounded shape and limit the formation of exostoses to the less harmful location at the sides. Hence, early functional use is the second prerequisite for end-bearing; the most careful surgical technic may be of no avail if the proper care of the stump is not begun at the earliest possible moment. This undoubtedly is the explanation for the fact that artificial-limb makers are, as a rule, not enthusiastic about the possibilities of end-bearing; the cases reach them too late for anything further to be gained in this direction, so that unless the surgeon has prepared the stump for end-bearing by the early institution and the persistent use of the necessary measures, end-bearing will be possible only in exceptional cases.

Muscular weakness and limitation of motion are two of the chief causes of discouragement in learning the effective use of an artificial limb. Considerable strength is obviously required to manipulate it satisfactorily. The demand is naturally greater with the shorter stumps and is still further increased if joint stiffness is present. When a contracture has been allowed to develop, this may make the use of an artificial limb difficult or impossible, as, for example, in amputation of the thigh the stump tends to become slightly flexed and abducted, and this may easily become sufficient to prevent the use of an artificial leg until it has been overcome. The preservation of the full range of motion of the joints above the site of amputation is, therefore, of particular importance. The incentive to movement of the part is absent and hence limitation of motion develops more rapidly, and is usually difficult to overcome, particularly in the case of a short stump, owing to the poor leverage afforded. Contractures must, therefore, be guarded against from the first and movements of the joint must be begun just as soon as the condition of the incision permits and persisted in until the full range of mobility in all directions is assured.

ROUTINE FOR PROPER STUMP TREATMENT.

To meet all indications the plan of treatment must be systematic. While the incision is healing, at each dressing the stump should be moved to the full limit in the opposite direction to that in which a contracture is likely to develop. In forearm stumps, movement should be carried out in supination and extension; in upper arm amputations, in upward and backward motions; in the lower leg, in extension; and in thigh amputations, in extension (securing hyperextension) and abduction. It is usually advisable to keep all stumps elevated while the patient is recumbent, and therefore particular attention should be directed to thigh amputations, because this position favors a flexion contracture; to counteract this tendency it is recommended that once or twice each day the pillow be removed from under the stump and placed under the buttock, thus allowing the stump to drop into hyperextension. Further, advantage should be taken of the position in which the stump is dressed in order to guard against the tendency to contracture; thus, in forearm stumps, where supination is hardest to control, the dressing should be applied so as to maintain the bones in this position. When the incision has to be left open, movement of the joint in the other directions also should be added as soon as conditions permit.

As soon as the wound is healed, or practically so, and while the patient is still confined to bed, the following routine (modified from Hirsch) is begun:

1. **Massage.**—The stump should be massaged for a period varying from ten to thirty minutes, once or twice a day, according to its size and position. The region of the incision should naturally be avoided for the first few times and care taken not to make undue tension on the fresh scar. As rapidly as the tolerance of the stump will permit, the depth and force of the massage should be increased up to the full normal limits.

2. **Bandaging.**—After the massage, the stump should be redressed with a cotton dressing, bandaged snugly in place, or, if it is well healed a bias flannel bandage alone may be used. The latter, when properly applied in several layers, gives a firm, even pressure.

3. **Pressure Exercise.**—The patient is directed to press the end of the bandaged stump against a cushion, placed in the bed or against a frame. This must be begun with care, pressure being made at first for only several minutes at four- or five-hour intervals; if there is no unfavorable reaction, it should be increased gradually up to five or ten minutes every two hours and then every hour.

4. **Movements.**—After each pressure exercise, active movements of the stump are to be made in all directions, to the full limits of the joint motion, for three to five minutes. Later, some form of resistance movements may be added to advantage, in order to still further build up the strength of the muscles controlling the stump, and so make the early use of the artificial limb more easy.

5. **Baths, etc.**—Hydrotherapy in the form of hot packs, or warm baths or electric-light baths are to be used as indicated to improve the circulation and hasten absorption. The contact bath is particularly valuable, the rapid dilatation and contraction of the bloodvessels which it produces causing a marked improvement in the local vascular

and nervous tone; the simplest method of application consists in the use of two buckets, the stump being plunged first into the hot water and then into cold, as rapidly as the patient can change it, for five to ten minutes.

When the patient is able to leave the bed, the measures just outlined are to be continued, but in the case of leg amputation the pressure exercise is to be discontinued as described and direct weight bearing on the stump begun. A stool of the proper height and a cushion are provided and the patient, supporting himself with his hands, allows at first only a little weight to rest upon the bandaged stump; the amount of weight borne and the time are then gradually increased in a manner similar to that used in the pressure exercise in bed, until the entire weight can be taken on the stump. The patient may then carefully begin to hammer on the stool with the end of the stump, in imitation of the pounding which takes place in walking with an artificial limb provided for end-bearing. As soon as the patient can stand alone for a long time without getting tired, and with no other support than that needed to balance himself, a temporary leg, properly provided for end-bearing, may be fitted and walking begun, crutches being used guardedly and dispensed with as soon as possible. For a long time, however, the patient should continue to practice standing on the bare stump on a hard surface three times a day.

The value of end-bearing is generally admitted. The measures suggested, both with respect to the amputation and the care of the stump, are simple and have borne the test of clinical experience. Their persistent use is urged upon all. While it is recognized that in very many cases the presence of long-continued infection will seriously delay the institution of proper after-treatment, yet much good may still be expected even when begun late, and there will be a large number in which the routine may be followed from the first. The ideal cases will obviously be those requiring reamputation, which will naturally be deferred until entirely favorable conditions can be secured and which can, therefore, be performed solely with regard to the requirements of the artificial limb. Even when the attempt to secure end-bearing is unsuccessful rigid adherence to the routine just described is still to be insisted on; the improved conditions of the stump, the greater freedom from pain and the avoidance of much of the discomfort usually associated with the early use of an artificial limb are more than sufficient to repay one for the additional trouble.

SYSTEMATIC EXAMINATION OF RANGE OF MOTION.

The joint motion should be tested by the surgeon at regular intervals, particularly in bedridden infected cases, in order to be certain that the full range is retained. At the elbow, in addition to verifying the presence of complete flexion and extension, the freedom of rotation of the radial head must be determined and particularly with reference to outward rotation (supination); the value of the movements of pronation and supination in activating the artificial hand will depend upon the degree possible, the loss of even a few degrees making a great difference. Of the movements of the shoulder girdle (upward, downward, forward, backward and circumduction), the upward and backward ones are the most important; these may be easily tested with the patient lying at the edge of the bed or turned on the opposite side. At the knee it is well to remember that there are normally a few degrees of recurvation. In testing the hip, the presence or absence of flexion deformity may be determined (following the method used in hip disease) by flexing the opposite thigh fully on the trunk, the stump rising from the bed when a contracture exists, or with the patient lying on the face, the degree of hyperextension may be determined (again as in the similar test used in hip disease) by lifting the stump with one hand while holding down the buttock with the other; in testing the amount of adduction, movement of the pelvis should be controlled with one hand while the other manipulates the stump.

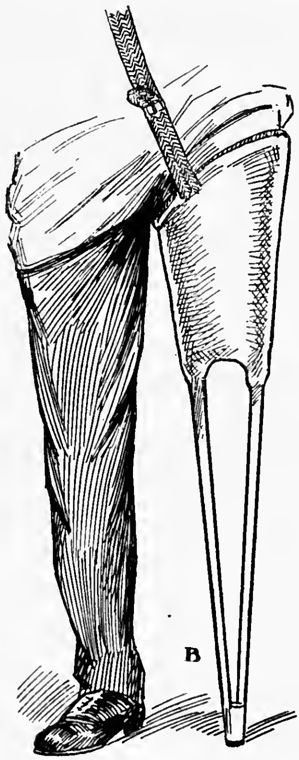

Fig. 261.—The peg-leg applied. (Courtesy of the Military Surgeon.)

TEMPORARY ARTIFICIAL LIMBS.

The many advantages in the early application of some form of artificial leg were fully demonstrated in the late war. Provided with a simple appliance, the patient is soon able to walk without any support or without any other than that afforded by a cane. The period of his incapacity for work is thus greatly shortened and vocational training can be begun much earlier. The benefit to the patient's morale is obvious. The necessity for such early functional use, if end-bearing is to be hoped for, needs no special argument, but the question as to whether a useful degree of end-bearing can be secured must still be considered as unanswered.

Of the various types of temporary artificial legs which have been suggested, the plaster peg-leg (Fig. 261) has proved the most satisfactory. It is cheap, comfortable and efficient, and can be made by anyone who understands how to properly apply a plaster-of-Paris cast. The plaster socket may be made either with or without an inner cuff of felt. Possible wrinkles in the plaster are not likely to give trouble if the felt is used; hence, it should be employed at least until the necessary skill has been acquired. In thigh amputations, the upright may be jointed at the knee, and in leg amputations a knee-joint attachment with thigh cuff may be added for greater security.

A temporary appliance may be made in a similar manner for the arm, but is necessary only in those cases where both arms have been lost.

THE REËDUCATION OF THE AMPUTATED.

Any plan for the reëducation of the amputated must necessarily take into account all the activities of the normal individual. The necessity for occupational reëducation has been so apparent and the results so encouraging that the importance of reëducation in sports is apt to be forgotten. Yet, perhaps one of the keenest regrets of the young soldier who awakens to find himself deprived of arm or leg is occasioned by his apparent cutting off from participation in all outdoor games. Hence, provision must be made for training in both work and play.

Many of these men have been inactive for long periods, and in many instances the mutilated extremities have been the seat of long-continued suppuration. General exercises to reëstablish as far as possible the coördination in the movements of the two sides are necessary. Provision should be made for a wide variety of both indoor and outdoor games. By pairing off the men according to their disabilities, equal conditions of competition can be established and much can be done toward the physical and the mental rehabilitation.

The first step in reëducation consists naturally of instruction in the performance of those everyday acts which were formerly the function of the lost member. In amputation of a lower extremity this is a relatively simple matter, but one nevertheless which requires time and painstaking care. Training in walking should be given individually and in squads, and under gradually increasing severity of conditions as regard unevenness of the ground, obstacles, etc.

Defects in the gait may be due to: (1) The character of the stump; (2) an improperly fitting socket or a poorly balanced leg; or (3) lack of skill in the individual. When walking has been mastered, more difficult exercises may be begun in suitable cases.

Those who have lost an arm should first be trained to do all necessary acts without an appliance. The skill of the remaining hand must be developed to the highest possible degree, so as to do not only its own normal amount of work, but also as much as possible of the work of the lost member. The stump also must be utilized to the fullest extent; it is surprising how much can be accomplished by its intelligent use. Even when both hands are gone, it has still been possible for individuals to learn to dress themselves, eat and perform all other necessary daily acts with reasonable comfort by the use of the most simple devices.

When the artificial appliance is applied, either the regular arm or the working tool, it must be remembered that the more complicated the device, the more likely is the wearer to become discouraged with it; hence, the more necessary that he be thoroughly trained in its use before he is discouraged. The chief discouragement in the use of the artificial arm is due, however, to its mechanical limitations; thus far it has not been possible to adapt it to the performance of movements requiring rapidity and precision. When to this is added the disadvantage due to the absence of the sense of touch it becomes at once apparent why the one-armed is so prone to discard all apparatus.

CONSERVATIVE OPERATIONS ON THE FOOT.

As it is very desirable to maintain the integrity of the sole, incisions or resections through it should be performed only when absolutely necessary. Every endeavor should be made to obtain primary union in every case. The same considerations apply to the dorsal surface of the foot when cicatricial contraction might interfere with the functions of the sole of the foot. It is even justifiable to resect certain bones in order to permit primary or secondary union and the maintenance of the skin of the sole in its normal condition. Amputation of one or several toes causes little inconvenience. The preservation of one toe, especially the first or the fifth, is often embarrassing.

Disarticulation of the metatarsal bones, with preservation of the corresponding toes, generally gives bad results. Resection of the first and fifth toes, with their metatarsal bones, generally gives a satisfactory result. The result of the preservation of the great toe alone, with its metatarsal bone, is not generally good. Excision of the second, third and fourth metatarsals produces a narrow foot, walking and standing are seriously impeded. As a general rule, the loss of three metatarsal bones seriously upsets the mechanism of the foot. The results of amputation through the metatarsus with a good plantar flap, whether performed through the anterior or posterior part of the metatarsus, are very favorable. After Lisfranc's disarticulation, walking may be easy and even elastic if the remainder of the foot is in good condition. As it is a difficult operation, it may be simplified by leaving the bases of the metatarsal bones. Prescaphoido-cuboid amputation gives good functional results. In short, all the operations through the front of the tarsus give good results if there be no complication due to the cicatrix or the conditions of the articulations. Chopart's amputation, when done under good conditions and carefully watched, may give a good result, but the equinism and the displacement of the stump often cause functional troubles which render it inferior to the amputations of Lisfranc and Syme. Partial resections of the astragalus and calcaneum, or horizontal resection of the calcaneum, check the tendency to equinism. Amputation below the astragalus (Pirogoff's amputation, and more especially Syme's) leaves the patient able to walk easily and quickly. On the other hand, operations on the posterior tarsus are very often followed by functional difficulties. Total or subtotal excision of the astragalus gives good results, but they are not so good as those obtained in peace; the causes of failure are infection of neighboring tissues, stiffness of joints and tendons, and insufficient supervision of the attitude of the foot after operation. Excision of the whole or greater part of the calcaneum, if bony regeneration does not take place, leaves a bad condition, very frequently attended by tibiotarsal or mediotarsal ankylosis. Partial resection, whether posterior or inferior, gives less unfavorable results if the foot is well maintained at a right-angle during the whole course of treatment. Combined resection of the calcaneum and the astragalus gives usually a bad result.

ATYPICAL OPERATIONS.

Resections of the anterior part of the tarsus involving the scaphoid and cuboid are often followed by equinism, with valgus or varus, or falling in of the arch of the foot. The functional condition can be greatly improved by an orthopædic boot. The seriousness of the consequences of excision of either of these bones seems to be about equally great. The results of atypical operations on several bones of the anterior part of the tarsus are determined much more by the degree of preservation of the arch of the foot, the strength of the points of contact of the sole with the ground, and the preservation of the action of the joints and tendons than on the site of the operation itself. Vicious positions of the foot, if the joints be freely movable, can be cured or improved by the division or transplantation of tendons. Transplantations are particularly useful when certain tendons have been destroyed. Some vicious positions with ankylosis call for secondary operations on the bones (resection of the cuneiform or astragalus). In short, conservative operations on the metatarsus are good, but in the posterior tarsus excision of the calcaneum or resection of several bones often causes functional disturbances which are graver than those following disarticulation or a Syme's amputation.

CAPACITY FOR WORK IN AMPUTATIONS OF THE LOWER EXTREMITY.

Irwin[1] publishes a most graphic representation of the capacity for work in amputations of the leg. Not only the diagram but also the text which accompanies it are so valuable and so filled with helpful suggestions that the article is reproduced in its entirety.

"The term 'capacity for work' ought to mean not merely the ability to do a certain class of work, but rather the ability to keep on doing it from day to day. A man's value in the general labor market depends as much on his being able to 'keep time' as on the actual amount of work which he can do. In regard to discharged soldiers, this question is put to the medical officer: 'By how much is the man's earning capacity lessened by his amputation?' The answer to this question does not depend alone on the length of the natural, as compared with the artificial limb, for while some low amputations are bad, giving a low capacity for work, other comparatively high amputations are good, allowing the man to become a very efficient and steady worker.

"Before considering the special features upon which capacity for work depends, let the functions required of an amputation of the leg with its prosthesis be for a moment considered.

"1. **Support.**—This demands an investigation of how the weight of the body is transmitted to the ground through the natural and the artificial limb. The best form of support is that obtained through a direct end-bearing stump. Indirect or lateral bearings at some time or other cause fraying and ulceration of the skin, and require much more care on the part of the patient if broken time is to be avoided.

"2. **Stability.**—This varies directly with the length of the natural limb, and with the length of the segment in which the amputation has been performed. With short stumps the grasp of the socket may not be sufficient and must be improved by a splice in the form of a laced socket, or in thigh stumps a pelvic band. In some cases stability has to be attained by stiffening of the joints of the artificial limb at the hip or knee, but this interferes with the gait.

"3. **Progression.**—This depends on the use of natural rather than artificial joints, good muscular power in the lever which activates the artificial limb, a long lever, and painless bearings. In short stumps we find progression accompanied by fatigue. This could be diminished by decreasing the weight of the artificial limb. The excuse of limb makers that the natural limb weighs much more than the artificial one is really irrevelant, for the muscular power of acting muscles is

[1] Brit. Med. Jour., 1919, i, 212.

greatly diminished by disuse, by interference with their insertions, and only a few muscles are effective at all.

"4. **Appearance.**—Appearance is of no importance as far as function is concerned. Compared with a limb giving comfortable support, efficient stability, good progression, and lightness, appearance counts for nothing. The French have long since recognized this by supplying a peg-leg with a broad base for special workers like farm hands who have to be on foot all day.

"**Estimation of Capacity for Work.**—Having laid down these general principles, what further considerations influence 'capacity for work?' They are:

"1. The length of the natural as compared with the artificial limb.

"2. The specific value of the ideal amputation at the particular level.

"3. The type of prosthesis most suitable for the particular stump. Prosthesis for some amputations are constantly requiring repairs while others last for years.

"4. The special conditions which prevail in the case under review—that is, how far the particular amputation falls below the ideal amputation at the same level.

"5. All these points ought to be considered in estimating the capacity for work of a man who has had an amputation in the lower limb. The fourth point will be governed by the disposition of the flaps, position of the scar, the presence or absence of pain, adhesions between the bone and skin, condition of joints, and by whether the surgeon has succeeded in obtaining an end-bearing stump. These points will demand consideration in every individual case and therefore cannot be reckoned with in attempting to map out a curve of 'capacity for work' in amputations of the leg in general.

"6. He represents in a graphic manner (Fig. 262) the fact that capacity for work does not vary in a regular manner as we pass up the limb, though it will be seen by reference to the graph, and conceded on general principles, that the longer the natural as compared with the artificial limb, the greater the capacity for work. The secondary irregularities on the curve are due, therefore, to variations included under heads 2 and 3, namely, the value of the ideal amputation and the type of artificial limb or appliance supplied for amputation at the given level.

"Following the graph from left to right it will be seen that amputation of the great toe is, in my experience, followed by some slight fall in capacity for work, though amputation of the other toes may be performed with impunity, the operation not being followed by diminution in the man's capacity for 'keeping time.'

"With a Lisfranc amputation there is a further drop in the capacity curve, which, however, falls much more with the Chopart operation. The French orthopædists, especially Treves, have shown that of all the amputations in front of the ankle the Chopart is the worst. Treves points out that every centimeter that can be saved in amputations of the foot increases the value of the anterior *point d'appui*, and, therefore, increases the efficiency.

"An amputation in front of the scaphoid is an improvement on the Chopart; one through the shaft of the metatarsals is better than a Lisfranc; and so on until we reach the toes.

"To explain why the capacity curve falls so low in a Chopart amputation we take the two heads already mentioned, and we find: (1) That even the ideal amputation interferes radically with the mechanics of the foot by removing completely the anterior pillar of the arch; the scar, at first placed anteriorly, or even above, the ends of the bones, will work its way downward; the bones themselves are gradually drawn upward by the tendo Achillis, and this gives rise to an increasing potential equinus, nearly always associated with some varus. (2) The prosthesis for Chopart's amputation requires very frequent alteration and repair owing to changes in shape of the stump and to the very nature of the prosthesis itself.

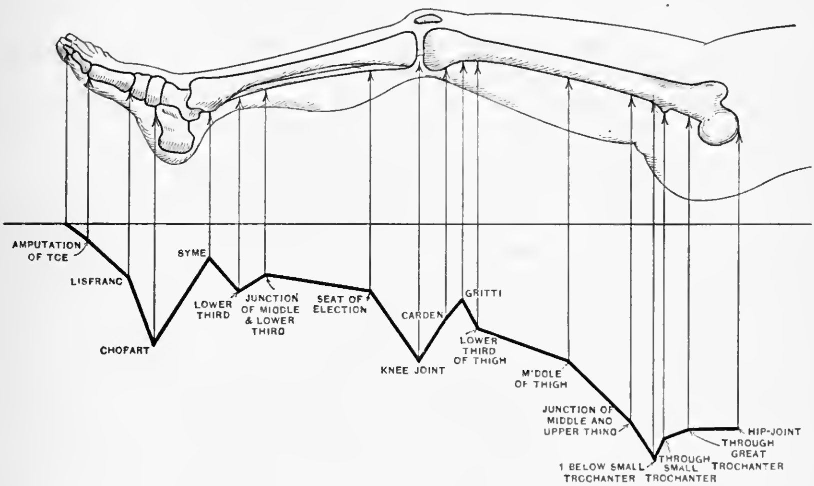

Fig. 262

"With Syme's amputation we find the curve rising abruptly, indicating that the ideal performance of this amputation leaves a stump which is, from the point of view of function, as nearly as possible perfect. It gives: (*a*) A complete and permanent end-bearing; (*b*) there is a long lever affording perfect stability; and (*c*) the preservation of the natural knee gives almost, if not indeed quite, perfect gait. The only criticism to be offered is that the artificial ankle, owing to the presence of the side bars, is rather bulky and *disgracieuse*.

"Proceeding upward to the lower third of the leg we find the curve dropping. According to Huggins an amputation should never be done at this level because of the atrophic condition of the skin, which tends to ulcerate, so precluding the possibility of a good end-bearing. The absence of an end-bearing entails a lateral bearing at the level of the tibial tuberosities with the disadvantages of irritation, blistering and often sepsis of the skin. The presence of the fibula causes a bunion, often painful, and pressure on the external popliteal nerve as it winds round the back of the fibula, will demand at some time or other surgical intervention.

"In the middle of the third of the leg the graph is gradually falling as we shorten the lever until we come to the 'seat of election' problematically so-called. This point must be regarded as the extreme 'limit of shortness' in below-the-knee amputations. The curve above this point rapidly drops, reaching its lowest point in the Stephen Smith disarticulation through the knee-joint. This is decidedly bad as a definite operation, because: (*a*) A complete end-bearing is never possible; (*b*) the skin over the condyles is stretched, thin and very prone to ulcerate, even apart from pressure; and (*c*) the fitting of an artificial limb is handicapped by the very shape of the stump, consisting as it does of a large bulk on the end of an attenuated shank.

"In the lower half of the thigh there is a gradual fall in capacity for work, dependent on the shortening of the lever formed by the stump. But with a perfect Stokes-Gritti operation there are advantages over the slightly longer Carden amputation, in that it gives a complete and permanent end-bearing, and the presence of a layer of compact bone, rather than a sawn surface, prevents any risk of adhesions between the bone and the skin over it. Above the mid-thigh there is, in addition to shortness, the disturbing factor of the pelvic band, which frequently gets out of order and calls for repairs. Therefore, we find a rapidly diminishing capacity for work above this point until the 'limit of shortness' in thigh stumps activated by the stump in an ordinary bucket is reached. Huggins lays it down that this point must not be less than three inches below the lesser trochanter. In amputations between this point and the lesser trochanter no satisfactory fitting can be supplied, and they are, therefore, the worst of all amputations, and should never be performed as definite operations. At the level of the small trochanter it again becomes possible to fit an artificial limb through the intervention of a hip platform. The thigh bone, being flexed by the psoas, does not interfere with the fitting, though an amputation carried through the great trochanter or the femoral neck, or a disarticulation through the hip-joint itself, gives a slightly better result."

ADJUSTMENT OF THE ARTIFICIAL LIMBS.

By HANS SCHIFFBAUER, M.D., F.A.C.S.

Artificial Limbs.—It is essential that the surgeon should have a knowledge of the application of artificial limbs, before he amputates any of the larger extremities. With this information correctly applied, he will aid the limb maker in making a serviceable fitting limb, and thus give the patient a more satisfactory result. He is also in a position to help advise the patient as to the proper kind of artificial limb to obtain, and instruct him how to use it and how to take care of it.

Kinetic Stumps.—Vanghetti and later Ceci utilized the latent muscular force of the stump, especially of the upper extremity, by freeing the tendons from the muscle bellies in such a way as to enclose them in skin flaps. These flaps could be moved by the voluntary contraction of the patient's muscles. The method never found many adherents, because the contraction of the muscle was insufficient to move the muscle flap the desired length nor was the proper prosthesis to be had at that time.

Sauerbruch made a careful study of the Vanghetti method in 1914 and ca ne to the conclusion that with the proper gymnastic exercises, the biceps muscle could be developed to such an extent that in contraction and relaxation the muscle belly would move up and down in a plane parallel to the humerus 2½ to 4 cm. and in some cases as far as 6 cm. It took three to six months to develop the biceps, much depending upon the site of amputation, the amount of atrophy present, and the interest the patient took in the exercises. The muscular stump was utilized by tubulizing the muscle with a skin canal. A skin flap 3 cm. wide is made extending across the anterior surface of the stump to the internal border, the flap being a little longer than half of the circumference of the stump at that point, the base of the flap being on the external surface. Skin flap is then sutured over three-eighths of an inch rubber tube with interrupted catgut sutures accurately coaptating the skin margins forming a tube lined with skin. The muscle belly is then perforated at its lower border with a blunt instrument, beginning on the outer surface of the arm at the base of the flap and extending transversely through the muscle, to the inner side of the arm. A small skin incision is made over the instrument, which allows it to be pushed through. The opening in the muscle is dilated with a Hegar or Goodell dilator, sufficiently large so as to have ample space to pull the skin tube through. A forceps is inserted into the muscular opening from the inner opening and the skin tube pulled through and sutured to the margin of the skin with interrupted nonabsorbable material.

An ivory peg coated with vaseline is then inserted into the canal. The skin defect is readily closed. Active gymnastics are begun as soon as the wound conditions permit. When a contraction of 4 to 6 cm. has been developed, a prosthesis is applied, connecting the lever which controls the fingers and elbow-joint to the ivory peg, with a special cord. Contraction of the biceps will cause the fingers to grasp small objects. The Henning arm, manufactured in Chicago is an ideal prosthesis for such a motor flap operation.

A kinetic stump can be developed in any amputation or disarticulation of the upper extremity. In a case of disarticulation of the humerus, a skin tunnel was used through the pectoralis major muscle, which through exercise was developed to such an extent that the muscular contraction transferred to the prosthesis, gave the patient a satisfactory working arm.

The kinetic stump has also been used in amputations of the thigh with good results.

The greatest educator of the stump is the artificial limb itself; therefore it should be applied as soon as possible. The use of a crutch for the amputated is an indication of inadequate treatment. The early use of the permanent artificial limb presents several difficulties; the stump is swollen, a large amount of fatty tissue is still present, and the muscles are flabby. In time the stump changes its shape so markedly that the artificial limb that fitted accurately when first applied is no longer suitable. To obviate this, especially in cases where it will require considerable time before the artificial limb is completed, it is advisable to make a temporary or provisional prosthesis. This can readily be made by the surgeon. Take for example an amputation in the lower third of the leg. An ordinary peg leg is made, somewhat longer than necessary so that it can be cut to the proper length; the peg is securely fastened to a disk, which in turn is fastened by two crosspieces on each arm so as to give more surfaces for support. The band iron runs from side to side and from before backward. The stump is covered with a double layer of stockinette and a plastered bandage is accurately applied; after several layers of plaster have been applied, the peg leg is applied and firmly incorporated into the cast. While the cast is drying, it is carefully pressed against each side of the tibia, just below the tuberosity, so as to get a good weight-bearing area. The peg is then cut off at the proper length and a rubber tip applied. Another simple method is to take the lower part of a crutch, cut it off at the right length, drive a number of large tacks on each side of the upper part of the crutch, so that the plaster bandage can get a firm hold. This gives a durable, inexpensive, readily made prosthesis which is very satisfactory for the patient. It enables him to use the stump at the earliest moment and does not allow him to get into the crutch habit.

For amputation of the thigh, the technic is similar, with the exception that the cast extends up higher and is accurately molded to the tuberosity of the ischium.

THE ARTIFICIAL LIMBS OF LOWER EXTREMITY.

The satisfactory artificial limb must fit properly, give the necessary support and comfort to the patient and it must have stability, lightness and simplicity.

To have a properly fitting limb, accurate measurements have to be taken for prosthesis above the knee-joint, and a plaster cast negative for those below the joint.

As each artificial-limb maker has his own methods of taking measurements, it is advisable to send to him for one of his special measuring blanks which give complete instruction as to just how the measurements are to be made. If the patient lives in or near a large city, it is advisable to have the patient go to the appliance maker or have him come to the hospital for measurements.

For prosthesis below the knee an accurate cast must be made. It is advisable to wait until the stump has resumed about its normal size. The prominent bony points are traced with an indelible pencil and then a No. 12 wire is placed next to the skin extending along the entire anterior surface of the stump, the wire facilitates the cutting of the cast. Over this a thin stockinette is applied. Some surgeons cover the hairy parts with vaseline and leave off the stockinette. The patient assumes a standing position, so as to have the stump the same size as when in use. The plaster-of-Paris bandage is then carefully applied, and especial attention is given to the stump. When the cast has begun to set, the wire is grasped in the left hand, which pulls the cast from the skin, allowing the plaster easily to be cut off. The cast is then covered, preferably with a starch bandage and sent to the bracemaker. It is also necessary to send the proper size shoe with the cast. It is important to state if the patient has a tendency to turn his toes outward, inward, or if he walks with the feet straight ahead.

For amputation of the thigh, it is important to distinguish between those stumps which are end bearing and those which are not. In the latter case, the success or failure of the artificial limb depends upon an accurate fit at the ischial tuberosity. Most brace makers fail to realize that the tuberosity does not slant from above downward and forward but in the reverse direction, namely, from below upward and forward. This upward inclination, be it ever so slight, must be taken into account. The usual type of support given by the brace maker does not conform to this anatomical fact but slants from above downward and forward so that the patient slips downward on the support and almost invariably suffers pain anteriorly near the pubic bone. This allows the stump to rotate externally and the artificial limb does not fit.

The adductor muscles are capable of bearing great weight when they have been properly hardened. The pubic bone, however, cannot stand pressure and must be left free. The gluteal muscles and vasti also help support the body weight.

The type of knee-joint used does not play an important role. In general the simpler the mechanism, the more effective. Complicated screws, ratches or springs add merely to the likelihood of breakage and to the cost of keeping the limb in order. The construction should be so simple as to permit the wearer himself to make the necessary repairs.

It is essential that the axis of the joint should be posterior to the center of the gravity of the anatomical joint. If this demand is not complied with the patient loses all sense of security, because the artificial leg tends to bend at the knee under the patient's weight. In placing the mechanical joint posterior to the center of gravity, the weight of the body locks the joint.

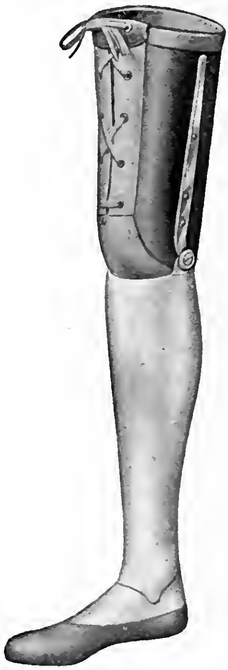

Fig 263.—Knee-bearing.

Fig. 264.—Prosthesis for amputation below the knee, where the stump is too short for short limb.

Artificial limbs can be made for cases with disarticulation of the hip and short thigh stumps but they are often very unsatisfactory for the patients. They cannot walk a great distance and the patients tire very easily on standing.

Fig. 263 shows an artificial limb for a knee-bearing stump or for a Gritti-Stokes amputation.

Fig. 264 shows a limb for amputations just below the knee in which it is necessary to have a mechanical joint and a thigh piece.

For stumps at the junction of the lower with the middle third, or about two inches below the calf muscles, a limb as shown in Fig. 265 can be used, being held in position by anterior strap which is fastened to a leather thigh cuff.

Fig. 265.—Short limb for amputation below the knee. These are for limbs which have not less than seven inches below the knee.

Fig. 266.—Syme's amputation.

Fig. 267.—Chopart's amputation

For stumps just above the ankle joint, the construction should be of the simplest type, allowing only flexion and extension such as Fig. 266 shows, an artificial limb fitted for a Syme amputation which gives a very good functionating leg. It is much better to amputate four inches above the ankle joint than immediately through the joint. Amputations through the middle third of the leg are not so satisfactory.

The Pirogoff and Chopart give very good results when properly done, and large anterior flaps are made. When in question as to where to amputate in or about a joint, it is advisable to do a Syme's amputation. Fig. 267 shows an appliance for a Chopart amputation.

I had a patient with amputation of both legs. On one leg a Syme's amputation was performed and on the other a Chopart. After three years of experience in wearing artificial limbs, I asked the patient which limb gave him the better service and caused him the least trouble. He said that "the one with the short stump was by far the best." Appliance makers of vast experience have made similar statements.

ARTIFICIAL LIMBS FOR AMPUTATIONS OF THE UPPER EXTREMITY.

A large number of the new artificial limbs have been put on the market during the last five years, in Europe and the States. I will only discuss the more practical arms that are manufactured in America. Among the best arms, are the Carnes arm, the Henning, the Dorrance Utility Hook and arm with an interchangeable hand put out by Sharp & Smith, Chicago.

The Carnes arm is very expensive, has a complicated mechanism, is quite heavy and requires considerable training before the arm can be properly manipulated.

The Henning arm as seen in Figs. 268 and 269 has an aluminum hand and fingers. The fingers and thumb are flexed by a lever placed in the mid-axis of the proximal end of the hand through a pull ofabout one and one-eighth inches. The fingers are so arranged that they can group themselves around an irregular object. By relaxing the shoulder muscles, the cord is released. The shoulder strap is arranged so that the muscular power is equally divided between the two shoulders. This allows the patient to close his hand without a visible motion of the shoulders. It has a lever lock, so that the hand can be fixed in any position. It is possible to carry an object weighing thirty pounds. The fingers being of metal with open joints, it is necessary to wear a glove to keep the dirt out of the mechanism and to give the hand a better appearance. It seems that this would be the ideal arm to use in connection with the motor flap operation or kinetic stump.

The Dorrance Utility Hook (Fig. 270) is a very good universal prosthesis. It combines cheapness, simplicity, stability and has a universal function. The hook is detachable so that an interchangeable hand can be coupled on in a short time. Figs. 270 to 277 clearly demonstrate the arm.

Constant muscular tension is not necessary in using the Dorrance Utility Hook. It is only necessary to make a short contraction, to

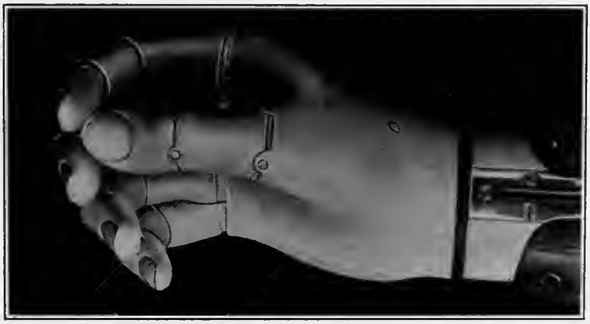

Fig. 268 —The Henning arm.

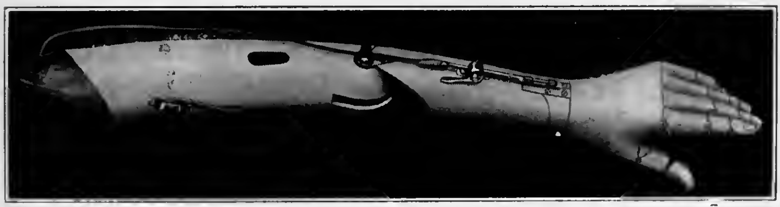

Fig. 269.—The Henning arm.

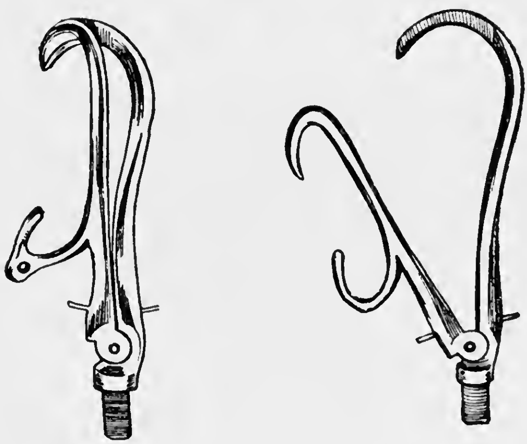

Fig. 270.—The Dorrance utility hook.

overcome the resistance caused by the rubber band at the base of the hook which then allows the hook to open and by relaxing the shoulder muscles the hook snaps shut. In most other arms a constant muscular

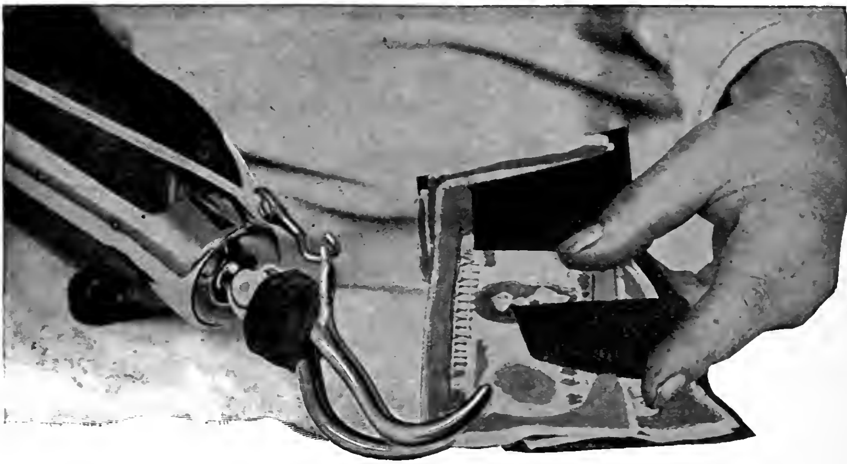

Fig. 271.—Dorrance utility hook.

Fig. 272.—Dorrance utility hook.

Fig. 273.—Dorrance utility hook and hand.

Fig. 274 —Dorrance hook.

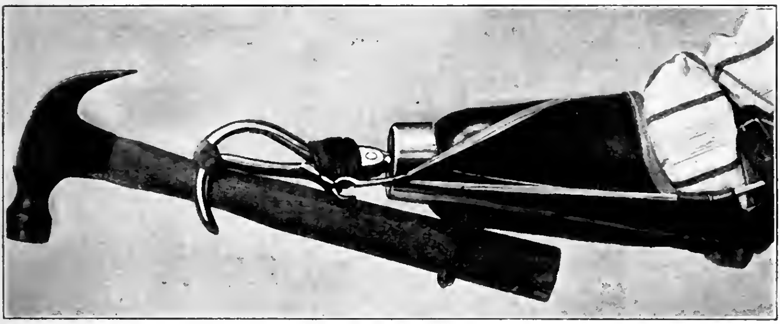

Fig. 275.—Dorrance hook.

Fig. 276.—Dorrance hook used for eating.

tension is required unless the object is to be held for some time when the hand is locked in the desired position. The Dorrance Utility Hook could also be used with a kinetic stump.

It is obvious that in all artificial limbs of the upper extremity the further the stump is below the elbow the easier it is to obtain good results with the prosthesis. At or just above the wrist joint the pronator muscles remain intact which assist in bringing the forearm to the mouth.

Another very useful artificial limb for the upper extremity with an

FIG. 277.—Dorrance hook.

interchangeable hand is seen in Figs. 278, 279. By pulling over a small button on the lower border of the forearm piece, the hand is pressed out of its socket and a hook or any of the various other instruments may be inserted. Fig. 280 shows a rubber hand that can be attached to this arm. The fingers can be molded with the opposite hand around any small object. In the palm of the hand a hook can be attached so that the wearer can carry a parcel or satchel.

The type of arm to be worn by the patient depends upon his vocation in life. For the farmer and laborer, the Dorrance Utility Hook or one of the numerous other hooks or claw hands would give the best results. For the office man, the Henning arm would be found satis-

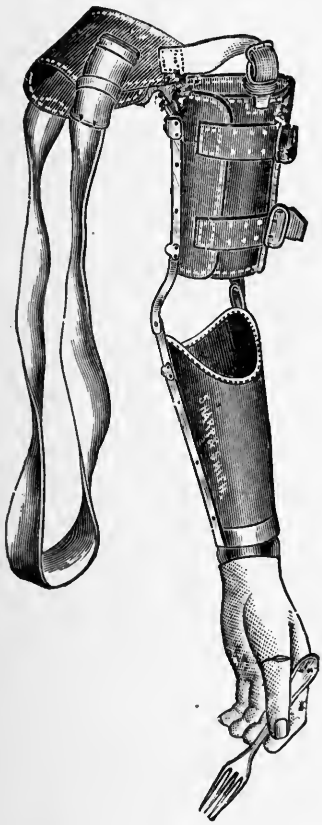

Fig. 278

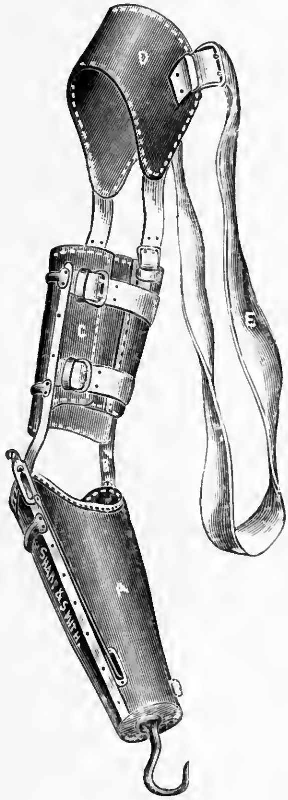

Fig. 279

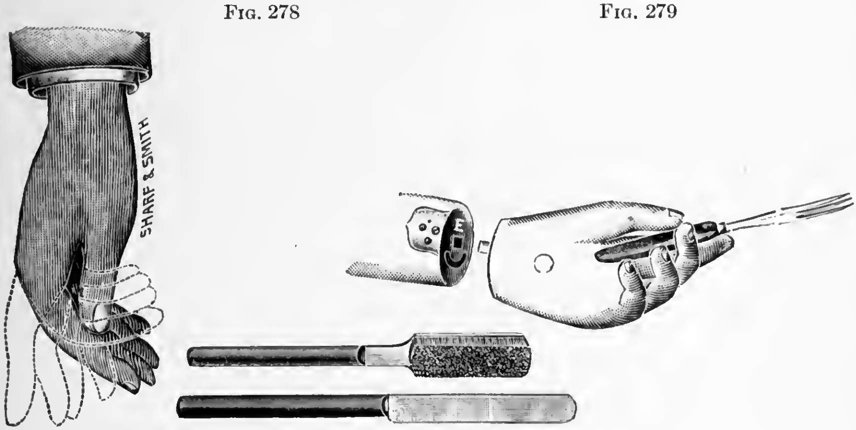

Fig. 280

endosteum or the lining of the Haversian canals or the surviving cells of the graft itself, or all combined, leaving out of account the surrounding tissues. If this be true, then the relative importance of the periosteum, as combined with the powers of the endosteum, the lining of the Haversian canals, and the surviving bone-cells, is as 100 to 55. The author has made three human transplantations *without* periosteum, all of which healed by primary union. In not one of these did the graft survive, all gradually becoming absorbed by molecular disintegration. In each of these transplants, without periosteum, there were endosteum, together with bone-cells and the Haversian canal linings. From this we see that the periosteum is a very important structure in osteogenesis and in bone-graft repair. Of the few reported successful bone transplantations made *without* periosteum, the influence of the endosteum has not been given sufficient attention, although its power of osteogenesis is evidently far inferior to that of the periosteum.

That the *surrounding* connective tissue, independent of the periosteum, has little influence on osteogenesis, I desire to show by the following interesting human grafting operation (Fig. 281), for which I am indebted to Dr. Brewer, to whom I extend my sincere thanks. In January, 1912, he removed $2\frac{3}{8}$ inches of the lower extremity of the radius with its entire periosteum, for sarcoma. Two days later, an adult pistol wound suicide was brought into the hospital and from his radius was removed a piece of bone exactly the same length as that which had been removed. This bone was boiled for an hour and then kept in sterile salt solution for four days, when the original wound was reopened and the boiled, homoplastic section from the radius was inserted in the defect, which it accurately filled up. It was not sutured in place but simply laid in, and about it the soft parts were accurately sutured. A plaster splint was applied. Healing by primary union. From the man, three and a half years later, was obtained the following roentgenogram (Fig. 281). The hand is much radially abducted, in fact, there is a well marked dislocation of the hand on the ulna, which latter can be distinctly palpated. The function of the hand is much injured, there is almost no abduction, and flexion and extension of the wrist are slight. The grasp of the hand is very weak. The roentgenogram is very interesting. The entire graft (*A*, Fig. 281) can be divided into three sections, *D*, *B* and *C*. *D* is the proximal portion of the graft which has been completely and perfectly regenerated and is thoroughly united to the old bone of the shaft. *C* is the middle portion of the graft which has incompletely been absorbed and regenerated, while *B* is the most distal part of the graft which has been completely absorbed with no attempt at reformation of the bone in the slightest degree. Since the operation occurred three and a half years ago, it is safe to say that as much regeneration of bone has taken place as ever will occur so that we may regard this as the permanent result. Several things are evident at once—first, the result of the transplantation speaks for the value of contact with living bone, for section *D* seems to be so perfectly regenerated because of its immediate contact with the living bone of the shaft. Section *C* is farther away from living bone, and as a result the new bone is only partially regenerated, being honeycombed; while section *B* is farthest away and shows absolutely no regeneration of bone after absorption of the original dead matrix, the distance away from the old live bone being evidently too great to produce new bone. It would seem reasonable to suppose that had there been live bone impinging on the carpal side of the graft the whole graft would have been regen-

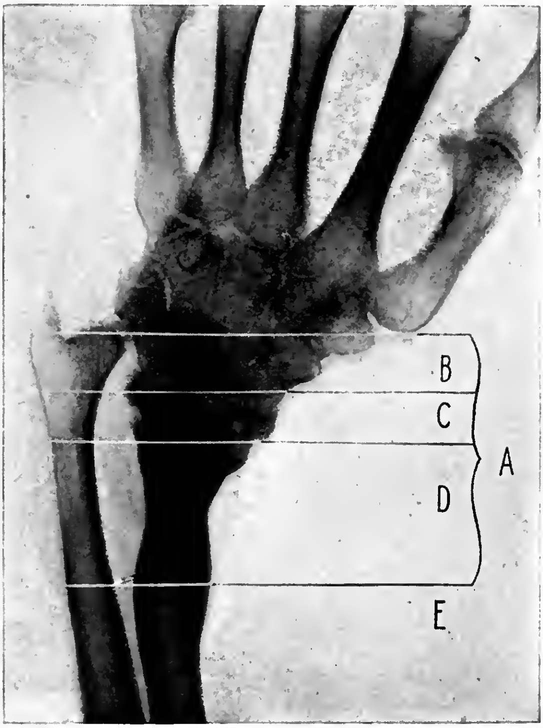

Fig. 281.—Brewer's case of boiled homoplasty, three years after grafting. *A* represents the entire $2\frac{3}{8}$-inch graft; *B*, the completely absorbed and entirely unregenerated portion of graft; *C*, the partly absorbed and but partially regenerated bone, osteogenesis being apparently unable to fully traverse the distance to *C; D* is the perfectly regenerated portion of the graft. Osteogenesis must have come from *E*, the portion of contracting old bone, since the periosteum from the resected bone was removed with the tumor. According to one or two authorities, osteogenesis comes from the surrounding tissues. If this be the case, why was not osteogenesis as perfect at *B* or *C* as at *D?*

erated. This transplantation, then, bears out Murphy's idea of the value of contact, certainly, at least, in dead homoplastic bone graftings. That the new bone did not come from the surrounding connective tissues is evidenced by the progressive lessening of its formation as one proceeds from the shaft toward the hand. Had this connective tissue a great influence in the formation of the new bone, then there should be as much new bone formed in section *B* as in *D*, whereas the fact is that in section *D* the new bone formation is perfect while in section endosteum or the lining of the Haversian canals or the surviving cells of the graft itself, or all combined, leaving out of account the surrounding tissues. If this be true, then the relative importance of the periosteum, as combined with the powers of the endosteum, the lining of the Haversian canals, and the surviving bone-cells, is as 100 to 55. The author has made three human transplantations *without* periosteum, all of which healed by primary union. In not one of these did the graft survive, all gradually becoming absorbed by molecular disintegration. In each of these transplants, without periosteum, there were endosteum, together with bone-cells and the Haversian canal linings. From this we see that the periosteum is a very important structure in osteogenesis and in bone-graft repair. Of the few reported successful bone transplantations made *without* periosteum, the influence of the endosteum has not been given sufficient attention, although its power of osteogenesis is evidently far inferior to that of the periosteum.

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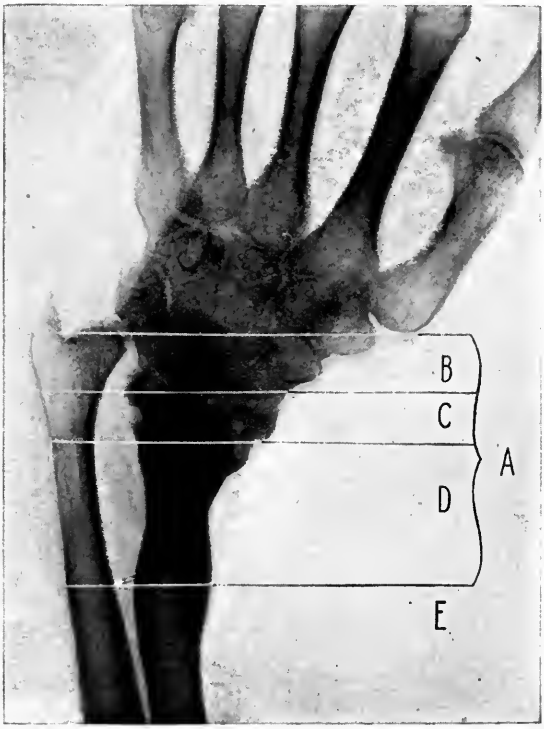

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B it entirely fails. It seems reasonable then to assume that the new bone in *D* was formed through the growing into it from the old, live stump of bloodvessels which penetrated a certain distance thoroughly and then these gradually faded out, producing less and less bone as they advanced.

FIG. 282.—(Experiment 3.) Operation February 20, 1912. Killed October 23, 1912, after eight months. Rib subperiosteally excised 2½ inches and slit into longitudinal strips. Incision over middle of left rectus, sheath divided and strips laid on muscle, separated from each other. Sheath sutured over these. Picture shows rib entirely reformed and growth together of bones in abdomen.

Conclusions.—The following conclusions seem justified by my experiments:

1. If a section of the whole diameter of a bone be removed, then the bone will regenerate between the ends of the fragments, if the whole, or a part of the periosteum, bridging the defect, be preserved. Proof:

Figs. 282 and 283.—Experiment 3. Dog 172. This animal was killed eight months after subperiosteally resecting a section of a rib. This rib without periosteum was then split into longitudinal strips and these were then transplanted into the abdomen. Result: The defect in the rib, from which the periosteum was not removed, has become entirely filled in with new bone. The strips, transplanted into

Fig. 283.—(Experiment 3.) Microscopic section of rib without periosteum into abdomen. The fragments of bone measure 0.2 cm. in diameter. Microscopic examination: The bone contains many cells with well-preserved nuclei, also perfect Haversian canals with red blood cells between them. The bone itself is intact. There are several osteoclasts within lacunæ on the margin of the fragments. Many osteoblasts are also present. The marrow is well preserved and contains blood spaces, many of them filled with red blood cells. Because of the osteoclasts there are present destructive processes, but at the same time proliferation is also in progress. The bone seems to be perfectly alive.

the abdomen, have remained intact, have grown together and have increased in size. A photomicrograph of a section of this abdominal transplanted bone, shows bone perfectly alive, not undergoing absorption, and containing well preserved and normal marrow. I attribute the living of these transplants to the fact that the splitting of the original rib allowed sufficient blood to get to the bone-cells.

Fig. 284.—Experiment 25. Dog 200. An inch and a quarter of two adjacent ribs were excised *with* periosteum covering half their surfaces. Result is seen after seven and a half months after the excision. There is no trace of any defects in the excised ribs, due to the development of new bone coming from half the extent of the entire periosteum which was left *in situ*. Further proof is afforded in human empyema operations when the rib is excised subperiosteally. In such cases the defect is filled in completely with new bone within a few months.

Fig. 284.—(Experiment 25.) **Shows perfect reformation of bone in subperiosteally excised ribs.**

2. If a section of a whole diameter of a bone be removed, there will take place very little subsequent filling in of this defect by new bone, if the entire periosteum has been removed from between the ends of the fragments. To have such a defect fill in, it is necessary that there shall be left either some portion of periosteum or a thin layer of bone, bridging the defect. Proof:

Figs. 285 and 286.—Experiment 2. This picture was taken six months after resecting 2 inches of the whole diameter of a rib, together with its periosteum. The defect has not at all closed in, due I believe to the lack of periosteum. The periosteum was stripped *bluntly* from the bone section and this strip of periosteum was transplanted into the abdomen (*A*). Result after seven months: A transverse section, Fig. 287, was cut through this periosteum (*A*), which was felt to be bone. A microphotograph of this section gives a picture of normal, healthy, living bone, surrounded by a closely investing, connective tissue capsule. There are no osteoclasts present nor any round cells, suggestive of either a destructive or an inflammatory process.

Fig. 285.—(Experiment 2.) Dog. 15. Operation April 1 to 15, 1912. Killed October 23, 1912. Left rib excised with periosteum. Periosteum placed on fascia posterior to muscle. Picture shows resected rib but no reformation of bone in the defect. *A*, indicates new bone formation from the transplanted periosteum.

Fig. 287.—Experiment 22. Dog 220. No. 2537. Two inches of two ribs were excised with their entire periosteum. Result four months after the excisions: the defects in the ribs have not at all become filled in with new bone. If the surrounding connective tissues have any influence on the formation of new bone, these two experiments do not show any such influence.

3. Periosteum alone when transplanted into the soft parts may produce living bone. Proofs: Experiment under the first experiment of the preceding conclusion, also the following:

Fig. 288.—Experiment 26. Dog 426. Sections from each fibula were excised. From the section from the right side, all the periosteum was bluntly stripped off from all its sides in one piece. This piece of

periosteum was vertically stretched out under skin of left leg. The bone itself from the right fibula without periosteum was placed in contact with the ends of the old stumps in the left fibula defect. Over the ends of the stumps of the right defect in fibula, muscle was sutured so that the graft would not be in contact with living bone and in the superficial

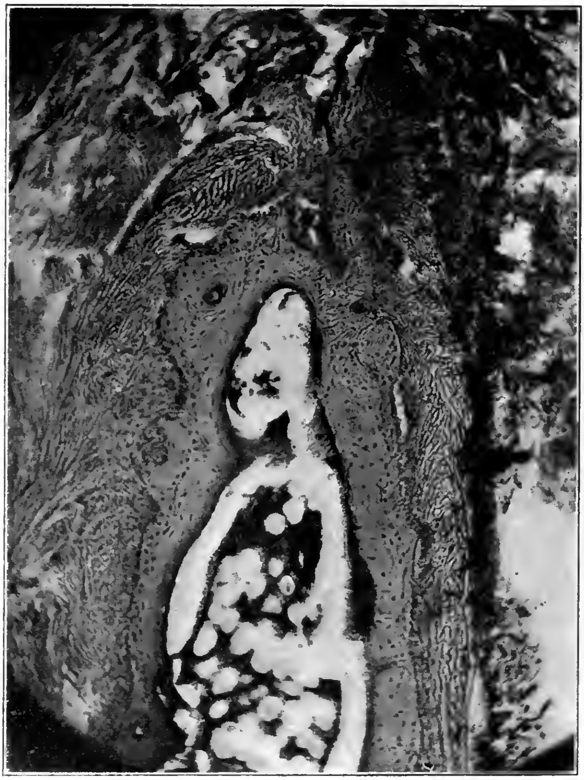


Fig. 286.—(Experiment 2.) Microscopic section of *A*, Fig. 286, shows that there is a distinct mass of bone, measuring 0.8 cm. enclosed in a definite connective-tissue capsule. The bone itself contains cells, the nuclei of which stain deeply with hematoxylin. At points on the periphery of the bone there are osteoblasts. In the actual bone substance itself there are Haversian canals which contain bloodvessels the size of large arterioles. Within the bone trabeculæ there are adult fat and marrow cells and the whole presents a normal appearance. There are many blood spaces in the marrow and these spaces are supported by a definite connective-tissue stroma. The red blood cells in these blood spaces, while not sharp and distinct in outline, have not degenerated. There are no osteoclasts nor any round cells suggestive of either a destructive process or one of inflammation. The bone is alive. Although but one thickness of periosteum was transplanted, there have been reproduced two layers of bone with intervening marrow, *i. e.*, the periosteum has reformed a normal rib.

muscles of the right leg was placed the section from the left fibula with its periosteum entire. Result 102 days after operation: The section of bone with periosteum in right leg, not in contact with living bone, has grown to two or three times its normal size and is certainly perfectly alive. The piece of fibula without periosteum into left defect from right fibula has entirely disappeared. This is probably due to the fact that the bone was transplanted entire. Had it been split, it more than likely would have survived, due to the consequent better blood supply. The periosteum on the other hand, transplanted under the skin of left leg, has developed a new mass of bone of the size and shape of the old fibula from which it was taken.

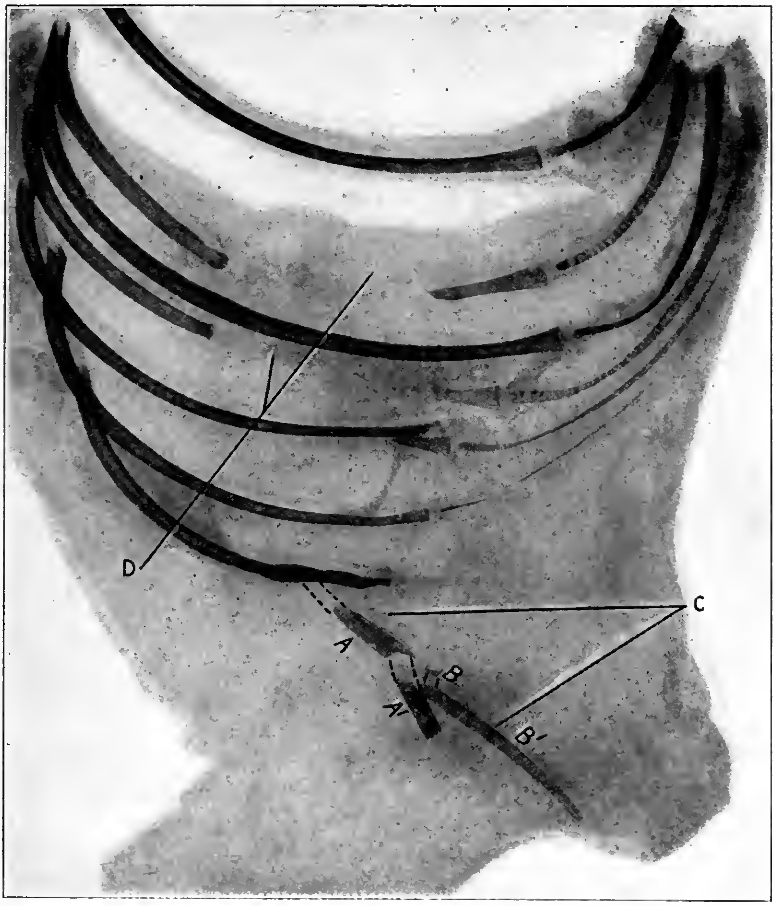


FIG. 287.—Shows result four months after excision of two ribs (*D*) with their entire periosteum. The defects show not the slightest tendency to fill in with new bone.

Since this conclusion is the subject of much dispute, I will add another instance where new bone was formed from transplanted periosteum.

Fig. 288.—Experiment 28. Dog 374. No. 2810. Two inches of each fibula with their entire periosteum were excised. The periosteum from the *right* fibula section was a perfect sheet, removed without scraping it off the bone by blunt stripping in order that as few bone

cells as possible from the surface of the bone should be adherent to the surface of the periosteum. This sheet of periosteum was transplanted just under the skin of the left leg lying on the muscle. Result after five months; the transplanted periosteum into the left leg not in contact with any bone has produced a fine piece of bone. It is worthy of remark that this piece of periosteum was removed bluntly from the fibula.

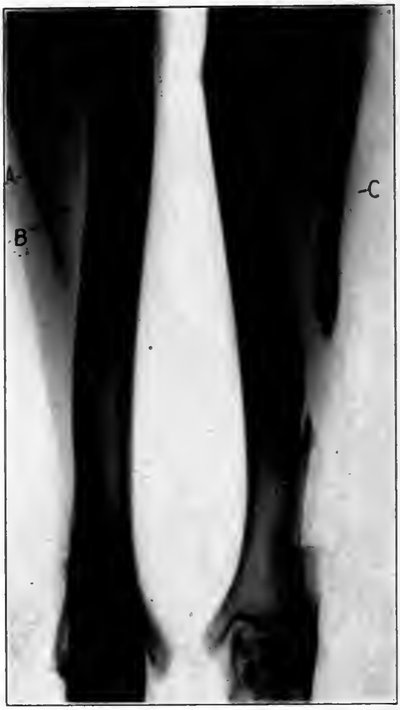


Fig. 288.—A section from the right fibula without periosteum was placed in the left fibula defect. After one hundred and two days this section had entirely disappeared. The periosteum from this section was stretched out under the skin of the left leg. This produced a fine strip of new bone. A section from the left fibula was transplanted into the right leg not in contact with bone. This transplant showed vigorous growth.

These experiments prove that transplanted periosteum may produce new bone contrary to the teachings of Macewen and others.

4. If minute fragments of a living graft be transplanted, then the periosteum may be disregarded because the osteoblasts in the fragments may not die because of an easier access of blood to them, and the pieces of bone may grow and coalesce and not become absorbed. Proof:

Fig. 290.—Experiment 9. This animal was killed five months after one inch of the radius was removed, together with its periosteum. The periosteum was then scraped off the fragment, which was split into as small pieces as possible with the rongeur. The small fragments were

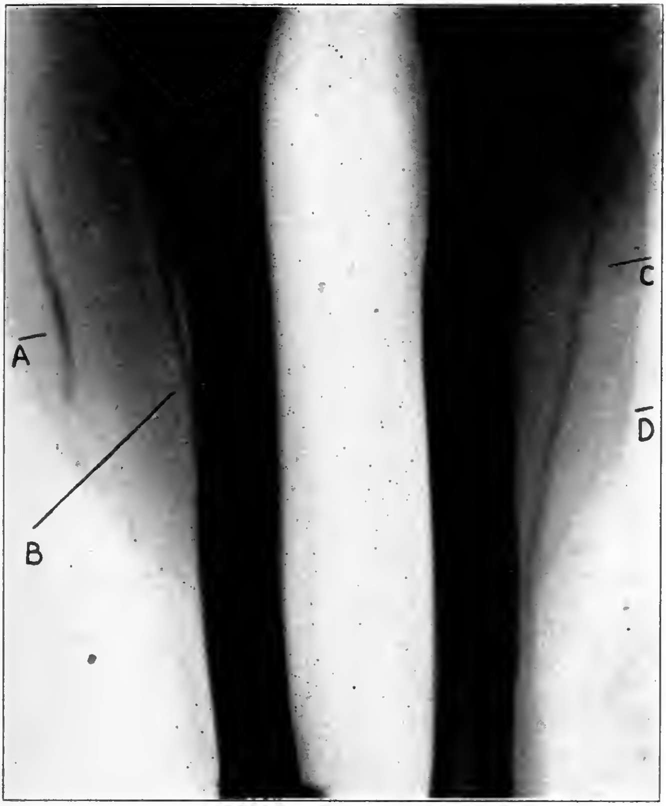


FIG. 289.—This roengenogram shows that both fibulæ transplanted without periosteum remained alive after five months. The transplanted periosteum into the left leg has produced a fine piece of new bone.

FIG. 290.—Fragments of bone without periosteum, transplanted into a defect in the radius, have remained living after five months and are all consolidated.

replaced, filling in the defect in the radius. Result: The small fragments have all remained alive, have coalesced into one piece, which has become united to the ends of the radius fragments.

Macewen in his book mentions the case of a boy, the whole of whose diaphysis he was compelled to remove for necrosis. There was no subsequent osseous deposition. Fifteen months later he was re-admitted with the request by the parents that the boy's useless arm be removed. Two wedges of bone were excised from another patient, aged six years, afflicted with anterior curves. These were cut into minute fragments, quite irrespective of the periosteum, and were then deposited into the muscular sulcus of the boy's arm, this being then a successful homoplastic, living bone transplantation. There was no pus formation. Two months later a portion of new bone, an inch in length and three quarters of an inch in thickness, was formed firmly attached to the upper fragment of the humerus. Here all the grafts proliferated, grew to one another, and also to the extremity of the proximal portion. Two other wedges of bone of larger size than the first were similarly dealt with and inserted two months subsequently to the first graft, and a third couple were placed in position five months after the first. These all fused together and to the condyles of the humerus, filling the gap in the arm to the extent of $4\frac{1}{4}$ inches. It is thirty years since the humeral shaft was rebuilt, and during all this period the man has depended on his physical exertions for the earning of his living. He worked as a joiner for many years, and is now an engineer's pattern-maker.

Macewen also relates the following experiment. This experiment I have myself duplicated with precisely the same result in several dogs but not always. The greater part of the shaft of the radius with its periosteum was removed. The shaft of the bone removed, destitute of its periosteum, was then cut into very small shavings and these shavings were placed between the muscles, which bulged into the gap left in the bone by the removal of the shaft. The neighboring muscles were then attached over the bone shavings in order to keep the shavings in position, and especially to prevent their being extruded from the wound. Examination of the specimen obtained seven weeks after operation showed that the continuity of the shaft was entirely restored. There was a marked increase in diameter of the shaft opposite the part where the shavings had been inserted. All the component parts had become fused by osseous tissue into one another and both ends of the shaft. These cases afford proof of the inadvisability of removing aseptic fragments from fractures for fear that the fragment will die.

That it is not the universal rule that the fragments will live if transplanted *without* periosteum the following experiment will show:

Fig. 291.—Experiment 19. Dog 309. This picture was taken nine weeks after the transplantation. Into a defect made into the left fibula were grafted fragments from a section of the right fibula from which all the periosteum was thoroughly scraped. Into the right fibula defect were transplanted fragments with periosteum still attached to them, taken from a section of the left fibula. Result after nine weeks

(Fig. 291), the fragments into the left fibula defect *without* periosteum have entirely disappeared. The piece into the right fibula defect with periosteum have markedly increased in size and have largely united

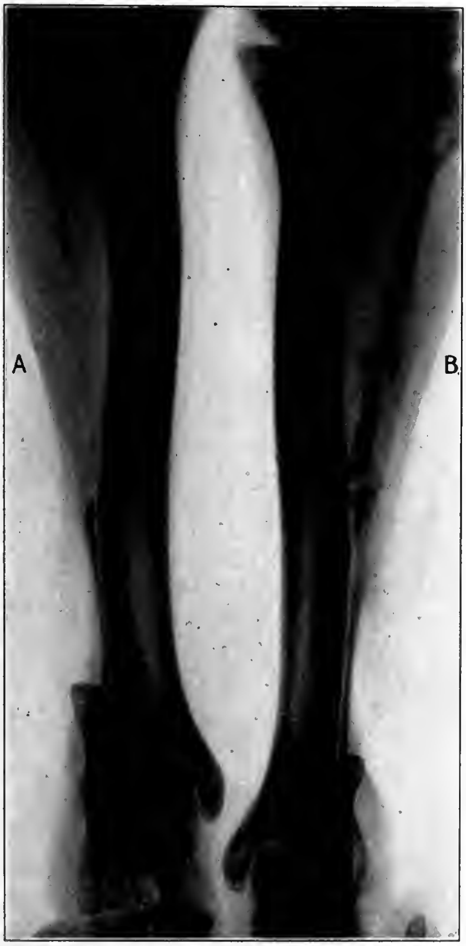


Fig. 291.—(Experiment 19.) Dog. 309. This picture was taken nine weeks after operation. Into a defect made in the left fibula were grafted fragments taken from a section of the right fibula from which all the periosteum was thoroughly scraped away. Into the right fibula defect were transplanted fragments with the periosteum still attached, taken from a section of the left fibula. Result: The fragments, without periosteum, into the left fibula defect have entirely disappeared. The fragments with periosteum into the right fibula defect have markedly increased in size and have largely united to each other. This experiment illustrates the value of the periosteum being on grafts in case there be a deficiency in the blood supply.

to each other. This case illustrates the value of the periosteum on grafts in case there is a deficiency in the blood supply. The feature to be particularly emphasized in this experiment is the pronounced increase in the size of the grafts with periosteum on them, transplanted into the right defect, which denotes an active life in the grafts; also the fact that, although the middle section of the right sided graft does not seem to be firmly united to the neighboring grafts, yet this middle section, from its deep shadow, appears to be as actively alive as the

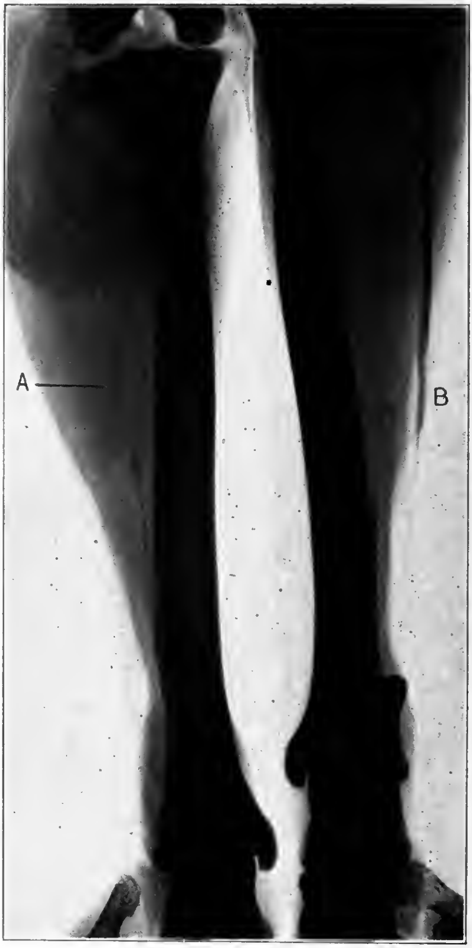


Fig. 292.—A section from the right fibula without periosteum was transplanted into the left fibula defect in contact with the old bone stumps. After eighty-one days this has almost entirely disappeared. Under the fascia of the right leg not in contact with any bone was placed the section from the left fibula with periosteum. This has remained perfectly alive. This picture shows the value of the periosteum and the doubtful effect of contact with living bone of grafts without periosteum.

sections which are in intimate contact with the ends of the old stumps. All of which still further goes to show that contact with living, old bone has probably not the important influence on the subsequent life of the grafts which Dr. Murphy has attributed to it.

5. A number of experiments were performed in which single large fragments were transplanted *with* and *without* their covering periosteum. Every one of 25 transplantations made *with* periosteum, or 100 per cent., lived, while of 38 transplantations made *without* periosteum but 21 lived, or 55 per cent. (Fig. 288.)

Fig. 292.—Experiment 23. Dog 423. Operation: A section from the right fibula intact, without periosteum, was transplanted into the left fibula defect in contact with the old bone stumps. The stumps of the right fibula defect were covered with muscle, which was sutured over them. Under fascia of right leg was placed the entire section from the left fibula with periosteum still on it uninjured. Result eighty-one days after operation (Fig. 292): The section into the left

Fig. 293.—Rib without periosteum transplanted into a defect made in the lower jaw for removal of sarcoma. Primary union. *A*, transplanted rib.

fibula defect *without* periosteum has almost completely disappeared. There is a slight line indicating a persistence of some of it. This disappearance has occurred notwithstanding that it was in contact at both ends with living bone. The difference the presence or absence of the periosteum makes is indicated in the right leg. The section from the left fibula into the right leg *with periosteum* has remained of its original size and seems perfectly alive, this, notwithstanding that it was not in contact with living bone.

Fig. 293 is added to show the value of the periosteum on a graft since a graft without periosteum into a defect in the lower jaw entirely disappeared in five months. In November, 1910, I removed half the lower jaw from a lad of twelve for a large giant-cell sarcoma.

Fifteen months later I grafted into the defect in the lower jaw a piece of rib which was entirely stripped of its periosteum. One end of the rib was bevelled and this was sutured to the freshened edge of the remaining half of the jaw. The wound healed by primary union. Fig. 293 shows the rib in position. In five months the rib entirely disappears.

Various Theoretical Views.—However theoretically authorities differ as to the value of the component parts of a graft, yet practically today every surgeon makes an autogenous graft, which contains upon it some of its covering periosteum, together with, if possible, some endosteum and marrow, since the whole of a thing is better that any of its parts. To show the various theoretical views of authorities, the author has made the following classifications: the weight of authority seems to favor the view that the most important element upon which the future life of the graft depends is the periosteum.

1. There is either none or only slight osteogenetic power in the periosteum:

Gallie and Robertson	Macewen
Davis and Hunnicutt	Wetherill
Baschkirzew and Petrow	Delbet
Brown and Brown	Bancroft
Murphy	Groves

2. Osteogenesis lies in the young connective tissue surrounding the transplant:

Baschkirzew	Bancroft
Barth (originally)	

3. Osteogenesis lies chiefly in periosteum and to a much less extent in endosteum, marrow and the Haversian canal linings:

De Gouvea	Lewis
Lexer	McWilliams
Streissler	Steida
Loberhoffer	Gill
Tomita	Barth (recently but not originally)
Axhausen	Nicholls
Ochsner	Codivilla
Albee	Schepelmann
Ollier	Ryerson
Phemister	Haas

4. Osteogenesis lies entirely in the osteoblasts within the bone of the graft itself, and its regeneration takes place independently of the periosteum.

Macewen	Groves

5. The graft is not osteogenetic in itself but it is simply osteoconductive of cells from the contacting extremities of other living bone.

Murphy	Barth (originally).

IS PERIOSTEUM NECESSARY FOR THE FUTURE LIFE OF GRAFTS?

Practically every operator today makes grafts always *with* periosteum, as the paucity of reported graftings made *without* periosteum strikes the student of the subject at once. Some authorities maintain that the answer to the question depends on the presence or the absence of the bone-cell upon the deep surface of the periosteum. The confusion existing in the results obtained by various experimenters in transplanting periosteum alone may depend upon the variations in methods of the several operators in obtaining periosteum. Some have stripped off the periosteum bluntly, others have pried it off with a blunt instrument, while others have used a sharp instrument against the bone to remove the periosteum, thus possibly carrying bone-cells off attached to the periosteum.

It is thus seen that all the operators have not included, nor excluded, the same components which may explain the differences in the results obtained. It is also not definitely stated, in several reported cases, how much periosteum remained in the surroundings of the region into which the graft was transplanted although the graft itself may not have had periosteum upon it. Some periosteum seems necessary, either upon the graft or else in its surroundings, in order to be always sure of success. Groves now maintains "that the osteoblasts necessary for new bone formation are contained in the dense bone but that the protecting and vascularizing matrix of the periosteum is necessary for their activity."

My own results in three human transplantations made *without* periosteum were so disastrous that I never now make a transplantation *without* periosteum. These cases are as follows:

Human Transplantations (Figs. 293 and 294).—Case 1. In November, 1910, I removed the horizontal ramus of half the lower jaw from a lad, aged twelve years, for a large, giant-cell sarcoma. Fifteen months later I grafted into the defect in the lower jaw a piece of rib which was entirely stripped of its periosteum. One end of the rib was bevelled and this was sutured to the freshened edge of the remaining half of the jaw. The wound healed by primary union. Fig. 293 shows the rib in position. Five months later, a rontgenogram (Fig. 294) showed an entire disappearance of the grafted rib. There never was any discharge from the scar. The result in this case is in opposition to Dr. Murphy's second conclusion, that "bone with or without periosteum, transplanted in the same individual and contacted at one or both ends with other living, osteogenetic bone, always becomes united to the living fragment, and acts as a scaffolding for the reproduction of new bone." Had I split the rib longitudinally so as to afford a better blood supply to the bone-cells of the graft, or had I transplanted the rib with periosteum covering half its surface, it seems to me that it would have lived.

Case 2.—The patient was a man, aged thirty-two years, who had received a compound fracture of the left humerus, a month before he

FIG. 294.—After five months, total disappearance of the rib without periosteum transplanted in the previous figure.

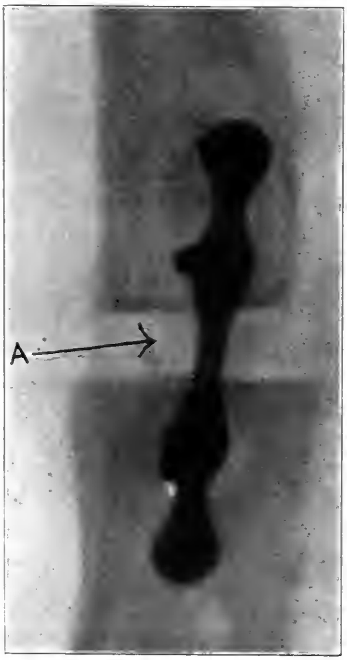


FIG. 295.—Non-union in a fracture of the humerus. The ends of the fragments were sawed off squarely, the medullary cavities were reamed out and a piece from a subperiosteally resected rib was inserted in the medullary cavities and a Lane plate was applied to hold the fragments firmly. *A*, the rib graft.

FIG. 296.—Shows result of previous transplantation (Fig. 295) after nine months. There is still non-union. The graft has not increased in size at all. The periosteum of the fragments has produced some new bone.

came under my care. He was operated on immediately after the accident in another institution and the fracture was wired. This was followed by violent sepsis and non-union. Two sequestra were picked out of the wound the next day after the man came under my care. The result of the application of a Lane plate to the fracture by me after it had entirely healed and after sawing off the ends of the fragments was still non-union. Five months after the previous plating, on account

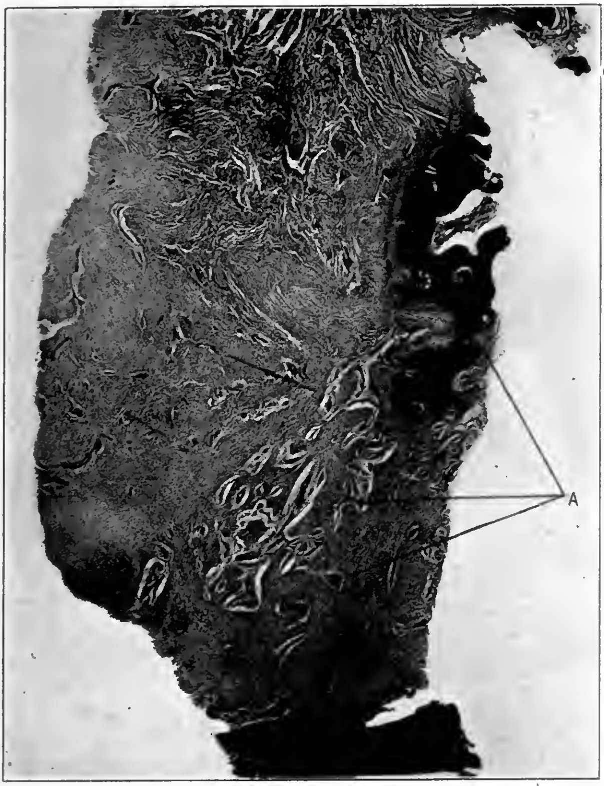


FIG. 297.—Photomicrograph of a section from the dead transplanted rib which was removed. The section shows fibrous connective tissue with only scattered areas of bone. The nuclei of the cells are well stained. The bone trabeculæ at many points show osteoblasts with an occasional osteoclast in places. The bloodvessels in the bone are numerous and of large size. The bone has undergone rarefying osteitis. This picture shows the value of the periosteum, as well as brings up the question of whether the intramedullary graft is as successful as an inlay graft.

of non-union, I grafted into the medullary cavities of the fragments, which were first reamed out, a section from a subperiosteally resected rib (Fig. 295). After the rib was in position, there was some side-to-side rocking of the fragments on each other, due to the fact that the rib was evidently a trifle too short. On this account I applied a Lane plate. The result of this bone grafting was very disappointing. A picture (Fig. 296) after nine months showed no proliferation whatsoever of its bone and there was no better union than at the time of the grafting. Nine months after the rib grafting, I removed (Fig. 297) the remains of the grafted rib. A section of it under the microscope showed that it was undergoing rarefying osteitis and that it consisted mostly of dense fibrous tissue with scattered areas of bone. The medullary cavities of the fragments were reamed out and into them was inserted a graft taken from the front of the tibia with periosteum on

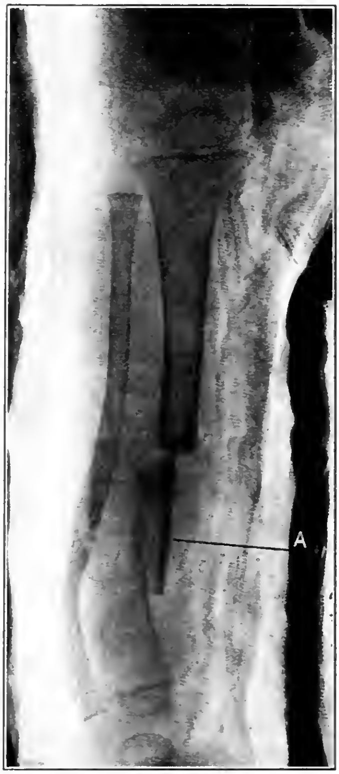


Fig. 298.—*A*, transplant from the opposite tibia, without periosteum, driven above into the medullary cavity of the upper fragment; below it was spliced to the side of the lower fragment. *A*, the graft.

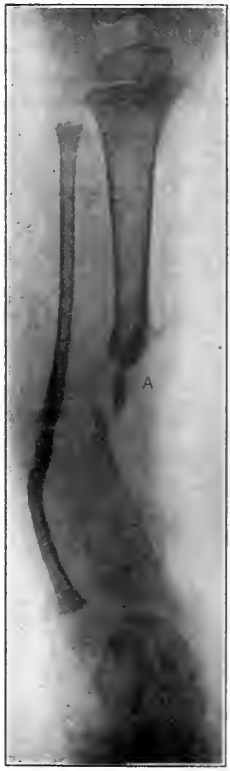


Fig. 299.—The graft *A* is disappearing. Taken six months after the grafting. The graft is not more than one-quarter its original size, and there is no union.

two of its sides. A nail was inserted in its upper end to prevent its riding up into the medullary cavity. Sepsis followed this operation, requiring removal of the nail and the graft with an unsuccessful result.

Case 3.—This is an exceedingly interesting case of non-union in a birth fracture of both bones in the leg of a child, aged seventeen months. The non-union I attributed to insufficient immobilization of the leg after birth. The author cut down on the fracture and after freshening the pointed extremities of the fragments, there resulted a defect of an inch and a half in the tibia, which made transplantation of bone necessary. A graft (Fig. 298) from the opposite tibia was chiselled out with its periosteum attached. The periosteum was then deliberately peeled off the graft with the object of confirming Macewen's view of its unimportance. One end of the graft was pointed

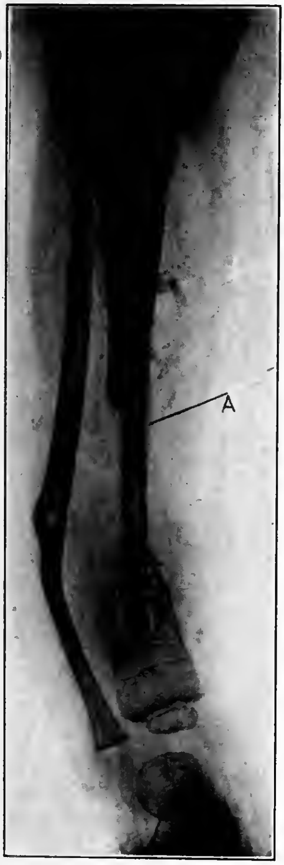


FIG. 300.—Two months after a second grafting operation, at which time five inches of the opposite, healthy fibula with its entire surrounding periosteum was transplanted into the medullary cavities of the fragments, an encircling wire suture being inserted below. Notice the new subperiosteal bone, *A*. Notice tendency to bowing due to growth of fibula.

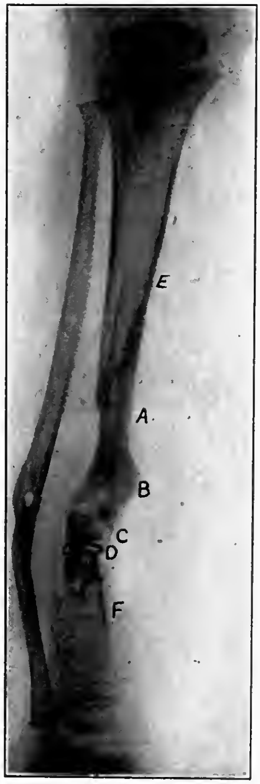


FIG. 301.—Seven months after the second grafting with periosteum. Notice the increase in size of the grafted fibula *A*, also the fracture in the lower portion of the graft *C*, the size of the callus *B*, coming from the graft and the erosion of the graft by the wire *D*.

and it was wedged into the medullary cavity of the upper fragment, and the lower side of the transplant was spliced to the side of the lower fragment with chromic gut after lifting up the periosteum. The subsequent union was by first intention. Fig. 299 shows the condition six months after the grafting. It was very disappointing to see the tibial graft gradually melt away in the tissues, so that after six months it was not more than one-quarter its original size. Since union was by first intention, there seems no way of accounting for the death of the graft save on the basis of a lack of periosteum, or of a deficient blood supply, or of both. Fig. 300 shows the condition eight months after the first grafting operation, and two months after the second grafting, at which time I transplanted 5 inches of the opposite, healthy fibula into the medullary cavities of the fragments, as seen. It was transplanted with the periosteum covering its entire circumference, and this was not split in the slightest. Below, a wire-encircling suture was used to hold the graft in place. Fig. 300 shows new bone being formed along the periosteum of the fibula graft, as a thin plate, two months after grafting. Fig. 301 was taken seven months after the transplantation. To my mind it seems to imply the necessity of revising Dr. Murphy's conclusion that a graft is not osteogenetic in itself. A fracture has taken place in the midthird of the transplant, due to the fact that the child kicked off the splint one night. We see that this fracture of the graft itself is consolidating nicely under an enormous callus. If we accept Dr. Murphy's conclusion, we must believe that all this callus came from the contacting old bone of the neighboring stumps. I do not accept this view for a moment, but believe that the callus arose either from the periosteum or from the bone of the graft itself. Along the outer surface of the graft we see at least a quarter of an inch of new bone evenly distributed. Were this new bone formed from the contacting ends of the old bone of the stumps it seems to me that it would shade off, becoming less the further we went from the old bone. As a matter of fact, the greatest amount of new bone is at the fracture spot in the graft, which is at some distance from either contacting extremity of old bone. Fig. 301 shows that the transplant (June 9, seven months after the grafting) has continued to develop. The upper part of the graft has become as large as the opposite healthy tibia. The fragment below the fracture, due to the inhibitory influence of the wire, has not

FIG. 302.—Fourteen months after the second grafting. Shows perfect healing of the fracture, disappearance of the callus and filling in of the erosion caused by the wire. The graft has increased throughout to the size of a normal tibia. *A*, junction of graft with lower tibial fragment.

developed well. In addition the wire is eroding the bone of the graft. I removed this wire June 14, 1913, with the object of preventing its cutting through of the graft.

Fig. 302 shows the result fourteen months after the grafting. The graft has developed well and the fracture seems to be consolidating nicely. Fig. 303 was taken nineteen months after the grafting because

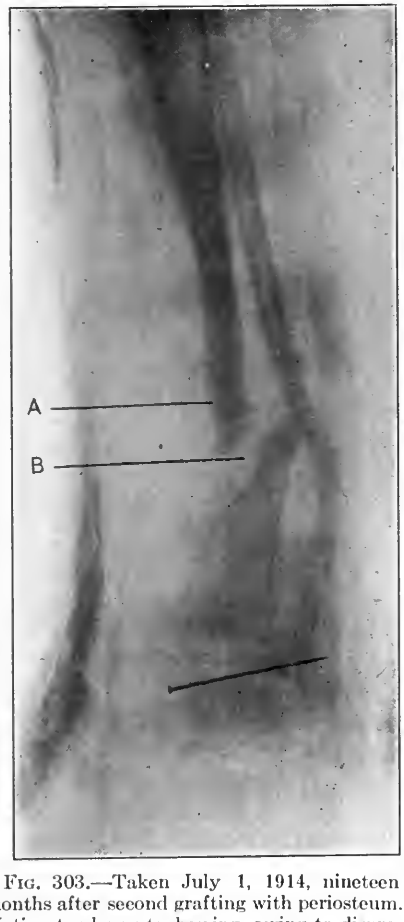


Fig. 303.—Taken July 1, 1914, nineteen months after second grafting with periosteum. Notice tendency to bowing, owing to disproportionate growth of fibula. *B*, ununited fracture.

Fig. 304.—Taken three years after the second grafting. Notice the curving of the leg, due to the growth of the fibula, the non-union in the fracture, the overriding of the fragments and the inefficient callus.

of increased mobility. This mobility was seen to be due to a refracture at the site of the old fracture.

The child has been followed carefully since and the last picture (Fig. 304) was taken March 21, 1916, three years and four months after the last grafting operation. It shows non-union of the fracture. The child had been fitted with an apparatus by Dr. Gibney; who aimed at preventing the inward curving or bowing of the leg, due to the growth of the fibula forcing the ununited fracture ends by each other which has resulted in an overlapping of about an inch of the ends. There is a large amount of callus about the upper extremity of the fracture indicative of an active life in that part of the graft.

Baschkirzew, Wetherill and Delbet have each made one transplantation without periosteum. Each was successful. The writer has made three transplantations without periosteum and all three were *unsuccessful*. Macewen and Vallas have each made successful transplantations, presumably without periosteum, of numerous small chips into defects.

During the writer's absence from the country, the child (then five and one-half years old) was seen by Dr. Albee, who again bone-grafted the ununited fracture on June 13, 1916, by the following method:

Technic of the Fish-Pole Transplantation.[1]—Exposure of the left tibia disclosed an ununited fracture at the junction of the middle and lower thirds. The ends of the fragments were conical-shaped, in very poor alignment and freely movable, one upon the other.

In the attempt to secure fixation and ultimate union of the fragments, it was decided to employ the mode of technic commonly followed by Albee in cases of fracture of the long bones in which one or both ends have become conical-shaped, namely, the *fish-pole technic,* so designated because of its similarity to the method of repair of a broken fish-pole.

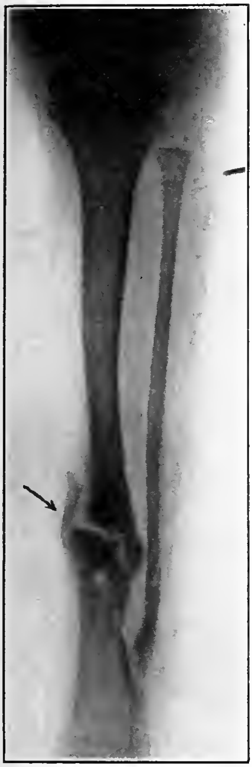
The ends of the bones were laid bare and the fragments placed in good alignment. With the single saw, one straight continuous cut was made through the two fragments, about 3½ inches in length, and extending down into the marrow cavity. Saw-cuts were then made extending in from the ends of the bone-fragments to the extremities of the original saw-cut, so that the pattern cut in the broken tibial shaft resembled a double wedge. The portions of the bone so cut were then pried out to form a bed for the proposed graft.

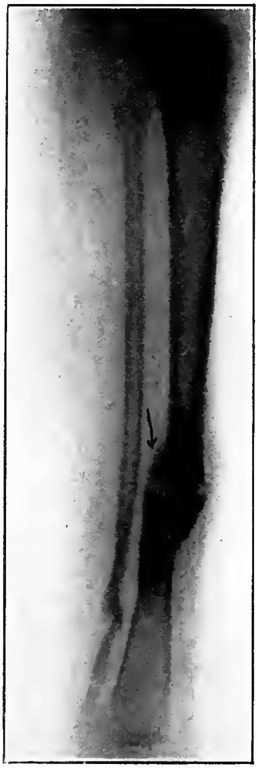
From the anterior internal surface of the right tibia, a graft was then cut and removed with both ends wedge-shaped and corresponding in dimensions to the bed which had already been prepared for its reception in the left tibial fragments. This graft consisted of all four bone-layers, namely, periosteum, cortex, endosteum and marrow, and was so inlaid into its bed that there was exact approximation of bone-layers of graft with corresponding layers of the host fragments. The graft was fixed with kangaroo-tendon. Sliver grafts, removed from the gutter in the right tibia, were then placed alongside of the main graft, to furnish additional foci for bone growth, and the wound was closed.

Results.—Proliferation of the graft and firm union of the fragments were demonstrated in subsequent *x*-rays (Fig. 307.) The last radiographic findings, recorded on March 22, 1920, nearly four years later, show solid union of the tibial fragments. The child runs about and

[1] See also Albee, Jour. Am. Med. Assn., February 28, 1920, p. 592, also Fig. 343.

plays with the energy and abandon of any other healthy, normal youngster, and functional restoration of the leg has been complete.





FIGS. 305 and 306.—Taken June 13, 1916, after fish-pole grafting by Albee. A double wedge-shaped incision was made in each fragment, into which was inserted a corresponding bone wedge-shaped graft taken from the opposite tibia. In addition the arrows indicate sliver grafts which were placed alongside of the main graft for the purpose of increasing the osteogenesis. (See Fig. 343 for technic.)

FIG. 307. — Result of bone grafting March 30, 1920, four years after the transplantation as shown in Figs. 305 and 306.

THE RESULTS OF INFECTIONS ON BONE GRAFTS AND THEIR USE IN INFECTED AREAS.

The original idea that transplants should be grafted only into clean, uninfected wounds may have to be somewhat revised, according to the latest clinical evidence, as well as that infection *necessarily* means the death of the whole graft. If the graft be *without* periosteum, infection will probably cause it to die entirely. If it have periosteum on it, then there may be a superficial necrosis of the bone but the periosteum may furnish sufficient blood to the bone of the graft to cause a greater resistance than it would have without the periosteum, consequently less of the bone will die. There may be some superficial necrosis which either the periosteum or the surviving bone-cells of the graft will regenerate. The chances are, however, more than ever that the graft will entirely die. The best rule is to make no grafting into any but a clean field, except for very exceptional conditions, awaiting before grafting the entire healing of any suppurating sinus.

Lewis has emphasized the effects of infection in the following two cases: the first one was in a patient who had previously had two Lane plates put upon an ulna and radius with resulting infection and sequestration of each. Operation and removal of dead bone. So much radius was removed that subsequent radial deviation of the hand was feared, hence a transplant (with periosteum) was removed from the tibia and inserted into the defect to act as a mechanical support, for even if it were later necessary to remove the graft it would have served a useful purpose. Later two small sinuses formed and several small cortical sequestra were removed. Union was firm in six months. The second case sustained a compound infected fracture of the radius, from which a tubular sequestrum was removed. In order to prevent radial deviation of the hand, a transplant, measuring about 4 inches in length, was at once removed from the anteromedial surface of the tibia and transplanted into the defect and the wound drained. A sinus remained about the wrist for some time but later closed without any sequestration. This transplant in roentgenograms has apparently increased in size and has survived in the infected wound. Lewis remarks about these cases, "bone grafts inserted into infected fields may live, and, even if sequestration formation occurs, necessitating operation later, they have acted as a mechanical support, preventing deformities, and the convalescence is materially shortened. Infection introduced at the time the graft is inserted, into a previously clean field, has a much more harmful effect and the entire graft or the greater part of it is apt to be lost. The autoplastic graft used in the treatment of old compound fractures, as in the last two cases cited, seems to have developed a certain amount of immunity to the infection, or perhaps the virulence of the infection has been greatly reduced."

Curtillet, Lambotte, Haidenham, Wetherill, Tomita, Brentano, Murphy, Hashimoto, Poncet, Schultze-Berger, Stuckey, Ochsner, and Barnes all report transplantations which later showed some suppuration. Despite some necrosis of the grafts, these did not entirely die but were finally successful. The writer reported a grafting operation into the inferior maxilla which showed some suppuration. The roentgenogram (see Fig. 335) elicited the fact that some but not all of the graft necrosed. The final result was excellent, as the bone of the graft remaining developed new bone. For this case see under Grafting Operations into Inferior Maxilla.

INDICATIONS FOR BONE GRAFTING (ALBEE).

1. To immobilize and stimulate osteogenesis in certain tuberculous joints.
2. To repair traumatic bone injuries.
3. To replace bone destroyed by infection.
4. To supply bone congenitally absent.
5. To strengthen or replace bone weakened or destroyed by benign or malignant growths.
6. To correct congenital or acquired deformities of the face.
7. To establish joints congenitally absent and restore those destroyed by disease.
8. To fix in place certain dislocated joints (acquired or congenital).
9. To close bone foramina in neuralgias.
10. To correct congenital or acquired deformities of extremities or trunk.

More specific indications for bone grafting are:

1. To immobilize, support, and stimulate repair in spinal vertebræ whose bodies are infected with tuberculous or other chronic infections where mechanical treatment is indicated. It is also applicable in cases of persistent non-union following fracture of the spine, presenting pain, disability and increasing deformity, and should be inserted as for Pott's disease. Further indications are for certain fresh fractures of the spine, spondylitis traumatica (Kummell's disease) and neuropathic spine (Charcot), where, on account of a rarefying osteitis, crushing of the vertebral bodies and increasing deformity are likely to produce cord compression.
2. In the support and immobilization of cases of tuberculosis of the sacro-iliac joint, in certain desperate cases of tuberculosis of the tarsus, and in the form of inlays to hasten or ensure bony union in erasure or excision operations for adult tuberculosis of the knee or hip.
3. In certain cases of paralytic scoliosis to support the weakened spine and prevent lateral deviation, due to superincumbent weight and unbalanced muscle pull.
4. To immobilize and support or replace bones of the tarsus destroyed, or partly destroyed by tuberculosis.
5. To correct deformity or restore balance in congenital club-foot and acquired deformity from local disease or paralysis.
6. As a substitute for all metal plates, screws, nails, spikes, and wires, as used in the internal fixation of fractures and other conditions. The graft, in the form of inlays and various sizes of nails or pegs, is employed by the author (Albee) in all types of fractures, such as fresh and ununited fracture of the long bones and of the neck of the femur.
7. To produce a permanent closure of nerve foramina after nerve resection for neuralgia (Kanavel).
8. As a prevention of luxating or slipping patella by raising the low femoral condyle by interposing a graft in the form of a wedge.
9. To aid, in the form of numerous small grafts, rapid bone union

where joint resection has been done or where a large graft has been used.

10. To strengthen and prevent lordosis or other deformity of the spine, and in cases of spina bifida, where a large amount of bone is congenitally absent.

11. To replace the head and neck of the femur, when previously destroyed by disease, the head and neck of the astragalus being used as a graft (Roberts).

12. In congenital and paralytic dislocations of the hip where the acetabulum is shallow and the femoral head will not remain in place. The upper half of the meager rim of the acetabulum is separated with a chisel and forced out and down, forming a pronounced rim. The cuneiform cavity thus produced is filled with wedge grafts.

13. To produce ankylosis of the ankle-joint in severe paralytic cases, or tuberculosis in the adult, by placing a bone graft peg through the os calcis and astragalus into the lower end of the tibia (Lexer).

14. To replace bone removed for osteomyelitis, tuberculosis, and spina ventosa.

15. For deformities of the nose, by contacting the graft with nasal bones. If the skin incision is made in the tip of the nose, the scar is not noticeable.

16. To replace or repair defects of the lower jaw; to fill in sunken spaces in the face, in the forehead following operation, in the bony defects, due to tuberculous osteitis, of the facial bones, in recession of the superior maxilla due to harelip. To replace a mastoid process removed by operation.

17. In intra-articular fracture-dislocations, the head of the humerus or femur, etc., should be replaced, at an open operation, as a graft.

18. To repair cavities in the cranial bones by transferring from the immediate neighborhood one or two segments of the external table covered with periosteum. The cortex of the tibia or a portion of the scapula may likewise be used; the latter source is preferable, as both surfaces of the graft are covered with periosteum.

PROCEDURE.

1. Most scrupulous asepsis is an absolute essential to perfect success. It is most important that no infection be introduced into a clean field at the time the graft is transplanted. To this end the operator, assistants and nurses should all wear rubber gloves and the same scrupulous Lane technic should be employed as in operating on simple fractures. Nothing that has been touched by the hand should go into the wound or touch the graft and all instruments and gauze wipes should be handled by instruments alone. It is advisable not to tie vessels but to allow the artery forceps to remain hanging *in situ* during the operation, after which they can be removed with little danger of bleeding. All sutures should be tied by means of clamps to avoid touching the suture with the hands. Instruments once used should be laid aside and reboiled before using again. Sterile towels should be clamped all

about the edges of the wounds so as to exclude the skin from the operative field. All this applies both to the site of the graft as well as to the field from which the graft is removed. A new knife should be used after the skin is incised and the old one should be laid aside. Tincture of iodine may be applied to the cut skin edges immediately after incision.

2. In general it may be said that all sinuses should be perfectly healed for two or three weeks (some say two months) before grafting is attempted so as to prevent infection of the graft. While infection does not necessarily mean the death of the whole graft, yet the danger that it may entirely die is very great. Lewis has demonstrated in two cases that a transplant may be inserted into an infected area with the object of acting merely as a mechanical support to prevent deformity, even if it is necessary to remove it later. In some exceptional instances such grafts may remain viable and hasten convalescence. (See under the heading "The Effects of Infection on Grafts.")

3. The graft should be taken living from the same individual who is to receive the graft (*i. e.*, an autoplastic or autogenous graft), if the best and surest means for success are followed. If this be not possible, which is very rare, then it should be taken from as near a blood relative as possible. Animal bone should never be used because such a graft will be absorbed owing to the changed serological and chemical relations. If taken from another individual, syphilis should be ruled out by the Wassermann reaction and tuberculosis should be excluded.

4. A living graft should be transplanted *always* with as much periosteum covering it as possible. *Without* the periosteum the life of a graft has proved to be uncertain. Its retention will ensure success, if asepsis be attained and immobilization maintained. The question of just what the function of the periosteum is, is an academic one. Practically the periosteum seems necessary for success in the greatest number of cases. Less important for success but still advantageous is to have endosteum on the graft, for the whole of a thing is greater than any of its parts. The value of marrow seems to be small, according to some authorities it is disadvantageous.

5. The success of a graft seems to depend upon a speedy adherence of the periosteum to the surrounding parts that the blood supply may be as quickly established as possible. Effused blood will prevent this adhesion, hence bleeding and oozing should be checked to the greatest extent possible. In addition a blood-clot about a transplant does not permit of a permeation of serum into the bone and also prevents vascularization. Lewis gives several instances in which hematomata caused absorption after graftings. On account of the oozing subsequent to the loosening of a tourniquet, this had better not be employed.

6. No drain should be used since this predisposes to infection.

7. A motor saw is of inestimable value in bone grafting operations. The best in my experience is Albee's motor saw.

8. In taking a graft from the tibia, its crest should not be employed, for this is the strongest part of the bone and its removal will predispose to subsequent fracture. Before this was appreciated, the author had two fractures of the tibia from whose crests grafts had been taken,

while other fractures have been reported. If the crest is used, the limb should be strengthened by a plaster splint for several months after transplantation, as new bone in such a defect is but slowly reformed.

9. All foreign, non-absorbable material, wires, nails, celluloid, horn, rubber, etc., should be avoided as implants unless under very exceptional conditions. Encircling wires will erode the bone and a fracture may result. These non-absorbable foreign bodies tend to irritate, if not invite suppuration, and often produce sinuses which will usually require their removal to cure such sinuses. Chromic gut or kangaroo tendon or bone screws should be used to fix the graft in position.

10. When the head of the humerus, or radius, or femur is fractured and dislocated and the joint is opened, then the head should be replaced and attached to the freshened, lower, fractured surface, even though the head be dead, provided it is still aseptic.

11. A graft increases in size according to the demands put upon it by the organism. Experience has taught that it is unnecessary to laterally fill up a defect completely with a graft. It is essential to fill up a defect vertically, leaving to Nature to do the remainder.

12. After transplantation, absolute immobilization is essential for success. This should be maintained for at least three or four months, or longer, if roentgenograms show its necessity.

13. The periosteum of the bone into which the graft is inserted is an important element and should be preserved and brought into contact with the periosteum of the graft or over the ends of the same, if possible.

14. The inlay graft in the treatment of fractures is to be preferred theoretically to the intramedullary splint since endosteum comes in contact with endosteum while the periosteum of the graft can be sutured to the periosteum of the bone. A much more successful method of treating non-union in fractures than a Lane plate is the bone graft. The intramedullary bone splinting has, however, given good results in the hands of many surgeons, particularly Murphy, also Davison.

15. Transplantation of long bones with their joint surfaces has been successfully performed as has been the case with half joints and with whole joints in a few instances. In most cases, however, the transplantation of joints has not been better in results than those accomplished by resections.

16. A suggestion by Huntington seems valuable. He has found that the periosteum of a graft may be preserved *in situ* during operation by wrapping the fragment closely with zero catgut. Before closing the wound the strands of gut are divided and removed or cut short.

17. In operating on comminuted fractures, whether simple or compound, replace the fragments, if possible, in their original positions. If this be not possible, fragment the pieces, retaining all the periosteum possible on the fragments, and replace them about the fracture spot.

18. The site from which a free graft may be obtained seems to depend upon the individual preference of the surgeon. The majority

seem to have used the tibia while the fibula has been chosen by others. In a few instances grafts have been taken from ribs, clavicle, scapula, crest of the ilium, and bones of the hands and feet.

19. Do not transplant a graft into the midst of dense connective tissue since the nourishment of the graft will thereby suffer. Excise the connective tissue and check the bleeding by packing before inserting the graft.

20. The bed into which the graft is to be transplanted should be prepared first. Then the graft is obtained and placed in its new bed just as quickly as possible that its cells may not suffer from lack of nourishment for a longer period than is absolutely necessary to make the transfer. In order that blood and serum contained in the graft be not washed away, theoretically it were more scientific not to immerse the graft in salt solution but to wrap it in gauze wet in salt solution if there is to be any delay in its transfer. This will prevent the drying out of the graft by evaporation.

Fig. 308.—Shows fracture of the tibia following removal of the bone from the crest for transplantation into the lower jaw. Illustrates effect of the body weight on the weakened tibia. The crest should not be taken for grafting. One of the author's two cases. If the crest be taken, however, a splint should always be applied if the patient is allowed to walk.

FRACTURES OF THE TIBIÆ FOLLOWING REMOVAL OF BONE FOR GRAFTING.

The writer (Fig. 308) had 2 cases of fractures of the tibiæ following the taking of bone from their crests for grafting purposes. Since these accidents occurred he never takes bone from the crest, but from the postero-internal surface, leaving a portion of the crest *in situ*. If any more than a small section of bone be removed, a plaster splint is applied to the leg for at least six weeks. The crest should not be taken if it can be avoided, because it is the strongest and most solid portion of the tibia and it is the key support for the whole bone. Morris reported a patient at the New York Surgical Society in whom a transplantation for a cranial defect had been done. A piece of bone, one and one-fourth inches in length and one and one-eighth inches in width, was removed from the internal surface of the tibia. Thirty days after the operation the patient returned to the hospital with a transverse fracture of the tibia at the site from which the transplant had been removed. Morris also stated that he had heard of four similar cases. A case of fracture of the tibia following transplantation into an ununited fracture occurred in the service of Dr. F. G. Dyas at the Cook County Hospital. A transplant, five inches in length and a half inch in width and thickness, was removed from the crest of the tibia. Eighteen days after operation the patient fell from a wheel-chair and fractured the tibia, from which bone for transplantation had been removed. A roentgenogram showed a transverse fracture of the tibia. The line of fracture extended from the upper angle of the defect caused by the removal of the transplant. Fracture of the tibia following removal of a transplant for a cranial defect occurred in one of Rhode's cases. The transplant was taken from the flat surface of the tibia and was about two inches long by one inch broad and practically the entire thickness of the bone. Twenty-seven days after operation, the patient fell in the street during a convulsion and sustained a fracture of both bones of his leg. The line of fracture extended from the upper end of the defect in the tibia. Solid bony union followed immobilization of the fracture in each case in the usual time. Roentgenograms of 6 cases of fracture of the tibia following the removal of bone for transplantations were privately shown during a recent meeting of the American Roengen Ray Society. The tibia should be protected for at least six weeks from fracture by a plaster cast during the period of regeneration of the defect caused by removal of bone for transplantation, provided the crest has been taken.

METHODS OF BONE TRANSPLANTATIONS.

For the sake of completeness the entire range of transplantations which have been done are now given here.

It shows the historical development of what has been proved to be the best clinical method of performing a successful transplantation; that is to transplant a free, living graft, with as much periosteum on it as possible, taken from the patient himself who is to be grafted. There may be some rare instances where some other one of the homo- or auto-plastic procedures, to be later mentioned, may be advisable but these are rare. A pedicle has been proved to be not at all necessary. It simply complicates what is ordinarily a much simpler method. There are instances, however, where it is necessary to supply not only bone but also soft parts in which a pedicle will be the best method, such instances are the supplying of soft parts as well as bone to make up the loss of the entire nose, or to supply not only portions of the lower jaw but also the soft parts over this, which may be lost, *e. g.*, shot away or resected for cancer, etc. In case a homoplastic transplantation is necessary the bone should be taken from a near relative, *e. g.*, from father to child as in a reported case of spina bifida. Heteroplastic transplantations have been proved to be very unsatisfactory and should be given up.

1. Heteroplasty:
    - (*a*) Foreign substances such as ivory, silver, magnesium, horn, etc.
    - (*b*) Animal bone:
        1. Living.
        2. Dead.
        3. Decalcified bone.
2. Homoplasty:
    - (*a*) Living bone preferably taken with periosteum either from a cadaver immediately after death or from a fresh amputation.
    - (*b*) Dead bone either boiled or sterilized in antiseptics.
    - (*c*) Transplantations of joints from fresh cadavera, resections, or amputations.
3. Autoplasty:
    - (*a*) With pedunculated bone flaps, necessarily with periosteum.
        1. With temporary pedicle, *e. g.*, Reichel's operation on tibia.
        2. With permanent pedicle either cutaneous or musculo-cutaneous or periosteal flaps.
            - (*a*) Ollier's operation par renversement.
            - (*b*) Ollier's operation par glissement.
            - (*c*) Ollier's operation par transplantation.
            - (*d*) Müller's two operations.
            - (*e*) Hahn's or Huntington's operation.
    - (*b*) With non-pedunculated bone, *i. e.*, free grafts.
        1. Transplantation with small chips with or without periosteum.
        2. Transplantation with large fragments always covered with as much periosteum as possible.
        3. Transplantation of a part of the shaft of a bone plus one of the articular ends.
        4. Transplantation of joints.
    - (*c*) With pedunculated or non-pedunculated periosteal flaps (Codivilla's operation).

1. **Heteroplastic Grafts.**—Heteroplastic grafts are those made up either of foreign or alien grafts, such as ivory, celluloid, horn, rubber, silver, magnesium, etc., or of animal bone either living or dead. They are absorbable or non-absorbable.

Little space need be taken up with a discussion as to the advisability of using these grafts. They are more than doubtful in their results and the method has been generally abandoned today. To understand, however, the development of the present successful methods of grafting, it will be necessary to consider heteroplastic grafts for a moment, for it was almost the first method to be employed. The more than doubtful results obtained led to further researches to find a successful method. In general it may be safely said that all these heteroplastic substances should be replaced by transplants of autogenous, living, periosteal covered grafts, since these assure the greatest certainty of the grafts living and assuming their proper functions, particularly as it is almost as easy to insert an autogenous graft as a foreign body and the success of the graft is thereby much more certain.

(*a*) **Foreign Substances.**—Since aseptic operations have become so successful, it is *possible* to have large, foreign bodies heal in the body tissue without irritation. A good example is the Lane steel plate for fractures. Non-absorbable material as such may remain *in situ* but it can never arrive at a firm, substantial adhesion of itself. It is encapsuled in connective tissue and this later can only become occasionally ossified provided osteogenetic tissue is present in the vicinity.

A situation where there is no osteogenetic power present, where, instead of callus formation, resorption processes have the upper hand, absorbable material will disappear without bone production, and the defect will be closed by connective tissue merely. Where the foreign substance is in osteogenetic surroundings, it may become encapsulated in a bed of new bone. On the irritating properties of the foreign material will depend how much secretion is produced. If this be large, a sinus will form and the foreign material will be extruded, or it must be removed before the sinus will heal. Such foreign material may serve a useful purpose in affording support until the periosteum of the vicinity shall form new bone. The present tendency in surgery generally is to avoid, as much as possible, implanting any non-absorbable material whatsoever.

Ivory transplants have been made by Kronacher, Gluck, Koenig, and Wachsner. Koenig gives his conclusions as to the implantations of ivory in 8 cases with the results after two years. He is enthusiastic in its use.

Mysch attained good results in 3 cases in which he transplanted cow's horn. The lower jaw seems to be the region into which foreign substances have most frequently been transplanted. Silver prosthetic appliances have been inserted by Murphy and others into defects in the lower jaw. Some have met with success.

(*b*) **Animal Grafts.**—Animal grafts both living and dead, with or without periosteum, show no ability to produce bone themselves and they have little stimulating effect upon the old bone to produce callus. At best they act merely as supports until the old bone and periosteum may perchance produce some new bone. This new bone is usually small in amount and insufficient. The influence of the changed serological relations will be spoken of under homoplastic transplantations. In 1891, Kummel reported a good result after he had transplanted into an ulna defect a piece from a decalcified ox's tibia. The limb was consolidated in four to five weeks. Patterson in 1878 reports a case of non-union of both bones of the forearm with a defect of $\frac{3}{4}$ of an inch in the radius, into which a piece of a dog's humerus with periosteum was transplanted, the redundant periosteum being brought over the periosteum of the radius where it was sewn. The graft was held in place by silver wires. Two months afterward the wires had to be removed.

The small wound remained open for twelve months when the dog's bone, reduced to half its size, came away, after which the wound healed completely. The forearm became very useful. No very definite statement is made as to consolidation. Tomita reports a bullet wound of the front of the right humerus. Profuse suppuration. When healed a thigh bone, 7 cm. long, from a fresh, living rabbit was transplanted, both ends being fixed to the freshened fracture ends by silver wires. Primary union. Twenty-three weeks after the operation, the lower fragment end was fast consolidated with large callus formation while the upper fragment had still some movability, although x-ray showed a large amount of callus which had grown around the implant so that it almost touched the lower callus. He reports a second case of a bullet wound of the middle of the tibia. Suppuration and sequestration. Defect was 12 cm. long. This wound healed finally. A piece of thigh bone with periosteum and marrow from a freshly slaughtered calf was inserted into the defect. Ends of transplant inserted into medullary cavities of fragments. Drainage. Primary union. Never any sinuses. Twenty-seven weeks after operation patient could walk without crutches and was discharged. Excellent result. Farquhar Curtis reported 3 cases in which he filled bone cavities with pieces of decalcified bone with successful results in all. Kuttner reported in 1913 the case of a child into whose congenital fibula defect he grafted the shin bone of a Java monkey. The operation was one and one-half years previous so that a judgment over the result is now possible. The roentgenogram shows that the monkey's bone is perfectly healed in the tissues and there is no trace of any absorption and the epiphyseal line is still clearly to be made out.

2. **Homoplastic Grafts.**—(*a*) **Living Homoplastic Transplantation.**—Homoplastic bone transplantation is the grafting of bone from *another* individual of the same species into the person who is to be grafted. The graft has been transplanted either living or dead. Dead bone, like animal bone and foreign material, plays the role of an internal prosthesis rather than that of a true graft. It simply furnishes a conductor, a matrix for the periosteal regeneration of bone coming from the neighboring, living, old bone. How much exciting or stimulating influence dead bone will have on this formation of new bone is questionable. The graft can furnish no new bone of itself. This form of dead bone transplantation has been given up for good reasons. Homoplastic bone grafts are far inferior to autoplastic bone grafts; but if perchance they should be used, the grafts should be taken *living* from as near a related individual as possible and always with periosteum. In transplanting joints, it will be necessary to make a homoplastic transplantation. To obtain a living graft, it will be consequently necessary to obtain it from a *fresh* amputation or from a cadaver soon after death. The success of such a joint graft will depend upon the serological relations between the individual from whom the graft is taken and the individual into whom the graft is to be transplanted. For, in the one case, the bone is originally laid down in serum of a

certain composition. Bone from this individual may be transplanted into an individual whose serum may be of somewhat different composition, hence the graft will be foredoomed to more or less chemical change with absorption. The chance for success of such a graft in homoplasty will be just about in the same proportion of success as will be attained in attempts to find two bloods for blood transfusion which will agree and will not hemolyze when mixed. This is advanced as a more or less theoretical suggestion. Certainly bones from different individuals have probably different chemical compositions and the chance of grafting from one individual into another, bone of exactly the same composition would theoretically appear to be doubtful, resulting in cytolysis and absorption. The same reasoning holds true for the transplantation of various organs from one individual to another. These organs almost always eventually disappear because of cytolysis, *e. g.*, the thyroid gland and the testes. We have, however, heard much of the temporary success of transplanted monkey's testes. Evidence is all against their permanently remaining alive, however. The skin seems to be about the only tissue which will not die when transplanted from one individual to another, this presumably being due to its lack of differentiation. In addition, the danger of sepsis and of transmitting disease as well as the inconvenience of waiting for a corpse or an amputation from an assured healthy individual have caused this method to be practically given up. Homoplastic transplants, as from a near relative, have been occasionally successful, but not as many of the osteogenetic cells remain alive and actively proliferate as in autoplastic grafts; hence the formation of new bone is slower, and its extent is less, consequently it is more uncertain as to its ultimate success.

(*a*) Living homoplastic bone transplantations:

Successful.	Unsuccessful.
Kuttner (2 cases).	Baum (4 cases).
Lexer.	Anschutz.
Haberer.	Ternier.
Anschutz	Ollier.
Grosse.	Poncet.
Stuckney.	Samter.
Trout.	Barth (2 cases).
Macewen.	Morrison.
Rovsing.	

(*b*) Dead homoplastic transplantations either boiled or in antiseptics:

Successful.	Unsuccessful.
Braman.	Franke.
Friedrich (2 cases).	Kausch (5 cases).
Kausch (1 case).	Grosse (2 cases).
Grosse (1 case).	Stieda.
	Kuttner.
	Streissler.
	Brewer (Fig 282).

The question of the success of some homoplastic transplantations is as yet insufficiently explained. It has been proved that now and then a homoplastic transplantation succeeds but a law has not yet been found to explain why one particular homoplastic transplantation succeeds and why another is a failure. In some cases we may find that the graft was transplanted into a bed which had more or less osteogenetic tissue about it and the new bone may come from this tissue. In other cases no such aid can be invoked, and we must plead entire ignorance as to where the new bone comes from. Undoubtedly in the future chemistry will shed light on this problem. The composition of the transplanted bone in the case which succeeds may have similarity to the blood and the bone of the individual into whom the graft is transplanted, just as two bloods when tested for hemolysis in transfusion may perfectly agree. In neither case, however, can we prognosticate what the result will be.

3. **Autoplastic Transplantations.**—Autoplastic bone transplantation is the grafting into an individual of a piece of bone taken from some other region of the same individual. The graft should always have some periosteum upon it. Some published experiments made by Neuhoff in the Surgical Research Laboratory of Columbia University are very suggestive. In the course of some experiments in transplanting fascia, he found that in every case in which he transplanted fascia into defects made in the bladder wall, there was new bone formed in the transplanted fascia. Beginning on the lumen side of the fascial transplant, there was first calcification and then later this became ossified. There was no evidence of any new bloodvessel formation, in or around the transplant, such as many investigators claim precedes ossification. When fascia was transplanted in other parts of the body, there was no new bone formed in the transplant. Neuhoff argues therefore from his experiments that there was first calcification in the degenerated fascial transplant, which was caused by the continuous presence of lime salts in the urine with the continuous bathing of the transplant by these salts. Not all calcified areas in the body go on to ossification, but every one of these bladder transplants did show ossification in the calcified areas. From these results one is justified in arguing that there is more than likely a local *chemical* stimulus to calcification and ossification in the body.

The author has made a large number of experiments in animals to see whether it were not possible to hasten the process of consolidation in fresh fractures by inserting through an open wound various substances into the fracture line. In general the animals were killed two weeks after the fracture and the insertion of the following substances and their combinations:

1. Powdered bone sterilized with the dressings.
2. Powdered bone.

$$\left.\begin{array}{l}\text{Calcium carbonate}\\ \text{Calcium phosphate}\\ \text{Calcium sulphate}\end{array}\right\} = \text{equal parts of each.}$$

Vaselin = q. s.

3. Powdered bone.
   Kidney calculus powdered in mortar.
   Vaselin = q. s.
4. Powdered bone.
   Cholesterin gall-stone.
   Calcium phosphate.
   Calcium carbonate.
   Vaselin = q. s.
5. Powdered bone.
   Cholesterin (human, pure).
   Lecithin.
   Tricalcium phosphate.
   Calcium carbonate.
   White vaselin = q. s.
6. Cholesterin (human, pure).
   Vaselin = q. s.
7. Cholesterin (human).
   Powdered bone.
   Vaselin = q. s.
8. Cholesterin (human) alone.
9. Tannin.
   Vaselin = q. s.
10. Calcium phosphate = 2 parts.
    Calcium carbonate = 1 part.
    Inserted as powder. The animal was fed 1 dram of the same compound three times a day for two weeks.

RESULTS.—Two and sometimes three experiments were made with each of the above compounds. After two weeks the animals were killed and the fracture removed and microscopic sections were made through the fracture line. In general it may be said that in not a single instance was there any appreciable influence exercised upon the fracture by any of these substances either in accelerating or retarding the consolidation. Neither did the continued feeding to the animals of calcium salts have any effect in hastening consolidation.

The various methods by which autoplastic transplantations have been made are given in the table on page 455. It has been amply demonstrated that all pedicles made for the purpose of a sufficient blood supply are unnecessary since free grafts, if taken with periosteum, have been proved to be eminently successful and leave nothing to be desired if asepsis be attained. Bone flaps pedicled by the soft parts should be used only in case soft parts in addition to the bone are to be supplied to fill a defect, *e. g.*, in the treatment of loss of the soft parts of the face and jaw by gunshot wounds (see lower jaw), or loss of both soft and hard structures of the nose by injuries or disease (see nose). For the sake of completeness the following procedures will be mentioned as having been performed. They should all be replaced by free, autogenous bone grafts (without pedicle) with periosteum on them.

1. **Autoplasty with Temporary Pedicle.**—Reichel in a defect of the tibia formed a flap of the skin containing periosteum and bone from the opposite tibia. This was transferred into a defect in the opposite tibia and the bridge of skin (which assured a good blood supply to the graft) was later divided. Coenen in two cases of defects in tibia successfully performed the same operation. Likewise Nove-Josserand, Van Mangoldt, Lambotte, Hasimoto, Codivilla, etc., have done the same procedure.

2. **Autoplasty with Permanent Pedicle.**—A graft with a permanent pedicle most nearly approaches the ideal method.

Codivilla reports a united fracture of the middle third of the tibia of nine months' duration. Resection of a fragment of the fibula which was pedicled by the soft parts. This was fixed by periosteal sutures to the external surface of the tibial pseudarthrosis. Consolidation complete.

Curtillet: Ununited fracture of the middle third of the leg. Graft of the superior part of the tibial crest with musculo-aponeurotic pedicle whose base was at the level of the pseudarthrosis, carried through the anteromuscular mass and fixed in the defect. Metal sutures. Good result after a year in spite of suppuration requiring incision.

Lambotte: Pseudarthrosis of the leg. Two periosteal flaps reflected from the vicinity of the fracture over the fracture. No consolidation. A year later, an osteoperiosteal flap was made from above the fracture which was fixed over the fracture by two screws. Aseptic healing. Removal of screws later. Consolidation.

Kauert reports a case of pseudarthrosis of the same right tibia in which he resected a section of the fibula one-half as great as the defect to be filled, retaining the periosteum *in situ*. Care was taken that the connection between the section and the soft parts and interosseous ligament, so far as possible, was retained. This fibula section was then passed through a hole made in the interosseous ligament and laid between the two freshened tibia fragments. Fixation by means of a plaster splint. Two years afterward there was a beautiful result. Consolidation was rapid and perfect and the lad could walk as well as ever. Roentgenograms showed complete bony consolidation in which the graft was buried.

Other Methods of Autoplasty with Permanent Pedicle are as Follows:—(*a*) *Ollier's Operation Par Renversement* (Fig. 309).—Expose the ends of the bone and excise the fibrous tissue between them. With a fine saw cut from one fragment a thin slice of bone after freshening the opposite end. The slice of bone is hinged by the periosteum at the other end of the same line. The triangular wedge of bone is now turned downward and its apex is sutured with chromic gut to the raw bone surface below, or it can be pushed into the medulla. As much as two inches of bone may be replaced by this method. The periosteum is the permanent pedicle.

(*b*) *Ollier's Operation Par Glissement* (Fig. 310).—Freshen the end of each fragment and remove the fibrous tissue. From the upper end cut a triangular piece of bone with periosteum on it, but do not separate this portion of bone from its connection with the soft parts. Slide this piece of bone downward and suture it to the lower fragment.

(*c*) *Ollier's Operation of Implantation* (Fig. 311).—This is only suitable when one of two parallel bones is the site of a defect. The sides of the ends of the fragments are obliquely vivified opposite the bone from which the transplant is to be taken. These surfaces make two sides of a triangle. From the opposite healthy bone a triangular piece of bone is cut which retains its connections with the soft parts. The graft is turned and implanted into the defect, where it is sutured.

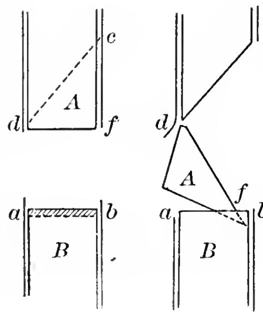


Fig. 309

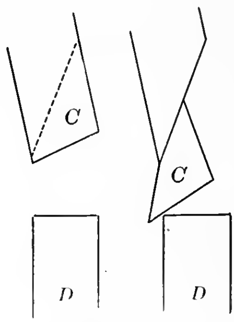


Fig. 310

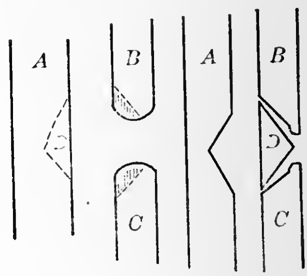


Fig. 311

Fig. 309.—Ollier's operation *par renversement*. *A*, the osteoperiosteal flap, *d c f* is hinged at *d* and reflected down in *B* until *f* comes in contact at *b*.

Fig. 310.—Ollier's operation *par glissment*. The triangle *C* is cut pedicled by the soft parts and reflected down and brought in contact with *D* .

Fig. 311.—Ollier's operation *par implantation*, applicable only to two parallel bones. The triangle *D* is reflected over, pedicled by the soft parts, into the freshened sides of the opposite fragments. (From Binnie's Operative Surgery, 1916, p. 908.)

(*d*) *Müller's Two Operations*.—The first (Fig. 312) is made by turning the flap which consists of skin, periosteum and bone, the pedicle being permanent. The ends of the fragments are exposed by a vertical incision which projects upward and downward, covering half an inch of the surfaces of each fragment. Remove all scar tissue interposed and freshen the ends and sides of the bone with a chisel. On the surface of the upper fragment outline a tongue-shaped flap, cutting through the periosteum with a knife. The pedicle, consisting of skin, is off to one side. With a chisel introduced through the upper flap incision, cut a slice of bone corresponding to the skin incision. Rotate this flap so that it bridges the osseous defect and fasten the bone in the flap to the raw surfaces of the fragments with chromic gut. Undermine the edges of the upper defect so as to bring them together, or close it by Thiersch's grafts.

The second method by Müller (Fig. 313) is one in which the twisting of the pedicle is avoided. Make a V-shaped incision, the open part of the V being about two inches below the end of the lower fragment and projecting upward about the same distance in front of the upper fragment. Elevate the flap, expose the defect between the fragments, remove the fibrous tissue, vivify with the chisel the ends of the bones

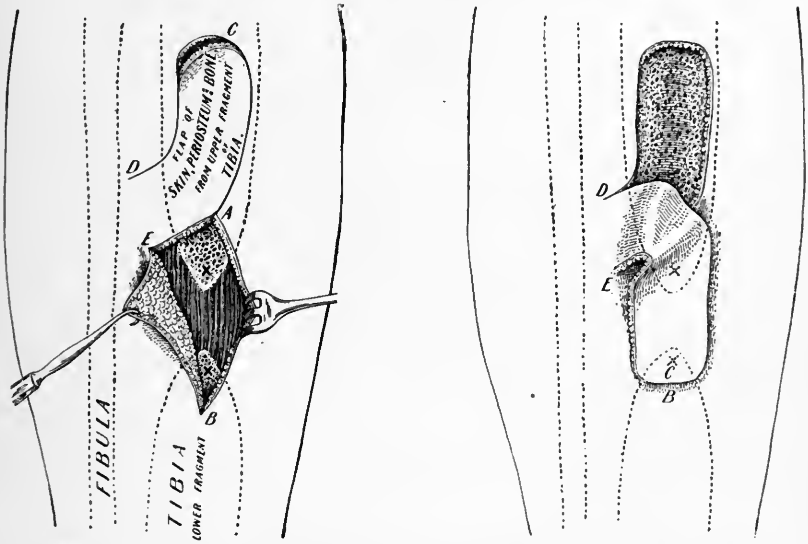


Fig. 312.—Müller's first operation, made by turning the flap, the pedicle being permanent. (From Binnie's Operative Surgery.)

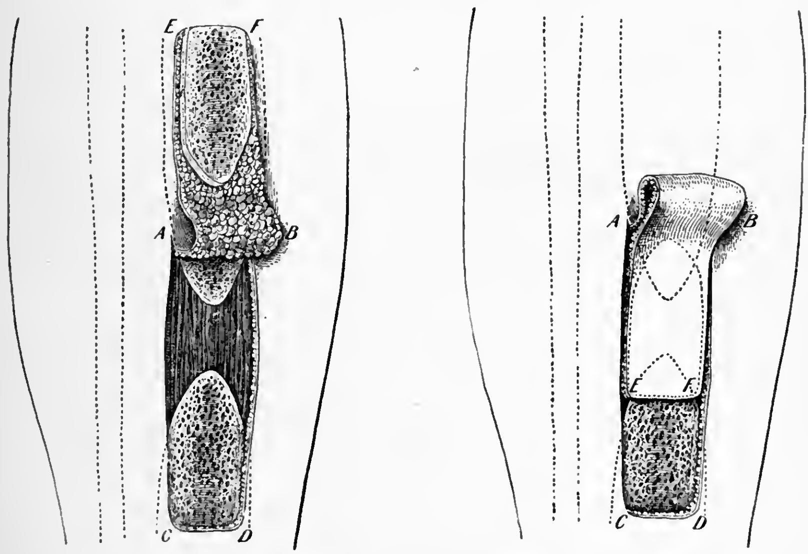


Fig. 313.—Müller's second operation, in which the twisting of the pedicle is avoided. (From Binnie's Operative Surgery, 1916, p. 909.)

and the front of the upper fragment. Carry the incision upward through the skin only on the surface of the upper fragment and loosen this part of the flap. Draw the flaps up until the bone in the flap bridges the defect between the upper and lower fragments. Suture the bone in this position. Carry the incision upward until the redundant portion of the upper part of the flap can thus be smoothed out. Undermine the edges of the lower defect and bring them together or Thiersch graft them. This operation has given Müller and Sprengel splendid results.

These operations are not of frequent applicability. If the defect be over 4 or 5 cm. they will be impossible. An objection which strikes one is the increased liability to infection, owing to the Thiersch grafts, or to tension on the sides of the defect, as well as to the small raw surfaces which are liable to be left at the sides.

Müller has performed 13 transplantations for pseudo-arthrosis according to his method. Of these, 12 were successful, consolidation quickly following. One only was unsuccessful, due to necrosis of the flap.

(*e*) *Hahn's or Huntington's Operation.*—See under Tibia, page 497.

(*f*) *Codivilla's Operation.*—This consists in surrounding the pseudo-arthrosis with very thin osteoperiosteal plates, taken from the internal face of the tibia. The periosteal sheets should be 3 or 4 mm. in thickness, and long enough to be fixed on each fragment by two sutures distant about 1 cm. This method employed by Brade, Ranesbusch, Codivilla, etc., can be applied only to loss of substance no greater than 3 cm. It is the choice of method in congenital pseudo-arthrosis and it has been employed in some acquired pseudo-arthroses. Delageniere has transplanted an osteoperiosteal sheet as thin as a piece of paper which he has rolled about the pseudo-arthrosis, a procedure which has habitually succeeded with him. Codivilla has published a number of reports of patients operated by his method with success. Streissler says that the grafts of periosteum alone, as we have known for a long time, will produce new bone.

METHODS OF BONE GRAFTING IN PARTICULAR LOCALITIES.

The first method under each heading is the one which as the result of evolutionary experience has been proved to be the best and most successful. This is followed by briefer mention of other methods which have been tried.

Skull.—The best method of closing a skull defect will depend on whether the skin over the bone defect is present or whether it is deficient, in this latter case there being a granulating surface beneath upon which the graft must be placed.

1. Where there is a deficiency of skin and a granulating surface is left beneath. In such a condition free bone grafts are inadvisable because of the probability of their becoming infected with resulting subsequent necrosis and extrusion. The exposed cerebrum cannot be covered with celloidin (Prime) or rubber tissue or gold or silver foil, likewise for fear of the infection. In such a condition the best procedure is first to excise all the granulating tissue and then to cover

the raw area with a free fascia lata graft or with a pedunculated temporal fascia flap according to the method of Carl Beck. A rubber tissue drain should be placed under one corner. The free fascial flap is tucked under the edges of the bone which have been freed of adherent tissues. If the edges of the dura are recognizable, the edges of the fascial graft should be sewn to the edges of the dura with catgut. Upon this fascial graft a Müller-König osteoplastic operation should be done at a second sitting as follows:

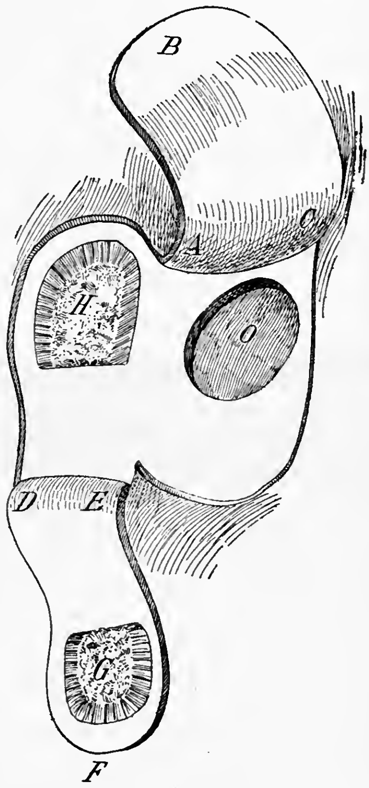


FIG. 314.—The Müller-Koenig operation. (Binnie, Oper. Surg., 1916, p. 12.)

Expose the cranial defect (*O*, Fig. 314) by reflecting the skin-periosteal flap *A B C*. Excise all scar tissue from the cranial defect and freshen the edges of the bone. Outline and reflect the flap *D F E*. In forming this flap cut away with the chisel a portion of the outer table of the skull *G*. The portion of bone *G* is the integral part of the flap *D E F*, and is of size and shape suitable to be inserted into the cranial defect *O*. Insert the graft *G* into the defect *O*, and suture the edges of flap *D E F*, to the bed from which *A B C* was raised. Implant flap *A B C* in the bed from which *D F E* was raised.

It will be found usually impossible to raise the bone in one piece as it will become fragmented. Great care should be exercised that the pieces be not separated from their attachments to the pericranium (periosteum). Possibly a simpler method (Hacker-Dirante) is to make a large curved skin flap including both the defect and the area from which the bone is to be removed to cover the defect. The edges of the defect are freshened. An inverted V-shaped periosteal flap is then formed beginning at the edge of the defect. The periosteum of the flap is then elevated for $\frac{1}{4}$ of an inch all about the edge and then subperiosteally a bone flap is chiselled from the outer table of the skull of shape to fit the defect. The chisel should be held tangentially as much as possible and elevated lightly after each blow. The adhesion of the bone flap to the periosteum is carefully preserved as the bone is elevated. The osseous-periosteal flap is reflected into the defect and the edge of the periosteum is sutured to the surrounding periosteum with catgut. Hacker has varied this operation by reversing the bone so that the periosteal surface is next to the brain with the idea of preventing adhesions between the brain, dura and flap. In cases where it is deemed advisable to cover the brain with fascia lata and then to add a bone flap or free bone, one should not do both transplantations at one sitting for fear of deficient blood supply to the bone grafts through the transplanted fascia. The two operations should be done at separate sittings.

Figs. 315 and 316 are photographs taken of a patient of the author who was operated upon in November, 1907, to close a skull and skin defect (Fig. 315), resulting from a collision between the patient and a trolley car, seven months previously. At this time the patient came into the hospital in coma with a compound, comminuted fracture of the skull from which brain and blood oozed. The wound suppurated and a brain abscess was opened. The patient finally recovered with a sluggish cavity (Fig. 315) of the size of a half dollar, at the bottom of which pulsating brain could be seen. After seven months it was decided to attempt to close the wound. Nothing was done to cover the brain with any further tissue. The granulating tissue was simply scraped. A pattern of rubber tissue was cut, one-third larger than the defect, and this pattern was laid over the forehead immediately to the right of the defect. A flap with pedicle above was then cut through the pericranium down to the bone outlining the pattern, one edge of the flap being formed of the edge of the defect. A chisel was then inserted through the incision and with the mallet the outer table of the skull was separated from the internal table at the diploë, the shape of the bone fragment corresponding to the shape of the flap. The bone, however, split into two or three pieces whose attachments to the overlying soft parts were carefully preserved. This tongue-shaped flap was then swung inward (*A*, Fig. 316) and its edges were sutured to the freshened edges of the defect. The raw area left at *B* was Thiersch skin graft taken from the thigh. The after-result was all that could be desired. The skin and bone flap healed by primary union but the Thiersch grafts succumbed and the raw area granulated in of itself. Fig. 316 is the result after the wounds had all healed. Nine years after the grafting operation the wound looks just as it is shown in Fig. 316 and is perfectly solid.

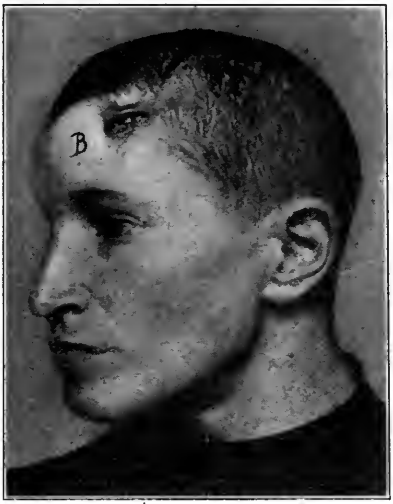


FIG. 315.—Author's case of skull injury before operation. Cavity, size of half-dollar, at the bottom of which was pulsating brain covered by granulating tissue.

FIG. 316.—Final result of Fig. 315 after a single flap. (Müller-Koenig operation.)

2. **The Skull Defect is Covered with Skin.**—A skin flap is made exposing the bony defect and the skin is raised from either the dura, or, in case this is wanting, from the cerebrum itself. If the dura be deficient whether one should cover the raw cerebrum with some one of the smooth aseptic materials employed for this purpose is as yet a question. Their use would be particularly indicated if the operation had as its object the improvement of epilepsy. In any case it would be well to substitute autogenous fascia lata or temporal fascia for these foreign materials. The simplest method of filling in the bone defect is that of Keen, also advocated by Macewen. Keen has used the method in a score of cases with uniform success. He fills in the defect in the skull with bone chips from the outer table of the neighboring bone. The margins of the defect are exposed and freshened. He then chisels a number of pieces of bone from the outer table of the skull in the vicinity and fills in the defect completely. The skull becomes in time very strong and solid, reproducing practically a normal skull so far as both outline and protection are concerned. The fascial transplantations and the bone graftings should not be done at the same sitting.

In order to do away with the necessity of operating in two stages in cases in which there was a defect in both the bone and the dura, Kleinschmidt circumscribed upon the median surface of the tibia a periosteal flap which had the entire width of the tibia and double the length of the skull defect. In its upper half a flat bone section in contact with the periosteal flap was chiselled loose from the bone, while in the lower half only periosteum was in the flap. After removal of the bone section he turned the lower half of the periosteum around and sewed it over the bare portion of the graft which in turn was sewn into the defect, having periosteum on both its sides. Periosteum was thus brought in contact with the brain as well as with the skin. Röpke[1] with the same object in view has used a part of the scapula as follows: After exposing the cranial defect by reflecting a flap of scalp, excise the scar tissue over the brain and vivify the edges of the bone. Temporarily pack the wound with gauze wrung out of hot water. Apply dressings. Place the patient on his right side and pull the left arm forward. Make an incision about one-half inch to the outer side of the vertebral border of the scapula, exposing the fascia covering the infraspinatus. Divide the fascia and infraspinatus just external to the vertebral border but do not divide the periosteum. With a sharp knife dissect outward, cutting the infraspinatus from the body of the scapula until an area of bone is exposed fully as large as or larger than the cranial defect. With surgical engine, sharp chisel or suitable forceps, *e. g.*, 'de Vilbiss', divide the bone all around the desired area, being careful to *leave the vertebral border of the bone intact.* Dissect the isolated plate of bone from the subscapular muscle. Place the fragment of bone in warm salt solution. Attend to hemostasis. Suture

[1] Zent. f. Chir., 1912, No. 35.

the divided infraspinatus muscle and fascia to the vertebral border of the scapula. Close the wound, dress. With scissors carefully remove all muscle attached to the bone implant, and replace the bone plate in the cranial defect. Replace the scalp. Close the wound. Dress.

Probably the simplest and best method of closing in these skull defects, in which there is no deficiency of skin, is a free, non-pedunculated, living, autogenous bone graft, as follows:

A scalp flap about $\frac{1}{4}$ to $\frac{3}{4}$ in. larger on every side than the skull opening is turned back. The separation of the scalp and the dura is carefully done. If the dura is thickened and adherent to the brain cortex, it should be dissected away, providing cortical symptoms have appeared. The bony edge of the aperture is freshened by drilling several holes, about $\frac{1}{4}$ to $\frac{1}{3}$ inch from the edge of the opening, with the Martel attachment to the Albee motor. The thickness of the skull is then measured and a thin strip of bone is removed all around the edge of the opening with the motor saw protected by a proper-sized washer. These saw cuts should be made markedly bevelled. Additional protection to the dura from the saw can be furnished by slipping a thin piece of ivory under the bony edge which the saw is cutting. All the dimensions of the operation are then taken with calipers or compasses, or an exact pattern is cut out of a sheet of rubber tissue, and are transferred to the upper portion of the posterior internal surface of the tibia selected as the source of the graft material. The exact size and contour of the graft is outlined in the periosteum with the point of a scalpel, from the caliper measurements. The graft is removed with the Albee small saw, the cuts being bevelled the same as those at the edge of the skull opening, so that the transplant will rest firmly on the skull and cannot be driven down upon the brain beneath. The graft is held in place by two or three ligatures of medium kangaroo tendon placed in corresponding drill holes in the edges of the graft and skull opening. The upper end of the tibia is selected rather than the lower portion because its cortex is thinner and its surface is flatter and broader.

Costal cartilages laid side to side in the defect have many times been successfully transplanted. The same is true of sections of ribs covered with periosteum on one side, the periosteal side being laid against the cerebrum.

Nose.—1. **Saddle Nose.**—Carter (Fig. 317) has devised the best method of correcting a saddle nose where the soft parts are intact, the bony framework being gone. His description is as follows: A curvilinear incision, convexity downward, is made between the eyebrows, extending down to the periosteum over the frontal bone. Lifting the flap up, a transverse incision is made through the periosteum and into the bone. This incision is at a point just below the glabella. Above the incision the periosteum is elevated for about three-eighths of an inch. With a sharp elevator the skin and subcutaneous tissues are then elevated over the dorsum of the nose, to an extent corresponding to the degree of the deformity, over the sides of the nose and in some instances over the cheeks. If any of the nasal bone is left its periosteum should be elevated so that the bone graft, when it is introduced, will lie in close contact with the raw bone and its torn periosteum. Two inches of the ninth rib are then removed, preserving the periosteum on the outer surface. This piece of rib is then split in its transverse diameter, the outer half is shaped to suit the deformity. The bone graft is then inserted nearly to the tip of the nose, and the upper end is carefully placed beneath the periosteum over the frontal bone. The semilunar flap is then brought down to its place and the wound is then closed with horse-hair sutures.

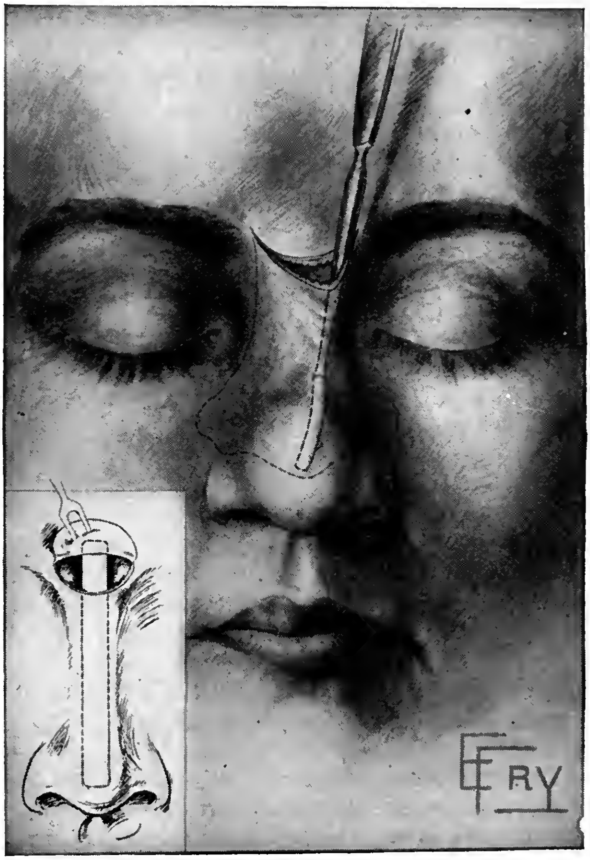


Fig. 317.—Bone transplantation for nasal deformity. The central figure shows method of elevating skin and subcutaneous tissues; the insert figure shows the bone in place.

An improved modification in two respects of this operation has been lately done to advantage: (1) Incision: In order to do away with the scar at the base of the nose, it is now made on the under side of the tip where the scar is insignificant. (2) A better material for the graft than bone is cartilage. It can very easily be cut out with a knife from the costal cartilage of the seventh or eighth rib and can be made into any desired shape by the knife. In addition, cartilage is more resistant to infection than bone, and if any infection occurs, the cartilage is more liable than bone to remain living. The writer would caution against going through a scar which may chance to be situated on the dorsum of the nose in order to insert the graft. The tension on the scar edges, after they are closed, will eventually inevitably cause the scar to break down. A new incision should be made on the tip and the tunnel should be carried underneath the scar.

Figs. 318, 319, 320, 321, show the result of a rib cartilage transplantation for congenital syphilitic saddle nose. These pictures were taken three weeks after the grafting. The graft was taken 'rom the left eighth rib and inserted through a transverse incision at the base of the nose into a tunnel made to the tip of the nose. It was fastened in place by catgut sutures. It was followed by infection due to opening into the nose, evidenced by bloody nasal discharge. The transverse incision was opened at its right angle and the pus was expressed out repeatedly. The wound healed perfectly without any deleterious influence upon the graft. There was no necrosis. The final cosmetic result was perfect.

2. **Where the Bone as Well as the Soft Parts of the Nose Must be Supplied.**—In general there are two methods which have been used: (*a*) The Indian, the bone and soft flaps being taken from the forehead. (*b*) The Italian, in which the flap is taken from the arm, the bone being obtained either from the ulna or by another piece of bone transplanted at a prior operation into the arm. The Indian is the preferable method as it gives better results. Morrestin carries this out today as follows: A transverse incision is made fairly high up across the forehead and through this incision in tunnels made radially from the root of the nose are slipped three strips of rib cartilage, after which the wound is closed. After a period of three or four weeks a flap is made which contains the cartilages with pedicle below and to one side. This flap is then reflected down and sutured into the defect in the nose as usual, the cartilages forming the supports for the new nose.

Ch. Nélaton also has a similar operation with preliminary transplantation of costal cartilage into the forehead. With oiled silk make a model or pattern of the flap necessary to cover the new nose with skin. Lay the model on the forehead and mark its outlines with silver nitrate. Without injuring the perichondrium excise by sharp dissection the whole cartilage of the eighth rib. Close the wound. With a knife pare about one inch of one end of the cartilage (the rib end) until it is not more than one-eighth inch (3 mm.) thick. This thin portion is destined to form the new column of the nose. Where the pared portion of cartilage joins the unpared portion cut a notch nearly through the cartilage so that it may be later bent in fashioning the nose. At the middle of the distal end of the flap outlined with silver nitrate on the forehead, make a cut down to the bone. With a director burrow a tunnel under the periosteum from end to end of the flap. Pass the graft of cartilage into this tunnel in such fashion that its thin or pared end lies subperiosteally near the skin wound and the notch at the junction of the pared and unpared portions faces toward

Fig. 318

Fig. 319

Fig. 320

Fig. 321

Fig. 318.—Front view before operation of author's case of rib cartilage transplantation into syphilitic congenital saddle nose. Note the syphilitic scars about the mouth, also the depression of left ala at its tip.

Fig. 319.—Front view three weeks after rib cartilage transplantation of Fig. 318. Wound at base suppurated and angle on right side was opened and drained. Notice transverse scar at base. Wound has healed without affecting the cartilage. Depression of tip of ala has been smoothed out.

Fig. 320.—Lateral view of Fig. 318, before operation.

Fig. 321.—Lateral view of Fig. 318, three weeks after cartilage transplantation. Eyebrow hairs have not yet grown out.

the skin. Close the skin wound. Apply dressings. After about two months the second stage of the operation may be undertaken.

Koenig's method is the foundation for the various modifications of the forehead flap. It consists in forming a flap containing skin, periosteum and bone from the outer table of the forehead, and in turning this flap down with the skin surface twisted externally and in fastening it in the defect. After several weeks the raw surface of this flap is covered by a skin flap taken also from the forehead and turned down so as to cover the raw area of the first flap, or after three or four weeks the raw area is skin grafted.

Schimmelbusch's operation is based on Koenig's method and Lexer's is based on Schimmelbusch's. (See Binnie, *Operative Surgery*, 1916, p. 194–196.)

Fig. 322.—Author's case of loss of entire nose by a machine. Side view shows nothing remaining but a small spur of soft parts.

Fig. 323.—Full-face view.

Italian Method.—Several operators in making a new nose have tried the preliminary inlaying of one or two thin bone plates (taken from the tibia) under the skin of the arm or forearm. After these have healed in place, a large pedicled flap is circumscribed about them and the raw surface of this flap is skin grafted. Later this pedicled flap is bent like a roof as near the transverse configuration of the normal nose as is possible and is sewn by its edges into the defect in the nasal structures.

Finger into Nasal Defect.—Finney,[1] McGraw and the author have each successfully grafted a finger into a defect consisting of a loss of

[1] Binnie: Operative Surgery, 1916, p. 199.

all the structures of the nose. Baldwin has suggested an improvement of this finger transplantation. He reports two cases. The modification seems very advantageous. It consists of making a double layer of skin so that one layer would be continuous with the cheek while the other would take the place of the mucous membrane on the inside. To accomplish this a flap was made on the abdomen, reversed and then its raw surface was sutured to the raw surfaces on the finger made by reflecting flaps on its ventral surface. The pedicle was later divided

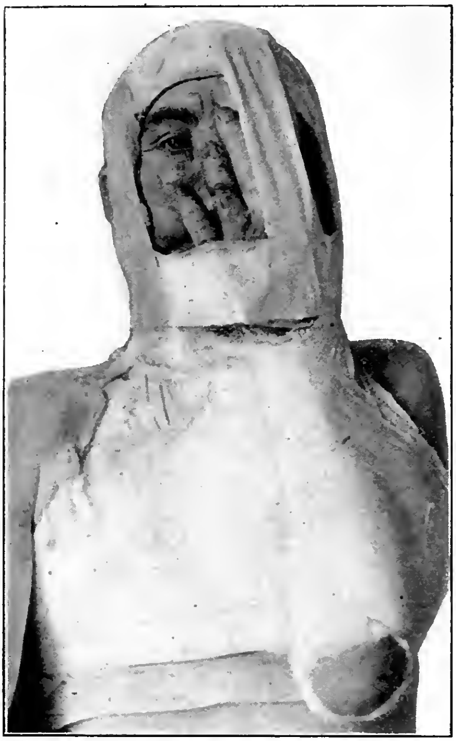


Fig. 324.—First stage of operation; finger joined to frontal bone after removal of nail and skin on the palmer aspect of terminal phalanx; plaster-of-Paris splint about head, arm and chest.

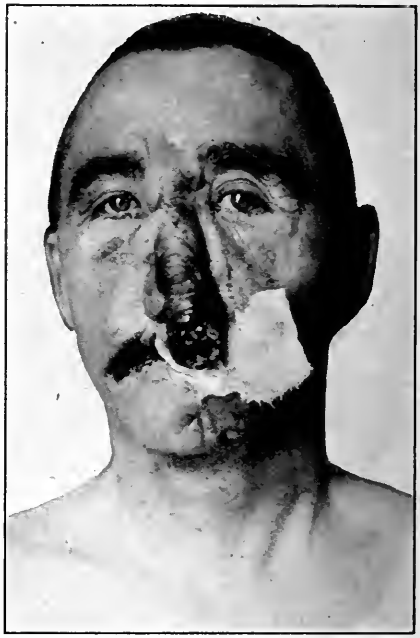


Fig. 325.—Second stage of operation; finger has been amputated, twenty-one days later.

and the finger was sutured to the nose. It was later amputated. The final result was "pleasing." McGraw could collect but eleven cases in which a finger had previously been used as a transplant into the nose. the writer's patient is seen in Figs. 322, 323, 324, 325, 326, 327 and 328.

Inferior Maxilla.—There are two lesions at least in which bone grafting is indicated in the lower jaw: (*a*) Ununited fractures. (*b*) Defects, the result of osteomyelitis or resections for tumors.

There is a principle which should never be forgotten in treating lesions of the lower jaw whether it be due to a fracture or to osteomyelitis, and that is that the lower teeth should be maintained in their proper relations to the upper teeth by either an interdental splint or

Fig. 326.—Roentgenogram of result after proximal phalanx had been turned antero-posteriorly. Distal phalanx in contact with frontal bone.

Fig. 327.—Result after the operation; lateral view two months after the operation.

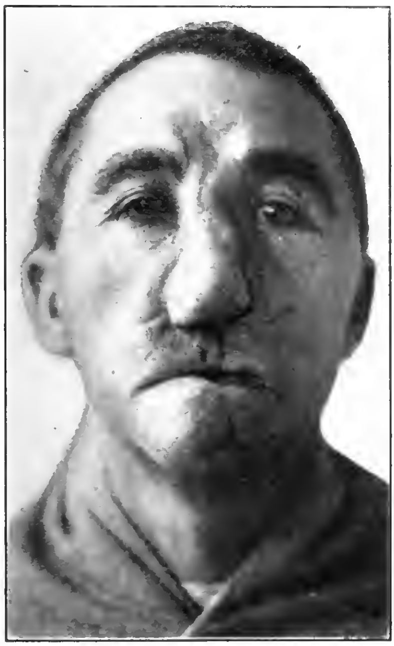


Fig. 328.—Front view.

by wiring. This proper occlusion should be kept up until the finish of the treatment, for the end of all treatments of lesions of the lower jaw is the obtaining of a good ability to chew properly. No grafting should be done until all necrosis of the bone is at an end and all dead bone has been removed. Neither should any grafting be done until all the sinuses have been closed perfectly for several weeks, for fear of infecting the graft. If, in preparing the bed in the soft parts of the defect to receive the graft, the mouth be opened into, one should not then insert the graft as it will become infected from the mouth and most certainly die and slough out. One should await the healing of the soft parts before inserting the graft, in the meantime maintaining the width of the defect by wiring the teeth on both sides of the defect to their

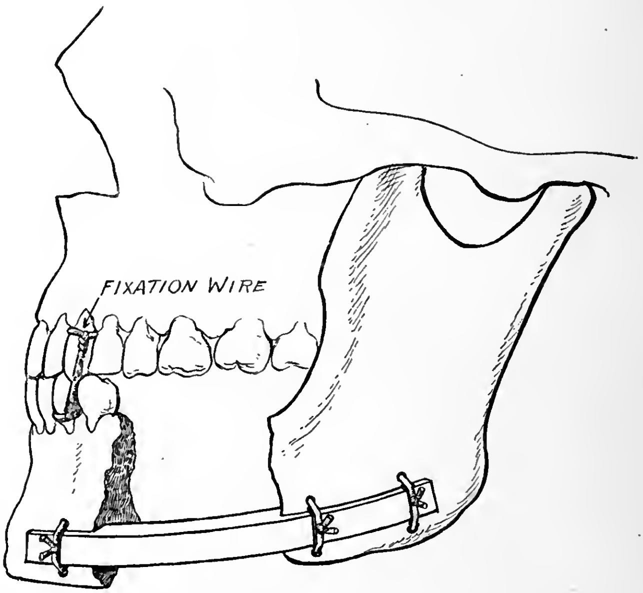


Fig. 329.—Diagram of a fractured lower jaw so badly shattered as to leave a gap where the proper position of the remaining fragments is maintained. This gap can be satisfactorily spanned and the fragments securely united through the inlay method with a graft and gutter produced by the twin motor saws adjusted at the same distance apart, producing an accurate fit of the graft which is held in position by kangaroo-tendon sutures passed through drill holes in jaw fragments. This was a frequent condition in the late war, resulting from trench warfare. (Albee, Bone-graft Surgery.)

proper opposite teeth on the upper jaw. The grafting should be done only through clean tissues in which there are no sinuses and in which the defect has been previously made and maintained by wiring to such an extent as will enable the patient to subsequently chew in a normal fashion. Intrapharyngeal ether is administered by tubes through the nostrils. A transverse incision is made parallel to the lower border of the inferior maxilla across the defect, exposing one to two inches of each fragment. Great care should be exercised not to open the mouth in preparing the defect. The soft parts should be carefully separated from the margins of the defect with the periosteal elevator. It will not be necessary to separate the soft parts from the internal or mouth surface of the fragments. The vertical bone edges of the fragments on

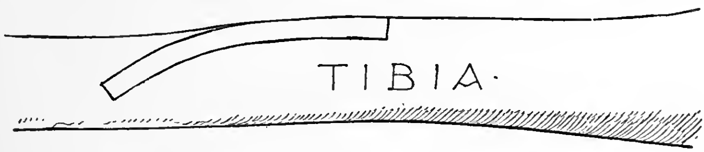


FIG. 330.—Diagram illustrating the curved graft as it is outlined on the antero-internal surface of the tibia preparatory to cutting the bone with the motor saw. This pattern has been previously determined by bending a flexible probe into the gutter on the side of the broken jaw. (Albee, Bone-graft Surgery.)

either side of the defect should be gently freshened with the chisel. With the bone twin motor saw a groove or furrow, $\frac{1}{4}$ to $\frac{1}{2}$ inch wide, should be cut transversely on the corresponding outer surfaces of each fragment (Fig. 329). A malleable probe is placed in the two grooves

FIG. 331.—Author's case of osteomyelitic defect of lower jaw. First operation was the removal of the pointed end of the posterior fragment, O.

and this is moulded so as to obtain the exact curve of the lower jaw. The internal surface of the tibia is prepared and exposed by a curved incision and the flap is reflected backward, leaving the periosteum uninjured attached to the bone. The moulded curved probe is laid upon the periosteum which is incised in two parallel directions exactly corresponding to the curve of the probe. The graft is then cut by means of the twin motor saws with a curve (Fig. 330) corresponding to that on the probe and of the same width as the furrows already made in the fragments of the jaw. The periosteum should on no account be separated from the graft. Before inlaying the graft into the furrow, two drill holes on each side of the defect should be made, the holes going

Fig. 332.—The result of the first operation, which consisted in the removal of the anterior projection of the posterior fragment and the pushing backward of the posterior fragment, which was very adherent.

into the furrows from the sides. Into these are threaded chromic or kangaroo tendon sutures. Metal sutures should not be used. The loops are left long and under these the graft is placed in the furrow after which the sutures are tied. No drain should be used.

The lower teeth should be absolutely fixed to the upper teeth by wires for from two to three months after the grafting operation. These wires will need frequent tightening and resetting and attention.

Figs. 332–338 illustrate three patients grafted for defects in lower jaw. There are four graftings in these three patients. Two of the grafts were wired and both became infected, one slightly with some

FIG. 333.—End-to-end placement of the graft from the tibia, with retention of it by wires. These wires are no longer used.

FIG. 334.—Removal of the wires because of discharge from the anterior one. Evidence of some necrosis of the anterior section of the graft.

FIG. 335.—Roentgenogram six months after last picture. There is no discharge. The graft has not entirely necrosed. Is firmly attached at both ends, and there is a firm bridge above the necrosed area, which holds the fragments well. Patient can chew perfectly. *C*, the mandible; *D*, the posterior end of graft; *E*, the defect in graft caused by the suppuration.

FIG. 336.—Author's second case of necrosis of the lower jaw. End-to-end placement of the tibial graft held by wires, a method now discarded. A communication with the mouth was established which resulted in necrosis of the entire graft, necessitating its removal.

necrosis of the graft while the second had complete necrosis of the graft. The wires had to be removed in each case. The other two graftings had the transplants fastened with kangaroo tendon sutures and each healed by primary union. The best method, employed in the third patient, is the inlay one. Two of these cases were published in *Surgery, Gynecology and Obstetrics,* September, 1915, p. 306.

FIG. 337.—The previous patient was regrafted with a section from the tibia, with periosteum, fastened in place by chromic gut. Primary union. This picture was taken five months after the grafting. The transplant has become firmly united to both fragments. Patient was cured.

Cole[1] in an excellent article on Ununited Fractures of Mandible reports 10 cases of bone grafting by free autoplastic grafts and 8 cases by pedicled bone grafts. The technic is fully explained.

The Spine.—The following lesions of the spine may in particular instances best be treated by a bone graft:

A. Pott's Disease.
B. Paralytic Scoliosis.
C. Spondylolisthesis.
D. Spina Bifida.
E. Fracture-Dislocation of the Spine.
F. Tuberculosis of the Sacro-iliac Joint.

[1] British Jour. of Surg., July, 1918, p. 57.

A. Pott's Disease.—There is no longer much doubt that the best method of treating this condition is by autogenous bone grafting according to the method devised by Albee, for description of which see Albee.[1]

Fig. 338.—Author's third case of graft, with periosteum, taken from the tibia, into a defect of the lower jaw, the result of a gunshot wound. In this case furrows were cut in each fragment with the twin motor saws. Into the furrows was inlaid a correspondingly wide fragment taken from the tibia with periosteum and fastened in place by kangaroo-tendon sutures passed through drill holes in the sides of the furrows. Primary union, resulting in a cure. The inlay graft without wiring is much the best method in all graftings when it can be employed.

B. Paralytic Scoliosis.—This is usually the result of anterior poliomyelitis causing asymmetrical involvement of the spinal and abdominal groups of muscles. The usual treatment for poliomyelitis should at first be carried out, consisting in rest in a gas pipe frame followed by plaster-of-Paris corsets or a metal frame brace. After two years, regeneration has reached a stationary stage and it must thereafter be decided whether the spinal curvature, resulting from the paralyzed muscles, is not better treated by a bone graft into the spine than by the usual braces. In many cases braces are insufficient and pressure neuritis develops which makes further measures necessary.

[1] Reconstruction Surgery, 1919, p. 100.

There are two methods which may be employed in the bone grafting: one is the insertion of the graft into the tips of the spinous processes as in Albee's bone grafting operation for Pott's disease, and the second method is the placing of the graft into the tips of the transverse process of the vertebræ on the convex side at the apex of the sharpest curve. From six to eight transverse or spinous processes should be included in the graft. A plaster-of-Paris corset before the operation should be moulded to the back and sides of the patient's trunk and allowed to harden while the patient is held in the corrected position (by extension). If the graft is to be inserted into the spinous processes, the technic should be employed as is customary in Albee's operation for Pott's disease already referred to. If the transverse processes are used, six to eight are exposed on the convex side of the curvature at the apex of the curve. The muscles and transverse processes are almost split into approximately equal halves with the scalpel. The transverse processes are split longitudinally into halves and the posterior half is pried over to make room for the graft. With flexible probe the necessary curve of the graft is ascertained and this is laid on the internal surface of the exposed tibia. The desired curve of the graft is outlined on the periosteum with a scalpel, after which it is cut through into the marrow by the twin motor saws. With the patient held in the corrected position, the graft is sewn into its bed in the transverse processes by drawing the muscles and ligaments together over the graft with kangaroo or chromic catgut. The plaster corset is then bandaged on and the patient remains in bed for six weeks, after which a light plaster corset is applied and the patient is allowed up. This corset is kept on for twelve weeks.

C. Spondylolisthesis.—This is a word used to indicate a luxation partial or complete of the body of one of the vertebræ, usually the result of a severe traumatism. Paralytic symptoms have at times appeared for which laminectomies have been performed. In some cases with great deformity, permanent support has been necessary. This is now best supplied by a bone graft which is inserted with exactly the same technic as that employed in lumbar Pott's disease. The lordosis is readily corrected under an anesthetic by placing the patient in a prone position on the operating table, supplemented, if necessary, by inserting a firm pillow under the lower portion of the abdomen. A long, strong, bone graft is inserted into the five or six spinous processes above and below the luxated one, as in the grafting operation for tuberculosis.

D. Spina Bifida.—In some severe cases of spina bifida, bone grafting may be deemed the only way to close the defect. The author has lost two babies because of shock as a result of attempting to take autogenous grafts. In his next patient he will follow the successful procedure of Trout, carrying the method out as follows: Fasten a blanket firmly between the upright leg-holders on an ordinary operating table. Hang the child over this by its groins, fastening the legs by bandages to keep it from slipping. The object of this inversion is to prevent the sudden drainage of the cerebrospinal fluid from the brain on puncture of the sac. In front of the blanket place a hot water bottle opposite the child's abdomen to prevent chilling. Have an assistant at the other side of the blanket to manage the head, and to administer the anesthetic. Sterilize abraded or ulcerated areas with pure carbolic acid followed by alcohol. Paint the whole area with tincture of iodin. A curved transverse incision is made above the tumor as far as possible from the anus. The sac is exposed, separated from the surrounding tissues down to the defect in the bone, aspirated until collapsed and replaced within the defect. If there are no ulcerated areas, bone grafting can be resorted to at once. If such areas are present, infection will more than likely ruin the transplant, which had in such a case better be deferred until the soft parts are all healed. The tissues from the side, including flaps from the erectores spinæ, are brought in and sutured over the bony defect. The skin on each side, from which all ulcerated areas are excised, is undermined and sutured over the muscles. Firm pressure thereafter is exerted over the defect until primary healing is complete. The bone grafting is done either at the primary or secondary operation, and, to avoid shock in these depleted children, the author believes the graft should be taken either from the father or the mother. An exact pattern of the defect is cut out of rubber tissue. This is placed upon the tibia of the donor and the graft, retaining its periosteum, is cut with the motor saw of exactly the same size and shape as the pattern. The periosteum is reflected from the sides of the defect in the child and the edges of the defect are freshened. Against the freshened edges of the defect are placed the fresh bone edges of the graft, completely covering the congenital defect. The periosteum, previously reflected from the cleft, is sutured to the periosteum of the transplant, and the muscles, if possible, on the sides are sutured together over the graft and the skin is closed.

E. Fracture-Dislocation of the Spine.—Mechanical treatment by plaster-of-Paris corsets or by spinal braces has been the treatment given previously to fractures of the spine with non-union, causing pain, disability and increasing deformity. If there has been pressure on the cord, the bone graft as inserted for Pott's disease furnishes the best means of relief. Slight vertebral displacement may be overcome when placing the graft. Pressure of any extent should be relieved by laminectomy. If subsequently a kyphosis appears as a result of the laminectomy, a bone graft may be inserted to include the laminectomized vertebræ, as well as one spinous process above and one below. Albee says: "The bone graft especially is needed in fracture of the cervical spine when a displacement has been reduced and there is danger of a relapse of the displacement." The method of treatment is indicated in spondylitis traumatica (Kümmell's disease) and neuropathic spine (Charcot), where, on account of rarefying osteitis, crushing of the vertebral bodies produces increasing deformities, with possible cord compression; also in certain fresh fractures.

F. Tuberculosis of the Sacro-iliac Joint (Fig. 339).—A bone graft offers the only satisfactory means of immobilization of this joint. The posterior-superior spine, the wing of the ilium and the first spinous process of the sacrum are reached by a curved incision. The posterior border of the wing of the ilium and the spinous process are split, with their attached ligaments, by a thin osteotome, forming a gutter to receive the ends of the graft. A cleft is made on the posterior wing of the ilium by driving a broad and thin osteotomy into it just anterior to its superior edge and in a direction laterally from within outward.

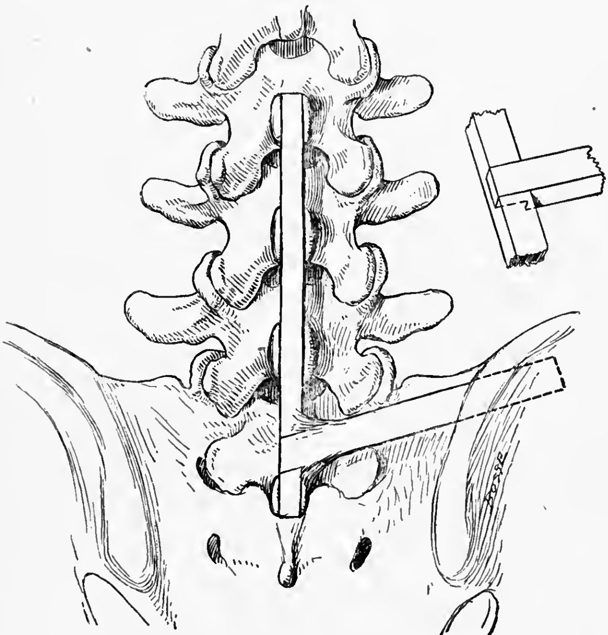


Fig. 339.—Diagram from the roentgenogram of an actual case of tuberculosis of the last lumbar vertebræ and the right sacro-iliac joint. The spinal graft was inserted by Albee's regular technic for Pott's disease. The graft controlling the sacroiliac joint was joined by a carpenter's half-mortise to the spinal graft (see small upper right-hand drawing). The callus uniting the two grafts is indicated. The graft was joined to the posterior wing of the ilium by shaping it into a wedge end which was forced into a split in the ilium made by an osteotome. (Albee, Bone-graft Surgery.)

The graft, which is later secured, is formed with a wedge end to be driven into this cleft. If practicable, a surface of the sacrum is denuded to furnish additional contact with the graft. The wound is packed with a saline compress and, with the patient still in a prone position, the leg is flexed and a graft of sufficient length removed from the tibia by the motor saw, as described in the use of the bone graft in Pott's disease, except for the just mentioned wedge end. The width of the graft should be three times the thickness of the cortex. The thickness should include the whole cortex, periosteum, endosteum and a small amount of the adhering marrow. The graft is placed in its prepared bed, and the ligaments are drawn over it by interrupted sutures of medium kangaroo tendon. The skin wound is closed, and the patient placed on the back on a fracture bed for a period of not less than five weeks. There should be no necessity for further mechanical treatment.

Clavicle.—Bone grafting into the clavicle is indicated in non-union of a fracture (a rare occurrence), for defects made in the bone for the removal of tumors and to replace the bone when it has been entirely resected for tumor. It may also be rarely indicated in fractures where the displacements of the fragments cannot be controlled by the ordinary means, producing a marked deformity. As a preliminary to the operation, the shoulder is fixed in a position upward, outward and backward by a Sayre dressing. The upper extremity is immobilized against the trunk by plaster of Paris. This expedient fixes the outer fragment of the clavicle during the operation and subsequent treatment without covering the field of operation. An incision following the clavicle exposes the defect in the bone. The fibrous and other interposing tissues are removed. The ends are freshened and fitted to each other in anatomical alignment. The periosteum is stripped back and a gutter is cut across the defect equidistant in the fragments. The gutter is cut, about 6 cm. long and 1 cm. wide, through the cortex and into the fragments for the reception of the transplant. The large vessels and nerves passing behind the clavicle are continually in danger of injury, and should be carefully protected. A transplant of the same length and width and sufficiently thick to fill the gutter is cut from the crest of the tibia. The periosteum is retained intact on it during the transfer. The transplant is wedged into the gutter with the cut surfaces in apposition to the cut surfaces of the gutter, and with the periosteal surfaces exposed. The periosteum which was reflected from the clavicle is replaced and sutured over the transplant. A strand of kangaroo tendon is secured around each end of the transplant and the clavicle to increase the stability of the repair. The wound is closed by sutures and dressed with aseptic gauze.

Humerus.—The humerus has been the location of many bone-grafting procedures. Sections from various bones for grafting have been used. The following is a partial list of the bones used with the operators. All are autogenous.

Head of the first metatarsal from hallux valgus in the same patient (Duval).

Tibia: Bier (2 cases), Braun (2 cases), Stieda, Streissler (3 cases), Stuckey, Davison (3 cases), Hashimoto (4 cases), Hacker, Murphy.

Fibula: Borelins, Gask, Huguier (3 cases), Brunètti, Stuckey, Fay, Gangolphe and Bertein, Rovsing.

Head of the second Metatarsal: Axhausen.

Rib pedicled: Bardenheuer.

Scapula pedicled: Codivilla (2 cases).

As a result of experience obtained from these various procedures, it may be said that bone grafting into the humerus may all be reduced to simple procedures. In the vast majority of cases the graft can be obtained easiest and best from the tibia. In a condition where the head of the humerus is gone, the upper extremity of the fibula with its periosteum may be used, its articular surface articulating with the joint surface of the glenoid, while its lower extremity is inserted into the medullary cavity of the lower fragment, or, what is perhaps better, is to inlay it into a groove cut into the side of the lower fragment.

Where the head of the humerus is gone together with more or less of the shaft of the bone, the defect, when perfectly healed, is exposed by Langenbeck's incision and the upper end of the lower fragment is dissected free and freshened and the medullary cavity reamed out. The upper portion of the fibula, if used as the graft, is dissected free, including its upper, articular surface, avoiding injury to the external popliteal nerve. The muscular attachments to the fibula are cut long to facilitate future suturing. As much as the fibula as is necessary may be excised. The whole diameter of the bone should be used with its entire periosteum. The cut-fibular end is stripped for an inch or more of its periosteum and it is then wedged into the medullary cavity of the lower fragment around which the separated periosteum of the graft is sutured to the periosteum of the humerus. The articular extremity is inserted into the glenoid cavity and the capsule of the joint is sutured around it. The divided muscular attachments around the joint are sutured to the graft, and the wound is sewn with interrupted silkworm-gut sutures so as to allow for drainage of blood between the sutures. No other drain is inserted and the extremity is immobilized to the body with plaster-of-Paris. Rovsing publishes a very successful case in which this procedure was carried out.

An equally good procedure is to take a section from the postero-internal surface of the tibia (avoiding the crest) with its periosteum, inserting the upper end of the graft into the glenoid cavity and its lower end into the medullary cavity of the lower fragment or into a groove cut in the side of the lower fragment where it is fastened with kangaroo tendon or chromic gut passed through drill holes made through the sides of the gutter.

In children the fibula should be taken as a graft because its upper extremity contains an epiphyseal cartilage, which will add to the growth of the extremity.

Defects in the shaft of the humerus produced by mutilating accidents or by operations for the cure of osteomyelitis, tuberculosis, or neoplasms may be made by grafts from the fibula with periosteum or by sections from the tibia also with the periosteum. The grafts may either be wedged into the medullary cavities of the fragments or grooves may be cut in the sides of the fragments into which the grafts are inserted where they are sutured in position. Albee uses the sliding inlay graft.

Ulna and Radius.—The indications for bone grafting into defects in the ulna and radius are the same as those into the humerus. Janeway and Streissler (2 cases) have each transplanted into the ulna sections taken from the tibia while Viannay and Tisserand have each transplanted sections from the fibula into defects in the ulna. Into the radius Walther and De Gouvea have each transplanted sections from the fibula while Delangeniere, Neumann, Lewis and Murphy have taken sections from the tibia. Teitze replaced the lower radius end, resected for sarcoma, by the first phalanx of the great toe whose base was used for the joint surface. The patient was a professional violin player. The result was so perfect that his ability to play the violin was not impaired in any degree whatsoever.

Fig. 340.—Author's case. Shows osteomyelitic defect of ulna perfectly healed. No evidence of new bone formation. Because of the removal of the head of the radius, the forearm at the defect is almost flail with no power in it.

Probably the best method to use in making a bone graft into the radius or ulna is the inlay method of Albee, taking the graft from the median internal surface of the tibia with its periosteum. The grafts should be inserted into the radial side of the radius and into the ulnar side of the ulna. Grooves are cut in the upper and lower fragments of the radius and ulna with the twin motor saws and a graft is cut of a corresponding diameter in the tibia with its periosteum. The graft is fixed in place by kangaroo tendon sutures passed about the fragments and the graft.

Figs. 340, 341 and 342 illustrate such an operation performed in a patient by the author. The patient, a man, aged thirty years, received a simple fracture of the head of the radius, which subsequently had to be removed. There was also a compound fracture of the ulna which resulted in an osteomyelitis of the ulna, for which several operations had to be done for the removal of the dead bone. Fig. 340 represents the result after the sinus had healed perfectly. Because of the removal of the head of the radius, thus taking away its support, together with the defect in the ulna, there was almost a flail condition of the lower forearm, pronation and supination being lost. Fig. 341 shows the result immediately after bone grafting into the defect. Grooves were cut into the medullary cavities of the fragments *A* and *B*, with the twin saws and a corresponding section with its periosteum was removed from the internal surface of the tibia (Fig. 342). The bone section was fitted into the grooves and held there by kangaroo tendon sutures passed about the fragments and graft. The forearm was put up with the fingers midway between pronation and supination in a plaster-of-Paris splint including the elbow at a right angle, and wrist-joints.

Fig. 341.—Graft from tibia with periosteum cut with the twin saws, placed in corresponding grooves in the fragments *A* and *B*, held by kangaroo tendon sutures passed through drill holes in the sides of the grooves. *C* is an extra piece of bone placed in the tissues. Roentgenogram taken five weeks after the operation.

Fig. 342.—Defect made in the middle of the internal surface of the tibia by the removal of the graft with the twin saws.

The wound was not dressed for five weeks. The patient made very satisfactory progress toward good pronation and supination by means of massage and bakings. The graft has taken perfectly, as roentgenograms show very clearly.

In my opinion the intramedullary graft is *theoretically* not as good a method to employ as the inlay graft. Should it be used, however, the ends of the graft should be trimmed off obliquely and be driven firmly into the medullary cavities of the upper and lower fragments, forming wedge joints. There is the best of authority for the use of the intramedullary graft.

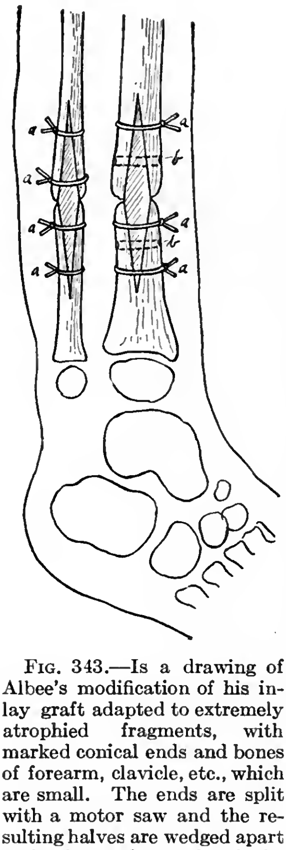


FIG. 343.—Is a drawing of Albee's modification of his inlay graft adapted to extremely atrophied fragments, with marked conical ends and bones of forearm, clavicle, etc., which are small. The ends are split with a motor saw and the resulting halves are wedged apart with the wedge ends of the grafts, which are molded into this form during their removal from the well tibia. *a*, *a*, indicate the fixing kangaroo tendon which can be wrapped completely about the fragment end, or it may be placed in drill holes through both graft and fragment ends; *b*, *b*, are bone-graft pegs, which may or may not be used in large bones to supplement the tendon in fixing the graft in place. This drawing is from the skiagram of an actual case. (Albee, Bone-graft Surgery.)

Should the ends of the fragments be atrophied producing marked conical extremities, Albee's "fish-pole" technic may be used to overcome this (Fig. 343). The ends of the fragments are split with the motor saw, and the resulting halves are wedged apart with the wedge ends of the graft which are cut into this form on removal from the tibia, after which the graft is sutured.

Fig. 344 is a roentgenogram of another of the author's cases of ununited fracture of the ulna, extending over a period of eighteen months. Three operations had been performed in another institution, two with nails and one with a Lane plate. The picture shows the disadvantage of using foreign material in the treatment of delayed union since the screw holes have not filled in even after the removal of the nails and plate. Foreign material decreases osteogenesis, while a bone graft, which should always be used in delayed union, stimulates it. Fig. 345 shows the previous fracture bone grafted with periosteum by the inlay method using kangaroo tendon sutures passed through drill holes in the sides of the furrows.

Hand and Fingers (Spina Ventosa).—Advanced cases of spina ventosa are treated best by excision of the diseased diaphyseal bone with its periosteum. If possible avoid injury to the epiphyseal cartilages which, in the metacarpals, are situated in the distal ends and in the phalanges in the proximal ends. If the excision be for a malignant growth, the epiphyseal cartilages must be disregarded. If the metacarpal or phalangeal stumps are not too short, the graft is mortised or inlaid into them, as in Fig. 346.

In Semken's case the distal three-quarters of the third metacarpal bone with its articular surface and periosteum had to be removed for sarcoma (Fig. 347). The defect was filled in with a tibial graft (Fig. 348) with periosteum, one end of which was mortised into the proximal stump, while the distal end articulated with the phalanx. In such a case the distal articular end may be covered over with a flap of fascia taken from the neighborhood, forming a sort of arthroplasty, to prevent ankylosis of the joint.

Fig. 344.—Author's case of ununited fracture of the ulna in which three previous operations had been performed, two with nails and one with Lane's plate, dating over a period of eighteen months, illustrating the inadvisability of using Lane's plate in ununited fractures.

Fig. 345.—Previous fracture. Bone grafted from tibia with periosteum by the inlay method held with kangaroo tendon. Twin motor saw was used to make furrows in fragments as well as for obtaining the graft.

Recently another method has been presented which makes use of the substitution of the whole phalanx of the toe for an entire diseased phalanx of the finger. The first of these cases was reported by Wolff in 1909. His patient was suffering from a spina ventosa of the basal phalanx of the fourth finger, which caused considerable interference with motion. Under ether narcosis he removed the entire phalanx with most of the diseased tissue. He put in the place of the removed phalanx the first phalanx of the second toe of the right foot, sewing it in with catgut. Into the defect of the foot he inserted a piece of cartilage from the sixth rib. At the end of one week he began active and passive motions. He reported a useful joint after a lapse of one year and eight months.

Leonte made an osteo-articular graft in a case of spina ventosa. He removed the entire metacarpal and replaced it by the fifth metatarsal. Primary union resulted. After a year there was perfect function of the fingers.

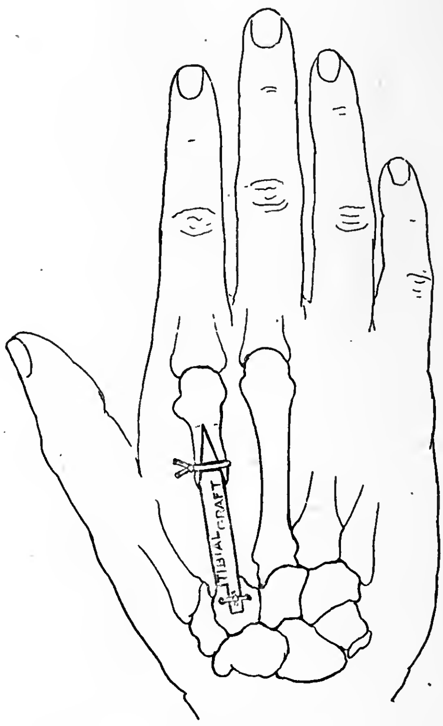


Fig. 346.—Illustrates completion of technic, with tibial graft held in place with kangaroo tendon. (Albee, Bone-graft Surgery.)

Petroff in a case of the first metacarpal, resected the entire bone except its head. Into the defect he grafted the first phalanx of the great toe, the distal extremity articulated with the trapezius, the proximal extremity, modelled slightly, was placed in contact with the head of the metacarpal. The result was excellent after three years, the graft becoming in form like that of the metacarpal.

Stubenrauch removed the first phalanx of the ring-finger for spina ventosa and replaced it by the first phalanx of the second right toe with a corresponding piece of the extensor tendon. The result was excellent.

Goebel resected the last joint of the left small finger of a violinist on account of a deforming inflammation. A free transplantation was made into the defect of the unopened middle joint of the second toe

FIG. 347.—Semkens's case of fibrosarcoma of third metacarpal bone. Three-quarters of the distal portion of the bone were removed and into the defect was grafted a portion of the tibia with its periosteum.

FIG. 348.—Roentgenogram taken seven weeks after the transplantation. The graft *B* has lived and has consolidated to the stump of the metacarpal bone.

of the left foot. After ten days movements were begun and after nine months the patient was able to appear in a concert. In another case he resected the first phalanx of the ring-finger. He transplanted into this defect the first phalanx of the second toe. He filled up the defect in the toe by a graft taken from the sixth rib. The day after the operation passive movements were begun and on the tenth day active movements were allowed. Some weeks after the operation, motions were as good in the finger as on the healthy side. Radiograms showed both grafts to be alive.

Sievers resected for sarcoma the entire second phalanx of the left ring-finger, including the two articular surfaces. He transplanted into the defect the first phalanx of the fourth toe, removed entire with its two articular surfaces. He filled in the defect of the toe with a small fragment of the anterior border of the tibia. The result was excellent.

Schmieden in 13 cases of spina ventosa of the hands and feet has used bone sections taken from the tibia of the patient to fill up the defect caused by the removal of the diseased bones. Good cosmetic and functional results were obtained in 8 cases. The author lays great weight upon thorough removal of the diseased bone with the avoidance of the epiphysis as much as possible.

Petraschewska removed the entire fifth metacarpal bone for sarcoma, and replaced the bone with the fifth metatarsal bone, which was sawed off at its base. The joint end (distal end) was placed into the first phalangeal joint and the sawed end was placed against the os hamatum. Primary union resulted. The function of the newly formed joint was identical with the sound joint on the other hand. The defect in the foot caused no disturbance.

Femur.—Albee has devised a transplantation operation for dislocation of the hip. The great trochanter is sawn off and turned up. The curved superior acetabular bone segment is pried downward and outward with the osteotome to deepen the acetabulum. This leaves a bone gap. The slack in the capsule is reefed by mattress sutures. To fill in the triangular bone gap in the acetabular rim, a segment of bone having a triangular cross-section, is removed from the crest of the tibia, long enough when cut into three or four portions, to fill in this gutter. The grafts are fixed in position by bone pegs. The trochanter is returned to its normal position and sutured with kangaroo tendon through the periosteal structures.

When a defect has been made in the femur following the removal of a tumor or for osteitis fibrosa cystica, it should be filled in with a large, strong graft taken from the tibia with its periosteum. A furrow should be cut in the two fragments above and below the defect with the twin motor saws. A graft corresponding in width to this furrow is cut from the tibia with the twin saws and this graft with its periosteum external is inserted in the furrow and held there by sutures of kangaroo tendon passed through drill holes in the sides of the furrow. Or the graft from the tibia may be inserted into the medullary cavities of the fragments. This latter method has been successfully performed by Murphy, Katzenstein, and others.

As is well-known the usual treatment of fractures of the neck of the femur is very unsatisfactory as to results. Undoubtedly the best non-operative method of treatment is the extreme abduction treatment of Whitman with a plaster-of-Paris spica. No weight should be put upon the limb for one year. For the surgeon who is competent to perform the operation, the most successful treatment seems to be the insertion of a bone-graft peg fitted into a hole drilled longitudinally through the neck of the femur with the fragments held in good position. This bone-graft peg should be substituted for the metal spike advocated by some surgeons which has an adverse influence upon osteogenesis while the autogenous peg stimulates callus formation in the fragments.

Sections from the fibula have been used as grafts into the femur by D'Arcis, Davison, Delbet (4 cases), Stuckey (2 cases), and Moskowitz (2 cases). It would seem wiser, however, to take the graft from the tibia since larger and stronger grafts can thereby be obtained.

Albee has made up the loss of the head and neck of the femur by implanting the excised astragalus.

Patella.—Bone grafting for fractures: Vulpius reports a case of fractured patella in which the upper fragment comprised three-fourths of the bone while the lower was comminuted. He formed a flap from the upper fragment, comprising periosteum and bone, turned this down and fastened it to the beginning of the ligamentum patellæ. Good result.

Rogers has likewise made a successful transplantation of bone in a fractured patella.

Habitual Dislocation of the Patella.—Albee reports a method of applying a bone wedge in habitual dislocation of patella as follows: A semilunar incision is made by Albee extending to the outer side of the patella, sufficiently long to reach below the tibial tubercle and to above the external condyle. Without unduly disturbing the underlying joint structures, the external condyle is incised with a broad, thin osteotome on its external surface, making a bone incision of from 1½ to 2 inches in length, and about ½ to ¾ inch below its anterior articulating surface, and nearly in line with the long axis of the femur. The bone incision allows the anterior surface of the external condyle to be raised to a plane above the internal condyle, by producing a green-stick fracture near the intercondylar groove, the object being to place a permanent and rigid obstacle in the way of the outward displacement of the patella. When the anterior segment of the external condyle has been pried forward sufficiently to demonstrate its obstructing effect, the width of the bone-gap thus formed is measured with calipers and a section of bone sufficiently large to fill this cuneiform gap is removed from the postero-internal surface of the tibia through the lower portion of the same skin wound extended below the tubercle. Before the graft is removed, it is drilled obliquely in one or two places so that it may be pinned to the under portion of the external condyle when put into place. Dowel pins, made from an additional portion of the bone removed from the tibia at the time the graft is obtained, are rounded to fit the drill holes in the graft.

Albee has devised an excellent procedure for the treatment of old ununited fractures of the patella with separation of the fragments. The fragments cannot be brought together, so the defect is spanned by a graft which is mortised into the upper and lower fragments as is shown in Fig. 349. The graft will hypertrophy and will fill in to a large degree the hiatus between the fragments.

The Use of the Bone-graft for Stiffening the Knee-joint in Infantile Paralysis and for Tuberculosis.—The following is Albee's description of this procedure: "Access to the knee-joint is through a U-shaped incision crossing the patellar ligament about one inch above its insertion. The patellar ligament, the lateral and the crucial ligaments are divided. With a narrow bladed bow saw the upper articular surface of the tibia is removed, cutting transversely so as to form a concave surface from before backward. With the same saw, the articular surfaces of the condyles of the femur are removed, forming a flat, convex surface from before backward. With the twin motor saw, two gutters are cut across the line of opposed femur and tibia, one gutter being made from the external condyle into the outer and anterior portion of the head of the tibia, while a second gutter is made of the same dimensions across from the internal condyle to the inner anterior surface of the head. The segments filling these gutters are cut across at the ends of the gutters with the small motor saw and are removed with the aid of a thin, narrow, sharp osteotome. The twin motor saw, adjusted to the same width as when forming the gutters, is used in cutting from the patella two strips which are used to span between the femur and tibia and fit tightly into the previously prepared gutters. Holes are drilled on either side of the gutters with the small motor drill, in which the femoral condyles and head of the tibia, and strong kangaroo tendon sutures are passed and tied over both ends of the two patellar grafts, holding them securely in position."

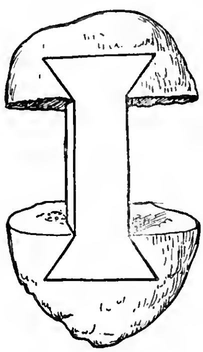


Fig. 349.—Dove-tailed inlay graft for ununited fracture of the patella, with unavoidable separation of the fragments. (Albee, Bone-graft Surgery.)

Tibia.—Probably the most frequent bone in the body requiring grafting operations is the tibia. Defects are either congenital or acquired being caused by the removal of tumors, or the effects of osteomyelitis or injuries. Before the trustworthiness of the free, autogenous bone graft was established, many modifications of pedunculated bone grafts have been described. On account of the added difficulty of operative technic together with the problematical blood supply being sufficient through the twisted pedicle, these methods are all now being replaced by free, autogenous bone grafts with their periosteum. Perhaps the fibula has been the bone most frequently employed in some form for these pedunculated grafts. Murphy spoke as follows regarding the use of the fibula as a graft into the tibia: "While the fibular transplant from the same leg into the tibia has given a considerable percentage of good results, failure of success is worse than mere failure, as it is disastrous to the limb, and this chance of disaster is entirely unnecessary, as a fragment with its periosteum representing the full length of the tibia from one epiphysis to the other and including the compact bony structure of the tibia can be transplanted from the healthy tibia into the defect of the patient's other tibia without in the least endangering the tibia from which it is removed, and with as great assurance of success as if the fibula were transplanted in the diseased leg. No evil effect has occurred in the tibia from which the transplant was removed in over 170 cases operated by Murphy personally."

A much more easy and just as efficacious a method is to transplant into the tibial defect a free bone graft with periosteum taken from the opposite tibia. It may be made just as long as is necessary to fill the gap. It is best to implant the graft into grooves cut into the sides of the fragments where it is fastened by sutures of catgut passed through drill holes in the sides of the furrows, or the ends of the graft may be inserted into the reamed-out medullary cavities of the fragments.

Transplantation of Fibula into Tibia.—Hahn first did this operation in 1884 and Huntington in 1905 as follows: Hahn's or Huntington's operation: This is suited to patients in whom there has been an extensive loss of tibia but the fibula remains intact. Through an appropriate incision (curved across the leg at the level of the upper fragment), expose the under surface of the upper fragment and vivify it. Cut the fibula off at this level and insert its end into the under surface of the tibial upper fragment where it is fixed. Six months later, a second operation is done. Expose and vivify the upper surface of the lower fragment of the tibia. Divide the fibula at about the same level and unite its lower to the fresh surface of the tibia. In some cases both operations have been done at one sitting. A graft increases in size according to the demands put upon it. This is seen in the case of the above transplanted fibula which evidently increased in size to that of the tibia.

Stone varied the technic somewhat in 1905. He inserted the upper end of the fibula into a mortise cut in the tibia. Six months later at a second operation the outer part of the lower end of the tibia and the lower end of the fibula were exposed through the same incision. The fibula was then split longitudinally for four inches. "Great care was taken to avoid separating the periosteum from either end of the bone At the lower end of the split made in the bone, the inner half was cut across transversely at the level of the upper part of the remaining lower epiphysis of the tibia. The inner half of the fibula was then sprung into its new position in the tibia where it was attached." The result was perfect.

Vicious Pott's Fractures.—Lewis offers a valuable suggestion in the use of a form of direct bone transplantation for the correction of vicious deformities associated with Pott's fracture. In his first case the eversion of the foot caused much pain and disturbance of function and the internal malleolus was much hypertrophied. The internal malleolus was divided at the line of fracture and dissected free. The fibula was resected, allowing overcorrection of the everted foot. Transplant into the fibula defect of a section of the tibia. The malleolus was then trimmed down to the desired size and nailed to the lower end of the tibia, the articular cartilage being preserved. The final result was good. There was no eversion of the foot. The second case was one in which the foot had evidently been dressed in extension, for the patient walked upon the toes and the foot could not be flexed dorsally, due apparently to outward displacement of the internal malleolus, as this part of the bone seemed to impinge upon the astragalus

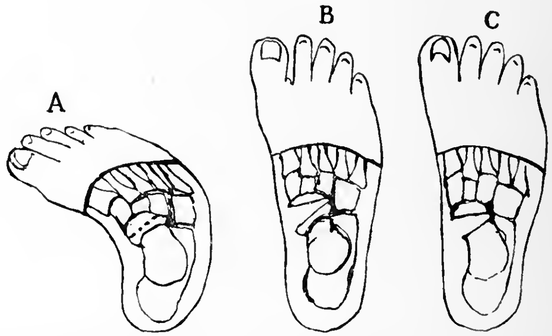


Fig. 350.—*A* is diagram showing the element of adduction deformity of a congenital club-foot. The dotted line indicates where the scaphoid is split. *C* shows the foot after osteotomy of the scaphoid and forcible correction of the adduction and varus deformity by the separation of the scaphoidal and a rotation, at that point, of the fore-foot on the posterior part of the foot. A wedge, cuboidal, or tibial graft may be used to fill this space, according to the severity of the deformity and hypertrophy of cuboid. *B* indicates the cartilage removed from the posterior surface of the scaphoid and the head of the astragalus in a case of acquired paralytic club-foot (talipes equinovarus) with hypermobility. A correction of the deformity causes a separation of these two cut bone surfaces. The cavity is filled by a wedge tibial graft.

when dorsal flexion was attempted. The internal malleolus was divided at the point of junction with the shaft, dissected free and removed, and preserved in salt solution. The foot could then be brought to a right-angled position and was inverted. The malleolus was then nailed in place. At the end of four months the patient walked normally and the function of the ankle-joint was almost normal.

Foot.—**Club-foot.**—Some cases resist all conservative methods of treatment such as tenotomy of the tendo Achillis to overcome equinus and forcible stretching followed by fixation in plaster of Paris or braces. Such cases are best treated by the method of Albee as follows (Fig. 350): The equinus is first corrected by tenotomizing the tendo Achillis. A U-shaped skin incision is made on the inner side of the foot and the flap with its subcutaneous tissue is dissected back, exposing the scaphoid bone. With a half inch, thin and sharp osteotome, the scaphoid is split into anterior and posterior halves. The foot is then forced into the required degree of overcorrection, and the gap between the halves is widened. All resistance by plantar fascia or other tissues is relieved by severing the structures with a scalpel through the wound already made. From the internal surface of the tibia a graft is cut of the required width and thickness, the two cuts converging toward each other as the medullary cavity is approached. Before being removed from the tibia, the graft is drilled with the small motor drill through the cortex for retaining the sutures and the graft is then removed from its bed with a small, sharp osteotome. The kangaroo tendon is then threaded through the drill holes of the graft wedge. With the graft in the center of the tendon strand, a strong, curved cervix needle is threaded on each end. These needles are thrust through the scaphoid edges from the cut surface side. The bone graft wedge is then forced into place between these scaphoid halves, the tendon is drawn tight and tied over the graft. The skin edges are then sutured and the foot is put up in a plaster-of-Paris splint in slight overcorrection with the knee included, flexed to a right angle.

Acquired club foot (paralytic equinovarus) due to infantile paralysis. In this the outer border of the foot drops, the foot adducts and the patient walks on the outer aspect of the foot. In this the equinus is overcome by the subcutaneous tenotomy of the tendo Achillis.

The astragaloscaphoid joint is reached by a U-shaped incision. The articulating surfaces of the head of the astragalus and scaphoid are removed with a narrow osteotome and mallet. The foot is overcorrected, producing a wedge-shaped cavity between the separated cut surfaces of the head of the astragalus and scaphoid. To overcome the dropping of the outer border of the foot due to the paralysis of the peroneal tendons, the external malleolus and tendons are exposed by a curved skin incision encircling the lower end of the malleolus. An osteoperiosteal flap with its overlying periosseous tissues is lifted from the external malleolus and turned posteriorly on the periosseous tissues as a hinge. The osseous incisions for forming this trap-door are easily made with the motor saw and further freeing of this flap is accomplished by a sharp osteotome. The peroneal tendon sheaths are split and the tendons are freed and placed under this osteoperiosteal trap-door. The foot is then forced into pronation and the peroneal tendons are drawn taut by reefing or suturing them securely to the periosseous tissues above this bone flap. The edges of this flap, as well as the adjacent cortex are drilled, the tendons fitted into the grooves, and the trap-door is closed over and held firmly in place by kangaroo tendon sutures passed through the drill holes and tied. The skin is closed. The outer border of the foot is thus held firmly elevated in an overcorrected position. In the wound on the inner border of the foot with the foot held in an overabducted position, measurement is taken of the resulting cavity between the head of the astragalus and the scaphoid. A corresponding graft is taken from the internal surface of the tibia by the method for congenital club-foot. The graft is drilled before its removal; after which the kangaroo tendon sutures are threaded through the drill holes, cervix needles are threaded upon each end and the needles are thrust through the head of the astragalus and the scaphoid at their inner borders from their cut surfaces. The bone graft wedge is then forced into place and the tendon suture is drawn taut and tied over the graft. The skin wound is closed and a plaster-of-Paris splint is applied over the knee which is flexed to a right angle.

The Future of the Epiphysis when Transplanted.—What the future of the epiphysis when transplanted will be, cannot as yet be accurately or positively stated. Not enough work has been done upon it as yet to determine whether the epiphysis will survive and functionate if it be transplanted or whether it will die. Jost goes into this unsettled question so far as it can at this time be discussed from the few data at hand.

The Transplantation of Joints.—In very rare instances the after-results of joint transplantations have been fair. Friedrich remarks that the number of poor results following joint transplantations has been "frightful (erschreckend)". In the vast majority of cases, the result has been the same as though a typical resection had been performed, *i. e.*, ankylosis. Space forbids a further discussion of this topic.

ADDENDUM.

Lately there have appeared many articles on bone grafting, which seems to be a procedure of greater and greater value. Many ingenious methods have been made, all depending upon the technical ingenuity of the operator. Only brief reference can be made to some of these measures. Albee[1] reports that in animals he has hastened consolidation in fractures by eleven days by injecting triple calcium phosphate. The method, he says, is now being tried out on human subjects with no reports as yet as to results.

Periosteal grafts with a sliver of bone as thin as cardboard, originated by Ollier, have been revived by Delageniere and also by Lemaitre. They have been used to fill in defects everywhere. The grafts are flexible, bend easily and can be applied on two sides of a defect, encircling it, periosteum being sutured to periosteum, or U-shaped as about the lower border of the jaw. These grafts are much simpler to apply than the ordinary grafts and the results are just as good, though the new bone takes longer to form than in the ordinary grafts. In four months there is 50 per cent. increase in the amount of new bone formed. At any time another graft of the same kind may be superimposed upon the first. This method because of its simplicity bids fair to find more

[1] Ann. Surg., January, 1920, p. 32.

and more favor among operators. There is none of the complicated dovetailing of grafts which the ordinary methods require. There is no doubt of the value of this method as there are many successful cases on record in France. It has proved particularly successful in jaw defects because the method does not require such dissections behind the jaw as are found necessary in the ordinary bone grafts, thus diminishing the danger of opening into the mouth with its certain infection and subsequent death of the graft. Davison[1] gives valuable points on the transplantation of bone in fractures of the head and neck of the femur. There are three types:

1. Recent fracture of the neck of the femur without impaction may be repaired by grafting a segment of fibula across the line of fracture.

2. Ununited fracture of the neck of the femur with diminished vitality of the capital fragment may be repaired by transplanting a segment of fibula across the non-union.

3. The head of the femur, destroyed by injury or disease, may be replaced and fair function reëstablished by transplantation of the head and upper part of the fibula into the upper end of the shaft of the femur in such a manner that the articular surface of the head of the fibula will articulate with the acetabulum. The part of the transplant which replaces the head and neck of the femur will hypertrophy until its size and strength are sufficient to meet the functional demands made upon the hip-joint in walking. For details see this excellent article:

Mauclaire[2] describes the technic of (1) total segmental grafts, (2) grafts "en plaques" as used by Codavilla, Albee, and others, (3) central intramedullary grafts, and (4) pediculated bone grafts.

In a paper presented by Mauclaire to the Société de Chirurgie in Paris he collected the reports of 128 cases of segmental grafts for war wounds. These were nearly all autografts and 72 were successful. In 24 of his own cases of segmental grafts Mauclaire obtained successful results in 8. These were cases of very extensive loss of substance or other difficult conditions.

Mauclaire believes that bone grafting as a surgical method is only in its infancy; that later on, the indications for different types of bone grafts will multiply and in the coming years surgeons will specialize in bone grafting.

Henderson[3] describes the use of beef-bone screws in fractures and bone transplantations. The summary of his views are these:

1. Beef-bone screws are a great aid in securing a firm fixation of the bone graft to the fragments in fractures, and of the graft of the spinous processes in the operation for fixation of the spine.

2. They are well tolerated by the bone and are gradually but completely absorbed.

3. Bone screws have not the strength of metal and must not be

[1] Surg., Gynec., Obst., August, 1919, p. 142.
[2] Presse Méd., 1919, xxvii, 212.
[3] Jour. Am. Med. Assn., March 13, 1920, p. 715.

expected to stand great stress. Careful provision must be made for postoperative fixation of the extremity.

4. Drills, taps and wrenches of the proper size are essential for the placing of beef-bone screws.

5. The bone graft as commonly used in the intramedullary and inlay methods is too small. Fracture of the graft rarely, if ever, occurs if the graft is large enough so that when the operation is completed there is from 20 to 25 per cent. more bone in the fracture area than there is normally.

Albee[1] reports the results of one hundred bone grafting operations in a valuable paper:

Final results in 48 cases. Too short a time has elapsed to pass judgment, at the present date, on the entire series of 100 cases of fracture. However, in 48 cases that were treated before March 1, 1919, and have, therefore, afforded opportunity for observation over a period of at least ten months, we feel justified in reporting definite conclusions.

Of these 48 cases, the results in 6 are questionable; the grafts are still *in situ* and the roentgen ray reveals bone growth, but the wounds were primarily infected and there yet remain one or more sinuses. Three of these questionable cases, however, show favorable indications of ultimate good results; the other 3 cases will probably be failures.

Four of the 48 cases are definite failures. Of these, 1 case, a sliding inlay from a tibia to a femur to stabilize a resected knee, was complicated by pneumonia five weeks after the operation; sinuses broke out on each side of the knee, with a resulting infection of the entire scar tissue of the knee and a failure of part of the graft to "take." Of 2 radius cases that were failures, 1 showed a positive Wassermann after, but not before, the operation, and the patient himself removed the fixation dressing on three different occasions. The other radius case showed a bad infection of dense scar tissue. The fourth, and last case of failure, was a humerus case with loss of three inches of substance, and with much scar tissue. The wound broke down, and examination by roentgen ray revealed that the lower end of the graft was not attached to the distal end of the humerus.

Subtracting this group of 10 cases, of which 4 are definite failures and 6 questionable cases, we have 38 cases remaining, all of which have shown perfect results in respect to postoperative primary healing of the wound, proliferation of new bone as demonstrated by the roentgen ray, and restoration of function. This yields a rate of 79 per cent. perfect results, with a possibility of an ultimate 85 per cent. should 3 of the questionable cases prove successful.

Albee has also formed a synthetic finger on a soldier's hand which had only a thumb upon the stump. This finger formed an opposing surface to the thumb thus enabling objects to be grasped. A rectangular flap of skin, made from the chest wall shaped like a finger, was sutured to the desired point in the hand. The pedicle was severed in

[1] Jour. Am. Med. Assn., February 28, 1920, p. 589.

four weeks. The boneless finger was tunnelled and a wedge-shaped opening was made in the bone at its base. Into this mortise was driven a bone graft taken from the shin. A sliver graft was placed beside the

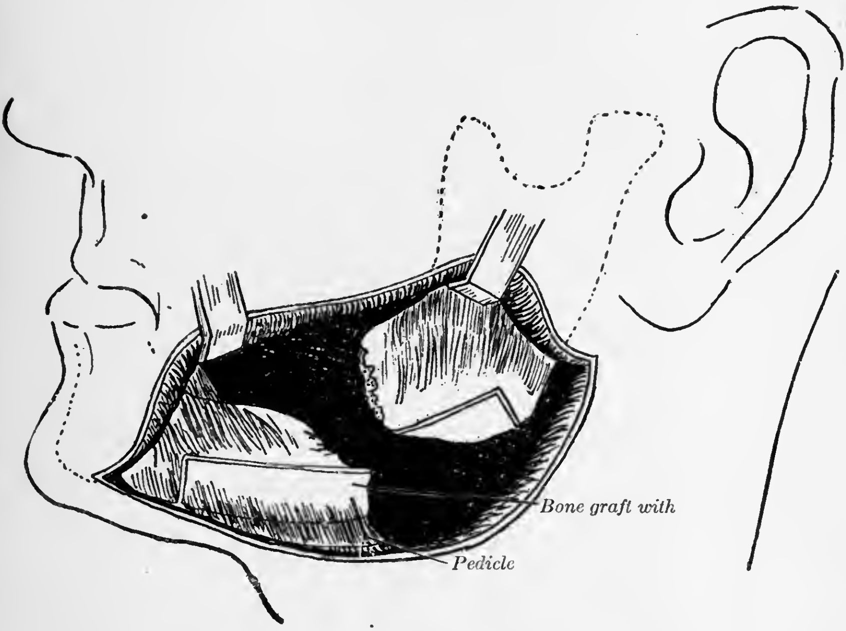


FIG. 351.—Pedicled bone-graft illustrating bone incisions.

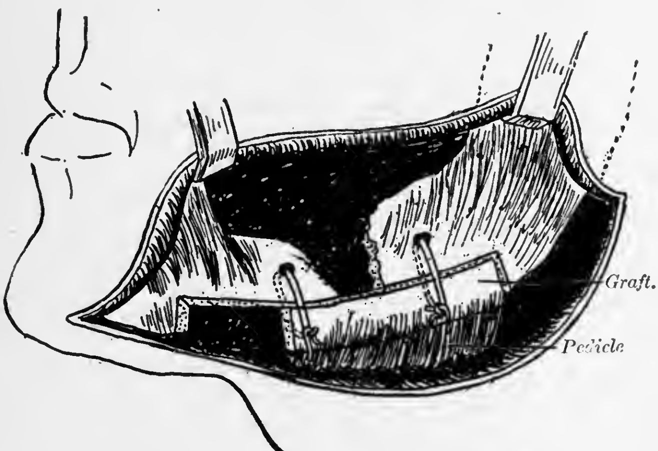
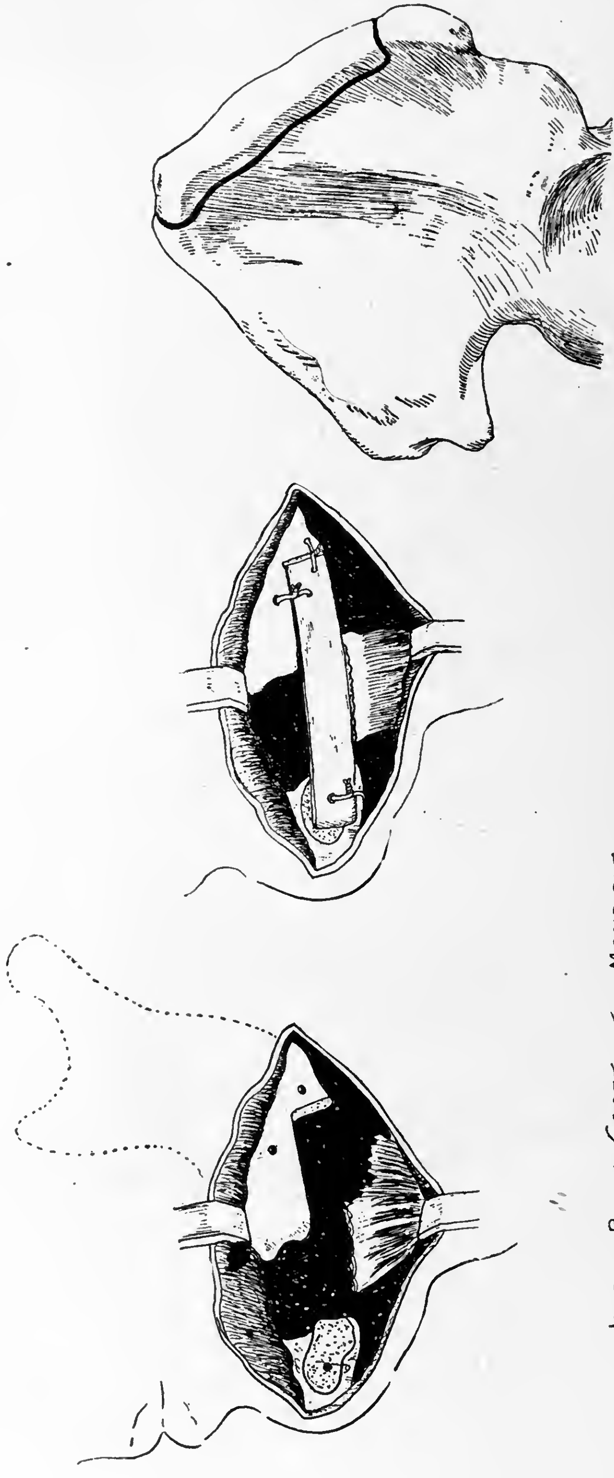


FIG. 352.—Illustrating position of sliding graft.

first graft to stimulate osteogenesis. Primary union resulted and the opposing surface was obtained from the thumb, thus obtaining many normal uses for the hand.



Portion of Bone Removed From Ilium.

Iliac Bone Graft to Mandible

Fig. 353

Captain Platt[1] has described a method of bone transplant which may still be considered under trial. It is an attempted reconstruction of the head of the humerus in order to obtain a fulcrum for scapular movement. He takes a large autogenous graft from the tibia, shaped like a wooden mallet. The shoulder-joint is exposed, the upper end of the humerus cleared, and the handle of the graft driven into the medul-

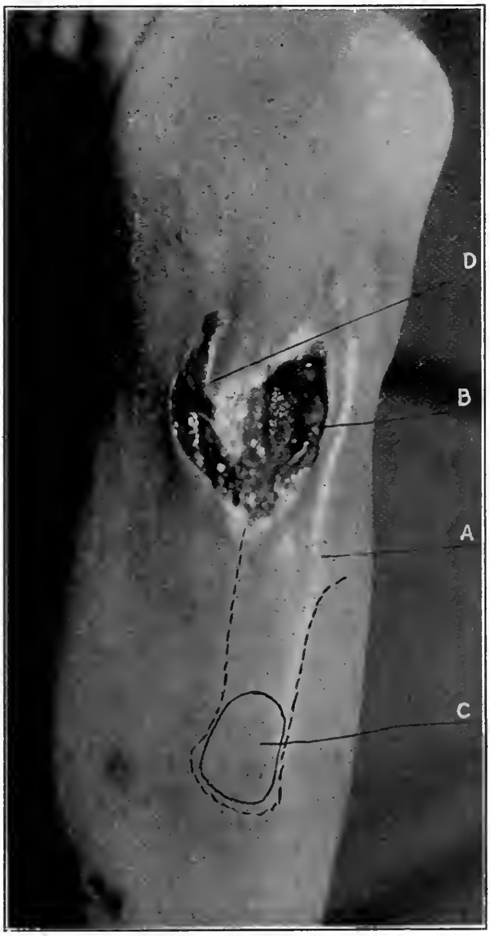


FIG. 354.—Osteomyelitic tibial cavity. *A*, pedicle; *B*, cavity in tibia; *C*, periosteum with attached osseous slivers attached to end of flap; *D*, cutaneous wound only.

lary cavity. The wide upper end is now brought into contact with the glenoid cavity, which has been completely bared as in an ordinary arthrodesis operation. On occasions he has used a long fascia lata sling carried through the upper end of the humerus, the upper margin

[1] British Med. Jour., February 7, 1920, p. 176.

the glenoid, and the acromion process. After completion of the operation the arm is placed in abduction until stability is secured.

The illustrations Figs. 351, 352, 355 are taken from an article by Lieut.-Commander L. W. Johnson, U. S. Navy, in the *United States Naval Medical Bulletin*, No. 1, vol. xiv, in a report of Queen's Hospital for Facial and Jaw Injuries, Frognal, Sidcup, Kent, England. In this article all the types of facial deformities occurring in the War are described and cuts given to illustrate the various measures devised to

Fig. 355.—Anteroposterior radiograph of Fig. 354. It shows a defect in the bone, measuring vertically 2¼ inches and transversely 1 inch. In the center there is an opening extending entirely through the tibia, the result of a bullet.

overcome the deformities. To anyone desiring to learn the technic of facial plastics, this report will be a mine of information. The Figs. 351, 352 and 353 show two methods of bone grafting applicable to filling bone defects in the lower jaw. Figs. 351 and 352 illustrate a sliding pedicled bone graft taken from one side of the defect moved over to fill the defect. Fig. 353 illustrates a free, autogenous graft taken from the ilium to fill in the jaw defect.

Mueller's operation of closing a cavity by a pedicled osseous-periosteal flap is illustrated in Fig. 354. It was the author's case of a British aviator who had had several accidents in plane and motorcycles. Osteomyelitis of left tibia resulted for which he had been operated upon fourteen times in various countries. Figs. 355 and 356 are radiograms of the resulting cavity after the author had scraped away some necrotic spicules of bone. There was an antero-posterior opening through the bone and laterally it could be seen that almost one-half the diameter of the bone was gone. At the time of the curetting cultures showed innumerable hemolytic streptococci. Carrel-Dakin treatment was

FIG. 356.—Transverse radiograph of Figs. 354 and 355. Roughly the tibia has suffered a loss of probably one-half its strength, none of which Nature could make up because of loss of periosteum. This made it desirable to add a pedicled graft (Müller) containing bone and periosteum, proliferation of which would fill the cavity with new bone.

instituted and was kept up for one month when five smears on successive days showed no bacteria present whatsoever. At the operation it was necessary to supply skin to close over the cavity as it was deemed impossible to bring the skin edges together even with the most extensive undermining of them that was possible. The cavity was oval, $2\frac{1}{4}$ inches vertically and 1 inch wide, and was covered with granulations throughout, and looked perfectly healthy with no dead bone. The Carrel-Dakin treatment has simplified the treatment of acute osteomyelitis, shortened its duration and diminished the amount of necrosis. In chronic osteomyelitis it is an invaluable aid in sterilizing the cavity. Preliminary to the operation a flap (Fig. 354) was outlined with silver nitrate on the skin on the inner side of the right tibia of such a sufficient length that it could be pedicled at *A* and turned about this pedicle so as to fill in the cavity. The lower extremity of the flap was modelled exactly of the shape of the cavity but one-third larger than it. At the operation the flap was cut as outlined in Fig. 354, through the skin, and a periosteal flap below was cut of a size to cover the cavity. Beneath this periosteal flap, a chisel was inserted and thin slivers of bone were chiselled from the tibia. These slivers were left attached to the periosteum which in turn was kept attached to the skin of the flap. In addition thin slivers of bone with small, free pieces of periosteum were chiselled from the surface of the tibia and placed in the bottom of the cavity. Then the flap of skin was rotated around its pedicle and its edges were sutured to the freshened edges of the cavity with silkworm-gut sutures. The skin on each side of the leg incision was mobilized half around the leg and its edges came together with some tension and they were held together by mattress sutures of silkworm gut. The cutaneous lateral raw area (*D*, Fig. 354) was covered in with a Thiersch graft, taken from the side of the leg. At the date of writing this (three weeks from the operation), all the grafts have taken nicely. There is primary union. It is confidently expected that the cavity will in the course of a few months become fully filled in with new bone.

Addendum (March 1, 1921).

I have tabulated the results of all the bone-grafting operations, classified according to the various methods, that I can find in the literature, combined with the results of individual operators, reported in answer to a questionnaire. As the result of such a study, some questions come up which I present for thoughtful consideration.

In general we may classify the methods of free bone-grafting as follows:

1. Bone Pegs.
2. Osteoperiosteal Method (Ollier, Codivilla, Delageniere).
3. End-to-End Method.
4. Inlay (Albee) Method.
5. Intramedullary (Murphy) Method.

In the following tables are given the results of the various methods. By success is meant the formation of a satisfactory amount of new bone.

TABLE I.

1. *Bone Pegs,* 24 cases, 23 successes, or 95.8 per cent.
    With periosteum, 8 cases, 100 per cent. of successes.
    Without periosteum, 16 cases, 93.8 per cent. of successes.
2. *Osteoperiosteal,* 426 cases, 372 successes, or 87.3 per cent.

3. *End-to-end,* 115 cases, 98 successes, or 85.2 per cent.
   With periosteum, 51, successes 39, or 76.4 per cent.
   Without periosteum, 64, successes 59, or 92.2 per cent.
4. *Inlays,* 439 cases, 367 successes, or 83.6 per cent.
   With periosteum, 393, successes 326, or 82.9 per cent.
   Without periosteum, 46, successes 41, or 89.1 per cent.
5. *Intramedullary,* 197 cases, successes 157, or 79.8 per cent.
   With periosteum, 133, successes 112, or 84.2 per cent.
   Without periosteum, 64, successes 45, or 70.3 per cent.

TABLE II.

COMBINED STATISTICS.

Total number of cases, 1201.
  Successes, 1017, or 84.6 per cent.
  Failures, 184, or 15.3 per cent.
With Periosteum, 1011.
  Successes, 857, or 84.7 per cent.
  Failures, 154, or 15.2 per cent.
Without Periosteum, 190.
  Successes, 160, or 84.2 per cent.
  Failures, 30, or 15.7 per cent.

From this table we see that the most successful method has been the peg driven through a tunnel. The peg is ordinarily without periosteum or endosteum (16 cases). Successes with this method were 95.8 per cent. The osteoperiosteal method (Ollier, Codivilla, Delageniere), *i. e.*, with a periosteal sheet to which is attached bone fragments of the thickness of a dime, was next most successful with 87.3 per cent. The end-to-end approximation method without inlaying or imbedding was next in successes with 85.2 per cent.; the Albee inlay next with 83.6 per cent., while the intramedullary (Murphy) was the last in the number of successes with 79.8 per cent.

It seems true that the adult bone cell in the interior of the bony transplant necessarily dies because of its being cut off from its nutrient supply—that it never proliferates a new bone cell, except *possibly* some of the few surviving cells on the surface of the bone of the graft to which blood can arrive. It has been raised as one objection to the electrically driven motor saw that the heat generated by it kills the bone cells. If the above statement is correct, that the bone cells always die, then the objection to the use of the motor saw falls away. The practical results of bone graftings show that there is little difference in the final success or failure of a bone graft whether it be made by a motor saw or by a chisel. Too much importance has been placed upon the bone cell as the necessary element in bone regeneration, and this error has obscured a right conception of the process. Bancroft says: "Bone is mesoblastic in origin, and in its repair we find that calcium salts are deposited on the intracellular elements of connective tissue forming new bone. The connective-tissue cell, then, by a process of metaplasia, becomes a bone cell. Periosteum is a connective tissue and hence is prone to form bone, but it is not the *only* connective tissue that has the function." Neuhoff has performed some interesting as well as surprising experiments on dogs. He transplanted fascia lata into defects made in the bladder, ureteral and stomach walls, to see how connective tissue would act when introduced into these localities. To his astonishment bone was formed in the fascial (*i. e.,* connective tissue) transplants in each of these three positions, that is, in a position where the transplants were each bathed in an acid fluid. That the acidity is not necessarily so much the determining factor in the new bone formation as the presence of connective tissue seems to be demonstrated by the formation of new bone in extra-skeletal tissues, such as in arteries, ovaries, kidneys, myositis ossifications, etc.

This transformation of connective tissue is theoretically an added reason for having periosteum and endosteum on transplants, yet practically when considering the results there is very little difference to be made out whether periosteum is on the transplant or not, as is shown in Table II. The successes in each are the same in proportion.

There is much about osteogenesis that we have to learn—that is, the physiology of the process. Why is it that sometimes a bone graft, which has remained in place without suppuration, will gradually melt away in the tissues, become gradually absorbed and its place not be taken by new bone? This is one of the most disappointing results of a well-conceived and well-carried out bone-grafting procedure that can happen, and it has occurred to all of us. It makes no difference what method is employed in grafting; it occurs in all methods, whether the periosteum is on the graft or not.

Suppuration.—Total number of cases, 1201. Among these suppuration occurred in 74 (6.1 per cent.). Of these, 23 succeeded (31 per cent.) and 51 failed (68 per cent.). Consequently, suppuration is the greatest factor causing failure. Walker[1] reports that "in 62 per cent. of 46 cases in the Army[2] which suppurated after graftings, the transplants were finally successful. Sufficient evidence has been secured to prove that bone-grafting is the most effectual method of treatment for non-union of fractures and very favorable results can be obtained in the largest percentage of cases." From the above statistics of 1201 free grafts, success was obtained in 84.6 per cent. of the cases.

[1] Annals of Surgery, January, 1921, p. 2.
[2] Surgeon-General's Statistics.

THE TREATMENT OF CUTANEOUS BURNS.

By EDWARD HAMMOND RISLEY, M.D., F.A.C.S.

There has existed for a long time a distinct need for a more definite effort to improve the treatment of patients suffering from the various degrees of cutaneous burns.

Present-day treatment both of the severe and of the less severe cases leaves much to be desired, both in the method of treatment and in end-results: represented by high mortality and disabling and deforming contractures.

This is a class of case of which every practitioner sees a certain number each year and about the treatment of which he knows very little, and of which every large hospital has from fifty to one hundred cases yearly in which results are obviously poor and in which very little real interest is taken either by the surgeon or the house officer in charge.

Mortality is very high, the period of disability is very long and avoidable contractures and deformity too common. From an economic point of view, to say nothing of suffering entailed, it is evident that these cases should have better treatment: represented by a keener appreciation of the importance of the subject, a more definite system of treatment of the case as a whole, and a greater attention to the minute details of the treatment of the burned area itself.

The subject is a broad one and success in treatment requires appreciation of the many phases of the problem: most important of which is the recognition at the onset that we have primarily a patient suffering from shock and later from toxic absorption to care for, and that the application of a dressing to this patient's burned area is of secondary importance in comparison. Failure to appreciate this fact has led to many deaths.

The burned case is always a tedious one to care for, the utmost patience and watchfulness is required. Lack of system in treatment, failure to appreciate the minute details of treatment of the burned area are reasons for prolonged confinement in bed and economic loss. Failure to appreciate that a large percentage of deformity is preventable through early and proper treatment of contractures, is further responsible for additional economic loss and often permanent disfigurement and disability.

Recent experience has demonstrated that much can be done for the apparently hopeless case. Many lives can be saved by proper care and attention to detail. The danger of sepsis and complications can practically be eliminated, contractures can largely be prevented and the period of disability can be greatly shortened if one follows certain well proved lines of treatment.

Exceptions must, of course, be made in differing individual cases, but the general plan of treatment outlined in the following pages should be productive of the best results.

CLASSIFICATION, DESCRIPTION AND PATHOLOGY OF BURNS.

The term burn is generally used to designate the lesion caused by the action of dry heat of about 140° F. and upward on the tissues. The term scald signifies the lesion produced by moist heat of 125° F. and upward. The lesions produced by moist and dry heats are so similar in character that separate description is not necessary.

Burns may be caused by dry heat, moist heat, chemicals (corrosives), electricity (including lightning) and by radio-active substance (radium and x-ray) and these latter have distinct peculiarities which are to some extent characteristic of the agent producing them and therefore need separate description.

The character of the lesion produced by any agent depends on the degree of temperature, the extent of area exposed and the length of time of the exposure. In general the extent of surface burned rather than the depth determines the seriousness of the injury. This rule, however, has exceptions as will be seen later.

In Europe Dupuytren's classification into 6 degrees is used but the simpler American classification into first, second and third degree is more practical and useful and is here employed.

1. **Burns of the First Degree.**—Burns of the first degree are those caused by the temporary action of heat of 125° to 140° F. Only the superficial layers of the skin are involved: the epidermis. There is erythema, slight swelling and a temporary sensation of smarting heat. The erythema persists for from three to twelve days and may or may not be followed by superficial desquamation. No scar, but often a faint blush, remains for some weeks or even months, especially when the part is brought later into contact with heat or cold. No constitutional symptoms supervene unless the burn be of considerable extent. In this case the patient may even be found in moderate shock, especially the very young or the old and feeble and a stuporous condition may last for several days. This is quite frequently seen after extensive sunburn of the back, legs and arms in those who go in bathing with scanty or no clothing.

The pathology of the first degree burn takes the following order: The initial action of the heat causes a dilatation of the superficial subcutaneous bloodvessels in and immediately around the affected area, clinically evidenced by the erythema. This is quickly followed by an exudation of serum and an infiltration of leukocytes which gives rise to the swelling. If not excessive this gradually subsides, giving rise to a wrinkled and later scaling, red surface. The processes of repair—because of only slight damage—are rapid, and, except for perhaps a persisting slight blush the tissues return to normal in a few hours or days.

2. **Burns of the Second Degree.**—Burns of the second degree are caused by a temperature of from 160° to 210° F. and involve all of the epidermis and down to the papillary layer of the corium and are characterized by the formation, in addition to the erythema, of blebs and bullæ of various sizes, depending on the rapidity of transudation of edema. These blebs or bullæ are the result of a rapid exudation due to greater heat and because of the serum being unable to escape by evaporation on the surface it collects in the meshes of the epidermis giving rise to the characteristic lesions. Such burns are at first very painful, depending on the degree of tenseness of the blebs and bullæ which at first contain a clear yellowish fluid which later becomes turbid. Should the bullæ break, a raw surface is left, bright red in color where the papillæ are exposed. This bleeds easily, is extremely tender to touch and painful when exposed to the air. The depth of the floor of the blister varies according to the position in the epidermis when it is formed and when superficial, on healing, leaves no scar, but if the papillæ are involved a slight scarring is sure to remain after healing, especially if any infection has supervened. Constitutional symptoms are practically always present in burns of this degree unless they be very small in area. Infection, which never supervenes in burns of the first degree, is very liable to develop in the second degree cases especially if the blebs or bullæ are carelessly handled or allowed to become of large size before being emptied. The longer they remain distended the greater the pressure on the tender underlying layers and the greater the destruction of this layer and hence the more likelihood of infection taking place in damaged tissue and therefore more scarring results. All blebs should therefore be incised near their bases as soon as they form, but the cover not removed, thus letting the cover down on the tender underlying layer and protecting it from trauma until nature forms over it, in a comparatively few hours, its protective coating of serum and fibrin.

In burns of the second degree primary shock and sepsis followed by severe contractures are always to be guarded against unless the injury is of a very limited extent. Toxic absorption is common.

3. **Burns of the Third Degree.**—These, under the American classification, dividing all burns into three degrees, include the injury produced to the deeper layers of the skin—the corium and the underlying structures: bloodvessels, nerves, muscle, fascia and even bone. The characteristic lesion of thermal injury to the whole depth of the skin is the "eschar" the brownish-black, leathery, non-sensitive (because of destruction of nerve endings) layers of dead skin, which is first closely adherent to underlying tissue, but which in the course of a few days begins to be separated around its edges by a suppurative inflammatory process which gradually spreads beneath the eschar and causes it to slough off in the course of twelve days to two weeks. Should the exposure to heat have been more intense or prolonged

definite charring or carbonization may take place. The charred skin is surrounded by a red inflammatory zone, the detection of which is of importance from a medico-legal point of view, as it only occurs in burns which have been received during life, those inflicted after death are more sharply outlined and have no surrounding red halo. Thrombosis of underlying bloodvessels may later give rise to dry gangrene and in the case of extremities amputation may have to be resorted to at a slightly later period.

On separation of an eschar a moist, raw granulating surface is left which begins to heal by the growth of new epidermis from the edges, or from small foci or "islands" of epidermis which have escaped injury. In this way epidermization spreads from one island to another and from the edges until the whole area is covered over with a fine film of granulation tissue.

Thus is seen the great importance of protection from any trauma of the fine granulations in the earliest stages of repair in all burned cases. The use of gauze is therefore contra-indicated because its removal uproots these delicate granulations and causes later a firmer, denser and more contracting scar. If medicated dressings are used they should be applied on soft linen or compress cloth and not on gauze.

Should the whole of the dermis have been destroyed granulation will take place only from the edges of the wound and the process of healing is therefore much slowed up. It is estimated that new growth occurs at the rate of about an inch a week.

When anything but saprophytic suppuration takes place healing is delayed much beyond this period. The ordinary pus organisms present in the inflammatory process in a burned area are mainly saprophytic and if the rules laid down in another part of this chapter are followed sepsis as such can be practically eliminated. In burns of the third degree, unless very limited, shock is always present and should be the primary consideration in treatment. In burns of both the second and third degree the secondary effects—toxic absorption, sepsis, contractures and complications such as gastro-intestinal disturbances and acute toxic nephritis—are to be watched for and guarded against.

During the stage of sloughing of the eschar or the later stages of bleb formation and rupture a mixed infection is always present. This, as has been stated, is largely of a saprophytic nature or of so mild a degree of virulence that it rarely takes on the characteristics of a serious infection. Streptococci, staphylococci, Bacillus fetidus, subtilis, proteus, and other saprophytes are to be found, and, consequently the bacterological charts (Carrel) show a very high count usually above 90, but this gradually becomes lower unless a real infection sets in. The wound is never bacteria-free though it can be made so with Carrel's technic and can be rendered practically sterile by other simpler methods described later.

It is evident therefore that a distinction should be made between burned areas which are clinically sterile and those which are really bacteriologically sterile. It is probable that all burns are both clinically and bacteriologically sterile at their inception, largely due to the action of heat on the skin surface, but they soon become infected either by contamination with dirty clothing or temporary dressings or later they become bacteriologically infected at some time during the course of healing. This low grade infection, however, does not seem to retard repair but is apparently a part of the physiology of repair and the thick, fetid creamy discharge that covers granulations exerts a beneficent rather than a harmful influence on the underlying granulations

It is only when the edges of the skin immediately surrounding the wound become invaded with bacteria and a real spreading infection of the erysipeloid or phlegmonous type occurs that there is real danger in the bacterial invasion. While such an invasion is not a common thing its occurrence should always be watched for and definite means taken to ward it off.

A late and rather rare after-effect is the development of malignant changes in the scar of an old burn. This is practically always of the epitheliomatous type and is much more likely to supervene in a scar which has been subjected to more or less constant irritation or friction. The well-known "Kangri cancer" of Kashmir is a typical example.

LITERATURE—EXPERIMENTAL WORK.

The literature on the subject of cutaneous burns has been notably lacking in any treatise of length or value until quite recently.[1] Numerous scattered articles, chiefly observations of individual cases, are all that are to be found. Text-book chapters are brief and much out of date, especially on treatment. The most valuable information to be obtained in regard to methods of treatment is found in the accounts of naval surgeons or men in charge of large collieries or oil works where large numbers of burned cases have been treated—often simultaneously.

For details of minute experimental work reference should be made to Pfeiffer's work which appears to be the only extensive research so far published on the pathology of thermal injury.

MacLeod's little clinical treatise on burns and their treatment excels even the modern text-books both in accuracy of description and the thoroughness with which the subject is covered. A valuable chapter on the cutaneous lesions or dermatitis caused by high explosives is of especial interest.

Experimental work on the effects of thermal injury has been very meager. Recent work, however, shows that changes are both local and systemic and are often of a complicated nature. A true toxemia is undoubtedly produced by severe or extensive burn. This is instanced by the fact that prompt removal of the burned area may be a life-saving measure in man as well as in animals and also the transplantation of a burned area on to an uninjured animal may produce death

[1] See bibliography under MacLeod—a clinical work—and Pfeiffer—a purely experimental work.

with the same toxic and urinary symptoms as if the burn had been originally inflicted on the recipient of the transplant.

The toxicity of the blood serum and the urine after thermal injury is clearly shown by injection into healthy animals and in animals after parabiosis. In these latter the injured animal dies quickly while the healthy mate dies later with the same symptoms unless severed early.

Marked changes are found in the blood as evidenced by injury to the erythrocytes resulting in heat hemolysis and hemoglobinuria, changes in blood viscosity and leukocytosis. These changes are direct, from the action of heat: indirect from the loss of plasma and from change in metabolism. The alkalinity of the blood is decreased and the fluidity after a slight transitory decrease, increases markedly until death, often resulting in a complete loss of the power of coagulation. The antiproteolytic serum reaction in severe burns shows a gradual increase in the products of proteid splitting progressing until death. These phenomena taken together with the clinically evidenced changes in blood-pressure, respiration, pulse-rate, and body temperature, all go together to paint a typical picture of a toxicosis from proteid destruction. This is an auto-intoxication which is analogous to anaphylactic shock and is due to the destruction of proteid bodies at the site of injury and their later absorption. Similar conditions may be found in peptone poisoning, hemolysin poisoning and uremia. When the burn is of slight degree and there is little destruction of tissue the kidneys are able to eliminate the toxic materials absorbed, but when the thermal injury is great an overproduction of toxic material results in the inability of the kidneys to properly eliminate these toxic products and death supervenes.

Clinically it is not difficult to follow the above outline of experimental work and to trace the development of the various stages of shock, septic absorption, toxemia and its effects on the circulation, blood picture and metabolism. The picture is a typical one and quickly recognized in all its details by the careful observer.

Even without the above experimental evidence it is possible to build up a definite rationale of treatment based alone on the clinical picture presented.

This has as its basis, first the treatment of the patient himself or his shocked condition: next detailed attention to the burned area and closely coupled with this, definite efforts to produce an elimination of the toxic products and to assist the process of metabolism so greatly handicapped by the trauma and destruction produced by the local injury.

The following pages aid to establish a rationale of treatment based on the foregoing evidence which may be readily understood and easily followed. No hard and fast rule can, of course, be laid down which will apply to every case, but with a few minor exceptions a general plan of treatment can be followed, based on experience, which will in the majority of cases lead to a favorable outcome with a minimum amount of suffering and disability.

THE PROBLEM OF THE TREATMENT OF THE BURNED CASE.

The effects of thermal injury are primary and secondary.

Practically the only primary effect is shock. Immediate secondary effects are toxemia, closely following on shock, and due to the absorption of broken down proteid material. This may be later followed by sepsis or other complications such as toxic nephritis or severe gastro-intestinal symptoms simulating duodenal ulceration.

Later secondary effects are those relating solely to the burned area itself and are evidenced by contractures of scar tissue and their results, deformity and disability.

The problem of the treatment of the burned patient is a broad and complicated one and divides itself, as follows:

1. The treatment of shock, when present.

2. The selection of the best form of treatment for the burned area, which subdivides itself into:

(*a*) The kind of first dressing to use.

(*b*) The prevention of sepsis.

3. The prevention and treatment of complications, especially those dependent on the toxemia: represented by acute toxic nephritis and possible duodenal ulceration:

4. The prevention and treatment of contractures.

5. The question of prognosis: The first two problems or phases of the problem are of greatest importance and should receive prompt and detailed attention, as each has its important separate bearing on the whole end-result.

The Treatment or Prevention of Shock.—This is absolutely the first consideration and has been noticeably neglected in the past. Lack of appreciation of the fact that it is the burned patient and not the kind of dressing which should receive our first attention has been responsible for many deaths from shock which could have been prevented by the exercise of caution and better judgment of the needs of the case. Our first thought should not be to get the patient's clothes off and get a dressing on (which, however, is generally the first thought on seeing any burned case) but it should be "How much is this patient in shock and how can it best be combated?" If we invariably follow this line of thought and procedure we will soon find that we have already lowered our primary mortality in this very fatal type of case.

No attempt should be made to move the patient until he has been relieved of his suffering by a good generous dose of morphin. If he is in marked shock he should be treated by methods best known to combat it, especially by the use of subpectoral salt infusion, and rectal shock enemata. Meanwhile exposed areas should be lightly covered with a warm blanket to prevent chilling; for the severely burned case in shock is always cold. If the patient received benefit from this treatment within a half hour, one of three courses is open to us.

The most effective means of overcoming shock consists in the transfusion of 400 to 800 c.c. of whole blood soon after the injury has occurred.—(Ed.)

(*A*) The clothing may be carefully cut away from the whole body and the patient placed exposed to the air, with the temperature of the room elevated to about 110° by open fire or other means: the open air treatment, or

(*B*) He may be treated with some form of medicated dressing.

1. He may be swathed with compress cloth saturated with a solution of from 1 to 5 per cent. picric acid. This dressing is best applied in sections and held lightly in place by roller bandage. If put on in sections it can be removed piecemeal and thus add less to the patient's later discomfort or shock. This first dressing may be left on for forty-eight hours before being disturbed at all.

2. The burned area if limited in area (hand, fingers, toes, etc.) may be painted with tincture of chloride of iron and left without dressing.

3. The more modern paraffin-film dressing may be used.

(The relative values and results of these forms of treatment will be discussed later.)

(*C*) Should the patient not recover rapidly from his shock he should be immediately immersed in a continuous hot (90° to 100°) saline or boric acid solution bath. The clothing should be cut away *after* the patient has been immersed and not previously. For in cases of severe burn the shock caused by the first dressing is always a serious consideration and may be fatal. This is substantiated by many case histories in hospital records in which profound shock and death followed the first attempt at dressing. For instance, there have been many cases which are brought to the hospital in moderate shock who recover somewhat while resting on the shock table but who after the agony of removal of clothing, or the application of the first dressing die an hour or so later with distinct signs of recurrent or delayed shock. This detail of treatment has often been overlooked and has been the actual cause of many possibly avoidable deaths. Therefore, the longer we can postpone the first dressing the better it will be for the patient, to whom every hour is of advantage in recovering from his primary shock.

After clothing has been removed, and this is greatly facilitated by the water, and clean water added, the patient is suspended in the bath by means of a sheet hung on a frame with a pillow rest for the head. A slit, like that in the ordinary laboratory sheet, will allow of the use of the bed pan after drawing off the water temporarily. During this whole procedure the room should be kept superheated and a blanket spread over the tub to prevent evaporation, care being taken to allow some ventilation in order not to produce the effect of a turkish bath.

Regardless of time, the patient should be kept in this bath until he has fully recovered from this shock and he should be reimmersed immediately should he on removal show signs of recurring shock.

While in this bath it will be found necessary to keep the patient well under the soothing influence of morphin in order to ensure quiet and freedom from restlessness which in turn result in less difficulty in controlling the patient.

During the first four or five days of practically any form of treatment of the extremely burned case sufficient morphin to keep the patient comfortable and quiet is essential to success.

The salt solution bath is of great benefit not only to the patient's general condition but it also furnishes nutrition to the devitalized cells that cannot be reached by the blood current now shut off by the thrombosis, produced by the heat of the burn, which occludes much of the superficial capillary circulation. It is essential to save the life of every cell, especially epithelial cells, which later are the regenerations of true skin. This bath has been found of great—even life-saving—value in the later or granulating stage of extensive burns when dressing cannot be borne and the patient is in an exhausted condition, this is especially true of children. The lives of many children or even older patients worn out by the long continued dressings of a deep, sluggishly granulating area such as often occurs on the chest or abdomen and which is arge in extent, have been saved by a twenty-four to forty-eight-hour immersion in the continuous bath. Cases in which skin grafts have failed previously are so much improved in general condition and so much vitality is added to the sluggish area, that grafts will immediately take and the area gradually close in. This has been a fairly common and most encouraging experience in many cases after weeks of discouragement and failure to gain under any other form of treatment. Such treatment is to be highly recommended.

The prime consideration therefore is the prevention and treatment of shock. This is done by minimizing as much as possible the trauma of the first dressing, by warmth, by plenty of morphin, by flooding the system with fluids (by mouth, by rectum, and perhaps by the saline bath) and by the use of medicinal stimulation if necessary. This is one's first duty and is a thing which has not secured the careful, detailed attention in the past that it should receive. The burned case suffers shock which is both psychic and physical. If one hastens to get some sort of dressing on to his local injury instead of first treating his psychic shock by the beneficent influence of morphin and his physical shock by this and other well recognized means, one misses the whole point in the solution of this problem and adds greatly to his already devitalized condition and increases his chance of death rather than of recovery. Too much stress cannot be laid on this very vital but often lightly considered part of the problem of the care of burned cases.

THE SELECTION OF THE BEST FORM OF DRESSING FOR THE BURNED AREA.

As shock and toxemia are for all practical considerations the only causes of early death let us turn to the second phase of our problem: the selection of the best form of local treatment which is so closely related to the problem of the prevention of sepsis.

In a series of 216 hospital cases in which the kind of first dressings were stated the following were used: Boric ointment, 196 cases; carron oil, 25 cases; ink, 2; picric acid, 1; soda bicarbonate, 1; zinc oxide, 1. This shows the strong tendency to follow a blind routine of treatment in spite of a 25 per cent. mortality and an average stay in the hospital of over three weeks.

Experience teaches that one should never use oily dressings. There is nothing in favor of an oily preparation except that it produces a fairly painless first dressing. The objection is that it is not as a rule sterile and favors the growth of bacteria, it does not absorb the discharges arising from the burned area but keeps them in contact with the wound, causing maceration, and it must be changed every twenty-four hours.

As opposed to oily dressings lotions are advocated and the one most favored by men with a large experience in the treatment of burns is picric acid in 1 to 5 per cent. solution. In favor of such a dressing are the following points: It can be sterilized. The discharges are absorbed by the dressing. The growth of bacteria is prevented which lessens the subsequent danger of constitutional symptoms. The first dressing can be left on at least forty-eight hours, thus giving the patient a chance to recover well from his shock before a second dressing is applied. The dressing is clean, is, in light of recent experience in war surgery, as powerful an antiseptic as iodine, is healing *per se* and above all acts as an analgesic. Poisoning is *not* a common complication, when the weaker strengths are used. It is stated by those who have used it on many cases, that should the urine become dark in color, showing absorption of the drug, the free use of salts to produce watery stools and the generous use of water internally will overcome this tendency. Most authors consider this danger of poisoning a negligible one and the advantages of this dressing to far outweigh any possible danger of absorption. This dressing is used from two to seven days, being changed every twenty-four to forty-eight hours as the case will permit and then either open air or salt solution compresses, or some soothing or stimulating ointment applied when the danger of sepsis seems passed.

Efforts should be made, possibly at the first or one of the early picric acid dressings to cleanse and sterilize the skin immediately surrounding the burned area—but not the burned area itself. Daily cleansing with alcohol will generally do much to prevent septic material from contaminating the wound or invading the surrounding skin.

Thus, if we treat our patient in such a way as to minimize primary shock, apply a dressing which relieves pain, and is in itself antiseptic, and prevent sepsis as far as we are able, by means which will not harm already devitalized tissue, we are well on the road to a higher percentage of recoveries and have our patient in a better condition in which to deal with contractures and perform early skin grafting, thereby shortening the convalescence to a noticeable degree.

Experience with the picric acid and the open-air methods tried side by side on a large number of cases places one in a position to positively state that the open-air treatment for extensive burns is vastly superior to any treatment in which any kind of dressing is used. Cases so treated recover more quickly from shock, suffer less pain, and get a better start than cases receiving *any* kind of dressing. The case that is not traumatized by any form of dressing, and whose pain is relieved by morphin, is much more likely to recover than the ones less carefully handled. Avoidance of trauma of any kind to the severely burned case is of vastly more importance than the application of any kind of dressing.

Experience also shows that picric acid is by all means a superior dressing to any of the oily substances. The author has seen no symptoms of poisoning in a large series of cases. In first degree burns it leaves a clean, dry and probably sterile surface and relieves pain very quickly. In second degree cases it has proved a splendid dressing, leaving in a few days a dry surface, all discharge being absorbed through the dressing, and an area which practically never becomes septic and heals quickly. Experience with it in third degree burns would lead us to favor it, provided the burn was of not too large an area.

Another drug of distinct value is the tincture of chlorid of iron which has been successfully used in a considerable series of cases. This drug is applicable to superficial burns of rather limited extent and the method has the advantage that no dressing is required, but a light bandage may be used if desired, simply as a protection. The method of application is as follows: The tincture is sopped on over the burned area every hour until the affected area is well coated over and a dry protective layer is formed. The application of the drug in most cases of more than first degree burns is painful at the very onset, but a state of analgesia very quickly supervenes, and after the first application patients never complain again but speak enthusiastically of the comfort and freedom from pain. The area is best left uncovered as a thorough drying is what is desired.

Under this treatment the area dries up more quickly than with picric acid, there is no tendency toward sepsis, and healing takes place apparently with considerably greater rapidity than with other forms of dressing, because a dry, clean area has been obtained instead of the usual moist, warm, foul one produced when oily dressings are applied. This treatment is of distinct value, especially on the genitals, and worthy of more extended use. The rationale of this treatment is, of course, based on the astringent action of the chlorid of iron and the antiseptic action of the alcohol in the tincture and the definite analgesic properties which are quite marked.[1] Its use should probably be confined to burns of very limited extent.

Thus we have, after recovery from shock, three distinct well-proved and valuable forms of dressings to apply to the burned area. To these should be added the modern paraffin-film method, extensively used in the recent war, and described in the following pages. Our selection

[1] This treatment was suggested in a personal communication from Dr. Henry R. Slack, of La Grange, Ga., who has used it with success for a number of years and whose results have been published in the southern medical journals.

should depend on two factors, (*a*) type of case, and (*b*) availability of material.

Probably no definite rules should be laid down, but experience teaches that cases can be grouped about as follows: In all extensive burns, of any degree, use open air or continuous bath. In second degree burns of limited area on the body, or for extremities, use picric acid. In superficial burns of rather limited extent—except on face—use tincture of chlorid of iron and do not apply a dressing unless necessary for protection against clothing. Or for all burns, except extensive ones, and especially for burns of the face, the paraffin film may be used with advantage. If oily substances, such as boric ointment and carron oil are avoided and one of the above methods used, results will be uniformly good.

These statements apply to the cases which one can control in hospital practice. Resort can be had to the use of any of the household remedies, such as cold cream, olive oil, carron oil, etc., as temporary dressings to be used to soothe pain until the physician arrives. But these dressings should not be continued.

It is believed, however, that first aid instruction by Red Cross and other teachers should emphasize the advantages of the ordinary salt solution compress as a most valuable one for a first dressing for any type of burn. This can practically always be made available and is as clean and desirable a dressing for first aid work as can be wished. Its value is far from being appreciated by most physicians. If used as a first dressing it leaves the burned area in a proper condition to treat with any of the approved methods which the physician shall later select as most desirable. It has slight analgesic properties.

We would emphasize the importance of the teaching (1) that when first aid to the burned is contemplated at home no dressing at all should be applied to the severely or extensively burned case, but that the patient should be covered up warmly, that paregoric may be given to soothe pain and that such a patient needs hospital treatment and therefore means to transfer the patient to a proper institution should be quickly provided. (2) that all but the very extensive burns may be dressed safely and comfortably with salt solution compresses until a physician can be secured and that this is a far better dressing—especially from the point of view of future treatment—than any of the oily dressings so commonly in use at present and is just as analgesic after it is applied. (3) if a physician cannot be secured or a hospital reached within a few hours the severely burned case may often be saved by immersion in a continuous hot salt solution bath. (Temperature 110° F.)

Avoidance of trauma to any burned area is one of the most important considerations in the treatment of every case no matter what its extent or degree.

The Prevention of Sepsis.—This depends fundamentally on the kind of first dressing used. Burned areas are presumably at first sterile due to the action of the heat, but they are immediately contaminated by the first covering of dirty clothing or possibly by the first oily dressing. There should be no sepsis in cases treated by either open air, picric acid, tincture of chloride of iron or paraffin film. In the first method the skin surrounding the burned area should be washed twice a day with alcohol, thus keeping the surrounding field as free from bacteria as possible. As soon as the area has crusted over, and seropurulent material collects and escapes from underneath the eschar it is incised or raised in order to allow of the free drainage of this material and the cleansing of the skin is continued. Within about six to ten days or less, warm salt solution compresses should be applied to small portions of the crusted area and after forty-eight hours the crust is removed from this area, leaving a clean raw surface, which, under the soothing influence of the compresses soon begins to granulate. The whole area should never be covered at one time with the compresses, nor rubber tissue used as a protective, for an immediate absorption of necrotic material and toxemia with rise of temperature results.

In the second method, the picric acid (which is a sterile dressing, and absorbs any serum collecting when applied on compress cloth) produces in a few hours a dry, sterile surface which may later (after forty-eight hours to four days) be treated either by open air (if extensive) or by salt solution compresses if the area is not satisfactorily clean, or by a continuance of the picric acid until healed.

If the third, or tincture of chlorid of iron method is used no dressing is applied, because this treatment is to be used only on first or slight second degree burns. Cleansing of the surrounding skin is practised here as in the open-air and picric-acid methods. The same technic is employed when the paraffin film is used.

It can be positively stated, therefore, that sepsis can be prevented in any of these methods by the repeated cleansing of the surrounding skin and avoidance of oily dressings at the onset.

Particular stress must be laid on the early and painstaking and frequent pricking of the blebs, the incising of large crusted areas, and the elevation of the eschar to effect constant and proper drainage. (By this is not meant only the pricking of the primary bleb that forms in the first twenty-four hours, but also the ones that begin to form after two to three days). To do this successfully a special nurse should be employed and if done carefully and gently very little discomfort is caused, toxic material is thus constantly drained off, the temperature is kept lowered and sepsis is much less likely to ensue. This must be done almost continuously to be successful and requires great patience and diligence, but the results obtained are worth all the extra labor expended.

The routine treatment of a severely burned case under open-air treatment should be carried out according to the following plan: The patient should be covered up warmly, given morphin enough to make him comfortable and salt solution by rectum and possibly hypodermically. If in a hospital the patient should be left on the shock table until fully recovered from shock before being moved to the previously prepared private room. This room should be a small one with open fireplace heated to, and kept at, 100° to 110° F. The bed should be covered with a sterile sheet over which is sprinkled fine sterile boric or stearate of zinc powder. When ready, the patient, whose clothes have previously, while on the shock table, been cut from the entire body, is placed naked on the bed, being protected from possible draughts from the door or window by properly placed screens. The morphin, forcing of fluids, and dram doses of soda bicarbonate are continued at stated intervals for the first three or four days. As they form all blebs are pricked near their bases and three times a day the skin immediately surrounding the burned area is cleansed with alcohol.

As the crusts form and sero-pus collects underneath, the edges of the crusts are elevated or the tough eschar incised, so as to allow of as free drainage as possible, and salt solution compresses are applied to portions of the burned area. The whole area should not be covered with one large compress as the removal of this large dressing, which must be done three times a day, is unnecessarily painful. Only small areas should be covered at a time or the compresses put on in sections so that only a small portion is disturbed at a time. In this way the whole area is gradually cleaned up with a minimum of trauma and pain. This combination of open air and salt solution is an excellent one and after three to six days the whole area should present a clean raw granulating surface which can be treated (*a*) by pin-point grafting if it does not seem advisable yet to subject the patient to so severe a procedure as Thiersch grafting (and many patients with large burned areas would not stand further removal of skin from any part of the body) or (*b*) by a continuance of the compresses so long as healing continues to take place at the edges of the wound or epidermization is going on satisfactorily in any part of the burned area.

The technic of treatment with picric acid is as follows: A warmed 1 per cent. solution is used. Smooth sterile compress cloth rather than gauze, which causes too much trauma to the tender granulations, is saturated with the solution and put on in sections with roller bandages, so that small areas may be changed at a time, the skin surrounding the burned area having previously been cleaned with alcohol and all blebs pricked near their bases. This treatment is particularly suitable for extremities and the first dressing may be safely left on for forty-eight hours before being changed.

General treatment with morphin, forced fluids etc., should be given as in the case treated by open air. By the end of forty-eight hours all first and second degree areas will be found dry and clean and the discharge largely absorbed by the dressing from the deeper areas. These dressings should be continued for the next three to seven days, sections of the dressing being changed every twenty-four hours, the object being to use this dressing until the danger of sepsis is over and until the greater part of the serous discharge has ceased. Resort may later be had to salt solution compresses to larger crusted areas or in absence of these the picric acid may be continued until the area is entirely healed, making the dressing smaller each day as healing progresses. With picric acid as with other methods great attention should be paid to the establishment of proper drainage of all retained discharges forming under crusts or eschar.

Tincture of chlorid of iron is an analgesic, astringent, antiseptic application which like picric acid produces a dry, clean, sterile area very readily. It should be applied only to small areas: preferably first and mild second degree burns of cheek, ears, fingers, toes and genitals. This drug is sopped on the burned area every half hour until a dried, coated-over surface is produced and no dressing is applied. After this one or two applications a day will suffice until the area is healed. Treatment with paraffin-film preparations is described more fully in the following section.

The Paraffin-film Treatment of Burns.—In the early months of 1917 there appeared in the lay press certain very glowing and enthusiastic accounts of a wonderful new French preparation for the treatment of burns. So enthusiastic were these reports that one was led to suppose that even bone, muscle and all other injured tissues regenerated under the healing influence of this preparation.

A few men going to Europe to do war surgery brought back scattered conversational reports as to its use, but all attempts to learn of the actual constituents of this preparation were met by evasive answers and hence "Hyperthermine" or "Ambrine," as the French compound is called, failed to be placed on a strictly ethical basis and much skepticism as to its real value resulted.

The facts in regard to Ambrine are in brief as follows: As far back as 1864 Lawson Tait used paraffin as a spray on burns and in 1896 Prof. Peters of Toronto reported on some clinical and experimental work along this line. Since then, however, paraffin as a substance with which to treat burns has not been in general use.

The first report of its use in the present war was made by Le Docteur Barth de Sanfort before the French Académie de Médecine in 1915; its application, especially in the gas burns of the face, was described and also its use as a dressing in such conditions as frost-bite, neuritis, varicose ulcer, phlebitis, neuralgia, rheumatism gout, etc., but its preparation and composition was not revealed and no detailed accounts as to its use and the reasons for its superiority over other preparations have since appeared in the foreign medical journals. A few scattered abstracts have been published in the *British Medical Journal* from time to time, but these added nothing to the lay reports.

In order that the approximate composition of ambrine could be determined and suitable substitutes prepared, samples of the original preparation have been obtained from the French representatives in America and careful analyses made. These show this to be a paraffin preparation with a melting-point of about 124° F. Specific gravity at 60° F. = 0.908. Its acid value (1.12) and its saponic value (5.62) are low. From various analyses by different chemists the essential constituents are about as follows:

Paraffin (melting-point, 124° F.)	about 96.0	per cent.
Fatty oil (sesame ?)	" 1.5	"
Asphalt-like body (resin ?)	" 0.5	"
Beeswax (Japan)	" 1.0	"
Coloring matter and undetermined	" 1.0	"
	100.0	"

It is dispensed in flat oblong cakes which have a peculiar gray-brown hue.

As would be expected, the American market was soon well supplied with substitutes and profusely illustrated advertisements appeared in the medical journals. Among the most prominent of these is "Parresine" (non-secret) which is composed of paraffin, 94 to 96 per cent.; gum elemi, 0.20 to 0.25 per cent.; Japan wax, 0.40 to 0.50 per cent.; asphalt, 0.20 to 0.25 per cent.; eucalyptol, 2 per cent., colored with anilin and gentian violet, and "Muline" (secret), which contains paraffin, beeswax, a fat-soluble red dye and considerable resin.

It is obviously undesirable in determining the value of such a new form of treatment to have in use a host of preparations of different and unknown composition. It is already evident that the value of this method depends on the mechanical and not the secret chemical properties of the preparation; hence, all coloring matter, deodorants, antiseptics, etc., can and should be omitted in preparing a suitable formula. Simplicity is what is most desired. The essential requirements of paraffin for surgical dressings are that it should be solid at body temperature, at the same time having flexibility and adhesiveness, together with a certain amount of strength. These desirable qualities can be obtained in a simple combination of

Paraffin (melting-point of about 130° F.)	95.0	per cent.
Japan beeswax	5.0	"

or of

Paraffin (white wax)	250	by weight
Oil resini	20	"
Resin	5	"

This latter is a little more pliable and adhesive than the former combination but the results obtained by both seem to be equally good.

Many writers have given us recently many and varied formulæ but their clinical use has shown that the simple preparations, which any physician can put together in his own office, are more desirable to use and give results just as good as the more complicated preparations. The simpler ones are also more desirable because of the difficulty in comparing results in known and unknown preparations; and only by comparison of results in known compositions can improvements be intelligently made. If only a good grade of paraffin such as used on floors, or in sealing fruit jars, could be obtained to treat an emergency burn it would probably prove as efficient as any of the above suggested combinations. The mechanical properties of the paraffin are the essential thing.

The method of application of a paraffin-film dressing is as follows:

The burned area is cleaned up very gently as far as possible by removing dead skin and traces of previous medication and all blebs pricked near their bases, but the cover not removed. The surrounding skin is cleaned thoroughly with alcohol and the part allowed to dry as much as possible, or drying is hastened by the use of any convenient warm-air blower. Meanwhile the paraffin preparation has been heated on a water-bath—or in a white enamel basin by the ordinary spirit lamp, or over an electric toaster (the round flat variety) to about 130° F. The heat can be tested by the ordinary bath thermometer (removed from its wooden case) or, as one will find from experience the right temperature (130° F.) can be judged fairly accurately by applying a small dot of the paraffin to the inside of one's own elbow. When not too hot for comfort here it can be borne by the patient and is at about the right degree of heat. The melted paraffin is then painted or sprayed quickly over the burned area and for about two inches over the surrounding healthy skin. Theoretically the spray is the better method of application as it does not injure the delicate granulations forming and the paraffin by this means can be blown into and fills up every minute depression of the injured surface. But, practically, the quick and gentle application with a flat camel's hair brush about $1\frac{1}{2}$ inches wide does not further harm the injured tissue and is a much less complicated method of applying the film. If applied gently and rapidly at this heat a thin smooth film is formed over the burned area which makes a firm, air-tight dressing.

The discomfort of the first application can largely be avoided by the refinement of technic which consists in first spraying the burned surface with liquid petrolatum before the application of the heated paraffin. In certain first degree burns no second application need at the time be made, but in the majority of cases, especially when it is desired to apply a more firm and snugly fitting dressing, a piece of sheet wadding, a little larger than the burned area, is peeled apart so that a very thin layer only is left and this is laid over the area and a second coat of the paraffin painted quickly over this. The part—if an extremity—is placed on a splint to immobilize and prevent cracking of the paraffin film, or it may—in other regions—be further covered with a bandage to hold the dressing securely in place. This dressing *must,* for the first four or five days, be changed every twenty-four hours. Generally enough serum or discharge collects to "float the film to some extent. It lifts off easily after being slit down its center and practically always comes off intact, as it practically never sticks to the burned part. The area is now washed gently with warm boric solution, dried with a blower and the preparation reapplied as before, repeating at first every twenty-four hours and later as healing and drying take place every forty-eight hours until the area is entirely healed.

The rather glowing lay reports have described this dressing as absolutely painless, producing extremely rapid healing and leaving no noticeable scar even in extremely badly burned cases.

Clinical experience with paraffin dressing in civil practice in America gives us the exact truth in regard to these points. The application of melted paraffin at 130° F. to as sensitive an area as a burn, would seem at first thought to be a means of torture. It, however, cannot be said to be more than momentarily painful. A rather uncomfortable sense of extreme heat is produced at the very first moment of application, but the very minute the first coating is on, this sensation quickly subsides and gives place to one of a rather soothing comfort. There is a slight feeling of constriction or adhesiveness for the first few hours after the dressing is first applied, but after that no particular sensation is noticed. Patients who have had more extensive burns thus treated all give evidence of the comfort of the dressing, but do not agree that the first application of the hot wax is absolutely without pain. It certainly is not what could be called a painful dressing. It is remarkably painless in comparison with any of the older forms of dressings used, and its removal is absolutely without discomfort of any kind. This latter fact is in such marked contrast to the torture of the removal of any other kind of dressing applied to a burned area that it makes the paraffin film method stand out most emphatically as a painless method of treating burns. Herein lies one of its chief advantages over other methods.

Absence of sepsis with this form of dressing is a second noticeable thing. It would rather naturally be supposed that such a dressing, confining discharges as it does, would give a favorable opportunity for bacterial growth. This, however, has been notably absent in all cases so far treated by the author. A distinct odor is given off on removal of the coating but this has a stale and musty rather than a putrefactive odor. The fact that the dressing is in itself sterile, is applied at a heat which might discourage bacterial growth, and that it is an air-tight dressing, seem to be the reasons for the non-development of infection. It can be definitely stated that sepsis with this form of treatment is extremely rare and not to be expected.

The question as to whether this form of treatment can be used safely in extensive burns is still an open one. Some cases of not too great extent or depth will do well and not get a dangerous amount of toxic absorption from confined secretions, while others in which there has been much destruction of tissue will show absorption early and in such cases paraffin-film dressings had better be discontinued in favor of salt solution compresses or the open-air method. No hard and fast rules can be laid down. The surgeon must be guided by the patient's symptoms and his own judgment. Experience would lead one to advise against the use of any form of confining dressing when any large area of body is involved.

The length of time necessary for healing is one of the important points to be made in discussing the paraffin-film treatment of burns.

The lay reports would lead one to believe that this was accomplished in incredibly short time and without pain or scar. This is not quite true. However, from a series of first and second degree burns of the fingers and hands it was found that the average healing time was under two weeks, many seemingly unpromising cases being completely healed in from nine to twelve days. First degree burns heal much more quickly with a paraffin film than formerly with boric ointment. But first degree cases heal rapidly with any dressing which allows of rapid drying and protection and avoidance of maceration. Picric acid and tincture of chloride of iron also heal first degree cases in very short periods of time. The rapidity with which paraffin film cases heal can be determined better when one takes the second and third degree cases into consideration. Twenty to forty days is the length of time often mentioned in lay articles. This is too long and no shorter than would be expected in cases treated by other means. With proper care paraffin cases, unless very extreme, should be well along in the healing process in eighteen to twenty-five days. It can be definitely stated that the length of time necessary for complete healing with this form of treatment is considerably less than with the older methods.

The resultant scar is noticeable for its softness, smoothness, and pliability. It rarely has scabs and scales and does not seem to crack or bleed as readily as burned scars under other forms of treatment. The softness and smoothness are the two most noticeable things about the scars following paraffin dressings.

It may now be asked "What is the reason for the apparently superior results obtainable by this preparation? Is it chemical or mechanical?" It certainly is not chemical in any sense that original "Ambrine" has some secret constituent which renders it superior to any paraffin substitute. So far as can be determined the substitute cases do exactly as well as the ambrine cases: they heal as quickly, are as comfortable, show no increased tendency to infection and leave just as smooth a scar. The effect of this preparation therefore must be purely mechanical in its action. It seems probable that this mechanical action is favorable, (1) because it immobilizes the affected area; (2) it is a sterile dressing; (3) it makes an air-tight, sealed dressing which may possibly be the reason why it does not favor bacterial growth; and (4) by its close adhesion to the part favors ingrowth of granulations while it discourages upgrowth or heaping up of granulation tissue. It also at first acts as a supporting framework for tender granulations to grow upon and later may act to some extent like adhesive plaster on the sluggish granulations of a varicose ulcer. It is not unlikely that the soft smooth scar may be due in some measure to constant contact with the paraffin —and of course to the absence of sepsis.

We must look upon the paraffin-film method of treatment of burns therefore as a purely mechanical one which, however, has certain distinct advantages over formerly employed medicated dressings.

1. It is superior to other dressings in that it is essentially a painless dressing.

2. It does not favor bacterial invasion.

3. Burns under this treatment do heal more quickly than with most other forms of dressing.

4. The resulting scar is more smooth, soft and pliable than with other dressings.

5. It is applicable in practically all but burns of very extensive area.

It is hard to get men away from older and tried forms of treatment such as open air and picric acid unless the newer method produces very startling results. It can be definitely stated that the paraffin-film method of treating burns is a distinct advance over older methods.

The Prevention of Contracture.—Among the most serious after-effects of burns are deforming and disfiguring contractures of scar tissue.

Very distressing late results often develop, such as the ectropion or pulling down of the lower eyelid which is accompanied by a continuous running down of tears on to the cheek, or contractures about the mouth may prevent proper mastication of food, or such distortion of the mouth that a constant "drooling" of saliva, a most distressing condition, is produced. The jaw may be drawn down on to the chest or, in burns about joints, permanent distortion of the joint may be produced which may be totally disabling.

The time over which scar tissue contracts is long, and efforts to prevent and overcome contractures must be instituted early and persisted in for months and sometimes years in order to prevent deformity of various kinds.

As disabling and deforming contractures occur in practically every case in which a burn of more than first degree involves a fold of skin or a neighboring joint, the great importance of prevention of this particular complication of thermal injuries is evident.

From a considerable experience with this type of case the author believes that it can be definitely stated that the percentage of contractures *can* be reduced at least 75 per cent. by three definite means.

First (and most important). The prevention of sepsis. As is well known a wound which has not become septic, heals more readily and with less contraction of scar tissue than the one in which infection has taken place.

Second. By the early immobilization of extremities affected, by means of properly applied splints. This is most important and should be employed at the very outset of treatment as soon as the case is over its shock, and is running smoothly and *before* granulation begins. As immobilization in any wound is of greatest importance, so in thermal injuries it is one of the first principles of greatest service.

Third. The early employment of passive motion and massage. To this should be added the use of Thiersch skin grafts at the earliest possible moment, as soon as the necrotic tissue has been removed and before contracture has begun. More than 95 per cent. of these grafts will take if cut and applied dry to the undisturbed granulations according to the method described in the chapter on Skin Grafting. This effectively prevents contractures. In case contractures have already occurred, when the patient comes under treatment, the scar should be cut transversely and the spaces formed after stretching should be filled in by means of ribbons of Thiersch grafts cut the proper size to fill in the respective spaces.—(ED.)

In hospital practice cases are sent to the Zander department as soon as they can be moved and treatment begins very gradually. Massage is applied to the skin immediately surrounding the burned area and as much passive motion used as is consistent with comfort. This is done daily during granulation and afterward until all signs of contractures have disappeared. After such treatment, in the early stages, the limb is returned to its splint as long as that seems necessary, being taken out occasionally to rest the part. In private practice this treatment can be carried out also but requires great perseverance and patience. It is believed that the above methods are of greatest value in effecting the early recovery to usefulness of these tedious cases.

Burns of the neck and face, which later tend to produce the characteristic and deforming drawing down of the mouth and lower jaw are most difficult to treat because splinting and immobilization of the parts is most difficult and uncomfortable in this region. For this type of case the orthopedic head brace for cervical vertebræ cases may be used and early passive motion and long-continued massage to the affected part are absolutely necessary.

When the axilla or elbow is involved the forearm is best bound on to an anterior wooden splint and this tied to the head of the bed for several periods of an hour or so each day. This later to be followed by passive motion and persistent massage.

When the lower extremities are affected, particularly in children, the Bradford frame is indispensable. Continued separation of the thighs, when the burn is on the inner side of the thigh, and the use of the ham splint or plaster gutter placed anteriorly for burns of the popliteal space are almost essentials of treatment. Variously moulded plaster-of-Paris supports and splints can often be utilized to great advantage. Without these aids contractures are bound to form and cause further disability. To be successful, however, in the use of splints and casts they must be employed early and continuously and with great patience.

Newly forming tissue, whether it be only the superficial or deep epidermization, begins to contract almost as soon as it is formed and this contraction goes on slowly and steadily from day to day all during the process of healing and continues slowly for weeks or even months after the wound is solid.

Thus is seen the greatest importance of keeping this scar tissue on the stretch as it heals, of keeping joint surfaces apart, or extremities abducted in order that, as the wound heals, it may be able to contract the minimim amount and thus produce the least amount of subsequent restriction of motion or deformity.

Particular stress should be laid on the early massage of the healthy skin surrounding the burned area, particularly in the neighborhood of joints, and on the early, persistent, and long continued massage of the newly formed scar tissue. This latter should be started as soon as the sensitiveness has subsided enough to allow of the gentle rubbing in of sweet oil and should be continued daily until the scar is solid and has become almost of the natural color of the surrounding skin.

Perseverance and the attention to minutest detail will practically always be rewarded by success even in the worst and most unpromising cases.

Scars resulting from burns may be merely red blotches on an exposed part, they may produce deformity from various degrees of contracture or they may become hypertrophic or even keloid in character. Varying degrees of tenderness persist for weeks or months after the lesion is healed, depending, as in other scars, on the extent and situation of the lesion.

Time will eradicate the blush from the red blotch. If the rules just laid down are followed there is little likelihood of contracture.

Treatment of the hypertrophic or keloid scar should be begun early and what has not already been accomplished by persistent massage and passive motion should be followed up by careful radiation either by *x*-ray or radium. It is during the first six months, or during the process of involution that such treatment is of greatest benefit.

With radium, several exposures of moderate doses over periods of ten to twelve hours, are generally necessary to effect any absorption of the underlying fibrous tissue. Great care must be taken not to set up a dermatitis or to actually break down the tender skin over the scar, as this often results in distressing after-effects, pain and further contracture.

With *x*-ray also it is extremely important to protect the skin against an *x*-ray dermatitis. Both of these methods should be used only in the hands of experts.

When contractures have already taken place palliative methods are rarely of any avail and resort must be made, preferably at the end of a year or so when the tissues have become fixed, to operation, removal or severance of the contracture, and skin grafting.

Prognosis and Mortality.—The problem of determining the relation between the extent of body surface burned and the question of making an accurate prognosis based on this factor has received careful attention. We have at our disposal two methods of measuring body surface: The first, that of Du Bois[1] gives a very accurate measurement but cannot be computed without consulting this special chart nor without knowledge of the patient's weight, which is often impossible to determine in severely burned cases. The second method furnishes a rough estimate but is accurate enough for all practical purposes. By this method the body surface in the male is taken as 20 feet and in the female

[1] Du Bois, D., and Du Bois, E. F.: A Formula to Estimate the Approximate Surface Area if Height and Weight be Known, Arch. Int. Med., June, 1916, Part II, xvii, 863–871.

16 feet. Using these figures it is easy to determine the approximate extent of surface burned, and this, as will be seen, is an accurate enough estimate for all practical purposes.

Clinical experience shows that the determining factor in prognosis is as likely to be the general condition of the patient as the extent of surface burned. So that to know definitely whether one or two square meters more or less are involved is of little importance in comparison with a sound appreciation of the patient's general condition. Therefore, the more accurate method is seldom used and the rough estimation serves fully as well to give one a probable prognosis.

Analysis of a large series of cases shows, however, that the prognosis is very variable and that young adults may survive after the burning of even extensive areas of skin and recover rapidly while young children and the old or feeble will often succumb to secondary shock with very slight and very small burns. The age and condition of the patient is of nearly as much prognostic value as the extent of the burn, provided the burn is not of extreme extent or degree. So that one should not adhere to the old text-book rules too closely in making a prognosis according to extent of surface burned.

The average mortality in a hospital series covering ten years was 23.5 per cent., which is about the usual mortality in this type of case.

The mortality is higher when the chest, back, or abdomen are involved than when equal or even greater areas of skin are burned on the extremities.

The presence of shock is the most important factor in making the prognosis at the onset. Practically all badly shocked cases die irrespective of previous condition or subsequent treatment.

COMPLICATIONS OF BURNS.

It has been stated by many writers that pneumonia is liable to supervene after burns of the chest and peritonitis after burns of the abdomen. Clinical experience has shown that pneumonia is only likely to occur in very feeble old people in whom a terminal pneumonia would be the expected end-result. Many cases of chest burns in people of all ages in whom pneumonia has not developed have been seen and it is believed that pneumonia as a complication in thoracic burns is no more common than in other conditions requiring confinement, unless the patient be aged or feeble, and here it is to be expected. No cases of peritonitis have been seen in a large series of hospital cases under personal supervision, nor has the record of such a case been found in over forty years of hospital case histories, nor has such a condition been demonstrated in any of the burned cases coming to autopsy since the foundation of the Massachusetts General Hospital. Evidence, therefore, would point to peritonitis as a complication of burns of the abdomen as so rare as to be entirely disregarded.

Duodenal Ulcer.—The question of the incidence and etiology of duodenal ulcer in severe burns is yet a disputed one. Just how many cases which have nausea and vomiting and epigastric pain within the first few days, are developing duodenal ulcer is not possible to say. The fact that many of these are quickly relieved by dram doses of soda bicarbonate makes it seem unlikely that the symptoms are due to anything more than the toxemia produced by the burn. The percentage of autopsies on burned cases is so small that detailed statistics are not available. We have failed to find a single case of duodenal ulcer in any of the cases autopsied at the Massachusetts General Hospital since its foundation. Out of all cases of multiple burns coming to autopsy, six had either nausea, vomiting, or pain in the epigastrium, but only three showed any pathology in the gastro-intestinal tract. Most of these cases were in profound shock and lived but a few hours. One case in whom there were no symptoms (probably because of the degree of shock) showed two feet of upper ileum congested, but no ulceration. One case with pain in the epigastrium showed at a point 125 cm. above the ileocecal valve, intense redness of the mucous membrane with discrete and confluent irregular black-red areas, but no ulceration.

One is therefore convinced, after a careful study and analysis of clinical and autopsy records taken in conjunction, that actual duodenal ulcer following severe burns is so rare as to be practically negligible. One recognizes, however, a distinct train of symptoms strongly suggestive of this condition but which it is believed are due to the toxemia as a general disturber of metabolism rather than as an exciter of distinct pathological changes in the duodenal mucous membrane.

The fact that these symptoms subside with the proper treatment also suggests toxemia rather than actual lesion of the duodenum. It has been our experience that cases given dram doses of soda bicarbonate three or four times a day, together with a general forcing of fluids by mouth, rectum, and subcutaneously, recover quickly from the symptoms of toxemia. Certainly physical examination of these cases show none of the well known signs of duodenal involvement.

Moynihan, in his historic monograph on duodenal ulcer devotes a whole chapter to the occurrence of duodenal ulceration in Burns or Scalds. He refers to the fact that the congestion of various mucous membranes in the alimentary tract, brain, and lungs, was recognized as a common complication of burns by Dupuytren some five years before Curling described the ulceration which now bears his name. Moynihan himself believes that the lesion, contrary to the generally conceived opinion, is an extremely infrequent one and states that in nearly twenty years no case has been observed in the postmortem room of his own hospital wherein cases of burns are frequently admitted. Nor has he ever met a case of duodenal ulcer in which a previous burn could have been said to have been the exciting cause.

Renal Complications.—Nephritis following extensive burns is of two types: (1) The so-called traumatic nephritis, which, in this instance, is undoubtedly an acute toxic nephritis from the overwhelming absorption of the broken down products of proteid metabolism formed at the site of the thermal injury. This condition is evidenced, according to the severity of the burn, by a transient albuminuria, hemoglobinuria, or partial or complete suppression of urine.

2. A true toxic nephritis coming on in the later stages of the burn, generally about the time of the separation of the eschar and due to a true toxemia from the absorption of septic material. This is rarely evidenced by hematuria, but there is profound disturbance of the kidney function and large amounts of albumin and evidences of degeneration. This nephritis may be recovered from as the septic absorption decreases or it may be the ultimate and later cause of death.

On the whole, involvement of the kidneys is comparatively rare. Many cases show nothing more than a slight transient trace of albumin. Hemoglobinuria of more than a temporary degree is of bad prognostic significance and partial or complete suppression of urine is of the very gravest import.

It can be definitely stated that complications are rare, that duodenal ulcer is so rare as to be a negligible factor. The symptoms simulating this condition are due to the toxemia, no definite pathology takes place in the duodenum and the patient can practically always be relieved by gastric gavage and the use of dram doses of sodium bicarbonate until symptoms subside.

There have been a few cases of supposed duodenal ulceration lately reported to have followed the application of the Percy cautery in carcinoma of the cervix uteri, but no detailed reports of autopsy findings are on record. Unless postmortem examination definitely demonstrates actual lesion in the duodenum one is not justified in ascribing the symptoms of toxemia to a suppositional lesion of the duodenum.

Regional Burns.—Burns caused by special agents such as electricity, lightning, *x*-ray and radium.

The Eye.—While the eye may be burned by fire, steam, hot liquids or splashes of molten metal, probably the most frequent cause of burns of the cornea and conjunctiva is from the effects of corrosive fluids being splashed into the eye. Such are sulphuric or carbolic acids, lime, caustic potash and caustic soda, vitriol, "Greek fire" (phosphorus dissolved in carbon disulphid). In all such lesions there is rapid and deep penetration of the caustic into the delicate tissues of the eye and much damage is done in a very short time. Corneal opacity will probably result even if there is not actual loss of sight. Adhesions between the cornea and the lid (symblepharon) may restrict the motion of the eyeball or the lids so that closing of the lids is interfered with to such an extent that the protection to the cornea is lost and an irritative process is set up which in time may end in ulceration or destruction of the ball.

Treatment of all burns of the eye is first the thorough washing out of the conjunctival sac with a warm boric acid solution until all traces of the caustic are washed away. This is to be followed later by the instillation of a drop or two of slightly warmed olive or sweet oil every two or three hours until the lesion is healed. (Boric acid only should be used in phosphorus burns as the oil is a ready solvent of phosphorus and may keep some of this drug solution in the conjunctival sac.) Oil is the best and only other agent besides boric solution which it is necessary to use in such lesions of the eye. It is analgesic, it keeps the injured or possibly ulcerated surfaces apart and prevents later adhesions if used continuously during convalescence. If there is much edema cold boric acid compresses may be used in addition.

In many cases castor oil seems to give better results than other oils because of its tendency to adhere.

Mouth and Throat.—These burns are generally caused by the ingestion of hot fluids or by swallowing of caustics or corrosives, rarely by inhalation of fire or steam.

The lesion is characterized by intense redness, swelling, and much pain. Inability to swallow even cooling liquids may cause later dryness of the mouth and throat, and great discomfort. Rectal feeding may have to be resorted to. The greatest danger, however, is from the rapid formation of edema of the glottis. This should be treated prophylactically with ice-bags and cracked ice inside the mouth on the assumption that it probably will occur anyway. At its onset it should at once be treated by scarification, and, if no relief is obtained intubation or tracheotomy must be resorted to.

Esophagus.—This is rarely burned by hot fluids for the simple reason that fluid hot enough to burn the mouth is generally spat out immediately and does not reach the esophagus. But the esophagus is commonly burned for its whole length by the action of caustics or corrosive drugs, swallowed by intent or mistake. In such cases pain is great and shock often present. Ulceration follows the stage of acute swelling and this is later followed by constriction due to contraction of scar tissue. Rectal feeding is absolutely essential from the onset and for many weeks or even months. The patient is confined to bed, loses weight, and needs great care. As soon as the ulcerations are healed dilatation of the esophagus should be gradually begun and must be persisted in for many months before complete recovery can be expected. Rarely gastrostomy must be resorted to in order to save the patient's life.

These cases are best cared for by the combined efforts of a throat specialist and the general surgeon. Esophageal bougies must be used with extreme care and skill, and complete dilatation requires much time and patience both on the part of the patient and the physicians in charge.

Burns from Electricity.—These burns are of especial interest because of their peculiar character and the difficulty in getting them to heal with any degree of rapidity. They may be caused by the electric current of high or low frequency or by lightning.

Normally human skin when dry is a non-conductor of electricity, but when moist as with prespiration or in contact with damp clothing it becomes a source of danger as a conductor of electric currents. These harm the deeper layers of the skin more than the horny epidermis.

The severity of the lesion produced is dependent upon the quantity of current which passes through the body and the duration of the contact. The current may be continuous or alternating; the former is more liable to inflict serious tissue injuries while the latter is more liable to kill almost instantaneously because of the degree of surgical shock produced. Voltage and contact are the determining factors. A low voltage with a perfect ground contact may result in death, while a high voltage with an imperfect ground contact may be safely withstood. Voltage as low as 65 has been known to kill when the current was alternating, and 95 volts with a continuous current. These are exceptionally low voltages, however, to produce a fatal result. Currents with a voltage in the neighborhood of 200 are quite likely to be fatal; such as may be found in the ordinary electric light.

The lesion caused may be a superficial burn of the skin, actual destruction of the deeper layers, grave internal injuries, or fatal shock. In practically all electric injuries a burn is produced both at the point of entrance of the current (anode) and also at the point of exit (cathode) the injury at the point of entrance being usually greater than that at the point of exit. This latter lesion often resembles the mushroomed appearance of the point of exit of a soft bullet.

The action of electricity is partly electrolytic from the passage of the current and partly due to the intense heat produced by the resistance of the skin to the passage of current. Electric burns differ from heat burns in that at first they present a peculiar dry, whitish, charred appearance which often seems superficial and deceives one as to the depth of the burn. In the course of a week, however, the real extent of the destruction of tissue becomes painfully evident and one is shocked to find, in place of what seemed a superficial scarring of the skin, a deep, sluggish, dirty looking necrotic area, the true effect of the electric burn. A tough eschar may be present or the lesion may resemble a dry gangrene with a strong, fetid odor. The sluggishness of these wounds and the extensive destruction in local areas is due to the intense devitalizing effect of the electric discharge and also to injury to nerves supplying the part, for nerve tissue is very prone to injury and is a ready conductor of electricity.

Currents of extremely low tension are capable of producing burns provided good contact is maintained. This is illustrated by the disastrous effects sometimes produced in the treatment of skin affections by ionization.

The general effects of contact with electric currents vary from none to fatal shock. In severely shocked cases unconsciousness is produced and a tetanic spasm of the muscles all over the body is set up. Respiratory failure may be due to spasm of the muscles of respiration and in such cases artificial respiration is the first treatment to be instituted. After recovery from shock marked secondary general disturbances may develop, such as temporary or permanent paralyses, psychic disturbances, such as hysteria, neurasthenic state, delirium, delusions, insanity or epileptiform seizures which are usually transient but may persist for indefinite periods and interfere seriously with the utility of the individual. The special senses may be affected, especially the eyes, ears and an impairment of the sense of touch. All sorts of bizarre physical symptoms without corresponding signs may develop but are of a transient nature unless some definite organic lesion has been produced.

There are several marked peculiarities of electric burns which should be borne in mind.

1. The injury may have the appearance of a wound caused by the exit of a bullet or that caused by a blunt instrument and in no way suggest a burn.

2. At the time of contact and for some hours, or even days, afterward the skin may not appear to be affected at all, and then for several successive days new lesions may continue to make their presence known by their surface appearance. The amount of injury to the skin or superficial tissues is not an accurate index of the extent of damage done to the body in the way of shock or general disturbances and *vice versa*, severe local injury may be caused by an electrical discharge which causes no internal disturbance, as when the current has passed in and out of a limb without having entered the trunk.

Because of the interference with the nerve supply, which may extend for some distance beyond the actual lesion, and the great devitalization of the tissue, healing takes place with extreme slowness in electric burns, even taking as much as two or three times as long as in the case of similar burns from heat.

The resulting scar is peculiar for its delicate atrophic appearance, it may be white in one place, pink or pigmented in another and telangiectases are generally present and it tends to break down with great readiness.

The pain of an electric burn seems to depend largely on the suddenness of the application of the current and may be entirely absent when even a large current is applied gradually or very severe when even a weak current is applied suddenly.

The first consideration in the treatment of electric burns is the treatment of shock. This often is so severe as to inhibit respiration and in this case artificial respiration is the first procedure; attention to be given to the dressing of the wounds later, after all shock has been recovered from.

As the separation of a more or less deep eschar, and in severe cases the formation of a line of demarcation, often must be waited for, on general principles the open or dry method is probably preferable in electric burns.[1] Here also picric acid and the tincture of chloride of iron are valuable as these agents produce a dry surface. Should there be much surrounding inflammatory reaction compresses of hypotonic salt or boric acid solution are of the greatest benefit. In more superficial degrees of burns the paraffin-film method is perfectly satisfactory.

[1] Burns from lightning are not considered in this work. An excellent brief description may be found in MacLeod's admirable little book (Cf. Bibliography).

Burns from X-rays and Radium.—These burns have their own individual characteristics although in general they are much alike. Both are due to overexposure to the rays either in one single large dose or from the action of several smaller doses each of which in itself might have been entirely harmless. The exposure may be too powerful or too prolonged. Some ray burns from seemingly moderate doses may be accounted for on the basis of individual susceptibility, but such cases are rare.

These burns are characterized by the fact that they do not appear at the time of the exposure but only after a certain latent period which varies according to the severity of the exposure.

There may be acute burns due to one excessive dose or chronic burns caused by frequent small doses repeated over a long period.

The *x*-ray burn is of varying degrees. A first degree burn is like that from other agents, a temporary erythema which appears in about two weeks after exposure and then gradually disappears. This is always accompanied by falling out of the hair in the region affected.

In second degree burns the erythema is more intense, there is intense itching, edema, and later desquamation, permanent loss of hair and slow recovery of the skin to normal and possibly the late formation of telangiectases in the area treated.

Burns of the third degree are much more severe and make their appearance before the end of six days. Vesicles and bullæ may develop followed by a broken, raw or ulcerated surface which takes months to heal and causes extreme pain and is extremely liable to break down at the slightest injury and form further ulcerations.

Burns of a further degree appear in from twenty-four to forty-eight hours and sloughing takes place almost at once and to a considerable depth and a deep sluggish ulceration with unhealthy base or fibrinous slough remains indefinitely causing excruciating pain and very much undermining the patient's health.

Chronic X-ray Burns or X-ray Dermatitis.—This condition is more common in those who are in constant contact with *x*-ray apparatus, the operators or tube makers. The commonest site for the lesion is the back of the hands and fingers, but even the face may be affected. Definite atrophy of the skin results and the development of brownish patches and telangiectases is characteristic. Symptoms are itching and burning which cold weather aggravates. The skin becomes so sensitive to the *x*-rays that even being in the same room with an unprotected tube may be decidedly unpleasant. Later dirty black scabs form, which when knocked off leave tender ulcerations which may later suffer malignant changes and become definitely carcinomatous. Metastases to the axillary glands and lungs are not uncommon. The nails are very liable to be affected in all degrees of *x*-ray burns. They become brittle and ragged and chronic suppurative changes often accompany them, causing much pain and tenderness.

The pathological changes in all *x*-ray burns are distinctly of the degenerative type, and healing is extremely slow with frequent relapses of the painful ulcerations.

Prognosis as to the recovery depends entirely on the severity of the burn, slight burns heal with complete restoration of function while severe burns may never completely heal.

Treatment of the acute burn is by protection and soothing lotions such as lead, or dusting powders, as stearate of zinc, or boric acid. Intractable ulcers may have to be excised and skin grafted. It has been found that by exposing areas in which there is indication of the formation of destruction of skin due to x-ray to the rays of electric light in the form of a therapeutic lamp the ulceration can be avoided or if already present it will heal rapidly. The light should be applied almost continuously.—(Ed.)

The treatment of chronic burns is a tedious and discouraging process. Protection is the *sine qua non*. Practically all other methods except this are unavailing.

Burns from Radium.—These resemble very closely the lesions produced by x-ray. Radium gives off an Alpha, Beta and Gamma ray. It is the soft Alpha or Beta ray which burns and not the more penetrating Gamma ray.

The burn as in the case of the x-ray does not make its appearance for from three to twelve days after the exposure. The degree of burn or the amount of radium reaction, as it is generally called, is dependent on the strength of the dose, the amount of protection or filtration, and the length of exposure. Transient erythema is an accompaniment of practically every application which is strong enough to therapeutically affect the underlying tissues. The most common lesion seen after radium treatment in effective doses is the ulceration covered with fibrin slough. This is generally painful and takes from twelve to twenty days to heal over.

The scar from a slight burn is slightly depressed, generally white or paler than the surrounding skin and practically insensitive to touch. The scar from a severe burn is deeper, more sensitive, and brownish in color or covered with telangiectases. The radium burn is sometimes very painful and surrounded by a large inflammatory zone but heals with considerably more rapidity than the corresponding x-ray burn.

Here again protection and the use of soothing lotions and patience are the essential forms of treatment.

The use of the therapeutic lamp has the same effect in these cases as in x-ray burns.

Summary and Conclusions.—A careful review and consideration of the evidence at hand in the study of cases of severe burns would point strongly to the sudden absorption of the disintegrated proteid substances broken down by the great destruction of various tissue elements involved in the burned area as the cause of the toxemia and resultant symptoms suggestive of duodenal ulceration, the rise of temperature and the suppression of kidney function and destruction of blood corpuscles. A definite symptom-complex is present which is the result of a true toxicosis. With this definite pathological condition before us the rationale of our treatment is easier to formulate: (1) We must treat the surgical shock produced by the burn; (2) we must overcome the toxemia by every means at our hand to favor the process of elimination and reduce the renal congestion and irritation caused by absorption of toxic products; (3) by proper treatment of the burned area itself, we must prevent absorption and favor drainage of the toxic products of destruction, and avoid sepsis. If we adhere to these three cardinal principles of treatment we place our patient beyond the chances of a fatal outcome and render the burned area favorable to early epidermization and healing without contracture and lessen to the greatest degree the likelihood of complications.

We would summarize briefly the important points in the treatment of burned cases as follows:

1. The three most important factors in the treatment of burned cases are:

(*a*) Prevention and treatment of shock.

(*b*) Prevention of sepsis.

(*c*) Prevention and treatment of contracture.

To these should be added the covering of the area with Thiersch skin grafts at the earliest possible moment to prevent contracture.—(Ed.)

2. The treatment of shock is by far the most important consideration and is often best combated by continuous immersion in the hot saline bath or the open-air treatment.

3. Many deaths have been caused by ill advised attempts at first dressing.

4. The form of first dressing is largely responsible for subsequent sepsis. Oily dressings should be avoided. Cleansing of the skin surrounding the burned area with alcohol aids in preventing sepsis. Constant drainage of discharges is essential.

5. The open-air treatment is far superior to that in which any form of dressing is used.

6. Picric acid is by far the best form of medicated dressing.

7. Contractures can be prevented in 75 per cent. of cases formerly contracting, by the early use of properly adjusted splints and by early passive motion and massage, and especially by the early application of Thiersch skin grafts.—(Ed.)

8. Prognosis in all shocked cases is bad. The extent of the burned area does not always determine the prognosis. The age and general previous conditon of the patient is of greater prognostic value than the extent of the burn; the very young or very old or debilitated succumbing at times to very trivial burns. Robust subjects with burns covering 8 to 10 feet of surface often recover.

9. Duodenal ulcer is an extremely rare complication and can be almost disregarded. The symptoms simulating this condition should be treated by gastric gavage and the giving of dram doses of sodium bicarbonate until relief is experienced.

10. Small amounts of blood or albumin in the urine are of no grave prognostic significance. Hemoglobinuria, however, is of grave import and partial or complete suppression of urine of the very gravest significance.

11. The tincture of chloride of iron applied repeatedly to the burned area is a distinctly valuable form of local treatment in that it produces a painless, clean, dry coated-over and protected area. Its use is strongly recommended in burns of small extent.

12. The modern paraffin-film method of treating burns is a distinct advance over older methods. It is a practically painless dressing and leaves a smooth soft scar, healing in shorter periods of time than other dressings. It should probably not be used in extensive burns of the body, but is an excellent dressing, especially for burns of the face.

PLASTIC SURGERY.

By CARL BECK, M.D.

General Considerations.—Plastic surgery is that branch of operative surgery which deals with correction of form or with reconstruction of parts of the body, or with the restoration of function of parts which have been injured so that the function has disappeared, or which have been formed by nature faultily. We fulfill our object if we obtain a result as nearly as possible normal in form and function.

Plastic surgery divides itself into two branches, which are, however, in most instances inseparable: (1) Restitution of form (cosmetic); (2) restitution of function (functional plastic). The latter class of manipulations and operations which implies the restoration of function is the more important, but in most instances both objects have to be kept in view, although if one is achieved, for practical purposes it is often sufficient.

In peace times we have to deal mostly with plastic operations upon subjects who are malformed by nature (congenital deformities), or malformed by injuries (in industrial life, in accidents, etc.). The restoration of form and function of organs, or parts of organs, due to war injuries is far more common at present. Although we have learned a great deal during this war, in the main the rules and indications remain the same as we have known them heretofore in peace time surgery. If we correct a saddle nose, we have not only to restore the form but oftentimes correct the obstruction in the nose. In the closure of a hare-lip, we not only improve the form and shape of the face but we correct the impediment of speech, of breathing. In the treatment of hypospadias, we correct not only the abnormal condition but enable normal micturition and sexual function. In making a plastic flap on the skull, we not only improve the condition as far as form and resistance are concerned but oftentimes cure epilepsy. These few examples show how intimately reconstruction of form is connected with restoration of function.

Methods of Plastic Surgery.—We have three surgical methods in the main which enable us to restore defects: (1) Autoplasty, that is the restoration of parts by using material from the same individual; (2) heteroplasty, the employment of parts from another individual, but from human, or cadaver of human; (3) alloplasty, by the use of material not from the human body but from animals or inorganic substances (metals, rubber, and other material). Sometimes we combine these three surgical methods. Far more desirable is the use of material from the same individual, and only in case of necessity should we resort to the others.

Conditions Necessary for Success in Plastic Surgery.—There are some very essential factors which are necessary for success in plastic surgery and without which our reconstructive work will prove a failure. They have been recognized through the experience of those who have for many years paid particular attention to this class of surgery. In the main they are the following:

1. Work on healthy subjects.
2. Work under normal conditions, especially absence of inflammatory changes.
3. Strict asepsis.
4. Exact hemostasis.
5. Good technic.
6. Personal attention of the surgeon.
7. Leisure and good facilities.

1. **Work on Healthy Subjects.**—Patients who have a low vitality, who are either too young or too old, or those who suffer from blood diseases: syphilis, tuberculosis, hemophilia, or other chronic infections or ailments, are not good subjects. Intercurrent diseases are also contraindications to operation.

Of course, we cannot always choose our subjects and leave those who are not perfect without help, but we may have to improve general conditions if we want to achieve a good result. We shall have to choose the right age in the correction of congenital deformities; we shall have to choose the best health conditions in our patient for the time of interference.

2. **Working under Normal Conditions in Patients, with Absence of any Pathologic Changes.**—This is very important, especially in injuries resulting from the war. Too early undertaken corrective measures will oftentimes prevent a good ultimate result. Of course immediately after the injury all those plastic corrections must be undertaken which will prepare for a good remote reconstruction, but injuries are seldom aseptic and the wounds saturated with microbes, often slough and lead to abnormal scar conditions, to retractions and contractures. A good surgeon will undertake the treatment of injuries always with the view of obtaining good functional and cosmetic results, but it may not be in his power to obtain them primarily. Gangrene and abscesses may prevent good form or function, and so it remains for the plastic surgeon to make later correction or reconstruction. But no corrective measures should be undertaken until full healing has taken place in all the injured parts and the healing process is concluded without reaction in the scar.

The diagnosis of absolute health of tissues is not always easy. Sometimes it appears on the surface that wounds are healed, but inside the tissues is lurking a slow infection, an infiltration which breaks down secondarily, and if at such time plastic work is undertaken, it may lead to infection in otherwise healthy tissues and may result in a loss of good material and unfortunate results. Every plastic surgeon knows this by experience.

3. **Strict Asepsis.**—It may not always be possible to exact absolute asepsis of the field of action. For instance, in our operations in the mouth, in the nose, in the sexual organs, absolute asepsis is impossible; but we should try to get conditions as ideally clean as possible. On the skin we should secure as clean and aseptic a field as for laparotomy. Especially all instruments and materials used should be absolutely aseptic.

4. **Hemostasis.**—This point is often overlooked. We have in our time become very bold as far as hemorrhage is concerned, and many surgeons look upon oozing and even bleeding with a degree of contempt. For a good result in plastic work it is essential that there should be as dry a wound as possible, inasmuch as bleeding invites infection, retards the healing process and may spoil a good operation.

It is not desirable to have many ligatures to secure hemostasis. One should make use of heat (hot sponges), pressure, and coagulating preparations, inasmuch as foreign materials, like ligatures, are not favorable to healing processes in plastic work.

5. **Good Technic.**—Technic is an essential point, which will probably be improved in the future. It is unfortunate that in civil life the material for plastic work is relatively scant, and some plastic operations are rare, so that only a few cases of certain operations occur in the lifetime of a surgeon. Practice alone makes perfect and since surgeons have to operate who have not much practice, a great deal of the work of reconstruction in peace times is amateurish. Many times surgeons not knowing fully the methods at our disposal, improvise new ones, and in this manner plastic work has suffered a great deal. This also accounts for many modifications of well devised and well tried methods, which are not so much the result of an intention to improve the method as they are makeshifts during the operation. If they succeed, virtue is made out of a misfortune, and they are described as new methods. This has led to the description of innumerable modifications of methods, often based upon a single case incorrectly or incompletely observed.

One should deviate as little as possible from recognized methods and types of operations which have their merits. This is the reason why I shall refrain from giving too many methods in this article and why I select certain types which will fit the majority of cases and may be safely adopted. They are not my own and although I do not mention the author in all of them, some have become such an essential part of surgical knowledge that their origin is forgotten.

In good technic one must include not only the choice of a method but a well laid out plan for that method. Cases must be studied much more carefully than in general surgery, where the experienced technician will in most instances modify his plans during the operation, as he encounters conditions of which before the operation he had no knowledge. In plastic work the surgeon must lay out his plan like an architect and adhere to it so far as possible.

In good technic one must include good general surgery; particularly the necessity of clean cuts, broad surfaces for union, careful handling of tissues, especially avoiding rough manipulations or tearing, always preferring sharp dissection and exact suturing. Nothing can mar good plastic operations so much as careless suturing. One must always have in mind the circulation and the nerve supply in marking out the method.

6. **Personal Attention of the Surgeon and Good After-treatment.**—No matter how carefully the operation is performed, it may be spoiled by the after-treatment. This implies an exact knowledge of the after-care of such cases. Only the surgeon himself knows what is best for his patient after the operation. He must watch and often even dress the case himself. To remove sutures in a typical surgical operation is a trifling procedure. Any good nurse can do it without harm to the patient, but the same procedure in a plastic case may prove fatal to the result, and therefore should not be entrusted except to the experienced. It is necessary that the plastic surgeon develop very good assistants if he is to entrust this work to them.

During plastic operations we often rely on retentive apparatuses, to keep portions of the body together which are far apart, like the arm to the head, a foot to the other foot, a limb to the other limb, positions which often cause the patient great annoyance and pain. The result often depends on exact and absolute rest, on certain manipulations, in cleaning and changing dressings. All this must be carefully watched, so as to obtain good results.

7. The last point, which is one of great importance, is the possession of good assistants and material and facilities to do the work. Unfortunately it is not always possible to have all of these because the material is rare. Unless a man makes a specialty of this work, he has little chance for good results, because he lacks these facilities. War reconstruction will furnish for years to come abundant work and the Government, I am sure, will furnish facilities to the men who devote their time to this class of surgery. It will secure for them assistants who are devoted to their work, and nurses who will learn all the intricacies of plastic reconstruction, and trained teachers and helpers in the physical after-treatment, who will follow up the surgical reconstruction with a scientific and methodic after-treatment. This latter part of the treatment, which follows the surgical reconstruction, has been altogether neglected in peace times.

People follow only such occupations as are lucrative or interesting. No one would choose for an occupation something which he could use only at long intervals, and there never has been such demand for reconstruction as there is now.

AUTOPLASTY.

Autoplasty means the use of tissue or tissues from the same individual to restore a defect. Injuries destroy any kind of tissue and the healing process replaces highly organized tissue with scar, usually connective tissue. In this manner function is lost and it is the duty of the plastic surgeon to restore the function by replacing highly organized tissue with tissue of the same kind, if it can be transplanted.

Defects of maldevelopment from birth usually have a lack of highly organized tissue, or else this tissue is crumpled and thrown together in such a manner that it cannot be effectively used by the plastic surgeon, and he has to unravel such malformations and bring about such relations that function will be restored. The best example of this is the club-hand or club-foot, where tendons and bones and cartilages are irregularly thrown together and have to be properly replaced so as to get a useful hand or foot.

As an example of an injury with loss of substance, we may take a deep injury of the skull with a retracted scar leading down to the brain and exposing the same through the scar to injuries, and leading to epilepsy. The patient has survived the injury but functionally he is in bad shape. We cannot replace brain cells but we can replace the covers of the brain and through plastic work restore the skull to such shape that he has neither bad symptoms nor is exposed to danger.

Fortunately most of the tissues of the body are transferable and will heal in the new bed in which they are placed under favorable conditions. Nourishment, the blood supply, and nerve supply in some cases are essential for this growth. Some tissues require better conditions for life, while others are very resistant and survive removal or discontinuity from the body longer. There is evidence that even tissues from a cadaver, provided they are free from contamination, can heal in without reaction. But the best conditions for the life of tissues in transfer, or transplantation as we call it, are given if they are transferred immediately or left in contact with the mother-ground or mother-tissue, to be nourished there until sufficient nourishment develops from their new seat of transplantation.

This leads us to a description of the three principal methods of transplantation; namely, (1) the immediate transfer from the mother-tissue to the new nourishing ground (free transplant); (2) the transfer from mother-tissue of a portion of the new tissue, leaving by circulation an avenue of nourishment through a pedicle into the mother-tissue (pedicle flap); (3) the transfer of tissues kept artificially moist and warm for some time, but free from contamination, until they are required (late transplant).

Of the tissues which can be transplanted, the most favorable for transplantation, as far as life is concerned, is skin. It is also the tissue which is transferred most frequently. But other tissues that can also be transferred are mucosa, fat, muscle, fascia, periosteum, bone and nerves.

SKIN TRANSPLANTATION.

Skin is most commonly transplanted. It consists histologically of the epidermis and subepidermal tissue with all appurtenances, glands, nerve ends, and bloodvessels. Any portion of these catches if transplanted into favorable ground.

The most superficial epidermis cells, if they have some cellular life in them, are still capable of producing new cells by division and thus cover a defect with epidermis cells. Still better is the nutrition if these cells are taken off and transplanted as a plate, consisting of several layers of such epidermis cells, on to a surface rich in blood or osmotic nourishment. Still better is the chance for life if the skin is transplanted with the subepidermal tissue, which allows the vessels to grow right into the skin and forms a very good bridge for nourishment, leaving the tissue cells to regenerate quite abundantly. And lastly, the best chance is given if the skin with all its histological parts is left in contact with the mother-ground through a pedicle, so that it receives its nourishment from its old place while it grows into the new.

There are four methods of skin transplantation:

1. **The Epidermis Graft (Mangoldt's Graft).**—This is done by scraping epidermis cells with a sharp knife and placing them upon a clean granulation. The granulation need not be scraped. The method is as follows: Clean aseptically the surface of the skin which has good surface epithelium, like the arm, or a limb. Scrape the skin several times until you accumulate on the blade of your knife a whitish material like dandruff. Then spread the same over the granulation, allowing it to dry, and treat this surface either under a wire screen or cover it with rubber tissue, in the same manner as Thiersch grafts. Leave it exposed to the sun if possible but if you cover it with rubber do not remove the rubber tissue until a few days have passed, otherwise you destroy the attachment of some of the cells to the granulation.

After a few days one will observe a few islands of white material like macerated tissue, on the granulation, as if it had been sprinkled with chalk, and from now on they should be treated with great care, so that these islands can spread and join until the surface is covered by a resistant scum of epithelium and even connective tissue.

This method is especially favorable where large surfaces of very superficial loss of epidermis, as in burns or abrasions, have to be covered. Oftentimes small remnants of cuticular glands, sweat-glands, sebaceous glands, furnish such epithelial material spontaneously. It develops all the better when treated in a peculiar manner, which we have described as the adhesive plaster method. It seems that granulations have no tendency to be covered by the scum of scar or epidermis if they are allowed to gather on their surface the discharges of such granulations, consisting of pus, blood, and débris of cells, which easily dries out into crusts, under which the moisture macerates the tissues. Especially if microörganisms are present, or saprophytes are abundant, the healing of granulating surfaces is slow. Sometimes the granulations have an abundant stimulated growth; they develop into regular granulomata, cauliflower-like even, and have no tendency then to heal. Scraping these granulations, or burning them with silver nitrate will improve their condition and make them more apt to cicatricize and more favorable for transplantation, but pressure from the outside and the exclusion of air and saprophytic infection are still better. Adhesive plaster should be used with the resinous surface toward the granulation (where it can exert some pressure and draw the borders of the granulation together). Then the process of self healing or epidermization from the borders takes place very rapidly. We have employed this adhesive plaster method very often and found it very effective in covering large areas of granulations with epidermis and scar. The same result has lately been achieved by sprinkling granulating surfaces with islands of paraffin in volatile vehicles, so that the paraffin covers the surfaces with a scum, which allows rapid cicatrization of large areas of surface defects.

2. **Reverdin Graft.**—The second method is the Reverdin graft used, unfortunately, too seldom, for it is an excellent method of grafting skin in its superficial layers upon granulating surfaces. It is especially valuable in places where Thiersch grafts are not applicable, such as in depressions in which a skin graft cannot be well spread, or where greater resistance is required than a Thiersch graft would offer.

The method consists in raising the skin with a fine tissue forceps and cutting it off with scissors or knife, in a small round piece, and placing this small flap of epidermis with the same forceps on the granulation, pressing it down on the same, after it has been scraped and made bloodless by a hot compress. It sticks very easily and spreads like a small white star of epidermis. It grows from its border. Several such Reverdin grafts placed next to each other can cover an irregular depressed granulating surface or a sinus. Their after-treatment is the same as that of the Thiersch graft.

3. **Thiersch Graft.**—This is the best known method of transplanting skin. It is used very extensively but is unfortunately abused a great deal by many. It is a transplantation of a plate of epidermis, cut with a sharp special knife in such manner that the upper layers of the cutis are left behind, so that there is no scar on the place from which the graft has been taken.

The best places from which to take a graft are the surfaces of the arms and legs. The method is very simple, and yet it has to be learned so that it can be done accurately and effectively. First, clean the skin of arm or leg very carefully, preferably not with water, as the water macerates the skin and is difficult to remove. Benzine or gasoline is better, to remove the fatty dead tissue from the surface. Then clean the surface with alcohol, and in cleaning rub it a little, not too much, however, so as to bring a little better circulation to the surface. Then stretch with your left hand the epidermis from which the graft is to be taken, lay the knife (holding it with the right hand) flat on the surface and with sawing movements cut the skin flat horizontally, going with a sharp knife through the pyramids of the skin in the shape of rectangular strips of a length as you require. It is not well to use too large a graft, although sometimes they adhere and heal in when of quite a good size. As the movements of the knife carry you toward the end of the rectangular flap, it wrinkles up on the knife blade, and it is an important trick to get the flap off square; otherwise by trying to get it off one pulls the flap from the knife easily and even has difficulty in

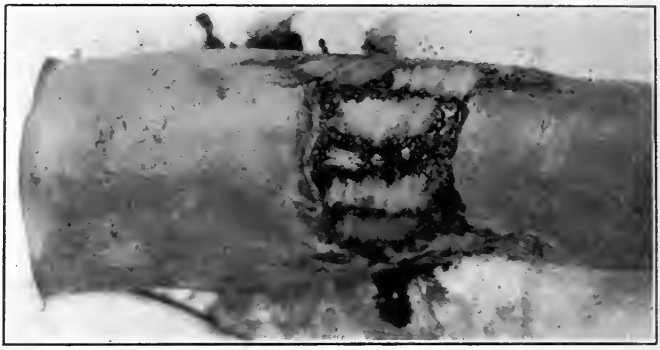


Fig. 357.—Photograph of an actual case of skingrafting with Thiersch graft. In the center two Reverdin grafts.

Fig. 358.—Showing the method of Thiersch grafting. Note the position of hand and knife.

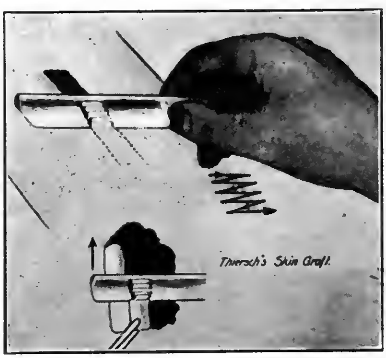
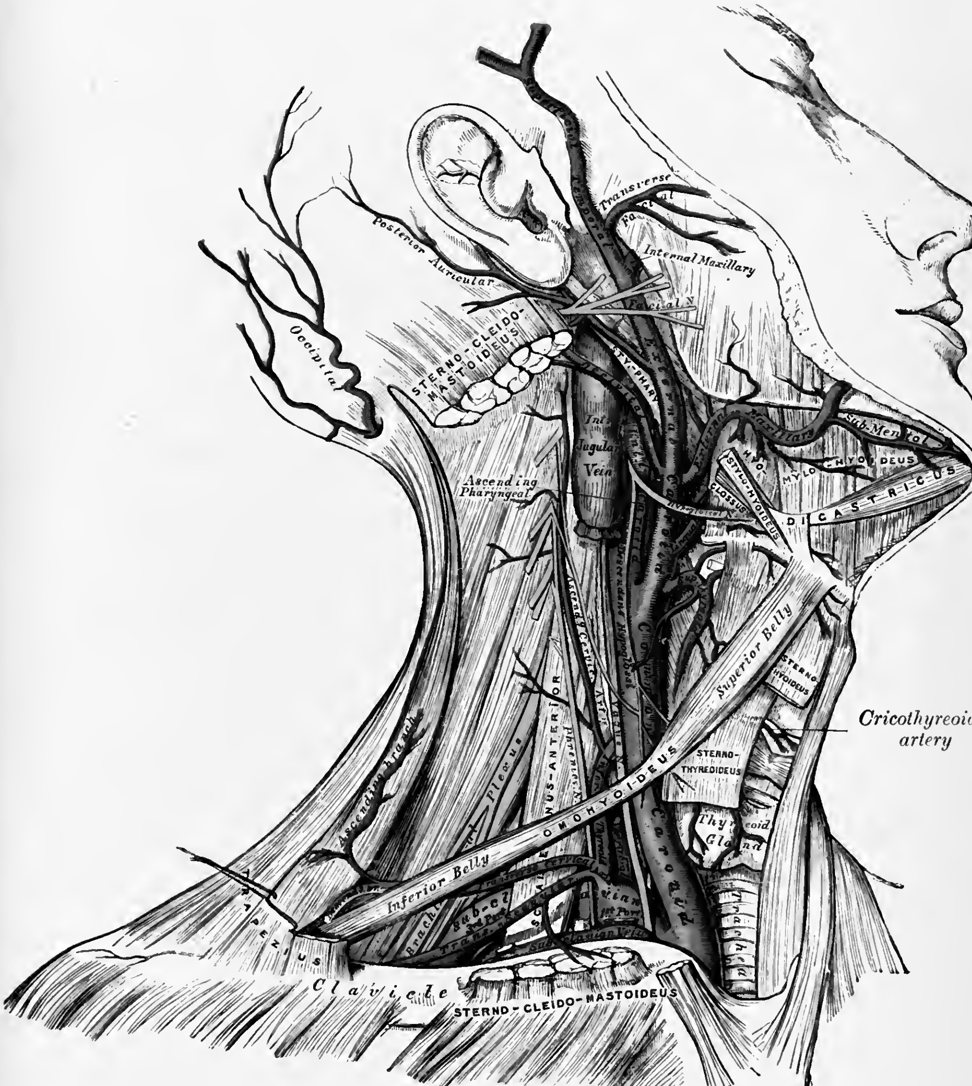


Fig. 359.—Showing the sawing motion and the method of spreading of the grafts on the granulating surface.

straightening it out again. Then the flap is carried over directly on to the surface to be grafted and spread over the same, graft next to

PLATE I



Applied Anatomy of the Arteries of the Neck, Showing the Carotid and Subclavian Arteries. (Gray.)

In considering the removal of tumors of the neck, it is of greatest importance for the surgeon to bear in mind the relation of the anatomical structure shown in this illustration, because this will enable him to avoid injuring any of these structures unintentionally.

graft, leaving possibly a very narrow margin of granulations between them so as to allow some secretion to escape. The granulation, as a rule, must be prepared by freshening it, as we call it. This may be done with a sharp curette, scraping off the granulations and the more resistant structure of connective tissue and applying a hot compress to stop the oozing. It is better to do that before the grafting is started, so as to assure perfect hemostasis and better sticking of the grafts upon a dry surface. The grafts should be spread out carefully like microscopical specimens, looking carefully after the borders, that the same should not be rolled, with their intact surface toward the wound. They may overlap slightly, but this is not a very good procedure, as a portion of them has to slough. And nature does this sometimes effectively and sometimes does not.

Fig. 360.—The same case as Fig. 357 after healing has taken place; connective tissue between the grafts is scarified and somewhat elevated.

The surface of the granulation has to be prepared in many instances especially, so that any infective material is removed.

It is not good to have air bubbles under the grafts. They can easily be removed by stroking the surface with a needle until the air is eliminated.

If spaces have to be covered which require a certain shape or size of graft, then it is best to outline the shape on the arm or on the leg with a sharp knife, cutting into the skin, and then cut the graft through these incisions, so that the graft will have the required shape; for instance a triangle.

After the granulating surface has been covered with grafts, it is well to allow the air to dry it for a certain time and then it can be treated in different ways. One good method is to use strips of gutta percha, spreading those strips over the surface so that they cover the whole grafted surface, criscross, then fastening, if possible, an adhesive strip over gauze over the whole wound surface, so that these grafts remain immobile. This is a very important precaution, especially when patients are unruly, or in children, before we apply an ordinary dressing. This must not be disturbed for about six or eight days, and when one changes it, one finds that the grafts which have taken have a reddish-blue appearance, are somewhat macerated on the surface, and after rinsing off with salt water the débris, oftentimes the most superficial layer of the graft floats off, as a dead membrane, while the bulk of the graft sticks and remains permanent. This is the best success. If they are bluish, dark, and bloody, they will not stick, or only small portions will. From now on they may be treated with salves or moist dressings until the skin appears covered with a dry coat of epithelium.

Another method of after-treatment of the Thiersch grafts is the open method. After the wound has been covered with the grafts, it is allowed to dry and the limb, or portion of the body, is covered with a wire basket, so as to protect it, and the air and sunshine is allowed to play upon the surface. The blood oozing from between the grafts will quickly form crusts between the grafts and after a few days, perhaps a week, these crusts will fall off and a dry surface of reddish color will indicate that the granulation is successfully covered.

Indications for the Different Kinds of Skin Grafts.—Thiersch grafts should not be used on any places which require a great mobility or which have a great deal of fat in the subcutis. Where one uses grafts on fatty subcutis, they shrivel up and disappear, but on regions like the forehead, on regions between joints, on the neck, they may be safely used. Over joints, over fatty regions, on the face, skin grafts should not be used; pedicled or free flaps are preferable.

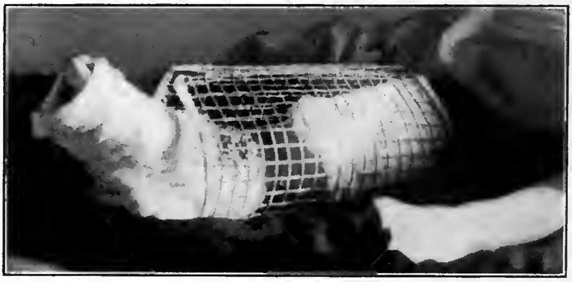


Fig. 361.—Basket method of skin grafting, the grafts being exposed to air.

One may use grafts from other individuals, heteroplastic grafts, but it has been my experience that in the majority of cases these grafts, even when they healed primarily, sloughed later on gradually, and left hardly any trace of their former existence.

The Mangoldt graft is especially indicated in cavities of large extent, like the pleural cavity, in the extensive thoracoplasty, after burns, etc. The Reverdin graft especially on narrow lanes of granulations, fistulous tracts, and dimples of granulations.

Free Flap Transplantation, Wolfe-Krause Grafts.—This is a method of transplantation of cutis which consists in cutting out a flap of skin, with the subcutaneous tissue, and transferring it without a pedicle into its new bed. The best place from which to take these free flaps is the upper region of the limb or arm, where the skin is usually abundant and well nourished. The femoral region is especially favorable when we have to take fascia at the same time.

The flaps are cut out in elliptical form, because this form allows the best approximation if a suture should be necessary. As a rule, it is not advisable to suture with many stitches; only a few points of attachment are necessary, sufficient to keep the borders in good contact. The size of the flap must be about one-third larger than the defect, because the flap shrinks after being removed. It is not necessary to have the flap absolutely free from fat but it is not well to have too much fat with it, as it liquefies and prevents a good adhesion between granulation and flap. It is best to have the flap appearing like thick glove leather. In this condition it sticks best to the surface.

The free flaps may be transferred to any part of the body but best to places where fat is usually present or expected to develop, like the cheeks, the hands, or the fingers. They are especially favorable for defect after the removal of tumors. The surface to which they are transferred must be in a good, resistant condition and if granulations are present, they must be scraped off and made absolutely dry. If a free flap is transplanted immediately after the removal of a tumor, complete hemostasis must be secured first, and the flap squarely pressed upon the surface, so that an intimate contact exists. A few points of suture may secure it. The after-treatment is similar to that of Thiersch grafts, with rubber strips or with open treatment, but a dressing may also be applied.

The results are not always very favorable, especially where the circulation of the new territory to which the transplant has been transferred is not very good. The flap then appears dry, getting darker and darker and parchment-like, sometimes sticking with a few points to the surface of granulation tissue underneath, but separating on the sides. If the flap appears in this condition, it is usually going to slough out. If the flap is moist, or macerated, it will slough, but the lower layers will usually adhere, and it may be weeks before the whole flap comes off. It is only when the flap shows very soon a reddish color that one can be sure that it is becoming adherent. Occasionally a bluish flap recovers color. Some additional help will be offered by local application of heat, a hot water bag. But too much heat may also spoil the graft, therefore, great caution is to be exercised.

On the whole I must say that wherever I can use pedicled flaps, I prefer them, and Wolfe-Krause grafts only where a pedicled flap cannot be obtained. Particularly unfortunate has been my experience with flaps of this character, transferred from one individual to another. In this manner we would have been able to secure a good deal of material; for instance, in a case of amputation we could have used large skin flaps for some granulations, but free flaps of this character do not heal very well.

Pedicled Flaps.—There are two means by which these pedicles, which convey the circulation into the flaps from the mother tissues, while they gain their circulation from the new locality, can be taken. The first method, which is very important and has to be practised a great deal before one can apply it successfully, is that of gliding or lateral displacement. It is only applicable when one uses flaps from the direct neighborhood, and there are some very typical rules about it, which have developed in course of years. So old are these methods of gliding that we find in Celsus's *Seventh Book of Medicine* (DeCutis) they are described in the main and I have no doubt that long before, in Assyrian and Greek medicine they were used to cover defects. We are making use of this method even in ordinary surgery when we remove large pieces of surface skin with tumors, like breast tumors,

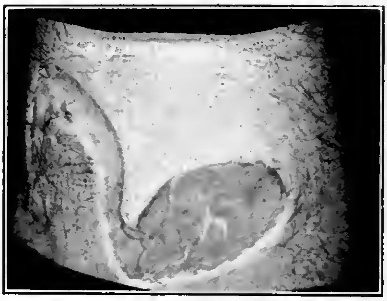


Fig. 362.—Method of transplantation of a flap, with pedicle.

and in emergency surgery where the integument is destroyed through an injury and the lower strata can be covered by such plastic methods. This gliding of a flap is nothing else but making skin of a very pliable character stretch over a defect by tension. Of course, that tension must not be too great, otherwise the circulation will suffer, stitches will cut through, and the result be spoiled.

Fig. 363.—The same after pedicle is transplanted and sutured into place. Defect caused by removal of pedicle is also united by sutures.

In the main there are several types of this gliding method. First, where we have a small triangular defect, we may suture the three sides, so that they form a three cornered suture or scar afterward, pulling the center together. If this is not possible, or if there would be too much tension because the defect is too large, we can make a rectangular flap with its circulation in the base. We can also use, if the defect is not exactly triangular but more or less rounded, the same method by making a double pedicled flap. In quadrangular defects we can also use the method by enlarging the incision and bringing skin from the neighborhood over the defect without much tension, so that after it heals there will be probably very little scar left.

A second way consists in the forming of a more or less tongue-shaped skin flap, which remains with its base permanently or temporarily in connection with its matrix tissues. The shape can be varied. It can be wider on the top, narrower at the base, or wider at the base and narrower at the top, but care must be taken that circulation runs from the base toward the top but not reverse. It is also well to preserve if possible the track of nerve supply. Both should run in the long axis of the flap. This flap with its pedicle must be somewhat larger than the defect, and must not be stretched to such extent as to cut off by tension or twist the circulation. Some twisting is oftentimes necessary but when doing so one should be careful not to obstruct the whole circulation. This can easily be ascertained by noting the fact that the flap after its adaptation to its new position soon regains a slight rosy color or at least the color of the tissue where it came from. If it appears blue or cold, it will die.

These flaps are best sutured with their borders as exactly as possible, and with as broad adaptation as possible, to their new place. One of the requisites for good healing is this broad apposition and exact suturing. It is important also that a portion of the flap should be in close contact with the new mother-tissue along the borders, and that slight pressure (by no means enough to retard the circulation) should be exerted by dressings or adhesive plaster, to keep these flaps in position. In a few days we can tell whether the flap remains alive. The color will soon betray its fate. Sometimes small parts of it die off. Then we will see that one part changes its color, becomes darker and finally black, and the blacker portion will demarcate itself and separate from the rosy portion. Sometimes only the surface dies off while the thickness of the flap remains, so that we have a thick flap with granulations on top of it in some portions. We call this a partial gangrene. As a rule it takes eight or twelve days to establish fairly good circulation in a flap. If it has only a temporary connection with the matrix, it can then be cut off at the pedicle and this pedicled side should be sutured into the fourth side of the defect opposite the pedicle, so as to secure good circulation for this side also. It is safer to wait a few days longer, if possible, before one cuts the base supply of the flap. The longer one waits the better will be the success of the operation. Of course, in the Italian method where the arm is fastened to the face, the arm cannot be left too long in its new position, because the discomfort is so great; but on the other hand, the face is so well supplied with nutrition that the flap will adhere quite quickly there.

The pedicled flaps are used in all cases where defects of skin have to be covered which require a great pliability, like hands, fingers, joints, and face. They may come from distant regions, from chest to arm, from one foot to the other, from hand to foot, from arm to face, and so on, and are often selected with a great deal of ingenuity. If one knows the chief principles of transplantation and expected circulation, one can invent innumerable variations of this character, some of them most bizarre and extraordinary.

Interesting experiments have been made where one can transplant a flap by double transplantation, so-called migrating flaps. For instance, if we should transplant the skin of the buttocks on the breast, it would seem impossible. But if we heal the arm first to the buttock and after firm adhesion has taken place, cut the flap loose from its pedicle and instead of uniting it to the fourth side of the defect of the arm, which does not exist in this case, transfer it to the defect on the breast, we may be able to obtain circulation from the breast to the flap and then after it is healed on tightly, separate it from the arm again, thus finally accomplishing the feat of transferring the flap from the buttocks to the breast. Of course, one has to give a great deal of time to this healing process, more than is necessary for ordinary direct flap transplantation.

The healing process of all these flap and graft transplants is well known and was studied very accurately many years ago. The nutrition is at first an osmotic nutrition. The cells are kept alive at first by a process of biochemical nourishment, without really having constant nourishment, and therefore they are in a state of lower vitality in the transplant. But it shows how much vitality there is in them if they can keep up without disintegration for days until a steady flow of nutrient material is secured by the budding of new bloodvessels into the tissues and the use of former avenues of nutrition by the new bloodvessels. One can observe in the microscopic specimens, especially those which have been prepared by the early observers, all these stages of transition, from the moment of transplantation up to full embodiment of the transplant into its new position.

Transplantation of Tissues Other than the Cutis.—1. **Bone and Periosteum Transplantation.**—Bone can be transplanted and has been used as a transplant for many years. It may be used as a free transplant, as bone alone, or bone with periosteum, or it may be transplanted by leaving it partly connected with its former position by a periosteal pedicle, through which it receives some nourishment while it grows into the new position.

Much discussion has recently taken place as to whether the bone after being transplanted grows in its new seat with or without its periosteum, or whether the bone is gradually absorbed and dies, and is replaced by new bone from the periosteum. There have been observations with the *x*-ray and microscopic examinations which seem to justify the conclusion that while under very favorable conditions bone remains after it has been transplanted and does not grow, under more favorable conditions, when periosteum has been transplanted with it, it grows better, and that sometimes bone grows when only periosteum has been transplanted. For practical purposes it is best to use bone with periosteum, if possible, for transplantation. In many of our transplantations we are able to transfer not only bone and periosteum but whole flaps of skin, subcutaneous tissue, periosteum and bone, leaving this arrangement of tissues in contact for a time with its matrix, so as to assure good circulation.

The growth of bone, when only bone and periosteum is transferred is slower. When periosteum has not been obtained, it may happen at times that the bone is partially absorbed by formation of lacunæ and gradual absorption.

It is always well, as Lexer points out, to cover bone with periosteum or with such remnants of tissue as the bed offers and to bring it in close contact with bone marrows or another substance of the same kind of well nourished tissue in the new bed. This condition is better fulfilled, he says, in long bones than in the small bones of the face.

An important matter in transportation of bone from one place to the other is to handle it as little as possible and to make the operation as complete and with as little damage to the bone as possible. I have found that in transportation of bone from the tibia, a sharp cut bone without many slivers on it, with a nicely bleeding surface and with a good slice of periosteum attached, which is not handled at all except by instruments, heals in best.

2. **Transplantation of Cartilage.**—Cartilage may easily be transplanted and heals in beautifully in the new location. The most extensive use is now being made of this transplantation. Mangoldt and Koenig have proved that cartilage heals in when the perichondrium is transplanted with it. Otherwise it is absorbed. I have used cartilage in a great many forms and in places where bone has formerly been used, especially in plastic surgery of the nose and ear, where form and resistance are to be given to some parts. Remarkable is the fact that cartilage and bone may be much more easily transferred from another individual, than other tissues. I have repeatedly, with good success, implanted submucous cartilage of the septum, removed by submucous resection, into the ear and nose, and found it healing in beautifully without reaction. It forms an excellent material in our plastic operations, the only requisite being that the cartilage be perfectly aseptic and cut very clean. But we can find plenty of cartilage on the individual himself, using the costal cartilages for our plastic operations.

3. **Transplantation of Fascia.**—Although fascia is a connective tissue with very little circulation (or perhaps because it is so resistant), it forms a good and easily obtainable material for transplantation into soft parts where resistance is demanded or where tissues require a sheath of some kind. We have in the fascia lata of the thigh abundant material for transplantation and being able to take some fat with it we can make a soft pillow for tissues, which require a great deal of protection, like nerves, or we can use it as a cover for the brain in a defect of the dura, or we can use it to cover a hernia, as in a flap to reinforce the hernial wall. It may be used to advantage to imbed nerves or muscles and may be used with great advantage to form sheaths for tendons. It is necessary to handle it very carefully with instru-

ments and not hands, to keep it strictly aseptic, and to fasten it where it is required to be stretched over a surface. It is a good material between ends of bones, to form a joint surface, in cases of artificial joints. Kirchner's work on fascia transplantation gives a remarkable review of all the possibilities.

4. **Transplantation of Fat.**—Fat was at first thought to be a very poor transplant, on account of poor nutrition, but Rehn has shown that it is well suited for this purpose. Even a fatty tumor has been transplanted to replace a breast after its removal by Czerney. Especially valuable is fat transplantation when it is used to prevent

Fig. 364.—Cranioplasty and fascia transplantation into a defect in the skull, after removal of the scar. It resulted from a kick by a horse, and was followed by epilepsy.

Fig. 365.—The same case after healing.

scar formation, as around tendons and nerves. If we transplant a tendon we want it to slide in a sheath, and that it can do only when there is no connective-tissue formation around it which binds it tightly to the neighboring parts. If we take fascia with fat and use the fat as a pillow around the tendon, the fascia as a sheath, we have an ideal material for tendons and for nerves for this physiological purpose. The fat gradually is absorbed and leaves behind a loose, very scant, fibrous network with a few fat cells between, which allows a good deal of motion.

Another very interesting use of fat is to fill cavities temporarily or permanently. I have used it repeatedly to fill out the defects in cheeks.

However, so great is its shrinkage that I had to take about ten times as much fat as ultimately I would like to have present.

5. **Muscle and Nerve Transplantation.**—The more highly organized the tissues are, the more difficult becomes their transplantation. Nerve and muscle transplantation is especially difficult, but it is possible to transplant them and have them physiologically active. A great deal has been written and an enormous amount of research work has been done in regard to nerve transplantation. The finer nerves, ganglionary cells, cannot be transplanted and retain their functional activity, but nerve fibers and particularly nerve trunks may be transplanted permanently, although the process of regeneration eliminates transplanted nerves and uses their structure only for a track of new formed fibers. The original nerves undergo regressive metamorphosis. Especially in nerve transplantation is it important to avoid everything which tends to form scars, and fat is one of the favorite co-transplants to prevent this.

Still more difficult is the transplantation of muscles, as the muscle is dependent upon nerve influence for its existence and with the cutting of nerves the transplanted muscles undergo regressive changes and the physiological part of them disappears and only fibrous connective-tissue structure remains. In fact only if the nerve and blood supply is left intact, may whole plates of muscles be transported from the place of their origin to their new attachments and then become physiologically active. Especially valuable are such transplants of muscles in connection with bone, cartilage, tendon, fascia, and skin, in a compound flap in amputations and under other conditions.

6. **Mucosa Transplantation.**—In many respects mucosa resembles the epidermis in its transplantation and it may be transplanted free or pedicled and will heal in very well. One interesting factor is the change of mucosa into epidermis and epidermis into mucosa when we change their respective locations. For instance, if we transplant skin into the mouth, we observe that it retains its resistance for some time, but gradually becomes rosy colored and thin and while it never becomes a real mucous membrane, to all appearances it is one, being sleek, red, and very thin. Hair, which has been originally present, grows at first, but the follicles undergo regressive changes, so that it may be pulled out very easily and falls out after it has grown to a certain size spontaneously. I have seen this happen in the mouth and in the urethra in a case of formation of a new urethra from the scrotal epidermis. In the latter case the hair proved a great nuisance, as the crystals of uric acid and phosphates formed around it in crusts which annoyed the patient a great deal. In our plastic operations on the lips and cheeks and eyelids we use mucosa considerably for transplants.

Hair and Tooth Transplàntation.—Both hair and teeth may be transplanted, and very interesting experiments have been made; but as a rule the toupée and artificial plate answer every purpose, so that the implantation of teeth in the jaws or hair on the scalp (even if such could be accomplished) has a more theoretical than practical interest;

but under certain circumstances we may have to transplant hair, into the eyebrow for instance, and this can be easily done by taking a narrow strip of the scalp and making either a free flap transplantation or else leave the flap in contact with its original scalp nutrition until it has healed in perfectly, then cutting it loose.

HETEROPLASTY.

The transplantation of tissue from one individual to another is called heteroplasty. A great deal of experimenting has been done upon animals and to some extent also upon human beings, by Lehr, Küttner and Payr, with joints, and some very encouraging results have been reported; but on the whole outside of cartilage, and bone, and some skin grafts, little which is encouraging has been heard from any source. We had great hopes when Carrel first published his results on the transplantation of organs with connection of circulation, that during the war there might be a chance to experiment to some degree in this line; but it seems that it was impossible to do the ideal work of transplantation of arms, or feet, or kidneys, which succeeds occasionally in the animal laboratory, and nothing definite is known at present as to such experiments.

ALLOPLASTY.

The implantation into the body or the use in plastic work of foreign inorganic material, such as gold, silver, hard rubber, paraffin, ivory, metal plates, screws, silk, etc., is already possible and a great deal of use has been made of these materials for various purposes. All the protheses belong to this chapter; the artificial eyes, the false teeth, the plates, the obturators, the artificial noses, the artificial limbs, show that enormous progress has been made in this direction.

ANESTHESIA IN PLASTIC SURGERY.

A great many of our plastic operations may be done under local anesthesia. No general rules can be laid down as to what can be done under local and what under general anesthesia. The individuality of the patient and of the surgeon in this respect plays an important rôle. While one surgeon would be unable to do anything with some patient under local anesthesia, another surgeon may be able to perform an extensive operation, simply by knowing how to handle the patient. I have done extensive plastic operations in very delicate portions of the body as for the relief of hypospadias, eye, nose and ear defects, under local anesthesia on some patients, while in others it was absolutely impossible to make even a Thiersch graft without general anesthesia. As a rule, I have preferred general anesthesia in all cases in which I have had to do a good deal of cutting, because the patients have done better and asepsis was easier. Of course the cumbersome apparatus of anesthesia will be in our way if we have to operate on nose or lips or ears, and in such cases we have to use the direct ether method, by placing a tube in the mouth. An exceedingly good method, which I have found very satisfactory in some cases, is the scopolamin-morphine anesthesia, by which a prolonged relative apathy of the patient can be obtained, and although he is not fully asleep, a great deal can be done while he is in this semiconscious condition. In fact, I have lately performed a most extensive rhinoplasty, working on the nose for about two hours, while using this method of anesthesia.

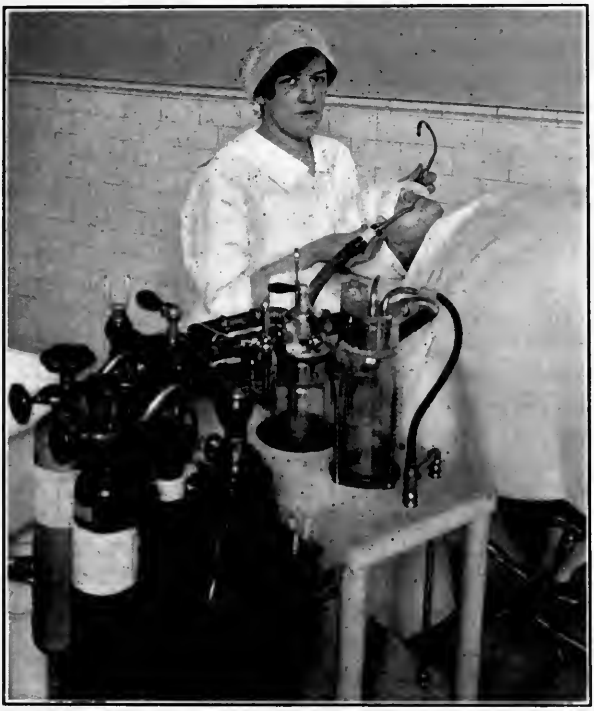


FIG. 366.—Method of administering ether directly into the mouth of a patient. A motor drives the vaporized ether through a curved tube, the nurse is holding in her left hand one to show the shape of it. The apparatus allows at the same time suction of fluid from the mouth and if necessary, also to administer gas through the same tube; as one can see, the patient's face remains absolutely free so that the surgeon can operate without being disturbed by any apparatus on the outside or any mask.

The local anesthetic we have been using almost exclusively is a 1 per cent. solution of novocaine. An abundance is injected into the structures to be attacked. The edematous condition which lasts for some time after the injection is rather irksome and gives a great deal of annoyance, although it may help to visualize scars.

The anesthesia is important in cases where we have to immobilize the parts operated upon, as motion of those parts during the dressing may destroy the results. In young children general anesthesia is absolutely essential.

PREPARATION OF THE PATIENT FOR PLASTIC OPERATIONS.

The preparations for a plastic do not differ from those for a general major operation. It is not good practice to scrub or rub tissues much before operation; it is much better to depend upon cleansing with benzine, alcohol, or iodine shortly before the operation. In the general preparation we have to use the same precautions as we do in all cases where we intend to give general anesthesia. The bowels and stomach should be looked after particularly. For instance, in nasal and mouth operations, repeated vomiting afterward may do great damage.

About the conditions of tissues necessary for plastic work, we will speak when we discuss the technic of operations and in the special part.

AFTER-TREATMENT OF THE PATIENT.

One of the important factors in the after-treatment is that the same should not be entrusted to general attendants. Success alone should be considered in plastic work and this can be achieved only when all is favorable. After-treatment often ruins the plastic result. It is more important than in general surgical work, which can often be entrusted to an assistant. Such trivial manipulations as the removal of stitches may in plastic surgery cause a separation of the wound which has recently healed and destroy the entire effect.

Oftentimes the only circulation that a flap has lies in the junction of borders and if stitches are removed too early, separation may lead to traumatism and hematoma. The flap which has healed by first intention, as we say, may become gangrenous secondarily, through faulty after-treatment. In some of the plastic operations, especially around the mouth, one has to maintain a certain cleanliness after the operation and that can be done only by an expert, as rough handling or inopportune manipulation may also destroy some of the finest surgical results.

Plastic operations often extend over a long period and *a priori* require more than one operation, many corrections, and they try the patience of the doctor and the patient. Therefore we often decide upon operations long before the indication is present and before the patients are in the best condition for a plastic operation. To rush the work is one of the common faults of plastic surgery. Never undertake a new operation until you are sure that the proper time has arrived.

CRANIOPLASTY.

Plastic operations on the skull and its cover are by no means rare. The causes of defects are congenital or acquired. Among congenital defects are some very rare affections which require plastic operations, although most of the cases of cranial defect are such that the individuals are not normal enough to warrant extensive operations. One of those in which operation may be indicated is a congenital defect of a part of the skull with meningocele in an otherwise normal child, which if untreated may suffer injury of the brain or epilepsy. The operation for such a case, which I have performed only once, is the same as for a defect due to traumatic injury and therefore I refer to the method indicated there. Remarkably common are the plastic operations for defects of the skull and scalp due to injuries, especially in war times.

1. **Injuries to the Scalp, with Defect of the Scalp.**—Small or larger portions of the scalp may be missing and if otherwise no deeper injury to the skull is present, granulation will take place and ultimate cicatrization, with the result of a more or less extensive scar of the scalp. A large portion of the scalp may be replaced by the scar, but such scars are unsightly, easily vulnerable, and often do not form because the approximation of the wound borders is not possible. Here is the opportunity for plastic flaps. Inasmuch as the borders of scalp wounds can be approximated in some directions better than in others, the flaps may be formed in different designs to cover such a defect. Especially the tongue-shaped flap, with its base directed toward one of the large ascending vessels, like the temporal, occipital or frontal artery, will be valuable to cover the defect. Skin grafts also may be used to advantage on the scalp.

2. **Skull Injuries with Defect.**—This condition is the most common in cranioplasty for traumatic injuries. Portions of the skull may be broken out, sloughed out, or even removed during operation because they could not heal in after the operation. Such portions of the skull can be replaced and the skull capsule made absolutely hermetic again by plastic surgery. War injuries are frequently objects of primary and secondary plastic operations.

For the sake of completeness I will describe a primary plastic operation. A skull which has been injured, let us say, by the kick of a horse (as in one of my cases) has a lacerated wound of the scalp, a compound comminuted fracture of the skull, portions of the brain with the ragged dura are hanging out. The first indication is to save the life of the patient. The second, to prevent damage, if possible, to the function of the brain. Third, to prevent any healing which might later expose to injury or discomfort, like a hernia of the brain.

The first indication is the most important. Shock, hemorrhage, infection, are the dangers. In such cases, which are very much like war injuries in their aspect, prognosis, and treatment, the first step is to prevent accidental infection by special care in all manipulations not to add any new dangers of infection and to make those which are already present as harmless as possible. After the patient's general condition is taken care of by stimulation, and the hemorrhage is stopped by aseptic compression or by grasping the spurting bloodvessels with forceps, clean the surface of the scalp as for an intracranial operation, shaving and cleaning the external surface with benzine, alcohol and iodine, removing all extraneous matter, snipping off badly lacerated portions of skin and brain substance and removing all loose particles of bone. If the wound is such that the extraneous matter might have entered under the scalp or into the mass of crushed tissue, incisions in three directions are made, so that the flaps lay the wound open. (Tripod Incisions.)

Up to this point all have agreed in pre-war times on the treatment and nine surgeons out of ten would have treated the wound with drainage, but the experiences at the different fronts during the war show that after removal of all objectionable tissue, the flaps in the three directions could be brought together and united over the defect, leaving a thread in the corner to allow the escape of liquid retention, and that the results are far better than to allow the wound to drain and intracranial masses to protrude and to granulate. Therefore, primary suture seems to be the advantageous method. Some plastic work might be necessary, in order to cover small defects. If by chance the portion of the bone which is loose can be placed over the wound, it may be of advantage to do so. As the reports of some of the brain surgeons of the late war show, this method gave greater satisfaction than drainage.

Remote Treatment of the Skull Defect after Injury.—If, as is usual, primary union or slightly delayed primary union takes place, then the question arises of secondarily filling the defect of bone with some more resistant material than the scalp, and for this purpose we have several means at our command. But no operation should be undertaken until everything is healed and inflammatory reaction has disappeared.

Cranioplasty after several weeks or months consists in the following steps: First, more or less of a flap incision over the defect and on the outside of that, with the base of the flap in the direction of one of the leading arteries. This flap includes the scalp and pericranium. The scar of the pericranium or periosteum leading to the dura and brain is resected. The defect in the dura is replaced most conveniently by a fascia-fat flap from the thigh, with the fat directed toward the brain, the fascia sutured with as few as possible single sutures of catgut into the border of the dura and the flap resutured. This will give a fairly firm plastic result but not strong enough to prevent injury. Bone, or some harder substance than fascia, should take the place of the defect in the skull. For this purpose cartilage has been found to be extremely valuable. It can be introduced between fascia and skull through small slits in the skin after everything is healed, until the whole plate of cartilage has been produced in this manner. The cartilage may be introduced at the first operation but in many instances it will slough out, because fascia and cartilage will not heal as readily as fascia alone. Bone may also be introduced but is not as good a material. The old Mueller-Koenig operation, which consists in taking a portion of the external table with the skin-periosteum flap, is a splendid operation in the hands of an expert. I have done remarkably well in some instances with this operation but I have failed in others because the bone crumbled away.

Frey's Method of Covering Defects in the Skull.—The method suggested by Frey, consisting of a double pedicled flap of periosteum, to cover the defect in the skull, without using any bone, is perhaps the nearest approach to the normal. It consists in the following steps: A longitudinal or flap incision over the skull defect and separation of the scalp above the periosteum to one side, far beyond the defect, making a parallel incision into the periosteum, loosening the bridge of periosteum from the skull and displacing it by traction over the defect, suturing it there with a few stitches.

I have no personal experience in this method but I should judge that only smaller defects can be covered in this manner, inasmuch as it is difficult to make such displacement of bridge flaps of the periosteum.

Fig. 367.—Cranioplasty in syphilis. Case of post-syphilitic scar with deep retraction.

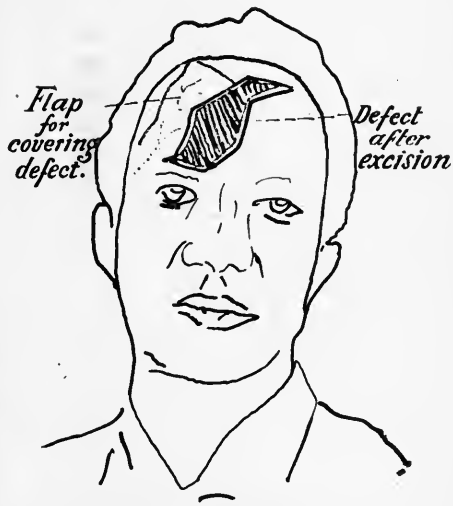


Fig. 368.—Method of cutting the flap and transplantation of the same.

Restoration of the Defects Produced by Disease (Syphilis).—There is one disease which has given a good many cases to the plastic surgeon, namely syphilis. It has a practical significance in plastic work because in the first place the process in itself is such that ideal results can be obtained only after the disease has been eliminated from the body, and second because the tissues of a syphilized individual or an individual that has had syphilis are entirely different in their healing reactions from normal. These two points have to be taken into strict consideration by the plastic surgeon. Fortunately we have in the Wassermann reaction a good test to assure us of the first condition, but we have no test as to the resistance and reaction of tissues. Implantations of bone, cartilage and foreign material, like metal, rubber, in such individuals must be undertaken with the greatest reserve, because very seldom do they remain within the tissues. On the other hand cicatrization and bone formation are very vigorous in syphilized individuals. The bones are especially apt to react with hyperplasia, which is a great help in syphilitic individuals. Cranioplasty is often necessary in individuals who have been afflicted with this disease. The skull becomes frequently the seat of necrosis and sometimes extensive necrosis of bones which leads to their exfoliation by depressions and loss of substance on the skull. Plastic operations in these cases should restore only the scalp, if there is a defect. The skull will take care of itself, as an example typical of this kind will show.

FRONTOPLASTY.

Frontoplasty is the restoration of the forehead. In a general way the forehead is not different in regard to plastic restoration of defects from the skull and scalp, but being free from hair and so easily exposed to view, it becomes important to treat the wounds and defects of the forehead particularly with respect to cosmetic results. Scars on the forehead, however, are rarely of the kind that leads to keloid. They become easily effaced and the forehead can stand a great deal of injury and plastic manipulation. The circulation is excellent and I have never seen gangrene of a flap taken from the forehead or implanted on the forehead itself. Besides, the forehead is a good place for using skin grafts. They heal excellently and for this reason it is one of the best places for their employment.

Defects in the skull on the forehead are relatively frequent. Their treatment is on the whole the same as the treatment of skull defects.

TEMPEROPLASTY.

Plastic surgery of the temples does not differ in any way from plastic work on other regions of the skull, except that in this case the replacement of bone is not so important. The thick temporal muscle, with the fascia, acts as a strong protection, even in cases of defect of the skull in this region, so that a hernia here is rather a rarity. Forehead and temples are particularly good regions for Thiersch grafts.

RHINOPLASTY.

General Considerations.—Rhinoplasty is one of the most studied and oldest subjects of plastic surgery, on account of two conditions. The partial or total loss of the nose and the very ugly deformity due to syphilitic lesions has led to the development of the "Italian plastic" of Tagliacozzi, whose patients came to him from all over the world to have their noses restored. He developed his method so well that it has ever since retained the name of "Italian plastic." The second great impulse for rhinoplasty was due to the fact that in India a method of punishment (a sort of national custom), was the cutting off of noses, and many of these people afterward applied to specialists for reconstruction. It is called the "Indian plastic." These two methods are supplemented by a third method, which is developed by the surgeons

FIG. 369.—Temperoplasty. A case of lupus, most of it healed, on the temple, by radium and skin transplantation.

themselves and consists in different experiments and trials to restore the shape of the nose *in toto* or in part by borrowing some skin from the neighborhood and some bone from a distant part of the body and twisting them into shape or position so as to reconstruct the nose gradually. Many of these methods are successful and their number is legion. It is impossible almost to go into detail. There are, however, a number

FIG. 370.—Transplantation of flap from the lateral portion of the face after excision to prevent retraction of the eyelids.

FIG. 371.—Result after healing.

of methods which go under the name of this or that author, which represent a type of reconstruction, partial or total. At a glance the surgeon can see from the schematic figure how that method works, and if he does not see it, no amount of description will add to his

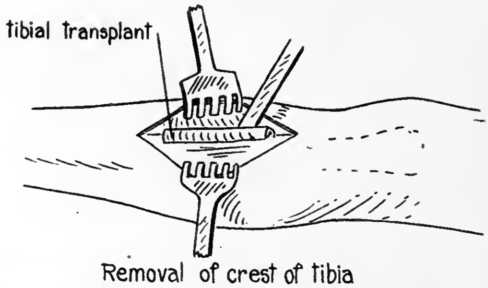


Fig. 372.—Method of removing a portion of the tibia to use for nasal transplant.

enlightenment. He must look upon these figures just as an architect looks upon a plan. They give him a general idea of the way the surgeon should cut a flap to cover a defect and how he should apply bony surplus from the neighborhood or from a distance to improve the shape.

One of the more modern ways, and one which I must describe a little more in detail is, however, based upon the fact that we can

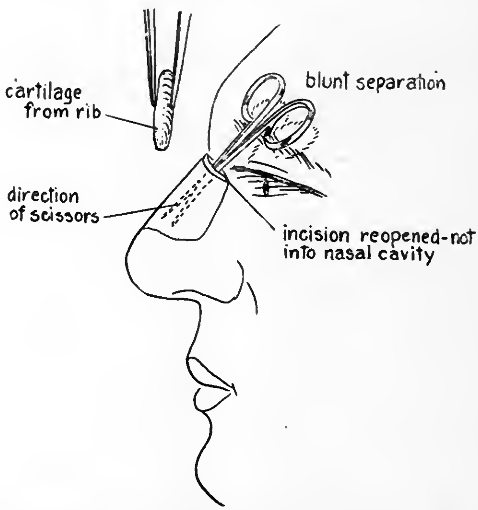


Fig. 373.—Method of tunnelling the nose with shears or pointed scissors before introducing a cartilage into the nose.

transplant and implant bone and cartilage into the nose taken from another region of the body as in cranioplasty, under skin which is already adherent and which is separated bluntly from its underlying structures, thus forming a pocket for the reception of the transplant. The simple method is this: Supposing I wish to implant on a certain place a piece of bone or a piece of cartilage, I would determine the exact spot where I want to implant it and try to raise the skin on this point from its base, so as to form a suffi-

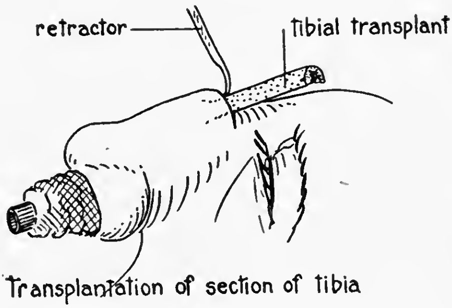


FIG. 374.—Method of inserting the tibial transplant into the nose to form a bridge.

ciently large pocket for the reception of that bone. This is best done by making an incision somewhere on the side, then entering this incision with a pair of blunt scissors which are pushed forward underneath the skin as far as our pocket should extend, then opening the

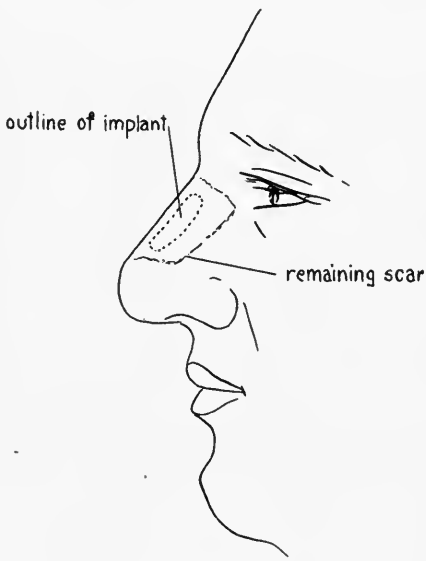


FIG. 375.—Position of implant after healing.

scissors wide enough to spread that skin. The result of this procedure is hemorrhage, which is, as a rule, not arterial but venous, and can be stopped by compression. The cavity will fill up with blood again, perhaps, if the hemorrhage is abundant, but by using compression and heat or cold, as the case may be, one will ultimately get a more or less dry pocket, surgically dry, as we call it, not necessarily fully dry. Then the bone or cartilage is pushed into that hole so far that it does not protrude and so that the original skin incision can be closed again. The result will be that the bone or cartilage will be surrounded by a slight hematoma which will act as groundwork for inflammatory wound healing and encapsulation of the foreign body. Care must be taken not to include any air, as saprophytic infection might injure this wound healing process. Also other microbic infection will do harm; but strange to say even slight infections have not entirely prevented union and encapsulation of such foreign material as cancellous bone or cartilage and it has remained permanently.

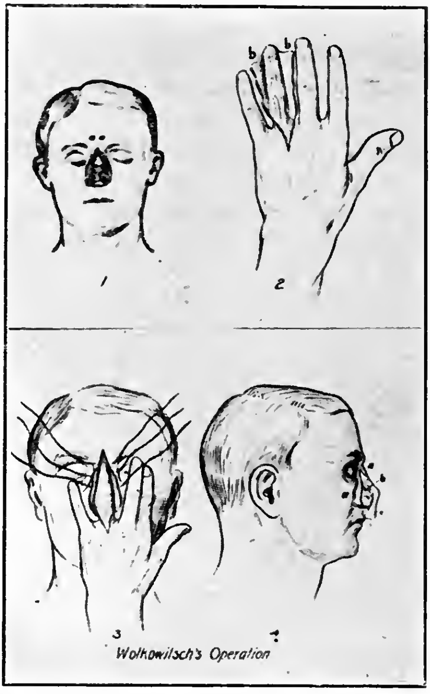


Fig. 376.—Wolkowitsch method of using a finger to form a nasal support.

This method gives us an excellent means of filling out depressions and raising flat noses and straightening curved noses. In a word, it is one of the most valuable means of plastic correction. The material is usually taken from the same individual. Cartilage is abundant near the border of the ribs and the sternum. There any quantity of it can be easily obtained without harm. Bone is preferably taken from the shin where it is easily accessible and can be shaped to any desired length and width, and easily transported and where its removal causes no harm.

This excellent method, of course, has supplanted a great many of the older methods of rhinoplasty; nevertheless there remain quite a number of cases, especially those in which pathological conditions have been the cause of the destruction, where complicated methods, like the transport of a finger or the use of other plastic operations become necessary.

In the following I give some of the most important and most useful methods of plastic operations on the nose, without going into detail, thinking that for the surgeon a glance at a small illustration will be sufficient.

The best way to deal with this large subject is to divide rhinoplasty, as it always has been divided, into three groups: (1) Partial Rhinoplasty; (2) Total Rhinoplasty; (3) Alterations in Shape.

FIG. 377.—Kausch method of rhinoplasty, by transferring a finger or toe from the center of the palm of the hand into the nose after it has been first transplanted into the palm, in a case of total absence of nasal support.

Partial Rhinoplasty.—The nose consists of a number of important anatomical parts. Any of these parts may be lost in an injury and have to be replaced and not only the histological structure but also the architectonic structure must be taken into consideration, and the latter is the most difficult task. Nature has provided the nose with a skeleton of bone and cartilage and it is very difficult to imitate with plastic surgery the architectonic structure and to reconstruct missing parts so as to make the feature closely resemble its normal shape. We often have to be satisfied with a nose shaped in such manner that it will not be an ugly appendage, worse than the original defect, and herein lies the great difficulty of the work.

Most important of all structures is the septum and the bridge, as they are the fundamental supports of the nose. If they are destroyed, it is hard to reconstruct them. The tip, the ala, the soft septum, are much more easily supplied.

We shall begin with the most simple part, the reconstruction of the ala, or wing. If the whole ala is missing on one side and the nose retracted so that its tip is turned to the affected side, the reconstruction is comparatively easy in cases where the cheeks offer plenty of material. In the first place, the scars have to be resected so that fresh wounds remain, lining the defect. This will leave more or less of a triangular defect of the side of the nose where the ala was situated. The nasolabial fold is an excellent means of hiding the scar and therefore a flap is made with its base toward the root of the nose, of more or less rectangular shape, then turned and implanted into the defect; folded on itself so that its extremity is turned toward the nasal cavity, the fold of the flap forming the border of the ala. In this manner we are in almost every case able to restore the wing of the nose, as far as the skinny part is concerned. As many points of suture should fasten this flap into the defect as is necessary on both sides of its insertion, and as wide a flap should be secured as is necessary, always considering

Fig. 378.—Method of Esmarch's operation.

Fig. 379.—Result after operation.

that in course of time flaps of this kind will shrink somewhat. It is quite important to take some of the fat of the cheek along, so as to make it as succulent as possible. The nostril of that side is packed with gauze. It keeps the part of the flap which has been folded into the nose in proper shape.

Ten days will usually suffice to heal this flap in position. The place from which the flap has been taken should be sutured longitudinally and exactly, so as to give as little scar as possible. Of course, it will not always be possible to use that direction of the flap for plastic and sometimes we have to borrow it from the middle of the cheek.

After sufficient time has elapsed, say three or four weeks, and the ala, which now consists entirely of skin and which would sink into the nostril and gradually shrivel more and more, has to be supplied with a cartilaginous skeleton, in order to keep it away from the septum. This can easily be done by implanting a small curved strip of cartilage into the ala, making a slit somewhere on the side and with a fine pair of blunt scissors burrow a canal or pocket for its reception. It will form a good support for the wing.

Partial Restoration of a Wing.—Sometimes only a portion of the wing is missing, an ugly deforming triangular defect, resulting from injury or disease, while the largest portion of the wing is present.

In such cases we often can restore the small defect from the nose itself, borrowing skin from the nose above the nasolabial fold, if there is an abundance of the same. These small defects, while often cosmetically bad, can easily be reformed and should only be treated in such manner as will not increase the difficulty by scar formation.

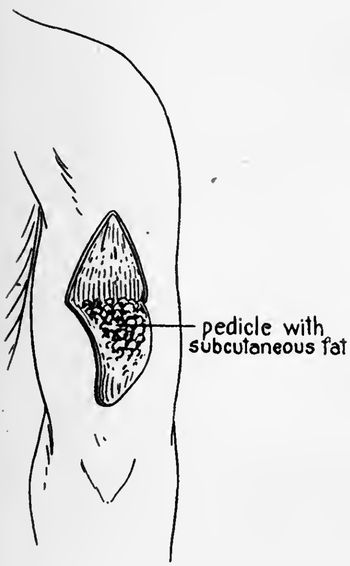


Fig. 380.—Method of cutting the flap on the arm before implanting it into the nose.

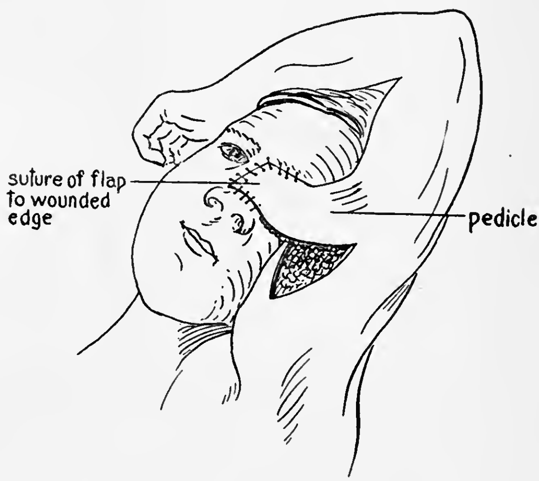


Fig. 381.—Method of "Italian plastic" from the arm upon the bridge of the nose.

In women, defects of the ala, just like other defects of the nose, can be replaced by borrowing skin from distant parts of the body by the Italian plastic, which will be described later, because the method is the same whether used for ala or bridge or tip.

Restoration of the Tip of the Nose.—The tip of the nose is often destroyed by injuries and disease. In such case the nose is flattened out in its apex and is cosmetically deformed. In such instances the tip can be restored in the best manner by Italian plastic. The procedure is described with the restoration of the nose in total rhinoplasty and is the same. In this case, however, it is much more simple, having to restore only a small portion of the nasal cover of the tip.

First, a sharp incision around the defect, within healthy skin, and the skin of the nose repaired so around the defect that the borders of the wound are as high as possible, to give as much contact as possible with the skin of the forearm or humerus. This is an important factor because the scars after the union will be less visible and the tip will be much larger.

After the flap has been severed from the forearm, then a very exact adaptation of the same has to be made into the nose and a much larger flap has to be taken than at first appears, since we usually have to implant some cartilage later underneath the flap, to give to the nose tip a prominence, and since we can always remove portions if it is too big; but the operation is hardly ever successful if we have taken too small a flap. Care must be exercised to take a piece of the forearm where enough fat tissue is present, so that there will be sufficient subcutaneous connective tissue for the later plastic work with cartilage.

Restoration of Bridge.—This deformity is perhaps the most common. An injury has destroyed part of the nose from its root down to its tip, and as a result there is a deformity which consists of a tilting up of the nose, a retraction of the bridge into scar tissue, and the nostrils instead of being directed downward are directed forward. Often a portion of the skeleton is missing.

The first indication is to remove all the scar tissue and bring the nostrils into their normal position downward. That will leave a rectangular defect over the bridge of the nose. Very often we can use the scarred tissue to make an inner lining of the nose in such manner that we dissect the scars without opening the nasal cavity, and if we have to open the nasal cavity, that we turn a portion of the scarified tissue toward the inside and expose the lower surface toward the outside, using it as a bed for the implanting of bone, cartilage, and skin. The best place for obtaining skin for these cases is from the forehead, from which a tongue-shaped flap, of such direction that the vessels supplying it run in its pedicle, is turned down upon the nose and sutured with exact fine horsehair sutures into the borders produced by the dissection of the scars. This would not prevent, however (even if it should heal very well), the nose from tilting up again, if we did not supply some resistant material for the support of the missing bridge or bony skeleton. We can best supply this from the shin bone, using a portion of the crest of the shin bone with its periosteum, pointed on both sides sharply, with the point on one side stuck into the root of the nose and the other into the tip of the nose, thus keeping these parts stiffly apart, and covering this bridge, which is closely adapted to its underlying flap surface, with skin from the forehead. The defect on the forehead is sutured as far as possible by adaptation of the borders; and at its root, where the flap is turned, left ununited, and after two or three weeks, when the flap is well supplied with circulation from the nose, it is cut at the root. This incision is closely adapted into the upper border of the former defect, while the flap pedicle is turned back on to the forehead and resutured in its former place. In this manner an excellent result may be obtained in the restoration of the root of the nose.

Sometimes we meet cases in which the wound on the nose is still healing. No plastic operation should be undertaken until the wound is healed and free from reaction, as given in the early rules, but preparatory to this, we may begin by implanting the bone underneath the forehead, so as to heal that bone in before we transplant the flap. This shortens somewhat the procedure of healing of the bone and in a certain way insures its union, but I have not found much difficulty in cases where there was no inflammatory reaction in transplanting the bone at the time of the flap operation and therefore have not made use of this method except once.

Fig. 382.—Method of putting up a case of "Italian plastic" in plaster of Paris. Mark the position of the arm.

Fig. 383.—The arm flap is cut loose and hangs down on the side of the nose and is allowed to shrivel before it is adapted.

Another plan for reconstructing the bridge of the nose is offered by the Italian method of Taglialozzi. This will be described more in detail in the restoration of total defect of the nose.

Restoration of the Side of the Nose.—The side of the nose is often the seat of injury, sometimes in connection with war injuries. Very important in this instance is the complication of laceration of the lachrimal sac, which in most cases is the seat of suppuration. This results in fistula, which easily closes, fills up with pus, and breaks open again, repeating this continually. It is therefore important to remove this obstacle before the side of the nose is restored, and if the sac is not affected, it is very important not to disturb it while operating for such defect.

It is a well known fact in plastic surgery that cavities like the nasal cavity cannot be bridged over simply by covering the outside with a flap and leaving the inside exposed. It may heal once in a while but in many instances it will suppurate later and cause disturbance. It is therefore important that a lining should be secured for the inside of the nasal cavity, and this can be done in perforating defects of the side of the nose, by turning some of the skin inward, by dissecting it from the side as far as one can, and closing the defect, with such dissected skin and scar toward the cavity, at the time of operation, of course, just as well as before. Then such defects of the side of the nose may very easily be restored by flaps from the forehead.

Total Rhinoplasty.—Total rhinoplasty means reconstruction of the entire nasal skeleton and cover. There are a large number of cases in which such an operation is indicated. Injuries destroy the skeleton in such manner that after all the acute inflammatory changes have disappeared, an unsightly hole remains in the center, with retracted scars, and hardly any of the original parts of the nose are left. But there are cases in which some of the original parts of the nose are still existent.

It is important when the plan is made for total reconstruction of the nose to make use of every particle of structure which is still in existence. It is not so difficult to gain a cutaneous cover for the nose but the prominence and shape of the nose are the two desiderata which are the hardest to attain.

1. As to the shape, a good result will have to show wings, point, and bridge distinctly. The wings are very hard to form, especially such wings as will stand off from the nostril and not collapse, but keep the nostril patent. The tip is not so difficult, although as a rule it is necessary to make a number of corrections before the best form is secured. The bridge is the easiest to obtain.

2. As to prominence, the plastic construction of the skeleton, by using bone to make a prominent nose, is very successful, and if correctly employed the results are satisfactory. There were many methods in former times by which the nose was built up by using parts of the skeleton of the frontal bone, of the cheeks, and the upper jaw. Today these have only a historical interest. For instance, the method of Israel, of Koenig, Schimmelbusch, Nélaton, and a host of others, are extremely interesting and have led to good results in the hands of their originators and imitators in a few cases, but the latest experiences with a large number of cases are in favor of using two methods, especially in the total reconstruction of the nose, namely, the Indian method, and second, the Italian method with bone or cartilage transplantation for skeleton. Because these two methods are also used in partial reconstruction, I shall give them here much more in detail. Some of the parts of the operation may be omitted or modified in partial reconstruction, as the case may be, because one can make use of existing material and scars.

The Indian Plastic.—If we have a case in which the whole nasal outer skeleton is missing, the scars retracted toward a central hole or two holes, as the case may be, representing the aperture of the nose, very much resembling the skull of a skeleton, then we have in the first place to supply the inner lining of the exterior nose and in the next place the outer cover. Both can be supplied from the forehead or forehead and cheek and the skeleton of the nose from the bone of the tibia. The first step is to resect the scar from the border of the pyriform external aperture and make quite a broad border of a wound toward the inside of the future nasal cavity as well as toward the outside. At this point many plastic surgeons make a mistake in not getting broad enough surfaces for adhesion and their stitches cut out or slough out very easily, as there is not sufficient tissue to hold them. It is therefore, best after circumcising the pyriform aperture to separate the two borders as widely as possible, turning the inner border toward the inside, the outer border toward the outside. In the center we have then the exposed border of the pyriform aperture of the nasal cavity of the skeleton. The next step is to cut off these borders with scissors or knife to such straight lines that the apposition of the flaps from the forehead will be linear and form as little scar as possible.

Fig. 384.—A perforated bridge from injury.

The second step is to outline on the forehead two flaps, one which is to form the inner lining of the nose and the inner lining of the septum between the two nostrils on the outside, with its epithelial surface directed toward the inside of the nasal cavity. This flap is tongue-shaped and has at its extremity a small portion which is going to be the future septum joining the lip. This flap has its pedicle corresponding to the largest vessel above the eye, the supra-orbital artery, and its extremity reaching toward the temple of one side or the other. It is turned down with its bleeding surface toward the outside and sutured exactly into the borders of the wound directed toward the nasal cavity and the extremity sutured into the nasal border of the upper lip.

The two nostrils are now packed with gauze, so that the nasal form is obtained, with the bloody surface directed outward. Now a second flap is made correspondingly on the other side of the forehead and this time it is turned with its bleeding surface toward the inside and its

FIG. 385.—A case of syphilis with total destruction of the nose and all skeleton parts.

FIG. 386.—The same case after the syphilitic condition has healed. Ready for plastic operation.

epithelial surface toward the outside and sutured exactly into the outer border of the wound and the extremity sutured into the lower border

FIG. 387.—The appearance of the case after transplantation. "Indian plastic."

of the wound in the lip. Before, however, this whole maneuver is finished, bone which has been chiselled out of the crest of the tibia and which is broken to an angle at one point corresponding to the future tip of the nose, is laid between the two flaps and even fastened with a couple of catgut stitches, so as to remain in place alongside the future bridge of the nose. It lies between the two flaps and has to heal in and give to the nose the shape required. The two borders of the flaps alongside the nostrils are sutured very accurately. Sometimes it is better to make the outer flap somewhat larger so as to place the sutures of the nostrils and the septum inside the nose instead of on the outside, which gives a better cosmetic appearance than when the scar is lining the outer border of the nose.

The results of this method of reconstruction of the nose are as a rule very gratifying. Secondary corrections, improvements, implantation of cartilage into the wings, interjection of additional cartilage into the tip, to make it more prominent, are necessary, but the shape of the nose is very good, the scars are all lying in such locations that they do not become cosmetically obnoxious.

Afterward the defects of the forehead are diminished as much as possible by some plastic procedure. The flaps after being cut off at their pedicles restore some of the defect produced by the original operation (we cut these flaps at the end of two or three weeks, which depends on the individual and the amount of nutrition present). One has to leave the pedicle rather longer than too short a time in those cases in which one suspects that an early cutting off of the matrix circulation might injure the life of the flap.

Modifications.—The modifications of this method are numerous and one of the most common is one in which one flap from the forehead is sufficient, because the scar and the outer remnants of the nose are sufficient to make the inner cover of the reconstructed nose. There are two ways in which such scar tissue may be utilized. One is by dissecting the outer skin from the cheek, about one-fourth inch near the root of the nose and about an inch near the lip. This triangular piece is dissected and turned with its outer surface inward and sutured in the median line together so that a groove appears, which is very apt to receive the bloody surface of the marrow part of the bone and produce very accurate adhesions here for the bridge of the nose.

Another way is the use of that scar and cutis around such a defective nose, by dissecting a flap downward, starting at the root of the nose with a small rectangular flap which is to form the future septum, then making a two-side incision, parallel with the border of the pyriform aperture and dissecting the flap downward and pointing it outward, suturing the end from the root of the nose into the median incision of the lip. In this way we have the advantage of getting on both sides projections which are very easily used for the wings of the nose. On to this is sutured the flap from the forehead.

Of course, there are numerous small modifications of this main method of Indian plastic. All have their importance and may be studied from the monographs or text-books in which they are described, but on the whole the method given above is observed in the majority of cases.

The Italian Plastic.—The second method is the Italian plastic, so called from the fact that Tagliocozzi, the Italian, devoted to this method of plastic surgery a great deal of his time and that he achieved a great success by using flaps from the arms on the nose. His original method was very simple. He made a flap of more or less rectangular shape on the arm, cut the defective nose squarely off, so that it formed broad borders, and either connected the flap from the forearm directly to the nasal defect or else allowed it to shrivel somewhat first and after it had formed on the arm a little shrivelled up appendix of free skin, united it to the nasal defect (see Figs. 380–382). After it had been attached long enough to establish circulation it was cut off from the arm, thus giving to the defective nose a lump of tissue with skin surface, imitating the nodule of a nasal tip; sometimes, and especially in his later experiences, he formed nostrils and other parts of the nose from these flaps. He kept his patients in quiet posture by apparatus which was made like a harness and which did not allow the slightest motion of the body but allowed the patient to eat and drink and kept him more or less free from the annoyance of the position, which was one that we no longer use, but which has been found fairly comfortable. The principle of the method, however, is in use up to this day, namely, the borrowing of skin flaps to cover defects of the face, not only for rhinoplasty but for other plastic purposes, such as repair of the lips, cheeks, ears, hands, feet or breast.

The Technic of the Method.—The patient is prepared by scrupulous cleansing of the face as well as arm for the operation. The patient is prepared for a day or two temporarily, holding his arm in such position as it will be held later on. In my experiments, I have found that the position of the arm across the head in such manner that the hand is put over the back of the head of the patient, the forearm joining the cheek, the elbow crease opposite the forehead, is the most favorable for the patient, and the one which he can stand the longest time. It allows feeding from one side as well as watching. It also permits the patient to sleep on one side very comfortably and also on the back.

After the patient has been prepared in this manner, the operation of plastic flap is performed as follows: The nose is prepared by dissecting the scars and sewing the same to the remaining skin, as in the Indian plastic for lining of the nose. If there is not sufficient of this material present one can use an Indian flap for lining. One can also use a lining from the arm, employing one flap with its skin surface toward the inside and the other with its skin surface toward the outside, either directly or indirectly. By directly, we mean we can use this at the time of that operation; by indirectly, that we prepare a flap on the arm first by allowing another flap to heal to its wounded surface before we join it to the nasal defect. I have found, however, that in most instances sufficient material was present on the nose defect itself to build upon, so that only one flap was taken from the arm and that to cover the outside. The flap from the arm has the quality of shrivelling up considerably after it has once separated. One can safely say that two-thirds of its thickness and about one-third of its size will be lost after it is fully healed. Therefore an extensive flap with a good deal of fatty tissue is better than a very thin cuticle for this plastic purpose. The flap is measured out by proper model and increased about one-third in its size before it is cut, and the broad pedicle, comparatively, is left to the arm. It is sutured in practically the same manner as the Indian flap, on three sides, into the defect, taking care that one brings broad surfaces into apposition.

The difficulty arises in the after-treatment. As soon as the flap is united, care must be taken to keep the arm in the same position as it is at the time when the operation is finished. This immobilization is best brought about by adhesive plasters, which are put around the head and the arm, the breast to the arm, in broad strips, in such manner that the circulation is not disturbed but at the same time the arm is securely immobilized. Care must be taken that all surfaces of skin which touch each other should be protected by gauze from the danger of eczema, which sweating and the contact of two surfaces causes so easily. Gauze and cotton is packed into every crevice between cheek and arm and then over the whole head and neck a retentive bandage of plaster of Paris is made, which assures perfect immobilization. The face can be free so that feeding, cleansing of the nose of the discharges in the after-treatment, is possible. Breathing must not be impeded; also care must be taken that if the patient vomit after waking up, the plastic flaps should not be soiled. In these cases it is important to have a very competent nurse to whom the many instructions can safely be given.

The position of the patient is rather unpleasant and this is one of the drawbacks to the operation, but the advantages are many. In the first place, there are no scars on the face or forehead of the patient, and there is plenty of material for plastic purposes. Its disadvantages are that we have to sever the pedicle a little earlier than we would like to do, because through his position the patient becomes very restless and if we leave the arm in that position too long, we will have (as I have seen in a few instances) a pressure paralysis of the nerve, which will take some time to restore to normal.

In about eight or ten days, if good union has taken place, the flap is cut loose from the arm and care must be taken immediately to insert it into its new place on the nose, with its free border so as to give a fourth side of circulation, at this moment when the circulation from the other three sides is not very strong. It may not be possible to give to the nose a most desirable shape at this time. Corrections may have to be done but the first important matter now is to give to the flap a good rosy color by waiting as long as necessary for the establishment of circulation. The corrections can be made subsequently. After the flap is healed fully and has good circulation, one can implant bone and cartilage to raise it. The arm wound heals as a rule by primary union and leaves very little scar.

The third group of plastic operations are those which concern only cosmetic changes of the form of the nose, and here we have to consider several types; some of them are due to disease, others to congenital deformity, still others to injury, some to the removal of a growth.

The Congenital Split Nose.—This is a rare but interesting condition to the plastician. I have seen it in several instances indicated slightly by a very broad nose, which has a slight depression in the center or sometimes only a tip which is split in the middle slightly, so that it appears that the nose has two tips, one on each side. These slight indications are rarely a matter of cosmetic plastic, but there is one condition where the nose appears split in the middle and the root of the nose very broad, a very unsightly condition. This is due to a congenital deformity caused by the improper union of the facial clefts in the embryo. In such a case we make use of the plastic implantation of bone and cartilage through the intranasal root. Cartilage is removed from one of the ribs. This can be done under local anesthesia; the nostrils are cleansed and then the septum slightly incised on one side, as for a submucous resection, the slit sufficient in size to allow a blunt, pointed pair of scissors to be spread, to raise the skin over the root and to make a tunnel above the depression of the bridge of the nose. This tunnel will not bleed very much but whenever blood comes, it is removed by pressure outward. Then after withdrawing the scissors, the bone or the cartilage is pushed in with its narrow point upward, with the broader point downward toward the tip, and one of the sides of the strip of bone or cartilage lying flatly upon the broad ridge, with the edge opposite to the side, forming a new straight, or slightly curved, bridge of the nose. The nostril is packed and a few adhesive plasters hold the bone or the cartilage down toward the surface, in order to make healing easier and accumulations of blood impossible between bone and cartilage or bone and bone. The results of this procedure are excellent.

The Congenital Saddle Nose.—There are people born with a stubby nose which has a depressed instead of a straight bridge, nostrils directed forward instead of downward, the French nez retrousse, or negroid nose. In some nationalities this form of nose in a very slight degree is prevalent, as in the Slav nations, but a high grade of it is very unsightly.

The method of correcting this unsightly deformity is the same as the one described under the title of Congenital Split Nose. It is the intranasal implantation of bone and cartilage.

The Syphilitic Saddle Nose.—This is one of the hardest cases to deal with. For a long time we have had a great deal of hope of being able to do something with this deformity. The mild degrees of it are easily treated, like the congenital saddle nose, but extensive degrees and particularly those combined with destruction of septum and holes in the palate, are very bad objects for treatment. Nevertheless the cases were from the start the most gratifying objects of experimentation for the plastic surgeons. Most of Tagliacozzi's cases belong to this class and this is the reason that many of those plastic flaps fell off secondarily, which gave rise to such fantastic stories as Hunter's Hudibras, about the falling off of the nose of a man in the North because the donor of the skin, a man in the South, had died.

The syphilitic saddle nose may be treated by a large number of methods. However, it should never be attacked by a plastic surgeon until he is satisfied that there is no active syphilis present in the patient.

The Hump Nose.—This kind of nose is very common and the plastic surgeon is applied to for correction in many instances. Not always cosmetic reasons bring the patient to the surgeon; oftentimes pathologic conditions are responsible for his seeking advice.

The hump is a projection on the bridge of the nose, mostly cartilaginous, sometimes, however, bony; in many instances, the result of an early fracture of the nose and subsequent hyperplasia of bone or cartilage. The skin overlying this projection in many instances is glistening, easily vulnerable, itching, sometimes the seat of rosy wine marks due to enlargement of vessels; but at other times it is white and shiny.

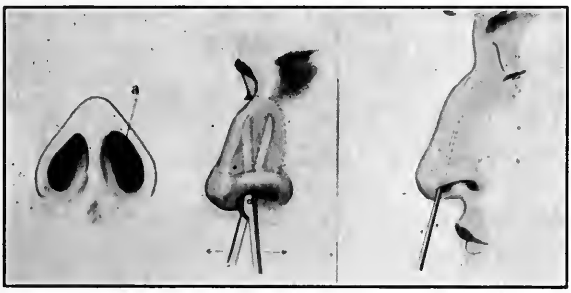


FIG. 388.—Roe's method of intranasal operation for hump nose.

Formerly we used to treat these cases by external operation, making an incision along the ridge, resecting the exuberant portions of cartilage and bone, making the bridge straight and reuniting the skin with very fine sutures, so that a linear scar was all that was left.

This is still the best method in those cases in which the skin is very thin. A better method, which leaves no scar on the surface, is the method of John Roe, an intranasal resection of the septum and bridge. An intranasal opening on the septum allows a pair of blunt scissors to enter, spreads the skin on the surface of the nose from the underlying cartilage and bone. With the scissors cut away the cartilage and the bone and remove it through the same opening in the nostril, whereupon a compressive bandage prevents the accumulation of blood in the cavity.

Primary union is the rule of this operation and the cosmetic result is excellent.

The Traumatic Type of Saddle Nose.—Through injury a portion of the septum may be lost and the nose sink in at its center, forming a saddle, complicated sometimes by a scar, if the fracture has been a compound, comminutive one. This is a very unsightly deformity and needs correction in many instances. If the nose is permeable and the cartilage or bone does not obstruct, intranasal operations need not precede, but if such is the case it is first important to remove the intranasal obstruction. Then it is necessary to correct the internal deformity. Both of these operations may be done at the same time but it is advantageous to do them in two sittings: (1) to remove the intranasal obstruction and in a secondary step, implant cartilage or bone through the intranasal route, so as to fill the defect of the bridge by this implant, in a manner similar to that in the other deformity of this kind. If scars on the outside are present, a method of scar elimination is practised first to make a very clean scar on the nose.

Lateral Dislocation of the Nose, So-called Crooked Nose.—This is often the result of a fracture of the nose in early childhood, which leads to a deformity of such nature that the tip of the nose is turned sideways. When this injury comes fresh under the observation of the physician a very interesting and successful operation can be performed, the resetting of the fracture with supports, but if the case comes under observation years afterward the deformity has assumed such a permanent character, with callus and hypertrophied bone and cartilage obstructing the nose, that it is not easily possible to obtain an ideal result in these cases. Special intranasal operations are the most successful, removal of portions of the septum with spurs with subsequent treatment with special apparatus, which by pressure and constant modelling may achieve a great deal of good. Complete restoration of the normal appearance of the nose is hardly possible in such conditions.

The Perforated Nose.—This is a condition which may result from injury or from disease. The injury may destroy a portion of the nasal skeleton and external cover and lead to the formation of a permanent fistula of small or large caliber on different portions of the nose and contractures of scars may also lead to a great deal of deformity (see Figs. 384 and 385).

The most important indication in these cases is to close the opening and this is done in the best manner in those cases in which the opening is of sufficient size, by using the external cover around the opening to form an internal line, dissecting it in the shape of flaps, wide enough, from the border of the opening and then fold it with the external surface inward, suturing it in the center, thus offering to the plastic on the outside a bloody surface upon which a flap from the neighborhood, with a pedicle, can be implanted. Secondarily, excision of scars and elimination of other things to produce a good cosmetic result.

The Pound Nose.—This is an old name for a peculiar condition of hypertrophy of the external nose cover which leads to an unsightly tumor of cauliflower shape, with a number of excrescences on the surface, hanging down over the lip in many instances.

This condition of hypertrophied nose is easily amenable to plastic treatment. The inside of the nose is usually perfectly normal, the outside has a large number of hypertrophied glands with a great deal of sebaceous matter occluded within them, sometimes cystic, sometimes infected, and usually very greasy. Its beginning is often

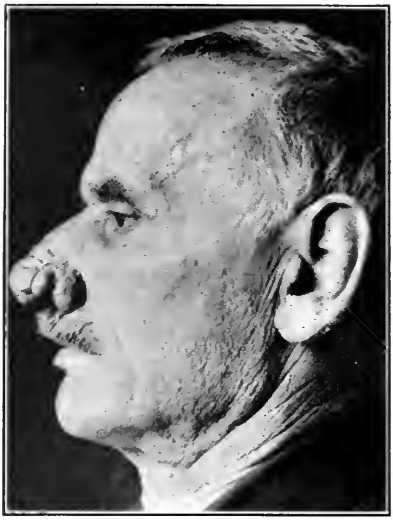


FIG. 389.—A case of rhinophyma (pound-nose). Lateral view. Dr. J. C. Beck

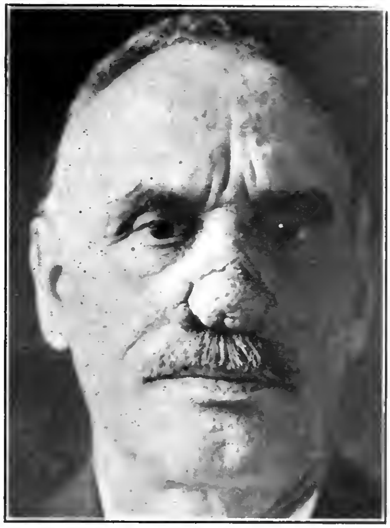


FIG. 390.—Same, front view.

FIG. 391.—Same case after cure.

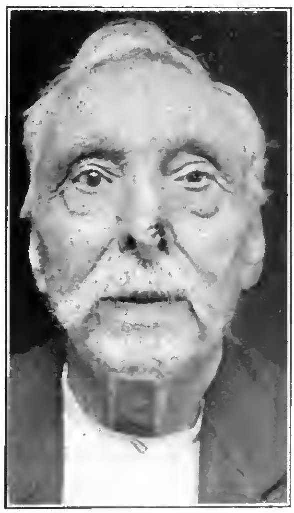


FIG. 392.—Front view after cure.

acne rosacea and only gradually after years the hypertrophy causes the unsightly abnormality.

The best method in this case is to slice this large tumor mass off with a sharp scalpel right down to the cartilage, leaving the nose in almost normal shape, and then let heal by granulation. The scar which is thus formed is at first very rosy and soft but gradually contracts and gives to the nose an excellent shape and color. Sometimes it is necessary to cover it with very thin skin grafts which give the nose an absolutely normal appearance.

The Carcinomatous Nose.—Primary carcinoma of the nose is not very frequent, although a certain number of cases come under the observation of every busy surgeon.

It is a slow growing epithelioma and can be radically removed by surgical means. Some of these smaller tumors of that kind yield very readily to the radium treatment. Others require the implantation of a flap, which can be purloined from the neighborhood, according to the usual rules of plastic, with the pedicle on the cheek, and if possible from the neighborhood of the nasolabial fold, so that the scar where it is taken from falls into the nasolabial fold.

The Artificial Nose.—There are cases in which a plastic of the nose from the tip itself is impossible. These are the cases in which disease will not allow any union or in which the skeleton is so far destroyed that to build it up would mean a very extensive bone operation with a doubtful success and prolonged after-treatment, which in many cases with people of advanced age is not desirable. These cases are satisfied by the use of an artificial nose made of aluminum or special material and painted the natural color, adapted in such manner that the line where the artificial nose joins the flesh is barely visible.

The art of making artificial noses has made such progress since the war that these masks are applied very frequently and unless a person is an expert he would not discover that they are artificial. They may be attached to spectacles very conveniently and the patient may be given some paste with which to obliterate the border lines.

CHEILOPLASTY. (LIP PLASTIC).

Historical.—Plastic surgery on the lips has been practised for many centuries in Europe. One of the oldest records is Fabricus' of Aquapendenta in his work on surgery.

The first impulse to forming of the lips was the restoration of the same after resection for cancer, which is quite common, but while occasionally operations have been done in the different countries for injuries of lips from other sources, it is only within the more recent decades that a systematic effort has been made to form lips and the lip-red through plastic operations. The old methods of Celsus have been revived by Thomas and Payan. In India and Italy surgeons have tried their skill, Branca and Tagliacozzi have both written on this subject, the latter trying his favorite method of using flaps from the arm, but it was Chopart, the celebrated French surgeon, and Graefe, the German oculist, who brought the modern methods into use, whereupon a large number of surgeons tried various modifications of older methods, so that by this time hundreds of different procedures are known to replace or restore defects of the upper and lower lips.

Pathology and Indication.—As in rhinoplasty, the operations of plastic reconstructions are called for by pathologic changes produced by:

1. Destruction of lips by injuries and burns.
2. Diseases of inflammatory or malignant tumor character.
3. Congenital defects.

1. *Injuries and burns* are characterized by irregular destruction, scar formation, and abnormal contractures and distortions of the remnant of the lips, but they have the advantage that there is oftentimes a great deal of material present which may be used for reconstruction and which is only distorted and displaced.

They should not be attacked by any plastic operations until there is absolute healing of the wounds without reaction and definite scars have formed, unless one does a plastic reconstruction shortly after the injury, bringing by primary suture the tissues together which belong together, thus avoiding a secondary dislocation or distortion by scar.

2. Diseases are of two kinds, inflammatory disease, of malignant pustule with necrosis and sloughing of the lip, also the rare condition of noma, and the chronic diseases of lupus or syphilis and cancer. Syphilis does not destroy the lips very often but lupus frequently does. Most of the destructions are due to malignant growths, however. Cancers, while not often extensive, leave extensive defects after their removal; the surgeon trying to incise within the healthy tissue, has to sacrifice a great deal of lip structure. This class of defect has evolved an extensive literature which has lost a great deal of its interest and significance because the diagnosis nowadays is made so easily and a knowledge of these conditions has pervaded the laity to such extent that the people do not wait until large tumors have developed on their lips but consult the surgeon so early that it rarely becomes necessary to sacrifice large portions of these structures; besides, when the growth has developed extensively, the individuals are in such condition that a plastic operation, no matter how carefully performed, is a waste of labor. Rapid recurrence destroys that work and surgeons do not feel like wasting their time and the patient's strength upon such unfruitful work.

One peculiar part of the pathology is that the destruction of the lips is intimately connected with destruction of the jaws and that while we discuss the repair of the jaws separately, there must always be allusions and references made to one and the other.

3. *Congenital Defects.*—This group is extremely large. An enormous number of children defective in this respect are born every year, and the degree of deformity of the lips due to this source represents all possible forms. From the smallest notch in the upper lip to the total absence of lip structure and a defect of a large portion of the upper jaw, we have a scale of deformities which have to be dealt with in books as a specialty. In fact, there have been surgeons who have made a

specialty of this class of work and have become experts in this one line of plastic.

The lower lip is hardly ever affected by a defect of congenital nature. It is the upper lip and the upper jaw that are usually deformed.

Technic.—There are some interesting considerations in the technic of plastic of the lips. The lips are composed of two structures, just like the nose, but of widely different significance. The solid skeleton of the nose is the interior structure of the same, the muscle is the interior structure of the lips, and in this respect the lips are rather harder to treat than the nose. The muscle is a highly organized tissue and cannot be artificially produced or transplanted in such manner that it becomes physiologically active and therefore a plastic of the lips becomes at the best an incomplete one, because we have to depend mostly upon the neighboring muscles of the mouth and the chin to replace what is missing in the lips. The best lips artificially supplied are stiff and rigid, consequently they are not ideal. Besides, the lips have the peculiarity of being covered on the outside by skin, on the inside by mucous membrane, and a borderline which gives to the face a beautiful outline and color, the lip-red. And while we can in some instances replace the lips even to such an extent that we supply the lip-red and the shape of the lip, it becomes a difficult task in others. Nature has in this respect supported the plastician by transforming skin in course of time, when in constant contact with the mucous membrane of the mouth, into a sort of rosy, soft skin, so that the epidermis turned inward becomes somewhat similar to the lip-red mucosa. On the other hand, very rarely does the lip-red or mucosa turned outward become in course of time epidermis. It always has the slick, red, glossy appearance of mucosa.

From these general considerations it follows that in reconstruction of these structures it is necessary to save primarily during the injury and secondarily during reconstruction all possible structures which may be of use in plastic, not to sacrifice any skin and particularly any muscle or mucosa if not necessary. Sometimes the mucosa is thin, or infiltrated, or scarified, but nevertheless after a time it becomes soft and pliable but if cut away it is missing afterward.

One more factor in the reconstruction of the lips is the technic of leaving the sac inside of the mouth, which will act as a retainer of the saliva, the gingival sac. There must be no such thing as a lip directly attached to the border of the gums, so that the saliva drools out of the mouth. This is also one of the important considerations of the technic in this plastic and there are several others:

First of all is the asepsis. It is a well known fact that the mouth cavity can hardly ever be made fully aseptic. It always harbors a large number of microörganisms and saprophytes, but by preparations, usually washes, care of teeth and external cleaning of the structures, one can at least make the field as aseptic as possible. In this respect one must say that structures in this neighborhood have a more marked tendency to heal than in many others and rarely have I seen any suppuration in my cases. That is also the reason that many of the surgeons in preaseptic times had such beautiful results in this kind of surgery. All that is necessary is to bring broad surfaces together and make very exact suture of the epidermis.

In order to facilitate the formation of a method of procedure in the reconstruction of parts of lips, one may observe the same general laws of plastic which obtain everywhere else. To reconstruct the external shape, we have to use flaps, either single or double. Double flaps may be used from the neighborhood of the lips, from the cheeks, from the neck, from the chin, from the sides of the face. They should always be chosen so that their pedicle lies outside of the center line of the face, with the view that the vessel supplying the flap runs from the pedicle toward the incision. One should ascertain the movability of the tissue of the skin beforehand, and flaps that are not twisted very much during direct transplantation are preferable, also flaps that remain in the same direction as they are formed. If they have to be twisted 35 or 45 degrees, creases and folds will form, which oftentimes are very annoying.

The general laws of flap formation described in the general part of this book are all applicable and one need not go very much into detail, inasmuch as every possible variation of flap has been used and to each one is attached the name of some authority, sometimes two or three different authorities have made a modification, slight enough but still sufficient to distinguish it from an entirely rigid observation of the technic in some other, so that the names of methods are legion. The second important point is that the flaps should be chosen so that they do not require any attention.

Another point is that if possible flaps of fat, muscle, and mucous membrane attached are used, so that the lip-red is supplied from the enormously stretchable mucosa of the mouth.

Anesthesia.—A great deal of operating can be done in this field of surgery under local, but in many instances a general anesthetic is required, and it is important to use an apparatus which does not cover the mouth. The best method in this respect has been found to be the tube method already described.

After-treatment.—The after-treatment in plastic operations on the lips becomes a very important part of the technic. We need the mouth for breathing and for eating and talking. Immobilization is an important factor in wound healing and consequently all motions should be avoided. While we have to breathe and to eat, we do not have to talk, and breathing does not interfere greatly with immobilization. Eating, however, should be supervised in such manner that food is not spilled over the wounds, that remnants be removed by rinsing after eating, and that discharges be carefully washed off.

Dressings in most of the cases have been found unnecessary. The wound can be left open and exposed to the air. Rarely have I found it necessary to apply any kind of external dressing.

Reconstruction of the Lower Lip.—Removal of the middle portion of the lower lip, with loss of about one-third of its substance is one of the most common operations. It is called the "V" shape incision operation of Horn. The difficulty in this case is to incise it in such manner that the two borders of the wound appear more or less alike,

Fig. 393.—A case of cancer of the lip.

so that the adaptation is very easy and can be accomplished by simply suturing the mucous membrane and skin accurately with as few points as possible. One can safely remove one-third to one-half of the middle portion of the lower lip in quite a good sized triangle down to the chin without impairing in the least any of the functions of the lip and in course of time the lip appears as if it had never been subjected to any operation.

Fig. 394.—The same after plastic removal.

Fig. 395.—The same case showing the result several years later.

Somewhat different is the reconstruction when more than one-half has to be removed. In such an event it is necessary to borrow from the upper lip or from the neighboring tissue to reconstruct, because the upper lip then becomes very much puckered and protrudes like a snout, even if primary union takes place.

There are several ways of reconstruction. We can describe about one-half of the most important methods, which bear the names of those surgeons who have practised and described them.

1. If there is a small portion of the lower lip left on both sides of the angle of the mouth between upper and lower lip, it can be brought together and then the angle of the mouth incised laterally, whereby the mucous membrane on both sides is sutured to the cut on the skin, so as to enlarge the lower lip laterally, and then an incision on the upper portion of the lip is folded on itself and sutured together without mucosa, so as to straighten out the upper lip to the length of the lower.

2. Mucosa and skin can be cut from the angle of the mouth into the cheek on both sides (Szymanowski) and also cut corresponding to a gingival sac in the mouth, thus forming two lateral plates lined with skin on the outside, with mucous membrane on the inside. These are drawn together in the center and sutured. In this manner the two sac incisions grow so that the angle of the mouth is formed by the former angle and the corner of the incision on the side; while the two plates in the center, in which the mucosa has been sutured nicely to the skin, offer a very nice lower lip.

3. This same effect can be produced by three or four different modifications, by using flaps from the chin, incising toward the chin and raising the flap from there toward the mouth, thus again forming a lip-red from the remnant of gingiva, especially if the sac behind the lower lip in the mouth has been a very deep one. (The methods of Ziess, Chopart, or Szymanowski.)

Reconstruction of Half of the Lower Lip, the Other Half Being Normal.—This can be done in a similar manner as reconstruction of a triangular defect in the center. Care must be taken, however, that symmetry is not disturbed too greatly. On this account the mucous membrane is sewed through a lateral incision to form the lip-red and then a triangular flap drawn over toward the center.

Reconstruction of the Entire Lower Lip in a Large Defect.—The upper lip can be used for reconstruction (Dieffenbach's method) which consists in incisions from the angle of the mouth toward the nostrils, thus bringing together the two angles of the mouth in the center of the lower lip forming a ring of the lip-red of the upper lip for both lips. This will necessarily produce the formation of a round, contracted ring of lip-red and the drawing together of the wound borders around it and furthermore to relieve the tension from the sides, to make vertical incisions which are needed in a horizontal line afterward about one and a half or an inch to either side of the mouth. After everything is healed an incision can be made on both sides through the whole thickness of the cheek and the mucous membrane of the mouth sutured to skin so as to give to the lips the necessary width.

The second method is to use flaps which are turned more than 45 degrees and are taken from the outside. For instance, flaps from the neck turned over healthy skin into the lip region, like an Indian plastic from the forehead to the nose.

The third method is the use of single or double flaps from the arm (Italian method).

Ectropion of the Lip.—This means scar formation on the outside of the lip or chin which leads to an eversion of the lip-red and the mucous membrane. A careful dissection of the lip-red with the preservation of every particle of this and the removal of all scar tissue is the first step of reconstruction. This will show the extent of the missing external cover. This skin is supplied by flap from the chin or neck, sometimes by two flaps, triangular in shape and shoved up horizontally, one on top of the other, but it is not difficult to use skin from the arm by the Italian method for this purpose.

FIG. 396.—Case of ectropion of the lower lip from burn.

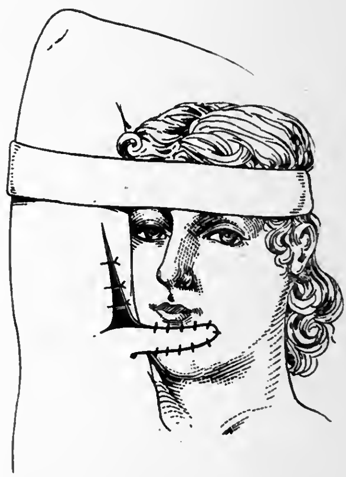


FIG. 397.—Method of Italian plastic in same case.

Reconstruction of the Lip-red.—It is one of the most difficult procedures and requires a great deal of ingenuity. First of all it may be supplied directly by using the mucosa from the mouth. Unfortunately this will not give to the lip that fulness and suppleness which is often required but will leave in some instances a thin border which is very unsightly.

A good method to supply a thick lip is to divide the upper lip, if necessary, and make two lips from the same. This can be done in several ways: First the method of Stein of Copenhagen. Bisect the lip in the middle and make two triangular flaps toward the septum of the nose. Turn both halves downward in such manner that there are really two mouth openings formed, one on each side, but very small. The center is united above and below. Then the bridge between the two mouth openings is cut transversely and a very neat, but very small pair of lips is formed.

A second method is the method of Dieffenbach; using the angles of one lip, separating them entirely and inserting them on the freshened border of the other lip; or the method of Tripier, cutting a transverse flap inside of the same lip further down in the mouth and raising it up on to the border, suturing it anteriorly and posteriorly to the freshened lip.

Finally, the method of Schulten, using the same kind of flap as described just now, from the opposite lip. For instance, if the lower lip has a freshened wound border but no lip-red and if the mucosa below is very short and does not allow the transplantation as in the method of Tripier, the upper lip which perhaps in this case has plenty of mucosa and lip-red may be everted, then incised transversely, and a strip the whole width of the lip liberated, turned with its wounded surface upon the wounded surface of the lower and sutured exactly in the defect. The nourishment in this case will be from both sides of the lip angle and from the wounded surface of the lower lip. Hardly ever do such flaps become necrotic.

Reconstruction of a Large Portion of the Lower Face. Whole Lower Lip and the Chin.—In such an event the method described by Ombredanne in the Congrès de Chigray in 1906 gives an excellent result. Two quadrilateral large flaps are formed by incising on either side from the angle of the mouth the whole mouth transversely, right down to the ear and in the right angle down along the grooves of the sternocleidomastoid to the middle of the neck. The portion next the middle line is folded on itself and sutured to the chin and the two flaps that are hanging down on both sides are inserted into the defect as closely as possible by insertion and suture.

The ultimate cosmetic result of such a procedure is remarkably good. The process is very similar to the one suggested by Bergman and even by Dieffenbach, only modernized.

Corrections of Deformities of the Mouth Due to Scar Formation.—There is no special treatment of these deformities except that the universally accepted rules of plastic surgery must be applied. For instance, first, in case of cicatricial contraction of the mouth or fishmouth by scar. Such is often the result of burns or inflammatory changes following necroses; if the mouth closes almost entirely, we call it atresia of the mouth. It will be difficult in such cases to eat, impossible to speak and even difficult to breathe if the nasal passages are somewhat obstructed. Extreme cases of this character are difficult to treat and from the extreme case down to the slight eversion of a corner of a mouth or a distortion of the angle upward or downward there are thousands of varieties. The chief objects of operation in these cases should be, in the first place, to remove all scarified tissue, to replace the same with flaps taken from the neighborhood or by Italian plastic and turned in the desired direction.

Ectropion of the Upper Lip.—This is a defect which is often connected with nasal destruction. The lip is drawn up in the direction of the nose and an operation is required to give to the same the desired width from the nasal septum downward. For this purpose it is important first to resect the scars into the healthy tissues and then use flaps from the neighborhood, which will replace the defect.

All the foregoing methods and operations have been more or less with respect to the defects produced by injury and disease.

Congenital Defects of the Lips.—The plastic surgery of congenital defects of the lip would make a chapter by itself; I shall describe only a few of the most important varieties. We distinguish—the unilateral hare-lip, the bilateral or double hare-lip, the hare-lip with a prominence or projection of the middle portion of the upper jaw. Besides these main changes there are many gradations, from the slightest notch in the upper lip to the deep defect with very scant tissues on the sides.

Fig. 398.—Removal of the upper lip. Method of plastic surgery.

Fig. 399.—Result in an actual case.

The Unilateral Hare-lip.—The Graefe method is the best, consisting in a curved incision around the notch, through the lip-red, dissection of the tissue down to the mucosa of the mouth, traction of the middle portion of the notched flap downward. This offers a line of union directed straight downward and if we are careful to unite the borders of the lips exactly with very fine sutures, we have an ideal cosmetic result. The same may be accomplished by a second method, the one by Nélaton, consisting of a curved linear incision, not going into the lip-red, but going entirely through the thickness of the lip and uniting the transverse incision in a longitudinal manner. This will be particularly favorable where the hare-lip is more centrally located, because it will leave at the mouth union a small projection similar to a natural projection of the upper lip.

The Lagenbeck-Wolfe method, where the incision is carried through the exact border of the lip-red in an angle to the lip-red, dissected down and as much of it resected afterward as is necessary to make an upper lip.

The operation of Malgaigne starts somewhat like the operation of Graefe, but uses two lateral incisions of the upper lip, so as to enlarge the vertical diameter, forming two flaps which are turned out downward and united in a vertical line, thus forming also a slight projection in the middle of the lip.

Giraldès' method which is based on the fact that one-half of the lip is somewhat less developed than the other. It uses the projections of the one side to fill the defect of the other in a sort of V-like incision. This is a method which is particularly favorable in cases in which the notch between the two parts of the lip goes clear into the nostril. The scar resulting from this operation is something of a zigzag.

Similar in its aspect to the above operation is that of Mirault. Both of these and also the next method have the object of sacrificing none of the tissues of the lip, except a very scant border. And even that is not necessary if one makes an incision along the mucous membrane and skin border and then separates the two so as to cut the broad surface for union. I found, however, that it is much more satisfactory to sacrifice a strip of this border-line, about one-sixteenth of an inch wide in a little child, in order to get a broad union.

The method of Koenig incises both of the half lips transversely and unites them longitudinally.

Another method is that of Dieffenbach. This method is particularly indicated in cases where the defect is quite a large one. In extreme cases one finds that the notch between the two halves of the lip reaches into one nostril, so that a portion of the nostril is missing or if not missing, is at least flattened out and separated from the septum. This makes the deformity of the lip in this simple hare-lip also a deformity of the nose, the part in which the nostril is incompletely closed is flattened out and the nose is drawn to that side. When the surgeon comes to the point of correcting the deformity, he has also to take into consideration the defect in the nostril and if the defect is such that there is very little material of the lip present, Dieffenbach's method becomes imperative, namely, the incision carried around the nasolabial fold and through the same, making two long flaps of the lip which are now long enough to be drawn together. Then incision of the lip border, as in Nélaton's or Malgaigne's operation and union in the vertical direction.

The results of these operations are, as a rule, very good. Cosmetically the lip appears almost like normal in those cases in which enough material was present and no additional extension incisions had to be made. In the other cases, in which the material was scant, the upper lip will be thin and somewhat lying back in profile compared with the lower lip, which gives to the face, especially from the side, a very peculiar appearance.

In order to avoid this deformity after operations, it is always well to take that into consideration at the time of operation and to make the line of union between the two halves as broad as possible. Of course, if the middle portion of the upper jaw is at the same time not

FIG. 400.—Double hare-lip.

FIG. 401.—Lateral view of the same case.

fully developed, as in some of those cases of hare-lip and cleft-palate, it becomes important in early youth to use the obturator temporarily, so as to give to the upper lip a chance to develop; otherwise it will shrink or only develop to such size as nature finds necessary.

FIG. 402.—Result after operation.

FIG. 403.—Result eight years later.

Double Hare-lip.—This deformity is characterized principally by the presence in most instances of a middle portion of a jaw projecting considerably from the level of the lip, somewhat like a snout of an animal. This projection is due to the fact that the septum of the nose is considerably enlarged in the anterior direction and at its end the prominence of the intermediary jaw projects, sometimes with one or two teeth imbedded in it. Then there are two notches, either symmetrical or asymmetrical, either both reaching into the nostrils or one reaching into the nostril and the other having a part of a nostril on top. The first indication is to restore the level of the upper jaw, that is, to bring the intermediary jaw into the level of the side portions of the same. In order to be able to do that, one has to excise a portion of the septum in the shape of a triangle, which can be done very simply by a submucous resection, through a slit of the frenulum. Then the intermediary jaw is pressed back very easily into the interspace of the two lateral jaws which are either separated down into the mouth cavity (total cleft-palate) or only half way down (partial cleft-palate).

Sometimes this intermediary jaw is absent entirely; and in these cases the middle portion of the lip is in the level of the two side portions, a condition, however, that is rather rare.

The operation for the double hare-lip is simple. After the restoration of the intermediary jaw into its normal place, the borders of the lip and mucous membrane are cut off to as slight an extent as possible and united. If the two lateral portions of the lip recede too much to the side, then incisions are made horizontally into the same and the notches produced by these incisions are snugly united, with the middle portion of the lip and their lower flaps immediately in the center. The very fact that there is no name attached to this operation shows that it has been practised by all surgeons without any special description by any authority as his own method.

A modification of this method is the resection of the intermediary jaw. This relieves one entirely of the difficulty of union of the lips, but in a later period this removal of the middle portion is often regretted as the result of the same remains through life. The defect and depression in that region requires correction by a dentist, in the shape of a crown, to remove the ugly sight of the incisor teeth standing about one-half inch apart.

MELOPLASTY (PLASTIC SURGERY OF THE CHEEK).

The reconstruction of a cheek by surgical methods is called meloplasty. The cheek is the space between a line drawn from the outer angle of the eye to the middle of the ear, the crease of the lower eyelid in the nasolabial fold down to the angle of the mouth in a straight line to the chin and from there to the ear.

This region has some peculiarities in anatomical structure which make it particularly important and interesting for reconstruction. In the first place the cheek is a very important feature of the face. Its destruction or injury can lead to very unsightly deformities. It contains muscles between epidermis and mucous membrane and is movable. It contains some very active nerve structures and the salivary duct. All these features make it an important structure. But as a rule it permits many plastic operations without disturbing its size or shape, because it is so very supple and can be stretched. Its nutrition is so good that hardly ever a flap taken from this region or transplanted in this region becomes necrotic. These are the salient features to be considered.

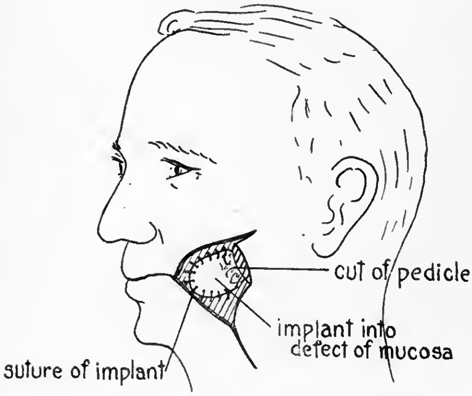


FIG. 404.—Method of meloplasty to reconstruct mucous membrane in the mouth from the cheek.

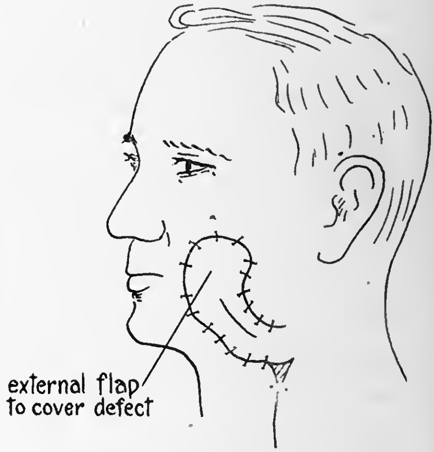


FIG. 405.—The same, showing the cover of the defect in the cheek, with a flap from the neck.

FIG. 406.—Result of meloplasty

Any operation undertaken on the cheek must be done with the idea of transferring scars resulting from such operations into some of those creases offered by nature between nose and cheek, eye and cheek, underneath the chin or alongside the ear. It must be remembered, however, that any contraction after healing will be sorely felt by eyelid or lip and will lead to what we call eversion or ectropion of these structures. It is therefore important to lay down some of the most salient laws in reconstruction.

Injuries to the cheek may lead to destruction of a part of the same or of the whole cheek. If the outer skin is missing, a very simple operation will restore it. Skin may be obtained from the neck where there is an abundance of stretchable skin for flaps. In fact, these flaps offer the best results and should be taken in such size and shape as to leave the scars afterward in the nasolabial fold or under the eye. Straight linear scars are not very objectionable and not very unsightly; retracted and deep scars, however, are very objectionable. On these scars there may be practised what I call the elimination of scar tissue, which I have described in the general part.

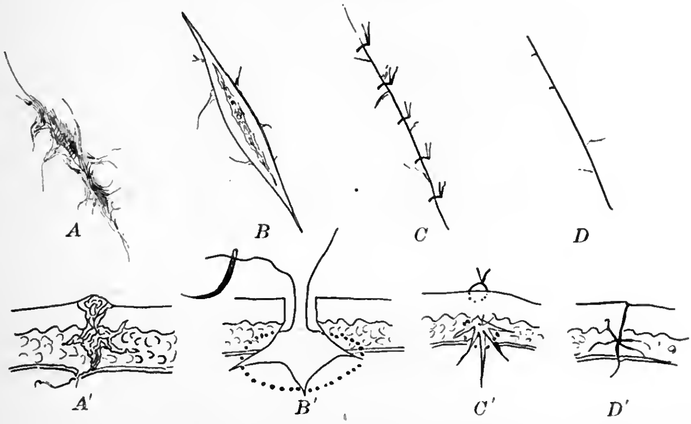


FIG. 407.—Scar elimination *A*, shows the appearance of the scar before operation; *B*, shows the elliptic incision and excision of the scar throughout; *C*, the minute union; *D*, healing. *A'*, *B'*, *C'*, *D'* show the same on a transverse cut.

Injuries to the Cheek, Involving Stensen's Duct and the Mucous Membrane.—Such injuries lead as a rule to fistula of the salivary gland, with continuous discharge of saliva. Plastic operations on these consist in turning of the fistula on the outside into the mouth, which is done in such manner that the duct if possible is probed from the outside fistula as far as one can toward its center. Then the duct is dissected with a portion of the skin at the end, like a cuff, and this cuff is pulled through a tunnel and buttonhole into the cheek and there fastened in such manner that the skin cuff is sutured to the opening in the buttonhole of the mucous membrane. The external incision is then closed by a suture. This operation has been found very successful.

If, however, a large portion of the skin and mucous membrane is missing and an opening is present in the cheek, the operation consists in the formation of mucosa from the skin and the formation of external skin from the outside with the flap. Israel's method is one of the most successful in this respect. It consists in the dissection of the scar, leaving a fresh healthy wound border of skin and mucosa. The mucosa of the mouth, while very stretchable, cannot be very well used for replacing defects of the mouth itself, but the external skin of the cheek offers very good material to patch the hole in the mucosa of the mouth. It must be selected in such manner that the flap has good nutrition. The flap is sutured there on three sides at first into the mouth and then when it is healed there, the fourth side is cut and sutured into the fourth side of the defect or else this whole procedure is done at once at the first operation; and a second flap, a tongue-shaped flap from the neck,

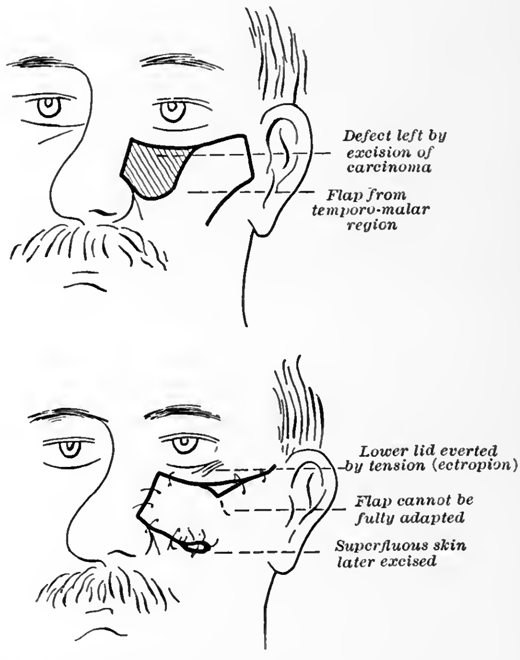


FIG. 408.—Method of cheek plastic. Removal of a tumor below the eye and side of the nose.

for instance, is thrown across the external gap and sutured into the wound border of the skin. The scars left after such operations become in course of time very smooth, especially if the union between the different structures has been smooth or accurate.

Meloplasty after Tumors.—The mucous membrane of the mouth is often the seat of tumors which require the resection of a large portion of the mucosa. If not replaced by plastic operation, such a defect if it heals may lead to absolute closure of the mouth by cicatricial contraction and to the impossibility of opening the jaws. It is therefore necessary to replace such a defect by skin. It is done in the same manner as the Israel operation in injuries.

Meloplasty after Resection of Tumors of the Outer Cheek.—This is a primary operation after the removing of carcinomatous masses of

Fig. 409.—Result in a case of meloplasty.

the cheek. The defect is best covered either from the rest of the cheek or from the neck, and offers no difficulty except that one has to take

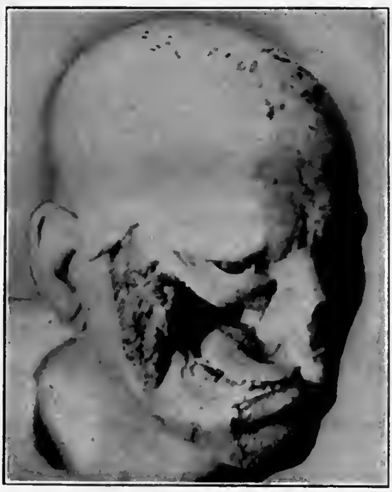


Fig. 410.—Case of removal of upper and lower jaw for cancer.

into consideration the retraction of those scars and the possibility of eversion and ectropion of the lower eyelid.

The defects of the cheek can be very extensive, so that the entire outer cheek has to be replaced. The accompanying figures show such a specific case under my observation. In a case of removal of carcinoma of the cheek and mucous membrane, the defect produced comprises the whole side of the face externally and internally, exposing to the view the tongue and the external surface of the jaw. In such a case the internal portion of the mucosa was supplied by taking the largest portion of the neck and implanting it into the mouth, forming the mucosa of the mouth and the upper lip. On to the surface of this was transplanted a large flap taken from the skin to the forehead, with its nutrition from the vessels behind the ear and sutured exactly into the defect in front. In defects from injuries this will give a fairly good result. In tumors, of course, it is problematical, inasmuch as a recurrence of the tumor inevitable after such extensive resection.

Fig. 411.—Plastic reconstruction of the side of the face by very large flaps from neck and skull.

URANOPLASTY (PLASTIC SURGERY OF UPPER JAW).

Destruction of the lower jaw or upper jaw requiring plastic operation on them is quite frequent. These defects are the result of injuries, disease, or they are congenital. The upper jaw offers one of the most important and interesting congenital defects, the cleft-palate. This defect has been the object of so many extensive treatises and even books that I shall present only a few of the most important varieties and methods of operating which are used for this deformity.

The cleft in the upper jaw may be a very wide one, so wide that in fact there is hardly any upper palate present, only two arches covered with mucous membrane, projecting on the side and not reaching each other in front. As a remnant of a uvula there is a small retracted projection of mucous membrane on each side. In the center of the cleft is a septum and the turbinated bones, even in this case, somewhat hypertrophied. This highest degree of cleft palate is usually combined with hare-lip of one of the described types. Its cure is a matter requiring great patience and repeated operations, and rarely leads to an ideal result. In early childhood the bones of the upper jaw are still quite soft and pliable, and then the Brophy operation has given the best results. By using perforated lead plates on the gingival processes, through which wires are drawn from one side to the other, one can by considerable traction bring the upper jaws nearer in their center and by freshening the arches of the projections of the palate and oftentimes by using the turbinated bones to fill out the gap, one can produce a cover of the mouth and uranoplasty of remarkable resistance and fairly good shape. However, it requires a great deal of experience to know how much traction and pressure may be used on these jaws so that no pressure necrosis shall take place.

Better results are obtained in milder cases, where the gap is not so pronounced, by this method. The technic is fairly simple.

Perforated lead plates are adapted to the outer border of the gingival processes. With a sharp awl a perforation is made in the gingival process through the palate in front and in the back. The borders of the gap are widely freshened and a silver wire drawn in through the holes of the plates and fastened by twisting them tight, so that the freshened surfaces in the jaws touch each other. This is left until healing takes place, which in many cases results in the whole line of the jaw uniting; but sometimes only portions are healed and others remain patent. These can afterward be closed by secondary small plastic operations.

In case of the presence of a small uvula, the parts of this soft structure are also freshened, on their median borders, and united by sutures.

Besides this method, there are several well-known methods of uranoplasty. First, the old Langenbeck method, one of the oldest, which is still in use in many instances and which is especially indicated in advanced age, where the Brophy operation is not possible, on account of the hard and unyielding bones of the jaw. In these cases the cleft of the jaw has to be closed by soft flaps of the palate. Two parallel flaps are cut alongside the cleft, one on each side, and entirely separated from the bone. The freshened borders are then sutured together with wire, bringing the broad surfaces of these flaps together as much as possible.

Modifications by this method of using portions of the septum have been made by Sabatier, or using a portion of the mucosa, by Lannelongue. Kraske advocated using the hypertrophied turbinate, which is twisted 90 degrees. Greig-Smith has used a double flap superimposed one on the inside of the nasal cavity and one on the mouth side of the nasal cavity, to close the gap between the jaws.

STAPHYLORRHAPHY.

Staphylorrhaphy is the operation of suturing the uvula of the soft palate. The best method is the ordinary Billroth method, which freshens up the soft palate and makes two incisions on the sides of the uvula to prevent distention. In many instances, however, all these methods of uranoplasty will not be available and it will require the formation of an obturator by a dentist, which will act in such manner as to close up the soft and hard palates. The apparatus of Case is a wonderful apparatus which makes it possible to use this method, but it requires a great many reconstructive educational methods to accomplish good physiological results. The training of muscles and the training of voice has to be done, so that the speaking should be free from the nasal twang.

Reconstruction of Traumatic Injuries of the Hard Palate.—Traumatic injuries and diseases may destroy portions of the hard palate, make a connection between nasal and mouth cavity, very similar in its physiological effect to that of a congenital defect, namely, nasal twang in speech, regurgitation of food into the nose during eating, infections of the nasal cavity, and so on. It is therefore important to reconstruct.

No general rules can be made, because there are so many varieties and possibilities that every plan must be made suitable for the individual case. On the whole, injuries in grown people in this region cannot be replaced by bony structures and we must be satisfied with soft structures. If the defects are too large, it is best not to try to replace the hard and soft palates by operations but it is advisable to use apparatuses which are attached to the teeth, if such are present, or to plates, which produce the best effect. A good dental mechanic can replace such a portion of the jaw by an obturator. Even one-half of the jaw can be replaced by such an apparatus, as in a case of unilateral resection of the upper jaw. Such an obturator has to be made in such shape that it brings about the projection of the cheek, which has sunk in because of the lack of support of the upper jaw.

If, however, operative measures are to be used on small defects, they consist in flaps similar to those in other regions of the body. Care must be taken that these flaps fit exactly into the defect and that they are there fastened with broad apposition of wounded surfaces.

Reconstruction of the Alveolar Processes of the Upper Jaw.—This line of reconstruction is of great importance. The defect of the alveolar process will lead to a sinking in of the most projecting part of the face and a very unsightly disfigurement. Plastic operations with implantation of bone might be tried in very favorable cases, to give a support to plates fitted by the dentist but in only very rare instances will they give good results and it will be necessary again to call on the dental mechanic, who in each individual case constructs an appliance which allows the patient to use his denture and which also gives to the patient that projection of the face necessary for the outlines of the same.

Reconstruction of the Lower Jaw.—The lower differs greatly from the upper jaw in its anatomical composition with relation to plastic surgery. While the upper jaw is a solid basis for shaping the face and for mastication, and with its apparatus for resonance that acts as a sounding board, the lower jaw is a movable structure with two distinct joints; a very complicated muscular apparatus and a firm half-ring of bone. Injuries and destruction by disease of any part of this important structure with its process containing the teeth, is capable of reconstruction and enormous progress has been made within the last few years in the technic of this reconstruction.

The bony structure is the most important one. It can be destroyed in its different parts and is easily fractured and can be deformed through faulty union or non-union of the fragments, so that there are a number of types of problems in reconstruction. The mandible consists of the horizontal and ascending arches, and the chin, a front part where they join. Malformations of this structure are relatively rare but there are two malformations which are so characteristic that they are well known even to the casual observer. One is the extremely projecting lower jaw or chin. In these cases the arch from which the jaw is formed is developed entirely out of proportion to the upper jaw and the lower row of teeth projects usually considerably beyond the line of the upper row of teeth. In early childhood this may be treated by orthopedic methods but in advanced age, it is a matter of operative surgery to reconstruct the normal shape of the lower jaw.

The second possibility is an undeveloped lower jaw. In this type the jaw recedes so considerably that the lower row of teeth stands behind the upper and the upper row projects as in an animal or in a bird, therefore "bird-face" is the name of this deformity.

Between the two extremes there are slight variations. I have never observed a regular cleft of the lower jaw and have never seen one mentioned in the literature, but slight notches in the lips and the chin are very common, sometimes so pronounced that it becomes a deformity requiring cosmetic improvement.

1. **Projecting Hyperplastic Lower Jaw.**—The treatment in this case is a very simple one and very effective. It consists in the resection on both sides of bone of the horizontal arch, which can even be done subcutaneously or from the mouth and adaptation of the two wound borders with union by primary intention, if done under aseptic precautions. The immobilization is very easily accomplished in a grown individual by wiring of the teeth, and the cosmetic result is excellent.

2. **The Bird-face, Receding Lower Jaw, Maldevelopment.**—This condition, much more unsightly than the first, may be treated by just the opposite method, namely, section of the lower jaw in its transverse processes, without opening if possible the buccal cavity, and the implantation of a section of bone or a portion of a rib between the two borders of the wound. This operation while delicate is by no means very difficult and those cases which have been done by experts have shown good cosmetic and physiological results.

3. **The Bifurcated Chin.**—The treatment of this can be done in such a manner that a subcutaneous separation of the skin from the chin is made by introducing through a slit in the skin beneath the chin a pair of blunt scissors and implanting a piece of cartilage, which fills the gap between the two ends of the horizontal arch of the jaw.

Destruction of Portions of the Jaw by Injury.—When the patients come under the observation of the plastic surgeon the deformity consists usually in a crooked jaw, portions of the skeleton are missing. Internal or external muscles below the jaw pull the bones in the direction of the least resistance, and the jaw assumes a position to one or the other side. As a rule the bones are not united. Often fistulæ persist, which are due to infection from the mouth, and a chronic osteomyelitis, discharging occasionally a spiculum of bone, which complicates the process.

The first indication in these cases is to remove all inflammatory conditions and heal every infection, remove dead bone, and produce a continuous smooth mouth cavity and clean external scars.

The next procedure is twofold: the first part is surgical and the second is mechanical by the dental mechanician. Oftentimes the latter method is far preferable to the surgical method. If the teeth are in good condition in the two portions of the broken and deficient jaw, they can be made a point of support for a bridge of metal. Martin, of France, a dental mechanical expert, for several years before the war held the reputation of making the best mechanical support. It was made of hard rubber and imitated the shape of the jaw which was missing, and fulfilled in a measure the indication of motion and shape of the lower jaw and face. Lately, however, a great deal of progress has been made in using very light metallic appliances with teeth, which were joined in the absence of the mandibular joint to the teeth of the upper jaw, and which were so successful that from the outside it was hardly apparent that such an appliance was in use, and for all purposes the jaw was as good as a natural jaw. Sometimes, however, these appliances are better if there is a bony continuous structure bridging the defect, and in these cases it is important for the surgeon to use the surgical method. Under aseptic precautions the two borders of the deficient jaw may be laid bare in a skin wound and a rib which had been previously resected may be introduced into the breach and by immobilization and exact suture be held there until firmly united. Wiring of the teeth in these cases into an immobile whole of upper and lower jaw, leaving only so much space between them as is necessary to feed the patient through a tube, is all that is necessary. Great care must be taken in such instances not to open the mouth cavity during the operation. The external wound in this region must be closed so accurately that the scars are not retracted. It is therefore necessary to unite very exactly the structures as they have been separated, muscle to muscle, fascia to fascia, and skin to skin.

Contracture of the Mandibular Joint, Ankylosis of the Jaw.—This is one of the many malformations which are either due to injury or to disease and require surgical reconstruction. A jaw which cannot be moved is an enormous difficulty for the patient and speaking and even breathing often become difficult. Diseases of the throat and pharynx become actually dangerous to life, even if in their nature they are harmless, because an edema of the pharynx may lead to suffocation if a tracheotomy cannot be quickly performed. Ankylosis may be due to cicatricial conditions of the soft parts or to bony or fibrous union of the jaw on one side or on both. The cicatricial contracture of the tissues around the jaw-joint can be cured by resection of such scars and an implantation of a flap of skin, as in meloplasty, in their place. Fibrous union, however, can also be cured by a regular arthroplasty. This operation is performed in the best manner from the outside. A small vertical incision in front of the ear along the external contour

Fig. 412.—Case of ankylosis of the jaw. Impossibility of opening the mouth.

Fig. 413.—Result of the case after arthroplasty.

of the joint, made with great care that the facial nerve is avoided, will lay the joint open with a very few strokes of the knife. The capsule, which is in such cases considerably retracted and scarified is resected or else a flap is made of fascia and muscle on the outside of the joint, and this fascia-muscle- (and perhaps) fat-flap is introduced into the breach, which has been made by resecting a portion of the ankylosed joint. Usually this operation is not difficult, and yields an excellent result.

Instead of fascia taken from the neighborhood and folded over the resected capitulum of the lower jaw, a fat flap with fascia from the femoral region may be introduced, but a local flap is preferable. This operation may be done on both sides if necessary. The after-treatment in these cases is very important. It is best to keep the mouth wide open during the first few days after the operation, as wide open as the jaws possibly allow it. This may be done by introducing a wedge between the two rows of teeth. After healing has taken place, the natural tendency is to close the mouth and from now on active and passive motion must be practised daily for a long time, to promote proper action in the new joint.

Reconstruction of the Entire Lower Jaw.—One of the most extensive injuries, of which the war offered a great many unfortunate victims, is one requiring a very difficult but feasible operation.

In such instances the oral cavity is wide open, the skin missing in parts, and retracted toward the neck, the tongue protrudes and drooling of saliva is constant. Eczematous eruption results from this and a condition is brought about which is most disagreeable. It may also be due to disease, as a necrosis of a jaw may lead to the entire exfoliation of the same. Fortunately for the individuals there remains a portion of the periosteum of the lower jaw, which has the great advantage of being a very active bone grower; so that often, if the whole jaw is destroyed, the shreds of periosteum gradually develop a small row of bones, which, though irregular in their shape, their total configuration imitates a diminutive mandible. In such instances good use can be made of this small remnant of bony structure. It can be split in the region of the chin, in such manner that an implantation of bone such as a portion of a rib resected from the angle of one of the large ribs, in the posterior axillary line will entirely replace the mandibular arch. The ribs of an individual in this line represent the identical shape of a chin if taken out to the extent of about two inches. This small arch of the rib can be fitted very exactly into the gap of the small arch which has been split.

An operation of this kind is not very difficult. A transverse incision is made below the chin and the skin widely separated from the remaining arch. Then the arch is separated in the center and the two pieces spread apart and a piece of metal at first introduced between them, preferably a silver jaw, which is allowed temporarily to heal in. It will form a bed. If it is not retained, it can be changed later on and the rib can be implanted, but sometimes the silver arch is retained and acts perfectly in conjunction with the jaw. The operation may be performed all at one sitting by implanting the rib in the first place into the bed formed by the dissection through the chin. If the skin has also been destroyed to a great extent, it will be better to do the operation in two sittings as it will be necessary to replace the skin of the chin first by taking flaps from the neck, and making a large pocket of skin which later on can be used with advantage to implant the bone. It is not a good procedure to do skin transplantation and bone transplantation at the same time, unless one can take, as has been suggested by some very daring operators, a flap from the neck, including in the flap a portion of periosteum and bone, for instance from the clavicle.

OTOPLASTY.

Otoplasty means the reconstruction of a part of or the whole external ear. This kind of plastic surgery has been done very effectively and with very marked success. The peculiarities of the ear with reference to plastic surgery are as follows: In the first place it must be said that the ear can hardly ever be reconstructed as a whole in such shape that it will resemble the very complicated and artistic shape of the natural ear. It is composed anatomically of so many flat cartilages which are so beautifully twisted, as to give to the ear its fine shape, with the external canal in its depth. It is covered with such delicate skin and has such thin borders that plastic work in the reconstruction is very difficult. But if we achieve only half of our object, we are usually satisfied, as an artificial ear can be supplied with great difficulty and is often in its best shape only a poor imitation of nature.

In the second place, injuries and disease and even malformations, do not as a rule comprise the whole ear and often a deformity produced by irregular healing of wounds, distortions of missing parts and clumping together of structures, may very well serve the purpose of reconstruction.

Congenital Deformities of the Ear.—These are very common, often on both sides, sometimes unilateral. They are due to faulty growth around the embryonic cleft from which the ear develops, and comprise all defects, from the so-called dog's ear, in which the cartilage is missing but in which a flap of skin is present which hangs down over the external meatus, down to the slightest aberration. Another malformation is the mouse ear, which is defective in the cartilaginous portion—a diminutive ear, pointed upward, with its upper portion so shaped that it resembles the ear of a mouse. Another deformity which is congenital is the enormously hypertrophied ear, which is too large for the shape and size of the face, oftentimes covered with a lot of excrescences and nodules, the giant ear. The fourth maldevelopment is an ear which stands off from the head so that it gives to the face a grotesque unsightliness. Each one of these deformities is amenable to plastic reconstruction. Our experiences in plastic operations on the ear, of which we made very good use for injuries, were just those which were gained in our experiments on these congenital malformations.

One part which is of great importance for the beauty of the ear is the shape and size of the lobule and lower part of the same. There are a number of deformities which are only differences in shape. For instance, instead of having an oval shape, the ear might have a rectangular shape, some part might project too much, or it may be so flat and thin that it is called a smooth ear. We will consider the reconstruction of these deformities first.

1. The Dog's Ear: The only way to reconstruct this to a more or less normal shape is to implant at first into the soft flap, of which there is an abundant mass, flat cartilages. They are obtained very easily from a submucous resection of the nose, an operation which is easily performed and which gives us beautiful flat pieces of cartilage that may be introduced through small slits into this lobe of skin, so that it is gradually transformed into a resistant ear. After a few of them have been introduced, the ear itself will assume somewhat of a normal shape,

except that it will stand off considerably from the skull. This deformity can be remedied by excising a portion of the crease behind the ear or by sewing a portion of the posterior surface of the flap into the defect which is made by excising a portion of the scalp behind the ear.

2. The Mouse Ear: This ear requires a ring of grooved skin with cartilage, as a contour, and this can be easily supplied by sewing a flap from the neck and from the portion behind the ear, into which a long thin cartilage is introduced by secondary implantation.

3. Irregularities of shape due to a conglomeration of cartilage by nature in the shape of a nodule around the meatus are best treated by dissecting the same in the way of natural cartilage, splitting it if necessary into thin plates, and temporarily allowing it to heal to the posterior surface of the ear. A great deal can be accomplished in this way but it is impossible to give exact rules for this method.

4. The Rectangular Ear can be remedied by excising a triangular piece wherever the corner must be rounded off.

Fortunately for the plastician, most of these small operations can be done in numerous sittings and it is better to do it in many sittings than in one, because the healing of these parts is excellent and it is better to do too little rather than too much at one time.

The Standing-off Ear is treated by the method of Pean, who excised a portion of the crease behind the ear and united the two borders so that the ear was drawn back into its normal position. Light degrees of this deformity may be treated in young individuals by retentive apparatus. It is often only necessary for the parents to put a band around the ear and thereby keep it close to the skull so that it may remain in that more pleasing position.

The Perforated Ear.—There may be a portion of the concha missing in the center. This might be congenital or due to an injury. This perforation is filled out by skin flap, best taken from behind the ear.

Restoration of the Lobule.—The lobule is in many instances lacerated, especially in European countries where the introduction of earrings causes perforations of the ear lobule in early childhood. Instead of a perforation, in many instances, a cut is made, or the lobule is destroyed by gangrene, or else the heavy earrings destroy the lobule by their weight, a split lobule being quite common. A reconstruction of the same is very easy, according to the common plastic principle of freshening and uniting by exact suture.

Restoration of an Entirely Missing Lobule.—The operation of Ombredanne is very good. The lobule is restored by a flap from behind the ear or the neck. This flap of right-angular shape is swung around and sutured on over a piece of gauze to the freshened wound anteriorly. After it is healed, the pedicle is cut off at its base and folded on itself, and by secondary operations it is shaped into a more pleasing contour.

Restoration of a Whole Ear.—This is one of the most difficult operations but it can be performed and give a fairly good result..

In the first place, according to the method of Szymanovski, a double flap is cut from behind the ear. The first portion of this flap imitates the shape of the ear and is not cut clear around but in its upper and lower half is left in contact with its duplication, which is the ear shape in reverse. These two flaps are folded on each other and sutured together in front, above and below. We have then an ear which is flat and has no depressions, no grooves. By gradual longitudinal cutting of small portions alongside the border and transversely suturing, we can gradually produce a grooved border. If we take another flap from behind the ear, cut a slit into the ear, right behind the meatus and introduce this flap into that slit, we can produce a deep recess, which afterward can be completed by cutting off a piece of the flap and suturing it in the opposite direction. Thus, after a number of operations, many sometimes, we are able to produce an ear of more or less normal shape.

Fig. 414.—Defect of the ear from electrical burn.

Fig. 415.—Otoplasty, shortly after the operation.

PLASTIC SURGERY OF THE EYE.

Plastic Operations on the Eyelids.—These are operations specially for the eye-surgeon rather than for the general surgeon. Nevertheless, there are several typical operations which in conjunction with other deformities and injuries of the face must be treated by the general surgeon and therefore should be included in general plastic work.

The eyelids have certain peculiarities which must be considered, of which the anatomical construction and the movability are the important factors. The anatomical construction includes such important structures as the cartilage, the tarsus of the eyelid, which gives it shape and if missing or destroyed prevents the eyelid from retaining the normal configuration. The skin which forms the eyelid itself is very pliable and thin and if replaced by other skin will not have this pliability and movability, unless the inside is lined with conjunctiva, a mucous membrane which is hard to replace, inasmuch as there is no such structure in the neighborhood. As to the movability, the lower lid depends upon the neighboring structures and muscles; the upper lid has its moving apparatus. Any contraction of neighboring structures, any scar formation, will deform the eyelids and this has to be taken into consideration when one performs operations in the neighborhood of the eyes, inasmuch as serious troubles may follow such contraction of the outside of the eye.

The most important operations of plastic nature in the eye are for entropion and ectropion of the upper and lower lid, missing lid, or missing portions of the lid, and displacement of lids through injuries in other than the above directions, and plastic operations necessary for artificial eyes.

Fig. 416.—Ectropion of both lower lids from burn.

Ectropion.—One of the most common deformities for which an operation is called for, consists in the shortening of the external skin cover in the vertical direction and a prolapse or eversion of the red of the conjunctiva toward the outside. Ectropion also is often the result of a flabby condition of the eyelid. In injuries, burns, after excision of tumors, such an ectropion occurs as a result of cicatricial contraction.

The greatest difficulty in the correction of this deformity, is to obtain such skin and so much only of the skin which will replace the missing epidermis and at the same time secure such a position that the flabby condition does not reappear. There are several methods of ectropion treatment:

First: The Snellen suture, which has the object of drawing the conjunctival portion inward, is only useful in plastic ectropion.

The Kuhn-Szymanovski method is only useful in senile flabby ectropion. It consists of a triangular incision of the conjunctiva and the transposition of half of the lower lid to the outside of the eye, thus narrowing the lower eyelid and attaching it to the outer angle of the eye.

Fig. 417.—First step of plastic operation is the removal of scars.

Fig. 418.—The second step, the transplantation of flaps from side of the face and temple.

Fig. 419.—Result of an extensive blepharoplasty.

For the cicatricial ectropion there is only one method, and that is to supply a pedicled flap from the outside, either from the cheek or from the temple or from the forehead, or by the Italian method from the arm.

Most important of all in these operations, however, is that the scar tissue which leads to the ectropion should be resected very exactly, so that only movable skin remains and if skin can be taken from the neighborhood, that it is not very thick but more or less of the same quality as the eyelids are. The upper eyelid is particularly difficult to replace. It takes a large amount of skin. If the eyebrow has to be replaced at the same time, it is very advisable to take the skin from the forehead and to take such a strip from the eyelid as will be advantageous, with a border of hairy tissue from the border-line of the hair of the scalp. This direction of the hair must be such as it is in the eyebrows and then this strip with hair must form the uppermost border of the eyelid. In this manner we can replace the eyebrow, the lack of which is unsightly.

Entropion.—The entropion of the upper lid is a serious and disagreeable deformity, usually due to trachoma. The best operation to remove it is the Hotz-Anagnostakis operation, in which a longitudinal strip of skin and tarsus is excised, just above the eyelashes and then sutured in such manner that the eyelid is bound outward instead of inward. There are several other operations for this deformity but the most useful is the above described operation of Hotz.

The undesirable feature of the entropion is that the hair which is turned against the eye constantly irritates the cornea and gives rise to serious cases of keratitis.

The Formation of Eyelids from Destroyed or Irregularly Shaped Eyelids.—In injuries, very often the eyelids are ulcerated and destroyed in such manner that after healing takes place, the scars draw them in different directions, so that sometimes the eyelashes with a portion of the tarsus extend vertically instead of horizontally, that portions of the border of the eyelid are missing, that half is drawn inward and the other outward, and so on. Numerous varieties of these injuries are the result of gunshot wounds and lacerations. The only indication that can be met by plastic surgery is to make use of all small portions or remnants of the eyelid, to bring it back as much as possible into the normal direction and by numerous operations gradually try to achieve what cannot be accomplished at one sitting.

If one examines very closely these destroyed eyelids, one finds that by excision of the scars he can usually reconstruct portions of the eyelids. Since the circulation is so good that these flaps hardly ever become gangrenous spontaneously, it is wise to retain everything, even the smallest shred of conjunctiva or portion of eyelid, to cut nothing away and to replace whatever is lacking by flaps, according to the rules of general plastic surgery. One can also make use here of free flaps, using mucous membrane from the mouth, the vagina and other portions of the body, and transplant it into the eyelid without suture. By simple immobilization, healing of these structures can be secured.

The formation of a whole eyelid can be made also by skin, using the same for mucous membrane.

The Dieffenbeck-Budingar operation uses a flap from the side of the face, which is folded on itself and forms a nice outline of the lower lid and is then inserted into the lid with the skin toward the eye.

An operation which is of some importance in plastic surgery is known as the Barreques operation. It consists in the bringing together of the muscles after the enucleation of the eye, in a lump, and covering this lump with conjunctiva, so as to make a small globe, which can be moved about just like the eyeball and upon which an artificial eye can be very easily fitted so that it forms an excellent support for the same.

Fig. 420.—Cicatricial contraction with ectropion of the lower lip and contracture of the neck, as a result ot burn, very extensive scar formation.

Fig. 421.—Lateral aspect of the same case.

PLASTIC OPERATIONS ON THE NECK.

The neck in regard to plastic surgery has considerably less significance than other portions of the body. There is in reality only one condition which requires plastic operation and that is the result of scar formation resulting in deformities or restriction in motion. The neck is by far the most movable part of the spinal column and if the spine and the muscular apparatus are perfect, the skin as a rule is very pliable, subcutaneous tissue quite loose, and there is no obstruction to its motion. If, however, through loss of substance by abnormal wound healing, scars are formed on the neck, the motion may be very much restricted.

It is impossible to give definite rules for plastic operations here, except those which are valuable for all regions of the body where substance has been lost and abnormal wound healing has taken place.

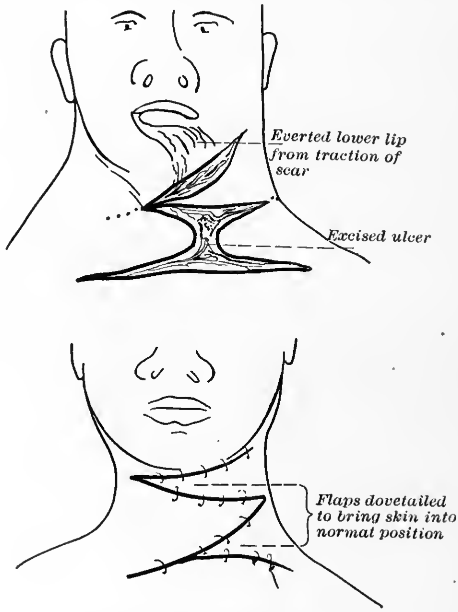


FIG. 422.—Method of straightening the cicatricial contraction of the neck by excision of the scar and sliding of the flaps.

FIG. 423.—Plastic reconstruction of the neck, shortly after the operation. Flaps are transposed by sliding. sutures still *in situ.*

FIG. 424.—Result some months later.

The regular procedure in regard to plastic operations of the neck is as follows: (1) Resect all the scars as deep down as the fascia or even deeper, if such scar contraction will obstruct motion. (2) Do not destroy any healthy structures of skin of subcutaneous tissue; even if they are irregular, small flaps, because they may be used in patching up a large surface. (3) After removing all the scar tissue, see whether the neck has a normal movability, or at least as much motion as can be accomplished. Sometimes the scars are so extensive and deep and the muscles have been so destroyed that it would be useless to replace the scars with skin and subcutaneous tissue, it would be a waste of labor and material. (4) If the wound which is obtained by resection of the scar is more or less rectangular or ovoid in shape try to get a tongue-shaped-flap from the back or from the chest to fill in. If, however, you cannot easily obtain one with good circulation, then use the arm or both arms to transplant skin and subcutaneous fat to the neck. (5) Often it will be possible by interlocking or dovetailing flaps from the neck itself to secure a neck of good shape and movability, because during the process of wound healing, this skin has been widely separated and irregular adhesions have been formed. There is usually a large amount of material for plastic work on the neck itself, so that it is often unnecessary to borrow from the neighborhood.

PLASTIC OPERATIONS ON THE THORAX.

The thorax offers a good many opportunities to perform plastic operations. Not so much the cosmetic, as the functional results of injuries are to be removed. Some minor plastic operations on the female breast are probably the only ones which require consideration.

Plastic Reconstruction of the Female Breast.—The fact that breasts are amputated for carcinoma or other reasons or are destroyed by injuries, necessitates in some instances reconstruction. Ombredanne has described one of the most feasible and successful methods of reconstruction, the longitudinal flap with its pedicle on the side of the chest, is rolled up on itself like a cornucopia, the point of the cornucopia forming the nipple. A large portion of the fat can be taken along from the side of the body and from the abdominal wall and in this way the breast can be imitated in its shape very easily. In some cases a lipoma might be transplanted underneath this plastic flap.

The reconstruction of the breast after removal of the same can be done also immediately by using different methods of plastic flaps from the neighborhood, according to the general laws of plastic surgery.

More important, however, are plastic operations on the chest of functional character. The thoracoplasty *par excellence* is the operation for closure of fistula from empyema, lung abscess and other destructive processes of the chest. The Estlander and Schede operations of old which have proved successful in many cases of chronic empyema are very extensive operations and do not guarantee success in all cases, especially in those cases in which the empyema is communicating with the bronchus or the abscess cavity of the lung. In these instances our operations of thoracoplasty which we have been perfecting for many years have given us much greater success.

If the empyema persists for some time after the initial operation, there usually is a cause for it. To go into the detail of such causes would lead us beyond the scope of this article, but one can in a general way say that the cause is mechanical, rather than bacterial. It is true that there are many cases which will never get well because the individual is tuberculous or syphilitic but in most instances the lung is retracted and the abscess cavity of the lung communicating with the bronchus continues to infect the cavity outside and the result is a permanent fistula and pleural empyema cavity.

Fig. 425.—Contracture of armpit after extensive burn.

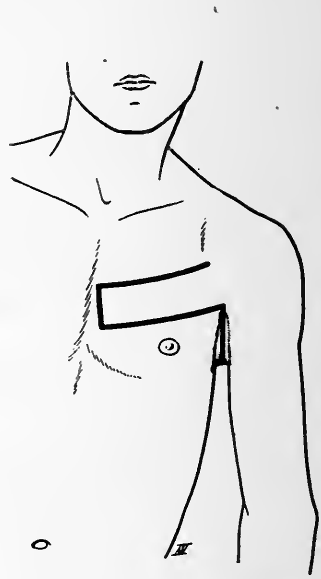


Fig. 426.—Method of operation.

Since this condition is so very frequent during war as a result of injuries from shrapnel or gunshot wounds we have to consider this thoracoplasty very seriously.

If it is possible to retain the function of the lung or restore it, and close the pleural cavity by any operation, it is a very desirable procedure, but it is not possible to make use of the lung and the only indication is to stop the suppuration and to restore the chest to such a condition that the patient is not deformed. If he has no use of his lung as a breathing organ, he has the use of his chest wall to support his body, and an operation which leads to curvature of the spine is not an ideal one.

Our thoracoplasty consists in most of the cases of the following steps: (1) Open the empyema cavity as wide as necessary to explore the size and shape of the same. Remove all the ribs that extend off from the cavity but preferably on the side or in the front of the chest and not in the back. (2) Do not depend upon the healing of the cavity by granulation, allowing the flabby chest wall after removal of the ribs to adapt itself to the opposite side of the pleura, because such is hardly ever possible. Only in the most favorable cases will such a cavity obliterate itself. (3) It is much better to cut one or two or more flaps of skin with the bases on the outside and turn them with their point into the chest cavity, fastening them with gauze against the granulating surfaces, so that they cling to them and after they are adherent crawl more and more inward, thus transforming the chest cavity into one with a wide opening toward the outside and lined gradually by epidermis and scar-tissue.

In this manner we are able to obliterate large cavities of the chest, often those which communicate with abscesses of the lung or with the bronchi and we have often obliterated the whole chest cavity, leaving it open and achieving this obliteration without the slightest curvature of the spine, because the ribs in the back of the body form a support and maintain the shape of the chest.

This method of thoracoplasty assures perfect dryness from the start, and if a large portion of the chest should be missing, a prothesis can always be made to overcome the defect.

Fig. 427.—A case of pendulous abdomen with hernia.

ABDOMINAL PLASTIC SURGERY.

The abdomen is perhaps the only region of the body where plastic operations are rare. Reconstruction of abdominal wall, for instance, is not necessary, in most instances, as the abdominal wall is very flexible and does not require much of any other structure except fascia and skin, both of which are absolutely necessary to give protection to the abdominal contents. There is only one plastic operation in which a defect is replaced, and that is abdominal hernia, or a diastasis of the recti muscles, in which a plastic reconstruction of the abdominal wall must be made, in order to prevent a prolapse of the contents. The other plastic operation is one in which an abundance of tissue of the abdominal wall is removed because it leads to deformity which simulates the hernia, namely, the pendulous abdomen. These conditions can be combined, in fact, they are, very often. Women who have given birth to a number of children have very flabby pendulous abdomens and often a hernia of the abdominal wall besides. The plastic operation for this deformity consists in the excision of a large section of the abdomi-

Fig. 428.—Result of operation in a case of pendulous abdomen.

nal wall, including the fat, in the shape of an oval, with its longest diameter transversely. This gives rise to a defect and exposes the

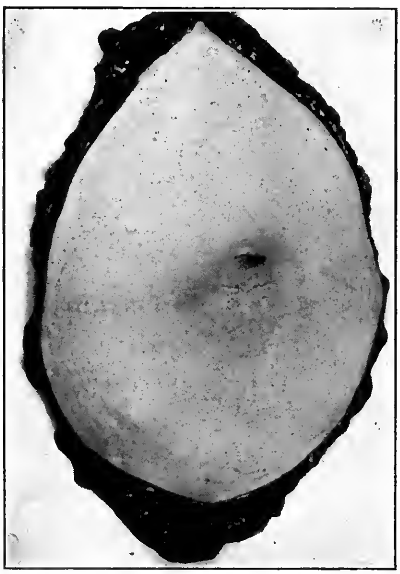


Fig. 429.—Size and shape of a flap taken in a case of pendulous abdomen.

Fig. 430.—Result in upright position.

diastatic recti muscles, with a central prolapse of the abdominal wall. A suture of these recti, bringing them together in the median line, with their fascia, is often necessary. But the abdominal wall is reconstructed by suturing transversely the two borders of the wound, so that the abdomen is diminished considerably in the longitudinal line.

Aside from this operation, the abdominal wall is of great use to the plastic surgeon, as it offers the largest areas of skin from which transplants can be taken. Extensive transplantations from the abdomen upon the arm, or from the abdomen upon the feet, by indirect transplantation, are well known and occasionally give excellent results.

PLASTIC SURGERY ON MALE GENITAL ORGANS.

In the male there are two pathologic conditions which require plastic operations, namely, epispadias and hypospadias. The epispadias is a slit of the urethra in the upper median line, usually connected with

FIG. 431.—Case of exstrophy of the bladder.

FIG. 432.—Result of operation in a case of exstrophy of the bladder with epispadias.

exstrophy of the bladder. Sometimes, however, it is only a remnant of the deformity, the bladder itself and the upper part of the urethra being normal. The hypospadias is the deformity of non-closure of the urethra in the inferior median line.

1. **Exstrophy of the Bladder and Epispadias.**—The anatomical relations in the exstrophy of the bladder are such that the symphysis as a rule is missing. The two horizontal arches of the pubic bone do not reach the center and there is a slit between the bones, in place of a bony junction. The mucous membrane of the bladder is usually everted upon the surface of the abdomen and the two bladder openings of the ureters project like two teats in the lower end of this raw mucous surface, which has the shape of a pear. The penis is like the small stem of the pear, the urethral mucous membrane lies open, but the scrotum, as a rule, is intact and the testicles are in the scrotum. The urine is projected from those openings of the ureters and can often be

distinctly seen squirting out with some force. The mucous membrane of the bladder, as a rule, after the condition has existed for some time, assumes a bluish, often a whitish-blue color. Sometimes it is irritated if not kept clean, and easily bleeds. Granulations are seen on some portions and scars are found as a result of such granulations.

However, there are cases which go on to adolescence, or even to older age in which no relief has been undertaken. These cases have kept themselves fairly clean by frequently changing the external dressings, and since the plastic operation of reconstruction is very difficult and requires a great deal of knowledge and experience, it may be said that it is even preferable for those cases to continue as they are instead of having some incomplete operation done.

There have been many plans devised, and many modifications of those plans, which only prove that there is no ideal method at present. I have come to the conclusion that the best method is the exclusion of the flow of urine from the abdominal surface by implantation of the bladder into the bowel, the old operation recommended by Maydl, or one of its substitutes. The great danger from such an operation still remains the ascending infection along the ureters leading to a pyonephritis, and destruction of the kidney through abscesses. But careful operative technic can prevent this.

First Method.—Trendelenburg Operation.—It consists, in the main, of using the bladder and closing the abdominal wall above it, so as to gain a viscus for the bladder with an exit through the natural urethra, which has to be formed also by closure of the epispadias. The weak points of this operation are the following: The muscular apparatus of the bladder is practically useless and even if we succeed in making a receptacle for urine, it is not a good one, not a bladder which will hold urine, it is only a bag which will direct the flow of urine through a smaller exit. The experiences are too few in which this operation has been performed on young individuals in whom there was a hope of developing a functional bladder in course of time. While I have performed this operation on the adult, I have never done it on an individual under ten years of age.

The method consists in dissecting the bladder around its external circumference and closing it in a median line by sutures and then using an abdominal flap to cover the raw surfaces of the inverted bladder. There is, as a rule, a defect of the muscles and of the fascia and a closure of the abdominal wall is hardly possible, without leaving a hernia. But if we succeed, we have a bag containing the urine long enough not to soil the external surface but dribbling continuously through the little opening left at the symphysis. If we at the same time make a tube for the urine to flow through along the upper surface of the penis, which is done by a very simple plastic operation, we can use a clamp on this tube and retain the urine in the bladder pouch long enough to develop muscular action and function of the bladder. This plan would be ideal if it could be accomplished, but thus far I have not been able to do it. In one of the cases in which I thought I had finally succeeded in doing this, the patient urged me after having achieved this stage to implant the ureters into the bowel, so as to get away from that continuous soiling with the overflow of urine.

Second Method.—The Implantation of the Ureters into the Bowel.—This operation can be done very successfully, in the following manner, as Maydl has described it: A square piece of the bladder containing in it the two orifices of the ureters, is cut out of the bladder wall and the ureters are dissected leaving all the tissues and the peritoneum on them, to a certain distance, sufficient to give the whole plate of the bladder some movability, in order to allow it to be twisted with its mucous surface toward the inside of a loop of the large bowel. The best place to implant it is the sigmoid flexure. A slit is made in the sigmoid flexure, longitudinally, opposite the omentum, and the mucous membrane of the bladder, the muscularis, are sutured to their respective layers, and then the peritoneum sutured on top of it, so as to seal it hermetically. A piece of omentum may be thrown around it, to insure against leakage and as a rule union will take place, with perfect function. The results of this operation have been fairly good in the hands of the expert. I personally have preferred in the few instances the separate implantation of the ureters, one into the right side and one into the left side, in cases in which I had to operate after surgeons had tried to perform this Maydl operation and had failed. In one case a surgeon tried to bring the ureter into the rectum, while passing a stitch from the rectum directly into the bladder (Simon operation). This created a fistula of the ureter into the rectum and spoiled the case for me for a Maydl operation. I therefore implanted the right ureter directly into the appendix, the left ureter obliquely into the sigmoid, leaving it hanging down into the mucous membrane with a free extremity and thus preventing a stricture of the ureter, which in my estimation has a great deal to do with the consecutive development of pyonephritis. This oblique implantation of the ureter into the bowel is very easy and gives a fair chance for healing by primary union. It is done in the following manner:

A right angle flap is cut into the surface of the large bowel, the muscularis is perforated obliquely by a sharp pointed forceps and the mucosa is pulled out of this perforation, and its point cut off, the mucosa is very movable and allows itself to be pulled out to some distance, one-sixteenth or a quarter of an inch. The ureter itself is cut off obliquely to a large external opening. A stitch is passed through the point of the cut and with a needle it is introduced into the bowel and pulled in through an opening of the mucous membrane. By pulling this needle out into the intestine and through the wall, a little distance from the perforation underneath the flap, one can pull the ureter into the lumen of the bowel with the needle, to some distance. Such a perforation with a needle does not harm anything at all and the ureter can be held in that lumen until it is fastened by very fine stitches in the oblique canal of the bowel wall. The peritoneal-muscular flap insures, by being sutured exactly, against leakage and against pulling out of the ureter. When the needle is cut off ultimately, the ureter slips back, but not entirely, and in this manner we have an absolutely good oblique implantation of the ureter. Animal experiments have proved that such is the result in almost every one of these operations and if after a year or longer this implanted ureter is examined, it still projects somewhat with a scarred end into the lumen of the bowel.

In cases of this implantation of the ureters, the exstrophy of the bladder can be cured absolutely and the patient left dry, the epispadias can also be fully cured and the configuration of the urethra restored in a simple manner by making two grooves of raw surface along the dorsum penis and uniting the raw surfaces together. If the openings of the ejaculatory canal are not obliterated, a normal function of these organs can be obtained.

Hypospadias.—This is the more interesting of the two abnormal conditions which require plastic surgery. It has led to the development of extensive literature but at the present date everything that is known concerning the technic of these operations can be condensed to a very small chapter. In hypospadias, the opening of the urethra instead of being at the end, as it ought to be, is alongside the course of the urethra, so that the urine and semen can flow out of the urethra on the side of this canal, instead of squirting out at the end. This condition is very unpleasant for many reasons. The elimination is such that the patient cannot stand during the act of urination but is obliged to sit down. There are many degrees of this deformity, and while most of them are due to congenital malformation, it is possible that such abnormalities exist as a result of injury or disease; for instance a chancroid or abscess may destroy a part of the urethra, and leave a condition almost identical to hypospadias. The same applies to injuries with gunshot or shrapnel. These injuries may destroy parts of the urethra and produce conditions which are entirely atypical but in some way related to hypospadias.

The cure of this condition depends entirely upon the malformation, the age and health of the patient, but most of all upon the patience of the surgeon. In no other field is the same tried as much as in this. Bad result after bad result must not deter the surgeon from ultimately arriving at a successful issue.

There are three forms or degrees of hypospadias which have been recognized ever since the malformation has been attacked surgically, namely, the location of the abnormal opening may be near the glans penis, the glandular hypospadias, or it may be between scrotum and glans, the penile hypospadias, or it may be behind the raphe of the scrotum, toward the prostatic region, the scrotal hypospadias. There is a possibility of an abnormal opening being present but the urethra being normal, as in injuries for instance, or after operation in a case of posterior urethrotomy. This plastic operation amounts only to the closure of a fistula. Somewhat different are the conditions when there is no urethra present, or only a very insufficient defective urethra. In these instances one has to perform a true plastic operation.

The methods which have been employed for the treatment and cure of hypospadias, are very numerous. Many of them are only of theoretical interest, as their authors and describers have used them on rather a limited number of cases and in the way of an experiment. Therefore, they are not recommended as practical.

Fig. 433.—Method of covering hypospadias, after Lauenstein and Thiersch.

1. **Glandular Hypospadias.**—The orifice of the urethra instead of being at the end of the glans is underneath the glans. There is rarely an indication for an operation, except for mental depression. The best method for this operation is the Beck procedure, in which the urethra is dissected with a cuff around the external opening, consisting of about $\frac{1}{16}$ inch or more of skin flap, a perforation of the glans with a sharp instrument, a knife or stiletto, wide enough to allow this cuff to be pulled through, suturing of the borders of the cuff to the external wound on the glans and closure of the wound underneath the glans (the old seat of the urethral opening) by lateral sutures. Simple as this method is, it requires some experience to overcome its inherent dis-

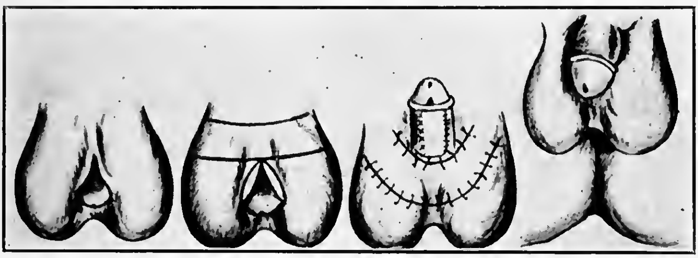


Fig. 434.—Method to form a urethra from a scrotum, after Lauenstein.

advantages. In the first place, the urethra in such cases is shorter by nature than it ought to be. But pulling it through the glans and not using too much of a cuff, makes it relatively still shorter, and in case of erection great tension will be placed upon the stitches and healing will be impaired or impossible, for the urethra will pull out of its new seat. It is therefore necessary to make the cuff of the skin quite thick, to prevent grangrenescence. It is also necessary to make liberal use of sedatives during the first week after operation.

In the second place, the lateral suture of the wound below the glans makes the back part of the skin very constricted and it also pulls out very easily, and besides on this place a new fistula often forms, so that if we have an anterior urethral opening, then we have beside that a small subglandular fistula. The worst disadvantage, however, is that

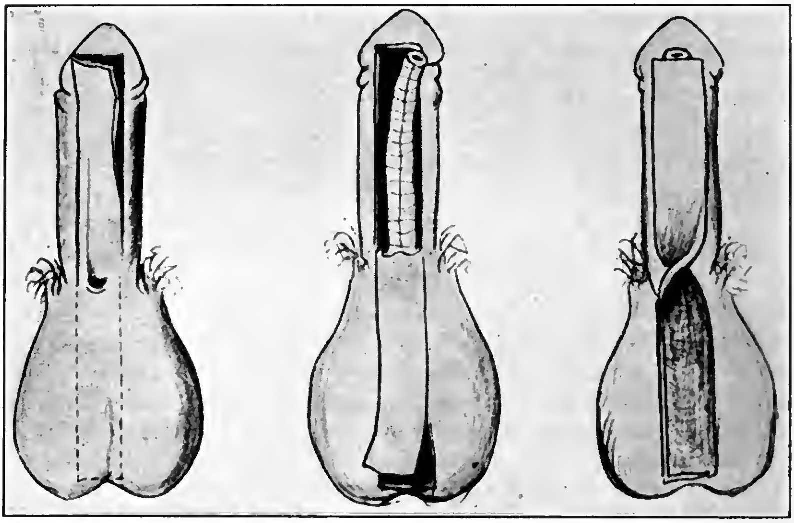


Fig. 435.—Plastic operation for hypospadias, according to the Beck method, showing the three different stages of the formation of a urethra from the scrotum and the cover from the same.

even if we achieve perfect healing, we have the complaint of the patient of discomfort during erection, due to a cicatricial bend at the place of the old seat of the urethra and more than once I had to make a

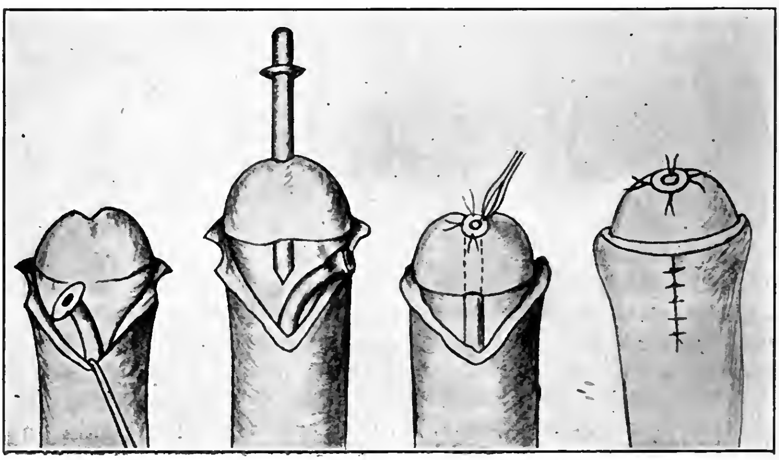


Fig. 436.—The method of operation of hypospadias after the original Beck-Hacker method.

secondary plastic operation to overcome this difficulty. If, therefore, an operation is undertaken for any degree of this deformity, connected with shortening of the urethra, one of the operations suggested for the second form, the penile hypospadias, is indicated.

Good methods for the light degrees of hypospadias are the following: The flap method of VanHook and Ombredanne, to supplant the urethra, which is short, by a tube, which is formed from the superabundant tissues of a foreskin. The foreskin is dissected in the shape of a flap, left in connection with its matrix at one end, this flap is sutured around a catheter, to make a tube out of it, with its epithelial surface toward the catheter and the wounded surface toward the outside. Then the glans is perforated widely with a knife or stiletto

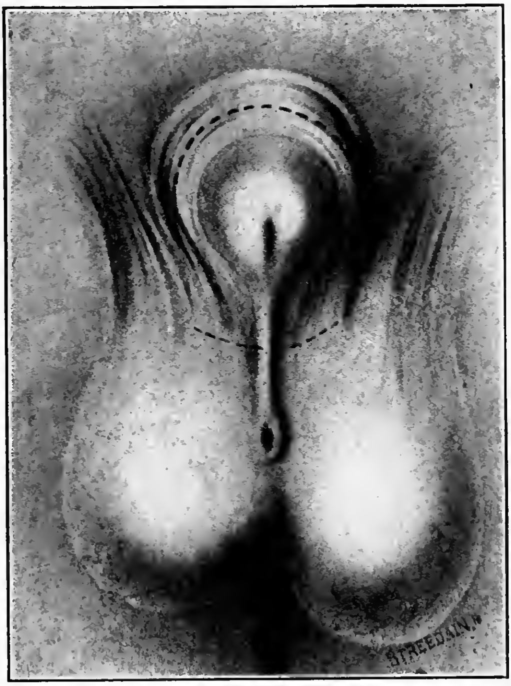


Fig. 437.—Outline of the incisions in a case of hypospadias, showing the rigid scar-like connection between urethra and the depression in the glans. Beck method for hypospadias.

and this tube is pulled into the tunnel backward from the glans toward the urethra until it reaches the subglandular urethra, to which it is attached. After it has healed, the fistula underneath the glans is closed by one of the various plastic methods and the prepuce cut off squarely in front of the glans penis.

Another method which is very good is the Thiersch-Lauenstein method. It consists of two flaps taken from the side of the urethra and covering each other, as explained in the accompanying figure. Such methods, however, are only possible when abundant tissue is present to cover the defect.

The Hamilton-Russell method is a very ingenious way to establish a short urethra in those cases in which the opening is subglandular and in which the Beck method is not entirely applicable because it would shorten the urethra. It is in reality the best way to establish a terminal opening. A sling is made out of the prepuce by cutting a narrow strip out of the same, leaving it to be nourished at both ends, and this sling is pulled through a newly made opening in the glans. It heals in and furnishes a urethral opening, whereupon the fistula is closed.

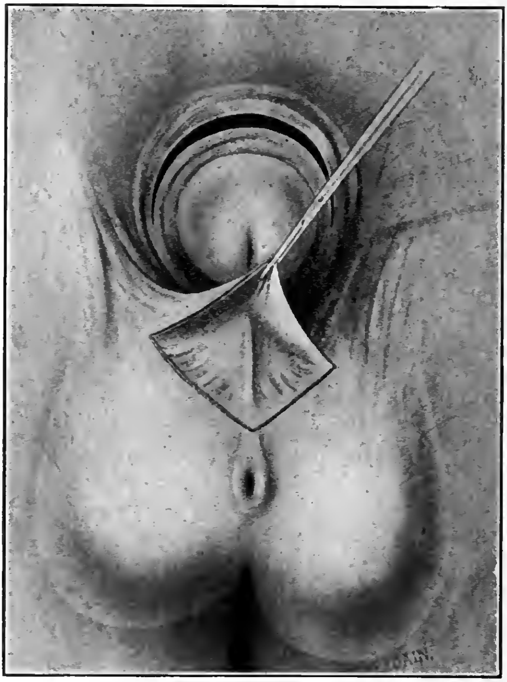


Fig. 438.—Incision made in prepuce, exposing the fibrous structure which has to be cut away.

The Ombredanne operation is another method which can be used for this light class of cases in some instances. It consists in the first place in making a large enough cuff around the abnormal urethral opening, so that when the same is folded on itself, it forms a tube. This cuff is especially well formed, is longer in the direction along the urethra than on the sides. After it has been sutured into a tube, so that its external opening corresponds to the normal opening of the urethra, a flap is formed from the abundant prepuce by cutting a buttonhole through it large enough to slip the glans through and using the double flap to cover the ventral surface of the defect. In this manner quite a complete urethra is formed.

2. **Penile Hypospadias.**—In this group one has to make two large divisions. In the first division of cases there is very little or no

urethra present and the corpora cavernosa are drawn closely on to the abnormal opening, which is near the penoscrotal line. The second division are those cases in which there is no urethra present but the penile extremity is perfectly free and normal, the corpora cavernosa are not drawn on to that opening. In one case the corpora cavernosa are straight in an erection, in the other they are badly curved and bent or crooked. This distinctive symptom makes it very important to treat these two types of the penile hypospadias in a different manner.

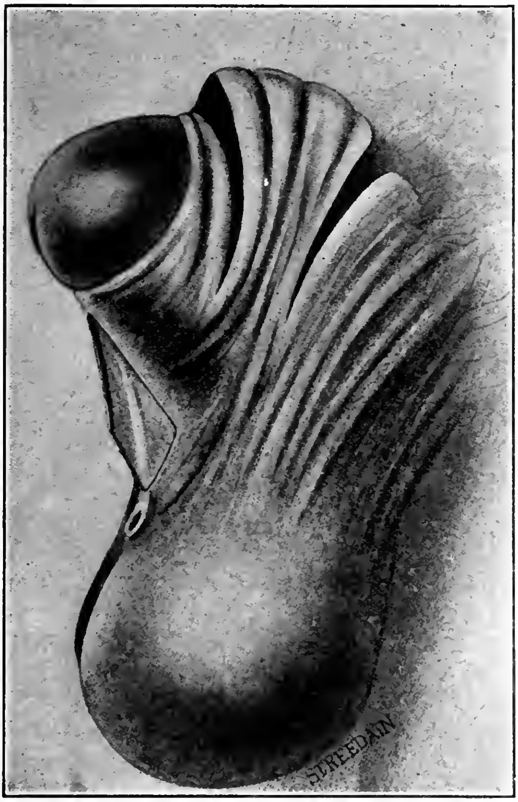


Fig. 439.—Lateral view of condition shown in Fig. 438.

The easier case is the one in which the corpora cavernosa are free and not bound down by abnormal adhesion. It is unfortunately the rarer class. In this class the method of treatment is the following:

First: The Beck-Rochet method. In this a urethral tube is made by suturing a rectangular flap around a catheter or a tube by tunnelization of the skin on the lower surface of the corpora cavernosa and passing this newly made urethral tube through that tunnel, and suturing its anterior border to a newly made opening in the glans penis. Temporarily, the patient should be catheterized in the after-

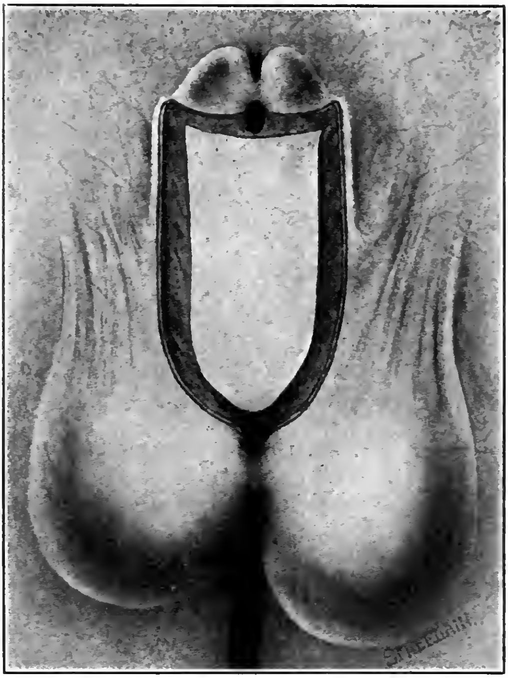


Fig. 440.—Freshening of the surface of the transplanted flap before forming of the urethra.

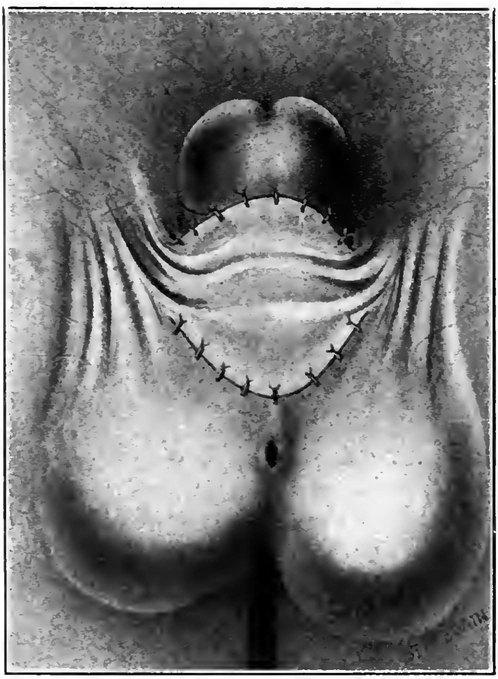


Fig. 441.—Transplantation of the prepuce and sewing of the flap into the defect.

treatment, until union takes place, perhaps for a week. A fistula often remains for a long time in the place where the newly made urethral tube is turned upward.

The second method is by Nové-Jusserand. In this case a tube is made out of skin from elsewhere than the scrotum, is sutured around a small staff of the width of the urethra, with its wounded surface toward the outside and then drawn through a tunnel made by a trocar or a long-bladed knife on the under surface of the corpora cavernosa.

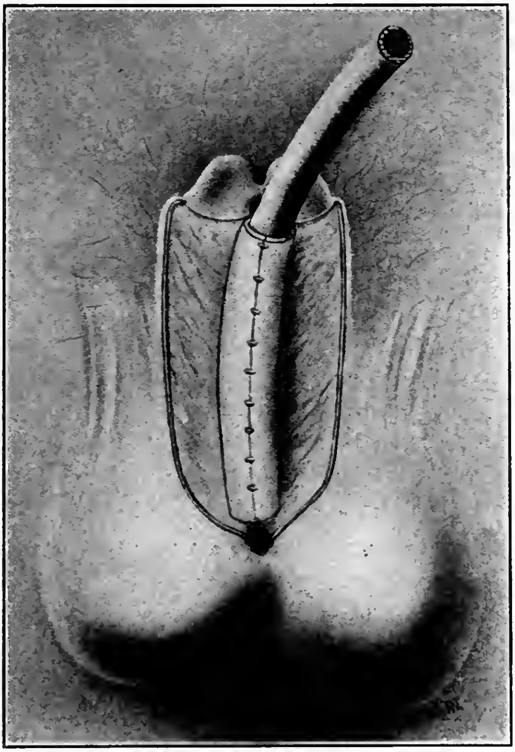


FIG. 442.—Forming of the urethra over a catheter.

The Schmieden method uses the appendix instead of the tube, and another method uses the vein from the neighborhood, for instance from the inguinal region (Tantot or Ruotte method). Cantas has used a flap of the skin of the inguinal region with the adherent vein, to be transplanted into the urethral region. The latter three methods I have never tried but I mention them simply as experiments in this connection. I have always been able to obtain results in the more simple Beck-Rochet method, or my own, which I shall now describe, as the best in the second and most common class of hypospadias, namely, the one with shortening of the ventral length of the corpora cavernosa.

In this class it is first of all necessary to lengthen the surface underneath the corpora cavernosa and allow the same to expand into absolutely normal length. The operations are performed in several stages, as may be necessary, because, an ideal result is not always obtained by a first operation. Sometimes, three or four attempts must be made before an ideal result is obtained. We begin with a transverse incision of the cicatricial bands which holds the glans to the urethral opening. By gradually cutting the same down to the corpora cavernosa we obtain a wound of a more or less rhomboid surface. This wound must be enlarged by excision of all

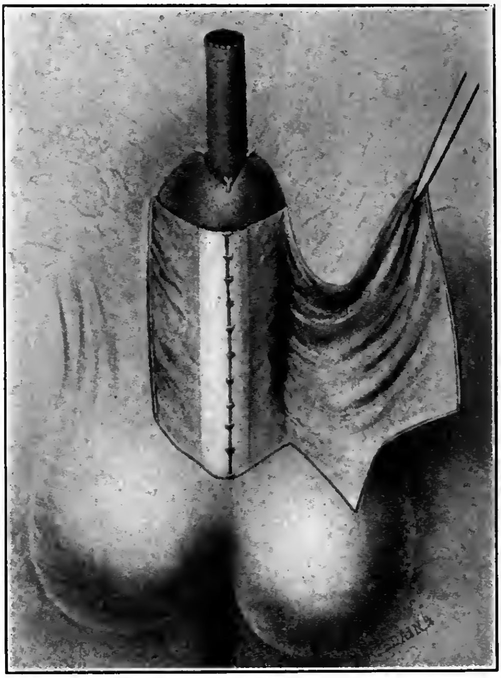


Fig. 443.—Formation of a large flap to cover the defect of skin from the side of the scrotum.

the cicatricial and fascial bands which are in the way of an absolute erection. Then the prepuce, which in such cases is always abundant, is buttonholed, as in the Russell and Ombredanne operation. This buttonhole is made large enough to slip the glans penis through. The prepuce is unfolded and its wounded surface sutured accurately over the wounded surface of the penile rhomboid. In every case of this kind we have had primary union; and sufficient skin to form a urethral tube is obtained by dissecting this skin on both its pedicled sides and suturing it over a catheter of large size. Then we have a urethra which has to be covered with a flap of skin, which has to be taken from the side of the scrotum in order to be pliable and sufficiently large to give abundant cover to the penile extremity. One should not be tempted to suture the skin over the tube by side-to-side adaptation, although it seems feasible. But it narrows the skin and endangers the healing. This method is applicable to almost any case of penile hypospadias. The fistula which remains for a long time on the site of the original urethral opening can be closed in a simple manner.

These methods do not exhaust by any means the possibilities of technic but they represent the most useful and most tried ways of correcting the abnormality.

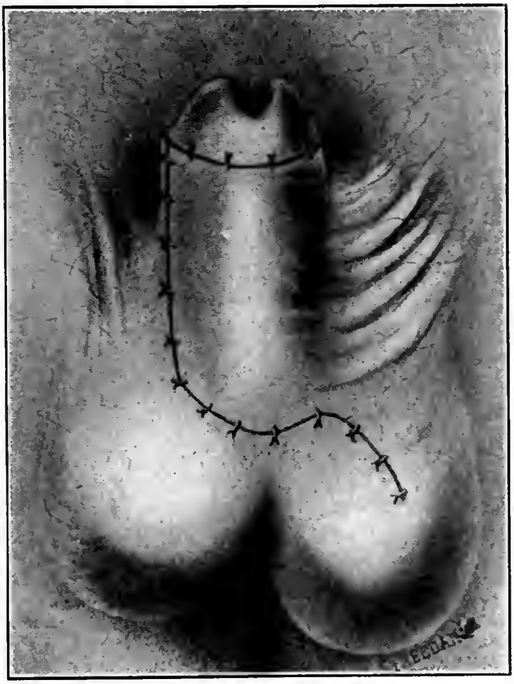


FIG. 444.—Operation completed with closure of the urethra.

The after-treatment of these cases is of greatest importance for success. One of the difficulties is the taking care of the urination. I have tried all the experiments in regard to taking care of the bladder function, from the suprapubic incision to the *laissez faire,* that is, let the patient urinate through the newly made urethra, immediately after the operation. Each method has its advantages and contraindications. With the suprapubic incision there is often unnecessary prolongation and complication. In many instances the leakage remains for a long time. The posterior urethrotomy often leads to a constriction and has also the disadvantage of not remaining open a sufficiently long time in many instances. The permanent catheter often leads to suppuration and necrosis if left too long and is especially objectionable where it has to go through a newly made urethra. The urination from the start through a newly formed structure leads invariably to infection and spoils the result of the operation. I have found the best method to be a regular strictly aseptic catheterization by an experienced man, until the bladder begins to get irritated and then to stop immediately and allow the patient to urinate spontaneously.

An important factor in older patients is the tendency to erection, which needs to be taken care of with anodynes, local or general as the case requires.

PLASTIC OPERATIONS ON EXTREMITIES.

Operations on the Arm.—One of the important operations on the arm is the correction of the cicatricial contraction of the shoulder, due to obliteration of the armpit through a scar. If the armpit is injured by a wound or burn, it often leads to adhesion of the arm to the side of the chest and inability to move the arm at the shoulder-joint. There are many degrees of this deformity. In some instances the arm is tightly adherent with a broad surface, to the chest. In other instances, it is connected by a scar which has been thinned out to a web-like structure, so that the arm may be extended to a certain degree but with difficulty, and between these two extremes there are many varieties. The correction of these conditions is possible by the following methods:

(1) Excise all the scar tissue down to the important structures of the armpit. Remove especially all the cicatricial bands which would prevent the full and easy extension of the arm to the physiological maximum. After this has been done, one can see the size and shape of the defect; and from now on, one may use any of the plastic methods known (see Figs. 425 and 426).

(2) Make flaps of tongue shape, taken from the back or from the chest, with the circulation so situated that the flap's life is not endangered and fill the gap with these flaps. One or more of these flaps may be necessary. Sometimes it is good to dovetail flaps taken from the chest and the back. There should be no tension of the flaps when they are adapted and they should be rather freely movable and closely adapted. The figures show several of the most common methods (Delafontaine, Piechaed, Berger, and my own) but there is no rule that can be laid down for every case of this kind. After the armpit is covered with flaps, it is dressed in the extended position and allowed to heal in this position, after which there is no difficulty in motion.

CONTRACTURES IN ELBOW OR WRIST OR FINGERS, HOLLOW OF THE HAND, ETC.

Injuries, burns, and disease often lead to destruction of skin over the region of the joints and make the extremity almost useless. If the contractures remain for a long time, muscles and tendons atrophy and it is impossible to restore function. The nerves become very short and in a secondary operation a long time afterward there is the greatest difficulty in overcoming this obstacle. It is therefore important not to wait too long after injuries for restoration of elbow, wrist and hand joints. On the other hand it is important to wait until acute inflammations have disappeared and healthy granulations have developed. One can restore large surfaces in the elbow-joint, dorsal and ventral, because it is just as important that there should be no cicatricial contraction over the olecranon, as in the inside of the elbow. In one case the arm will be overextended backward, and in the other case it will be contracted forward. The difficulty in obtaining skin to cover defects in this region is not great. Abdomen and chest and in some instances the back offer great possibilities in plastic operation on the arm. One should never try to do skin-grafts over joints, as they have no viability, and one should never try non-pedicled flaps, but should use pedicled flaps from the chest, abdomen, or back.

The process of operation is the following: 1. Remove all the scar tissue and the granulations down to fascia or if need be, the muscle. Leave no scar behind. Have the borders of the wound within healthy skin and broad, to make good adaptation.

2. Measure the defect and cut a model of the same out of paper or gauze, then outline on the chest in front or on the side or over the hip, as the case may be, that defect. Cut about one-third larger than the model shows and leave the flap in contact on the fourth side where the circulation supplies it, and suture the flap into the defect on the remaining three sides as far as possible.

3. Keep the arm in close contact, immovable, on the chest or abdomen, by passing adhesive strips over them, so that they cannot be torn off or moved during the state of healing. Sometimes I suture the arm to the healthy skin of the chest, in order to keep it directly in apposition, but adhesive plaster, as a rule, will be sufficient. Dress with gauze in such manner that you can look at the wound without having to remove the adhesive plaster, so as to relax sometimes a few sutures which would cut through, if left too long.

4. Wait long enough to have good union and absolute healing without reaction. Then cut the pedicle in about two weeks from the time of the first operation and suture it exactly into the fourth side of the defect. Take out the stitches of the first operation.

5. Adapt the borders of the wound from which you took the flap, in the direction in which they can be brought together most easily, in linear adaptation. You can use for this purpose with great advantage lead plate sutures with silver wire. You can bring wound borders together in a chest four and five inches apart from each other, so that when they have healed, they appear as a line of scar.

In this manner any defect of the arm, clear down to the fingers, may be replaced, even the whole surface of the hand. Sometimes it is better to use a bridge-flap, when we deal with a defect on a finger or hand. A bridge-flap is one which is formed by two parallel incisions

—the raising of the band of skin between the same and passing of a finger or hand or a forearm underneath this bridge and suturing the

FIG. 445.—Italian plastic in a case of loss of portion of the hand, attaching it to the chest.

flap into the defect, thus giving the flap a bilateral circulation, insuring better healing and better coaptation.

It has, however, one disadvantage, which is not to be underrated. In this bridge-flap, normal skin is placed against wound tissue under-

FIG. 446.—Result of this plastic operation after removal of the flap.

neath the flap on the opposite side of the flap. It is hardly possible to sterilize these structures to such degree that the sweat should not pour out its microbes into the wound and a saprophytic foul pus forms, as a rule which leads to formation of ugly granulations, to keloid formation, and sometimes to fever. I have therefore refrained in the last few years from making these bridge flaps, whenever I could get along without them.

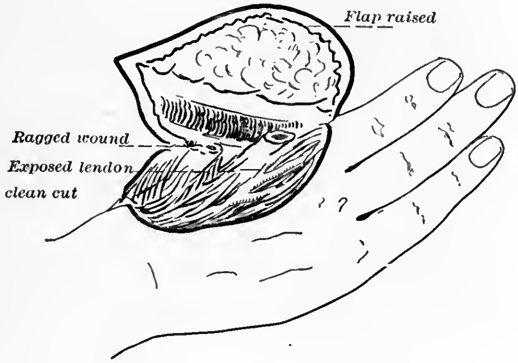


Fig. 447.—Diagram showing the method of transplantation.

Operations for Contractions of Fingers.—Contractures of fingers are quite frequent results of injuries. Whenever tendons are destroyed by an injury or by suppuration through infection, the result is a flexure of the finger and a contracture, followed often by ankylosis, even if the joint is not at first affected.

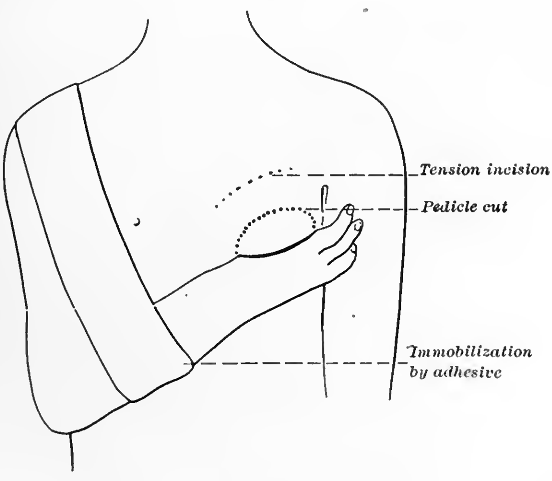


Fig. 448.—The same as Fig. 447.

This condition is unfortunately a very difficult one to treat, and for practical purposes it is often better to leave a contracture than to attempt a plastic operation. But there are favorable cases in which an operation might be performed with good result. The method to lengthen tendons which are shortened by cicatrices or which are tied down by adhesions within the tendon sheath and thus are deprived of motion consists in using fat and fascia transplants to wrap such tendons in while they are healing, to prevent their adhesion and fixation. As an example we take the cicatricial contraction of an index-finger. In that condition the finger is in the way of the patient and would be better amputated; but an attempt can be made to restore the total function of the index-finger. Three operations are probably necessary. In the first place the ventral surface of the finger requires a new skin cover, because the skin covering the joint is contracted, by cicatrices. The tendon of the flexor is to be restored and lengthened sufficiently and the joint which is ankylosed must be made movable.

Under anesthesia one can try first if the joint is totally ankylosed or only immobilized by cicatricial contraction of its capsule. If it is cicatricized in its capsule a forcible breaking of the adhesion will make the joint movable. If it, however, is permanently ankylosed and the joint surfaces are gone, then a resection must be made and a portion of the fascia and fat must be implanted to make it movable. The tendon may be replaced by a portion of the other tendon or through some method of tenoplasty and the skin must be supplied by an Italian skin plastic from the chest or from the side of the body. The best method to supply the skin from the chest is to make a flap in the region of the mammæ and to suture this flap, which is still adherent with its pedicle to the breast, into the defect. After union has taken place the flap is severed.

A great deal of physical exercise, active and passive motion, electricity, is used to restore the action of the finger and while it may not be that the surgeon achieves an ideal result in most of the cases, a good functional result can be obtained. By a chest flap I have been able to restore the function of all fingers which were affected with this contracture in a case of burn, with very good function of all of them. The patient, a laundress, had gotten her fingers between the hot rollers and burned the volar surface, with the tendons, but she still had fairly good motion after the plastic work was completed.

Plastic Surgery of Stumps of the Hands and Arms.—This portion of plastic surgery is one of the most important. When the extremities have been maimed in such large numbers as in the recent war, there remain thousands of cases with stumps of arms or hands or fingers which through plastic work might still be made useful functionally.

One cannot go into every detail of possibilities but can describe a few types, in which the technical principle is the same, only modified to apply to the individual case. The usefulness of the hand of the workingman consists in the first place in a good grip produced by the flexion of the hand and particularly the fingers toward the wrist, and secondly by the possibility of the opposition of the thumb toward the other finger, allowing the grasping and holding of bodies.

In plastic work these two functional results should be constantly in the mind of the surgeon. It will be important to conserve as much as possible and to sacrifice as little as possible during the treatment, immediately following the injury. It is important to prevent as much as possible the retraction of muscles and if such muscles are already retracted, it may be desirable to find them and bring them forward and attach them again to distant portions of flexible finger ends or stumps. If such fingers are entirely lost, the hollow of the hand itself can be transformed into fingers, with the possibility of opposing the thenar and antithenar parts and thus making a sort of small hand out of an apparently useless stump. The way this is done is as follows: Anatomically the hollow of the hand is divided into three portions, the outer portion corresponding to the fourth and fifth metacarpal bone, the middle portion corresponding to the second and third and the inner portion corresponding to the thumb. Incisions are made toward the wrist into the median line and flaps of skin may be obtained from the chest or elsewhere to be interposed into these freshened spaces so as to keep them from growing together. Three clumsy fingers, or at least what appear like fingers, are the result of this operation but functionally after they are healed and well trained, these three fingers are able to perform good work. If the skin is missing after an injury, or granulation is exposed and the tendons retracted, and the stump looks more like a deformed clumsy club, still something can be accomplished by gradually unravelling this conglomeration of scars and distorted bones until some functional end of the extremity can be obtained.

With this group belongs that class of cases which by nature are condemned to be born with this kind of club hand or arrested development of fingers. I have had several cases of this kind. This is a malformation which is not uncommon; children are born with a hand that looks more like a foot, the fingers being either small nodules or movable appendages, without any cartilage or bone, and the hand much smaller and shorter in general. Parents are very anxious to have a hand and I have in repeated cases been able by dissection of the metacarpal bones downward toward the wrist and introduction of flaps into the angle and transplantation of skin from the chest or abdomen to transform these into fairly good, useful hands, although they were not cosmetically as nice looking as they might have been, but it is remarkable what functional results patients obtain thorough exercise of these deformed hands.

One of the most important points in dealing with these cases is to supply sufficient skin. Only with abundant skin cover can we expect to have enough motion in structures which are not destined by nature to be very movable.

ARTHROPLASTY.

Arthroplasty is the formation of a joint. This can be either the restoration of the movability of an ankylosed joint or the formation of a movability of bones at a place where there is no joint normally present. We have learned from nature how to go about this plastic work.

Fig. 449.—Method of Italian plastic growing one limb to the other.

We have known for a long time that people who had a fracture and had the misfortune of having soft structures interposed between the

Fig. 450.—Method of sliding bipedicled flap for covering of ulcer.

fractured ends which were not easily absorbed, structures like periosteum or tendon or fascia, and fat, often developed a pathologic condition called pseudo-arthrosis, or a new joint at the place of fracture. Everyone who has had a chance to examine one of these cases of pseudo-arthrosis noticed that there was really not a joint present but that the fractured ends were covered with a deposit of tissue-like cartilage and that this was surrounded by a bag of scar tissue and filled with a sort of mucoid substance, so that the two fractured ends were moving within that bag, more or less. If we could imitate these conditions, we could produce a false or new joint every time. What is necessary therefore is to interpose between the bones which form a joint some substance that cannot be easily absorbed and that prevents the healing of the two ends of bone. If we take fascia and fat, either from the neighborhood or from a distance and place it between the two freshened ends of bone, and prevent infection, we will have

Fig. 451.—Result of such an operation after healing.

movability of the two ends of bone, or a joint. If we apply this principle to the stiff joint, it means that we have to resect the ankylosed ends and interpose fat and fascia and after it is healed, keep on moving the joint until we have restored its function. Let us take as an example the elbow-joint, in which this plastic work is so important. Supposing we have a stiff elbow in the extended position, the arm is useless and more in the way than if the patient had an amputation. The operation in this case consists in the following steps: Incision on the outside of the joint over the olecranon, formation of a flap like a tongue, consisting of fascia and fat from the neighborhood if possible, resection of the elbow-joint, introduction of fascia and fat into the depth of the resected joint, and closure of the wound. After primary union, as much motion as possible is achieved by physical exercise and active and passive motion. The same method with a few variations is applicable to most of the joints of the body.

But it is also possible to form a joint at a place where there has been no joint before, simply by resection of the two ends of the bone which one wants to join together and the introduction of fascia, preferably with fat, between them in the same manner. For instance, it is possible to join the humerus to the side of the body, to a rib, thus making a joint much lower than the shoulder-joint. Or it is possible to make a joint in a metacarpus of the thumb to produce a little better flexion of an opposing stump to the thumb.

It is most important in cases of arthroplasty to look out for the muscular action which is to move the joint. There is no use for instance, in creating a joint or making a joint movable where there is no possibility of action of muscles to move the same. While making the joint therefore, one has to prepare the muscular apparatus or if there is such a muscular apparatus one must not let it decay or atrophy while healing is going on. Electricity keeps up the muscular contractions and the life of the muscles even in the absence of motion and the treatment of these cases with electricity and passive motions is therefore important before active motions can be accomplished.

Fig. 452.—A bad stump after an amputation.

STUMP PLASTIC, AND TREATMENT OF AMPUTATION STUMPS.

The amputation of a leg or an upper extremity at different points for injuries or disease has developed along certain lines of thought. The surgeon was always led to choose the point of amputation by two indications, (1) to be as conservative as possible and not to sacrifice more than was absolutely necessary and (2) to amputate at such a point that the stump should not cause any inconvenience in action or in applying an artificial limb or an artificial arm or hand. To sacrifice an extremity is a misfortune but it is often better to have a good stump for an artificial limb than a contracted, abnormally distorted extremity, or a hand which is more in the way during work or a finger which is an obstacle. Gradually there have developed certain rules for amputations, which have left the stumps favorable for an artificial limb or a prothesis. For instance, the amputation below the knee was not very favorable if the stump below the knee was not long enough, because the little stump would be drawn up in a right angle, backward, a very unfavorable position for an artificial limb but very favorable for a wooden crutch. Therefore if the stump below the knee was to be of the greatest value, it had to be at least two-thirds of the part below the knee, and then the knee-joint would be used. Otherwise the artificial limb had to be up above the knee and the motion in the knee had to be left to an artificial motion in the knee-joint. An important matter was the quality of this stump. If the bone was too long and the skin scanty in making the skin flap, the bone was

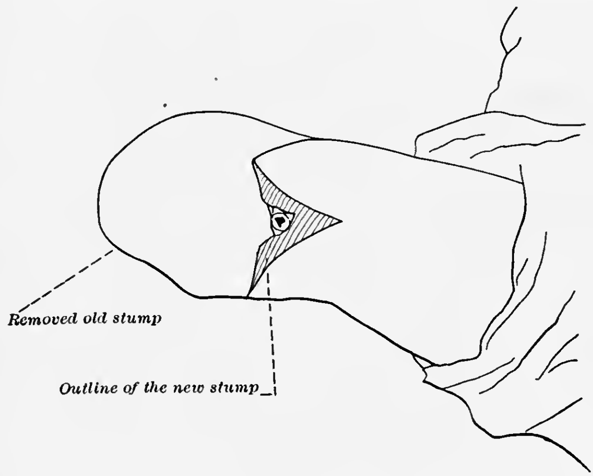


Fig. 453.—Method of operation for such a bad stump.

closely adherent to the scar, easily ulcerated and gave rise to many discomforts and troubles. Therefore a great many reamputations had to be performed, after primary amputations had been made by less experienced operators. The plastic operation of an amputation stump consists in an excision of a portion of the stump, leaving a good pillow of skin, fat, muscle, covering the bone end, a wedge-shaped piece is usually excised and the scar placed in such position that it will not be lacerated easily by the artificial limb or apparatus after it is healed.

During the recent war great progress has been made in the treatment of amputation stumps, in making use of muscles which heretofore have been left to waste and to atrophy. This method is especially useful in what is called the kineplastic amputations.

THE TRANSPLANTATION OF SKIN, FASCIA AND FAT.

By LEONARD FREEMAN, B.S., M.A., M.D.

THE TRANSPLANTATION OF SKIN.

Anatomy.—The skin of the average male adult has a superficial area of 10,500 to 18,700 sq. cm., and a mean thickness of 1 to 2 mm. It may be divided into three layers—on the outside the *epidermis,* on the inside the *tela subcutanea,* or subcutaneous connective tissue, and between these the corium, or true skin.

Epidermis.—The epidermis (cuticle, scarf-skin) contains no bloodvessels and consists of two layers. From the inner (stratum germinativum), which lies upon the corium, is developed the more dense and horny outer portion, the *stratum corneum.*

Corium.—The corium (cutis, cutis vera, derma) is composed of dense connective tissue containing elastic fibers, fat and a small amount of muscle. There are also numerous bloodvessels and nerves together with hair follicles and glandular elements. Small papillæ containing vessels and nerves project from the corium into the epithelial layer. These are usually shaved off in skin-grafting, thus causing the slight hemorrhage that accompanies the cutting of even the thinnest grafts.

The under portion of the corium, which gradually merges into the subcutaneous or superficial fascia, contains elastic fibers and bundles of connective tissue interspersed with more or less fat; the looseness and elasticity of the skin being due to the horizontal and oblique disposition of these elements. Where they are perpendicular to the surface the skin becomes comparatively immovable. The ability to stretch the cuticle in plastic work depends both upon its looseness and elasticity, while the marked contraction of flaps and grafts as soon as they are cut is due to their elastic fibers alone.

Terminology.—*Transplantation* (occasionally referred to as the first or older "Indian method") differs essentially from plastic surgery in that non-pedunculated "grafts" are employed, instead of "flaps" with nutrient pedicles (second Indian method).

Implantation is sometimes used synonymously with transplantation, although it more properly refers to the employment of non-living substances, such as decalcified bone, celluloid, ivory, etc. Other somewhat obsolete synonyms are *dermanaplasty* and *dermepenthesis.* The term *insition* refers solely to vegetable grafting.

When the material for transplantation is obtained from the patient's own body, the process is called *autografting;* when from some other person, iso- or homografting; and when from an animal, hetero- or zoögrafting. (Heterografting has also been used synonymously with homografting.) Skin grafts are known as autodermic, heterodermic, etc., according to their source.

Epithelial or *epidermal* grafts are those taken from the outer portion of the skin. Strictly speaking they should contain epithelium only, as in "blistergrafts," but practically they nearly always include more or less of the corium, thus becoming in reality *dermo-epidermal* in character.

Whole-thickness grafts comprise all of the layers of the skin, with or without the subcutaneous fat and fascia.

Reverdin grafts consist of small portions of epidermal or more properly dermo-epidermal tissue, usually about the size of a grain of wheat, which are snipped from the skin with a pair of scissors.

Thiersch grafts are thin dermo-epidermal shavings, perhaps an inch or so in width and of considerable length. They are usually cut from the thigh with a razor.

Historical.—There is reason to believe that transplantation of the skin was among the earliest of surgical achievements, it having been successfully practised by the Hindus some two thousand years ago in the restoration of the nose. Between that time and the present, however, the process was largely lost sight of, except for isolated reports of more or less doubtful cases, mostly emanating from charlatans. This is all the more remarkable because the reunion of accidentally severed portions of fingers and noses, which was recorded from time to time, should have called greater attention to the possibility of the transplantation of skin.

General scientific attention was first given to skin grafting in 1869 when Reverdin[1] demonstrated that small pieces of cuticle would grow when placed upon a granulating surface. Like most medical innovations, however, the idea was at first regarded with skepticism; and then, as experience grew, it was accepted with overcredulity, which often prompted the most exaggerated assertions regarding its functional and cosmetic effects, until its possibilities and limitations finally became properly recognized.

Comparative Value of Grafts from Different Sources.—Grafts from the patient's own skin grow better than when taken from another, and *much* better than those from animals.[2 3] Autografting is hence always the method of choice, while zoögrafting should be resorted to under exceptional circumstances only. But in spite of these well known facts, the temptation to use homo- and even zoögrafts is often, for obvious reasons, very great. Such operations are frequently heralded as marvellous successes in the daily press, but are generally reported too soon to be of any real statistical value. Shawan comes to the interesting conclusion, from observation and experimentation, that "skingrafting obeys the principle of blood grouping, as in the transfusion of blood;"

[1] Bull. de la Soc. de chir., December 10, 1869. [2] Lexer: Ann. Surg., lx, 166.
[3] Oshima: Arch. klin. Chir., No. 2, ciii, 440.

hence if the donors in isografting are selected from an appropriate group, the results should be satisfactory.[1]

Grafts from Animals and Homografts.—Grafts from animals, although they may adhere at first, often perish within a week or two, and the same may be said to a less degree of homografts, even when they are obtained from blood relations. For instance, in one of the writer's cases a granulating surface was covered partly with autografts and partly with grafts from the patient's mother, a healthy woman of middle age. The autografts all lived, while the homografts, although seeming to flourish equally well for the first two weeks, ultimately disappeared without exception.

It should be noted, however, that the experience of some surgeons has led them to express considerable confidence in homografting. Davis,[2] for example, reports 40 cases with 19 successes, 16 partial successes and only 5 failures; but these results are undoubtedly better than those obtained by most others. It is scarcely necessary to add that such operations should be done, if possible, under local anesthesia in order to spare the donor of the skin the dangers of a general anesthetic.

Grafts from the Cadaver.—Grafts from the cadaver have often been used, but they must be employed with great caution for fear of transferring some disease, especially syphilis. They should be cut as soon after death as possible and may be preserved for as long as several weeks in cold storage, at a temperature of about 3° C. (Carrel). It is claimed that the younger the subject the better the prospect of success, which is not very great under any circumstances.

The Skin of the Young.—The skin of the young, according to frequent assertions, is supposed to have more vitality than that of the old. However this may be, the difference is certainly not sufficient to counterbalance the advantages of autogenous over homogenous grafting; but if the latter method must, for some reason, be employed, a young donor should be selected rather than an old one. It should, however, be understood that in general the transplantation of skin may be accomplished quite successfully in persons of advanced years, so that age alone is not a contraindication.

The Effect of Systemic Diseases upon Transplantation.—In the homoplastic grafting of skin and other tissues the possibility of *transferring diseases* of various kinds (syphilis, acute infectious diseases, tuberculosis, etc.) must be recognized. Syphilis is particularly to be feared, hence it is advisable to insist upon a Wassermann test whenever there is a possible ground for suspicion. An unfortunate instance is mentioned by Deuvel in which lues was communicated in this way from a son to his father.

The general condition of the patient has something to do with success in skin grafting as well as in other procedures, especially if a disease of the skin itself is present, such as syphilis, erysipelas, or one of the acute

[1] Shawan: Am. Jour. Med. Sc., 1919, p. 503.
[2] Johns Hopkins Hosp. Report, 1910, vol. xv.

exanthemata. On the other hand, if an existing disability is due simply to the effects of sepsis from a suppurating area, such as a burn, the transplantation of skin is strongly indicated, and is usually not only successful but markedly beneficial both locally and in general. It must not be supposed, however, that the mere existence of syphilis always will interfere with the proper adhesion of transplanted skin, unless the disease is active or the field of operation directly affected; but nevertheless, when practicable, it is safer to carry out a preliminary course of specific treatment. The presence of such systemic affections as anemia, tuberculosis, syphilis, diabetes, or chronic nephritis can inhibit more or less the proper adhesion and growth of transplanted skin, and old age may cause its desiccation, but this is by no means always true.

Surgical Cleanliness.—In the transplantation of many tissues surgical asepsis is strictly indicated; but where the integument is concerned, although always desirable, it is often not necessary to success. The grafting of epithelium, for instance, must frequently be done upon granulating areas in the presence of profuse suppuration, or upon surfaces which cannot be sterilized, and yet, under proper precautions, failures are surprisingly infrequent. Even grafts comprising the whole thickness of the skin will often grow in the presence of sepsis, but such results are much less certain than when epithelium alone is employed.

It is of course obvious that the field from which the grafts are obtained should be carefully cleaned and maintained in this condition during the course of the operation, which means that when the transplant is deposited upon a septic surface all contaminated instruments must be carefully recleaned before another graft is cut.

If strong antiseptics are employed in an effort to obtain asepsis of the skin they should be removed by irrigation before transplantation is done, and it is generally conceded that it is better not to use them at all for fear of injuring the vitality of the grafts. This also applies to the use of iodin less than twelve hours before the grafts are applied. It should also be borne in mind that the application of chemicals to a granulating surface, which are forceful enough to injure the superficial cells, is always of questionable value and may prevent the adhesion of new skin unless the damaged granulations are removed before the transplantation is done.

Preparation of Granulating Surfaces for Grafting.—The transplantation of skin can successfully be done upon either fresh wounds or granulating surfaces. In operations for cancer of the breast, for instance, the denuded area may at once be grafted, or the operator can delay until granulation sets in. If the latter method is chosen the surface can be left intact or it may be scraped away, down to the firm tissue beneath, as was insisted upon by Thiersch; but if the granulations are allowed to remain they must be in appropriate condition or failure is apt to result. This can usually be accomplished by applying compound tincture of iodin to the granulating surface twenty-four hours before grafting.

Both whole thickness grafts and Thiersch-grafts grow well upon fresh wounds, but the latter usually give more reliable results upon granulating surfaces.

Blood Supply.—The successful transplantation of skin is much interfered with by a poor supply of blood, such as occurs in old ulcers of the leg with indurated borders and bases. In such cases the vascular condition can be improved in several ways:

1. *By elevation* of the part, which is indicated in all crural ulcers, but especially in those dependent upon venous varicosities. If the patient is put to bed and kept there *continuously*, improvement is often as rapid as it is striking.

2. *By pressure,* which may often be accompanied to advantage by heat and moisture. An old and favorite method was to strap the ulcer tightly with imbricated strips of adhesive plaster, beneath which was sometimes placed a coin or piece of metal of appropriate size. The whole dressing was changed once a day or once in several days, according to the demands of the individual case, the softening effects of the accumulated secretions being of service as well as the pressure. An ordinary Martin's bandage snugly applied directly over the ulcer will sometimes answer the purpose equally well. Richard Harte places a flax-seed poultice, enveloped in gauze, over the indurated area, and binds this firmly in place with a rubber bandage, so as to get the combined effects of heat, moisture and compression. This method is often very effective and deserves to be more frequently resorted to.

An objection to these procedures, however, is the danger of producing inflammation of the surrounding skin from moisture and confinement of irritating secretions, hence this must be watched for and the treatment altered if necessary.

3. *By incisions* through the callous borders and floor of the ulcer. These should be numerous, and may conveniently radiate, like the spokes of a wheel, from the center of the ulcer to beyond its periphery, penetrating entirely through all of the cicatricial tissue to the softer and more vascular layer beneath (Fig. 454). The resulting pain is often surprisingly small, but if necessary the part may be lightly frozen with a spray of ethyl chlorid. The object of the procedure is to loosen the cicatricial envelope of the ulcer and permit a better supply of blood to reach it. Nussbaum introduced a method which consists in making a deep incision entirely through the skin down to the deep fascia around the ulcer and about 2 cm. beyond its margin, severing all bloodvessels entering the area occupied by the ulcer and relieving the tension. This method is especially valuable in varicose ulcers.

4. *By excision of the entire ulcer,* induration and all, the subsequent grafting being done immediately upon the resulting raw surface or later when granulation has taken place. Providing the ulcer is not too large, this is a particularly valuable method when the induration is very marked, or when adhesion to an underlying bone exists, or especially when malignancy is suspected.

The condition of the surface to be grafted must also receive attention. It should be free from sloughs and necrotic tissue and the granulations must be "healthy,"—of moderate size, red and reasonably firm. Soft, flabby, pale or exuberant granulations, as well as those that are too small, hard and "dry," are unsuitable. It is, of course, next to impossible to obtain a granulating area without some suppuration, but the pus should be moderate in amount and "laudable"—a thin, watery or foul pus often leading to failure. Actively syphilitic ulcers or those due to tuberculosis should never be grafted. Although Kraske and others have succeeded in transplanting skin to the ulcerating surfaces of malignant growths, such attempts, for obvious reasons, are seldom if ever justifiable.

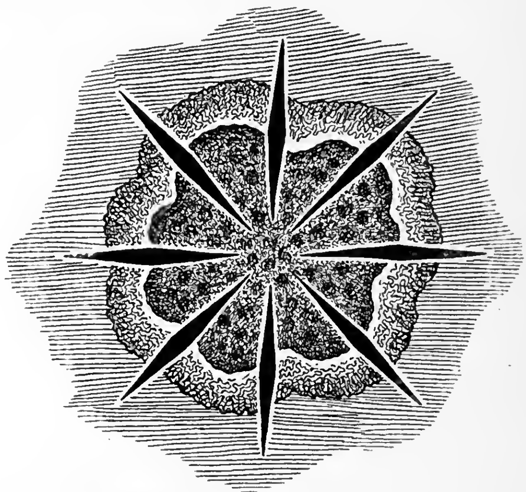


Fig. 454.—Incisions through callous base and border of ulcer.

It is apparent from what has been said that the grafting of lesions resulting from burns should not be attempted too soon. In most instances there should be a delay of several weeks, until all sloughing tissues have disappeared and the surface becomes clean and well covered with firm and healthy granulations, one of the best indications of fitness being the appearance of a pellicle of new epithelium around the edges.

When the granulations are unsuitable they may often be "stimulated" and improved by lightly cauterizing them every few days with a stick of nitrate of silver with pure carbolic acid or with tincture of iodin, in the meantime using gentle pressure by means of a bandage, and applying a mild antiseptic ointment containing boric acid, aristol, acetanilid, etc. When grease is not well tolerated antiseptic powders may be substituted, or compresses wet with liq. sod. chlorinat., acetate of aluminum, or even a weak solution of bichlorid of mercury, carbolic acid being contraindicated owing to its tendency to produce gangrene. Balsam of Peru is of much utility especially with indolent ulcers.

The various ointments should never be spread upon gauze, but always upon lint, linen or perforated rubber tissues, because the gauze absorbs them too rapidly, permitting the dressing to stick to the delicate granulations and new epithelium, thus injuring them upon its removal.

The main points to be observed, then, in preparing the granulations are—blood supply, cleanliness, cauterization, antisepsis and moderate pressure. These procedures are to be observed with especial care in the method of Reverdin, in which the grafts are always placed upon an intact granulating surface. In the procedures of Thiersch and of Krause, however, the granulations are generally scraped away down to the firmer tissue beneath, and hence it is possible, although by no means always necessary, to attempt the sterilization of the operative field without fear of injuring the vitality of the grafts.

This cannot be done with watery solutions, even though they be very strong, but a relative success can sometimes be attained by painting with tincture of iodin, or with pure carbolic acid. The transplantation can then be done immediately, after scraping away the cauterized tissues, or a dressing of boric acid ointment or Balsam of Peru can be applied and the operation deferred until suitable granulations appear. Wilcox cleans the ulcer on the evening before with green soap and peroxid and applies overnight a compress with 1 per cent. formaldehyd, the hardened surface being scraped away just before placing the grafts. Davis uses in a similar manner tincture of iodin, with Balsam of Peru and castor oil (1 to 3) as a dressing, the granulations either being removed before operating, or left intact.

It is questionable whether much if anything is gained by exposing the area to be grafted to the direct rays of the sun or by douching it with hot air, as has been advocated, although adhesion of the transplants is facilitated in this way.

Where to Obtain Grafts.—When the circumstances demand it, skin for transplantation may of course be obtained from almost any portion of the body. Usually, however, the anterior or external surface of the thigh or upper arm is selected; but if particularly thin or pliable skin, without hairs, is required, as often occurs in whole-thickness grafting about the face, the internal surface is preferable.

It is doubtful if there is any advantage, as has been asserted, in employing skin from the prepuce, the scrotum, or from points where it is subjected to especial tension, such as the insertion of the deltoid. Neither is there anything to be gained by the creation of an artificial hyperemia through brushing and beating the surface or by the application of dry cups or sinapisms (Hirschberg, Berger, Granbury, et al.).

Small epithelial grafts may be shaved, if desired, from *callosities* upon the feet or hands, but they are apt to be of inferior vitality. *Warts and moles* have also been employed, the former being separated into their component "epithelial rods;" but the use of such material is generally unnecessary and a homogeneous grafting might lead to the transference of malignant disease.

A large amount of epithelium may easily be obtained from *blisters* produced by cantharides or otherwise,[1] and in certain instances this source of supply may be of the greatest value. But the new skin resulting from such thin grafts, devoid of all subepithelial structures, is not apt to be sufficiently durable, hence the procedure is, in general, suited to the smaller and less important operations only.

As a matter of interest it should be mentioned that any dry scraps of epithelium will often adhere and grow upon granulating surfaces under favorable circumstances, as will also mere superficial scrapings from the surface of the skin ("epithelial dust"), the chance of success being greater the less the suppuration.

Attempts have been made to employ amniotic membrane as a substitute for skin grafts,[2] but with rather indifferent success, the material having less utility, perhaps, than the epithelium from blisters and but little more than the vitellin membranes of eggs.

When it is necessary to operate in two sittings, or when homodermic or zoödermic transplantation is attempted, the grafts may be preserved a number of hours in sterile gauze moistened with normal salt solution or for many days in cold storage at 3° C, or in sterile yellow vaseline (Carrel[3]).

Care of Wounds due to the Cutting of Grafts.—The same principles apply here as in the aseptic care of ordinary wounds. The spindle-shaped openings produced by the removal of whole-thickness grafts can usually be closed by sutures, especially if the subcutaneous fat is excised and the edges undermined, but the raw surfaces accompanying epithelial transplantation must be otherwise disposed of. In order to prevent the dressings from drying and sticking, which will cause much discomfort, the part should be smeared with sterile boric acid ointment and covered with rubber tissue before the usual gauze and cotton are applied or coated with paraffin, as in the treatment of burns. Such a dressing may often be left in place until healing is complete.

Dressings.—These are not really necessary to the adherence or growth of the transplanted skin, but are used merely for purposes of protection. They vary according to the nature of the grafts and the circumstances under which the operation is done.

To prevent adhesion to the new skin, which might prove disastrous when the dressing is removed, it is customary to cover the grafted area with *rubber protective,* which may be cut in strips or punched full of holes in order to facilitate drainage. For this purpose goldbeater's skin, oiled silk, isinglass plaster, tin or silver foil may also be used. Paraffin films, as used in the treatment of burns, are said to be equally successful in skingrafting.[4]

An excellent method of holding the grafts in position, which does not, like rubber protective, cause their maceration by confinement of the

[1] Freeman: Skin Grafting, C. V. Mosby Co., St. Louis, 1912.
[2] Sabella: Med. Rec., March 15, 1913, p. 478.
[3] Jour. Am. Med. Assn., 1912, No. 7, p. 523.
[4] Haworth: Surg., Gynec. and Obst., November, 1917, p. 558.

secretions, is to cover the field with a single *layer of gauze,* pinning it around a limb or fastening its edges to the surrounding integument with collodion or adhesive plaster as the circumstances may indicate (Fig. 455). This may be left permanently in place, the superjacent dressings being carefully changed as required without disturbing it.

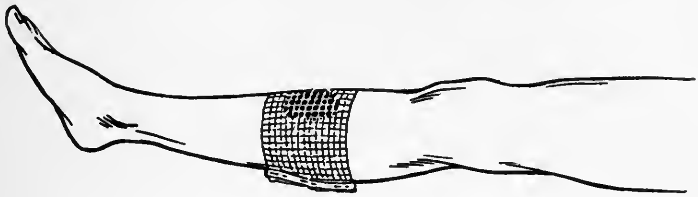


Fig. 455.—Strip of gauze pinned about leg for holding grafts in place. (Freeman.)

Davis[1] "*splints*" *the grafts* in a similar manner with curtain-netting having a mesh of about $\frac{2}{5}$ of an inch, which is of course applicable to large grafts only (Figs. 456–459). In order to destroy the capillarity of the netting and lessen its tendency to adhere, he soaks it in chloroform (150 parts) containing gutta-percha (30 parts), afterward placing it between layers of gauze and sterilizing for thirty-six hours in 1 to 1000 bichlorid, changing the fluid every twelve hours. The antiseptic

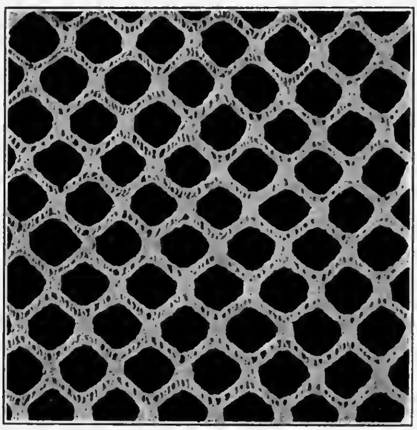


Fig. 456.—Curtain netting for holding graft in place. (Davis, Annals of Surgery and Bulletin of the Johns Hopkins Hospital.)

must of course be carefully rinsed off before the netting is used. Book muslin treated with varnish, or silk netting with paraffin, have been similarly employed.

A method of holding grafts in place, especially in difficult situation about the face, has given good results at the British Facial Reconstruction Hospital. It is called "*stint grafting,*" because of the employment

[1] Ann. Surg., 1909, xlix, 416.

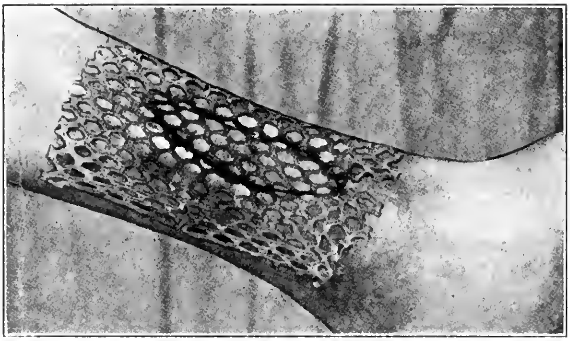


Fig. 457.—The material splinting a whole thickness graft on ulcer following osteomyelitis of tibia. Note cuts to allow accurate fitting. Photograph taken four days after application of mesh. (Davis, Annals of Surgery and Bulletin of the Johns Hopkins Hospital.)

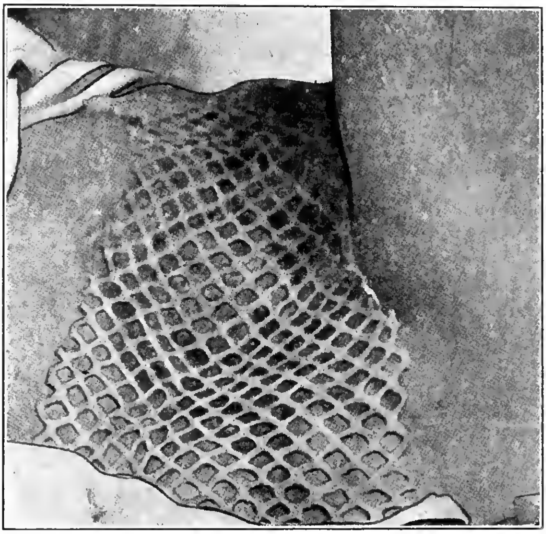


Fig. 458.—Illustrates the close fitting of the mesh over a Thiersch graft on deep breast wound following excision of carcinoma on a very fat woman. (Davis, Annals of Surgery and Bulletin of the Johns Hopkins Hospital.)

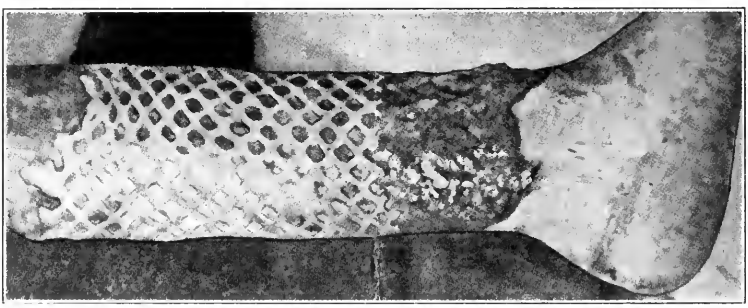


Fig. 459.—The mesh over whole thickness graft on burn, with the overlapping edges resting on granulation tissue. Photograph taken seven days after application. (Davis, Annals of Surgery and Bulletin of the Johns Hopkins Hospital.)

of a dental modelling compound known as "stint." After sterilization in bichloride, the compound is softened in hot water and molded into the concavity to be grafted. When hard the cast is removed, enveloped in a Thiersch-graft, raw side outward and then replaced, thus accurately pressing the transplant against the surface to be grafted. The "stint" should be held in position by sutures or adhesive strips passing over it from the skin on either side; or the skin itself may be sutured over the cast, or the eyelids, when grafting within the orbit. In the case of whole-thickness grafts the compound is molded over them and the adjacent parts, so as to obtain a uniform and gentle pressure without too much disturbance of the circulation. It is usually unnecessary to disturb the splint for several days, often not until healing is complete.

Moist dressings were originally advocated by Reverdin and by Thiersch and used almost exclusively by others, but more recently they have been largely discarded in favor of the "dry" and the "open" methods. When used with proper discrimination they nevertheless give good results, especially in epithelial grafting, although often unnecessarily troublesome.

Vosburgh[1] covers the grafts with strips of sterile adhesive plaster, the ends of which are made to adhere to the skin upon either side. They are left in place from six to eight days.

The usual procedure is to cover the operative field with thick pads of gauze saturated with normal salt solution. These must be kept constantly moist, which can be done with but little trouble if evaporation is retarded by a covering of oiled silk. Artificial warmth is detrimental because of its tendency to increase maceration and decomposition, which are the chief objections to the moist method.

Some operators prefer to moisten the dressings with sterile olive oil or with liquid vaseline, while others cover the grafts directly with boric ointment or with bovine, the latter being supposed to furnish nutriment to the growing cuticle, which is doubtful, to say the least.

The dry method is in more general use than the moist, because it gives better results with less trouble. It is particularly indicated in Wolfe-Krause and in Thiersch grafting. Before protecting the grafts with rubber tissue or splinting them with gauze or netting they may be sprinkled with a mild antiseptic powder, such as boric acid; but this is of uncertain utility and may do harm by aiding in the formation of crusts beneath which purulent discharges are apt to accumulate. The dressing is completed with layers of gauze and cotton in the usual manner.

If the grafts do not cover the entire raw area and there is considerable discharge, as is always the case in the Reverdin method and sometimes in that of Thiersch, the dressings must be changed frequently, the time varying according to the necessities of the particular case, but seldom being oftener than once daily. Otherwise, when there is no exposed

[1] Ann. Surg., lv, 891.

surface and but little secretion, the dressing need not be disturbed for several days and occasionally not until healing is complete. When it is necessary to remove superabundant secretions this should be done by gentle irrigation with warm salt solution and never by sponging. If blisters appear upon the surface of the transplanted skin they should be opened and emptied by gentle pressure with moist gauze.

The open method deserves to be more extensively used in selected cases than it is at present, a reason for its lack of recognition being, perhaps, a fancied difficulty in the technic, which is in reality quite simple.

Care should be taken to make the grafts adhere as firmly as possible, because they are not to be supported from without by any form of dressing. This is accomplished by attention to hemostasis, and by waiting until the operative field dries slightly before pressing the transplants into place with a pledget of moist gauze.

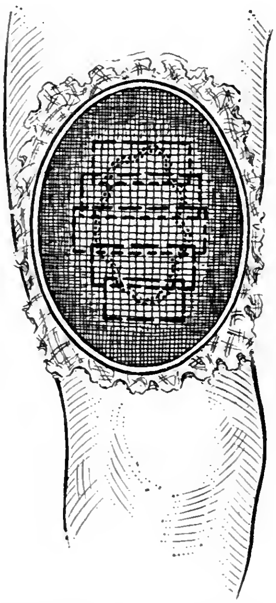


FIG. 460. — Showing use of wire cage in "open method" of dressing skin grafts.

The best way to protect the grafts from external injury, and at the same time to admit air freely, which is the prime object of the open procedure, is to enclose them in "cages" made of wire gauze, the padded edges of which rest upon the surrounding skin (Fig. 460). The wire "strainers" of different sizes used in kitchens and obtained in hardware stores answer the purpose admirably and may be held in place by encircling strips of adhesive plaster.

The open method will sometimes succeed where other measures fail. The greatest objection to its use, however, is the occasional formation of extensive crusts from drying of the secretions, which is of course most likely to occur when the grafts are small and widely separated.

If desired, a wire cage can be converted into a moist chamber by covering it with gauze saturated with salt solution, but the indications for such treatment are uncommon.

The "sand-bath" method (Fig. 461) is an effective although somewhat troublesome procedure suggested by Thies,[1] which insures fixation of the grafts, together with rapid absorption of the discharges and prevention of their coagulation. He covers the transplantation with a layer of sand, of small smooth grains such as is found on the seashore, which has been sterilized by boiling in 1 per cent. sodium carbonate and dried in small bags. It is applied with a spoon and changed frequently.

[1] Zentralbl. f. Chir., 1911, p. 458.

When *changing dressings* they should never be pulled off recklessly, for fear of dislodging the grafts, but ample time should be taken to soften them if necessary with warm salt solution or sterilized oil before their removal is attempted.

In the *after-care of the grafts* it should be remembered that it requires from seven to ten days for adequate adhesion to take place. Full protection should be maintained for at least two weeks and often longer, in order to guard the delicate epithelium from injury until its resisting power is sufficiently developed. Even then the new skin is apt to become dry and exfoliate unless a little boric acid ointment is occasionally applied. The time required for mobilization can be shortened and the circulation and nutrition increased by appropriate massage—not of the grafted area itself, but of the surrounding integument.

Fig. 461.—Sand-bath dressing. (Thies.)

If on *inspection of the grafts* subsequent to the operation they are found to be pinkish in color, success is probably assured; although a considerable amount of cyanosis, indicating defective circulation, does not always mean failure. The blisters which occasionally appear, especially upon whole-thickness-grafts, are usually of but little moment, although they should be opened and drained. At times the surface of a graft will disappear so completely that at first sight it seems to be utterly lost; but more careful inspection will show that the underlying layers still remain, and upon this foundation the epithelium will eventually reform in a satisfactory manner.

Local Anesthesia in Skin Grafting.—Whenever expedient, local anesthesia should be employed because of its freedom from danger, although general anesthetics are not detrimental to the growth of the grafts as has been asserted.

The most satisfactory local anesthetic is novocain with adrenalin, in solutions of $\frac{1}{4}$ per cent. and $\frac{1}{2}$ per cent. These should be newly prepared for each operation, by boiling the novocain for a few minutes only and then adding five drops of adrenalin for each 30 c.c. of solution.

To anesthetize the skin, a hypodermic syringe filled with the weaker solution is first employed to raise a number of wheals, like urticarial elevations, in the long axis of the limb (Fig. 462). This is done by inserting a small needle into the skin, not through it, and as nearly as possible parallel to its surface. These little areas at once become white and anesthetic and through them may painlessly be inserted the larger needle of a syringe of greater capacity, by means of which an extensive subcutaneous infiltration is accomplished with the stronger solution, its diffusion being aided by gentle massage.

Care should be taken to inject while the needle is being advanced or retracted only, so as to avoid danger of placing the fluid within a vein, and the quantity of fluid employed should not greatly exceed two ounces. In about ten minutes grafts of any kind may be cut without discomfort to the patient, the anesthesia lasting from half an hour to an hour or even longer.

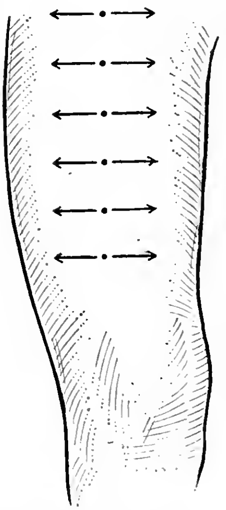


Fig. 462.—Diagram for anesthetization of skin of thigh.

When it is necessary to scrape a granulating surface this may sometimes be done painlessly by surrounding and undermining it with the $\frac{1}{2}$ per cent. solution, being careful not to pass the needle into or through the infected tissues.

Grafts may also be cut quite easily and painlessly by freezing the skin with ethyl chlorid, but the anesthesia does not last long enough to be very satisfactory and it is possible that the process may occasionally injure the vitality of the transplanted cuticle.

Postoperative Phenomena.—The transplantation of various tissues depends primarily upon their ability to live independently, for a short time at least, without any direct connection with the vascular or nervous systems of their host. This power is particularly apparent in the skin, approaching in the epidermis even to a kind of parasitism. During this period the grafts are probably nourished to a certain extent by imbibition. In this connection Carrel[1] has demonstrated that an independent life and even growth may be maintained for long periods outside the body by placing the tissues in appropriate culture media under favorable surroundings, such as a proper temperature, the absence of bacteria, etc. In fact, bacterial decomposition plays such a leading part in the destruction of tissues severed from the body that if this is prevented by placing them in cold storage their powers of reunion may be conserved for an astonishingly long period, this being

[1] Jour. Am. Med. Assn., 1912, No. 7, p. 523.

particularly true of the skin. The epidermis may also be conserved almost indefinitely when thoroughly dry, and, like the seeds of plants, be capable of germination and growth when surrounded by the proper conditions.

Transplanted skin at first merely sticks to the underlying surface by means of an adhesive substance formed from exuded fluids and disintegrated leukocytes, which rapidly penetrate it in large numbers. If this primary adhesion be disturbed within the first few days failure is apt to occur. In about eighteen hours, according to Thiersch, new bloodvessels, represented by their endothelial walls alone, begin to penetrate the graft, the old vessels disintegrating and disappearing. In the meantime the layer of exudative material is absorbed and replaced by a stratum of fibroblasts which ultimately forms connective tissue containing a variable quantity of fat.

The behavior of homodermic grafts is different. Owing to antagonisms between the biochemical constituents of the tissues and fluids of the donor and the recipient, inflammatory reaction occurs, characterized by an excessive infiltration of leukocytes, and ultimately leading to dissolution and loss of the transplanted skin.[1]

Firm adhesion takes place in about ten days, although it is much longer before healing is complete. The epithelium often rises in blisters, or even temporarily disappears leaving a raw-looking surface which may excite fear that the transplant is lost, but reformation soon takes place from the sides and from beneath.

The color of the grafts is at first white from anemia, or perhaps livid in the thicker ones from stagnated blood, but they soon become pinkish as the circulation improves. Later, the vessels may dilate into an unsightly vascular network, but fortunately this is rare.

The ultimate movability and softness of the new skin depends upon the thickness of the transplants, the amount of underlying elastic fibers and fat, and the extent of the associated cicatricial tissue. Reverdin grafts, being thin and set far apart, produce the least movability, often but little superior to that of an ordinary scar, while whole-thickness grafts especially, and even Thiersch grafts which have no cicatricial spaces between them often produce skin which closely approaches the normal in pliability. Urban contends, with some reason, that movability is more apt to result from grafting upon fresh wounds than upon granulating surfaces.

Sensation is usually regained in the new skin in the course of time, progressing gradually from the periphery, but it may require months before the process is complete.

Hairs are never successfully transplanted in thin grafts, and even in the thick ones they may fall out rapidly or become deformed.

Finger-nails cannot be satisfactorily transplanted even though the entire matrix and the contiguous skin be transferred. Like hairs, they become deformed or are rapidly cast off.

[1] Braun: Arch. klin. Chir., No. 1, cii, 12.

Contraction always takes place to a greater or less extent, its most prominent cause being the formation of cicatricial tissue between and beneath the grafts; hence it is most pronounced in the Reverdin method, less so in the Thiersch, and very slightly in evidence when the skin is transplanted in its entire thickness. Thiersch thought that contraction was largely due to the presence of granulations, hence he scraped them carefully away before applying his epithelial grafts; but further experience has resulted in considerable modification of this view. The minute wrinkling of the surface occasionally observed in thick grafts is due to a slight contraction of the deeper layers, which may also impede the circulation and give rise to enlarged and bluish veins or to objectionable pigmentations.

Irregularities of the surface, owing to the grafts originally lying below or above the general cutaneous level, have a remarkable tendency to disappear in the course of time, unless the tissues are too poorly nourished, as in certain old ulcers of the leg.

A kind of "*epithelial stimulation*" seems to result from the proximity of grafts to each other, so that the closer they are the better they grow and the more rapidly they cover the exposed surface, this being probably due to the inhibition of bacterial growth and the increase of nutritive supply. To get the full effect of this "stimulation" the transplants should not be placed more than half an inch apart.

Skin when transplanted to an individual of another color undoubtedly assumes in time the color of the receptor (Karg.)[1] Although there has been much discussion of this question it is really of but little practical importance except in zoögrafting, for instance from the pigmented cuticle of the frog.

Cheloids, both false and true, occasionally develop from the cicatricial areas between grafts. McBurney thought that this unfortunate complication was due in a measure to the use of dry dressings, but further experience has shown that the assumption was without foundation. Tuberculous individuals appear to be particularly susceptible to these overgrowths of fibroid tissue.

EPITHELIAL AND DERMO-EPITHELIAL GRAFTING.

Method of Reverdin.—This was introduced by Reverdin,[2] in 1869, although it previously had been done to a limited extent by others. The method soon came into very common use, but in reality its shortcomings are sufficient to limit its present employment to cases in which the cosmetic results are subordinate to the requirements of convenience or safety. The greatest argument in its favor is really the triviality of the procedure, but even this has lost much of its force since the development of local anesthesia.

The essential feature of the operation is that the grafts are small and placed at a distance from each other, without attempting to cover the

[1] Zentralbl. f. Chir., 1888, p. 944.
[2] Bull. de la Soc. de chir., December 10, 1869.

entire raw surface. The extent and gravity of the procedure is thus minimized, although the rapidity of healing and excellence of the final result are correspondingly lessened.

Cutting the Grafts.—This is best accomplished by elevating a small fold of skin with toothed forceps, or a needle inserted parallel to the surface, and snipping off a portion about the size of a grain of wheat

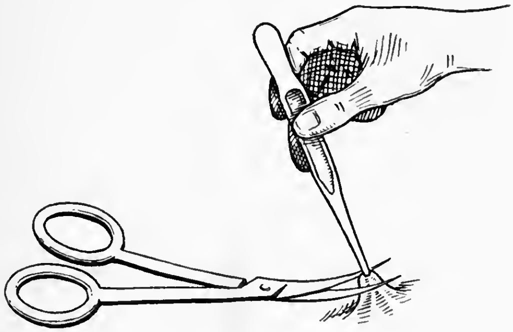


FIG. 463.—Cutting Reverdin grafts.

with iridectomy scissors curved on the flat (Fig. 463). The epithelium and a thin layer of the corium are thus obtained, a slight oozing of blood resulting. The small amount of pain can be obviated by the use of local anesthesia, but this is seldom necessary, especially with adults.

Placing the Grafts.—Placing the grafts (Fig. 464) upon the granulating surface should be done as soon as they are cut, it being unneces-

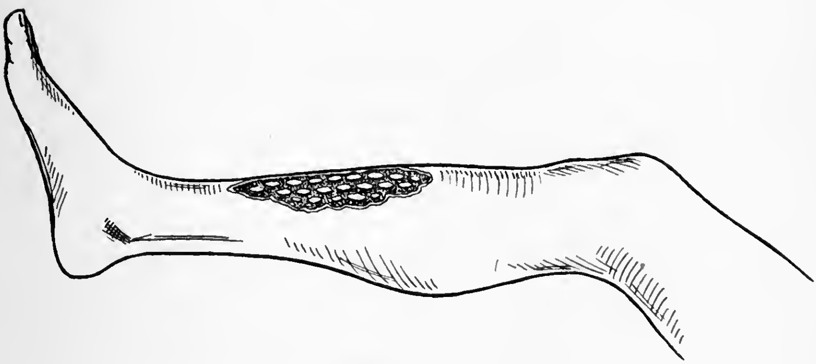


FIG. 464.—Reverdin grafts in position.

sary first to float them in salt solution as is often practised. They are then pressed lightly into position with a moist gauze sponge thus securing their firm adhesion; and if the edges have a tendency to curl under they should be unfurled by sliding the transplant gently from side to side with the moistened end of a probe. The bits of skin should not be placed more than half an inch apart, as their capacity for independent growth does not permit them to enlarge to much more than the size of a silver dime.

It is neither necessary nor desirable to employ sutures nor to bury the grafts in any way among the granulations. In fact it is better to leave the grafting-surface intact; simply irrigating with salt solution, to remove the pus, and refraining from scraping away the granulations or otherwise injuring them, thus justifying the main argument in favor of the Reverdin method—its simplicity and comparative painlessness.

Davis[1] claims that where an especially firm and durable result is required, it may be obtained by using what he terms "small deep grafts," which are merely Reverdin grafts comprising most or all of the thickness of the skin.

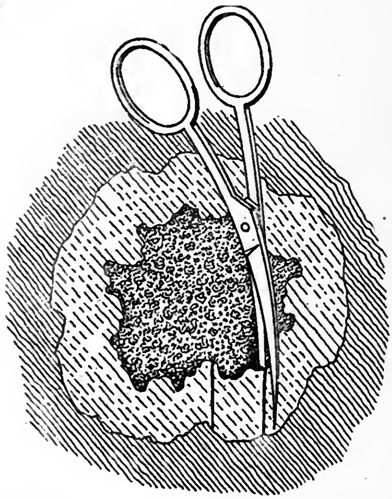


Fig. 465.—Cutting grafts from border of healing ulcer. (Freeman.)

Quite satisfactory "floating-grafts" (Souchon[2]) may sometimes be obtained from the new epithelium which "floats" out from the borders of granulating surfaces which have already begun to heal, by carefully undermining the delicate film and clipping it away with a pair of small scissors (see Fig. 465).

Method of Thiersch.—Although this procedure was used to a limited extent by Ollier as early as 1872, nevertheless to Thiersch,[3] in 1886, belongs the credit of perfecting it and bringing it into surgical prominence. It is really the most widely applicable method of grafting, differing from that of Reverdin in that an attempt is made to cover the entire raw surface by means of large grafts which overlap each other instead of small ones set far apart. It can be used upon fresh wounds or upon granulating surfaces, with or without removal of the granu-

[1] Jour. Am. Med. Assn., September 19, 1914, p. 985.
[2] Ibid., July 17, 1909, p. 207.
[3] Kong. deut. Gesell. f. Chir., Berlin, 1886.

lations, and under ordinarily favorable circumstances the chance of success is always good.

Cutting the Grafts (see Fig. 466).—This is done most conveniently with an ordinary razor, which may be flat on one side, although a number of special instruments have been invented for the purpose. The skin of the thigh is cleaned, shaved, and put tightly on the stretch by the hands of an assistant grasping the opposite sides of the limb. The operator, standing with his back toward the patient's feet, places the razor, well moistened to prevent sticking to the skin, flat upon the thigh transversely to its long axis and, cutting toward himself with a side-to-side sawing motion, removes a thin shaving of skin about as thick as a sheet of writing paper, which folds up compactly upon the upper surface of the razor. The strip is generally an inch or so in width, its length varying according to the requirements of the case and the skill of the surgeon. The cutting may be greatly facilitated by pulling the fingers of the left hand forcibly along the skin just in front of the advancing razor, so as to add a longitudinal tension to the transverse maintained by the hands of the assistant.


Fig. 466.—Cutting Thiersch grafts.

E. H. Ochsner demonstrated in a large series of cases that perfect results can be obtained in more than 90 per cent. of cases of Thiersch grafting if the razor, the surface from which the graft is taken and the surface to be grafted are kept perfectly dry.

Although the procedure is really simple enough, considerable practice is necessary before long, thin and perfectly even grafts can be obtained with certainty. They should not comprise the entire thickness of the skin, except for particular purposes, but should include the epithelium and a portion of the corium only; hence with the thin integuments of the very young and the very old care must be taken to prevent the razor from penetrating to the subcutaneous tissues.

Placing the Grafts.—As soon as the skin is severed it is transferred, folded on the razor, directly to the area to be covered. The edge of the instrument is then so placed that, while the border of the graft is held with a probe against the marginal skin, it can be unfurled into position by sliding the razor across the raw surface (see Fig. 467). When the configuration of the field of operation is such, however, that this cannot easily be accomplished, other maneuvers must be resorted to, such as the preliminary spreading of the transplant upon rubber tissue, cork paper, silver foil, etc., which may remain in place as part of the permanent dressing. A piece of gauze, moistened to prevent sticking, is used to press the new skin into place, thus forcing out air and fluid and promoting firm adhesion. If the edges are inclined to turn under they may be adjusted by gently sliding the graft

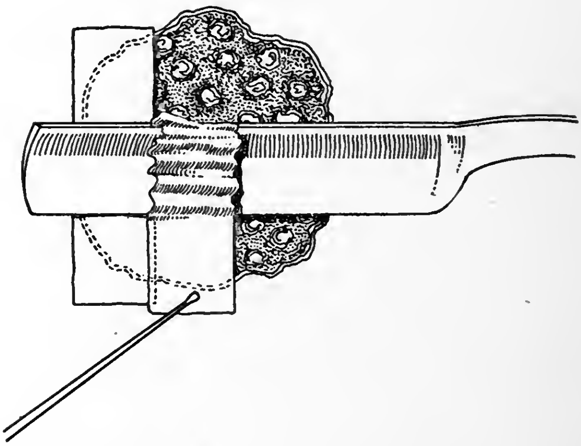


Fig. 467.—Sliding Thiersch graft from razor to surface of ulcer. (Freeman.)

backward and forward by means of a moistened probe pressed against its upper surface. Two ordinary sewing needles grasped by small hemostatic forceps serve admirably for spreading these grafts. The points of the needles should be held by the forceps.

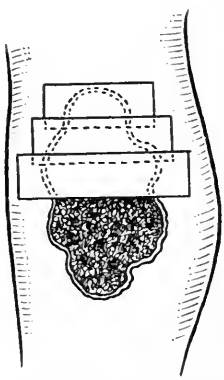


Fig. 468.—Showing how Thiersch grafts should overlap each other and the borders of the ulcer.

An effort should be made so to arrange the grafts that they not only overlap each other slightly, but also project beyond the margin of the surrounding skin, completely concealing the raw surface and thus limiting suppuration and subsequent contraction (see Fig. 468). When this is satisfactorily accomplished the healing is often remarkably smooth and without evidences of infection.

Removal of Granulations.—In the grafting of fresh wounds no preparation is necessary except the careful checking of hemorrhage, but with a granulating surface the situation is different. If it is decided to remove the granulations, this should be done thoroughly, down to the firmer layer beneath, even though this may seem to be rather a reckless sacrifice of tissue. This is usually accomplished by scraping with a sharp spoon, but some operators prefer to shave off the surface with a knife or to rub it away with a brush or a piece of gauze.

Hemorrhage.—This is often brisk and rather hard to check, but it must nevertheless be accomplished or failure may result. An Esmarch strap upon a limb above the field of operation will of course control all hemorrhage, but its use is seldom advisable owing to increased oozing upon its removal, thus undermining the grafts and endangering their vitality. The larger vessels should always be twisted rather than tied. Pressure with moist gauze is generally sufficient, but sometimes it fails, even when aided by peroxide or adrenalin, owing to adhesion of the gauze during its removal. When this occurs it may often be remedied by interposing a sheet of rubber protective. When a limb is the seat of the operation a Martin's rubber bandage may be turned around the part directly over the bleeding area, thus providing compression without fear of adhesion.

Fig. 469.—The boards in place holding the skin of the thigh flat and taut. The edge of the Catlin is engaged in the skin. (Photograph by Schapiro.) (Davis: Annals of Surgery and Johns Hopkins Hospital Reports.)

The Method of Halstead.[1]—The method of Halstead is of utility when especially large grafts are desired, as in operating for cancer of the breast. In order to properly stretch and flatten the skin before cutting it, two pieces of board, like shingles, are placed with their edges against the thigh and transversely to it. The upper one is held firmly by an assistant while the lower is used by the operator to keep the skin under strong tension while as large a sheet as possible is being shaved off with an amputating knife (see Figs. 469–471). To assist in placing these extensive grafts they can first be spread raw side up on rubber protective or silver foil, and while in this position may be perforated at

[1] Davis: Ann. Surg., 1909, l, 542.

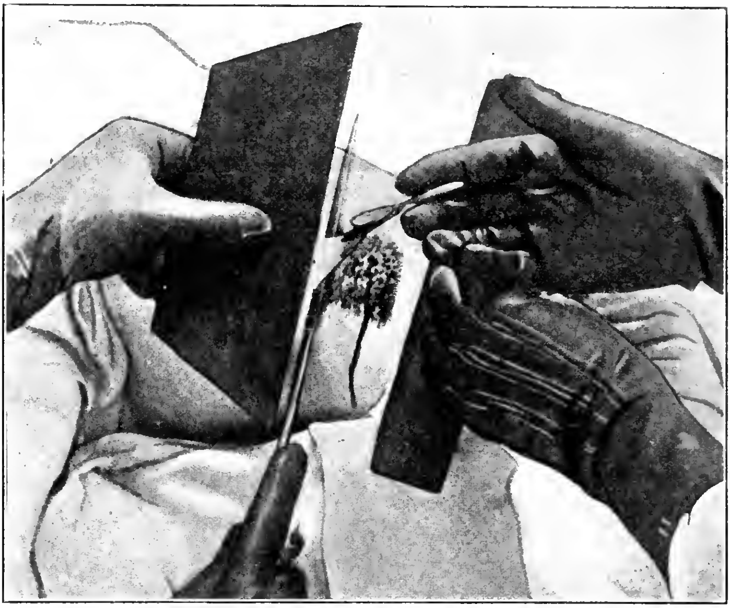


Fig. 470.—The cutting is nearly completed. The graft is held up by an instrument The fine punctate bleeding from the tops of the papillæ can be seen. (Photograph by Schapiro.) (Davis: Annals of Surgery and Johns Hopkins Hospital Reports.)

Fig. 471.—Shows the area from which the graft was cut. The graft is being spread out on rubber protective, raw surface up. (Photograph by Schapiro.) (Davis: Annals of Surgery and Johns Hopkins Hospital Reports.)

frequent intervals, through protective and all, with a suitable punch or a pair of curved scissors, in order to facilitate drainage and prevent the accumulation of fluids beneath them.

Accordion Grafts.—An ingenious procedure suggested by Lanz[1] not only insures drainage, but also enables the operator to cover a larger surface with a given amount of skin, which is of importance when the supply is limited. After cutting the usual grafts they are spread upon a board and stamped with a special die or nicked with a sharp knife in such a way that they can be expanded, accordion-like, to twice their original length (see Fig. 472.) If desired, they can then be cut in two, one-half being used to cover the raw surface from which they were removed. Such grafts should of course always be "splinted" in place with gauze or netting in order to prevent their retraction.

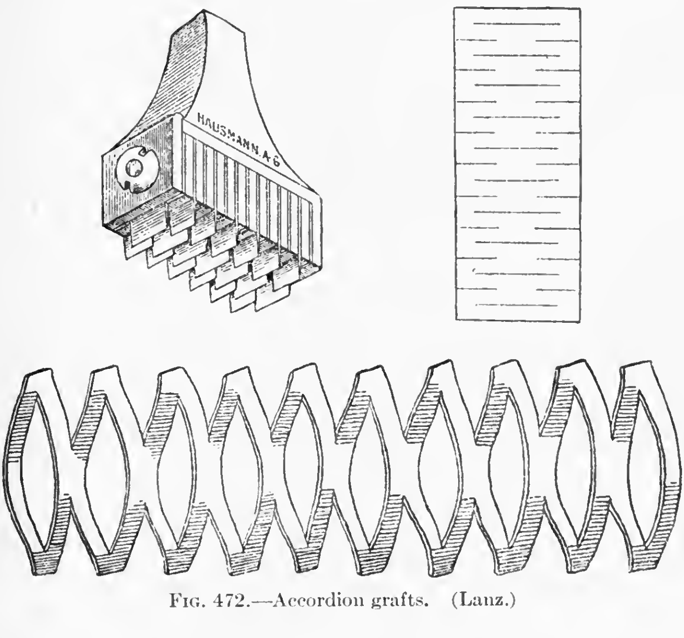


FIG. 472.—Accordion grafts. (Lanz.)

Statistics.—The following statistics give some idea of the proportion of successes to be expected in Thiersch grafting: Thorndyke, 123 cases with 102 successes; Jungengel, 119 cases with 100 successes; von Elsberg, 37 operations on fresh wounds with 33 successes, and 13 operations on granulating wounds with 11 successes; Plessing, 78 cases with 58 complete successes and 12 partial successes; Davis, 544 cases done in the Johns Hopkins Hospital with 341 complete successes.

Thiersch Grafting in Special Cases.—The method of Thiersch can nearly always be used in repairing cutaneous defects, whether in con-

[1] Zentralbl. f. Chir., 1908, p. 3.

nection with fresh wounds, old ulcers or granulating surfaces of any kind, although occasionally whole-thickness grafts are preferable on account of durability or sightliness. They will adhere under favorable circumstances to bone, tendons, periosteum and cartilage; but in these situations success cannot be relied upon, so that plastic procedures are generally preferable.

Burns.—The desirability of covering with new skin the granulating surfaces resulting from extensive burns should be strongly emphasized, especially upon the face, neck or hands or upon the flexor surfaces of joints. By this means prolonged septic processes may be cut short, and unsightly scars and embarrassing contractures prevented. Nothing can be done, however, until the sloughs have all separated and the granulations become firm and healthy, which may require several weeks.

In large burns the temptation is always great to employ the skin of others, especially if the patient is young or feeble; but if this is done care should be exercised regarding the conveyance of disease and it should be understood that the risk of failure is considerable. The numerous instances of "successful" homogeneous grafting noticed from time to time in the daily press are usually reported too soon to be of statistical value.

The Face.—Thiersch grafts may often be used to great advantage in this location, although they remain lighter in color than their surroundings and are always noticeable. The entire raw area should always be covered, in order to avoid the formation of unsightly lines of cicatricial tissue. Even upon so prominent a feature as the nose the results are often surprisingly good. Depressions which may exist immediately after the grafts are applied soon fill up to the surrounding level.

In repairing defects of the lips, nose and cheeks with pedunculated flaps from the arm or neck, it is often desirable to line them with epithelium in order to prevent subsequent cicatricial contraction. This can more or less readily be done by separating the flap, grafting its raw surface, and then waiting until the new skin has become adherent before placing the flap in position.

New Growths.—In the removal of cancers, for instance of the breast, it is desirable to excise the skin freely in order to avoid cutaneous relapses. With the aid of Thiersch grafting this may be done with a much freer hand, as has been so strongly emphasized by Halstead.

The method is also of the greatest service in dealing with large nevi, "port wine stains," hairy moles, etc.; but when hairs are present care must be taken to remove the bulbs completely or new hairs will force their way through the grafts and ruin the result.

Scars and Contractures.—Although the value of the prophylactic use of Thiersch grafting in this connection has been mentioned previously, it cannot be too frequently reiterated. In operating upon deformities which already exist, the most important thing is to remove *all* cicatricial tissue before the transplantation is done. It should also be borne in mind that pedunculated flaps and whole-thickness grafts are often preferable upon the hands, neck and face and in the vicinity of joints.

Grafting in Cavities.—This may be done to promote healing in old empyemas where a portion of the chest wall has been removed, or in bone cavities following operations for osteomyelitis, but it is generally better to wait until granulation has set in, unless the raw surface is in unusually favorable condition.

When the opening into the cavity is small, it is often difficult to place the grafts and hold them in position; but this may sometimes be accomplished by spreading them upon a piece of rubber sponge, which is then inserted while compressed and allowed to expand within the cavity. Support may also be obtained by packing with bits of sponge or gauze.

Leg Ulcers.—In these intractable lesions grafting is of great utility; but it should be employed with discrimination and attention must be given to the preliminary preparation and after-treatment.

These ulcers are often closely related to defective circulation which must be improved before reliable results can be obtained. Hence varicose veins require attention, by radical removal or by palliative measures, and callous margins and bases should be incised or softened (see page 649). In some of the worst cases it is even best to excise the whole ulcer, margins, base and all, in order to obtain a surface suitable for grafting. Great assistance is obtained from rest in bed, for days or even weeks, during which everything possible should be done to improve the condition of the granulating surface (see page 649).

After the transplantation has been done the limb should not be used too soon, as the grafts are often delicate at first and require time to become firm and resisting. They may be prevented from drying and scaling off by the occasional use of a little boric-acid ointment, and protection can be given them by the application of an elastic-mesh bandage to the entire lower limb. Daily massage of the surrounding skin, avoiding the grafts themselves, is of considerable aid in promoting circulation and movability.

Grafting upon Mucous Surfaces.—Mucosa may be replaced satisfactorily with Thiersch grafts, for instance within the mouth or the vagina; but in the former locality, at least, the process is attended with many obvious difficulties, the principal of which are the dangers of infection and the impossibility of easily holding the transplanted skin in position. Moskowicz[1] has succeeded in certain instances, however, by incising through the skin beneath the chin or through the cheek and forming subcutaneous aseptic cavities, which are then lined with Thiersch grafts. When these have grown firmly in place, the cavities are connected with the mouth by appropriate incision. Extensive adhesion of the tongue or cheeks can be overcome in this way. A new urethra can sometimes be made by tunnelling the tissues and inserting a graft wrapped around a permanent catheter.

[1] Arch. klin. Chir., cviii, 216.

The character of the transplanted cuticle soon approaches nearly enough to that of the surrounding mucous membrane to be quite acceptable; although in some more or less confined situations, such as the urethra or a frontal sinus, the excessive exfoliation of epithelium may cause embarrassing complications. The thinness of Thiersch grafts precludes the possibility of the transplantation of hairs.

WHOLE THICKNESS GRAFTING.

This is the ideal method of skin grafting, in spite of the fact that it is somewhat less easily accomplished than the procedures of Reverdin or Thiersch. Although occasionally employed by various operators ever since the time of the ancient Hindus, it was not extensively introduced into surgery until 1872, by J. R. Wolfe[1] of Glasgow, who used it in various operations about the eye. The original technic, however, has been so much modified and improved by Fedor Krause[2] that it is often referred to as the "Wolfe-Krause method."

Preparation of the Operative Field.—Particular attention must be given to this, especially if a granulating surface is to be grafted (see page 648); and it is in this form of transplantation that the complete excision of ulcers is so often preferable to an attempt to operate in the presence of surrounding indurations which interfere with the vascular supply.

It is of so much importance to check all oozing without the use of ligatures, both in fresh wounds and after the removal of granulations, that it rarely may be necessary to operate in two stages, as advocated by Porter and others. When this is done it is possible to cut the grafts during the first stage and preserve them for many hours in cold storage, or wrapped in gauze moistened with salt solution. They can then be applied at the second sitting without the use of anesthesia.

Cutting the Grafts.—These are usually taken from the thigh or upper arm, being careful to choose an area free from hairs, unless it is desired to transplant them. The inside of the arm should be selected in operations about the face, because of the comparative thinness and softness of the cuticle.

The grafts are best cut in the shape of a spindle, *allowing about one-third for shrinkage,* and afterward trimmed to suit the requirements of the particular case. This facilitates the subsequent closing of the wound, which may also be aided by removing more or less of the subcutaneous fat. The utmost care should be taken not to pinch the skin with forceps or otherwise injure it, unless this be done in connection with an end which is to be cut off and thrown away.

As soon as the graft is severed, it should be laid raw side up across a finger or the palm of the hand and the subcutaneous fat snipped off with a pair of curved scissors; for it is quite generally conceded, contrary to Hirschberg,[3] that the presence of much fat is detrimental to

[1] British Med. Jour., September 18, 1875. [2] Samm. klin. Vortr., 1896, No. 143.
[3] Verhand. d. deutsch. Gesellsch. f. Chir., 1893.

success. It should then be carefully trimmed to fit the area to be grafted.

Placing the Grafts.—This should be done so as to completely cover the raw surface, either with one graft or with several, moderate pressure being employed to remove air and blood and promote adhesion. Sutures should be avoided, if possible, as they are both unnecessary and undesirable in the majority of instances, although "splinting" is often of service.

Krause strongly recommends the dry method of operating, considering the use of solutions of any kind as detrimental to the vitality of the grafts. He also advocates a dry dressing. This does not mean, however, that success may not otherwise be obtained.

After-treatment.—In three or four days the dressings should usually be removed, if necessary soaking them off with warm salt solution, in order to open superficial blisters and clean away the accumulated secretions, although it is possible that healing may take place in a perfectly satisfactory manner without this. The dry dressings can then be renewed, or an ointment containing boric acid employed, according to circumstances.

From three to six weeks are generally required to obtain satisfactory healing, the process being materially aided by judicious massage of the surrounding skin. Even when necrosis of the surface of the graft occurs, failure should not too hastily be assumed, as the slough is quite often superficial, the lost epithelium being reproduced in a short time.

Skin-periosteum-bone Grafts are generally obtained from the tibial region in such a manner that the adhesion between the different layers remains intact. This is accomplished by cutting directly down to the bone when outlining the graft, and then carefully chiselling away the osseous surface without disturbing the tissues above. Such grafts are seldom employed and then usually about the skull and in certain rhinoplastic operations.

Tunnel Grafting.—Tunnel grafting suggested by MacLennan[1] is perhaps of more theoretical interest than practical importance. A number of "tunnels," an inch or two in length, are bored through the tissues beneath the fibrous base of the granulations and parallel to the surface, by means of small, curved forceps. Through these channels are pulled full-thickness grafts, one to two inches in length and one-fourth inch in width, so that they are completely concealed from view. A length of horsehair is also threaded through the tunnel and its ends tied together above the roof of granulations in order to locate the positions of the buried strips of cuticle. The individual grafts are cut from a long narrow strip of skin obtained from the inner surface of the thigh.

In five to seven days the granulations above each graft are cut away so as fully to expose it, the horsehair acting as a guide.

Caterpillar Grafting (MacLennan).—This is really not skin grafting in the true sense, but merely an adaptation of the "wandering-flap

[1] Practitioner, 1913, xci, 79.

method used in plastic surgery. Its designation comes from the ingenious manner in which a strip of skin cut from the vicinity of an ulcer, and at right-angle to it, is made to "crawl" onto the granulating surface by loosening the distal end, while the proximal end remains attached, and doubling the strip upon itself, like the progression of a caterpillar. The loosened extremity is then permitted to grow fast in its new position, after which the proximal end is freed and the flap straightened out across the surface of the ulcer.

Subcutaneous Skin grafting.—As a general rule, admitting of few exceptions, skin grafts must never be buried beneath the tissues or placed within a closed cavity; the principal reason being the great danger of infection, owing to difficulties in sterilization. Quite recently, however, Rehn[1] and Lowe[2] have succeeded, more or less, in evading this

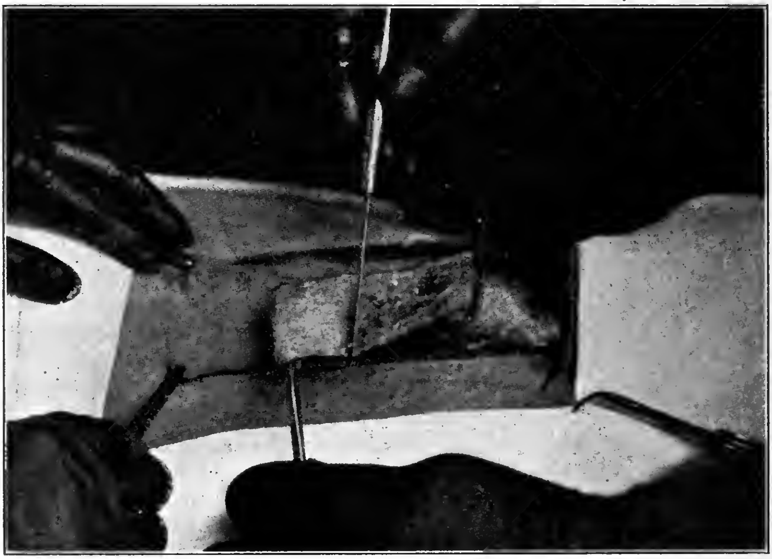


FIG. 473.—Cutting subcutaneous skin grafts. (Rehn and Mizauchi.)

danger by the employment of a special technic. This consists in cleaning the skin in the usual manner, cutting out a whole-thickness graft, and then putting it on the stretch with hemostatic forceps and removing its outer layers with a sharp scalpel (see Fig. 473). Or the method may be simplified by at once shaving off the surface of the skin much as one would remove a thick Thiersch graft, excising the flap, comprising the deeper layer of the corium and the subcutaneous connective tissue, and then replacing the Thiersch graft, thus immediately closing the wound.

This procedure of course does away with most of the microörganisms; but, unfortunately, a sufficient number may remain, for instance in the

[1] Arch. klin. Chir., No. 1, cv, 1.
[2] München. med. Wchnschr., September, 1913, p. 1320.

deeper hair follicles, to cause subsequent disaster, hence the method has failed to receive very general recognition.

Such specially prepared grafts have been used for various purposes, such as the formation of tendons, the closure of the pylorus, etc., but for most of them, at least, the employment of fascia lata would seem to be equally efficient and more rational from the standpoints of convenience and safety from infection.

GRAFTING OF MUCOUS MEMBRANE.[1]

This may be accomplished similarly to the grafting of skin; but obviously the necessary material is not so readily obtained, nor are the results so reliable, principally, perhaps on account of increased difficulties in the technic. The procedure has been used most frequently for filling defects in the conjunctiva and urethra, the grafts being variously obtained from the mouth, from the vagina, or from a prolapsed rectum. If taken from animals they are of course subject to all the shortcomings of zoögrafting. When possible, they may be shaved off like Thiersch grafts, but usually it is more convenient to use the entire thickness of the mucosa. Dressings manifestly can seldom be employed, but sutures are often necessary to prevent displacement.

When the transplantation of mucous membrane is under consideration, it should be borne in mind that Thiersch-grafts will often answer the purpose sufficiently well, their original characteristics undergoing a gradual alteration until they come to closely resemble their surroundings; just as mucous membrane, under reversed conditions, will soon change practically into skin. An objection to the use of cuticle, however, is the occasional embarrassment from excessive epidermal exfoliation, hence one would hesitate before lining, for instance, a frontal sinus with Thiersch-grafts unless ample egress were provided for the epidermal detritus.

SKIN GRAFTING FROM ANIMALS (ZOÖGRAFTING).

Value.—If this method were only sufficiently reliable it would be chosen in many cases instead of subjecting the patient or his friends to inconvenience and suffering; but unfortunately it is so uncertain that it is being resorted to less and less frequently, although formerly in quite general use. The new skin may seem to flourish at first, but later usually breaks down and disappears, granulations pushing through from beneath; and even if it survive, it is seldom as satisfactory as human integument. In illustration, Cousin had but fifteen successes out of 165 transplantations from animals, while in 122 cases in which human grafts were employed he succeeded 115 times—a sufficiently drastic comment upon the method. It is only fair to add, however, that other operators have recorded more encouraging experiences,

[1] Axhausen: Arch. klin. Chir., No. 1, cii, 12.

although in many instances the cases have no doubt been reported too soon to be of much significance.

Technic.—Material for zoögrafting has been obtained from frogs, chickens, lizards, pigs, dogs, cats, rabbits, guinea-pigs, the lining membrane of eggs, etc., each source having had its enthusiastic advocates.

In frogs and other animals the skin of the abdomen is usually the most suitable, and in chickens the soft bare cuticle beneath the wings. It can be removed in small pieces, by snipping it out with scissors, or in strips as long as may be desired. Frog skin, which is the kind most frequently employed, soon loses its pigmentation, producing a beautifully soft, pinkish covering; but it lacks firmness and durability, and unless guarded with the greatest care is liable soon to disappear.

Aievoli has grafted with thin sections of the testes of rabbits and Alimihano with portions of the wattles of roosters; but although the experiments were successful there is no reason to suppose that there is any especial advantage in repeating them.

It is also interesting to note that occasionally skin has been successfully transplanted from man to the lower animals.

SKIN GRAFTING FOR SPECIAL PURPOSES.

Lupus.—A few years ago excision followed by the transplantation of skin was the accepted method in the treatment of bad cases of lupus,[1] but recently the Roentgen and Finsen rays have largely taken its place. If excision is decided upon, however, it must be extensive enough to include 2 or 3 mm. of apparently sound skin, as well as some of the subcutaneous tissues, in order to remove all possible microscopic foci. A considerable depression is thus produced, but when covered with whole-thickness or Thiersch-grafts it soon fills up to the general level. Although the transplantations are always visible, mainly because of their lighter color, quite satisfactory results are obtained even upon the most conspicuous portions of the face.

X-ray Burns.—These may vary from a slight, unimportant dermatitis to such extensive, stubborn and serious alterations of the cuticle that excision followed by transplantation is demanded, especially if malignancy is suspected. When this is the case, the diseased skin, with its ulcerations, eczematous areas and papillomatous excrescences, must be completely excised into sound tissues and the resulting wound covered with grafts so that no raw surface remains exposed. This thoroughness is essential because of the marked tendency of the disease to reappear around the edges of the grafts and even force its way up through their centers. Whole-thickness grafts often give better results than the thinner ones, because of their greater resistance to invasion; and they should always be used about the knuckles, in the interests of pliability and firmness. The edges of these thicker grafts may often be bevelled

[1] Deutsch. Ztschr. f. Chir., 1892, xxxiv, 187.

to advantage, as it makes them fit better, and seems to add something to the probability of success.

It is particularly desirable that hemostasis should be complete, although for this purpose it is seldom necessary to operate in two stages, as the oozing, which is often free, can usually be controlled by one of the methods previously described.

The special and somewhat elaborate technic advocated by Porter[1] and others, seems to be superfluous, as equally good results may be obtained by the ordinary methods.

Fig. 474.—Drilling through outer table of skull into diploë. (Mayo, Annals of Surgery.)

Grafting upon the Denuded Cranium.[2] [3]—Scalping accidents are not infrequent in factories, when a woman's hair becomes caught in some revolving portion of the machinery, the whole of the skull sometimes being bared in this way, from the eyes to the neck and from one ear to the other.

When possible, the scalp should immediately be cleaned and replaced, if not the whole at least portions of it, in the faint hope that adhesion will occur; but this so seldom takes place that a subsequent transplantation of skin is almost invariably necessary.

[1] Jour. Am. Med. Assn., January 23, 1909, p. 323; Johns Hopkins Hosp. Rep., xv, 320.
[2] Davis: Johns Hopkins Hosp. Rep., xvi, 257.
[3] Law: Surg., Gynec. and Obst., August, 1914, p. 229.

Although grafts might grow directly upon the bone, when not too bare, it is undoubtedly safer to wait until granulation sets in, meanwhile preventing desiccation of the denuded skull by the application of boric acid compresses or some mild antiseptic ointment.

Fig. 475.—Granulations appearing through outer plate for blood-supply to graft. (Mayo, Annals of Surgery.)

When granulations fail to appear, as may occur when the surface is large, it can be promoted by drilling numerous holes through the outer table of the skull into the vascular diploic structure beneath (Sueve, Law, Mayo[1]). In doing this, however, great care must be taken to avoid sepsis, and in cases where this is liable to occur the holes should

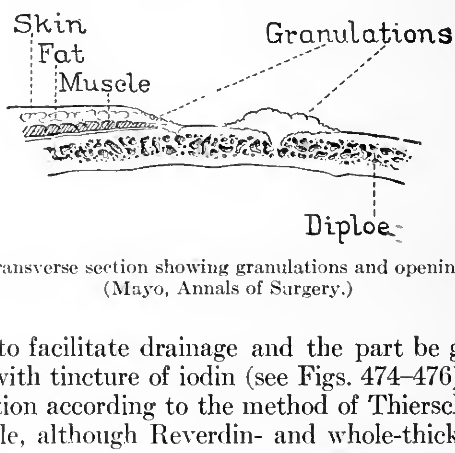


Fig. 476.—Transverse section showing granulations and opening into diploë. (Mayo, Annals of Surgery.)

be made large to facilitate drainage and the part be given a preliminary painting with tincture of iodin (see Figs. 474–476).

Transplantation according to the method of Thiersch is usually the most practicable, although Reverdin- and whole-thickness grafts are

[1] Annals of Surgery.

occasionally of service. If the Reverdin procedure is chosen it may advantageously be done in several sittings, placing one set of grafts around the edges and permitting them to become firmly adherent before applying the next lot, thus insuring, it is claimed, better nutrition for the new cuticle as the center is approached.

The Eye.—Transplantations are often required in connection with the lids, the conjunctiva and the cornea.

Ectropion.—Ectropion may be remedied by dissecting out the offending scar, or dividing it transversely, replacing the lid, and covering the resulting raw surface with a Thiersch graft, or better, one comprising the whole thickness of the skin, because less liable to contract. If the latter is selected it should be obtained from a region where the skin is thin and pliable, for instance behind the ear, on the inside of the arm, or even from the redundant folds of the upper lid.

Stitches are seldom necessary and should always be avoided if possible, although it may be desirable to suture the imposed margins of the lids together for a few days to prevent movement. When necessary the grafts may be splinted in place with gauze and collodion (page 653), or by "tethering-stitches" passing backward and forward across them from the sound skin on either side.

Symblepharon.—A symblepharon when divided leaves two apposed raw surfaces which must be covered in some way to prevent readhesion. This has been done with Thiersch grafts, with mucosa shaved from the red margins of the lips, and with sections from the conjunctivæ of rabbits; the first mentioned method being the most convenient and usually giving sufficiently satisfactory results. Sutures should be omitted if possible and the margins of the lids temporarily united if necessary.

Pterygium.—A pterygium may be treated in various ways, one of them being to remove it and cover the resulting wound with a dermo-epithelial graft, which should not, however, reach quite to the margin of the cornea for fear that subsequent swelling might cause it to project over that structure. The thin transplant, though always discernible upon close inspection, soon adapts itself sufficiently well to its environment, so that the more troublesome and uncertain grafting from animals or with mucous membrane seems rather unnecessary.

The Walls of the Orbit.—The walls of the orbit may be lined with Thiersch-grafts after the removal of a malignant tumor, thus hastening convalescence and improving the cosmetic result; and sometimes raw surfaces upon the stumps resulting from enucleations may advantageously be grafted to prevent contractures which might interfere with the wearing of an artificial eye.

Corneal Grafting.—Corneal grafting has frequently been attempted, the material being obtained both from man and from animals; but the results, although encouraging, have not been very satisfactory, the new cornea nearly always becoming rapidly cloudy and practically useless. The consideration of this subject belongs more properly to works upon the eye.

Ear and Mastoid.—When granulating surfaces within the external auditory canal require transplantation the graft can be wound about a section of rubber tubing, as is done when lining a new urethra, or they may be spread in position with a probe and the canal packed with pledgets of gauze or of rubber sponge.

Perforations of the Tympanum.—It has been claimed that perforations of the tympanum can be closed temporarily and sometimes permanently with dermo-epithelial transplants or even with the lining membrane of an egg. The procedure is not difficult, the graft being placed with forceps or picked up on the end of a medicine-dropper by gentle suction and deposited by forcing the air out again. No dressings are of course necessary.

Mastoid Operation.—Mastoid operations often leave open wounds the healing of which may be hastened by skin grafting. All of the various methods have been employed for this purpose, but that of Thiersch is perhaps the most universally applicable. When the walls of a considerable cavity are to be covered, the grafts may be held in place by packing with bits of gauze or rubber sponge.

CHOICE OF METHOD IN SKIN GRAFTING.

Reverdin grafting is the most easily done and savors less of a formal and perhaps dreaded operation; but the cosmetic and functional results often leave much to be desired. The new skin is apt to be thin, adherent, and more or less unstable and unsightly, owing to the smallness of the grafts and the cicatricial spaces between them. Hence the method should be used with reservation in exposed portions of the body, where cicatricial contracture must be avoided and where movability or durability are required.

The Thiersch method is the most universally applicable, because the grafts are easily obtained in large quantity and the results are remarkably satisfactory in most instances.

Whole-thickness grafts form a more durable skin and are therefore better suited to the palms of the hands, the soles of the feet, the extensor surfaces of the joints, for the relief of contractures,[1] etc. They also give superior cosmetic results in many instances, particularly about the face, where they adapt themselves more naturally to their surroundings, both in appearance and function. The technic of their application is, however, more exacting than that of Thiersch grafting, especially if the surface to be covered is a large one and if infection is present, and the results are somewhat less reliable. When the material for whole-thickness grafting is insufficient, the covering of the raw surface may sometimes be completed advantageously with Thiersch grafts, although this is apt to detract from the smoothness of the general effect.

[1] Davis: Surg., Gynec. and Obst., 1917, xxv, 1.

The anomalous methods of grafting are seldom used at present because much better results can otherwise be obtained. Under this head come grafting from callosities, blisters, warts, etc., as well as the use of amniotic membranes and the lining membranes of eggs.

The transplantation of mucosa, although giving results which are satisfactory enough, is comparatively difficult and uncertain. It is seldom called for, because the same ends may usually be obtained more easily by the method of Thiersch.

Zoögrafting is so unreliable that Reclus is inclined to call it a mere "laboratory experiment." Even when successful the result is generally unsatisfactory owing to lack of stability in the new skin. It should not be attempted except under the most unusual circumstances.

THE TRANSPLANTATION OF FASCIA.

During the last few years the free transplantation of fascia has assumed a remarkably prominent position in surgery. Following its introduction by Kirschner[1] in 1909, its importance was at once recognized and it was soon employed for a great variety of purposes, among which are included:

The bridging of defects: in tendons and muscles, in the abdominal and chest walls, in the alimentary and spinal canals (spina bifida), in the bladder and urethra, in the trachea, larynx and esophagus, in the capsules of joints, and even in the walls of the layer arteries (Neuhof).

The closure of the pylorus and the lumen of the intestines by constricting strips of fascia.

The suspension of prolapsed organs, such as the kidney, stomach, rectum, uterus, etc.

The reinforcement of weak lines of suture, in connection with inguinal femoral, umbilical and ventral hernia, and operations upon the alimentary tract, esophagus, trachea, urethra, ureter, bladder, blood-vessels, lungs, etc.

The treatment of paralysis, by reinforcing the paralyzed muscles with bands of fascia lata.

The mobilization of anchylosed joints and adherent muscles, by the interposition of sheets of fascia.

The closure of fistulæ—vesical, rectovaginal, intestinal, tracheal, etc.

The covering of stumps resulting from the removal of limbs, lungs, eyes, etc.

The isolation of adherent tendons, nerves, etc.

The replacement of the dura in an effort to prevent adhesions and cerebral hernia.

The construction of ligaments, about the joints, in the foot (talipes), in the treatment of habitual luxations, deviations of the scapula, etc.

[1] Arch. klin. Chir., 1910, No. 3, lxxxii, 888; also (original article) Verhand. d. deutsch. Gesellsch. f. Chir., 1909 and Beitr. z. klin. Chir., lxv, 472; also Beitr. klin. Chir., 1913, 5. See also Davis: Ann. Surg., xliv, 734. Denk: Arch. klin. Chir., 1912, xcix, 888.

The formation of suture material, which grows into the tissues, does not irritate or become absorbed, and may be used to advantage where great permanency is desired, as in the union of broken bones.

The control of hemorrhage in such parenchymatous organs as the liver, spleen and kidney—by ligating in mass with strips of fascia, by sewing fascial grafts to the bleeding surface, or by placing supporting rolls of fascia on each side of a wound and connecting them with a system of intraparenchymatous catgut sutures. The writer has easily resected a large portion of the liver without hemorrhage by tying it off with strips of fascia.

The strengthening of aneurysmal sacs by winding pieces of fascia around them, and the narrowing of the lumen of bloodvessels by similar means in the attempted cure of aortic aneurysms.

The underlining of cicatrices when there is great longitudinal tension upon them, in an endeavor to avoid the occurrence of unsightly hypertrophy.

The fixation of undescended testes to the perineal fascia or adductor tendons.

The use of fascia to cover denuded areas within the peritoneal cavity in an attempt to avoid adhesions is contra-indicated. In this situation it tends to increase the adhesions rather than to prevent them, thus resembling the various kinds of devitalized membranes and other inanimate material which from time to time have been employed. When possible, such raw surfaces are best treated by grafting them either with peritoneum or omentum, success being much more likely with these than with anything else. (The subject of abdominal adhesions is elsewhere considered.)

Anatomy.—The term fascia includes not only the more or less compact layers of connective tissue beneath the skin, between the muscles, etc., but also the sheaths of the muscles themselves.

The Subcutaneous Fascia.—The subcutaneous fascia or *tela subcutanea*, is a loose layer of fibrous tissue lying between the skin and the muscles and containing within its meshes, in most situations, a variable amount of adipose tissue (*panniculus adiposus*). In some localities, particularly about the lower abdomen of thin individuals, it develops a comparatively distinct fibrous sheet containing nerves and bloodvessels.

The Fascia Lata.—The fascia lata constitutes the covering of the muscles of the thigh. Its heaviest portion lies upon the outer aspect of the limb below the trochanter major (iliotibial tract) and it is from this that nearly all of the material for fascial transplantation is obtained. It appears as a thin, firm, tense, glistening-white aponeurosis lying between the panniculus adiposus and the muscular surface, being quite loosely attached to the latter and somewhat more firmly to the former. It is composed of two layers of easily recognized bundles of fibers; the superficial ones being the more numerous and distributed longitudinally while the deeper are transverse and much less in number. A few elastic fibers are scattered throughout the tissue and an occasional bloodvessel runs between the two layers.

Value of Fascia from Different Sources.—It is possible to transplant fascia from almost any source, such as the sheaths of the recti, the pectorals, muscles of the arm and leg; also the subcutaneous fascia of various regions of the body including the firm layers found in the neck; but the *fascia lata* has so many advantages that it is almost universally employed. It exists in practically unlimited quantity as a convenient, aseptic, living material; it is thin, pliable and easily handled; it will not stretch nor will it shrink to any objectionable degree; it is extremely firm and tough, withstanding great strain and holding sutures securely; it possesses such extraordinary vitality that it will grow into any sort of tissue anywhere, even when a portion of one of its surfaces is exposed externally or within a cavity, such as that of the chest or the abdomen; it is believed by many to retain its individuality indefinitely in most instances, without undergoing absorption or change of structure; and lastly the presence of infection, although detrimental, does not always preclude a more or less successful transplantation.[1] In other words, fascia lata seems to have some of the "semiparasitic" characteristics of the skin, which enable it to exist for a time without direct vascular connection with the surrounding tissues, and which render it peculiarly well adapted to grafting.

Subcutaneous Fascia.—The subcutaneous fascia especially that from the abdomen, is supposed to be superior for some purposes, such as the formation of tendon sheaths, the isolation of adherent nerves, etc., because of the large amount of fat in connection with it.

Sheaths of the Abdominal Recti.—The sheaths of the abdominal recti have been employed frequently to strengthen lines of suture in herniæ and about the bladder and the alimentary tract; but owing to the undesirability of complicating the operative wound it is usually preferable to make a separate incision, although if this is done fascia lata might just as well be used, especially as it is generally better suited to the purpose.

Autoplastic Grafts.—Autoplastic grafts are undoubtedly superior to those obtained from other individuals, but this is not true to the same extent as in the transplantation of skin. If, however, homografting is done, the greatest care must be exercised to avoid the transference of disease, especially syphilis.

Portions of fascia lata may be preserved for many hours or even days in sterile salt solution or moist "salt gauze," particularly in cold storage, thus making it possible easily to utilize, with proper precautions, material obtained from amputated limbs or even from the fresh cadaver if necessary.

Zoöplastic Fascial Grafts.—Zoöplastic fascial grafts may also be employed with some chance of success; but it can seldom be necessary or advisable to resort to so troublesome and uncertain a procedure when such an abundance of autoplastic material is so readily available.

[1] Law: Journal-Lancet, April 1, 1916.

Subcutaneous Skin Grafts.—The use of subcutaneous skin grafts which necessarily contain much fascia, has already been described in considering the transplantation of skin.

Operative Technic.—Cutting the Grafts.—Upon the outer aspect of the thigh an ample incision is made directly down to the fascia lata, beginning near the anterior border of the base of the trochanter. After clearing a sufficient area, mostly by "gauze dissection," an appropriate graft is outlined with a knife and stripped bluntly from the underlying muscle, with as little injury to the latter as possible. This can best be done before severing the ends of the graft. There being plenty of material, care should be taken to make the graft amply large, especially as a small amount of shrinkage always occurs. Unnecessary traumatism should be avoided in the use of forceps and sponges so as to lessen the danger of subsequent necrosis.

Ordinarily no fat is removed with the graft; but sometimes, as in the isolation of adherent tendons and nerves or in filling defects in the dura a layer of adipose tissue is desirable. This is obtained by making the original incision through the skin only, which is then dissected up for a sufficient distance on each side, leaving the subcutaneous fat adherent to the fascia. The graft and its superimposed fat are now outlined and removed in one piece without disturbing their connections with each other.

Closure of Opening in Fascia.—It is unnecessary to close the opening in the fascia, irrespective of the size or shape of the portion removed, although this may be done when the graft is a long and narrow one. A slight bulging of the relaxed muscle may supervene, but under contraction this is not apparent, and no real hernia or disturbance of function results. The missing fascia is ultimately replaced to a certain degree by new fibrous tissue.

Application of Grafts.—Sutures should nearly always be used, to guard against displacement and to prevent the fascia from curling upon itself, as it may do owing to the elastic fibers which it contains. The sutures should be of fine catgut and traumatism must be avoided in their insertion. Careful, water-tight, over-and-over stitching is especially necessary in closing defects in the walls of cavities or in the dura. The upper surface of the fascia, being smoother, is usually turned inward.

Contact with the surrounding tissues should be as broad as possible in order to insure firm adhesion and ample nutrition. It is of course better to have both surfaces of the transplant covered, but nevertheless it is possible for vitality to be preserved when one side is completely exposed, sometimes even in the presence of infection.

Tension.—When it can be done readily it is advisable to put the transplant under at least moderate tension, especially in the replacement of tendons and ligaments. This tends to increase the size and strength of the fibers in the direction of the pull, thus adding to the firmness of the result.

Postoperative Phenomena.—Histological.—Immediately after transplantation the graft swells somewhat, from inhibition of fluid and invasion of leukocytes; but later, as new vessels appear, the nutrition improves and the fascia, except near its edges, resumes practically its normal condition.

Adhesion to the surrounding tissues takes place rapidly, especially if the contact is broad and intimate. This is at first a mere agglutination, but subsequently becomes a firm union, the transplant merging into its cicatricial and fascial surroundings so intimately that a dividing line is scarcely perceptible. Elastic fibers from the graft often grow out into the neighboring cicatrix, thus adding to the elasticity and resistance of the whole operative area.

The formation of bone or cartilage occasionally takes place in connection with fascia lata when grafted into openings in the bladder, stomach, etc. (Neuhof).

Retention of Structure.—Not only does fascia lata retain its vitality under adverse circumstances, but it also has a remarkable tendency to preserve its morphological integrity, especially when not subject to much tension or pressure. Tension, such as occurs with ligaments and tendons, causes hypertrophy of the longitudinal fibers and atrophy of those running crosswise, so that the graft finally becomes indistinguishable from the structure into which it is inserted. Pressure gives rise to a thickening of the whole transplant and causes it to blend more intimately with its fascial surroundings, as in the patching of defects in the walls of the abdomen.

Shrinkage.—The presence of elastic fibers causes a somewhat negligible diminution in the size of the graft as soon as it is cut, but of far greater importance is the secondary shrinkage which takes place later and is due to the contraction of new fibrous tissue formed within and around the transplant (Kolb[1]). This occasionally may lead to trouble where fascial strips are wound around the bloodvessels or portions of the alimentary tract for the purpose of narrowing the lumen without obliterating it, or in operations for the relief of ptosis of the eyelid. In such cases allowance should be made for a small amount of postoperative contraction.

Adhesions.—There is a strong inclination for fascia to grow fast to the surrounding tissues, in fact upon this depends its greatest usefulness; hence its employment is generally unsatisfactory in the prevention of adhesions, for instance of tendons, of nerves, or of the dura to the brain, although in joints the results are more satisfactory. The new adhesions, however, may prove to be less objectionable than the old ones, thus affording at times an excuse for trying the procedure in various cases.

Clinical Applications.—Reinforcement of Suture Lines.[2]—In order to obtain the most reliable results, the graft should spread over as much tissue as possible and should be fastened securely under some tension

[1] Deutsch. Ztschr. f. Chir., cxxv, 398.
[2] Stewart: Surg., Gynec. and Obst., February, 1917, p. 141.

with stitches of fine catgut. In this way a large area of adhesion is obtained, which, in proportion to its size, not only takes the immediate strain from the line of suture, but also adds to the firmness of the ultimate result by reinforcing the whole operative field.

In inguinal hernia a strip of fascia is used about two inches broad and long enough to reach from the spine of the pubes to well beyond the internal ring. The conjoined tendon is stitched to Poupart's ligament in the ordinary way and the graft spread over the line of union, the cord being conducted through a transverse or a longitudinal slit in the outer end (see Fig. 477). With catgut the borders of the fascia are then firmly united to the underlying tissues, including Poupart's ligament, the slit closed around the cord, and the aponeurosis of the external oblique closed over all.

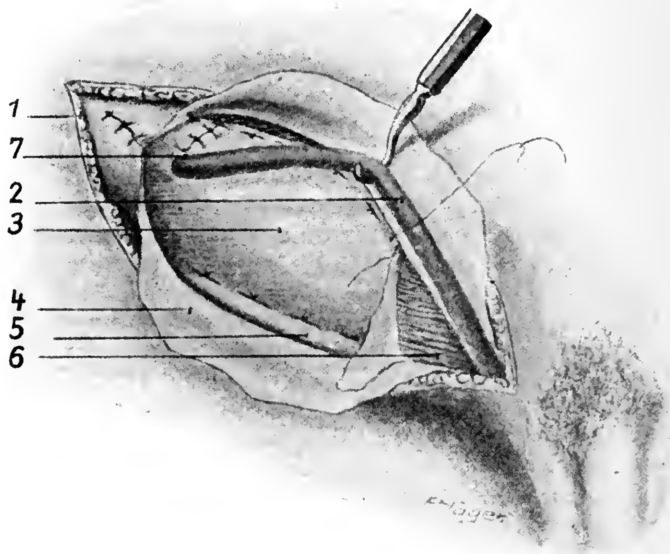


FIG. 477.—Inguinal hernia. 1 and 4, aponeurosis external oblique; 2, cord; 3, fascial graft; 5, Poupart's ligament; 6, conjoined tendon; 7, slit in graft for admission of cord to hole in graft.

Femoral hernia, although notoriously subject to recurrence under the older methods of operating, may be cured with great certainty by covering the opening with fascia lata; in fact, according to some surgeons, this should always be done.

An incision is made parallel to Poupart's ligament and a little above it, extending down through the aponeurosis of the external oblique. By retracting the inferior margin of the wound the sac can be freed and removed and the stump shoved through the femoral ring. The peritoneum is then pushed well upward so as to leave a free space above the ligament, the floor of which is the pectineus while the femoral vessels form the outer border. An ample fascial flap is cut and folded upon itself, the fold being sutured to Poupart's ligament, while the two leaves fall like a curtain over the internal aspect of the femoral opening and extend upward along the floor of the space and the surface of the great vessels. A few extra sutures are employed to unite the graft to Gimbernat's ligament, to the underlying muscular fascia, and to other convenient points. A simpler, but quite effective method, consists in exposing and removing the sac in the usual manner, returning the stump through the ring, and with the finger loosening the peritoneum so as to form a small cavity, which together with the femoral canal, is

Fig. 478.—Closure of femoral canal by a tampon of fascia. (Kirschner.)

then packed with a long, narrow strip of fascia (see Fig. 478). According to the experience of the editor there have been no recurrences after operations for the relief of femoral hernia in which the entire sac has been removed to a point within the femoral ring, the transfixed and ligated stump dropped within the peritoneal cavity and no attempt made at closure of the opening according to Socin's method because the circular opening invariably closes spontaneously and permanently.

Postoperative or ventral herniæ are subject to frequent relapses following operation owing to tension upon the sutures. This usually may be overcome, however, by applying a patch of fascia lata, which must be large and held under tension by many catgut stitches (see Fig. 479).

Suture of the bladder following prevesical cystotomy undoubtedly can be rendered much more secure by reinforcement with fascia. Catgut should be used throughout, in such a manner as to render the union watertight, and the recti completely closed over the graft with the exception of a small opening for a drain, which, however, must not come in contact with the transplanted tissue. A similar procedure may also be resorted to in connection with operations upon the pelvis of the kidney and in ureteral anastomosis.

The alimentary tract in the greater part of its length is covered by peritoneum, which, in general, renders the reinforcement of suture lines unnecessary; but with the esophagus, the retroperitoneal portion of the duodenum and the rectum patching with fascia is of the utmost value, although grafts of omentum or peritoneum are often equally effective and much more convenient.

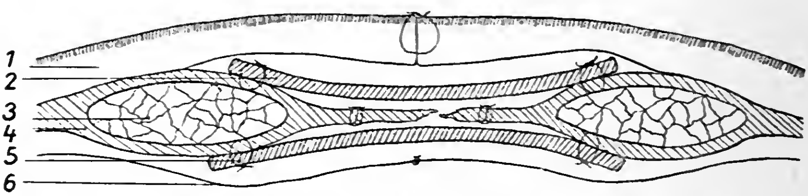


FIG. 479.—Diastasis of recti muscles. Cross-section. Closure reinforced by two fascial grafts 2 and 5, one internal and one external to the line of suture.

Closure of Artificial Openings.—*Hollow viscera* having fistulous or other openings in their walls not over 2 cm. in diameter may often be effectually patched with fascia lata, provided traumatism is avoided, the tissue-contact of the graft is large and the suturing accurate. This has been accomplished many times, both experimentally and clinically, with the stomach, intestines and bladder, including exstrophy. In the closure of bladder-openings it is advisable to cover the seat of the operation with as much tissue as possible, including the muscles, and to avoid placing drains in contact with the transplant. Even should the graft die, it may often be left in place in order to retain the advantage of its mechanical action in holding the edges of the opening closer to each other.

Defects in canals and tubes, including the urethra, the esophagus, the trachea and the spinal canal (spina bifida), may sometimes be closed with fascia. In the trachea this has been accomplished successfully even when the external surface of the graft could not be covered completely, but such results of course can not be depended upon. With the urethra the outcome is rendered more certain by diverting the urine from the seat of operation by suprapubic drainage. Where the esophagus is concerned, the transplant should be large so as to come in contact with as much tissue as possible and the suturing should be very accurate.

Openings in the abdominal wall,[1] due to ventral hernia, to muscular diastasis, to the removal of tumors, etc., even when large, may be closed with astonishing and lasting success by the transplantation of fascia if certain precautions are observed—broad overlapping on to adjacent tissues, careful suturing under moderate tension, and complete closure of the wound in the skin. In animals, even the entire abdominal wall has been replaced in this manner!

The peritoneum should always be brought together if possible; but if this cannot be done an attempt should at least be made to line the opening with omentum, not only to limit adhesions, but also because the graft tends to become edematous and less resisting when exposed within the peritoneal cavity. If such exposure is, however, necessary, its bad effects may be overcome to a certain extent by employing a double layer of fascia.

Openings in the chest wall, following, for instance, the removal of tumors, even when large and including the pleura as well as the ribs and muscles, can be closed very satisfactorily with fascia, thus enlarging materially the scope of thoracic surgery, especially in connection with malignant growths. The writer has succeeded in closing in this way a thoracic opening larger than the palm of the hand. The suturing must of course be as air-tight as possible and the operation is best performed under anesthesia produced by one of the methods under which collapse of the lung is prevented.[2]

Neuhof,[3] from extensive experimentation, claims that much better results are obtained with openings into cavities and hollow organs by suturing the fascia *into* the defects, edge to edge, than by patching it over the margins. By this method he obtained unusually good results in defects of the bladder, large intestine, stomach, trachea, pleura, abdominal wall, etc.

Closure of the Pylorus, etc.—At present many surgeons consider a gastro-enterostomy incomplete without simultaneous closure of the pylorus, unless this has already occurred. An effective way of accomplishing this is by plicating the stomach close to its outlet and firmly encircling it with one or two turns of a narrow strip of fascia, the ends being fastened together with silk or linen and the whole infolded as far as possible (see Fig. 480). Recently a plan has been introduced by Strauss of making an incision through peritoneum and muscle on the proximal side of the pylorus in a longitudinal direction and carrying a band of fascia around the pyloric end of the stomach at this point between muscle and mucous membrane and then closing the longitudinal incision, thus completely burying the graft.

In a similar manner the intestinal lumen may be narrowed or obliterated for various purposes, such as the formation of a valve in an effort to prevent the backward movement of feces in ileosigmoidostomy. Attempts have also been made to promote the clotting of blood in

[1] Mann: Ann. Surg., 1914, xl, 481.
[2] Hirano: Beitr. klin. Chir., lxxxvii, 238 (literature).
[3] Surg., Gynec. and Obst., 1917, xxiv, 383.

aortic aneurysms by partial closure of the vessel above the sac by means of a loose fascial ligature.

Satisfactory results have likewise been obtained, as has been the experience of the writer, in *prolapse of the rectum* by encircling the anus, according to the method of Thiersch, with a fascial band instead of silver wire. The advantage lies in the fact that the fascia remains as a living tissue without causing necrosis or irritation.

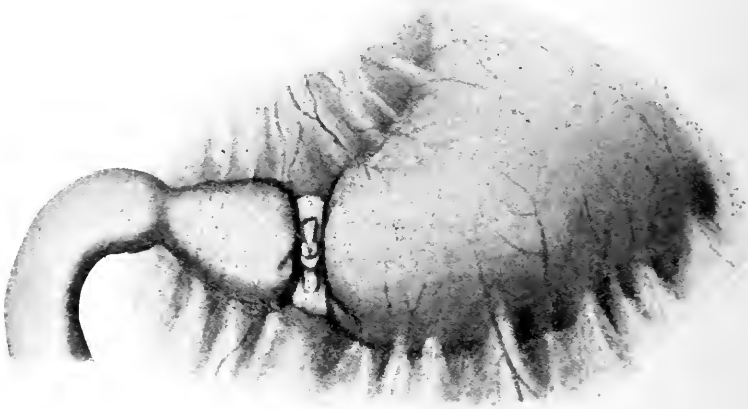


Fig. 480.—Closure of the pylorus with a strip of fascia lata. (Kirschner.)

The Dura.[1]—Although fascia lata has been extensively employed to replace lost portions of the dura, it is by no means certain that it is an ideal material for the purpose, in spite of the fact that the patch can be made water-tight and that its firmness lessens the danger of cerebral hernia. The one thing lacking is its inability to prevent adhesions, although it is claimed that they are not so dense as they would otherwise be; but this deficiency is not surprising when it is remembered that the surface of the brain when injured always grows fast to even the normal cerebral membranes themselves.

The results are said to be improved, however, by leaving attached to the fascia a layer of fat, which is placed next to the brain, the adhesions being then less firm and disturbing in character. If sufficient adipose tissue cannot be secured in connection with the fascia lata, the subcutaneous fascia from the abdomen may be employed, although it is a less substantial substitute for the dura itself. Even peritoneum obtained from hernial sacs is said to be inferior to fat in cerebral surgery, while periosteum deserves but little consideration.

Arthroplasty.—The first operations of this kind were done with pedunculated flaps, and these are still in use by many surgeons, but it has nevertheless been demonstrated that free fascial grafts answer the purpose equally well and are easier to obtain in adequate quantity. A layer of fat should be included if possible, and all raw surfaces within

[1] Lewis: Surg., Gynec. and Obst., February, 1917, p. 127.

the joint should be well covered, although it is unnecessary to use more than one piece of fascia between the ends of the bones even though both of them have been denuded of cartilage. A sufficient number of catgut sutures are required to insure against displacement of the transplanted tissue.

Tendons and Ligaments.—A very useful way in which fascia lata may be employed is in *the splicing of tendons,* for which purpose it is better adapted than either transplanted tendons (which are not easily obtained), or silk strands (which are objectionable as foreign bodies).

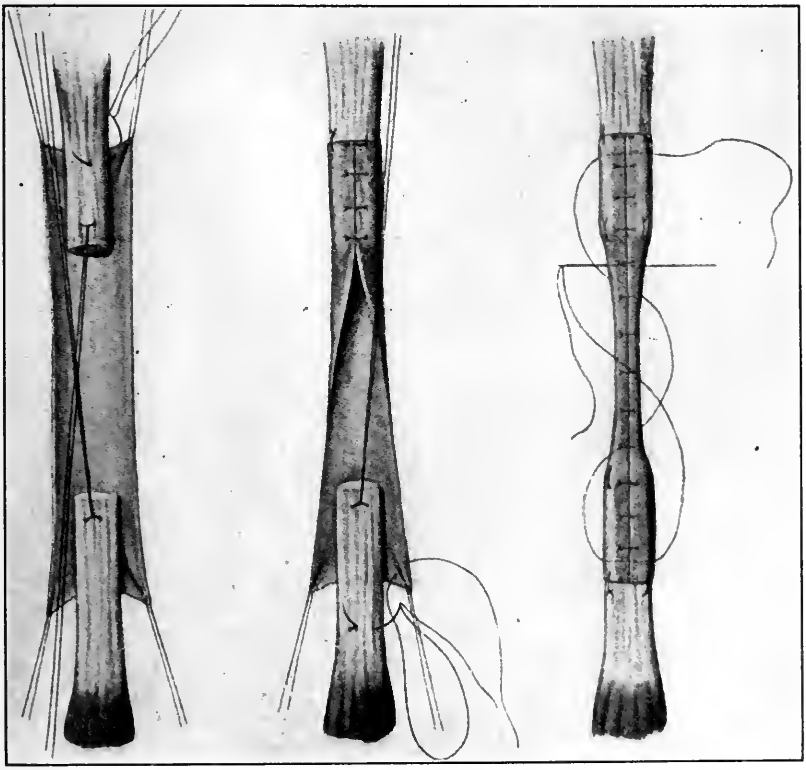


FIG. 481.—Technic in the splicing of tendons by fascia. (Kirschner.)

(For the use of "subcutaneous skin grafts" for this purpose, see p. 673.) A tube is formed from the fascia, into the extremities of which, under tension, the ends of the tendon are inserted and firmly sutured in place with fine silk or chromic catgut, the sides of the cylinder being also closed by a few stitches (see Fig. 481). Passive and then active motion are instituted quite early, sometimes within a few days, in order to guard as far as possible against adhesions. In the course of two or three months the transplant can scarcely be distinguished from the remainder of the tendon, even microscopically. This transformation is probably due to atrophy of the cross fibers and hypertrophy of those running longitudinally, together with intimate amalgamation with the ends of the original tendon; although it has been insisted that the fascial tube acts merely as a sort of temporary channel through which the stumps of the real tendon gradually grow and finally unite.

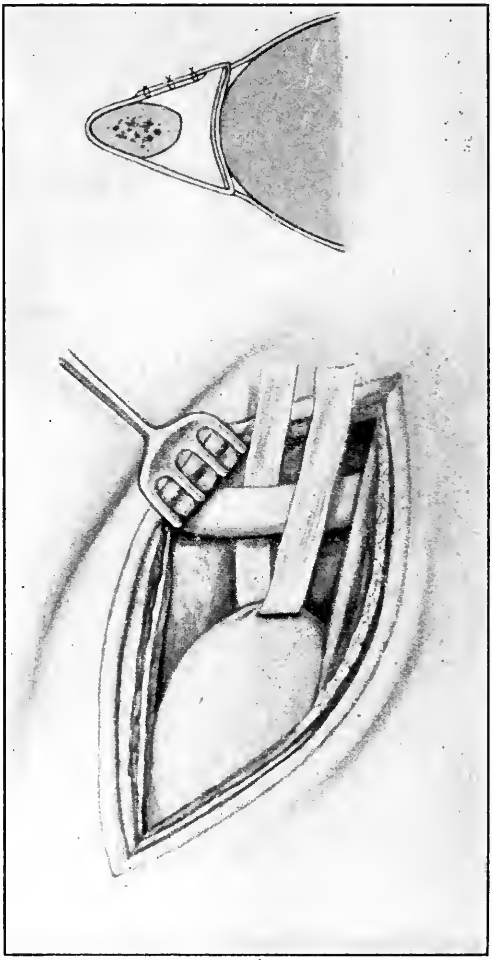


FIG. 482.—Nephropexy. (Kirschner.)

Fascia lata has also been used in *the formation of sheaths for tendons;* but it is not well adapted to this purpose, owing to its tendency to form adhesions, although the results are reasonably satisfactory if a layer of adipose tissue is included.[1] For this reason subcutaneous fascia with its abundant supply of fat, usually obtained from the abdomen, is better adapted to the purpose—much better than any kind of prepared membrane, or even than peritoneum from a hernial sac.

[1] Ceden und Rehn: Arch. klin. Chir. civ, 65 (literature).

Ligaments may easily and satisfactorily be constructed by suturing folded strips of fascia to the periosteum or even by passing them through holes in the bones themselves, as in the formation of a tibio-navicular ligament in flat-foot, or as done by the writer, in holding up the hand in wrist-drop due to paralysis of the musculospiral nerve.

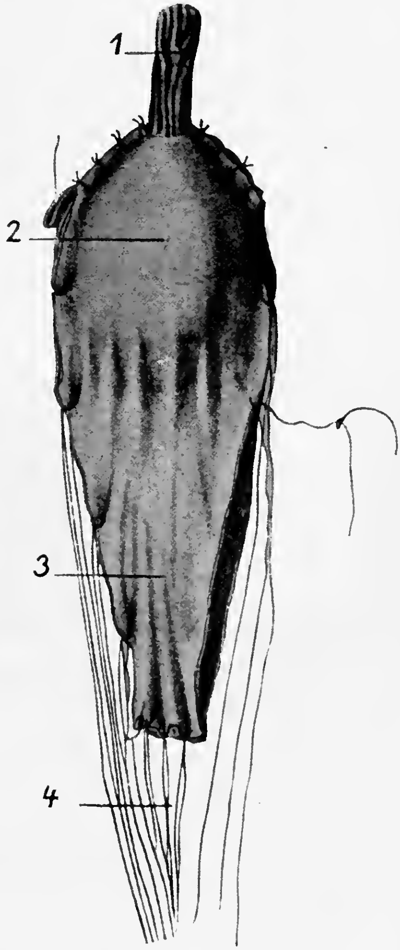


FIG. 483.—Orchidopexy. 1, cord; 2 and 3, fascia lata enveloping testis; 4, perineal fascia to which the fascial "cloak" is sutured.

Prolapsed Organs.—Prolapsed organs can be held in position by fascia lata, for instance *the kidney,* which may be suspended to the sheath of a neighboring muscle or to the last rib. Two narrow strips are often used for this purpose, passing around the organ near its poles and held in place by weaving them in and out through small openings in the capsule (Fowler[1]); or the kidney may be completely

[1] Jour. Am. Med. Assn., January 31, 1914, p. 367.

enveloped in an oblong sheet of fascia, having a slit beginning at one end and terminating at the center, so that it can be slipped around the vessels (Henschen); or a bridge may be formed by undermining the capsule through two slits at the upper pole and passing beneath it a fascial band the ends of which are united over the last rib (Kirschner.[1] (See Fig. 482.) In addition to the mere relief of ptosis, the kidney can be so tilted, when desirable, as to correct malpositions of the ureter in relation to the pelvis, thus promoting more efficient drainage (Fowler).

FIG. 484.—Treatment of facial paralysis by transplantation of fascia.

A badly prolapsed uterus may be easily and permanently suspended in position, through a suprapubic incision, by passing a strip of fascia from side to side through the muscle of the fundus above the tubes and just beneath the peritoneum and fastening the ends around the tendons of the recti muscles, so as to bring the fundus firmly against the anterior abdominal wall (Freeman.[2])

Undescended Testes.—Undescended testes may be anchored to the perineal fascia by enveloping them in a sheet of fascia much as in suspending a prolapsed kidney (see Fig. 483). This "cloak" may be made of any desirable length and is attached below by undermining the skin until the perineum is reached. The method has the advantage of great reliability combined with the absence of injury to the organ.

Underlining Cicatrices.—Certain scars subject to longitudinal tension, such as those about joints and in the neck, are apt to undergo hypertrophy and become thick, elevated and red. This occasionally very objectionable deformity may sometimes be corrected by excision and

[1] Arch. klin. Chir., 1910, No. 3, lxxxii, 888; also (original article) Verhand. d. deutsch. Gesellsch. f. Chir., 1909, and Beitr. z. klin. Chir., lxv, 472; also Beitr. klin. Chir., 1913, 5.
[2] Surg., Gyn. and Obst., 1919.

underlining of the new scar with a strip of fascia lata, the ends of which are anchored to the adjacent parts in such a way as to take the tension from the skin—for instance, to the mastoid and clavicle in the cervical region. The method is not applicable to ordinary keloids.

Paralyses.—*Facial.*—When it is considered undesirable to attempt nerve grafting, much relief from passive deformity can be obtained by elevating the corner of the mouth with a strip of fascia. This is done by making three small incisions, two just external to the oral angle and the other over the zygoma. Through a subcutaneous channel made with appropriate forceps between these openings, a long, narrow strip of fascia is looped about a portion of muscle below, over the zygoma above, and pulled tight enough to bring the corner of the mouth up to its proper level (see Fig. 484). The results, although not perfect, are said to be satisfactory in most instances.

Ptosis of the eyelid may also be relieved in a similar manner by tunnelling between a transverse incision in the lid and one upon the forehead and suturing one end of a fascial strip to the tarsal cartilage and the other to the occipitofrontalis, thus obtaining muscular action as well as direct elevation.

THE TRANSPLANTATION OF FAT.

Adipose tissue is merely connective tissue, the cells of which are distended with fat. It is found universally beneath the skin with but few exceptions, such as the eyelids, the penis, the scrotum and the nymphæ. In spite of a somewhat prevalent idea that fat is of very feeble vitality, it nevertheless may be transplanted with almost the same certainty as fascia itself, to which it is, in fact intimately related. Like all tissues, however, with a minimum blood supply, when necrosis once begins it is apt to be annoying and protracted.

Operative Technic.—Grafts of adipose tissue are best obtained in most instances from the abdominal wall, the thigh or the gluteal region, unless some fatty tumor conveniently presents itself. They can be removed in lumps or in more or less extensive sheets as required. Care should be taken to touch them as little as possible with the fingers and to avoid unnecessary traumatism with instruments. They should preferably be transferred directly to their point of insertion rather than to let them dry in the atmosphere or to float them in salt solution; they may, however, when necessary, be preserved for long periods in cold storage like skin or fascia.

The ease with which transplants of fat may be obtained in abdominal sections or in work upon the kidney is of course evident. In the former instance it is seldom even necessary to enlarge the original incision, although when an especially large graft is required it is often better, in the interest of a smooth and uncomplicated wound, to excise the overlying skin rather than to undermine it.

Postoperative Phenomena.—Numerous experiments have demonstrated that fatty tissue nearly always remains practically unchanged after transplantation and without undergoing appreciable absorption. It becomes surrounded, however, with more or less connective tissue, which occasionally may penetrate its substance. The contraction of this fibrous envelope can cause moderate shrinkage of the graft, allowance for which should be made under exceptional circumstances.

There is a strong tendency toward the formation of adhesions, but these are likely to be less firm than with other transplanted tissues, owing to their tenuity and to the softness of the overlying fat, this being of particular importance in operations upon the brain and for the relief of adherent tendons and nerves.

Clinical Applications.—The closure of defects in the dura affords a very useful field for the transplantation of adipose tissue, at least from an experimental standpoint, because of the cushioning effect of the fat and the comparative looseness of the adhesions. Lexer,[1] however, although he insists upon these theoretical advantages, admits that he has observed clinically but little if any difference in the ultimate results of the various methods employed, such as the use of periosteum or of peritoneum from a hernial sac.

The fat may be obtained in connection with fascia lata or from the abdominal wall; the former being perhaps preferable, when it is possible to get enough adipose tissue, owing to the fact that the tough fascia forms a better substitute for the dura than the lighter material from the abdomen, although the latter seems to answer the purpose reasonably well. The graft, with the fatty side next to the brain, should overlap the edges of the dura, if possible, and be sutured to it on all sides securely with fine catgut. When practicable it should also be tucked in between the bone and the dura. If drainage is used, the tube should not come into contact with the graft.

Cavities in the Brain.—Cavities in the brain itself, following operations for tumor, etc., must become obliterated either by the formation of a cyst or by expansion of the substance of the organ. The former alternative is of course objectionable, while the latter is said sometimes to cause large and puckering cicatrices which may give rise to irritative symptoms. Surgeons have tried to avoid these difficulties by filling the hole in the brain with an appropriate lump of fat. This undoubtedly grows in place, and its hemostatic effect may be desirable, but its advantage in other respects, although theoretically considerable, has not been demonstrated beyond question.[2]

Adherent Tendons and Nerves.—These have always presented an embarrassing surgical problem which has not been solved by enveloping them in periosteum, fascia, inorganic substances or dead membranes. It has recently been found, however, that the results are reasonably satisfactory when flaps or grafts of adipose tissue are employed, owing to the yielding nature of the material and the lightness of the adhesions.

The grafts should not be too thin. They can generally be obtained to the best advantage from the inferior abdominal wall; although fascia lata, when covered by plenty of fat, may be useful in some

[1] Ztschr. f. Chir., 1914, p. 1591; also Ann. Surg., 1914, lx, 166.
[2] Binnie: Uses of Fat in Surgery, Surg., Gynec. and Obst., 1914, xviii, 336.

instances, as in the palm of the hand or sole of the foot, owing to its greater firmness.

Unsightly Depressions.—Unsightly depressions about the face, due for instance, to adherent scars or to frontal-sinus operations, may often be obliterated satisfactorily by undermining the skin through a small incision and inserting into the resulting cavity a graft of fat of the proper size.

Removal of the Breast.—After removal of the breast for benign lesions, which may be done "subcutaneously" with retention of the nipple, the organ, if not too large, may be replaced with a mass of fat from the thigh, abdomen or buttocks with excellent cosmetic effect. Even lipomata have been employed for this purpose.

Chest.—In the chest, when it is desired permanently to collapse a portion of the lung on account of a tuberculous cavity or a bronchiectasis, this may be accomplished by the use of free masses of fat (Tuffier). The usual procedure is first to resect several inches of each rib near the spine, from the first to the eleventh. The intact parietal pleura is then freely separated with the fingers from the chest wall over the site of the cavity and an ample graft of fat packed into the depression. When the overlying tissues are reunited and the side of the chest shrinks in from the rib resection, the mass of fat is firmly pressed into place. The results of this form of treatment are encouraging, and seem to be more rational than the use of paraffin for the same purpose (Sauerbruch).

Hemostasis.—Bleeding from injuries of the kidney, liver and spleen is sometimes very difficult to control; but even when quite brisk this can often be done by the application of fatty tissue—as a tampon in the deeper wounds, or as a closely applied covering in those which are more superficial. The fatty capsule of the kidney and the adipose tissue of the abdominal wall furnish an abundance of convenient material. In order to be effective, the graft must often be held in place by sutures of catgut, which, with tampons at least, should grasp the tissues deeply on each side of the wound in order to get the additional effect of lateral pressure. The omentum, which is also employed for a similar purpose, although containing great quantities of fat, belongs to another variety of tissue and owes much of its hemostatic property to its remarkable power of adhesion. A possible objection to its indiscriminate use is that its ligation occasionally gives rise to capillary hemorrhage from the stomach, as the writer has observed in several instances.

In cerebral surgery, troublesome oozing from the brain, the meninges and even the bone can often be controlled by firmly pressing pieces of fat against the bleeding surface, although unless a transplantation has also been done the necessary material is not so easily obtained as muscle, which of course answers the purpose equally well.

Hilse,[1] by a convincing series of experiments, has demonstrated that fat, like fascia, muscle and omentum, contains in equal amount a substance which materially lessens the time of coagulation of the blood, thus rendering it actively as well as passively hemostatic.

[1] Arch. klin. Chir., No. 4, ciii, 1042.

SURGERY OF THE PAROTID GLAND AND STENSEN'S DUCT.

By ALBERT J. OCHSNER, M.D., F.A.C.S.

In all surgical operations involving the parotid gland it is important to bear in mind the relation that this gland bears to the facial nerve. It is well to have a clear idea of the course and position of the nerve branches as shown in Plate I, Vol. I, and in Figure 485 and to keep this thoroughly in mind during every step of every operation involving the parotid gland.

In operations upon Stensen's duct, one must always bear in mind the above facts and the further fact that when once an external fistula has been formed one often encounters much difficulty in correcting this condition, hence the wisdom of planning all operations with a view to avoid this complication.

CONDITIONS REQUIRING OPERATIONS INVOLVING THE PAROTID GLAND.

1. Abscess.
2. Cyst due to obstruction of duct.
3. Benign tumors, (*a*) fibroma, (*b*) adenoma; (*c*) lipoma; (*d*) enchondroma (*e*) myxoma; (*f*) tuberculosis.
4. Malignant growths; enchondrosarcoma; sarcoma and carcinoma.

Abscess.—This condition occurs most frequently as a complication of one of the diseases which are associated with infections, like typhoid fever, scarlet fever, measles and diphtheria. It also occurs quite frequently after surgical operations, apparently more commonly after operations involving abdominal section.

Prophylaxis.—Extreme care in cleansing the teeth and the cavity of the mouth and pharynx during the progress of the diseases mentioned above and the same care previous to and following surgical operations will serve to reduce the frequency of abscess of the parotid gland.

The use of chewing gum following operations will stimulate the flow of parotid gland secretion and will prevent formation of the abscess. In many cases even after there is some swelling and marked tenderness of the parotid gland, the vigorous chewing of wax or gum will inhibit the process.

After an abscess has formed it should be opened freely by means of an incision directed so as to avoid cutting nerve fibers (Fig. 485). The pus is often quite thick hence the necessity of making a free incision.

Cyst of Parotid Gland.—This condition occurs as a result of obstruction of some portion of Stensen's duct due to the presence of a calculus or an obstruction caused by cicatricial contraction following an inflammation involving the walls of the duct or the invasion of the duct by a malignant growth.

Treatment.—The treatment consists in reëstablishing the lumen of the duct, if this is possible, or the removal of the gland in case the duct cannot be restored. In case the gland has to be removed for the relief of this condition, the operation performed is identical with that about to be described for the removal of the parotid containing a malignant growth; with the exception that in the former all nerves are preserved, while in the latter they are sacrificed.

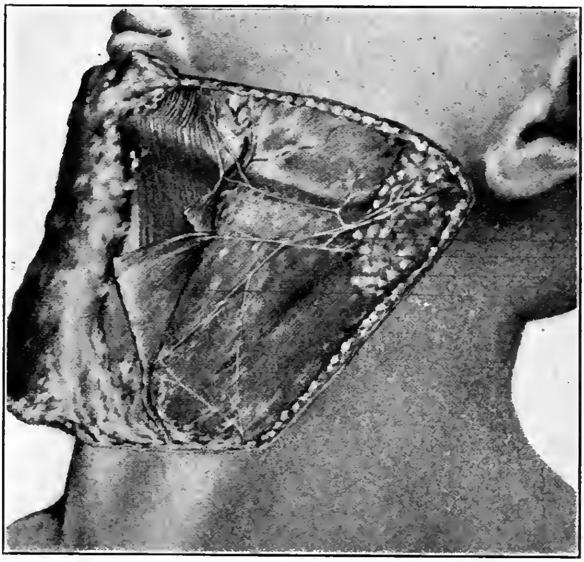


Fig. 485.—Dissection showing lower filaments of the facial nerve, especially the "ramus anastomaticus collomandibularis," Jaffé, which supplies the depressor labii inferioris. (Dowd, Annals of Surgery.)

In case of non-malignant stricture of the duct it is well to attempt dilatation by means of graduated bougies used, at first daily and later less frequently, continuing the passage of bougies at least once a week for months. In the meantime, great care should be given to the teeth, mouth and pharynx.

The ordinary filiform urethral bougies followed later by the larger sizes up to No. 6 French are most useful in this work.

If the stricture is so low that it can be reached from the mouth but too persistent to yield permanently to treatment with bougies, it is well to split the duct longitudinally for a distance of 2 to 3 cm., making an incision down upon a grooved director which has been introduced through the partly dilated stricture from the mouth.

The result of this treatment will usually be healing free from a recurrence of the stricture or a fistula of the duct into the mouth through the incision above the stricture which will act normally.

If the stricture is located too high for this operation, an attempt should be made to accomplish the same end by performing the same operation through the cheek. In this case, however, one should make the incision carefully in order to avoid injury to the branches of the facial nerve (Fig. 485).

This operation is frequently followed by a permanent external fistula which will later be very difficult to heal and may result in the necessity of excising the gland. Before this step is taken, however, long continued dilatation of the lower segment should be practised.

Obstruction due to stone in the duct is treated precisely in the same manner with the exception that the longitudinal incision is made down upon the stone instead of the grooved director. Here again the operation should always be made from the inside of the mouth if this is possible.

Following all these operations the patient should be instructed to chew wax or gum for half an hour at a time after the operation and to carefully cleanse the teeth, tongue and pharynx before and after eating.

If there is any doubt as to whether the obstruction is due to stone or tumor an x-ray should be taken with the apparatus generally in use for the examination of teeth.

Tumors.—All benign tumors are treated by making a careful incision in the direction of the nerve fibers, proceeding slowly and carefully, preferably under local anesthesia, picking up all the bloodvessels, so as to have an absolutely clean field. After the tumor has been exposed it is enucleated and the wound closed. The same steps are taken in the removal of tuberculous lymph nodes within the gland.

In case of enchondroma it is of the greatest importance to remove the capsule with the tumor because, although enchondromata themselves seem to be non-malignant still they are likely to recur in the form of enchondrosarcoma in case any portion of the tumor or the attached connective tissue is overlooked in the removal.

In all of these cases, too much care cannot be exercised in protecting the nerve fibers because their destruction will result in an unsightly deformity.

Malignant Tumors.—Malignant growths occur usually in the form of enchondrosarcoma, sarcoma or carcinoma.

In these cases the entire gland together with the nerves should be removed, notwithstanding the unavoidable paralysis of the muscles of the face. In all of these cases it is well to give intensive x-ray treatment before and after the operation.

Technic of Operation.—Begin 3 cm. above the zygoma and make a vertical incision directly in front of the external ear to a point 3 cm. below the angle of the jaw to the sternocleidomastoid muscle. Expose the deep jugular vein and clamp and ligate any small branches encountered in order to keep the wound free from blood. Reflect a skin flap freely on both sides of the incision and draw this well out of the way with sharp retractors. From this point on it is well to continue the operation by cutting all tissues with the electric cautery in order to avoid cancer infection.

All vessels are caught between two pairs of forceps as soon as they are exposed, then they are cut and ligated in order to keep the field of operation thoroughly free from blood.

It is well to dissect out all lymph nodes along the internal jugular vein and the external carotid artery.

The transverse facial artery and Stensen's duct are ligated below the lower edge of the zygoma, also the internal maxillary branch of the external carotid and the superior temporal. It is usually best to ligate the external carotid above the point at which the external maxillary is given off and also the posterior auricular near its origin.

It may be necessary to remove any or all of the tissues to which the tumor is attached always with the electric cautery in order to make a radical operation.

A small drain is inserted and the skin wound is closed. Intensive *x*-ray treatment should be applied as soon as possible after the operation.

The prognosis following these operations is quite favorable but one should bear in mind the importance of making a very thorough operation the first time because secondary operations even though done very thoroughly are much less likely to be successful. It is quite as important to make a thorough operation for enchondroma because this condition is likely to return as a sarcoma.

Fistula of Stensen's Duct.—This is a very troublesome condition and very distressing to the patient because it causes a constant stream to flow over the patient's face. It usually results from an injury or an operation.

Treatment.—First we must determine whether the duct is open into the mouth, by probing downward from the fistula. If it is not open the obstruction must be removed by means of the same method that one employs to overcome a stricture.

If the fistula is low down in the course of the duct, it is best to make an opening into the cavity of the mouth and attach the mucous lining of the duct to the mucous lining of the mouth by means of fine silk sutures and then to cut around the external fistula, invert this by means of fine catgut sutures and suture the skin over this.

If the fistula is too far up to apply this method an attempt may be made to excise the cicatricial tissue, thoroughly dilate the distal end and unite with fine catgut suture, or if this fails, keep the distal end dilated and permit the wound to heal by granulation, stimulating the tissues by the use of tincture of cantharides.

If all attempts fail excision of the gland is indicated with preservation of all nerve filaments.

TRAUMA.

By OLIVER J. FAY, M.D.

The subject of traumatology is of absorbing interest, not alone from an economic and sociologic standpoint, but from the standpoint of clinical medicine as well. The infinite variations in the traumatizing agent, and in the resistance of the individual, result in a complexity of clinical manifestations which make early diagnosis one of the most difficult problems the surgeon has to face. It is also one of his most urgent problems, for the final outcome of the case is often determined within the first few hours, or it may be the first few moments by the surgeon's decision for or against early operation. Diagnosis must be based largely upon the clinical picture as a whole, with only certain general considerations to serve as guides. The wide variations of the individual case demand corresponding variations in treatment. If all cases of severe injury, especially those of subcutaneous abdominal injury, could be referred to the experienced surgeon, the operative technic might best be summed up by saying that the operative treatment to be employed must depend in each case upon the nature and extent of the injury, the general condition of the patient, and the judgment of the operator. In the very nature of these cases, however, it follows that a large number of them will be out of reach of the well-equipped hospital and the experienced surgeon, and the responsibility of the operation must fall upon the attending physician, however unwilling he may be to assume it. For this reason some brief description of the treatment most commonly required is given here.

SHOCK.

Shock is the usual sequent of severe contusions of the abdomen and is also frequently met with following severe trauma to other parts of the body. Much has been written on the nature and cause of shock but its clinical aspects alone are of interest here. Its symptoms are so marked, often so alarming, that the diagnosis is readily made. In severe contusions of the abdomen its onset is, as a rule, simultaneous with the receipt of the blow, while in the case of other injuries it may be delayed; the loss of consciousness is usually of brief duration, but the patient remains dazed; the pupils are dilated, the face drawn and extremely pale, the mouth half open; the skin and extremities cold; the pulse thready. Later there is meteorism and the patient is nauseated and suffers from thirst. The symptoms disappear gradually, usually one by one, and while the condition is variable in its duration, simple shock (I am not speaking here of collapse due to hemorrhage, etc.) seldom persists for more than three hours.

Shock varies greatly not only in duration but also in intensity and while, in a general way, we are justified in considering its degree and persistence an index to the severity of the injury, the equation of personal susceptibility is one not to be ignored. Not infrequently following an injury, the patient is found to be in an alarming state of shock which subsides slowly but the patient, once he has recovered from it, shows no further evidence of injury. Again, a patient, following an injury, walks to his home, to the doctor's office or to the hospital; on examination he presents no symptoms of severe injury until, after some hours, he collapses or develops peritonitis. On operation or at autopsy, a ruptured or even a severed gut, severe lacerations of the liver or spleen are found.

All necessary examinations of a patient in shock must be made with the greatest gentleness. His head should be lowered and heat applied to the body but the danger of burns must be excluded. Many drugs have been tried to raise the blood-pressure in cases of shock but few have been found of any real service. Normal salt solution, a few degrees warmer than blood heat, should be administered subcutaneously, intravenously or per rectum. Where shock is associated with hemorrhage, saline solution is peculiarly effective. One dram of adrenalin chloride in 500 c.c. of the normal salt solution should be administered in the shock of acute anemia and in other cases which do not readily respond to treatment, or 20 minims of adrenalin may be injected subcutaneously. This may be once or even twice repeated at intervals of some hours. When intravenous infusion is the method used, it must be remembered that rapid infusion or the administration of large quantities of fluid may cause death. Atropin is sometimes effective especially when perspiration is profuse. Strychnine is worse than useless, and anodynes should be used but sparingly and only when absolutely necessary to control pain. An exception must be made in the presence of probable active hemorrhage, for morphine lowers the blood-pressure and thus aids in controlling the bleeding. Crile's pneumatic suit is of great service in increasing the amount of circulating blood and consequently the blood-pressure; but where it is not available, something of the same result may be obtained by bandaging the extremities. The abdomen may also be bandaged over several thickness of elastic cotton.

Operation should never be undertaken in shock except in the presence of the most urgent indication, such as hemorrhage, obstruction to the bowel or to the air passages. It is then absolutely essential that the least possible time be consumed—hemorrhage should be controlled, enterostomy or tracheotomy performed, the peritoneal toilet made, but it is safer to leave all complicated and time-consuming procedures for later execution. The necessity for secondary operation is of course to be deprecated but in this class of cases, the patient who requires secondary operation is to be congratulated, for after a time-consuming primary operation, he is more apt to require autopsy.

HEMORRHAGE.

The differentiation of hemorrhage from shock is not infrequently difficult in cases of subcutaneous abdominal or thoracic injury. The symptoms of hemorrhage are those of acute anemia: Colorlessness of skin and mucosa, profuse, ropy perspiration, small, rapid pulse, rapid superficial respiration, air-hunger, glassy eyes, contracted pupils, a feeling of anxiety, restlessness which may even amount to convulsions, vertigo, roaring in the ears, vomiting, cold extremities, and a fall in temperature.

The physical signs of hemorrhage are, for the most part, to be detected by percussion—the determination of an area of dulness especially in the dependent portions of the abdomen. Meteorism, muscular rigidity or extreme tenderness may prevent the detection of even extensive extravasations of blood; again, in a flaccid abdomen, the presence of liquid blood may sometimes be detected by fluctuation. By vaginal or rectal examination, the presence of free blood in the rectovesical space or in the pouch of Douglas may be revealed. In acute anemia, the hemoglobin content of the blood is decreased, while it undergoes no change in shock. A sudden drop in blood-pressure also is indicative of shock or of hemorrhage.

In many respects, the treatment of hemorrhage and of shock do not differ. In hemorrhage absolute rest is required; morphine should be employed to lower the blood-pressure and to control restlessness.

Intra-abdominal hemorrhage, however, demands immediate operation even in the presence of shock. On opening the abdomen, bleeding may be so profuse as to prevent the finding of its source. Digital compression must then be applied to the aorta, or the abdomen may be packed with large sponges, which are then removed one by one in the search for the bleeding point. Any operation must be of the briefest possible duration. In hemorrhage from the liver, large vessels may be ligated and the organ then firmly tamponed; suture and tamponing may also be effective. In lesser isolated injuries to the spleen, the same treatment may be employed, but if ruptures are multiple or very deep, splenectomy is the operation of choice. Bleeding points in the mesentery must be ligated and, if the blood supply of a portion of the gut is thus cut off, resection becomes necessary. Rents in the stomach and bladder are sutured. When the hemorrhage comes from the abdominal wall, ligation of the damaged bloodvessels is employed.

When hemorrhage has been controlled, adrenalin in normal salt solution should be administered. In very severe cases of hemorrhage, the transfusion of whole blood is of the greatest service. The agglutination test removes one element of danger but, where this cannot be employed, the selection of a near relative of the same sex is said to greatly lessen the danger of hemolysis.

Even lesser hemorrhage in hemophiliacs presents great danger and greater difficulty in treatment. Any operation upon a known hemophiliac should be preceded by the transfusion of whole blood. Recently, after excising an inguinal gland for the purpose of diagnosis, we found it impossible to control the hemorrhage and some questioning elicited a history of hemophilia. After the usual expedients had been exhausted, a syringeful of blood was withdrawn from the father and injected into the tissues of the boy's back, with resulting hemostasis within an incredibly brief space of time. Since the inheritance is usually through the mother, the father would appear to be the preferred donor. Because of its simplicity and freedom from danger, this method of controlling hemophilic bleeding in cases of trauma might well be given a trial.

WOUNDS.

Wounds still make up by far the largest number of the cases of trauma which the average surgeon is called upon to treat, for under this head we may class any dissolution of surface continuity, the result of injury. An *incised wound* is a cut made by some sharp edge; the minimum amount of tissue destruction results. The pain is usually not severe, or at least is of very brief duration, but hemorrhage may be profuse. *Stab wounds* are in a sense also incised wounds but the expression carries with it the idea of depth rather than of length, since they are made by a pointed instrument or narrow blade. Here the danger of hemorrhage is of special importance, particularly when some cavity of the body has been penetrated. The expression, *punctured wounds*, emphasizes even more than does the term stab wounds, the idea of a deep wound with a small surface opening, such as that made by a needle, the tine of a pitchfork, an awl. Drainage is usually shut off and infection often occurs; where a large bloodvessel has been punctured, an aneurysm may develop. *Contused wounds* are the result of blunt force; with trivial "bumps" and the crushing of limbs, as in railroad accidents, as the two extremes. The surface wound is jagged and the surrounding tissues crushed and torn. In *lacerated wounds* the wound edges are also jagged and rough, the tissues being torn apart; they are more or less bruised but it is the open wound rather than the crushed tissues which occupies the foreground of the picture. A *brush burn* is inflicted by some rapidly moving object against which a surface of the body is pressed, as by a belt or a pulley rope. It is usually superficial but the large area of abraded tissue makes it peculiarly painful. *Gunshot wounds* may be likened to *punctured wounds* or to *perforating wounds*.

In treating wounds our first consideration must be the arrest of hemorrhage. All larger bloodvessels must be ligated, while the capillary bleeding may be controlled by pressure and the application of heat. All tissue which is damaged beyond repair should be cut away, all the foreign matter removed, and the wound and the surrounding skin thoroughly cleansed. If the surface is hairy, it should be shaved, then scrubbed with soap and washed with water and with alcohol. Tincture of iodin is then applied.

The question of the closure of wounds and their drainage is determined by two factors—the probable presence of infection and cosmetic requirements. All wounds on and about the face are closed without drainage because the space between the stitches is sufficient to permit of the escape of the wound-secretion. A large or deep wound must be drained, at least for the first twenty-four or forty-eight hours; a simple tube, a cigarette drain, a wick made of strands of some suture material, and gauze are all suitable for this purpose, the choice depending upon the nature of the wound and the individual preference of the surgeon. Infected wounds should always be thoroughly drained.

In the selection of suture material, certain general rules must be followed: In closing wounds about the face, very fine sutures must be used to avoid stitch scars. The use of noncutting needles is also indicated. Muscles and tendons or any wound upon which there is much tension must be closed with strong suture material. Aside from these general considerations, the selection of suture material is largely a matter of choice. For face wounds, many surgeons use clips but I have a personal preference for horse-hair. For tension sutures, chromic catgut, silkworm gut or silk are used. My own choice is as a rule silkworm gut for tension sutures; for other wounds plain catgut.

In closing deep wounds, buried sutures are required and the needle should be carried well to the base of the wound to prevent the formation of a hematoma in the cavity which might otherwise remain. Sutures should bring the edges of the wound in approximation but they should not be too tightly drawn or tissue necrosis will result. Where wounds are prone to gape, a stay suture should be employed to relieve the tension on the sutures used in bringing the lips of the wound together. As for the method of placing the stitches, the interrupted suture is the usual one employed. Halstead's subcuticular suture is used in closing clean wounds where the avoidance of scar formation is especially important. Where there is much tension, a quilled or a button suture may be required. The continuous suture is used when a perceptible scar is not of great importance and it is desired to close the wound hurriedly.

In all clean wounds the dressing applied should consist of dry sterile gauze; some surgeons make it a routine practice to sprinkle all wounds both before and after suturing with an antiseptic drying powder but this is not required in clean wounds. It is not necessary to change the dressings at stated intervals. If the patient's temperature is normal and the dressings remain dry, they may be left untouched for days and the wound will be the better for being undisturbed. On the other hand, if the dressings become soaked with secretion, they should be changed at frequent intervals and, at any rise in the patient's temperature or at any other sign of infection, they must be removed at once and the wound inspected. Infected wounds should be treated with hot wet dressings. A wide piece of gauze several feet in length is dipped into a hot boric acid solution—four parts saturated boric acid solution and alcohol one part—and then wound about the hand

and arm, or foot and leg, carrying the dressing up to the body. If a finger or toe is the site of the infection, the dressing should be wound about each digit separately. Over this, several thicknesses of cotton are placed; the cotton is covered with gutta percha or with a rubber sheet and then with a bandage. The dressing is soaked with the hot solution at frequent intervals, and changed not oftener than once in forty-eight hours. The injured limb should be elevated, and the patient kept in bed.

The exigencies of war have brought into prominence a number of antiseptic solutions of greater or less merit. Even the large number of wounds treated has not yet finally decided their relative merits, perhaps in part because the technic of the preparation of any given solution has varied widely. The boric acid solution is recommended here, not because it is superior to other antiseptic solutions, but because the simplicity of its preparation makes it everywhere available.

Avulsion of the scalp, of fairly common occurrence in the days of Indian warfare, is now always an industrial accident, as where the hair is caught in machinery or by a belt. The bleeding may be severe and hemorrhage must be controlled by the ligation of all visible blood-vessels. If the scalp is only detached in part the flap should be sutured in place. If it has been entirely detached but is in good condition grafting may be attempted. In all other cases, after cleansing the wound, an antiseptic dressing is applied for some hours, or even days, and Thiersch grafts are then made. Where the pericranium has been torn away, difficulty is often experienced in getting a good granulatin surface upon which to graft. In such cases, holes may be drilled int the skull, through which granulations may grow up.

SPRAINS.

The term sprain is a rather loose expression applied to injuries to the joints in which the ligaments, tendons, or synovia are involved but no fracture or dislocation of the bone is present. The sprain is the result of the extension of motion beyond normal limits, and children and adults in whom the musculature is poorly developed are especially liable to such injuries.

Diagnosis.—Immediately following the receipt of the sprain the pain is often intense, sometimes even causing nausea and vomiting; later there may be a feeling of numbness. Swelling usually develops within a short time and the resulting deformity may be very marked especially when there is also effusion into the joint. Ecchymosis may also appear and is often extensive. Tenderness to the touch and on any attempt to use the joint is observed and is one of the last symptoms to disappear. The diagnosis of sprain is so easily made that many unfortunate failures to recognize a fracture or dislocation occur; the only way to insure against such errors is to make it an invariable rule to take an x-ray of every supposed sprain or, where this is impossible, to examine under an anesthetic.

Treatment.—In treating severe sprains, our first efforts should be directed toward preventing the development of swelling and effusion

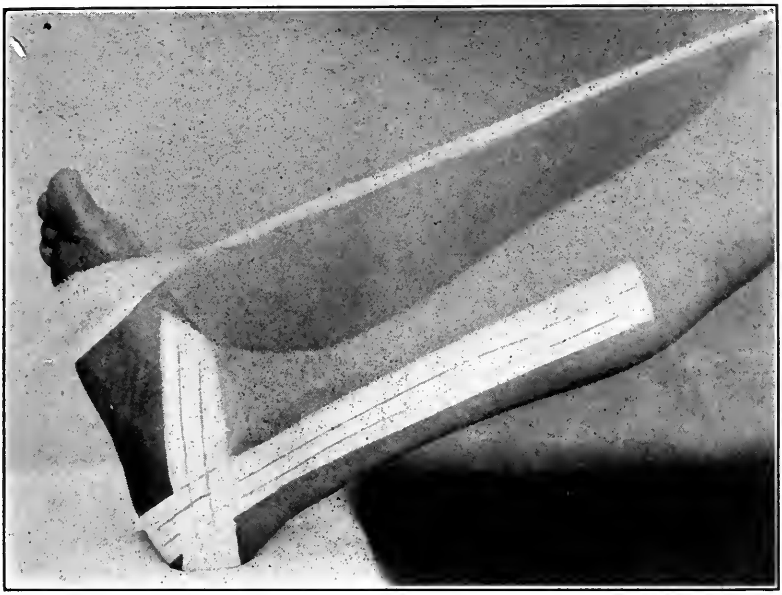


FIG. 486.—A gauze sling holds the foot in position.

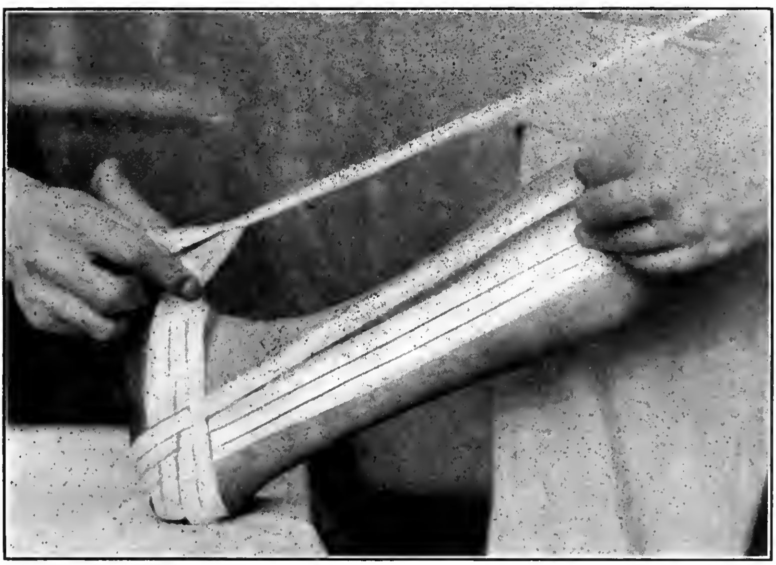


FIG. 487.—Alternate application of long and short strips.

by judicious bandaging, careful elevation of the part in as comfortable a position as possible and by the application of an ice-bag. Occasionally heat is more welcome and it is usually equally effective. As soon as the acute symptoms of a severe sprain subside and in every case of

FIG. 488.—The half inch strips are in position, the broad strips which cover them ready for application.

FIG. 489.—The dressing completed.

moderate pain, the joint should be partially immobilized to prevent excessive motion and to provide light massage. In sprains of the ankle, which is the joint most frequently affected, this partial immobilization is secured by strapping with half-inch adhesive straps. The first long strip (approximately twenty-eight inches in length) is applied just posterior to the malleoli, passing over the sole of the foot and well up onto the calf of the leg on either side. A short strap (approximately seven inches in length) is then applied on either side of the foot, extending from the center of the posterior aspect of the heel to the tarsometacarpal joint. A second long strip is then applied immediately in front of, and overlapping the first for one-fourth its width, then two short strips overlapping the first short ones an eighth of an inch, again a long one, and so on until the dressing is complete (see illustration).

A method as effective for strapping the knee, wrist, and elbow, the other joints most frequently sprained, has not been worked out, but the principle of applying bandages and adhesive straps is the same, *i. e.,* the dressings used should limit but not prevent motion.

SPRAIN-FRACTURES.

A sprain-fracture is the separation of tendon or ligament from its insertion, the bone to which the tendon or ligament was attached being separated from the bone shaft as the result of increased tension or direct violence.

Momberg's epicondylitis and Schlatter's disease are such sprain-fractures. Until within recent years all these cases have been diagnosed and treated as simple sprains and to this fact may be attributed some, at least, of the cases of persistent pain and functional weakness following so-called sprains. The tendons and ligaments about the ankle-, knee-, elbow- and shoulder-joints are the ones most frequently involved.

Diagnosis.—The *x*-ray is the most important adjuvant to diagnosis, but negative results do not rule out the possibility of sprain-fractures since faulty technic, lack of experience in interpreting the findings, or the minuteness of the detached particle may obscure the diagnosis. Most characteristic is a circumscribed area of marked tenderness over the site of attachment of a tendon or ligament. This persists for some time and even in old fractures is still latent. Swelling is usually localized and there is consequently deformity unless there has been injury to the joint with a resulting effusion. Preternatural mobility and bone crepitus are rarely met with but joint crepitus may occasionally be elicited.

Prognosis.—When these sprain-fractures are seen early and are properly cared for they usually give no further trouble, but in neglected sprain-fractures or in those improperly treated, the possibility for future trouble is unlimited: The joint may be weakened or the source of more or less constant pain; an exuberant callus may form, or there may be non-union, permitting the detached piece of bone to become locked in the joint; chronic arthritis may develop and subacromial bursitis is without doubt often attributable to a sprain-fracture of the greater tuberosity.

Treatment.—When it is realized that this injury is properly classed under fractures rather than under sprains, the question of treatment is readily answered: The sprain-fracture with the neighboring joint must be immobilized in a plaster cast for three or four weeks—in case the tarsal or carpal bones are involved the cast must extend over the hand or foot as well as over the wrist or ankle. During this time absolute rest must be enforced. Following the removal of the cast, passive motion may be cautiously begun, followed, after the passage of some days, by massage, but active motion and the free use of the foot should be postponed for some weeks. This statement of the time required is, of course, only approximate, for it will differ in the individual case and the individual injury.

BURSITIS.

Following a strain or a contusion, acute bursitis may develop, or an often repeated minor trauma may result in the development of a chronic bursitis (*e. g.*, housemaid's knee). There is circumscribed swelling, discoloration, moist crepitus, fluctuation and pain on active or passive motion. In the case of the deeper bursæ it is difficult to make a diagnosis between bursitis and synovitis, the inflammation of the bursa often extending to the neighboring joint. The distended bursa may rupture as the result of a blow; the escape of fluid and blood into the surrounding tissues is followed by pain, and an area of diffuse swelling and moist crepitus develops. Later this area is discolored as a result of the hemorrhage.

Treatment.—In acute bursitis, the affected part should be put at rest and pressure be applied over the bursa. We also apply iodin though I think that its use is probably of sentimental rather than of practical value. Where this does not bring relief, the fluid should be aspirated and pressure again applied. Or the bursa should be cut down upon and removed. If the bursa becomes infected, it must be incised, swabbed with iodin and the cavity packed with gauze. In chronic bursitis the use of pressure and blue ointment is often effective; where it fails, incision and the removal of the bursa is necessary as in acute bursitis.

INJURIES TO THE KNEE-JOINT.

Discarding the expression "internal derangement of the knee-joint" as too loose a term, non-perforating injuries of this joint may be divided into traumatic synovitis, traumatic bursitis, traumatic arthritis, traumatic osteo-arthritis, ruptured ligaments, torn semilunar cartilage, and loose bodies in the joint (joint mice).

Traumatic Synovitis.—Traumatic synovitis is at once the commonest and the most benign lesion of the knee resulting from injury, and under this term we may classify all effusions into the knee in which injury to the ligaments, the semilunar cartilage and the patella can be excluded. The stability of the joint is not affected unless very extensive effusion has resulted in temporary stretching of the ligaments, but there may be considerable pain and tenderness. The condition should be treated immediately by rest and cold applications and as soon as pain and tenderness have subsided judicious exercise should be urged to aid in dispelling the effusion. In the occasional case in which the condition becomes chronic, elastic pressure and moderate use of the joint will usually effect a cure.

Whether *traumatic arthritis* and *traumatic osteo-arthritis* really exist as clinical entities is still open to question. Frequently when arthritis or osteo-arthritis has developed following an injury to the knee-joint examination of the other knee and of other joints will prove the condition to have existed previously. The patient may be entirely honest in his belief that the condition is due to a given injury for it is undoubtedly true that an osteo-arthritis joint which has given no troublesome symptoms may cause pain, stiffness, and instability of the joint following even a trivial injury. The symptoms bear an unfortunate resemblance to those met with in torn semilunar cartilage—there may be a click at the time of the accident and inability to complete extension. For this reason, careful examination of the other joints (it would seem superfluous to emphasize the necessity for an x-ray examination in knee-joint cases) is imperative for operation is of no benefit. The treatment does not differ in any essential from that required in the same conditions without a history of trauma.

Ruptured Ligaments.—Ruptured ligaments are not infrequently met with, especially in the industrial world and in the world of sport, the rupture of the posterior, the back of the internal lateral, and the anterior crucial as a result of forced hyperextension being perhaps the most common. Again forcible adduction may result in the rupture of the external lateral ligaments, or forcible abduction may tear the internal lateral ligaments. The anterior (patellar ligament) is also occasionally torn, either as the result of direct or indirect violence. especially when the muscles of the thigh are tensed, or of the sudden and forced flexion of the knee. Since any of these lesions is apt to result in a weakened joint and hypermobility, careful diagnosis and proper treatment are imperative. An accurate history of the manner in which the injury resulted is a first aid in diagnosis. In rupture of the crucial ligaments, hyperextension is possible; tearing of the lateral ligaments results in abnormal lateral mobility; where the patellar ligament is torn it is impossible to extend the leg on the thigh. The defect in the internal lateral and the patellar ligament is easily felt The knee-joint is swollen, there may or may not be an effusion into the joint; pain is at first severe.

When a case of ruptured ligaments due to hyperextension, is seen early, it should be treated by splinting in a slightly flexed position for three or four months, followed by massage and exercise. Where the internal lateral, external lateral, or anterior ligaments are torn, primary suture of the torn ends with chromic catgut, followed by rest in the extended position for two or three months will give the best results. This treatment is also satisfactory in cases in which the condition is complicated by loosening of the semilunar cartilage.

Injuries to the Semilunar Cartilages.—These injuries are of more frequent occurrence than was supposed formerly when they often masked under an indefinite diagnosis of "sprain" or internal derangement of the knee-joint," and are most often met with in coal miners and football players. The mechanism of the accident is much disputed but it seems probable that the cartilages are caught between the joint surfaces during flexion and rotation, and torn. The internal cartilage is much more frequently injured than is the external, probably in the ratio of 16 to 1, but this may be explained by the anatomical relations which give to the internal semilunar cartilage a far greater range of motion. The injury is usually situated in the anterior part of the cartilage and varies from a slight notch or split to a virtual fracture of the cartilage.

Here, again, an accurate story of the nature of the accident will be of great aid in diagnosis, but often the patient does not come to the surgeon until long after the receipt of the injury when its details have been forgotten. Extreme pain is the first symptom, affecting the entire joint at first, but later localizing about the site of the injury. At the instant of the accident, a click or snap is felt in the joint and the patient usually falls; the joint is generally locked and complete extension is impossible. After some manipulation it is usually again possible to extend the joint and the pain is then relieved in part. Later there is effusion into the joint, but under treatment this subsides in the course of a fortnight, though a tender point persists for some time on the inner or outer side of the joint, according as the internal or external cartilage is injured. In rare instances the cartilage remains impacted in the joint and it is impossible to extend the leg completely until the cartilage has been removed by operation. Where the injury occurred some time before, there is usually a history of recurrent attacks, the accidents which called them forth becoming more trivial in the later instances. Pain and effusion are also less marked in these recurrent attacks than in the primary one, though the tender spot over the injured lateral cartilage still persists. From the standpoint of differential diagnosis, the cases of osteoarthritis giving a history of trauma offer the greatest difficulties since here, too, there is often the localized spot of tenderness, the inability to extend the leg completely and pain on the inner side of the joint. These osteo-arthritic patients are, however, generally beyond middle life, while the people suffering from torn semilunar cartilage are usually in the years of physical activity. Crepitation of the joint is apt to be present in osteo-arthritis and an examination of the other knee is often sufficient to clear up the diagnosis.

While healing of these tears may occur, the difficulty of obtaining coaptation makes this improbable, and operation offers the best promise of unimpaired function. The indications for operation are primarily social ones, for while operation is indicated in the case of the laborer who must return to work at an early date and must have a sound joint, operation is a matter of choice in the case of the patient who can give up violent exercise and is content to wear a knee brace.

Absolute asepsis is the prime requisite here as in all joint surgery. The joint should be freely exposed through a longitudinal incision. If the tear is in the anterior part of the cartilage it may be readily seen but if it lies posteriorly it may be necessary to divide the anterior attachment of the cartilage and exert strong traction. A posterior tear is readily overlooked and careful examination and scrutiny may prevent the necessity of a second operation. The entire cartilage should be removed, the capsule and synovial membrane sutured, then the aponeurosis, and lastly the skin incision. A dressing is then applied. Using the joint is encouraged from the first, and the patient is able to return to work in a little over a month, sometimes sooner. On the two first days following operation, there may be a rise in temperature but this is of no significance; sometimes one or two hypodermics will be necessary to control pain.

In cases treated conservatively there is almost always an increased mobility in the joint and unless a knee brace is worn, there is danger of a second accident. Operation gives excellent results.

Joint Mice.—Some of the loose bodies found in joints are undoubtedly of traumatic origin, for not only is a definite history of injury obtainable in many of them, but examination of the body after removal has demonstrated it to be a fragment of the articular cartilage, a detached piece of the semilunar cartilage, or a fibrinated blood clot. A common history is that the patient while running feels something slip and experiences sudden pain in the side of the joint. The knee cannot be completely extended at first, as in ruptured semilunar cartilage, but after some manipulation, motion is again restored. Rarely a large body may become wedged between the patella and condyles, rendering complete extension impossible until it is removed by operation. The knee-joint is the joint most frequently affected, but traumatic joint mice may also occur in other joints.

Diagnosis.—Diagnosis may present considerable difficulty at first but eventually the loose body is detected. The knee is locked by the loose body becoming fixed between the joint surfaces during extension, preventing the completion of the movement. In the primary and subsequent early attacks, this accident is followed by an effusion into the joint of perhaps ten days' duration. In late cases there may be little or no effusion. The patient is often conscious of something moving about in the joint and eventually succeeds in locating the body. The latter is extremely elusive and slips away out of reach at the slightest pressure. Flexing and extending the leg several times, simultaneously pressing gently about the patella often locates the body.

Treatment.—If the loose body is a source of trouble, it should be removed but operation should not be undertaken until after the body has been located and fixed in some accessible position by thrusting a harelip pin or a long needle through the skin into it—after the skin has been thoroughly cleansed and painted with iodin. An incision is then made under local anesthesia, when the body can be removed with ease. Where the strict asepsis required in all joint surgery is observed, the operation is a safe and simple one, the result certain.

INJURIES TO TENDONS.

Severed and Ruptured Tendons.—In incised wounds of the limbs, a tendon is often severed and every open wound, particularly those of

Fig. 490

the hands and feet should be examined for such injuries. Subcutaneous ruptures of tendons are far less frequent; such ruptures may result from a sudden strain and spasmodic contraction of the corresponding muscle, or from a sharp blow over a tensed tendon. A tendon which has undergone pathologic changes is much more liable to such injuries than is a normal one.

Diagnosis.—In open wounds the diagnosis is as a rule readily made from inspection of the wound. If the tendon is completely severed, the proximal portion may retract for a greater or less distance, depending upon the presence of a sheath, and of fibrous attachments. In subcutaneous ruptures, during a violent exertion, or upon the receipt of a blow over a tensed muscle insertion, a snap is felt or even heard, accompanied by acute pain. A depression is seen and felt; swelling and ecchymosis develop within a short time. The loss of function in the corresponding muscle may be partial or complete. On contraction,

Fig. 491

Figs. 490 and 491.—Flexion and extension following the repair of a 3-inch defect in the tendon of Achilles with a fascia transplant from the gastrocnemius. The tendon and both bones of the leg had been severed by the blade of a mowing machine.

the muscle is found by palpation to be softer than its fellow, though it may appear larger. If the quadriceps is ruptured above the patella, or in case of rupture of the patellar tendon, there is effusion into the joint; in the latter case the knee-cap is displaced.

Treatment.—In the care of wounds of tendons, and in tendon operations, the greatest precautions against sepsis are imperative since these tissues offer little resistance against bacterial invasion, and infections here are peculiarly dangerous because of their likelihood to travel up the tendon sheaths. Where infection occurs, there is intense pain, redness and swelling along the course of the tendon. A red streak may extend up the limb, marking the course of the lymph glands (lymphadenitis) and there is danger of septicemia and, locally, of deformities and loss or limitation of function. Hot, wet, antiseptic dressings should be applied; and when infection has localized, drainage should be established. Absolute rest must be secured by the use of large dressings and splints, and the limb should be elevated.

The space between the severed or ruptured ends of a tendon is filled with blood and lymph which is gradually grown through and replaced by granulation tissue which has its origin in the tendon and the tendon sheath. This process requires approximately two months for its completion. In the case of extensive gaps such repair is impossible, and where there has been much laceration of the surrounding tissues or infection, there may be a fusion of all the tissues involved with consequent loss of function. Even in favorable cases, there is more or less lengthening of the tendon with a resulting loss of muscular power and for this reason conservative treatment—an attempt at approximation followed by immobilization for some weeks—has gradually given place to operation. Primary operation and suture should be the rule in every open wound involving a tendon and in all cases of rupture in which a tendon of any importance is severed.

Various suture materials and various methods of suture, simple and complicated, have been recommended for uniting severed tendons but any suture material and any method of suture which holds the severed ends in approximation will be successful. Even where it is impossible to bring them together, good union may follow the bridging of the gap with a number of strands of catgut. The fibers of the tendon have a tendency to divide where direct traction is exerted upon them and a suture which passes through the tendon in various directions is to be preferred for this reason.

Difficulty is frequently encountered in bringing the retracted end of a tendon into position. Sometimes the tendon may be forced downward by pressure upon the muscle belly or by the application of an elastic bandage beginning at the insertion of the muscle and extending downward. In some cases the retracted end may be seized by a pair of forceps passed up the sheath; the sheath may be split where the retraction is considerable. Or a probe may be passed up the sheath until the end of the tendon is found, a small incision made and a suture passed through the tendon, the suture drawn through the sheath by means of the probe and the tendon then drawn into position. If none of these methods is successful, traction must be avoided by lengthening the tendon by one of the various methods of tendon division. The gap may be bridged by transplanting a section from a neighboring less important tendon which has also been injured, or a piece of fascia may be folded into a strand of the required size and sutured to either end of the tendon. When the proximal end of the tendon cannot be found, the distal end may be passed through a slit in an adjoining tendon and sutured there. When the proximal end alone is available, it may be sutured to the periosteum as near as possible to its normal insertion. Or here, too, the end of the tendon may be attached to the side of a neighboring tendon. In order to attach the tendon to the bone, a flap of periosteum must be raised. The tendon is sutured to this or is united to it by a cable of chromic catgut. Or the periosteum is reflected to either side and a groove made in the bone in which the tendon is placed; it is then sutured to the periosteal flaps which are also united to each other.

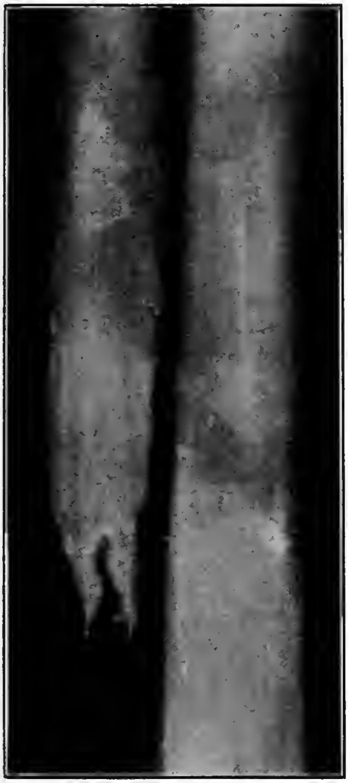


Fig. 492.—Parosteal callus in the vasti. The clear-cut lines of the bone shaft, the area of light, separating bone from callus mass, the forked end, are all characteristic.

Fig. 493.—Traumatic parosteal callus in the vasti. In this case, too, the bone shaft has clear outlines but the zone of light is absent because the callus masses saddle the bone.

PAROSTEAL BONE AND CALLUS FORMATION.

Myositis ossificans traumatica, or, more properly speaking, traumatic bone and callus formation, may develop following a single severe trauma or after a lesser trauma often repeated. As instances of a single injury resulting in parosteal ossification, there are the many reported cases of ossification in the quadriceps extensors, following injuries on the gridiron, or the kick of a horse, and in the brachialis anticus following the reduction of a dislocation of the elbow. While the literature contains several hundred case reports, a large majority

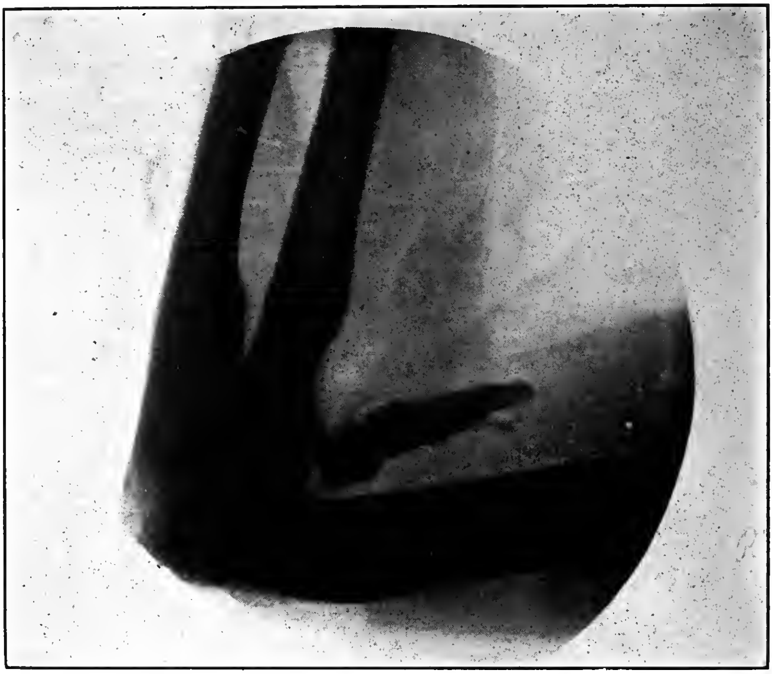


Fig. 494

Fig. 495

Figs. 494 and 495.—Typical parosteal callus in the brachialis anticus following the reduction of a dislocation. Extension and flexion.

of these masses remain unrecognized. Machol[1] who found parosteal bone and callus present in each of a series of 17 cases of dislocation of the elbow which he observed, goes so far as to say that such formations are the invariable sequent of dislocations of the elbow. Muscle ossification following repeated trauma is most frequently recorded in military annals—the infantrists' bones in the biceps, the cavalrists' in the abductors—but it may also be found in artisans (shoemakers, etc.) as an occupational injury. Whether ossification results from a single injury or from repeated trauma, the process is a reparative one, the cells of the intramuscular tissue reacting to the stimulus of a changed environment and changed nutrition with the formation of metaplastic bone.

Of the two processes, the development of parosteal bone and callus following a single injury is the more striking phenomenon. At first the symptoms are those of a simple severe contusion—there is swelling and ecchymosis, often a certain amount of inflammation, while pain and disability are present in varying degrees. After the passage of some days, the ecchymosis gradually subsides, there is little or no pain except on manipulation but on palpation, the swelling is found to be indurated, and the disability gradually grows greater instead of less. Following the reduction of a dislocation of the elbow, the increasing instead of decreasing impairment of function is usually the first symptom to attract attention, while in the muscles of the thigh, where the bone and callus formation is often extensive, the presence of an indurated area of rapid development and its sinister suggestion of malignancy may first call attention to the condition. Definite diagnosis must rest upon the roentgen findings. In the muscles of the thigh or of the upper arm, we must differentiate between osteosarcoma and parosteal callus. In the latter, the bone shaft has clean-cut outlines, there is an area of light between the underlying and the new-formed bone, and the fine inner lines seem to correspond to the direction of the muscle fibers. In sarcoma the outlines of the bone are roughened, the overlying shadow merges into it, the inner markings radiate from the bone, giving the characteristic comb-like appearance. In traumatic parosteal callus formation about the elbow-joint, the new-formed bone must not be mistaken for detached fragments of bone; here again, the sharp normal outlines of the bone and the site of the ossification in the brachialis anticus are characteristic of the parosteal bone mass.

Where the parosteal ossification follows repeated traumata (the so-called myositis ossificans traumatica chronica), there may have been no sign of injury, but only soreness and lameness following certain exercises, as in bayonet exercises or broadsword practice, or a twist or strain while riding. Again the initial injuries may have resulted in trivial swelling and tenderness, usually not sufficient to keep the recruit or apprentice from his duties (the ossification usually develops within a short time of the bearer's admission to the army or his assumption of a new employment). Often the difficulty encountered in performing

[1] Beitr. z. klin. Chir., Tübingen, 1908, lvi, 775–832, 4 pl.

the accustomed tasks is the first symptom to attract attention. In this type of cases, the ossification never attains the large size often seen in the preceding group, and with the exception of the rider's bones which are sometimes attached to the os pubis, they are practically always free within the musculature.

Since the presence of the parosteal bone and callus masses is not a menace to life or health, the question of the advisability of removing them is largely an economic and a personal one, *i. e.*, operation is indicated when functional disability interferes with the patient's means of livelihood, or when love for sports and active exercise makes too irksome the restriction which its presence imposes upon him. In the occasional cases where there is interference with the blood or nerve supply, operation is also indicated.

If operation is decided upon, the time for operation is a most important consideration. Too early removal of the callus masses before the process has come to a standstill, results in a recurrence. The removal of the mass should, therefore, be postponed until the outlines as seen on the *x*-ray plate are clearly defined and the roentgen and physical examinations give corresponding pictures; in other words until the mass is "ripe." As a rule, this will require some three months but in one of my cases these conditions were fulfilled and operation performed within six weeks and there was no recurrence. Operation may well be postponed until a much later date if the social condition of the patient permits.

Where these conditions are fulfilled the operation may be conservative, as little as possible of the normal tissue being removed, and success may be considered assured if the parosteal callus lies in the free musculature. Where the mass is attached, a "bone scar" is often formed, the *x*-ray disclosing considerable proliferation at the site of attachment, but the functional results are usually excellent. If much peri-articular ossification is present (as is not infrequently the case following the reduction of a dislocation), the patient will of course benefit little by the simple removal of an accompanying parosteal mass, but it seems not improbable that a greater or less degree of ankylosis has often, in the absence of an *x*-ray examination, been attributed to periarticular ossification when nothing but a small parosteal callus was present.

TRAUMATIC MYOSITIS.

Simple traumatic myositis may be the result of a blow, of very slight ruptures of the muscle, or of prolonged strain. No infection is present and the process is in reality a reparative one. Granulation tissue is formed which, maturing, may result in restitutio ad integrum; where the injury and consequent tissue destruction has been extensive, more or less scar tissue is formed.

There is inflammation, swelling and pain, especially when an attempt is made to use the muscle or muscles involved. At this stage, the history of the injury and the physical findings make diagnosis easy;

palliative treatment alone is indicated. When much scar tissue has formed, especially deep in the muscle, it is sometimes palpated as a marked resistance but a roentgenogram is sufficient to differentiate this condition from traumatic ossifying myositis.

Ruptures and Hernia of the Muscles.—Ruptures of the muscle are of comparatively frequent occurrence in muscles which are subject to sudden brisk contractions, such as the adductors of the leg and the biceps of the arm. "Rider's thigh," in which a few of the muscle fibers of the adductors are torn and "tennis leg," in which there is a

Fig. 496.—Rupture of the triceps.

partial rupture of the gastrocnemius, some fibers of the plantaris being also involved in occasional cases, are common instances. In muscle hernia, which is often confused with a rupture of the muscle, the muscle, which is uninjured, protrudes through a tear in its fascia.

At the instant of receiving the injury there is a sudden exquisite pain felt in the muscle but this is usually transitory, and gives place to a feeling of soreness when any attempt is made to use the limb. If the rupture is extensive, a soft tumor (hematoma) develops at the site of the rupture but when this is absorbed a groove may be felt in the muscle. The proximal fibers contract, forming a hard mass which may be mistaken for a muscle hernia, while the distal fibers, deprived of their nerve supply, degenerate. The differentiation of muscle hernia from a ruptured muscle is not difficult if it is remembered that in muscle hernia the tumor is prominent when the muscle is at rest, and disappears when the muscle is contracted, while, on contracting a ruptured muscle, the tumor mass grows larger and harder.

When the rupture has not been extensive, conservative treatment gives a very satisfactory result. Treatment by rest is fairly effective, but massage and strapping with early exercise, are to be preferred. Where the rupture involves any considerable part of the muscle, myorrhaphy is to be recommended and operation should be performed early before degeneration and retraction have taken place. An incision is made parallel to the fibers of the muscle and the injured portion is freely exposed. After cleaning out the wound and stopping all hemorrhage, the torn ends of the muscle are approximated by heavy catgut sutures, tension being relieved by one or two relaxation sutures if necessary. The incision in the fascia and skin is then closed, unless the danger of infection makes the employment of drainage necessary. The muscle must be kept relaxed and quiet for a period of three weeks.

In non-operative cases, there is usually a certain degree of improvement, as the intact fibers of the muscles and the neighboring muscles assume in part the function of the ruptured portion. In operated cases, the prognosis is excellent if operation is performed early before there has been any considerable amount of scar tissue formation and muscle degeneration; the old and neglected cases are not promising.

Muscle herniæ are sometimes troublesome enough to require operation. The muscle is exposed, the protruding tumor excised, and the wound in the muscle closed. After the fascia has been undermined about the hernial opening to relieve tension, the edges are overlapped where this is possible, and the skin wound sutured.

INJURIES TO SALIVARY GLANDS AND DUCTS.

Injuries to the salivary glands and ducts are of common occurrence in countries in which duelling with the broadsword is the custom, but in this country they are by no means rare as the result of falling upon some sharp object, gunshot and stab wounds, or as a complication in compound fractures of the jaw.

Diagnosis.—The *parotid gland* is the most frequent site of injury. Diagnosis is made from inspection of the wound, the gland being readily recognized by its characteristic granular appearance. Hemorrhage may make its recognition more difficult, but the position of the wound alone is, as a rule, sufficient evidence of the nature of the injury. A flow of saliva does not occur in early cases unless a main efferent duct has been severed, when a flow of saliva may follow stimulation of the secretion.[1]

[1] Heinecke, H.: Verletzungen und chirurgische Krankheiten der Speicheldrüsen, Leipzig, 1913, No. 2, Pt. II, p. 326.

Treatment.—Infections are less frequent following such injuries than we might anticipate in view of the frequent severity of suppurative parotitis. The cut surfaces of all clean wounds should be carefully approximated and sutured, the overlying fascia closed by a second row of sutures, using fine catgut. If the gland has been badly lacerated, all tissue which has been too badly damaged to undergo repair should be cut away, and the cut surfaces of the gland be brought into apposition as in the case of simple incised wounds. The flow of saliva must be checked as far as possible to prevent the formation of a fistula; liquids alone should be administered, and the sight and smell of any tempting food be avoided. Chewing and even talking should be forbidden, and a compressing bandage be applied about the head to prevent any infringement of the rule. If saliva does collect within the wound, these same measures rigidly persisted in may prevent increased extravasation. If there seems to be danger of perforation, the fluid should be aspirated, daily if necessary. The injection of a few drops of alcohol or iodin is often effective. Though this aspiration may in itself result in the formation of a salivary fistula, the damage done is far less than if spontaneous perforation were allowed to take place, and by preventing excessive distention the formation of an unsightly scar is avoided. In some cases, it is possible to pass a sound through Stensen's duct and establish drainage.

Stensen's Duct.—This is less frequently injured than is the parotid but the greater tendency to fistula formation makes injuries to it an important subject. The traumatizing agents are on the whole the same as in the case of the parotid, blunt force playing a lesser part than do edged instruments.

Diagnosis.—The diagnosis is usually made from an examination of the wound, the thick walls of the duct being clearly visible except when the duct is severed at right angles to its course and the ends have retracted. The placing of a drop of vinegar or lemon upon the tongue is followed, in the course of a few seconds, by a flow of saliva from the proximal end of the severed duct while the distal end may be located by passing a fine sound or a piece of catgut through the buccal opening.

Treatment.—The severed ends of the duct should always be sutured when this is possible, since these wounds seldom heal spontaneously without fistula formation. A fine sound is passed into the duct through the buccal opening and the severed ends sutured over it with fine catgut stitches. The external wound should then be completely closed. The sound should not be left in the wound as is the custom of some operators, for its presence favors infection.

Where there has been extensive laceration or destruction of the duct, in the presence of infection, and finally in all penetrating wounds of the cheek, the formation of a buccal fistula must replace suture of the duct. The external wound alone is sutured, the wound in the mucosa left wide open.

If, after suture of the torn duct, saliva collects in the wound, forming a fluctuating tumor, it may often be emptied by simple pressure if the buccal end of the duct is still patent. Sounding with small elastic sounds is also often effective. If, however, the tumor increases in size in spite of this conservative treatment, the fluid must be aspirated from the inner side. If none of these methods is effective, an incision should be made through the mucosa, and a drain inserted, or the duct may be split until it is possible to introduce a small tube into the tumor. The drain must be left in place for eight or ten days, and a bougie passed through the duct for a time after its removal in order to insure its patency (Heinecke).

Jianu[1] replaced a defect in the parotid duct (the result of an operation for carcinoma of the cheek) with a section of the vena facialis. The vein, which had been mobilized until it could be brought into the defect, was left adherent to the surrounding tissues. The proximal end of the duct was then invaginated in the vein and sutured, while the opposite end of the section taken from the vein was brought out through an incision in the mucosa. Two years later, the duct was still patent.

The postoperative treatment does not differ from that indicated in injuries to the parotid gland.

Subcutaneous injuries to the *submaxillary* and *sublingual* glands and ducts do not often occur; but they may result from gunshot or stab wounds, and from lacerations of the submaxillary region and floor of the mouth, especially by bone splinters in compound comminuted fractures of the lower jaw. They heal spontaneously and without the formation of an external fistula.

INJURIES TO THE THYROID.

Open wounds of the thyroid need no explanation; stab wounds, gunshot wounds, and lacerations are those most frequently met with. Subcutaneous wounds of the normal gland, or even of the gland which has undergone cystic degeneration, are rarely reported. Overlying muscles and the free movability of the normal thyroid gland protect it very effectively from such injuries, while the relatively small number of people who have an enlarged thyroid and who suffer a severe trauma of the neck explains the small number of reported subcutaneous injuries to this gland even when pathologic.

Rupture of the cystic goiter and hemorrhage from a ruptured vessel are described in the literature and Kolaczek[2] reports a case of crushing of the parenchyma of the gland when the patient, a woman aged forty-two years, fell, striking the left side of her neck against the edge of a tub.

Symptoms.—In open wounds, the location of the wound and the free hemorrhage should make diagnosis easy. In subcutaneous ruptures, there may also be free bleeding, the blood escaping into the pleural cavity, the posterior mediastinum, or the surrounding tissues of the neck, where it may greatly increase the size of the neck, and cause

[1] Spitalul, 1916, p. 457.

[2] Beitr. z. klin. Chir., 1909, lxiv, 539.

bulging of the posterior pharyngeal wall. The fluid, in the case of a ruptured cyst, may escape in the same manner.

Hoarseness and dyspnea are other pressure symptoms which may be observed. Fever is an interesting symptom, comparable to the fever observed following thyroidectomy.

Prognosis.—From the few reported cases, it is impossible to draw any conclusions in regard to the prognosis in this class of injuries. The greatest danger is from hemorrhage and if the patient is seen soon after the receipt of the injury, the prognosis should be little worse than in a series of goiter cases.

Operation.—In open wounds of the thyroid, hemorrhage is the immediate danger to be met, infection the late one. Unless there is extensive laceration, a few deep sutures should be passed through the gland to approximate the torn edges, and the gland then sutured with fine catgut. Over-and-over sutures might also be employed as in controlling hemorrhage following partial thyroidectomy. Where the gland is badly lacerated, or where it is impossible to control hemorrhage from the wound, thyroidectomy must be performed. In subcutaneous ruptures also, where there is much destruction of tissue and where a certain degree of degeneration is probably always present, thyroidectomy is indicated. A rubber tube drains the wound.

INJURIES TO THE TRACHEA.

The occasional subcutaneous injuries to the trachea result from the direct application of force, as in accidental or suicidal hanging, falling upon some hard object, or more frequently from blows; or from indirect violence when the head is struck or overextended. In severe injuries to the thorax the lower segments of the trachea are also occasionally injured.

Diagnosis.—In simple contusion of the larynx, ecchymosis and edema may develop; loss of voice from temporary paralysis of the vocal cords is rarer, while dyspnea is only present in exceptional cases. Rest and the application of cold are usually sufficient to relieve the symptoms. The condition of shock which sometimes develops following an apparently trivial injury to the larynx is treated as is traumatic shock from any other injury.

Extreme intratracheal pressure or the lateral crushing of the trachea may result in fracture of its cartilages. These fractures usually result in the transverse section of the trachea, and the ends are more or less retracted; longitudinal or tangential rents are also occasionally met with. Localized pain, subcutaneous emphysema, dyspnea, and a bloody, frothy expectoration are the characteristic symptoms while in the case of a transverse rupture, the defect in the trachea can frequently be palpated. In the case of intrathoracic ruptures the trauma is usually so violent that other injuries obscure the early symptoms and death supervenes before a diagnosis can be made.

Operation.—When a diagnosis of fracture of the trachea has been made, tracheotomy should be at once performed before the development of emphysema renders operative procedure difficult. When the tube has been placed, any rents in the trachea may be sutured, the cartilage being crushed to facilitate the passage of the needle; more extensive injuries and defects must be left for later repair. The removal of the tube and the repair of such defects must not be too long delayed, however, for such delays render more difficult a procedure which at best offers many difficulties. From 2 to 4 cm. and sometimes even 5 cm. of the trachea may be sacrificed in the closure of a defect. Small defects may be closed by a fascia transplant but this repair is not suitable where there is any considerable gap since the fascia may be drawn into the lumen of the trachea causing an obstruction.

INJURIES TO THE ESOPHAGUS.

Most injuries to the esophagus are due to force applied from within (instrumentation, foreign bodies); penetrating wounds and ruptures are rare as isolated injuries because of the extreme proximity of the esophagus to more vital structures, wounds of which entail imminent danger to life.

Symptoms.—In penetrating wounds of the esophagus particles of food may escape through the wound. There is coughing and retching; vomiting may occur, or there may be bloody expectoration.

Treatment.—Wounds in the cervical portion of the esophagus should be closed by suture, and the wound packed. No food should be given by mouth, rectal feeding being employed for at least ten days. Ochsner suggests that a small rubber tube or catheter may be passed into the stomach three or four days after operation, and small quantities of food be introduced into the stomach several times a day; that the tube may be passed through the nostril and left in place. Injuries to the thoracic portion of the esophagus are not promising surgical material—mediastinitis, dyspnea, emphysema, and collapse usually bring a fatal termination within the first few days. Thoracic surgery, however, is still a new field and where a diagnosis of rupture or penetrating wound of the lower portion of the esophagus has been made, an attempt at suture is indicated.

INJURIES TO THE THORACIC DUCT.

Injuries to the thoracic duct are extremely rare as the result of surgical accidents and are even more unusual as the result of trauma. The cervical portion of the duct is so intimately associated with more vital structures, that isolated injury to the duct is all but impossible; a wound which involves the duct is thus fatal within a very short time and the fact that the thoracic duct was also involved in the injury is usually recognized only at autopsy. Injuries to the thoracic and abdominal portions of the duct are also most unusual but are occasionally reported as the result of crushing injuries (especially where vertebræ have been fractured), gunshot and stab wounds.

Diagnosis.—Diagnosis is only possible from the escape of the chylous fluid. If the injury is due to an open wound, it is early recognized, but in the chest or abdomen large quantities of fluid often gather in the pleural or peritoneal cavity (chylothorax, chylous ascites) before aspiration reveals the nature of the extravasation.

Prognosis.—In the reported cases of isolated injury to the thoracic duct, healing has been the rule but it is quite possible that other cases which terminated fatally have not found their way into print.

Treatment.—The escape of any considerable amount of chyle results in marasmus and eventually in death. The closure of every recognized wound of the thoracic duct is therefore indicated. A small wound has been successfully sutured with a very fine needle and fine silk thread. (Cushing.[1]) Simple tamponing has also been effective. If the duct has been completely severed, it may be implanted into the internal jugular vein; simple ligation is also fairly safe because of anastomoses or the existence of a right-sided duct in many cases. The diet should either be very carefully limited or rectal feeding resorted to until the discharge from the wound has ceased.

ABDOMINAL TRAUMA.

In penetrating wounds of the abdomen (whether incised, lacerated, or gunshot wounds), diagnosis and therapy are one, and surgical indications are clearcut. In every case, the patient should be taken at once to the operating room. He is placed on the table and prepared for laparotomy—tincture of iodine should be used freely over the field of operation. Under ether anesthesia (local anesthesia may be used where a general anesthetic is contraindicated), the abdominal wound is carefully enlarged, layer by layer, until its base is reached. If the peritoneum is found penetrated, laparotomy is at once performed, either through the wound opening or through a median incision, and hemorrhage controlled, perforations closed, damaged tissue resected.

In subcutaneous abdominal trauma, the surgeon is without well-defined precepts; here the problem of diagnosis and indications for operation is one of the most urgent and difficult in the entire field of surgery. Internal hemorrhage and peritonitis from a ruptured viscus make any delay perilous, on the one hand, while an unnecessary operation upon a patient suffering from the effects of shock is, on the other hand, not without danger and is always to be deprecated. There is an unfortunate disparity between the severity of the contusing force and the resultant injury; rupture of the gut has followed a fall upon the buttocks where even ecchymosis did not result, while again no viscus is injured although the force has been applied directly over the abdomen and the parietes show the effects of severe contusion. The degree of force and the manner of its application should be ascertained as far as possible in every case of abdominal trauma, but such data is suggestive, never decisive.

Shock is dependent upon several factors, and the nervous equilibrium and individual susceptibility to fright and pain have so close a bearing upon its development and duration, that it is not a safe criterion of the

[1] Ann. Surg., 1898, xxvii, 719.

presence or absence of visceral injury. Shock which is a manifestation of general nerve trauma and not of organic lesion normally responds to treatment and there should be a gradual though perhaps a slow subsidence of alarming symptoms. Where no such improvement is manifest within the first few hours, a probable diagnosis of subcutaneous visceral injury is justifiable.

Closely associated with the degree of shock, are early variations in pulse and temperature. A fast or slow pulse-rate and a rise or fall in temperature are alike of uncertain significance in the first few hours after the receipt of an injury. Later an increasing pulse-rate or a rise in temperature speaks for beginning peritonitis and is a danger signal. The temperature may remain normal, however, even in the presence of a perforation and developing peritonitis (Kotzenberg[1]) and is thus never a guarantee of safety.

Spontaneous pain is, like shock, dependent to a certain degree upon individual susceptibility. Localized spontaneous pain and pain on deep pressure over a given area (to be carefully distinguished from the superficial pain of bruised abdominal walls) have a certain diagnostic value, however, and are of especial significance when associated with muscle rigidity and thoracic breathing, not only in indicating the presence of visceral injury but also serving as an approximate guide to its location.

Tympanites developing immediately after the receipt of an abdominal injury may be of benign significance—a reflex intestinal paralysis manifesting itself as tympanites in the absence of muscular rigidity. Tympanites developing after the passage of some hours means peritonitis and signifies that the medical attendant has failed to make a diagnosis during the hours when operation offered the best chance of success.

An increasing area of iliac dulness means hemorrhage when the patient exhibits symptoms of acute anemia or the blood shows a marked decrease in hemoglobin. In the absence of these confirmatory symptoms, iliac dulness suggests the escape of gastro-intestinal contents, especially when the injury has been received within a few hours after taking a full meal. In either case immediate laparotomy is indicated.

Thoracic breathing may be of reflex origin or an attempt to escape the pain due to bruised muscles, but it is often a protective phenomenon —the superficial breathing saving an injured viscus from further trauma. A diagnosis of subcutaneous abdominal injury cannot be based upon the presence of thoracic breathing alone but this superficial breathing is confirmatory evidence of especial value when abdominal rigidity is also manifest.

Rigidity of the abdominal muscles is not an infallible symptom of a ruptured viscus—there is no infallible symptom—but it is a most valuable one. Its absence does not preclude the possibility of serious injury and in exceptionally rare cases it may be absent even when a perforation of the gastro-intestinal tract has occurred, but its presence is

[1] Beitr. f. klin. Chir., Tübingen, 1914, xciv, 31.

decisive—in every case of abdominal trauma in which a board-like rigidity is demonstrable, operate at once. The symptom has added value because it is most frequently encountered in cases of perforation of the gastro-intestinal tract (though often met with in the case of injury to other viscera), *i. e.*, in just those cases in which we cannot depend upon signs of intra-abdominal bleeding to guide us in determining for or against operation.

The early treatment in these cases before the question of operation can be decided is clearly defined—combat shock, and under any and all circumstances refrain from the use of any opiate until the question of operation has been decided. Morphin gives the patient an unwarranted sense of security and is thus directly and indirectly deceptive. It is absolutely contraindicated until the patient is on his way to the hospital and the operating room.

There is an unfortunately large number of these patient who do not come under the surgeon's care in time for early operation. Many who could easily have been saved by early surgical interference do not reach the surgeon until to the traumatism has been added the far graver condition of peritonitis from peritoneal contamination with gastro-intestinal contents. In such cases, the treatment depends not only upon the character of the injury but, primarily, upon the character of the secondary condition.

INJURIES TO THE DIAPHRAGM.

Penetrating wounds of the diaphragm have the varied etiology of penetrating wounds of other parts of the body. Subcutaneous injuries of a sort closely related to penetrating wounds result from the perforation of the pleura and lung by the fragment of a fractured rib, but the majority of the subcutaneous injuries are the result of great violence—crushing between the buffers of a train, falling from a height, or being caught beneath some heavy object. Where so much force is applied, it follows of necessity that subcutaneous ruptures of the diaphragm are accompanied by other lesions, particularly by injuries to abdominal organs, in very many cases, so that death often results immediately or within the first few hours. Injuries to the stomach are the most frequent complicating injuries, the diaphragm being injured in approximately 25 per cent. of the penetrating wounds of the stomach. The liver, lung, colon, spleen, and the left kidney may also be injured. In rare cases a rupture of the diaphragm results from violent muscular contraction but in these cases it is probable that some congenital defect is to be assumed. In the latter injuries, it is the central or tendinous leaf of the diaphragm which ruptures, while in injuries from external violence the lateral or muscular leaves are torn. The left side of the diaphragm is ruptured five times as frequently as is the right according to Merkel,[1] probably because the right diaphragm is protected by the many firm attachments of the liver which distribute the force applied

[1] Cited by F. A. Suter, Beitr. z. klin. Chir., 1905, xlvi, 348.

over a larger area. Both penetrating and non-penetrating wounds are probably of more common occurrence than a search through the literature would seem to indicate, for they have no characteristic symptoms and their presence may be unsuspected, especially when concomitant lesions of other organs are present.

In non-penetrating injuries, this absence of definite symptoms is particularly striking. Pain radiating to the shoulder, vomiting, nausea, thoracic breathing, muscular rigidity, dyspnea and an anxious facial expression have been observed but these symptoms are neither of constant occurrence nor characteristic. In penetrating transpleural injuries, the prolapse of abdominal organs, particularly of the omentum, may lead to diagnosis.

Prognosis.—A definite prognosis cannot be made from the statistics available since there can be no question that the majority of cases of injuries to the diaphragm remain unrecognized or at least unreported. In isolated injuries of the diaphragm, spontaneous healing undoubtedly occurs in very many cases but the possible development of a diaphragmatic hernia is a danger not to be ignored, some 50 per cent. of all such herniæ having a traumatic origin.

Suter[1] gives an operative mortality of 12.3 per cent. but we may consider the outcome a more favorable one than these figures would seem to indicate, for in only two of the nine patients who died was the injury to the diaphragm the only traumatic lesion. An infection of the pleura developed in only 7 of the 73 cases collected by this author, *i. e.*, in only 9.5 per cent. of the cases, a remarkably low incidence particularly when it is remembered that in some of these cases infection from a rent in stomach or gut had been possible.

Operation.—Since subcutaneous injuries of the diaphragm are almost impossible of diagnosis and the penetrating wounds are usually recognized only by the prolapse of abdominal contents, it follows that the question of operative interference is usually decided by the presence or suspected presence of accompanying lesions of other organs. Where there is a probability that the diaphragm has been penetrated by a stab wound or a bullet and the general condition of the patient is good, the injured side should be immobilized and the patient treated expectantly. The external wound should be cleansed, a small pad of sterile gauze laid over it, and strips of adhesive, from two to four inches in width, and overlapping about half their width, be placed entirely around the chest beginning a little below the last ribs and extending to the axillæ. If the presence of a wound of greater extent is suspected, either from the general or the local symptoms, an exploratory operation should be performed. An injury to the diaphragm, if discovered during any operation, should be repaired, if this is possible, without unduly prolonging the operation. In the case of a stab wound or a bullet wound in an inaccessible part of the diaphragm, the edges of which are closely approximated, it is better to refrain from suture than to prolong operation.

[1] Loc. cit.

In operating, the diaphragm may be approached transpleurally, through a laparotomy incision, or by a combination of the transpleural operation and laparotomy. In cases in which injury to abdominal viscera may be excluded with some degree of probability, the transpleural route has the advantage of best exposing the diaphragm. The formation of an osteoplastic flap (the eighth, ninth and sometimes also the seventh ribs are those most often removed) or the resection of one or more ribs is usually necessary. If the rent is near the thoracic wall, the median edge of the wound may be sutured directly to the thorax wall immediately above the incision. The thoracic cavity is thus completely closed off from the abdominal cavity. The further the tear is situated from the thorax wall, the greater the difficulty which may be encountered in approximating the edges of the wound and placing the interrupted sutures. Such sutures are more readily placed during deep expiration. The question of drainage is dependent upon the probable presence of infection and concomitant lesions of other viscera.

If injury to the abdominal viscera is suspected a high median incision is, of course, the method of choice. Here, again, it is the injury to other viscera which primarily demands attention and which decides for or against drainage.

INJURIES TO THE LIVER.

The size and weight of the liver, its inelasticity and the readiness with which the ribs yield to pressure make the liver especially liable to injury. Geill[1] reports a series of 494 autopsies performed in cases of subcutaneous abdominal injury in which injuries to the liver, isolated or associated with injuries of other organs, were present in 296 cases, or in 60 per cent. In Edler's statistics, injuries to the liver were present in 189 of the 365 cases, or in over half of the total number. In Amante's compilation, being run over by a vehicle was the most frequent of injury (42 of 203 cases), with the kick of a horse as a close second (35 cases). Falling from a height (25 cases), railroad injuries (19), blows over the abdomen (18) and the forcible impact of the abdomen against solid objects (14) were other frequent causes of injury. The statistics on open wounds of the liver are naturally largely of military origin and the impossibility of carefully examining the dead on the battlefield makes the figures secured of little value. According to Nussbaum,[2] Fischer,[3] and Siegel[4] the liver would appear to be the site of the injury in about 16 per cent. of the cases of penetrating abdominal injuries.

In subcutaneous lesions of the liver, the right lobe is more frequently

[1] Ch. Die Ruptur innerer Organe durch stumpfe Gewalt, Vierteljahrschrift f. gerichtliche Med., No. xviii, 205.

[2] Die Verletzungen des Unterleibs, Deutsche Chir., No. 44.

[3] Handbuch des Krieges, Stuttgart, 1882.

[4] Beitr. z. klin. Chir., 1898, xxi, 395.

injured than the left; a compilation of statistics of Amante demonstrates that it is injured in two-thirds of all cases. The median lobe is somewhat less frequently injured than is the right one. In open wounds of the liver, exactly the opposite seems to be the case; the same author collected 50 cases of open wounds of the liver, in 34 of which the left lobe was penetrated, in 14 the right, in 2 the lobe of Spigelie, and in 2 the posterior margin of the viscus. As for the types of injury met with, ruptures of the liver involving parenchyma and capsule are by far the most frequent and may consist of simple tears of greater or less extent and depth, of complete tears severing a portion of the organ, or crushed tissue. Where the parenchyma is detached from its capsule, or is torn, the tear not involving the capsule, subcapsular hematomata of greater or less extent may result. Intrahepatic extravasations of blood may also occur—the so-called liver apoplexies—and may be isolated or multiple, and of the most varied extent. Gunshot and stab wounds are most closely related to the injuries of the first group with the added complication of the external wound and of probable infection.

Hemorrhage, because of the great vascularity of the liver and its lack of connective tissues, is the dominating feature in cases of injuries to this organ. The old view, fathered by Hippocrates, that every wound of the liver must result fatally has been disproved by modern surgery and by the frequent discovery at autopsy of scars of the liver, demonstrating the possibility of spontaneous healing. In routine operations upon the liver or the biliary passages, scars of the liver are occasionally seen. Hemorrhage, which plays such an important part in determining the ultimate fate of the patient, is also of first importance in differential diagnosis and in determining upon operation. When examination of the patient discloses iliac dullness, and there are symptoms of acute anemia, it is easy to make a diagnosis of intraperitoneal extravasation of blood, but the determination of the source of the bleeding presents greater difficulty and may be even impossible. Generally speaking, if the catheter fails to disclose blood in the urine, the kidney and bladder may be excluded as a possible source of the hemorrhage. In the same way, the absence of blood from the stomach contents which are vomited—vomiting is common to all severe contusions of the abdomen—and from the feces, obtained by spontaneous defecation or by intestinal lavage, speaks against hemorrhage from the gastro-intestinal tract. It is more difficult to eliminate hemorrhage from the spleen and the mesentery, and in the latter case particularly, differential diagnosis is often impossible; the odds, however, are in favor of injury to the liver. In hemorrhage from the spleen, the extravasation is often limited to the left side of the abdomen, especially soon after the receipt of the injury, and the pain is at first chiefly in the left side, later sometimes becoming generalized.

Since the parenchyma of the liver, in common with the parenchyma of other organs, is but poorly supplied with nerves, an injury to the parenchyma alone would cause but little pain; but the subcapsular hematoma which may develop following such an injury may, by pressure, give rise to severe pain, since the capsule is richly supplied with nerves. This pain is of a peculiar character, intense but dull and boring. It may radiate to the epigastrium or to the right shoulder and scapula. This shoulder radiation, while occurring less frequently than has sometimes been supposed—in only about 7 per cent. of all cases—is pathognomonic of injury to the liver when it does occur.

An extensive extravasation of bile is rare; it is met with where there have been deep ruptures of the liver involving many and large bile ducts or where lesions of the biliary ducts are also present. Icterus, resulting from the absorption of bile, does not develop until the third or fourth day after the injury and thus becomes valueless as an indication for early operation. It may fail to appear even where there has been a considerable escape of bile, and in other cases its development is due to the occlusion of a large duct by blood clots or by masses of crushed hepatic tissue. Comparatively little systematic work has been done in the frequent, careful chemical analysis of the urine following abdominal, and particularly liver injuries; but examinations for biliary salts made at short intervals would be of great help in the early diagnosis of lesions of the liver and gall passages. (N. Biagi.[1]) Glycosuria and albuminuria are not infrequently met with but are of little significance since they also often occur in traumatic lesions of other organs; moreover, in many cases it is impossible to exclude their preexistence.

Nausea and vomiting are of frequent occurrence in this as in other lesions of the abdomen, and are usually of reflex traumatic origin, or are of later appearance and due to peritoneal irritation. Singultus is reported rather frequently but does not appear to be of much significance. Occasionally the patient prefers to lie on the left side, evidently to avoid the weight of the body on the injured side. The thoraco-abdominal breathing is modified in some cases in an apparent attempt to protect the injured side from the incursions of the diaphragm but this symptom is met with in injuries to other viscera as well, especially those of the thorax.

The area of hepatic dullness varies in different individuals and at different ages in the same individual. Immediately following the injury, the liver retains its normal size unless escaping blood has for the moment been dammed back. The distention of the intestines may later lessen the area of hepatic dullness, while after the passage of some days the development of traumatic hepatitis, which often persists for some weeks, may again increase this area.

We have seen that wounds of the liver may, and do heal spontaneously. In cases in which a diagnosis of probable injury to the liver has been made, when is operation indicated? In addition to the indications for operation common to all injuries of the abdomen, the danger from hemorrhage here forms a special indication. All open

[1] Policlinico, Sez. Chir., 1902, p. 384.

wounds of the abdomen, whether gunshot or stab wounds, should be operated upon; spontaneous recovery is not infrequent in these cases, but operation gives a much higher percentage of recoveries. In subcutaneous injuries, the question is less readily answered because diagnosis is difficult; but the danger from hemorrhage is again the deciding factor. Symptoms of increasing anemia call for laparotomy before the patient becomes exsanguinated and unable to bear the shock of operation.

When it has been possible to make only a tentative diagnosis of injury to the liver, the high median incision from ensiform cartilage to umbilicus will permit of the examination of the organs of the upper abdomen, and if the diagnosis of injury to the liver is confirmed, it may be supplemented by an incision parallel to the costal arch or it may be prolonged to enable the operator to exclude the presence of a ruptured gut. Because of the friability of the liver, it is better to mobilize it by severing one or more of its ligaments than by the application of much force at the hands of an assistant.

Wherever practicable, tamponing the liver is the operation of choice, since the minimum of time is consumed in operating and the drainage does much to prevent secondary infection; this method of treatment also frequently obviates the necessity of further mobilizing the liver. Gauze should be employed in long and rather wide strips save in exceptional cases where the wound is very narrow. The gauze must be firmly applied and may be held in place by catgut stitches when necessary. The end of the gauze is brought out through the wound, providing drainage and simplifying the removal of the tampons.

Where it is impossible to pack the wound without performing a more formidable operation than the condition of the patient seems to warrant, indirect tamponing should be resorted to. The subphrenic space is very firmly packed, and the subhepatic space is also filled with gauze to afford pressure from both sides. This maneuver is indicated in the case of ruptures high in the right lobe, but it is also useful as an added measure of safety in ruptures of the concave surface of the liver or of the extrahepatic biliary passages.

Tamponing of the liver may be combined with the ligation of large vessels which are bleeding profusely, and with suturing of the wound. Rather coarse catgut and blunt round needles should be used to prevent further hemorrhage from the use of the needle. When deep wounds are sutured care must be taken to carry the needle well to the lower angle of the wound to prevent the formation of a hematoma. Where the rupture is so extensive as to threaten the vitality of a lobe or of a considerable part of it, the condition of the patient must decide whether the operation shall be limited to hemostasis or whether a resection shall be done. The method of controlling the bleeding by through-and-through sutures does not differ in technic from that employed in surgery of the liver in malignancy or other pathologic conditions.

Where hemorrhage cannot be controlled by other means or where the tissue is so friable that the stitches cut through, the use of autoplastic tissue should be tried. Muscle, fascia, subcutaneous fat, and omentum have all been recommended for this purpose and clinical and experimental evidence is offered in support of the merits of each. Any of them may fail under certain conditions to secure hemostasis, none of them afford absolute security against later hemorrhage, but at present they are the best means at our command with which to control obstinate bleeding from parenchymatous organs. The availability of the omentum, rendering unnecessary a second wound and saving decisive moments, would seem to give it the preference over muscle and fascia. Jeger and Wohlgemuth[1] recommend the employment of a thin porous sheet of animal tissue, prepared somewhat after the fashion of catgut and stored in alcohol, but until this material becomes available to the profession as a whole, the method has no practical significance.

The use of chemical styptics has practically been abandoned and with good reason. They are at best an ineffectual method and the danger from secondary hemorrhage is exceedingly great. Amante's experimental work with the use of antipyrin as a local styptic is of much interest, though further clinical experience must be gained before the exact value of this drug can be ascertained. In a 50 per cent. solution in water or normal salt solution, made absolutely sterile by fractional sterilization, it might be used to control oozing, the application being made either directly to the bleeding surface, or by means of tampons moistened with the solution.

Following operation and the control of postoperative shock which is especially frequent in these patients, already weak from the loss of blood and the shock of injury, secondary hemorrhage is the most immediate danger to be feared. The patient must be kept from tossing about and from violent movements of the limbs by the administration of morphin; vomiting must be controlled as far as possible; straining at stool must be prevented by free enteroclysis, glycerin being added to the water used.

Dilatation of the stomach is another threatened danger; it is best combated by gastric lavage, by placing the patient flat on the abdomen and elevating the foot of the bed, and by leaving a stomach-tube in position for several hours after performing gastric lavage.

As later complications, there is suppuration of the wound with the possibility of abscess formation in the liver; subdiaphragmatic and subhepatic abscesses are also of not infrequent occurrence. Septic peritonitis may supervene but is less frequent here than in perforating wounds of this organ. Fibrinous peritonitis is not so apt to develop as in injuries to the extrahepatic biliary passages and is of more benign course. Exudative pleurisy, and even pneumonia and bronchitis are not rare. Pulmonary embolism, of hepatic tissue or of fat, is reported in a certain number of cases.

[1] Arch. f. klin. Chir., 1914, cvi, 104.

INJURIES TO THE BILIARY PASSAGES.

Bile Ducts.—Subcutaneous injuries to the bile ducts and the gall-bladder are rare, owing to the depths at which they lie, their small size and a certain degree of movability. Amante could find only 101 cases of such injuries recorded and of these the greater number affected the gall-bladder as one would anticipate from its greater size and its proximity to the abdominal wall. The traumatizing agents are on the whole those met with in injuries to the liver, but for the most part they act over a more circumscribed area; or where a large surface was exposed to the force of the blow, the contusing object was supplied with corners or other projections of some sort. The mechanism of the injuries probably varies; in a certain number of cases an injury to the concave surface of the liver is carried on to the neighboring bile ducts, the accompanying bloodvessels escaping injury because of their greater elasticity. Again it is possible that the biliary passages may be ruptured by direct violence, being caught between the traumatizing agent and their skeletal background. Other authors have ascribed these injuries to hydraulic and to endocanalicular pressure and this theory seems to be borne out by the pathologico-anatomical observations of the cases.

Penetrating wounds are of even rarer occurrence than the subcutaneous ones, Amante's statistics comprising only 25 isolated injuries of the biliary passages, and 21 associated with lesions of the liver or other organs.

In exposed wounds of the biliary passages as in other penetrating injuries of the abdomen, the existence of an open wound is in itself sufficient indication for operation. After the subsidence of the phenomena common to all cases of subcutaneous abdominal injury, there are no characteristic symptoms to reveal the presence of the ruptured biliary passage until after the lapse of some days, when symptoms of the absorption of bile are manifest. In every case where injury to the liver or the biliary tract is suspected, the careful and systematic chemical examination of the urine should never be neglected for the extravasation and absorption of bile is usually revealed here before icterus has had time to develop. Icterus does develop in the majority of these cases but it may be of slow onset or its development even be prevented by the walling off of the biliary exudate. Percussion may disclose the presence of free fluid in the peritoneal cavity; more often the exudate is walled off and limited to the right side of the abdomen.

Ransohoff[1] called attention to the pronounced icteric discoloration of the skin about the umbilicus as a symptom of the intraperitoneal escape of bile. When the rupture is in the choledochus permitting the escape of the entire output of bile into the peritoneal cavity, the feces may be colorless. In cases which are not submitted to operation,

[1] Jour. Am. Med. Assn., 1906, xiv, 395.

the symptoms become more grave. The patient loses flesh rapidly as a result of intoxication and mechanical interference with the function of the abdominal viscera from the free fluid in the peritoneal cavity.

Prognosis.—Since differential diagnosis in the subcutaneous injuries is impossible until symptoms of biliary absorption appear, it is indeed fortunate that delay in operation is of less sinister significance here than in injuries to other abdominal organs. The development of adhesions, an early result of the extravasation of bile, may present great difficulty in late operation and the gradually developing intoxication lessens the resistance of the patient. Routier[1] says that while immediate operation is theoretically indicated, practice contraindicates it. Statistics give an apparent advantage to late operation but the comparison has no real value since the severer injuries, presenting early alarming symptoms, are those most apt to be operated upon within the first few days while the lesser injuries are diagnosed later and only submitted to operation after the passage of some days. Too much delay is dangerous, however, as demonstrated by several reported cases where the failure of the operation seems to be directly attributable to this cause.

Septic peritonitis is less frequent in these cases than in cases of rupture of the liver, but biliary fibrinous peritonitis is of frequent occurrence. Pulmonary complications are not rare. In cases of subcutaneous injuries to the biliary passages not operated upon, the mortality is practically 100 per cent., the patient eventually succumbing to intoxication, mechanical interference with the vital functions, or to inanition. Amante gives the mortality in operated cases as 35.71 per cent. The prognosis in penetrating wounds of the bile tract not subjected to operation is apparently graver than in similar injuries to the liver but I have no exact statistics. The 25 operated cases recorded in the literature gave a mortality of 20 per cent.

Operation.—The operation of choice is always laparotomy since it permits the surgeon to inspect the wound and to adapt his treatment to the conditions found. Aspiration has been largely used in the past but with this method the surgeon is working in the dark and the treatment is symptomatic rather than radical.

Gall-bladder.—Where the rent in the gall-bladder is small and its edges smooth, it may be sutured. This gives the most rapid recoveries but unfortunately few of these wounds are cleancut. In the case of larger wounds, where calculi are present, or where infection is to be feared, cholecystostomy is to be preferred. Besides providing free drainage, it has the advantage of consuming the minimum of time, an important consideration when the condition of the patient is grave. Where the gall-bladder is badly lacerated or detached from the liver, cholecystectomy is indicated.

Cystic Duct.—Theoretically, the suture of ruptures of the cystic duct is possible but its small calibre renders such suturing extremely

[1] Bull. et mém. de la Société de Chirurgie de Paris, 1892, p. 773; Rev. de Chir., xiii, 142, II.

difficult in practice. In the majority of cases the stumps should be securely ligated and cholecystectomy performed. In cases where the time consumed in these maneuvers is prohibitive, drainage alone may be employed.

Hepatic Duct.—The suture of ruptures of the hepatic duct has also been proposed but in practice the inaccessibility and small caliber of this duct would present almost insurmountable difficulties; in exceptional cases partial suture might be employed but even this is impracticable in children. Theoretically, the implantation of the superior stump of the duct into the duodenum would be an ideal solution of the problem, but here again in practice it would be found extremely difficult and time-consuming. Simple drainage is the most satisfactory method and many fine drains should be introduced into the two stumps in an attempt to secure union. This method of drainage was employed by Hildebrand,[1] who alone has a recovery to report.

Choledochus.—The inaccessibility of the choledochus makes it difficult even to locate wounds here, and suture of the rupture and anastomosis of the stump with the duodenum, (the two methods which theoretically have the most in their favor since they most nearly restore normal conditions) are so difficult and so time-consuming that the chances of the patient's living to profit by them are but slight. Cholecystoduodenostomy (or cholecystenterostomy) is the method to be chosen; the choledochus is here excluded and the bile from the gall-bladder and cystic duct introduced directly into the intestine. Lewerenz[2] first performed this operation on a child of two and a half years. His patient, and one of the two others treated by this method, recovered. (Sterlin and Heymann,[3] operation by F. Krause.) When this method of operation is also impossible, the surgeon must have recourse to simple drainage which offers a fair promise of success, especially where the rupture is not complete. Cholecystoduodenostomy, however, is always the operation of choice.

Whatever the method of operation, in any and every operation for rupture of the biliary passages, drainage must be employed.

The method of operating in penetrating wounds of the biliary passages differs in no essential from the operative treatment of subcutaneous injuries. Stab wounds of the gall-bladder, however, more often permit of suture than do subcutaneous ruptures, for in the latter the laceration is usually extensive.

INJURIES TO THE STOMACH.

Ruptures of the stomach of traumatic origin are of infrequent occurrence compared to ruptures of the lower portions of the gastro-intestinal tract and are usually associated with injuries to other viscera; simple contusions are far more common. Force applied over a

[1] Rupture des Ductus Hepaticus, Deutsch. med. Wchnschr., 1907, p. 483.
[2] Arch. f. klin. Chir., 1903, lxxi, 111–146.
[3] Deutsch. Ztschr. f. Chir., 1903, vol. lxxxiii, Freie Verh. d. Chir., Berlin, June, 1906.

circumscribed area is responsible for by far the largest number of subcutaneous injuries to the stomach—the kick of a horse, the blow from a club, a missile thrown with force are common illustrations of this type of violence. The stomach is caught between the spinal column and the contusing object, or the ribs as they react to the force applied; if the organ is distended, it may rupture from the pressure of the gas or liquid which it contains; if empty, it may be so bruised that tissue necrosis and secondary perforation result. Occasional cases of rupture of the distended stomach from sudden violent contraction are reported. Less frequently ruptures of the stomach result from falls, or even from jumping from a height and landing forcibly upon the feet. The ruptures of the stomach are, as a rule, found in the lesser curvature and are vertical tears.

Diagnosis.—Shock is usually profound though occasional patients may show but slight reaction. Pain is generally manifest at an early stage and persists after the symptoms of shock have subsided; it is at first localized but with the onset of peritonitis it becomes diffuse. There are nausea, eructations and vomiting; the vomitus may or may not contain blood. Thoracic breathing and muscular rigidity are present.

The clinical picture is, in other words, that common to all grave subcutaneous injuries. With the escape of stomach contents, symptoms of intra-peritoneal extravasation and peritoneal irritation develop —the rapidity of onset of the latter depending upon the quantity of gastric contents which has escaped and upon its bacterial content. The fluid may be detected in the lower abdomen as an area of iliac dulness, or escaping air may obscure the area of hepatic dulness. Gradually, or with startling rapidity, symptoms of circumscribed or general peritonitis or of peritoneal sepsis develop—the temperature rises, the pulse grows rapid, there is diffuse tenderness to pressure, and the muscular rigidity has given way to abdominal distention.

In any case which is early brought under the care of the surgeon, tentative diagnosis should have been made and operation performed before symptoms of peritonitis develop. There are no symptoms which are pathognomonic of rupture of the stomach but abdominal rigidity, thoracic breathing, and localized, spontaneous pain speak for a probable rupture somewhere in the gastro-intestinal tract, and with this diagnosis of probability, immediate operation is always indicated. With a history of the nature of the accident, or in the presence of contusions over the stomach or of pain definitely localized here, we may further limit our diagnosis and suspect the stomach as the site of the perforation but such differentiation is of interest from a clinical rather than from a practical operative standpoint since operation is always indicated in the probable presence of any part of the gastro-intestinal tract.

Prognosis.—While it cannot be doubted that a rupture of the stomach may occasionally be walled off by the formation of adhesions and only a localized peritonitis result from which the patient recovers, experience has shown that ruptures of this viscus given expectant treatment, have a very high mortality: The development of a fatal septic peritonitis is the rule and the isolated case which goes on to spontaneous healing is the rare exception. In operated cases, the death-rate is in direct proportion to the time of operation.

Operation.—An incision is made from the xyphoid process to the umbilicus; if the force was applied over the entire abdomen, it may be necessary to extend it to permit of a careful examination of the gut. The tear in the stomach is closed by a double row of sutures, the first including all three layers of the stomach, the second muscularis and serosa only. The peritoneal cavity is carefully wiped out to remove all extraneous matter and the incision closed, the abdominal cavity being drained through stab-wounds in the pelvis; the patient is placed in the Fowler position, and constant proctoclysis begun, all food per orem being withheld as in Ochsner's treatment of appendicitis.

INJURIES TO THE PANCREAS.

Isolated subcutaneous injuries to the pancreas are extremely rare; associated with injuries to the liver, stomach, spleen and kidney, they are of more frequent occurrence and the failure to examine the pancreas when repairing the damage done to one of these other organs, has in many cases made vain an operation which but for the oversight might have been a success. This is equally true in the case of penetrating wounds of the upper abdomen, in which injuries to the pancreas are not infrequently associated with injuries to the neighboring organs, and the operator should make it an invariable rule to expose and carefully examine the pancreas in every case of injury to the posterior wall of the stomach and in all cases in which the gastrocolic membrane shows any evidence of traumatization.

Diagnosis.—The necessity for this careful examination becomes apparent when it is realized that rupture of the pancreas has no pathognomonic symptoms. This lack may, in part, be ascribed to the very small number of reported cases. The presence of muscle rigidity in the epigastrium indicates the probability of serious visceral injury and the necessity for early operation. Shock has not been severe in most of the reported cases nor has the patient given the impression of being in a serious condition. After the passage of some hours, severe pain is felt in the epigastrium,[1] and vomiting frequently occurs, the patient presenting the picture of an acute pancreatitis. Where injuries to other organs are also present, symptoms arising from them usually obscure any symptoms resulting from the injury to the pancreas. If the splenic vessels have been injured, hemorrhage is profuse, though in Villieré's case the bleeding from the severed splenic vein and artery had ceased spontaneously. If the gland alone is injured, the hemorrhage is not excessive and it is the escaping

[1] Garré: Beitr. z. klin. Chir., 1905, xlvi, 233.

pancreatic juice resulting in fat necrosis and peritonitis which threatens disaster, and makes the earliness of operation a vital factor.

Prognosis.—In injuries to the pancreas resulting in laceration or destruction of gland tissue, which are not operated upon, the mortality is 100 per cent. The number of operated cases recorded in the literature is still too small to permit of any conclusion being drawn but if early operation is made the rule in all cases of injury to the epigastrium in which abdominal rigidity develops, the prognosis in these cases should be better than in operated cases of acute pancreatitis in which we have the added factor of infection with which to contend.

Operation.—In all injuries to the epigastrium, the abdomen is opened through a high median incision extending from xyphoid process to umbilicus, or half way between symphysis and umbilicus when the intestines are also to be carefully inspected. After examining the other organs of the upper abdomen, controlling hemorrhage and repairing any injury to them, the pancreas is exposed, either by splitting the gastrocolic membrane and passing through the lesser peritoneal cavity or by displacing the omentum and the transverse colon upward, and splitting its mesentery at a point where no bloodvessels will be severed. In all patients with even a moderate degree of enteroptosis, the former method will be the one adopted and many surgeons consider it the method of choice in all cases. All free fluid in the abdominal cavity must be carefully sponged away and the pancreas should be completely isolated by large sponges before attempting suture.

Simple tears in the gland are closed by sutures. Two or three sutures are passed deep into the gland to approximate the torn surfaces and control hemorrhage, and the edges of the capsule are then closed by continuous suture with fine catgut. If the pancreatic duct has been severed, it must be approximated and sutured to prevent the stasis of pancreatic juice in the tail of the pancreas and the subsequent development of a retention cyst. Because of the destructive effect of pancreatic juice upon the tissues of the abdomen, free drainage is imperative in all these cases. Ochsner says that the secretion may be made non-irritating by instituting gastric lavage immediately upon completion of the operation, and the administration by mouth of the white of an egg every three hours for several days, no other food being given during this period. The injured area must be carefully tamponed and the strips of gauze brought into the wound. Drainage through a counter incision in the back is also used in some cases.

Where a portion of the gland has been crushed or in those cases in which the severing of the tail of the pancreas has been complicated by injury to the splenic vessels, thus shutting off its blood supply from both the splenic artery and the pancreatico-duodenalis, a resection of the injured, or the isolated portion of the gland will be necessary. There has been much discussion as to the amount of gland which might be resected without danger to the patient and experimentally it has been proved that four-fifths of the pancreas may be removed from a dog without permanent injury. A personal experience has convinced me that this holds true in the case of human beings as well. A young man of twenty-two was operated upon for acute pancreatitis and a necrotic portion of the gland (perhaps a fourth) was removed. He made a very satisfactory recovery for a patient who had appeared so desperately ill, but a day or two before his contemplated discharge from the hospital, he again developed symptoms of acute pancreatitis and on reöpening the abdomen, the entire tail of the pancreas was found to be necrotic and so friable that it could be scooped out with the flat of the hand. The necrotic portion, apparently the entire body and tail, was removed, the cavity packed and drained, and after a rather stormy convalescence, the patient left the hospital in very fair condition. Through the courtesy of his physician, I have been enabled to keep him under observation and now, after the passage of more than a year, he is in good health and has no symptoms of glycosuria.

INJURIES TO THE SPLEEN.

The protected position of the spleen and its relatively small size give splenic injuries a secondary place among traumatic lesions of the abdomen. The isolated injury to the spleen thus becomes the exception, splenic injuries which are associated with injuries to other viscera the rule; and the latter class of cases is more often seen on the post-mortem than on the operating table. In Edler's[1] compilation of penetrating and subcutaneous injuries to abdominal organs, there were only 160 injuries to the spleen as against 543 to the liver. If we except military statistics, subcutaneous injuries outnumber penetrating injuries in the proportion of 10 to 3, but in the former the spleen had undergone pathologic changes in something less than one-half of the cases, subcutaneous injuries being particularly common in regions in which malaria is prevalent. In the type of accident resulting in injury, in the mechanism of the injury, and in the pathology of the traumatic lesion, injuries to the spleen are most closely related to those of the liver; such differences as are observable may be attributed to its lesser size and its greater vascularity and movability. Force applied over a circumscribed area is of relatively greater importance here than that which acts upon the entire abdomen. Here, as in the liver, isolated and multiple ruptures are met with, subcapsular hemorrhages occur as the result of contusions and tears which involve the parenchyma only; these intra-parenchymatous hemorrhages may be multiple in the spleen also, in analogy to the "liver apoplexies;" a portion of the spleen may be entirely severed, as may a lobe of the liver, and the entire spleen may be torn from its hilum, the ligamentary attachment of the liver guarding against such an injury to that organ.

Diagnosis.—In subcutaneous injuries to the spleen, the most vascular viscus and one without any characteristic secretion, symptoms of hemorrhage of course occupy the first place in diagnosis and prognosis.

[1] Arch. f. klin. Chir., 1886, xxxiv, 343.

As shock is often present following an injury to the spleen, the difficulty of early differentiating shock from intra-abdominal hemorrhage makes early positive diagnosis impossible. In only 5 of the 30 operative cases which Lewerenz[1] collected had a diagnosis of injury to the spleen been made. In the majority of cases it has been the threatening character of the increasing anemia which led to exploratory operation. Sometimes the hemorrhage is localized in the left side, an area of dulness extending down the left half of the abdomen and associated with iliac dullness. In the presence of much free blood in the peritoneal cavity and of clotting about the spleen, differential diagnosis may be made by shifting the patient's position—the dulness disappearing from the right side when the patient is placed on the left side, but remaining unchanged in the left side when he is placed on the right side—but the advisability of thus changing the position of an injured person already in a critical condition may well be questioned.

In many cases of ruptured spleen the pain is general rather than local. In the occasional case in which it is localized in the splenic region (sometimes even radiating to the left shoulder) diagnosis is not difficult.

In Lewerenz's statistics on non-operated cases, 85 per cent. of the deaths resulted from hemorrhage within the first twenty-four hours. The imperative need for early operation is thus apparent: In every case of abdominal injury, an increasing anemia and the presence of fluid in the peritoneal cavity are absolute indications for operation before the condition of the patient becomes so critical as to make operation hopeless.

Muscle rigidity is not present in a large majority of cases as it is in the case of ruptures of the gastro-intestinal tract, and a soft abdomen does not speak against an injury to the spleen. The presence of muscular rigidity, however, justifies the assumption of a severe abdominal lesion and when associated with symptoms of intra-abdominal hemorrhage, the possibility of injury to the spleen is suggested—a possibility which becomes a probability if the hemorrhage is localized in the left side. Variations in the quality and rate of the pulse are reported in many cases, particularly a rapid pulse, but it is hardly necessary to point out the worthlessness of this symptom in differential diagnosis. Immediately following the injury the pulse is largely influenced by the state of shock; a rising pulse-rate in the first few hours should suggest hemorrhage, at a later stage beginning peritonitis.

Prognosis.—The prognosis in unoperated cases is very grave, the mortality given in different statistics varying from 92.5 per cent. to 97 per cent. In cases which do go on to spontaneous recovery, it is quite probable that previous disease had resulted in the formation of adhesions. With the exception of an occasional late death due to sepsis; hemorrhage, either primary or, in the exceptional case, secondary, is responsible for the high mortality. The mortality in cases treated by splenectomy is 35 per cent. (Johnston.[2])

[1] Arch. f. klin. Chir., 1899, lx, 951.

[2] Ann. Surg., 1908, xlviii, 50.

Operation.—A high median incision, extending from xyphoid process to or beyond the umbilicus, is the one employed in practically all cases, since operation is at first exploratory and a thorough examination of the upper abdomen should be made even where a diagnosis of probable injury to the spleen has been made. When the spleen alone is found injured, the European surgeon has a preference for exposing it by making a second incision at right angles to the first, severing the left rectus, but few American operators employ a transverse abdominal incision except in meeting an emergency. A left rectus incision, analogous to the right rectus incision used in gall-bladder work, gives good access to the spleen and is far more readily dealt with both at the time of suture and in the after-course.

Both the concave and convex surfaces of the spleen must be examined for injuries. An isolated rupture, if not too extensive, may be sutured. The needle used should be very fine, the suture material fine silk, the capsule alone be caught in the stitches. An interrupted or a continuous suture is equally effective. If any artery, which may have been severed, is caught and ligated, the venous hemorrhage is readily controlled by this method. (Danielson.[1]) A cigarette drain should be placed at the line of suture and out through the incision or through a stab wound in the loin to give warning in case of secondary hemorrhage, and the incision should then be closed.

In the majority of cases, particularly in cases of multiple rupture, splenectomy is the operation of choice, because of the brevity of the operation and the guarantee against secondary hemorrhage which it affords. Where there are many adhesions to complicate the operation, and there is need for haste, the operator may have to be content with suture or even simple tamponing of the wound. The artery may be ligated, if it can be exposed without unduly prolonging the operation, thus cutting off the functional blood supply while the nutrient blood supply safeguards the organ from necrosis. Hemorrhage may then be readily controlled.

INJURIES TO THE INTESTINES.

Second only in frequency to injuries to the liver, injuries to the intestines are second to none in point of interest and urgency. Cases of spontaneous recovery from supposed rupture of the gut have been reported, it is true, but in none of these cases is the diagnosis above question. On the other hand, carefully compiled statistics by Siegel[2] and others demonstrate an increasing death-rate proportionate to the increase in the number of hours which have elapsed between the time of the injury and that of operation. After the sixth hour the rise in the mortality percentage is especially marked so that we are justified in speaking of the first six hours as the period within which operation should always be performed in cases in which it is possible to make a

[1] Beitr. z. klin. Chir., Tübingen, 1908, lx, 158.
[2] Ibid., xxi, 395.

tentative diagnosis of a ruptured gut. When allowance is made for the time which must be consumed in most cases before the patient reaches the hospital to be placed under the surgeon's care and the even greater length of time which often elapses before reaction from shock, which in many cases dominates and obscures the clinical picture; the brevity of the time left for observation of a case, which at best presents manifold difficulties in diagnosis, makes a ready knowledge and clear-headed evaluation of its kaleidoscopic symptomatology imperative.

Direct violence is responsible for the largest number of these injuries. Great force acting over a circumscribed area (the kick of a man or a horse, a missile thrown with force, etc.) is the usual form of force applied, while lesser violence acting upon the entire abdomen (traffic accidents, crushing between the bumpers on a train, etc.) is also responsible for a certain number of these injuries. In the former instance, the gut is probably usually caught between the spinal column and the impinging force and crushed or torn; in the latter, and in some cases of the first group, the injury is evidently often due to rupture from increased internal pressure, the force isolating a loop of intestine containing fluid or gas. The condition of the gut at the time of the accident always plays a more or less important part in determining the injury, for in a fall upon the feet, back or buttocks a loop of the gut, distended with fluid, may rebound with such force as to rupture at a point opposite the mesentery. Bonanome[1] reports the case of a young man who had jumped to the ground from a height of only two feet but alighted with some force. He could not continue work but went to his home, two miles distant, on foot, and then from there walked to the hospital. His condition did not appear alarming until twenty-seven hours later; laparotomy disclosed a rent in the ileum at a point opposite the mesentery, and beginning peritonitis. In another group of cases, perforation is secondary, the wall of the gut, or the mesentery from which it derives its blood supply being so injured at the time of the accident that it becomes necrotic. This may leave time for the isolation of the damaged gut by adhesions which prevent the development of peritonitis and give us our so-called spontaneous recoveries from rupture of the gut. In these cases and in those exceptional ones in which the serosa or the serosa and muscularis alone are torn, narrowing of the lumen of the intestine often results and a partial or a complete obstruction of the bowels may occur.

Force applied below the umbilicus is responsible for so large a proportion of subcutaneous ruptures that this area is often referred to as the "danger zone." The duodenojejunal flexure and the ileocecal region are especially prone to injury because these are the points most fixed; in crushing injuries they are exposed by their firm bony background to the full force of the blow, and are thus prevented from escaping the injuries. In injuries due to falls from a height, they are more apt to be torn loose from their mesentery, or even to be com-

[1] British Med. Jour., Epitome of Current Literature, August 27, 1904, p. 30.

pletely divided, than are other parts of the intestine. The large intestine is less frequently ruptured than is the small gut, but injuries to it are particularly dangerous. The bacterial contents of the gastrointestinal tract increase from the stomach downward and the increased danger from infection is only in part offset by the fact that greater solidity of the contents of the colon and its peristaltic inactivity lessen the outpouring of fecal matter. Moreover, the pouting of the mucosa which often closes defects in the small intestines for the first few hours until the musculature becomes paralyzed, is less apt to occur here because of the thin walls of the colon and the lessened ring musculature. (Föderl.[1])

Diagnosis.—Diagnosis must be made rather from a consideration of the clinical picture as a whole than from the presence or absence of any single symptom but special significance is to be attributed to the presence of muscle rigidity. Its diagnostic value has been much disputed, but this appears to be due in part to a misinterpretation of the term. The momentary contraction of bruised abdominal muscles during examination does not constitute muscular rigidity; in muscular rigidity the abdominal walls have a board-like resistance which once recognized is not readily forgotten.

Spontaneous localized pain is also of value in making a tentative differential diagnosis. Like all other pain phenomena it varies with the nervous stability and susceptibility of the individual, but is present in a large number of cases until, with the passage of the hours, it gives place to the generalized pain of beginning peritonitis. Nausea, eructations, and vomiting have all been observed in cases of ruptured gut and diagnostic significance is often attributed to them. Following any severe contusion of the abdomen, whether or not it determines serious visceral injury, and the resulting state of shock, the patient is often nauseated and vomits; soon after the receipt of the injury, these phenomena can have no pathognomonic significance. When they recur after the passage of some time they are an indication of peritoneal irritation, the onset of peritonitis, and operation should not be delayed until the development of such symptoms. Thoracic breathing is observed in many cases of ruptured gut but it is also a common manifestation in injuries to the thoracic organs and in other injuries to the abdomen, especially in injury to the liver, stomach and spleen. Localized pain on deep pressure may aid not only in diagnosis but in determining the approximate location of the injury as well.

In the first hours following a rupture of the intestines, the variations observed in the rapidity and quality of the pulse are conditioned rather by the state of shock than by any direct effect of the rupture. Tomaselli[2] reporting a series of abdominal injuries, mentions a pulse of 42 and of 110 in two successive cases in both of which recovery took place without surgical intervention. Increasing rapidity in the pulse-rate or a rise in temperature some hours after the receipt of an abdomi-

[1] Med. Klin., Berlin, 1910, vi, 1643; 1688, 1730.
[2] Gazz. d. osp., Milano, 1911, xxxii, 803–807.

nal injury means the onset of peritonitis and that the expectant treatment has been too long prolonged. Tympanites developing some hours after injury is again indicative of the onset of peritonitis, while its development immediately following an accident is, in many cases at least, of benign significance, since it is not apparent in cases with abdominal rigidity owing to the presence of the latter.

The so-called Hippocratic or abdominal facies has by some authors been considered a characteristic symptom of rupture of the intestines; in reality, it belongs to the preceding symptom group—while it may be present early, it is as a rule of rather late appearance and signals a developing peritonitis.

To sum up the symptomatology, then, we may say that board-like rigidity of the recti, while occasionally observed in cases of injury to other abdominal organs, and even in cases which go on to spontaneous recovery, is present in so large a proportion of the cases of ruptured gut, that its existence is strong circumstantial evidence of such a rupture. When accompanied by spontaneous localized pain and by thoracic breathing, an exploratory laparotomy should never be delayed and even when rigidity alone is present, I believe that exploration is always to be preferred to expectant treatment.

Prognosis.—The direct relationship which the time of operation bears to the mortality has already been pointed out. Siegel's compilations give a mortality of 15.2 per cent. for the cases operated upon within the first four hours, 44.4 per cent. for the next four-hour period, 63.6 per cent. for operations within the ninth to twelfth hour, and 70 per cent. for operations after that time. The mortality for operations within the first twelve hours gave an average of 28 per cent.

Operation.—On opening the abdomen, a systematic and careful search of the entire gut must be made for these tears in the gut wall are easily overlooked, particularly when they are multiple as they are in perhaps 10 per cent. of the cases. The intestines must be gently handled and exposed for the shortest possible period of time in order to lessen the danger from shock. When a damaged loop is found, it is wrapped in a large moist sponge and is held by an assistant until the entire length of gut has been examined. Any deposit of plastic lymph upon the intestine calls for closer inspection since it is early poured out about a damaged spot. If the rent is small, either longitudinal or transverse, it may be closed by a double row of fine silk sutures, the first row passing through all the layers of the gut while the second includes the muscularis and serosa only. If there is an uneven tear, or a ragged hole opposite the mesentery (a "typical blow-out" from increased pressure), an "elbow anastomosis" may be formed by trimming away the damaged portion of the gut and suturing it at an angle, the mesenteric portion of the gut with its blood supply being left undisturbed.

Where the laceration is extensive, there are multiple tears within a relatively small area, or where there has been an injury to the mesentery interfering with the blood supply of the gut, a resection must be performed.

In cases of rupture of the intestines in which the condition of the patient makes any prolongation of the operation inadvisable, the ruptured loop of gut should be brought into the abdominal wound, *i. e.*, an enterostomy should be performed and the anastomosis left for secondary operation when the patient's general condition has improved. Again, when the vitality of a loop of intestine seems imperilled, the transplantation of a free flap of omentum may afford added security. The free flap is folded about the bowel and secured to the mesentery by a few stitches. This method should never replace resection where it is possible to employ the latter, but in cases where resection is impossible or where an added security is desired, omental grafting may prove a valuable aid.

INJURIES TO THE MESENTERY.

Hemorrhage from the mesentery may be profuse and these symptoms of intra-peritoneal hemorrhage are the only ones which differentiate an injury to the mesentery from one to the gut. Where the symptom-complex points to one of these conditions, the presence of free bleeding suggests an injury to the mesentery—its absence is of no significance. Wounds of the mesentery may be divided into three classes, according to their extent: (1) Subserous wounds are those which affect only the membrana mesenterii propria, the serosa on either side remaining intact; clinically they are manifest as hematomata, eventually even as cysts of the mesentery. Pressure may interfere with the blood supply of the bowel and necrosis develop secondarily. (2) Penetrating wounds are those which involve one serous covering only; the membrana mesenterii propria may be involved to a greater or less extent, the laceration sometimes extending to the serous covering on the opposite side. (3) In perforating wounds all the folds of the mesentery are torn. For the most part the subserous lesions are due to crushing or to "recoil" but occasionally they are due to hypertension, the elasticity of the membrana propria alone being exceeded. The penetrating wounds are as a rule of the same mechanical origin but in exceptional cases they may be due to sharp instruments (knife thrusts, etc.). Perforating wounds may result from any form of injury.

Diagnosis.—A diagnosis of probable rupture of the gut or mesentery demands immediate operation. Whether or not an injury to the bowel is found, the mesentery must be inspected with the greatest care, since injuries here are often overlooked. Small tears or the holes made by small caliber projectiles may sometimes be sutured. Here the criterion is always the blood supply of the gut and much depends upon the distance of the injury from the gut. Any injury within the territory of the terminal arches makes necessary the resection of the corresponding section of the intestines. Where the laceration is at some distance from the bowel, the development of a collateral circulation is possible and this possibility should be tested somewhat in the manner by which the viability of the gut in strangulated hernia is tested. Where there is any room for question, resection with anastomosis must replace simple suture.

Prognosis.—The mortality in cases of injury to the mesentery not submitted to operation is 100 per cent. Prutz, W.[1] and Monnier, E. report 10 stab wounds of the mesentery which were operated upon and gave a mortality of only 20 per cent. In the 16 cases of subcutaneous injury to the mesentery, submitted to operation, there was a mortality of 50 per cent.

Treatment.—Under unusual circumstances, *e. g.*, when the patient's condition is such as to make a resection of gut impossible, or when a resection seems unnecessary though some further securing of the blood supply is desired, free transplantation of the omentum may be resorted to. After the rent in the mesentery has been closed, a piece of omentum of the desired size is resected, and folded about the damaged loop, an interrupted suture attaching it to the mesentery here and there. Experimentally this procedure has been frequently tested and in at least four cases it has been employed clinically with good results. (Lanz,[2] Rosenstein[3] (two cases), Moschowitz.[4])

The presence of a small hematoma is as a rule of little significance and requires no operative treatment. A large hematoma may, on the other hand, cause necrosis of the gut by pressure upon the bloodvessels which supply it; where such an interference with the blood supply seems probable, a resection of the loop of gut involved must be performed.

INJURIES TO THE KIDNEYS.

The kidneys, lying well up under the costal arch, and possessed of a considerable degree of movability, are fairly well protected from direct trauma, and isolated injuries of the kidneys do not form a large per cent. of traumatic cases. Where the trauma has been extensive, injuries to the kidneys are often associated with injuries to other organs, especially the liver and spleen, and are then usually overshadowed by the gravity of the latter. The mechanism of injuries to the kidneys has been the subject of much discussion; without entering into the details, we may say briefly that by far the greater number of them are due to direct violence, the kidney being crushed between the contusing object and the spinal column; occasionally it is possible that a sudden violent contraction of the abdominal muscles may result in the kidney being caught between the floating ribs and the spinal column causing traumatism, usually of a lesser degree. In the latter case, hydraulic pressure has been supposed to play a part. Concussion and contre-coup have also been urged as possible factors.

[1] Die Chirurgischen Krankheiten und die Verletzungen des Darmgekröses und der Netze, Stuttgart, 1913, Ferdinand Enke, p. 186.

[2] Zentralbl. f. Chir., 1907, xxxiv, 617.

[3] Verh. d. Deutschen Ges. f. Chir., 38 Kongr., 1909, i, 172.

[4] Ann. Surg., 1913, lviii, 562.

Symptoms.—When the kidney is alone injured, diagnosis is as a rule not difficult. Hematuria is the most constant symptom but it is not an index to the severity of the injury since it may be present alike in insignificant lacerations and where the kidney has been completely severed from its hilum. Occasionally the severing of the ureter, or its blocking by coagula prevents the escape of the hemorrhage, and the presence of the blood clot may also give to the hematuria an intermittent character. This hemorrhage may persist for days or even weeks and then cease spontaneously; again the hematuria is transitory. The pain is usually well localized and the kidney may be palpable and tender. Anuria is often present, varying from a diminished output of urine which returns to normal within a short time to complete suppression of urine of a most threatening type. The muscles of the epigastrium are often rigid over the injured kidney, especially in the severe cases. A mass may become palpable in the lumbar region, due to the formation of a hematoma or to pseudo-hydronephrosis—the escape of urine into the perirenal tissues. Where there is extensive hemorrhage, iliac dulness develops and the patient becomes increasingly anemic. Cystoscopy and ureteral catheterization are often of service in clearing up a diagnosis but the use of cystoscope, and of ureteral catheter is severely condemned by some writers because of the added danger from infection. The possibility of such infection cannot be denied, yet in my opinion the danger is outweighed by the advantages of accurate diagnosis and, all other diagnostic means having been exhausted, I should not hesitate to employ it, using all precautions to guard against infection.

Prognosis.—Injuries to the kidneys given expectant treatment have a more hopeful outlook than injuries to other abdominal organs because the surrounding tissues act as a tamponade which often controls hemorrhage. Watson[1] gives a mortality of 29.6 per cent. for the cases given expectant treatment, 21.7 per cent. for those treated by nephrectomy, and 7.7 per cent. for operations other than nephrectomy.

Operation.—Indications for operation have been the subject of much disagreement, as in the case of injuries to other organs—ultra-conservatism on the one hand has found operation indicated only in cases which were practically moribund, while the opposing camp has found radical procedure justifiable in all cases except those of simple contusion. Injuries to the kidneys seem to be relatively benign, *i. e.*, spontaneous healing frequently occurs; but extreme temerity or extreme caution in the surgeon are alike fraught with danger to the patient. Hematuria even when it persists for a week or ten days is not an indication for operation unless the amount of blood lost is considerable, giving rise to anemia. A mass in the epigastrium, indicative either of a hematoma or of a perirenal effusion of urine, does not demand operation if there is a gradual decrease in size. Anuria, if transient or incomplete, may be treated expectantly for a short time. On the other hand,

[1] Boston Medical and Surgical Journal, 1903, cxlix, 26, 61.

operation is always indicated where there is much hemorrhage, manifest in increasing iliac dulness and growing anemia; where hematuria is excessive and persistent, or increases instead of gradually subsiding; where a mass in the epigastrium remains unchanged or increases in size; where anuria persists; and, finally, in any case of infection.

When on exposing the kidney, the injuries are found to be superficial, simple tamponading may be sufficient. Isolated lacerations may be sutured if the tear is a recent one and the kidney parenchyma has not yet undergone serious changes. Where a small part of the kidney has been crushed resection has been recommended but I prefer nephrectomy in these cases as well as in those in which the entire kidney has been damaged, or the ureter severed. If the perirenal tissues have been infiltrated with urine or with blood, drainage must be employed.

INJURIES TO THE URETER.

Injuries to the ureter as the result of trauma are extremely rare—the majority of such injuries occur during the course of operation, especially during operation for carcinoma of the uterus. In some cases the injury to the ureter is in reality an injury to the kidney, *i. e.*, the kidney has been torn loose from its ureter; very rarely the injury is the result of great violence, especially of traffic accidents. Here it is the first part of the ureter which is injured and we may explain the mechanism of the injury by supposing that a sudden violent displacement of the kidney has drawn the ureter taut over the first lumbar vertebra, crushing it. Symptoms of severe injury do not develop until the injured tissue become necrotic.

The great force which results in these injuries is usually also provocative of shock; other primary symptoms are local pain, anuria and a small amount of blood in the bladder. If the peritoneum is also torn permitting the urine and blood to enter the peritoneal cavity, iliac dulness may be detected. If the rupture is extraperitoneal a fluctuating tumor will be formed retroperitoneally, the rapidity of its development or of the increase in the area of iliac dulness, depending upon the extent of the tear in the ureter.

Operation.—If the ureter has been injured near the bladder, it may be exposed through a Gibson incision. Longitudinal cuts may be sutured with fine catgut. Where the ureter is severed or encircled by a necrotic zone, the distal end must be ligated and the proximal end implanted in the bladder. Where the break in the continuity of the ureter is farther up, Van Hook's lateral anastomosis should be attempted.

An injury in the upper three-fourths of the ureter is reached through a lumbar incision, as for a nephrectomy, which has been carried downward and forward just anterior to the anterior iliac spine, then parallel to Poupart's ligament until a point is reached above its middle. In old injuries to the ureter, it may be impossible to locate the tear and in this event the operator will have to be content with drainage, usually followed by secondary nephrectomy. In some cases resection of the injured portion with ureterorrhaphy may be attempted, but a stricture is the usual sequent of this procedure, with its unpleasant sequelæ—pyelitis, hydronephrosis, pyonephrosis, etc.

INJURIES TO THE BLADDER.

Isolated ruptures of the bladder are of rare occurrence but in fractures of the pelvis, the bladder is not infrequently also torn. Distention is the most important contributory cause, since the filled bladder rises in the abdomen and is then no longer protected by a bony superstructure; by distention it also loses its elasticity and the contained liquid increases the shock of concussion. Intoxication, prostatic enlargement, urethral stricture and pathologic changes in the bladder walls are other contributory factors. The direct cause of the rupture is, as a rule, the application of great force over the abdomen, as when a vehicle passes over it; a fall upon the feet, back, abdomen or nates may also result in rupture of the bladder, especially in the intoxicated, while again muscle strain alone may produce a rent in a distended bladder, as during lifting or in labor. Gunshot wounds and stab wounds not rarely penetrate the bladder and a spiculum of bone from a fractured pelvis may also produce a laceration. The location of the tear in subcutaneous injuries varies widely since the weakest point in the bladder is anatomically and physically not the same. The bladder is in part surrounded by a bony ring which not only protects it from direct force but also affords counterpressure. It must rupture at the point where this counterpressure is not afforded and the location of the tear thus becomes dependent upon the degree of distention and the angle from which the force is applied. If the blow comes from above, the elastic pelvic floor offers the least resistance and the bladder will rupture here; while, if force is applied to a distended bladder reaching above the pelvic brim, its summit, supported only by the elastic coils of intestines, becomes its weakest point and it will yield here. Tears in the bladder wall are usually vertical for the vertical muscular fibers are better developed than are the transverse fibers, and when the latter have been torn, the vertical fibers separate. The mucosa of the bladder may alone be ruptured, giving rise to profuse hemorrhage in the bladder.

Diagnosis.—Rupture of the bladder often lacks characteristic symptoms. Shock is usually severe, sometimes even fatal, though the great individual variations in susceptibility to shock observed in trauma to other organs are not lacking here. The most characteristic symptom is a great desire to urinate and the inability to do so, though a few drops of blood or of bloody urine sometimes are passed. There may be severe pain in the bladder and suprapubic region and violent tenesmus. A catheter passed into the bladder may bring away pure blood, bloody urine or even clear urine; again the bladder may be found empty, while a second attempt at catheterization will bring away a large quantity of fluid, the catheter having passed through the rent in the bladder. The injection into the bladder of a measured amount of boric acid or of normal salt solution has been recommended; if the same quantity is obtained upon catheterization, a rupture of the bladder is improbable. The distention of the bladder by air pressure has also been suggested; the normal bladder rises above the symphysis as a conical prominence and gives a tympanic sound, while the ruptured bladder cannot be thus distended. This gaseous distention is not entirely reliable and its harmlessness is open to question. If the patient is unable to urinate, and no urine is obtained per catheter, a measured amount of fluid should be injected. If the same amount is not drawn off, the abdomen should be at once opened and a search made for a rent in the bladder.

If the patient is not seen until after the passage of some time, diagnosis is readily made. If the urine has been escaping through an intraperitoneal rent, the development of peritonitis is only a question of time. If the injury was extraperitoneal extravasation of urine and later, suppuration and necrosis result.

Prognosis.—In the days before the treatment of rupture of the bladder by operation, the mortality from intraperitoneal ruptures was practically 100 per cent. Following the general acceptance of operative therapy, the mortality as shown by the first series of reported cases fell to from 42 per cent. to 50 per cent.; statistics of the last few years give a mortality of only 20 per cent. to 25 per cent. The mortality in extraperitoneal ruptures of the bladder not treated by operation was approximately 90 per cent.; with operative treatment the prognosis does not differ greatly from that of intraperitoneal ruptures.

Operation.—When a rent in the bladder has been found, it is immediately closed by suture. Catgut should be used to suture the mucosa but the stitches should not penetrate because of the danger that they may act as a nucleus for stone formation. Silk is used for the remaining sutures. The wound is sutured in two or three layers by the Czerny-Lembert method, a continuous suture being employed. A drain is now placed in the pelvis behind the bladder and brought out through the abdominal incision which is closed to the drain. If the rupture is in or near the trigone a retention catheter is necessary; in other cases it need not be used if the patient is catheterized at frequent intervals.

In extraperitoneal ruptures in which extravasation has taken place, all pockets must be cut down upon and free drainage established. Fuller's[1] method of perineal dissection with drainage of the post-prostatic area probably gives the best end-results.

INJURIES TO THE URETHRA.

Penetrating Wounds.—Penetrating wounds of the urethra rarely occur as isolated injuries. Diagnosis is made from inspection of the

[1] Jour. Am. Med. Assn., 1914, lxiii, 2114.

wound. A longitudinal wound is simply sutured; healing is rapid and there is little danger of stricture. Transverse cuts should be sutured over a catheter which is then left *in situ* for the first few days. If it is impossible to introduce a catheter, suturing should be attempted without its aid but the wound must then be carefully watched and reopened at once if symptoms of extravasation develop. The treatment is then that of rupture of the urethra.

Rupture of the Urethra.—Rupture of the urethra may result from a kick, a blow, or from falling astride some hard, narrow object. In most cases the rupture is situated near the juncture of the bulbous and membranous portions of the urethra, only rarely in the penile. The mucosa and spongy tissue may alone be torn permitting the escape of urine into the cavity during micturition. When the fibrous coat is also torn, free egress is given into the perineal tissues in which a large hematoma first gathers, and is later replaced by extravasated urine and pus.

Symptoms.—Pain and shock are often severe. Usually the patient is unable to urinate from the first and any attempt to do so aggravates the pain. In the occasional cases in which retention is not absolute, some blood or blood-clots are usually first passed and the urine itself has the bright red color characteristic of arterial bleeding, due to the escape of blood into the bladder. There is considerable hemorrhage, persisting for some hours, and the developing hematoma is manifest as an increasing swelling in the perineum, sometimes also in the scrotum and penis. Later this mass increases in size at each attempt at urination; pressure upon it may cause blood to exude from the meatus. Unless an outlet is afforded the extravasated urine, it burrows into the tissues of the thighs, the abdominal wall, the space of Retzius, etc., with resulting necrosis, sloughing and sepsis.

Treatment.—Suture of the ruptured urethra is the ideal procedure, but is possible only in exceptional cases. In most cases it is necessary to expose the damaged area through a median perineal incision; tissue damaged beyond repair is trimmed away; the roof of the urethra is sutured with silk; a catheter is then passed and the suture completed from without. Should it be impossible to pass a sound from the meatus, a suprapubic incision must be made and retrograde catheterization performed. In this event, the bladder may be drained for a time; otherwise, frequent catheterization must be performed. Where extravasation of urine has occurred, free incision over the infiltrated area must precede operation, and the wound should be packed with gauze. The bowels are kept closed for some days.

Healing is slow, sometimes requiring two months or more, and when the wound has closed, large sounds must still be passed at intervals over a period of years to prevent the development of stricture.

In exceptional cases, extensive laceration or neglected suppurative processes may have destroyed the perineum and so great a portion of the membranous urethra as to prevent its reconstruction by the usual procedure. Ekehorn[1] reports two such cases; in one a gunshot wound, in the other suppuration had destroyed so large a portion of the urethra that its reconstruction was impossible; the surrounding tissues had been destroyed to so great an extent that the urethra would have been left unprotected even if suture of the urethra had been possible. By means of two semicircular incisions which, beginning posterior to the scrotum continued up on to the abdomen, approximately parallel to the spermatic cords, a flap, consisting of the scrotum, the penis, and the corresponding part of the urethra was formed. The ligamentum suspensorium penis was severed, the flap freed from the pubic bone as far as its superior border, and a piece of bone, one centimeter in depth, was removed from the lower border of the pubic bone. It was then possible to unite the two stumps of the severed urethra without tension. In the second case the same good results were obtained without the removal of the bone.

INJURIES TO THE PROSTATE.

Simple contusions and the severer forms of crushing injuries to the prostate cannot occur because of the protected position of this gland. Penetrating wounds are occasionally met with; such isolated injuries are the result of falling upon a sharp stick, a pitchfork, or some similar object, the sharp point of which penetrates to the prostate through the perineum or the rectum. In fractures of the pelvis, fragments of bone may penetrate the prostate, and in gunshot wounds of the pelvis, injuries to the prostate may be associated with injuries to rectum, bladder, or pelvic bones. Otis[2] reports only 8 injuries to the prostate in 3174 gunshot wounds of the pelvic organs.

Diagnosis.—Hemorrhage is the first symptom of injury to the prostate. Bleeding may be very severe if the posterior part of the gland has been injured, the blood escaping through the wound, through the urethra, or through both. Again the blood may be dammed back and escape into the bladder, or may infiltrate the cellular tissue of the pelvis. If the bladder and sphincter are not injured, the patient may retain control of the bladder and blood be passed only on voluntary urination. If the wound is a wide one, the prostate may be examined through it; in all other cases urethral and rectal examination is usually sufficient to confirm the diagnosis.

Operation.—Hemorrhage must be controlled by tamponing the wound. If the urethra is also injured, the patient must be catheterized frequently or a catheter must be left in the bladder the first few days to avoid infiltration of the surrounding parts with urine. Where there is extensive laceration of the soft parts, suprapubic incision and drainage is the best method to hasten healing and prevent the development of a phlegmon.

[1] Arch. f. klin. Chir., Berlin, 1912, xcvii, 507.
[2] Medical and Surgical History of the War of the Rebellion, Pt. II, ii, 303.

INJURIES TO THE UTERUS.

The structure, movability and protected position of the normal uterus make isolated injuries of this organ within the limited sense in which the word trauma is here used, almost impossible. Ruptures, stab and gunshot wounds of the pregnant uterus are occasionally reported. Indirect trauma (jumping, a fall) is more frequently the cause of rupture than is direct violence; in these cases the anterior wall of the fundus is usually the site of the vertical tear. (Hinterstoisser.[1]) The rent may be a small one with resulting hemorrhage of greater or less severity, or it may be large enough to permit of the escape of the fetus and membranes into the peritoneal cavity.

Diagnosis.—In no class of cases are the variations in the reaction to injury more striking than here. Collapse may be profound while in rare cases there may be no general reaction to the trauma. Hemorrhage from the uterus is usually but not invariably present, and there are colicky pains, particularly in the cases in which the symptoms are not fulminating. Symptoms of intra-abdominal hemorrhage may indicate immediate operation and with palpation, make possible differential diagnosis.

Prognosis.—If operation is performed before the patient is exsanguinated the prognosis is not unfavorable, though the number of reported cases is too small to permit of an accurate estimate of the mortality. In Hinterstoisser's case and in one reported by Orhan-Bey[2] the rupture of the uterus and the escape of the fetus into the peritoneal cavity had occurred some months, and three years, respectively, before operation, the patients continuing their work and enjoying fair health in the interim.

Treatment.—Rupture of the uterus always represents a grave crisis and calls for immediate operation. Where the rent is small, suture or packing is sometimes resorted to but Cesarean section is often to be preferred in these cases because of its greater safety. Hysterectomy is necessary if much laceration has resulted, and in the presence of infection.

[1] Monatschr. f. Geburtsh. u. Gynäk., Berlin, 1911, xxxiv, 652.
[2] Beitr. z. klin. Chir., Tübingen, 1914, xciv, 104.

GANGRENE.

BY LEO BUERGER, M.D.

GANGRENE (Fr., gangrène; Latin, gangræna, from Greek γάγγραινα, an eating sore γραω, γραειν, to gnaw) signifies the death of macroscopically visible portions of the body, the invisible liquefaction of tissue being known as *molecular death* or *ulceration.*

Mortification is synonymous with gangrene, being more frequently used in the parlance of the laity.

Mummification refers to that type of gangrene in which drying or desiccation of the tissues takes place.

Sphacelation means total death of all of an affected part, the dead tissue being known as a sphacelus.

Sloughs are dead masses of tissues, the result of a process of sloughing. The act of sloughing which results in the formation of sloughs may be brought on by ulceration or inflammation. Thus, a core is an inflammatory slough; when it is sufficiently large and possibly putrid, it is termed gangrenous slough.

Properly speaking, *necrosis* is a general term that should include all types of tissue death. Although used in this way by the Germans, in English medical parlance, it is more frequently applied either to the disintegration or death of internal organs, when the mortification is unattended by decomposition, or to the death of bone tissue.

General Causes.—Gangrene is usually the result of impaired or absent blood supply. Other causes, however, must be able to bring about mortification in the presence of a patent and apparently intact or adequate circulatory system, as in the so-called vasomotor varieties of gangrene, of which Raynaud's disease is an example.

It is by virtue of the development of an adequate collateral circulation that gangrene can be prevented, so that we can distinguish between the clinical picture of impaired or arrested circulation with gangrene as a sequence, and where gangrene has been averted through the development of sufficient secondary circulatory paths.

In addition to the factors, impairment of circulation and establishment of collaterals, other influences may determine the development of gangrene. These are the general condition of the patient and the local condition. An enfeebled general condition, a weak heart, the debilitating effects of prolonged illness, of infection or diabetes, all these, not only lower the vitality, but also militate against recovery. Local conditions such as extravasations of blood, inflammatory exudates, localized vascular disease, stasis or congestion resulting from tight bandages, and improper posture, are additional impediments to the formation of collateral paths. The tissues, too, vary as to their vulnerability, the vitality of bone, cartilage, tendons and fascia being apparently greater than that of muscles and nerves, while the glandular organs and the elements of the simple nervous system seem to succumb within a very few hours after complete blockage of the main avenue of blood supply. In certain tissues, such as muscles and nerves, impairment of circulation produces temporary ischemia, which, if not of too long duration, leads to degeneration, functional disturbances, so-called ischemic contracture and palsy, but not to gangrene.

Symptoms of Gangrene.—For a thorough comprehension of the clinical manifestations of gangrene or impending gangrene, it is essential to be able to recognize not only the signs that appear when the condition is definitely and well developed, but all those objective evidences of impaired circulation that may precede by months or even years the advent of true gangrene or even of trophic disorder. The signs and symptoms of gangrene and those of impaired circulation will be merely mentioned here, a detailed description being given under the discussion of the various types of gangrene.

Signs of death of a limited part are the following: (1) loss of pulsation in the usually palpable vessels; (2) coldness of the part; (3) absence of sensation or, paresthesia followed later by anesthesia; (4) loss of active motion in the part, or loss of function; (5) change in outward appearance, chiefly in color. At first there may be intense blanching, the skin having a waxy, cadaveric or ivory tint. Or, if the part be engorged with blood, by virtue of intense venous stasis, a cyanotic livid hue will predominate. Later, the color and appearance of the part will change, as the condition of *dry* or *moist* or mixed gangrene is developed.

Premonitory Symptoms of Gangrene.—These are best illustrated when the extremities are the seat of impaired or arrested circulation. It is quite as important to be cognizant of the objective and subjective phenomena antedating the advent of gangrene or trophic disorder, as it is to recognize the death of tissue itself, for, in most cases in the clinic, the diagnosis of the arterial lesion leading to gangrene should precede by a longer or shorter period the onset of the gangrene itself.

Symptoms of Impaired Circulation.—Certain definite clinical manifestations of diminished blood supply are frequently the precursors of gangrene. Or, gangrene may occur in one limb and never develop in the other, although both limbs offer the signs of diminished blood supply. The most important of such clinical signs are the following:

1. *Symptoms of Intermittent Claudication.*—By this term is meant cramp-like pains in the calf of the leg brought on by walking or running, and causing the patient to rest the limbs. The pain regularly disappears when the muscles are in a state of repose. Less typical pain referred to the ball of the foot or the ankle, or the instep, must be regarded as of the same nature. Erb's syndrome called "intermittent claudication" should not be regarded as a clinical entity, for the symptoms described as intermittent limping do not belong to any one group

of cases, but occur in almost all of the cases in which obstructive or obliterative disease of the arteries of the lower extremities is present. Thus, intermittent claudication is a symptom of thrombo-angiitis obliterans, athero- or arteriosclerotic disease, arteriosclerosis with diabetes, or with thrombosis, of endarteritis, and aneurysm of the popliteal artery. The feeling of *weakness* in the affected part also influenced by motion, properly belongs here, since it is so frequently associated with the pain and cramp-like phenomena.

2. *Coldness of the Extremity.*—Coldness of the extremity, particularly influenced by climatic conditions, occurring spontaneously or brought on by exertion. It is manifested subjectively and objectively.

3. *Bluish Discoloration* (*Cyanosis*).—Bluish discoloration of the tips of the toes, particularly the great toe, sometimes the ball of the foot, attended with coldness and particularly noticed after walking.

4. *Whiteness or Blanched Condition.*—Whiteness or blanched condition of the extremity, occurring when the limb is in the horizontal, rarely ever in the dependent position, and which can be elicited on examination by elevating the affected limb 60 or 90 degrees above the horizontal (also known as ischemia.)

5. *Redness or Rubor.*—A condition of redness or rubor, involving the toes, sometimes the dorsum and the plantar aspect of the foot for varying distances to the ankle or even higher, frequently involving the lower extremities when these are allowed to hang down, occasionally occurring even in the horizontal position of the limb, and independent of infection, gangrene, or trophic disorder. Buerger has termed this phenomenon "erythromelia."

6. *Absence of Pulsation.*—Absence of pulsation in the usually palpable vessels of the extremities, the dorsalis pedis, posterior tibial, popliteal or femoral of the lower extremity, the radial, ulnar and brachial arteries of the upper extremity.

7. *Trophic Disorders.*—Trophic disorders including indolent fissures, ulcers, hemorrhagic areas, superficial ulcers, perforating ulcers, a withered or atrophic condition of portions of the extremities, foot or hand, impaired growth of nails, etc.

8. *Thrombosis.*—Attacks of thrombosis with the following symptoms referable to the sudden closure of vessels: pain in the calf of the leg or foot, inability to walk, pallor of the forepart of the foot, coldness, blanching of the foot on elevation, loss of pulsation in the dorsalis pedis, posterior tibial or popliteal arteries, or all of these, sometimes followed by the development of trophic disturbances, and even gangrene, or at other times eventuating in more or less complete recovery.

Forms of Gangrene.—One of the oldest classifications and one which has but little value since it throws no light upon the etiology, is the subdivision into *dry* and *moist gangrene.* Some authors add an additional variety, *microbic gangrene.*

Dry Gangrene.—Dry gangrene ensues when the arterial circulation is suddenly impeded while the venous flow continues, the tissues being drained of their fluid by the veins. Mummification follows and the part becomes desiccated or dry. This variety is not infrequently met with in the aged, when, by virtue of the slow process of athero- or arteriosclerosis, the lumina of the arteries become occluded, the blood supply diminishes progressively, and finally gangrene of a distal part occurs. Although the words *senile* and *dry gangrene* have at times been used synonymously, this restricted application of the term is incorrect, since dry gangrene takes place in many other conditions.

After preliminary blanching, paresthesiæ, coldness and loss of sensation, cyanosis usually follows. The skin gradually becomes dry, then brownish or black, the whole part being converted into a shrivelled, hard, blackish mass. The changes in color are ascribed to the disintegration of hemoglobin with the elaboration of black by-products.

Moist Gangrene.—Moist gangrene results when there is an impediment both to the influx of arterial blood and to the venous return, so that the affected part retains sufficient fluid to leave the dead tissues moist. Complete obstruction of the chief veins of a part, without occlusion of the arteries, may also lead to gangrene, although this is of rare occurrence. The condition of the circulation in the limb before the arrest of arterial circulation takes place, may be the determining factor in the production of either the moist or dry type of gangrene. Intense edema associated with nephritis or impaired heart action usually favors the development of moist gangrene, as in the embolic or thrombotic gangrene complicating pneumonia or other infections.

Characteristic for moist gangrene are the following clinical stages: (1) A stage of pallor which may pass so rapidly as to be overlooked; (2) a stage of extensive ecchymosis; (3) a stage of subepidermal exudation with reddish discoloration of the part; (4) a stage of disintegration.

Although these stages are not always clearly defined, they may be recognized in a fairly large percentage of the cases. The initial pallor may be evanescent; it may be accompanied with paresthesiæ but more regularly with frigidity and anesthesia. Soon a bluish and purplish mottling that rapidly spreads over the affected part becomes the striking objective manifestation, being succeeded by the exudation of bloody serum under the epidermis. When the latter is lifted off, larger or smaller bullæ are formed (Plate II) many of which attain considerable size. When the epidermis has been separated and no considerable fluid is present, the angry red cutis vera shines through (Plate III). Higher up, the limb is usually cold for a variable distance, often intensely edematous and brawny, mottled here and there by areas of purplish discoloration (ecchymosis). Later the intense red disappears as the disintegrating cutis vera, and the gray green epidermis combine to form a peculiar ashen purplish hue (Plate IV). The serum from the bullæ now makes its escape in many places, the separated epidermis lying in folds over it, here and there torn off, exposing the weeping derma. With the advent of putrefaction, an intensely foul odor develops, secondary pyogenic infection complicated by lymphangitis, and cellulitis above the site of gangrene may supervene and be associated with toxic general symptoms.

PLATE II

Early Stage of Moist Gangrene, Showing Bulla.

PLATE III

Extensive Subepidermal Exudation in Moist Gangrene.

PLATE IV

Later Stage of Moist Gangrene.

Microbic Gangrene.—Microbic gangrene has been termed acute microbic gangrene, fulminating gangrene, emphysematous gangrene and traumatic spreading gangrene. Here a virulent infection usually with a gas-producing microörganism is responsible for the mortifying process. A severe injury usually precedes the infection.

Course and Termination.—Gangrene is very frequently self-limiting, a definite line separating the dead and the living tissue, known as the *line of demarcation* being ultimately formed. At this line granulation tissue is developed, as the result of a reactive inflammatory process. By virtue of the action of the emigrated leukocytes, certain ferments are elaborated which bring about the separation of the dead from the healthy tissue. Soft parts yield relatively soon to the sequestrating effects of the inflammatory process, while bone is much more resistant. When a considerable part of a member is thus separated so-called *spontaneous amputation* results.

When the area of necrosis or mortification is infected, the process of separation is accomplished in a different manner. The usual phenomena of suppurative inflammation of greater or less virulence are manifest, the products of inflammation being instrumental in causing disintegration of the part at its junction with the living, but may also spread in the healthy tissues, requiring surgical intervention. If sufficiently severe, a rapidly ascending lymphangitis may occur, general infection, bacteriemia and toxemia. In these cases the end-result will depend upon the virulence of infection, and on the possibility of its control.

Classification.—From the clinical standpoint, a pathological and etiological grouping is most satisfactory. It must be remembered, however, that an absolutely satisfactory classification is impossible, both because cases may simultaneously belong to several groups, and because the causative factor in certain instances is not well understood.

Three large groups may be recognized: (1) gangrene due to external or direct causes, such as bring about immediate death of tissue; (2) gangrene due to internal or indirect causes, which act by impeding or arresting the circulation of blood in the larger vascular channels, and (3) neuropathic gangrene in which the cause resides somewhere in the nervous system.

1. **External or Direct Causes.**—(*a*) *Mechanical Causes.*—Mechanical causes in which death or necrosis is the direct result of the physical injury. Tissues may become completely separated in continuity and thus die; or necrose because of the disorganizing effect of a crushing force. Continuous pressure upon bony prominences, particularly in the emaciated, produces gangrene or necrosis to which the name *decubitus* has been given. Compression by a tight bandage, torsion acting upon a portion of the intestine, or strangulation at the neck of a hernial sac—are all mechanical causes of gangrene.

(*b*) *Thermic Causes.*—Intense heat or cold may cause death of tissue in a very short time, either by the direct coagulating or carbonizing effect, or indirectly by the formation of thrombi in the vessels.

(*c*) *Chemical Causes.*—Chemical causes include the action of a fairly large number of substances. Some authors include some of the bacterial toxines, although many of these would not properly belong here, if their action were understood. The action of tissue juices in the normal secretions and excretions may, however, be included here, since they produce digestion necrosis.

The most common chemical substances leading to gangrene are strong acids, hydrochloric, nitric, sulphuric, acetic, trichloracetic; also carbolic acid, lysol and alcohol when applied as wet dressings. The secretions and excretions that bring about necrosis through their specific ferments are, gastric juice escaping through a gastric fistula, extravasated urine, and the feces.

(*d*) *Microbic Gangrene.*—Certain virulent bacteria, particularly in the presence of intense traumatism, may bring about a combination of infection and gangrene often called *microbic gangrene.*

The toxines produced in bacterial inflammation are also regarded as being responsible for destruction of tissue, or even gangrene.

2. **Internal or Indirect Causes.**—*Injury of the main nutrient vessels* may be brought about by mechanical force in several ways. When a limb is crushed or receives an intensive trauma, when a large vessel is pierced by a gunshot, when pressure effects are produced by an aneurysm or a malignant tumor, then the circulation may be impaired indirectly, through interference with the continuity or patency of the chief nutrient vessels. Ligation of a vessel, such as the spermatic artery during an operation upon the testicle, or for hernia, or ligation of a renal or middle colic artery, may lead to necrosis and gangrene. Ligation of the internal carotid artery is followed by necroses of the brain, in almost 50 per cent. of the cases. In the case of the extremities, ligation of one of the main arteries may be followed by gangrene if adequate collateral circulation does not become established. The general condition of the patient, the heart action, the presence of complicating diseases (such as anemia, diabetes and infections, atherosclerosis), of inflammatory conditions, exudates or hematomata in the affected limb, and tight bandages—are all contributary causes that hinder the establishment of collateral circulation.

Diseases of the bloodvessels including (1) *athero- or arteriosclerosis* (senile, presenile, diabetic, with or without thrombosis and embolism); (2) *thrombo-angiitis obliterans,* and (3) *endarteritis* (including syphilitic endarteritis).

Thrombosis or Embolism.—These may be responsible for gangrene by completely obliterating the lumina of either normal or diseased vessels. When these occur in diseased vessels, they may be regarded as complications of the primary vascular lesion, and, therefore obstruction by thrombosis or embolism in vessels relatively patent only, will be discussed under this caption.

Emboli and thrombi may be composed of red clot, mixed clot, bacteria, calcareous, purulent or even tumor material. For practical purposes we need consider merely clots; other embolic material more frequently evokes small areas of necrosis, suppuration or aneurysm, than true gangrene.

Embolism most frequently affects the femoral or popliteal artery, and may then result in gangrene of the foot and leg. More rarely the brachial and axillary arteries are involved. It occurs most commonly in the course of severe infectious diseases, or as a complication after the disease has subsided, also with valvular heart lesions, and after abdominal or pelvic (particularly gynecological) operations. In typhoid fever, pneumonia and influenza, sudden blockage of the popliteal or femoral artery may occur, or there may be extensive thrombosis of the femoral vein. Although it is not generally understood why an embolus in the popliteal artery should cause extensive gangrene, when there are adequate avenues of blood supply through collaterals, the explanation is to be sought in the fact that extensive red thrombosis is soon superadded above and below the site of the original clot, red and mixed thrombi extending in both directions with great rapidity into many of the smaller vascular branches and tributaries, preventing in this way the establishment of a subsidiary collateral circulation.

3. **Neuropathic Gangrene.** — In this group may be placed all those cases in which the arteries and veins are organically intact, or have suffered no alteration of their patency, and in which, in the present state of our knowledge, we assume that a neurogenic causal agency is responsible.

The following symptom-complexes, Raynaud's disease, erythromelalgia, acroparesthesia, multiple neurotic gangrene, and chronic acro-asphyxia belong here. It has been generally accepted that in some of these, the vascular disturbance and arrest of circulation may be accounted for on the theory of a spastic condition of the nutrient vessels, but in others, the true mechanism still remains unrecognized.

Clinical Examination in Gangrene and its Prodromal Stages.— In order to understand and give the proper dignity to all of those clinical manifestations that constitute the prodromal signs of symptom-complexes that eventuate in gangrene, it is wise to follow a certain scheme of procedure in the examination of all cases in which we suspect impaired circulation. When we are confronted with cases of vasomotor disturbance, of trophic disorder, such as ulcers and atrophy, when the patient complains of pain which arouses the suspicion of intermittent claudication, as well as in the presence of true gangrene of the lower extremities, the following scheme of the author will be found of value in diagnosis. It includes the investigation of the following points: (1) the general appearance of the limb in the horizontal position; (2) in the dependent position; (3) the presence or absence of ischemia in the elevated position; (4) the estimation of the *angle of circulatory sufficiency;* (5) pulsation in the palpable vessels, iliac, femoral, popliteal, posterior tibial, anterior tibial and dorsalis pedis in the case of the lower extremities, radial, ulnar, brachial and axillary in the upper extremities; and, (6) the occurrence of *induced, reactionary rubor* or *erythromelia.*

1. **General Appearance of the Limb.**—Any departure from the normal should be noticed. The presence of fissures, ulcers, perforating ulcers, bullæ, ecchymoses, impaired nail growth, gangrenous areas, distinct gangrene, signs of infection or lymphangitis or venous thrombosis. Evidences of malnutrition, such as atrophy, exceptional prominence of the bony landmarks and extensor tendons, conservation or effacement of the normal irregularities of contour through edema or through thickening of the skin and subcutaneous tissues, are features of importance. Variations from the normal color—particularly marked pallor in the horizontal position, a play of color over the foot, even in the horizontal position; cyanosis, increased redness—all these, are manifestations of either impaired circulation or vasomotor disturbance.

2. **Rubor or Erythromelia.**—With the foot in the pendent position and in the absence of inflammation, a red flush involving the toes and dorsum (Plate V), as well as sole of the foot, extending upward for a variable distance, rarely farther than the ankle, is a phenomenon that is characteristic of many cases and many types of reduced circulation due to vascular obturation. This is a condition of *rubor* or *erythromelia* (Gr. *erythros* = red, *melia* = limb). It is brought about by a compensatory dilatation of the superficial capillaries, and is most characteristic of the disease, thrombo-angiitis obliterans, although also found in other arterial affections attended with closure of larger vessels. It is frequently present in arteriosclerotic and diabetic cases as well. It seems to be an effort on the part of nature to make up for the impairment of circulation by virtue of dilatation and engorgement of the superficial capillaries. Although more striking in the pendent position, the rubor may also be present in the horizontal position, and when continuously in evidence, may be termed *chronic rubor, chronic erythromelia,* in contradistinction to the *reactionary rubor*[1] that may be induced by depressing the limb after previous elevation.

3. **Ischemia or Blanching.**—This usually sets in rapidly when the affected limb is elevated, whenever mechanical interference with the circulation is present. The extent of blanching and the rapidity with which it appears, are both valuable aids in the estimation of the amount of obstructive arterial disease. When the affected limb is cold, the tips of the toes may remain slightly blue or cyanotic. Should the blanching be slow in appearing, or very hard to determine, pressure upon the tips of the toes after the limb has been elevated for some time will demonstrate whether the part has become depleted of blood or not ("Expression test"). Compression of the toes of the elevated foot in normal cases, will reveal the presence of sufficient bright arterial blood (rarely slightly cyanotic), while a varying degree of ischemia, with

[1] These terms, *erythromelia chronic rubor, reactionary rubor, induced rubor, angle of circulatory sufficiency,* as well as others employed here, have been adopted by the author in an attempt to facilitate expression of various conditions of circulation, and if adopted must be carefully applied in the sense here suggested.

PLATE V

Erythromelia in Thrombo-angiitis Obliterans.

or without marked cyanosis, will accompany obliterated or obstructed arteries.

4. **The Angle of Circulatory Sufficiency.**—The estimation of this angle is based on the supposition that the normal limb, when elevated so as to be perpendicular to the horizontal plane, that is 180 degrees, still retains most of its color. When the circulatory mechanism is defective, and the limb is elevated to the vertical, a variable degree of blanching of the foot occurs. If the leg is then gradually depressed, *the angle at which reddish hue returns* (angle of circulatory sufficiency) will be found to vary considerably. In some cases it will be necessary to depress the limb to the horizontal before evidences of return circulation are manifest. The angle of circulatory sufficiency would then be 90 degrees. If the reëstablishment of visible circulation in the skin necessitates depression below the horizontal, the angle will be correspondingly less than 90 degrees. In many cases of arterial disease, the estimation of this angle is a valuable adjuvant, not only in the recognition of the extent of the circulatory disturbance, but also in prognosis.

5. **Absence of Pulsation as an Indication of Arterial Occlusion.**—We should be able to feel the femoral, posterior tibial, popliteal and dorsalis pedis arteries, pulsating in almost all individuals who possess patent arteries. In rare cases the dorsalis pedis may be aberrant in its course, and therefore not palpable in its usual situation, or, neither the dorsalis pedis nor popliteal may be accessible to the touch because of the stoutness of the patient.

To palpate the popliteal satisfactorily, the patient is placed on his abdomen, lying prone. The leg is held at right angle, that is, vertical, the patient being asked to relax the hamstring muscles. The artery is then sought in the upper half of the popliteal space, just outside of the semimembranosus and semitendinosus tendons, the fingers being pressed downward against the femur. In the upper extremities, the radial, ulnar and brachial and axillary arteries should be examined for pulsation.

The absence of pulsation is, as a rule, an indication of occlusion at the point palpated, although in rare instances, postmortem dissections have shown that the site of obliteration is somewhat higher up.

6. **Reactionary Hyperemia, Rubor or Reactionary Erythromelia.**—By this term we mean an *induced rubor* that manifests itself in the dependent position of the foot, after it has been previously elevated to the vertical. It is a physiological phenomenon, that ischemia or blanching of a limb artificially produced by an Esmarch or Martin bandage, will be followed by sudden dilatation of the capillaries of the peripheral parts, when the circulation is allowed to return. So, also, blanching will occur in a leg whose larger arteries are occluded, on mere elevation from 60 to 90 degrees above the horizontal, without the use of any artificial means. When such a blanched limb is then depressed to the pendent position, a similar induced or reactionary rubor will become manifest. This well-known manifestation may be evoked in the examination of cases in which impaired circulation due to arterial

occlusion is suspected. It will be found particularly useful in cases of thrombo-angiitis obliterans, although also demonstrable in other cases of organic vascular disease. In early cases, it is a particularly valuable sign, for it may be present long before the chronic condition of rubor or erythromelia develops.

The various clinical forms of gangrene will be grouped and described according to the following classification:

I. Gangrene due to external or direct causes, viz.:
   (A) Trauma.
   (B) Thermal influences.
   (C) Chemical causes.
   (D) Microbic action.
II. Gangrene due to indirect or internal causes, including:
   (A) Injury to main nutrient vessel of a part.
   (B) Diseases of bloodvessels.
      1. Arteriosclerosis.
      2. Thrombo-angiitis obliterans.
      3. Endarteritis (luetic).
   (C) Thrombosis and embolism.
III. Neuropathic gangrene.

I. GANGRENE DUE TO EXTERNAL OR DIRECT CAUSES.

(A) Traumatic Gangrene.—Traumatic gangrene results from the direct action of a mechanical force. Tissue which has become totally separated must needs become necrotic or gangrenous, if the conditions for healing and restitution of the circulation in the wound are not favorable. Such adverse conditions arise when severe traumata bring about crushing and mangling of tissue, extravasations of blood and bacterial infection. Only in the case of transplantation by operation under strictest aseptic conditions are the conditions favorable for restitution and growth of the transplant satisfactory.

A blunt crushing force may also lead to gangrene of tissue, partly by reason of the disintegrating and destructive action of the force itself, and partly through thrombosis in larger vessels. The severe traumata inflicted in various accidents by machinery, which produce extensive laceration of tissues, may be followed by gangrene of a part or the whole of an extremity.

Finally, injuries leading to rupture and consequent ligation of larger vessels are not infrequently complicated by gangrene. Such an eventuality may be expected, when extensive hemorrhagic extravasations are present.

Symptoms.—The clinical manifestations of threatened gangrene of an extremity begin with the picture of ischemia or venous stasis, coldness, and absence of pulsations in the usually palpable arteries. After initial paresthesia, or dull pain, complete absence of sensation and motor paralysis set in. Intense pain and tenderness, however, may persist above the area of gangrene. Within forty-eight hours, the evidences of beginning dry or moist gangrene make their appearance.

Treatment.—The treatment of traumatic gangrene includes (1) the surgical treatment of the wound produced by the injury, according to the principles of aseptic surgery; (2) the methods for enhancing the circulation, so as to limit the gangrenous process as much as possible; and (3) the amputation of the affected part.

(B) Thermic Gangrene.—Intense heat or cold may bring about necrosis of tissue within a very short time, while moderate degree of heat and cold may have the same effects when in action for a longer period of time. Gangrene from cold apparently differs in no essentials from other forms of mortification. The death of tissue is supposed to occur in two ways: (1) from the direct action of cold upon the protoplasm; (2) from the ischemia due to vascular spasm and thrombosis. Although gangrene may be due to the fact that the part has become completely frozen, restitution would occur in most instances were it not for the fact that extensive thrombosis of the arterial and venous channels has already occurred.

(C) Grangrene Due to Chemicals and Drugs.—Certain chemicals or drugs taken internally and applied locally may cause gangrene. Ergot, although not taken in the form of a drug, may be considered here as one of those substances that may produce gangrene when taken internally. Mercury, orthoform, phosphorus, carbolic acid, trichloracetic acid, strong acids and alkalies, all are reported as being able to produce gangrene under certain conditions.

Gangrene from Ergot.—This results from eating bread made from spurred rye, and practically never when ergot is taken for medicinal purposes. This disease was not uncommon in the eighteenth century and the early part of the nineteenth century, particularly in Europe, where epidemics of so-called ergotism are known to have occurred. At present the disease occurs rarely, and then only sporadically. Two types are described, a convulsive and a gangrenous type, although both types may be combined.

After preliminary gastro-intestinal disturbances, such as diarrhea, colic, occasional vomiting, disturbances of the circulatory and nervous system appear. The extremities may become cold, numb, blue; the pulses may become weak and muscular spasms may occur. When the spasms become more general, seizures of an epileptic nature develop. In the gangrenous type of case, either the toes or fingers are usually affected. They become cold, painful, show cyanotic or purplish patches which gradually mortify, gangrene being usually of the dry type.

Thrombosis of the peripheral arteries has been described. Kobert regards the presence of *sphacelinic* acid as the cause in the gangrenous form, and *cornutin*, as the poison, responsible for the convulsive type of disease. Certain authors have attributed the gangrene to prolonged contracture of the smaller vessels, or vascular spasm due to the ergot.

A history of ergot intoxication is of greatest importance for the diagnosis. The clinical picture of ergotism may closely resemble that of

Raynaud's disease. Ergot is known to produce a contraction of smooth muscle tissue, inclusive of that of the vessels, so that the manifestations of local asphyxia may be explained in this way.

Treatment.—Abstinence from bread containing the poisonous ergot, and the use of eliminants or purgatives to hasten the removal of the toxic substances in the blood are indicated. The general laws and rules for treatment outlined in other types of gangrene may also be followed here.

Gangrene from Other Drugs.—*Mercury* is reported to have produced local sloughing at the site of injection, gangrenous patches in the gastro-intestinal tract, and sloughing of the skin, the labia and vaginal region being involved in one case.

A gangrenous form of eruption is recorded in the literature as following the use of *orthoform*. Gangrenous patches and ulceration are supposed to have followed the use of this drug about the fingers, anus and nipples. In these cases the gangrene was attributed to the use of orthoform.

Phosphorus.—Phosphorus may produce necrosis of the jaws in persons who work with this substance. From 2 to 5 per cent. of the individuals in match factories are affected sooner or later.

Carbolic Acid Gangrene.—The fingers or toes are usually affected following the local application of ointments or wet dressings. The gangrene may result after the application of even a very weak solution (such as 0.5, 1 or 2 per cent.). After the dressing has been applied for a few hours, the finger or part becomes blanched, and a pricking sensation is felt. Within twenty-four hours or less, the skin becomes dusky, discolored, dry gangrene may occur, the part becoming gradually mummified.

Various theories have been offered to explain the cause of gangrene from the use of weak solutions of carbolic acid. According to some authors, thrombosis is produced in the peripheral vessels, according to others, carbolic acid is supposed to have a particular action upon the trophic and vascular nerves.

Lysol, too, may be regarded as dangerous in solutions that are not thoroughly mixed, as the case of Sowles[1] demonstrated.

In a patient, who soaked his right index finger four times (over a total period of about fifteen minutes) in a basin of water, into which an "indefinite amount" of lysol had been added, the whole distal half of the finger became much swollen on the following day. Examination twenty-four hours later revealed marked redness and swelling with a sharp line of demarcation. The epidermis of the dorsal distal half of the finger was white and raised from the subcutaneous tissue, appearing to be dislodged by serum or pus. However, on removal of the dead skin, the subcutaneous tissues were evidently dry and gangrenous.

[1] Boston Med. and Surg. Jour., 1919, p. 510.

Gangrene Due to Acids and Alkalies.—Even weak solutions (about 5 per cent. of muriatic, nitric or sulphuric acid, as well as of caustic potash, may produce gangrene when applied as moist compresses, in from twenty to twenty-four hours. These drugs lead to maceration of the epidermis, necrosis, the deeper tissues becoming subsequently affected. Trichloracetic acid is also dangerous, if it be incorrectly used in the form of a wet dressing, when applied to the surface to remove warts.

(D) Microbic Gangrene.—The more important types of *microbic gangrene* are the so-called *hospital gangrene, noma* and *emphysematous gangrene.*

Hospital Gangrene (*Sloughing Phagedena, Pulpy Gangrene, Putrid Degeneration, Traumatic Typhus, Nosocomial Gangrene*).—Hospital gangrene has practically disappeared since modern antiseptic methods have been introduced into surgery, and needs, therefore, but slight mention here. It occurred either in epidemics, or was endemic in hospitals, particularly in the military hospitals. Hospital gangrene may be regarded as an acute progressive gangrene with putrid decomposition or degeneration of the wound, initiated by local symptoms, but followed rapidly by severe constitutional manifestations. The cause is doubtless an infectious one, anaërobic bacilli being probably responsible. Matzenauer[1] claims to have isolated a bacillus which, however, he could not demonstrate in pure culture. Nasse[2] found an ameba.

According to the clinical course, authors have described a superficial and a deep form, and according to the external manifestation an ulcerative and a pulpy variety.

Erichsen[3] describes the disease as follows: "A disease characterized by a rapidly destructive and spreading ulcer, covering itself as it extends by an adherent slough, and attacking open sores and wounds. When sloughing phagedena invades a wound that is previously perfectly healthy, the surface of the sore becomes covered with gray, soft points of slough, which rapidly extend until the whole of the ulcer is affected. At the same time it increases rapidly in superficial extent, and commonly in depth; the surrounding integument becomes edematous, swollen, and of a livid-red color; the edges of the ulcer are everted, sharp-cut, and assume a circular outline, and its surface is covered with a thick, pulpy, grayish-green, tenacious mass, which is so firmly adherent to the sore that it cannot be wiped off from it, being merely swayed to and fro when an attempt is made to clean it. There is usually some dirty, yellowish-green or brownish discharge, and occasionally some bleeding; the pain is of a severe burning, stinging, and lancinating character, and the fetor from the surface is considerable. The ravages of the disease when fully developed are very extensive. The soft parts, such as the muscles, cellular tissue, and vessels, are

[1] Arch. f. Dermat. u. Syph., Bd. lv.
[2] Arb. aus von Bergmann's Klinik, 5ter Teil, 1891.
[3] Science and Art of Surgery.

transformed into a gray, pulpy mass and the bones are denuded and necrosed."

The diphtheritic form is characterized by certain alterations in previously healthy, granulating wounds. Associated with fever and pain, there appear yellowish-brown areas of discoloration in the granulations, hemorrhages and superficial sloughs. The diphtheritic form may become *ulcerative* when disintegration of the surface takes place. The discolored areas will soon give rise to a foul odor, leave sharply demarcated ulcers which rapidly fuse together, or the bottom of the ulcers becomes hemorrhagic and gangrenous, their margins eroded, the neighborhood tender and painful, and inflamed far beyond the zone of the wound.

The Pulpy Form.—Marked swelling takes place here, gas may develop in the tissues, a mass or pulp being developed, which may be likened to brain substance. Associated with it, extensive hemorrhages may give rise to the hemorrhagic type. In the *superficial form* the process would often be self-limited, whereas in the *deep form* a putrid phlegmon would develop, leading to bone necrosis, even ulceration of vessels, and death due to hemorrhage. Or, the deep form may be associated with toxic general symptoms, that lead to a lethal outcome within two or three days.

As complications, erysipelas, metastatic foci of pus, and lymphangitis have been described.

Treatment.—This consists of the rapid and energetic cauterization of putrid areas with Pacquelin cautery, opening of the abscesses and surgical cleanliness. Sloughs are to be removed, and general stimulants freely administered.

Noma.—This form of gangrene, also called *cancrum oris, gangrenous stomatitis, cancer aquaticus,* is a special form of ulcerative stomatitis with gangrene, that occurs almost exclusively in children between the ages of two and twelve, and often follows some debilitating disease. The affection has its origin in an infiltration of the mucous membrane in the neighborhood of the angle of the mouth. The exudate or infiltration then becomes gangrenous, and converted into a bluish-black, dry mass, which is cast off, the mortifying process progressing, however, in depth and laterally, so as to involve the lips, chin and cheeks. Within a few days a considerable portion of the cheeks becomes destroyed and even the bone becomes exposed and necrotic. Rather characteristic is the perforation of a cheek which may ensue within a few days. Externally, in the pale, swollen cheeks, a bluish-black hard spot with a reddish zone of demarcation appears, or with this, there may be associated a large bleb. After the gangrenous area is cast off, the perforation or hole is left leading into the cavity of the mouth.

The disease seems to affect poorly nourished children, often in the course of an infectious disease, such as measles, scarlet or typhoid. As a rule, fever, cerebral symptoms of loss of consciousness, accompany the malady which is fatal within two or three weeks.

The etiology does not seem to be the same in all cases. Schimmelbusch[1] and Babes[2] isolated a special type of bacillus. Perthes found a streptothrix. Others, such as Buday[3] believe that a spirillum and a fusiform bacillus growing in symbiosis are responsible for the affection.

Treatment.—This consists in the destruction of the gangrenous areas with the Paquelin cautery, frequent irrigations of the mouth, prevention of aspiration pneumonia, and, according to some authors, the extirpation of the affected area with the knife. As prophylactic measures, the mouths of all children suffering from severe debilitating illnesses should be kept scrupulously clean, all ulcers should be cauterized, and carious teeth carefully attended to.

Emphysematous Gangrene (*Microbic or Traumatic Spreading Gangrene, Gangrène Foudroyante*).—This form of gangrenous infection characterized by rapidly spreading infections of the subcutaneous tissues is a clinical symptom-complex produced by a number of different virulent gas-producing organisms. Much confusion has arisen regarding the nomenclature and etiology, authors, however, being generally agreed regarding the intensity of the infection, its virulence, the production of gangrene, and the presence of gas in the alveolar tissues. It has been variously termed, traumatic emphysema—gas phlegmon—acute microbic gangrene, fulminating gangrene, gangrenous cellulitis, malignant edema, anaërobic gangrene.

The more important organisms responsible for the affection are the *bacillus* of *malignant edema* and the *Bacillus aërogenes capsulatus* (Welch and Nuttall), both of which are anaërobes. A number of anaërobic organisms either singly or in symbiosis, such as the *Bacillus proteus vulgaris, Bacterium coli communis* and other pyogenic bacteria are also regarded as possible offending agents. The *bacillus of malignant edema* (bacillus edematis maligni) was cultivated in 1878 by Pasteur, Joubert and Chamberland, but first thoroughly studied by R. Koch in 1881. It is an obligatory and spore-bearing anaërobe which occurs in garden earth and also in the intestinal tract of animals. The *Bacillus aërogenes capsulatus* (Welch) described in 1892, and again called "*Bacillus phlegmones emphysematosæ*" by E. Frænkel in 1893, is another anaërobic bacillus that is rapidly fatal for guinea-pigs, and rabbits, copious gas-formation being characteristic of its growth.

Symptoms.—This form of gangrene is distinguished by the fact that infection occurs first, and gangrene is a sequence. There is either a dirty wound or abrasion, or an extensive injury with or without compound fracture; or, the gangrene supervenes after injuries received in a railroad accident or in the street, where contused, lacerated, and particularly dirty wounds have been inflicted. Within a few hours after injury, evidence of infection manifests itself in rapid swelling of the part, which becomes dusky red or purple. This soon gives way to a dark, mottled appearance, bullæ appear, and emphysematous crackling can be demonstrated in the cellular tissue, the extension of the process being so rapid as to involve the greater part of a limb within

[1] Deut. med. Wchnschr., 1889. [2] La Romaine Med., 1894.
[3] Beitr. z. path. Anat., 1905, xxxviii,

a few hours. Death occurs in more than 55 per cent. of the cases. Characteristic is the absence of pus formation, an incision through the skin liberating dark, watery, offensive, bloody fluid in which bubbles of gas appear.

The general symptoms are usually severe, the pulse becoming rapid, soon weak, the temperature falling to subnormal, other signs of profound intoxication being present.

Treatment.—Heroic treatment is necessary in these cases. Wide and free incision or high amputation far above the region of the disease are recommended. In certain situations radical excision of the affected area supported by measures that stimulate the heart and tend to keep up the strength of the patient must be considered.

Lawson[1] believes that the best results can be obtained by treatment of the subcutaneous tissues with nascent oxygen in the form of injections of neutral hydrogen peroxide. Infiltration of the healthy tissues with oxygen above the line of spreading gangrene is sufficient to check the advance of the infection, and in the majority of cases, the limb may be saved. He believes that amputation of the limb for acute emphysematous gangrene is unnecessary, unless all of the tissues are involved over an extensive area, thinking that high amputation may prove fatal from shock.

Gas Gangrene in the War (*Gas Bacillus Infection, Emphysematous Gangrene*).—Our knowledge in regard to this subject has been much increased by the experience gained in the great war. Recently gathered statistics seem to reveal that both its morbidity and mortality have lessened very appreciably in the later years of the war. The severe wounds, particularly those of the lower extremity, associated with fracture, vascular injury and muscle damage seemed to be especially prone to it. The incidence of the infection seemed to depend to a great extent upon the character of the soil upon which our soldiers fought. It was by far more prevalent while fighting took place on the well fertilized fields of Belgium and France, than in the mountainous regions of the Italian and neglected forest regions of the Russian fronts.

A number of organisms were found,[2] namely the Bacillus edematous maligni (Vibrion septique), the Bacillus Welchii (Bacillus perfringens), the Bacillus edemacieus, and other varieties such as the Bacillus hemolyticus, the Bacillus belloneusis, the Bacillus egeus, the latter three playing but a secondary role. According to McIntosh[3] the above anaërobes are most frequently found in varying combinations, the number and kind of bacteria found in war wounds depending chiefly on the time elapsing between the hour of the injury and the beginning of treatment. Cultures were negative until at least four hours had elapsed after the trauma. After that time several varieties of aërobes and anaërobes could be found to develop rapidly in untreated wounds.

[1] Birm. Med. Rev., 1915, lxxviii, 67.
[2] Park and Williams: Pathogenic Microörganisms, 1920, p. 499.
[3] Classification of Chief War Wound Anaërobes, Public Medical Research Committee, London, 1917, p. 74.

The Gas Wound.—The usual war wound favorable for gas bacillus infection is of larger extent beneath than in the skin and of surprising irregularity. Its depth hides one or more rough missiles, and bits of clothing or equipment. Its crevices are filled with blood clots, large and small, and it is walled by muscle, fascia and aponeurosis, severely torn, contused, and loaded with indriven fragments of comminuted bone and with extravasated blood. The regional blood supply is locally or massively interfered with by pressure obliteration, or occlusion of the vessels by thrombosis.

Van Beuren[1] says that "gas" infection runs up within a damaged muscle sheath like a flame up a flue, and follows the vessel sheaths and blood filled intramuscular spaces.

Subsequent changes due to the infection are: loss of contractility, the wound and parts involved assume a dark reddish color which later becomes greenish yellow and ultimately a black mass. Gas appears as bubbles between muscle fibers, spreads to areolar tissue under pressure, then through spaces in the fascia into the subcutaneous tissues.

The general symptoms are those of a very acute toxemia which may be very rapid in onset and terminate fatally in twenty-four hours or less. In these cases the pulse is small and rapid, the temperaure falls and remains subnormal, there is incessant vomiting and the extremities are cold and clammy. Less severe cases have an accelerated pulse, sudden elevation in temperature and usual signs of inflammation, acidosis and toxemia. The patient appears restless and pain is out of proportion to apparent existing local conditions. Locally, the infection manifests itself by pain, swelling, crepitation, with the overlying skin tense and blanched, later mottled and finally discolored a greenish yellow. If the patient survives long enough, the skin becomes dark purplish in color and bullæ containing blood-stained serum form on the surface. The wound presents a dirty sloughing appearance, with a seropurulent exudate having a peculiar fecal-like odor. The surrounding tissue is red and tender, with all signs of cellulitis. Gas bubbles may or may not be expressed from the wound.

Morbidity and Mortality.—Early in 1916, Gross[2] had 2796 wounded men pass through his ambulance, of whom 101 (3.6 per cent.) developed gas gangrene. In late 1916 the same man treated 1676 wounded men,[3] 33 of whom (1.9 per cent.) developed gas gangrene. In October, 1918, Sieur and Mercier[4] reported that fewer than 0.5 per cent. of the wounded developed gas gangrene in the advanced and intermediate zone. This was undoubtedly due to improved hygenic conditions and character of the soil (non-fertilized). Lardennois[1] in 1916 reported

[1] Jour. Am. Med. Assn., July 26, 1919, lxxiii, 239.

[2] Gaseous Gangrene: Statistical Documents, Bull. de l'Acad. de Méd., December 26, 1916, lxvi, 586; abstr. Surg., Gynec. and Obst., Int. Abstr. Surg., June, 1917.

[3] Gross, G.: 134 Cases of Gas Gangrene, Bull. et mém. Soc. de chir. de Paris, 1917, xliii, 636; abstr. Surg., Gynec. and Obst., Int. Abstr. Surg., September, 1917.

[4] Gas Gangrene in 1918, Bull. de l'Acad. de Méd., October 29, 1918, lxxx, 394; abstr., Jour. Am. Med. Assn., December 28, 1918, lxxi, 2181.

500 cases of gas bacillus infection with 15 per cent. mortality; and Ivens[2] in 1917, 460 cases with 9.5 per cent. mortality.

Regarding definite gas gangrene as distinguished from gas bacillus infection in general, Gross, in 1916, listed 101 cases with 56.5 per cent. mortality, while Ivens, in 1917, reported 107 cases with a mortality of 26.4 per cent. It must be emphasized here, however, that of the cases reported by Gross, those which were treated within twelve hours after the wound was received had a mortality of only 10.9 per cent. This indicates more clearly than any description could the importance of early treatment.

Treatment.—The general principles include the following: Detoxication by serum; control of shock; the intravenous injection of sodium bicarbonate for acidosis; the early and thorough removal of all injured tissue, infectious agents and foreign bodies by surgical intervention, although it is not always necessary to remove large areas of skin and subcutaneous tissue. All suturing is to be avoided; free drainage is to be instituted; the proper splints applied; and Carrell-Dakin solution used. The question of amputation depends on the condition of the patient, the extent of infection, its proximity to the body and whether or not the infection can be controlled by conservative measures.

Van Beuren gives the following general rules used for treatment of gas bacillus infection during our recent War: (1) Operate as early as possible. (2) Use nitrous oxid-oxygen anesthesia if possible. (3) Prepare the part with the minimum amount of delay and trauma. (4) Avoid tourniquets. (5) Make incisions longitudinally and half again as long as you think they need be, both in skin and fascia. (6) Leave as much skin as you dare, in your débridement. (7) Go between rather than through normal muscles and do not cut across them unless you have to (better a long separation between two than a short cut across one). (8) But open the wound as thoroughly and freely as you possibly can. (9) Excise all torn, crushed, discolored, non-contractile muscle, until you have left only that which is firm, of normal color, actively contractile, and which bleeds readily. (10) make a careful and conscientious search for and remove all loose bone and foreign bodies, especially clothing and blood clots. (11) Stop the bleeding; leave the wound wide open and separate its walls with wet gauze, laid in, not packed in. (12) Use Carrell-Dakin tubes, if you know they will be properly cared for. Otherwise omit them. (13) Use plenty of dressings and make careful splint fixation of the part. (14) Do it all as rapidly as you possibly can.

[1] The Malignant Infections of War Wounds by Anaërobic Microbes, Presse Méd., November 16. 1916, xxiv, 506; abstr., Surg., Gyne . and Obst., Int. Abstr. Surg., June, 1917.

[2] A Clinical Study of Anaërobic Wound Infection: an Analysis of 107 Cases of Gas Gangrene, Med. Press. and Circ., 1917, ciii, 12; abstr., Surg., Gynec. and Obst., Int. Abstr. Surg., June, 1917.

Serotherapy.—Statistics in regard to the efficacy of anti-gas serum are somewhat meagre, but are on the whole favorable.

Elser[1] advises the following routine for serum treatment:

1. A prophylactic dose of polyvalent serum, given as early as possible after the receipt of the wound, combined with tetanus antitoxin.
2. Bacteriologic examination of the wound and establishment of the presence of gas bacillus infection and determination of the variety of the bacteria. The determination can be made in about twenty-four hours.
3. Administration of the specific serum, either single or polyvalent or "pooled," according as there are one or more gas-formers found and also antistreptococcus serum.

Sacquepee[2] recommends the following procedure for differentiation to determine the type of anaërobe present.

In each of four test-tubes is placed 1 c.c. of macerated gangrenous tissue and to three tubes respectively is added 1 c.c. of each of the three antiserums. After incubation for half an hour the contents of each tube is injected respectively into one of four guinea-pigs. The one protected by the serum shows no reaction. The others die. They usually become sick in from six to twelve hours.

The various reports generally agree that intravenous injection (while not always possible) is to be preferred, in combination with deep muscular injection, proximal to, but in the vicinity of the wound.

Dosage: 5 to 15,000 units of specific or pooled serum intravenously and can be repeated in two hours if no improvement. At the same time an equal amount is given intramuscularly in divided doses. This can be repeated in twenty-four hours followed by daily injections.

Anaphylactic reactions are rare.

It is emphasized that serotherapy is entirely auxiliary, and in no way replaces operative treatment of wounds. The time of application should be as early as possible, since it is practically useless when the infection reaches the stage of septicemia.

II. GANGRENE DUE TO INDIRECT OR INTERNAL CAUSES.

(A) Gangrene Due to Injury of a Main Artery or Vein.—Wounds of large arteries give rise to symptoms that vary according to whether there is a sufficiently large wound to permit of the escape of the blood, or whether infiltration of the deeper tissues with the escaping blood takes place, with the formation of a hematoma. When one of the chief vessels of an extremity is torn, the peripheral portions of the limb become pale, cold, somewhat insensitive to pain or anesthetic. These manifestations may persist, or be evanescent. As a rule, the collateral circulation becomes rapidly established, and it is only in rare cases that gangrene follows an arterial injury, or wound, when the blood can escape externally. However, when the tissues are infiltrated

[1] Van Beuren.
[2] Bull. de l'Acad. de Méd., 1919, lxxxi, 506.

and a large hemorrhagic exudate is formed, gangrene is more frequently the issue.

According to Goodman[1] experiences gained in the Great War confirm the view that ligature of the main vessels of an extremity may lead to gangrene and that this danger may be averted in many instances by arterial suture; that the treatment of lateral and perforating wounds of the large vessels by suture in war surgery has resulted in only varying degrees of success, and that possibly the limitation of the surgical achievements is attributable in a great degree to lack of regard for details of technic.

In the Balkan War Wieting Pasha and Vollbrecht sutured wounded vessels whenever permissible, believing that the danger of gangrene is thereby considerably lessened, and that a lumen contracted by suture is better than one obliterated by ligature.

The treatment of wounds of the femoral artery is important, not only because this occurs oftener than injuries of other large arteries, but because the large caliber of this vessel makes ligation a dangerous procedure, gangrene being a possible sequel. Ligation of the superficial femoral artery is relatively well borne, while ligation of the common femoral is extremely dangerous. The appearance of gangrene as the result of ligation of the femoral has been estimated at about from 5 to 10 per cent., which figure is probably too low. Simultaneous ligation of the artery and vein is much more grave than ligation of either the artery or vein alone. Ligation of the common or superficial femoral vein is followed by gangrene in some 25 to 60 per cent. of the cases. From the practical standpoint, it is important to remember that ligation of the femoral vessels when necessitated by injury, is not free from danger, and that ligation of the common femoral is exceedingly dangerous. Therefore, it is incumbent upon us to make an attempt to suture these vessels whenever conditions are favorable.

(B) Gangrene Due to Diseases of Bloodvessels.—1. **Athero- or Arteriosclerotic Gangrene.**—The clinical picture resulting from intense arteriosclerotic disease of the vessels of the extremities, particularly of the lower extremities, is attributable to the effects of impaired or even arrested circulation in arteries whose lumina have become narrowed or completely obstructed. By virtue of proliferative changes that occur in the walls of the vessels, particularly in the intima, and because of the deposition of atheromatous and calcareous material, the lumina of the arteries become gradually narrowed, and the normal elasticity of the vessel walls becomes lost. In addition to the two factors, obstruction by hyperplastic products and loss of normal elasticity, *occlusive thrombosis* may be superadded, these three elements being responsible for the circulatory changes in the diseased arteries.

Although gangrene is the most striking and most severe termination or outcome, when the vessels of the lower extremities are afflicted with intense and extensive arteriosclerosis, the evolution of this final

[1] Surg. Gynec. and Obst., November, 1918.

stage is for the most part gradual, the affected limb passing through a number of *prodromal stages,* in which definite evidences of defective circulation can be detected. These clinical stages should be recognized and properly appreciated, for, then only can the proper prophylactic measures be instituted to delay or even prevent the development of the mortifying process. The most important of these clinical pictures are briefly the following:

CLINICAL FORMS OF ARTERIOSCLEROTIC DISEASE OF THE LOWER EXTREMITIES.—1. *Intermittent Claudication.*—This symptom-complex may be the only indication of arterial disease. Intermittent claudication may be the only manifestation of obstructive disease of the arteries, or, it may be associated with absence of pulsation in the dorsalis pedis, posterior tibial and popliteal arteries. Later on, it is overshadowed by other symptoms. *It is not to be regarded as a disease per se, but as one of the manifestations of a number of diseases in which the arteries of the lower extremities are narrowed or obliterated.*

2. *Intermittent Claudication with other Evidences of Arrested or Impaired Arterial Circulation.*—Such other phenomena are ischemia on elevation, possibly also erythromelia or reactionary erythromelia, attended in some instances with coldness and paresthesiæ.

3. *Cases Without Trophic Disorders.*—Pallor of the foot in the horizontal position, or increased pallor on elevation; and moderate or fairly marked hyperemia, rubor or erythromelia in the dependent position with absence of pulses, may be associated with coldness or occasional cyanosis, in patients who may or may not have had symptoms of intermittent claudication.

4. *Cases with Trophic Disorders.*—In cases with intermittent claudication, ischemia on elevation, rubor, coldness, paresthesia, absent pulses in certain vessels, *trophic disturbances* in the form of ulcers may develop slowly or suddenly after exposure to cold or some other insult.

5. *Chronic Cases with Inability to Walk.*—These may have been preceded by intermittent claudication. There gradually develops chronic rubor, inability to walk, with pain in the foot. The usual signs of impaired circulation can be elicited. In short, the picture is that of chronic erythromelia, sometimes with edema, without trophic disturbances, but with moderate or even intense pain.

6. *Cases with Attacks of Thrombosis.*—With any of the above pictures or preceded merely by indefinite history of intermittent claudication, sudden thrombosis may occur in some of the larger vessels, giving rise to the following symptom-complex. The patient will be attacked by sudden pain in the calf or in the foot, with inability to walk, and with pallor and coldness of the forepart of the foot. On examination, the blanching is seen to be intense upon elevation, the dorsalis pedis and posterior tibial arteries may be pulseless, while the vessels of the other leg are pulsating. After a variable period of time, gangrene may set in, or indolent trophic disorders may develop. In other cases a condition of *chronic rubor* may result, with gradual return of circulation,

the usual physical signs of impoverished circulation persisting. Careful treatment instituted at the very inception of the thrombotic attack, may ward off threatening gangrene.

In short, the prodromal signs of gangrene, namely, symptoms that may precede by days, months or years, the development of the mortifying process are in the main: intermittent claudication, paresthesia, pallor, coldness, pain, chronic rubor (erythromelia) in the horizontal and dependent position, attacks of thrombosis, blanching in the elevated position of the limb or even in the horizontal position, loss of pulsation in the dorsalis pedis and posterior tibial, sometimes in the popliteal, more rarely in the femoral arteries, development of trophic disturbances such as ulcers, fissures, impaired nail growth, atrophic skin and edema.

Trophic Disturbances and Gangrene.—It is important to distinguish between the two large groups of tissue disintegration, which result from imperfect and arrested circulation: (1) *trophic disturbances,* and (2) *gangrene.*

1. *Trophic Disturbances in Arteriosclerosis.*—Trophic disturbances include all manifestations of impaired nutrition of the skin and its adnexa, and may develop months or years before gangrene is established. They occur much less frequently in arteriosclerosis than in thrombo-angiitis obliterans.

The skin may be atrophic or withered, and the nails may show evidence of impaired growth. Ulcers at the tips of, or between the toes, the sequelæ of abrasions or small wounds, are occasionally found. More rarely, punched out indolent ulcers over the dorsum of the foot, or over the lower half of the leg, may be complications of attacks of extensive thrombosis.

Small bullæ, the precursors or prodromal signs of small patches of gangrene, may lead to ulcers or to the separation of a nail. They may heal, or may lead to extensive gangrene. Perforating ulcers more often attend the diabetic cases of arteriosclerosis, and are to be found most frequently in the plantar aspect of the foot. They are chronic in their course, and often associated with deep necrosis and suppuration. When they involve the toes, they lead to necrosis of bone. The toe may become enormously enlarged. A granulating strawberry-like wound may be formed, which lies at the orifice of a tract leading down to dead bone.

A bunion at the metatarsophalangeal joint of the great and fifth toes, not infrequently affords a good nidus for an ulcer which almost always leads to necrosis of the underlying bones.

Small ulcers of the perforating variety, near the base of a toe, often represent the orifice of penetrating abscesses, the necrotic and suppurative process extending along the tendons and bone, and causing necrosis of bone for a considerable distance beyond the site of the wound.

In the case of the *upper extremities,* trophic disorders associated with arteriosclerosis are very rare, and their presence should, therefore, suggest either the existence of thrombo-angiitis obliterans, vasomotor disease, or other neuropathic cause. Gangrene, too, of the upper extremities is exceedingly rare, though a symptom-complex comparable to intermittent claudication in the lower extremities is occasionally encountered. In rare cases there may be intense rubor of the hand. The radial artery may fail to pulsate and can be palpated as a rigid cord. *X*-ray examination will reveal intensely calcified arteries, or at least calcareous deposits along the course of the larger vessels.

2. *Arteriosclerotic Gangrene.*—Although it is most commonly seen in the aged and, therefore, has been termed *senile gangrene* (chronic or Pott's gangrene), it may also afflict younger individuals between the ages of forty or fifty, when the atherosclerosis is precocious in development, or when a secondary thrombosis occurs early in the disease. In most instances dry gangrene develops. In some, however, we may see the moist type or combinations of the two.

Dry gangrene in arteriosclerosis usually involves the toes, the big toe being the site of predilection. Or, there may be multiple areas of gangrene involving the peripheral parts, and in the more severe cases, extensive dry gangrene of the greater portion of the foot may be expected. The process may be a slow one, the toes being spontaneously amputated or removed by operation. The extent of the gangrene cannot be exactly estimated in the atherosclerotic and diabetic cases, from the external appearances, nor from the line of demarcation when it is present. For, if such an amputated limb be dissected, extensive, widespread sloughing of the deeper tissues with necrosis of bone extending for a considerable distance beyond or above the apparent line of limitation will often be revealed. It is incumbent upon us, therefore, in every case to make an *x*-ray examination of the foot, as this may demonstrate that the destruction has implicated tissues beyond the zone of skin involvement.

Where infection is superadded, the usual signs of phlegmon formation or lymphangitis will be in evidence. The suppurative inflammation will spread into the healthy tissues from the site of the gangrene, either in acute fashion, or subacutely without causing any considerable rise of temperature, but evoking intense pain.

Moist Gangrene.—Early evidences of threatening gangrene will be intense cyanosis, coldness of the affected part, usually the toe, and the appearance of a hemorrhagic bleb or a number of blebs filled with pinkish serum (Plate II). The part will have a dark-bluish or purplish appearance, or even angry red where the epidermis becomes lifted off (Plate III). In the immediate neighborhood, there will be ecchymoses over smaller or larger areas, and edema with exquisite tenderness just above the mortifying tissues. Where there is infection, the typical signs of lymphangitis usually following the course of the internal saphenous vein will be encountered.

In some cases there will develop spontaneously a number of large bullæ over the toes or dorsum of the foot, and in these clear or bloody serum alone will collect. This is the early stage of moist gangrene.

As the gangrenous process extends, all those changes that have been previously cited and described under moist gangrene will make their appearance. If infection occurs, the phlegmonous process is more rapid and intense than in the case of dry gangrene, and particularly in diabetic cases will the resistance on the part of the body be inadequate, and the inflammatory process difficult to check.

Clinical Course in Athero- or Arteriosclerotic Disease.—Although the variations from the given types are manifold, and it is, therefore, impossible to recount all the various types of clinical course, the following summaries include the most common: Many patients have intermittent claudication and pain on walking for a long time, then develop coldness of the toes or of the whole foot, paresthesia, but rather rarely are afflicted with ulcers or other signs of trophic disturbance so characteristic for the disease, thrombo-angiitis obliterans. They may have attacks of thrombosis, complicated with ulcers or patches of gangrene, or such attacks may be followed by healing and a state of chronic erythromelia with discomfort and some disability in the affected leg; or, practically all symptoms may be absent until after some insult, traumatism or cold, or without cause a patch of dry or moist gangrene develops. In a number of cases, particularly in the diabetic, a perforating ulcer brings the patient to our notice, and this is complicated by necrosis of bone and the usual signs of deep infection. Many patients complain only of disability, particularly difficulty in walking. Some develop an ulcer of the nail-bed with a patch of dry gangrene that heals. Others never develop gangrene, but the signs of insufficiency of circulation are manifest if the limbs be examined, as blanching on elevation, slight erythromelia, and absence of pulsation are regularly present.

When gangrene develops, usually of the dry variety, the onset is often ascribed to some previous injury, the paring of a corn, the wearing of too tight a shoe, exposure to cold, a bruise or the application of some strong medicament. The big toe is usually the first to be involved. Its tip or the whole of it becomes dusky red or purple, gradually becoming purplish-black. These changes in color and evidences of mortification are attended with intense pain in the affected region and in the foot. If the gangrene remains dry and no infection takes place, mummification ensues, the toe becoming dry and shrivelled, into a hard black mass. This, however, may be associated, as referred to above, with necrosis and suppuration in the depth. A line of demarcation may form, or gangrene may spread, depending upon the presence or absence of infection, the resistance of the tissues and the condition of the arteries.

Arteriosclerotic Gangrene with Thrombosis.—Sudden thrombosis or extension of old thrombotic process in arteriosclerosis must be regarded properly as being a complication of extensive arteriosclerotic or atherosclerotic disease of the vessels of the lower extremities. If we study the pathological findings in the arteries of legs amputated for gangrene, and compare these with the clinical history, we will note the following causes for gangrene in athero- and arteriosclerosis: (1) That the circulatory inadequacy or insufficiency is partly due to the loss of elasticity in the vessels, partly to concentric diminution of the lumina of the vessels through atheroma, thickening of the intima, and calcification; (2) that these stages are not sufficient to account for the sudden advent of gangrene in some cases, nor can other causes, such as cardiac weakness and trauma alone, be considered sufficient as immediate causes. But there is a distinct pathological cause in the occlusion produced by sudden thrombus formation. This usually occurs in the popliteal artery and extends upward into the femoral, more frequently passing downward into the posterior tibial artery. Histological examination of the femoral, popliteal and posterior tibial arteries in such cases has demonstrated conclusively the importance of the role of thrombosis in the causation of the gangrene, the thrombus having been found in various stages of organization, depending upon its age, that is, upon the time that has elapsed between the time of its formation and the time of amputation of the limb.

Clinical History.—There is usually a previous history in elderly individuals (over forty-five years of age) of intermittent claudication, or indefinite pains in the lower extremities, particularly in one limb. Suddenly, the patient will develop the following symptoms: trophic disturbances terminating in gangrene of small extent (one toe or more); or, dry gangrene of a toe or toes, the foot, or portion of a leg; or, extensive moist gangrene. In other cases the signs of sudden impairment of circulation due to thrombosis of the popliteal or femoral arteries make themselves manifest without the development of ulcer or gangrene. These are sudden pain in the calf of the leg or foot, attended with paresthesia, coldness, pallor and weakness of the limb. Examination reveals absence of pulsation in the dorsalis pedis, posterior tibial, possibly also in the popliteal arteries, pallor of the foot, slight erythromelia on depression of the limb, at times thrombosed veins, particularly the external saphenous. Hemorrhagic areas and cyanotic patches suggestive of impending gangrene may also appear. Improvement in circulation may then take place, so that the limb gradually becomes warm, the pallor and cyanosis disappear, a state of chronic erythromelia (rubor) being usually the manifestation of improved circulatory conditions. Sooner or later, however, even such cases may have fresh attacks of thrombosis leading to gangrene.

Pathology.—A study of the vessels in such cases has shown either recent organizing thrombi in the popliteal artery, or a combination of these clots with old organized clots, the recent thrombosis extending for a variable distance downward into the posterior tibial artery. From the observations on the conditions of the arteries, it seems that extensive obturation due to atherosclerosis, atheroma, etc., and old thrombosis in the popliteal artery may be compatible with fairly good circulation of the limb. But when an additional extensive recent thrombosis takes place, or when extraneous causes (cold, cardiac weakness, etc.) are added, the limb succumbs to the mortifying process.

Arteriosclerotic Gangrene with Diabetes.—This should not properly be classed as a distinct form of gangrene (so-called diabetic gangrene), inasmuch as the pathology is the same as that of arteriosclerotic gangrene. The mortifying process cannot be regarded as being due to the diabetes, but as the result of extensive arterial obliteration. The disease may take a course somewhat different from simple arteriosclerosis, because of the presence of the complicating diabetes. The symptomatology may be identical with that discussed under arteriosclerotic gangrene, or may be modified after trophic disorders and gangrene have definitely developed by the presence of hyperglycemia.

When ulcers are present, a phlegmonous process is more apt to ensue with the trophic disorders as the starting point. Necrosis of the deeper tissues is likely to be more extensive, and moist gangrene is more frequently seen. As far as the changes in the arteries are concerned, these are identical with those of arteriosclerotic gangrene, and the calcification and atheroma are usually intense.

Cases of diabetes in elderly people with fairly marked arteriosclerosis may present none or very few of the typical signs of impaired circulation, and still may develop patches of gangrene. Such gangrene usually eventuates after traumatism, thermal or mechanical. The development of a gangrenous patch over the shin bone after an abrasion, or after careless rubbing, scratching or massage is common. The abrasion, scratch or burn becomes converted into a small area of dry gangrene, involving merely the skin, rarely the subcutaneous alveolar tissues.

On examination it will be found that blanching on elevation is absent. Erythromelia or reactionary erythromelia is also absent. The dorsalis pedis and popliteal may pulsate. The general color of the limb is good. In short, there are none of the usual manifestations of circulatory deficiency, and yet gangrene occurs.

These are the cases in which inadequacy of circulation is not sufficiently great to produce the definite objective phenomena of vascular obturation, so characteristic in the peripheral parts. And still the narrowing and rigidity of the arteries, coupled with the presence of the metabolic deficiencies due to the diabetes are sufficient to lead to gangrene of the tissues upon the mere action of a trifling trauma. The prognosis in these cases is usually good if treatment be directed toward the diabetes, if infection be prevented by giving free exit to pus, when it collects under the gangrenous patches of the skin, and if the author's "Postural Method of Treatment" be employed (p. 811) together with other methods for enhancing the circulation.

Pathology.—We have grouped both the arteriosclerotic and diabetic cases together, for the pathology of the vessels is the same. A study of the condition of the arteries and veins in limbs amputated for so-called diabetic gangrene reveals the fact that in each and every instance we are dealing not with a gangrenous process due to the diabetes *per se*, but a mortifying process dependent upon extensive arterial disease.

In both arteriosclerotic and diabetic cases there is an extensive and intense athero- or arteriosclerotic process. In some cases there is *marked occlusion* due to the heaping up of atheromatous and calcific material, or to a combination of this process and secondary thrombosis, or a moderate degree of atherosclerosis with obturating thrombosis. These cases may be grouped under the caption *intense, obturating atherosclerotic process.* In another series of cases we find that, although very few of the vessels are completely closed, the atherosclerotic process is very extensive and intense, making the vascular walls rigid, or producing a dilatation or pouching of the walls of many vessels. Both of these lesions will have as their sequence impaired nutrition of the parts, by virtue of the loss of elasticity in the arterial walls. This type may be grouped under the caption *atherosclerosis with slight or no occlusion.*

Common to both types, the diabetic and arteriosclerotic, is the fact that the larger veins are but moderately involved, although they may have suffered a moderate degree of endarteritis or thickening of the intima.

The arterial lesions may be summed up as follows: extensive degeneration of the arterial walls, intense atherosclerosis, calcification, sometimes bone formation, often occlusion of a large part of a vessel's course, the arteries being converted into rigid pipestems; at other times, less pronounced atherosclerosis with dilatation of the vessel walls in places or a combination of intense atherosclerosis with thrombosis. A reference to Fig. 503 will show the nature of the occlusive process in some of the cases of diabetic and arteriosclerotic gangrene. The elastic tissue stains show a proliferation and heaping up of the elastic layers or lamellæ and that the remnant of the lumen may be occluded by organized clot. Another type of lesion is that in which marked calcification of the vessel walls takes place, sometimes attended with bone formation.

Diagnosis.—Except for the rare cases developing at a relatively early age (forty to fifty-five), the advanced age of the patient is significant. The history of intermittent claudication, the absence of arterial pulsation, evidences of defective local nutrition, the development of trophic disorders, the blanching of the foot on elevation with occasional rubor, in the pendent position, the presence of distinct calcareous vessels in the roentgen picture, and finally, the development of trophic disorders followed or attended by severe pain or gangrene are the chief points to be relied upon for a diagnosis.

Although the chief clinical features of the disease, thrombo-angiitis obliterans will be discussed later (see p. 787), the following differential points may be noted here: (1) The symptoms in thrombo-angiitis obliterans, as far as the development of gangrene is concerned, are apt to come on much more slowly, the prodromal symptoms or signs lasting for weeks, many months or even years. (2) Blanching and erythromelia (rubor) are not so regularly present in arteriosclerotic and diabetic cases, and if present, are usually not so marked. (3) Gangrene may in either instance cover a small area at the beginning and slowly advance, but in arteriosclerosis and diabetic cases its advance is apt to be more rapid. Moist gangrene is less apt to occur in thrombo-angiitis obliterans. (4) Alteration in the outward appearance of the limb in arteriosclerosis may be almost imperceptible before trophic disorders and gangrene develop, whereas in thrombo-angiitis obliterans the distinct evidences of the disease make their appearance many months previously. (5) The absence of migrating phlebitis, phlebitic nodosities, so typical of thrombo-angiitis obliterans is of differential value. (6) The occurrence of gangrene of the upper extremities is extremely rare in arteriosclerosis, relatively common in thrombo-angiitis obliterans. (7) Racial (Hebrews) and sex (male) predilection, so typical of thrombo-angiitis obliterans, does not obtain in arteriosclerosis.

Prognosis.—In arteriosclerotic gangrene the prognosis is usually grave. In general, the outlook will be favored by age (the older the patient, the more dubious the chances) and the general systemic condition. When extensive thrombosis is absent, threatening gangrene may be controlled either spontaneously by rest, or with the aid of the proper therapeutic measures. Or the patient may get well with the mere loss of a phalanx or digit. Patients of very advanced age, with extremely poor circulation, must be regarded as gravely ill, for high amputation, above the knee or at the middle of the thigh, will eventually become necessary. Even this procedure when it is well borne, may be followed by continued sloughing of the skin flaps, necrosis of the exposed tissues and finally a lethal outcome.

The outlook is always bad in cases of arteriosclerotic gangrene of the diabetic type. As a rule we are dealing with patients advanced in years. The arteriosclerotic process is intense. The vitality seems to be diminished, both by virtue of the condition of the vessels, as well as by the general systemic condition of the patient. In spite of the best conservative treatment, failure to heal even a small ulcer is common, and extensive, subacute, phlegmonous formation is to be expected in many of the cases. Even when a line of demarcation has developed, the spontaneous sequestration of the part and spontaneous healing is only to be regarded with a degree of hope in those cases where but a small part is involved, such as a toe or a part of a toe. When amputation above the knee has to be performed, the danger of coma supervening is great.

This type of gangrene may be regarded as one of the least hopeful, the mortality being higher than in any other type of gangrene due to arterial disease.

Treatment.—The simple arteriosclerotic and diabetic cases may be considered together, although the special exigencies of the diabetic cases will require particular attention. Treatment includes the systemic therapy of the diabetes and generalized arteriosclerosis, and prophylactic treatment against complications. Local management comprises methods of enhancing circulation in the affected extremity, the care of trophic disorders, secondary local infection and methods of amputation.

Prophylactic Measures.—The patients with diabetes as well as those with athero- and arteriosclerosis should be given a list of rules that must be carefully observed, lest they run the chance of developing trophic disturbances and gangrene.

First, walking for great distances should be avoided, particularly if there is a history of intermittent claudication, cold extremities, previous attacks of gangrene, or trophic disorder, together with the objective findings by the physician pointing to impaired circulation, such as ischemia, pulseless vessels, or erythromelia. Second, exposure to cold, with possible frost-bite is dangerous; even moderate degrees of cold are poorly borne. Third, the wearing of tight shoes should be carefully shunned. Wherever possible, a sojourn in a warm climate will be found beneficial. Fourth, all manipulations, such as cutting corns, callouses, ingrown toe-nails, bunions, should be left to a physician or surgeon, for the very beginning of trouble is often traceable to the manipulations of a pedicure. Fifth, the smallest injury should be scrupulously cared for by a competent surgeon. Sixth, daily cleansing of the feet, with more than ordinary care, and the use of sterile dusting powder should be insisted upon. Seventh, tobacco and alcohol should be indulged in with great moderation, or not at all. Eighth, diabetes, if present, should be treated according to present-day methods with a view to making the patient free of acetone and diacetic acid and reducing the sugar content of the blood.

Methods of Improving the Circulation.—This includes (1) the author's postural treatment; (2) the hot air treatment; (3) the diathermic treatment; (4) the heat of electric lamp; (5) the thermophore.

All these methods may be given a trial. They are described under the section of thrombo-angiitis obliterans. They are not applicable, however, in all cases and only experience can teach us what the best methods may be in any given case.

The *postural treatment* (see page 811), which consists in the induction of a reactionary hyperemia in the affected part by preliminary elevation of the leg, followed by depression of the limb in a dependent position, may be used with some benefit in almost all cases, except where gangrene has already become extensive, where a phlegmon has developed, or where such change of position is too painful to the patient. When recent extensive thrombosis has taken place, it is also contraindicated.

Hot air treatment must be very carefully applied; and should exclude the part affected by trophic disturbances or gangrene. The temperature should be gradually elevated, being no higher than 125° to 150° F. at the beginning of treatment and raised no higher than 220°. Séances of fifteen to thirty minutes twice a day have given good results. Great care must be exercised in the use of hot air to avoid burning the patient, since dire results may follow such additional insult to the already damaged part. Here, too, in the presence of extensive gangrene, phlegmon formation, attacks of acute or recent thrombosis with threatened dry gangrene of a large portion of a limb, this method is contraindicated.

The application of heat by means of special lamps will be useful where a hot air apparatus is not obtainable. So also an electric thermophore is a valuable aid to other methods of treatment, and should be wrapped around the thigh and leg over a flannel bandage, the temperature being controlled by a thermometer.

The diathermic treatment may be tried in the arteriosclerotic and diabetic cases, if thrombophlebitis, extensive gangrene, phlegmon, ulcer and infection are not present. It is, therefore, limited in its usefulness to those early cases in which symptoms of intermittent claudication are present together with threatened trophic disorders and gangrene, without actual gangrene or ulceration.

Treatment of Trophic Disorders and Gangrene.—This includes, (1) all those conservative measures which have for their purpose the attempts to heal trophic disorders, such as ulcer, infections and gangrene of small extent; and (2) methods of amputation.

Wherever possible, particularly in cases of arteriosclerotic gangrene complicated with diabetes, every effort should be made to prevent extension of the local process, and to bring about a cure without amputation. Absolute rest and strict asepsis are essential. Where dry gangrene is present, diligent attention to cleanliness of the part, sponging with weak alcohol, powdering with dermatol or bismuth subnitrate, are measures that are indicated until sequestration or demarcation begins. Where sloughs are present, no attempts should be made to separate these artificially unless this can be done without causing bleeding. Where infection is present, daily baths of warm saline solution from fifteen to twenty minutes twice or thrice daily, followed by sponging with weak alcohol over the intact skin, and then the application of wet dressings (liquor Burrowi 1 part, glycerin 2 parts, water 3 parts) changed twice or three times daily, and kept moist without the use of impervious rubber tissue or other means will tend to accelerate the separation of sloughs and limit the inflammatory process. Incisions must be made whenever there is an extension of the phlegmonous process, nitrous oxide gas, or nitrous oxide with oxygen being administered for this purpose. Local anesthesia should not be used under any circumstances. When a toe or a small part has become sufficiently loosened, the part may be removed under nitrous oxide gas. Or, when the gangrene is limited to one toe, or more, and the pain becomes too great to bear, the removal of one or more toes under nitrous oxide gas is indicated.

Amputation.—Indication for amputation will depend upon whether conservative measures are successful or not, upon the general condition of the patient, and on the severity of the pain. It will, furthermore, be influenced by the rapidity with which the gangrene extends, and by the presence of very extensive phlegmon, which will not become arrested by conservative incision.

There seems to be no unanimity of opinion regarding just where and when to amputate in cases of this sort. In general we may say that when conservative treatment has failed, which includes methods of enhancing circulation, conservative incisions, dressings, amputation of small extent, and when gangrene shows evidence of progression, no line of demarcation forming, and the suppurative process threatens the patient, amputation above the knee, preferably at the lower third or middle is to be performed. This should be done under nitrous oxide anesthesia, by the circular method, the aperiosteal method of amputation being preferred. The femur should be cut high enough so as to avoid the production of a conical stump when the flap retracts. Since we may expect slight sloughing of the periphery of the flap even in favorable cases, it is wise to make provision for this in advance. The wound should be left fairly wide open, although several catgut sutures may be placed into the muscles to bring them together and control bleeding. Sterile adhesive plaster may be employed to approximate the edges of the flap loosely, wide drainage until granulations have formed, giving the best results.

Thrombo-angiitis obliterans[1] is a clinical and pathological entity which has been, and is still, incorrectly called "endarteritis obliterans" by many authors. The names, presenile, infantile and juvenile gangrene have also been applied to it.

At the onset, thrombo-angiitis obliterans is essentially an inflammatory process, involving particularly the deeply situated and larger arteries and veins of the *lower* or *upper* extremities. Almost immediately after the inception of the lesion, there follows extensive occlusive thrombosis, that subsequently gives way to a stage of healing or organization, the final result being the complete closure of arteries and veins over a large extent of their course by vascularized and canalized connective tissue. Although no extensive study has been made of thrombo-angiitis in the vascular domain outside of the extremities, the typical lesions have been observed by Buerger in the spermatic vessels, and according to Murphy, are said to occur in the renal vessels.

Characteristic is the involvement of the superficial veins of the lower and upper extremities in the form of a *migrating* or *thrombophlebitis* in about 20 to 25 per cent. of the cases. It is in this territory that the most thorough and reliable investigations on pathology can be made, as the lesions in the vessels then become accessible at the very onset of the malady before the effects of organization and healing have confused the histological picture.

Clinical Symptoms.—The disease manifests itself in most instances with indefinite pains in the sole of one foot (usually the left) in the ankle, or in the toes, the patients being soon disturbed in their walk by these symptoms, or by the sudden onset of cramp-like sensations in the calf or elsewhere in the leg (intermittent claudication). These feelings make the patients take frequent rests, often inducing them to investigate the condition of their limbs. Some take off their shoes and rub the part in the hope of dispelling the pains or banishing the uncomfortable numbness of the toes and feet; others say that the feet become

[1] This name was suggested in 1908 by the author for this interesting and remarkable disease and has been very generally accepted in the United States.

cold and numb when the temperature is low and the weather is inclement. After the lapse of weeks, months or even years, evidences of *trophic disturbances* make their appearance. Following the cutting of a nail, or without apparent cause, an abraded spot or hemorrhagic bleb, a pustule, or a dry, dead patch of skin develops near the tip of one of the toes or under a nail. Now the local pain becomes excruciating during the night as well as day, so that some of the sufferers beg for amputation of the affected part.

It is usually during the first attack of trophic disorder, but sometimes when only intermittent claudication is present, that the physician or patient notices another characteristic symptom, namely, a peculiar blush of the toes and forepart of the foot, sometimes extending to the ankle or slightly above, when the limb is in a pendent position (Plate V). Upon allowing the limb to hang down, the affected toe soon turns color. It assumes a bright red hue which is seen to pass to the other toes and then up the back of the foot for a variable distance. This reddening is often termed *rubor*, or may be called *erythromelia*. The elevated extremity, on the contrary, rapidly becomes blanched (ischemia). Sometimes the superficial ulcer will heal under conservative treatment and the patient will either recover perfectly or his symptoms will become chronic. At this period his limb will show the scars left by previous ulcers. The dorsalis pedis and the posterior tibial arteries usually fail to pulsate, and ischemia in the elevated position and redness of "erythromelia" in the pendent position are regularly elicited. Sooner or later, however, a patch of gangrene develops, the local pain becomes intense, and amputation will be the issue.

Because of the striking condition of redness in the dependent position, and because of the increase of local pain when the limb is hanging down, a number of clinicians have been accustomed to diagnosticate "erythromelalgia" in these patients. Some cases have been regarded as examples of Raynaud's disease, because in them the symptoms of blanching and cyanosis of the parts were prominent features. Although resembling erythromelalgia and Raynaud's disease in a number of symptoms, the clinical picture of thrombo-angiitis obliterans is so characteristic and definite, and its pathological lesions so typical in this disease, that it consitutes a distinct clinical entity.

Clinical Characteristics.—In a study of 200 cases by Buerger there was 1 in which the typical picture of thrombo-angiitis occurred in a Gentile. In 100 cases there were 76 Russians, 17 Austrians, 3 Americans (of foreign extraction), 2 Roumanians, 1 German, 1 Turkish (of Russian extraction) Hebrew. Of 100 cases there were 99 males, 1 female.

Most of the cases were heavy smokers, the average amount being almost 21 cigarettes daily. Two cases (1 male and 1 female) asserted that they had never smoked.

Limbs Affected.—In 100 cases there was a history of 171 legs having been involved. Both legs were affected in 71 cases; the right leg alone in 7 cases, the left leg alone in 22 cases. In other words, the majority of cases of thrombo-angiitis obliterans if followed for a sufficiently long period of time, will show the lesion in both lower extremities.

The upper extremities are less frequently involved. There were 21 cases with 30 arms affected. Both arms were affected in 9 cases; the right arm only in 5 cases; the left arm only in 7 cases.

Age at Onset of Disease.—The average age obtained by addition of all the cases was thirty-two years and five months. The youngest patient was seventeen years old at the age of onset, the oldest patient fifty-six. These figures, however, are much too high, since it is very difficult to estimate the exact age at which the disease began, because of the insidious nature of the onset, and the fact that the onset is overlooked in many cases.

Duration of Symptoms before Onset of Gangrene.—About one year and eight months represents the average time elapsed before gangrene appeared. In some cases the gangrene set in within a short time or almost simultaneously with the apparent onset, the longest period being twelve years after the beginning of the complaint.

Amputation.—This became necessary in 52 cases out of 100 (52 per cent.) according to the records of the periods of observation. Doubtless in many of the cases amputation became necessary at some later date, when they were no longer under observation, so that a percentage of 75 per cent. or 80 per cent. would not be too high an estimate.

Etiology.—The cause of the pathological process in thrombo-angiitis obliterans has not yet been definitely established. By his studies of the clinical aspect and pathology of the disease, Buerger has established the following facts: (1) That the disease *is not an endarteritis obliterans;* (2) that it is an occlusive thrombotic process involving the deep arteries and veins of the upper and lower extremities, or the superficial veins; that the early stages of the disease manifest themselves in an inflammatory lesion which shows a specific and characteristic morphological picture, while in the process of healing; and (3) that in the early or acute stage, certain purulent foci make their appearance that would suggest a microbial agent or infectious causative factor. No organism, however, has as yet been demonstrated, even in the superficial veins, when these are in the stage of acute inflammation.

Syphilis has been regarded by some as a possible cause, but a study of the histories and of the Wassermann tests in more than 30 cases[1] has shown that lues is not responsible.

It is a striking circumstance that of a series of 200 cases, Buerger found only 1 case in a woman, and in this patient no amputation was performed, so that the diagnosis was made on clinical signs alone.

[1] Buerger and Kaliski: Med. Rec., October 15, 1910.

Furthermore, it is interesting that but 1 case out of 200 did not belong to the Semitic race.[1]

Tobacco is probably a predisposing factor, and may be regarded at least as causing some alteration in the vessels that makes them liable to the attacks of inflammation and thrombosis. Most of the cases are heavy smokers, although smoking was denied in 1 per cent. of Buerger's cases.[2]

Classification of Thrombo-angiitis Obliterans.—For purposes of clinical diagnosis it is useful to divide the cases of thrombo-angiitis obliterans into four groups:

I. Typical thrombo-angiitis obliterans of the lower extremities.

II. Thrombo-angiitis obliterans with associated thrombophlebitis or migrating phlebitis.

III. Thrombo-angiitis obliterans with involvement of the upper extremities.

IV. Thrombo-angiitis obliterans with secondary or complicating athero- or arteriosclerosis.

It must be remembered, however, that this grouping is artificial, for many cases may belong to one or more of these subdivisions at the same time. Thus, cases in group I may be affected with migrating phlebitis, or may have symptoms of thrombo-angiitis obliterans of the upper extremities. The classification is helpful for description and study.

For purposes of treatment it is often useful to divide the cases according to the stage of the development of symptoms at the time of clinical observation, into:

1. The prodromal stage, that of intermittent claudication (sometimes with migrating phlebitis.)
2. The stage of trophic disorders and gangrene.

I. **Typical Thrombo-angiitis Obliterans of the Lower Extremities.**—The clinical picture varies considerably, depending upon the duration of the disease when the patient is examined, the severity of the disease, the effects of exposure, traumatism and complications. The following case types may facilitate the recognition of the disease, although they must not be considered as exhaustive. They should be recognized, since they are in most instances but the prodromal manifestations of gangrene.

1. Symptoms of intermittent claudication, namely, pain in the calf of the leg or in the foot, made worse by exercise and walking, may last for a variable period of time, and then distinct rubor or erythromelia develops, the picture being a combination of these two chief symptoms.

2. Symptoms of intermittent claudication may predominate for long periods, may remain unrecognized, but should be regarded with suspicion if they are accompanied by blanching of the foot upon eleva-

[1] Since writing the above three additional cases among non-Semitic races were encountered.

[2] Since this observation (1916) was made several additional cases in non-smokers have been observed (1920).

tion, rubor upon depression of the foot after elevation, and loss of pulsation in the dorsalis pedis, possibly posterior tibial, or both, or even the popliteal arteries.

3. Symptoms of pain or intermittent claudication may give way after a variable time to trophic disturbances, ulcers, fissures, hemorrhagic blebs, scaling of the skin, etc., but when these are present, the typical phenomena elicited by physical examination are regularly to be found.

4. Thrombo-angiitis obliterans may develop silently in one limb without symptoms, indefinite signs of pain, indefinite intermittent claudication having been present and having been unnoticed or undiagnosticated, being only elicited when the patient seeks advice for characteristic symptoms of thrombo-angiitis obliterans in the other limb. Physical examination will reveal absence of pulses in one or both limbs.

5. The symptoms of thrombo-angiitis obliterans may develop in an orderly and typical sequence, namely, (1) stage of indefinite pains or intermittent claudication; (2) stage of rubor or erythromelia with absent pulsations, ischemia on elevation; (3) a stage of trophic disorder; finally a stage of gangrene.

6. Cases may pass through any of these stages and the progress of the disease may become arrested spontaneously, or with treatment. Those in which the signs of intermittent claudication and pain alone have developed will regularly show upon examination the ischemia on elevation, or at least some reactionary erythromelia, absent pulses in at least one of the larger peripheral vessels, such as the dorsalis pedis and posterior tibial, or often both. When the disease comes to a standstill, the subjective symptoms disappear, but the objective may persist for a long time, *i. e.*, the ischemia on elevation, the absent pulses and the erythromelia. In some of these, however, even the ischemia and the reactionary erythromelia may become absent, the pulseless vessels alone remaining as indications of the disease. When erythromelia becomes marked, it is likely to persist for a long time, even after the disease is spontaneously arrested, or apparently cured by treatment.

When trophic disorders develop, the pain is wont to become severe. Ulcers may spontaneously heal; the pain may leave the patient; the intermittent claudication may abate; the ischemia and erythromelia being the last phenomena to disappear.

Those patients with gangrene who become spontaneously cured, pass through the same stages as indicated above, the typical stages of mortification involving as a rule only small portions of a toe, or a toe being followed by a long period of convalescence lasting months or even years, resulting finally in cure. In these, too, the pulseless vessels, erythromelia persisting for a long time, will tell the tale.

7. *The Chronic or Incurable Cases.*—These are common, the disease in most instances being a progressive one. The advent of the various stages, although often delayed may be expected to develop. In the chronically progressive type, amputation may become necessary,

either in a stage of trophic disorder, or in a stage of gangrene. The pain may be so excruciating that sleep is impossible, amputation finally being the last resort, even though the lesions are merely those of ulceration with or without infection; or the control of pain in cases of gangrene may also be impossible, amputation being the only method of obtaining relief.

8. Cases in which any of the above symptoms, or symptom-complex may affect first one lower extremity, then the other, possibly abating in the extremity first involved, and making more marked progress in the other. There are cases in which one or both lower extremities are involved, and in the further course of the disease one or both upper extremities also give manifestations of the same affection. These will be considered under the group, Thrombo-angiitis Obliterans of the Upper Extremities.

9. *Fulminating Cases.*—Although the regular course of the disease is a chronic, progressive one with a long prodromal period, there are cases in which (according to the histories) very rapid development of gangrene can take place. It is possible that the prodromal phenomena were unnoticed, being of slight degree, or developing insidiously. In these patients coldness of the foot and pain in the toes may be the first symptoms, leading rapidly to areas of mortification.

II. **Thrombo-angiitis Obliterans with Migrating Phlebitis.**—One of the associated characteristic phenomena in about 20 to 25 per cent. of the cases of thrombo-angiitis obliterans is a lesion variously called migrating phlebitis or thrombophlebitis, affecting the superficial veins of the extremities. Attacks of thrombophlebitis may occur during any period of the disease, and may even be the prodromal signs or precursors, manifesting themselves long before definite signs of involvement of the deep vessels are apparent.

Usually along the course of the internal or the external saphenous vein, sometimes over the dorsum of the foot, frequently along the inner border, and sometimes along the course of the internal saphenous of the thigh, and more rarely involving the median cephalic or ulnar veins or their tributaries, the signs of occlusive, acute thrombophlebitis make their appearance.

The characteristic clinical lesions are of two types. One of these appears in the form of small indurated areas, a centimeter or slightly more or less in diameter, red and tender, phlebitic nodules, consisting of thrombosed venules with periphlebitic inflammation. Since these thromboses occur directly under the skin, the skin appears to be attached, and as the lesions heal, slight retraction occurs. After a week or more, the tenderness may diminish, but the nodules may persist for several weeks or even a month or more.

The second type of lesion is a typical inflammatory thrombosis of portions of superficial veins, the process frequently starting in the periphery and ascending, although it may skip certain territories, or appear simultaneously in the upper and lower parts of the leg or even in the thigh. Such attacks of thrombophlebitis have a tendency to recur and may last for a year or more. Sooner or later, the typical associated phenomena of thrombo-angiitis obliterans, even when not discovered by the patient, should not fail to be revealed on physical examination.

Pathological examinations of such thrombosed and inflamed veins, when they are exsected and submitted to histological studies, giving the acute symptoms, have shown *a specific type of lesion* which is identical with that found in the deeper vessels affected with thrombo-angiitis obliterans, when these are in the so-called "acute" stage of the disease. A description of the lesions will be given under the section on Pathology.

Thrombo-angiitis obliterans attended with thrombophlebitis may be divided into five groups:

1. *Thrombophlebitis without Symptoms.*—There are patients who have no knowledge of the occurrence of the trouble in the veins of the leg, but in whose amputated limbs extensive, old, or old and recent thrombophlebitis of the internal saphenous or its tributaries is discovered.

2. *Thrombophlebitis with Symptoms of Limited Vein Involvement.*—In this group belong the cases of thrombo-angeitis obliterans who seek relief for active and acute thrombophlebitis, and periphlebitic manifestations. They have tender, red, slightly indurated patches that correspond to the tributaries of the saphenous vein, and they have other typical signs of thrombo-angiitis obliterans.

3. *Migrating Phlebitis Causing the Patient to Seek Treatment.*—When the attacks of migrating phlebitis make their appearance early in the history of the case, and when the attendant discomfort and pain are sufficiently great, then the symptoms belonging to the true deep-rooted affection, thrombo-angiitis obliterans are sometimes wholly ignored by the patient and remain undiscovered by the physician. Medical advice is sought only for the "lumps" and "hard, tender strands" or "cords" that are oftentimes so disturbing.

4. *Cases in which both migrating phlebitis and thrombo-angiitis play equally important roles in the symptom-complex.*

5. *Cases in which Migrating Phlebitis Involves both the Upper and Lower Extremities.*

From the *diagnostic standpoint* the association of the migrating phlebitis is of twofold importance: (1) Because the resection of portions of such veins during the acute stage with subsequent examination under the microscope will throw light upon the presence of associated thrombo-angiitis obliterans, and (2) the presence of the lesion should suggest careful examination for the presence of the usual typical signs of thrombo-angiitis obliterans. All the more so, since the thrombophlebitis process may precede by months or even years the evidence or signs of the deep-rooted affection.

III. **Thrombo-angiitis Obliterans with Involvement of the Upper Extremities.**—The recognition of thrombo-angiitis obliterans when it affects the upper extremities is important, since it is here that the disease may manifest itself particularly with vasomotor phenomena. For this reason, the malady is often confounded with Raynaud's disease or even sclerodactyly.

The upper extremities may be clinically involved in the following ways: (1) without subjective symptoms; (2) with vasomotor symptoms predominating; (3) with trophic disturbances alone; (4) with gangrene of slight extent; (5) with extensive gangrene threatening the viability of the extremity; (6) with extensive atrophy of the hand and forearm; (7) with changes simulating scleroderma and sclerodactyly.

1. *Thrombo-angiitis Obliterans of the Upper Extremities without Symptoms.*—Just as in thrombo-angiitis of the lower extremities, there are cases in which the radial or ulnar artery or both, become gradually closed without the patient's experiencing any noticeable symptoms. In some instances, absence of pulsation may be discovered during a routine physical examination; in others, where symptoms are present in the lower extremities, investigation of the radial and ulnar vessels will demonstrate their occlusion.

2. *Cases in which Vasomotor Phenomena Predominate.*—In these the symptoms of Raynaud's disease may be closely mimicked. After a history of intermittent claudication or migrating phlebitis or typical thrombo-angiitis obliterans, one hand may become affected with the following symptoms: sudden pallor in cold weather followed by cyanosis, often relieved by warmth. Later, trophic changes may develop with the formation of scales or small gangrenous patches. Physical examination shows one or more fingers very cold to the touch, and the radial and ulnar arteries still pulsating. In other cases, the vasomotor phenomena are still more marked; both hands may become cyanotic, the color changing while the patient is under observation, bright red or crimson colored spots appearing, scattered in the midst of a general blue. Some of the fingers are cold, but the arteries pulsate. Both of these types of cases may be found in the vasomotor stage of thrombo-angeitis obliterans of the upper extremities.

3. *Cases with Trophic Disorders Only.*—In some patients, distinctive signs of an affection of the upper extremities manifest themselves as trophic disturbances not extensive enough to lead to gangrene. The disease may be wholly overlooked by the patient, and when the lesion has healed, it may be subsequently referred to by him as a slight "sore" or "ulcer" developing without cause. Were it not for the presence of the disease in the lower extremities and for the changes in the radial pulse, the nature of the trophic disorders would be difficult of solution.

4. *Cases with Gangrene of Slight Extent.*—Not a small number of the patients that suffer with occlusion of the vessels of the upper extremities come to us with a history of having had pain in the tip of one of the fingers for a considerable time. This is followed by a change in the color of the skin, usually reddening of the tip of the fingers, as if it were inflamed. Later, there develops a sore or the skin changes color and becomes gangrenous, usually at the tip of a finger, although the lateral margin of the finger may be the first affected (Fig. 497).

5. *Extensive Gangrene Threatening the Viability of the Extremity.*—In such cases the symptoms of involvement of the upper extremities can be compared to those of the lower. There is a history of coldness and pallor of one or more fingers with the development of an ulcer or a patch of gangrene. Now the pain becomes severe, and the gangrene rapidly extends. The radial artery may be felt as a hard cord, or both the radial and ulnar are pulseless. The appearance of the typical thrombo-angiitis obliterans symptoms in the lower extremities may follow those of the upper, although the rule is just the reverse.

Fig. 497.—Loss of phalanges in thrombo-angiitis obliterans of the upper extremities.

6. *Cases Simulating Scleroderma and Sclerodactyly.*—Perhaps most interesting of all are those cases in which the vascular occlusion has led, by virtue of the effects of malnutrition to a condition of dystrophy or atrophy, the clinical picture being akin to that of sclerodactyly. The fingers have the typical appearance of the skin in scleroderma. Motion of the distal phalangeal joints is markedly impaired in extent. The skin is atrophic and dry and the circumference of the fingers is distinctly diminished. Both the radial and brachial pulses are absent. The brachial artery may be felt as a hard cord.

Collecting the cases in which vasomotor symptoms predominate, we have, on the one hand, those in which the symptoms of thrombo-angiitis obliterans of the lower extremities are well marked, and on the other hand, those in which we are compelled to investigate very carefully in order to elicit evidences of vascular occlusion.

The symptoms simulating Raynaud's disease and acro-asphyxia are cyanosis of the finger tips, coldness of the fingers with or without trophic disturbances, and alternating cyanosis and rubor, involving the fingers or the whole hand. Rather characteristic in the symptomatology of thrombo-angiitis is the apparent dependency of the vasomotor symptoms upon variations in temperature, the chronicity of the manifestations, the absence of pain in some of the cases, and the absence of paroxysmal nature of the attacks so characteristic in Raynaud's disease.

In those patients in whom the trophic disturbances seem to be unassociated with evidence of vasoconstriction and vasodilatation there is merely a history of the development of a spontaneous ulcer of the fingers. It seems more than likely that in many of these this history of the absence of the vasomotor phenomena would be found unreliable if it were possible to observe the cases throughout the whole course of the disease.

In the largest group, that in which gangrene develops, some cases may be mistaken for simple paronychia. Others claim that the development of a gangrenous patch or of the felon was preceded for a long time by distressing pains in the tips of one or more fingers. The vasomotor symptoms may be absent or the cyanosis and redness may be quite striking. The following sequence of symptoms may be observed and is interesting, because pain and trophic disturbances alone are complained of. The onset is marked by severe pain in the tip of a finger. This is superseded by atrophic changes in the skin, the development of a dry, hard patch, mortification, and also formation of an ulcer. In still other cases, the similarity with Raynaud's disease is even more marked for the symptoms are pain, cyanosis, rapidly followed by gangrene.

More rarely do we meet with those interesting examples of the effects of arterial occlusion in which the development of intense atrophy of a hand or limb or the production of the typical picture of scleroderma and sclerodactyly is the significant feature of the clinical picture.

IV. **Thrombo-angiitis Obliterans with Arteriosclerosis.**—The clinical picture of thrombo-angiitis obliterans becomes confused when it is complicated with arteriosclerosis. In most of the cases the patient must have had either the insidious or silent form of thrombo-angiitis obliterans which developed gradually with only an indefinite history of intermittent claudication. These are followed by spontaneous cure so far as evidences of impaired circulation are concerned. Later, between the ages of fifty and sixty-five or even at an older age, either because of the gradual occlusion of the collateral vessels by the atherosclerotic process, or by virtue of a recent thrombosis complicating the arteriosclerosis in the popliteal artery or higher, the symptoms of insufficient circulation return often very rapidly, and gangrene may result. In such patients we are apt to find not only pulseless vessels on the affected side, but also in the limb which shows no symptoms.

Or, more rarely do we find thrombo-angiitis obliterans developing rather late as far as can be determined by the anamnesis with a period of temporary recovery followed later on by recurrence of the symptoms in arteries markedly sclerosed or calcified.

The pathological investigation of the arteries in such cases has demonstrated two lesions side by side, that of the arteriosclerosis with its degenerative sequelæ, and that of thrombo-angiitis obliterans. (Fig. 498).

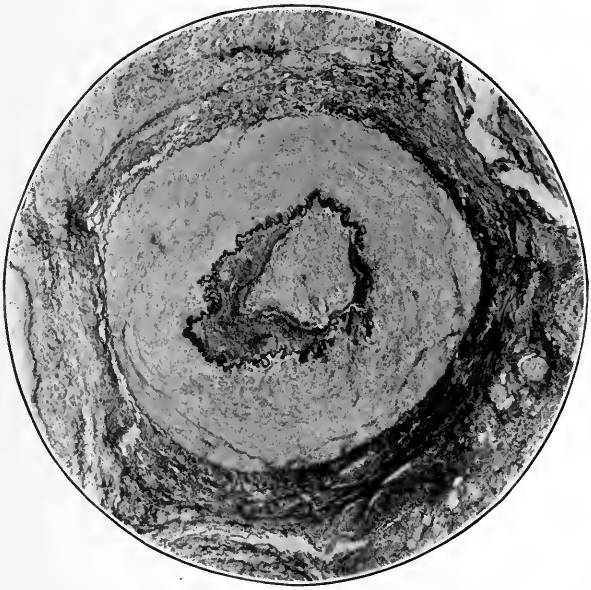


Fig. 498.—Arteriosclerotic plaque (on left) and thrombo-angiitis obliterans completely occluding vessel (elastic tissue stain).

Pathology of Thrombo-angiitis. — Thrombo-angiitis obliterans has been previously described by the Germans under the name "Spontan Gangrän" and "Endarteritis Obliterans." In 1879 von Winiwarter published the results of the pathological findings in one case, and reported an obliteration of practically all of the arteries of the leg by reason of a chronic proliferative process due, in his opinion, to a new growth of tissue from the intima. He, therefore, proposed a new name for this condition, namely, "Endarteritis Obliterans."

This theory has been accepted by most authors, and even today, it is to be found in many text-books. Somewhat later, Wilonski pronounced the opinion that the essential change in the vessel walls was due to a multiplication of the elastic fibers, and proposed the name "Arteritis Elastica" for the condition. Perhaps the most important contributions are those of Weiss and Zoege von Manteuffel, because these authors placed an entirely new interpretation upon the pathological findings. Basing his paper upon the studies of his assistant, Weiss, von Manteuffel suggests that the extensive occlusion of the vessels in this disease is dependent upon a primary arteriosclerosis; that the obliterative process commences in the popliteal artery, where it owes its inception to the formation of a parietal white thrombus; and that by virtue of a gradual extension of the parietal thrombus downward, followed by organization, a picture resembling an obliterative endarteritis is produced. In his cases the veins did not seem to be involved in the process. Von Manteuffel comes to the conclusion that the thrombosis is due to desquamation of endothelial cells, and that this occurs where the intima shows most advanced lesions of arteriosclerosis, namely, somewhere in the popliteal artery.

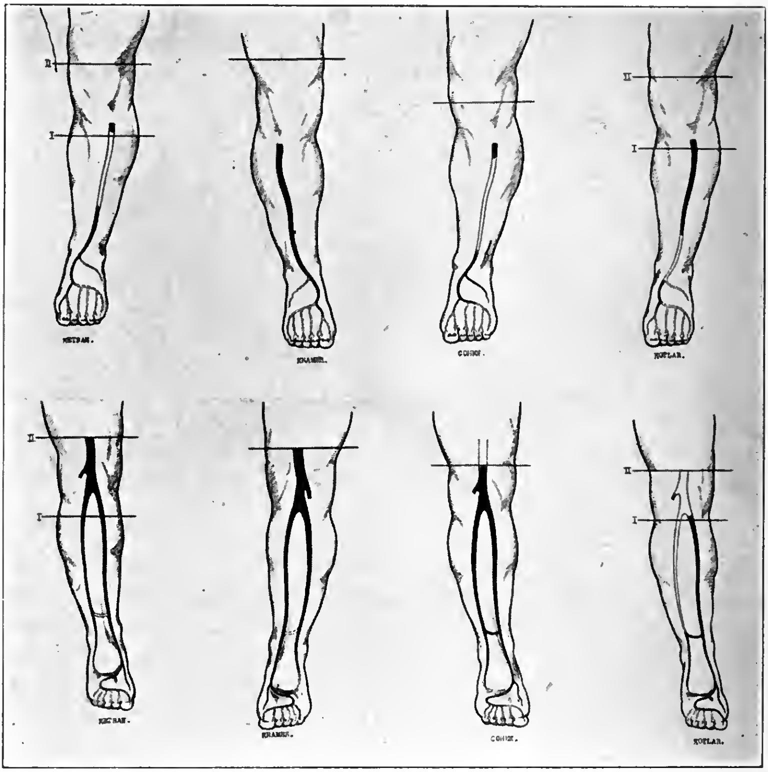


Fig. 499.—Schematic representation of extent of occlusion (black) in larger vessels of lower extremity in four cases of thrombo-angiitis obliterans; cross lines indicate point of amputation; above are anterior vessels, below the posterior.

In 1908 Buerger pointed out that the name, endarteritis obliterans as applied to the clinical picture just described, should be discarded, since the occlusive lesion is a thrombotic one, affecting arteries as well as veins of the extremities, and that it is independent of athero- or arteriosclerosis. He proposed the name *thrombo-angiitis obliterans*, which has now found almost universal adoption in English-speaking countries.

Buerger's investigations[1] which included a thorough pathological

[1] Am. Jour. Med. Sc., October, 1908. Proc. New York Path. Soc., February and March 1908. Int. Clin., 1909, iii, 19th series. Jour. Med. Research, 1914, No. 2, xxi. Am. Jour. Med. Sc., February, 1915, p. 210.

and histological study of the vessels in 45 amputated lower extremities, 1 upper extremity, and 25 pieces of superficial veins resected and exsected from the lower and upper extremities during attacks of so-called migrating phlebitis, have demonstrated that when the patient comes to the physician for observation, the larger arteries and often the larger veins are completely obliterated. The extent of this obliteration is depicted in Fig. 499. As a rule, the plantar vessels, dorsalis pedis and many of its branches, anterior tibial, posterior tibial, peroneal and sometimes the popliteal are already completely closed, although any one or more of these vessels may escape. One or both the venæ comites may partake of the same lesion. The obturating tissue is for the most part representative of or indicative of a healed lesion, or the end-stage of a process whose incipiency is marked by an acute inflammation of the vessel wall, with consecutive, red, occlusive thrombosis of the affected vessel. It is only in rare instances that the early stages of the vascular lesion are found in the deep vessels, but in superficial veins, when they are affected with the lesion migrating or thrombophlebitis the early or acute stage of the disease can be studied.

Gross Pathology.—The deep vessels of the amputated legs regularly show an extensive obliteration of the larger arteries and veins. Besides this, there are two other lesions which vary greatly in their intensity, namely, the peri-arteritis and the arteriosclerosis. The appearance of the vessels on gross section depends upon the age of the occluding process. Usually the vessel is seen to be filled with a grayish or yellowish mass that can be distinctly differentiated from the annular wall of the vessel, and that appears to be pierced at one or a number of points by an extremely fine opening, through which a minute drop of blood can be squeezed. Such obturating tissue is firm in consistency, and does not at all resemble the crescentic or semilunar occluding masses typical of arteriosclerosis. The vessel itself is usually contracted, so that its wall appears somewhat thickened. This picture is characteristic of arteries or veins which are the seat of a very old obliterative process, and is to be found most frequently in the peripheral portions of the vessels, although at times this type of lesion may extend throughout the whole length of the vessel, from the dorsalis hallucis into the popliteal artery.

As we trace certain of the obliterated arteries or veins upward, we are apt to meet with a change in the character of the obturating tissue. Frequently it becomes softer, more brownish in color, and terminates abruptly in the lumen of an apparently normal vessel; at other times the brownish tissue gives way to soft reddish masses which are evidently the results of recent thrombosis. In some cases this thrombotic process occupies large portions of the vessel's course; in others, it is of short extent and terminates in a long cone of recent thrombus.

The veins share equally with the arteries in the lesion of occlusion. In some cases the veins are more extensively involved than the arteries, and this is particularly true of the collaterals of the posterior tibial, which are often closed when the anterior tibial veins are open. As for the arteries, we usually find an obliteration of a part or the whole of the anterior tibial of the dorsalis pedis, and dorsalis hallucis, an occlusion of the posterior tibial and plantar vessels with or without involvement of the peroneal. Sometimes the anterior tibial is practically normal in its upper half or upper two-thirds. More rarely a large portion of the dorsalis pedis is open with the beginning of the occlusion in the upper part of this vessel or in the lower part of the anterior tibial.

Besides the lesion of occlusion there are two other striking changes, namely, a certain amount of arteriosclerotic thickening and periarteritis. Arteriosclerosis is absent in the younger cases; when present, it is never pronounced, except in those rare instances in which the patient has suffered from the disease for many years, and has reached the age of forty or more. As a rule, we note but a very slight degree of whitening or thickening of the intima here and there in the patent portions of the vessels. In a very few cases small atheromatous patches are present.

A much more interesting and more important change is the fibrotic thickening of tissues immediately about the vessels. Wherever the vessels are occluded, there is apt to be an agglutinative process which binds together the artery and its collateral veins, and sometimes also the accompanying nerve, so that liberation of the individual vessels by dissection is difficult. The adhesive condition is due to fibrous tissue growth, and varies considerably in its amount. The peri-arterial fibrosis varies, sometimes being almost absent, at other time so great, that isolation of the vessels or nerves becomes impossible, and the vascular structures make up one dense rigid cord.

Histopathology.—The lesions may be considered in two stages: (1) the healed or organized stage; and (2) the acute or incipient stage of thrombosis. Between the earliest alterations in the deep arteries and veins, and superficial veins, and the finished product, there are a large number of intermediate pictures that illustrate the metamorphosis of the obturating clot into the intravascular cicatrix. Buerger has published studies of these elsewhere.

1. *Healed or Organized Stage.*—The most common lesion is a total obliteration of the lumina of arteries and veins by connective tissue (Fig. 500). Histologically this may be extremely varied in the general appearance, but each picture can be interpreted correctly as having its origin in the lesion of occlusive thrombosis. This obturating connective tissue usually harbors numerous small vessels, pigment containing hemosiderin, and a fair amount of connective-tissue cells. The canalizing vessels, when they become dilated form smaller or larger sinuses, giving the fenestrated or cribriform lesion seen on microscopic section of the vessels, or when the canalizing vessel becomes eccentrically placed, and sufficiently large, this sinus is responsible for the appearances which have been incorrectly interpreted as the product of an endarteritis obliterans (Fig. 501).

Elastic tissue stains demonstrate characteristic differences between

FIG. 500.—Typical fibrotic tissue closing artery in thrombo-angiitis obliterans.

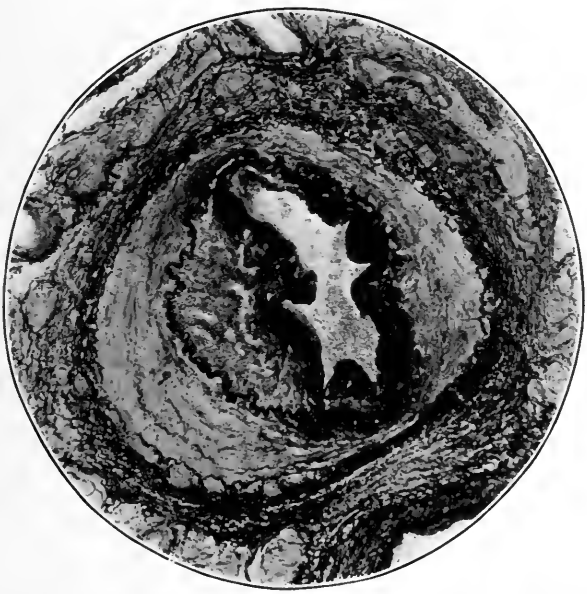


FIG. 501.—New formed elastic tissue about large canalizing vessel emphasizes the similarity between picture of thrombo-angiitis obliterans and endarteritis obliterans (from a case of thrombo-angiitis obliterans).

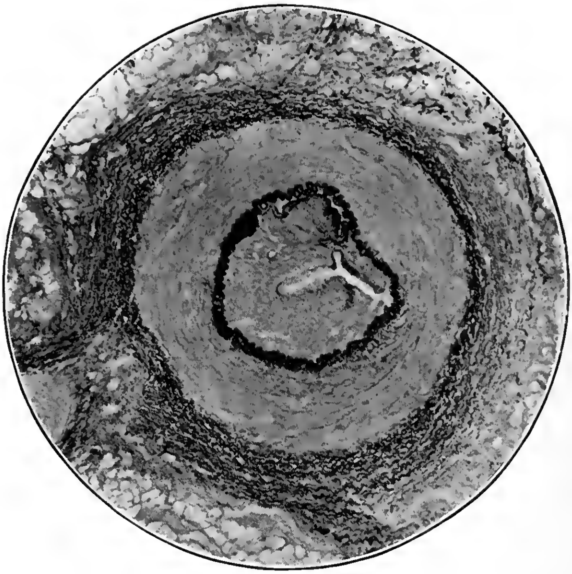


Fig. 502.—Elastic stain of same section seen in Fig. 500; occluding tissue free of elastic lamellæ except about new formed canalizing vessel; typical of thrombo-angiitis obliterans.

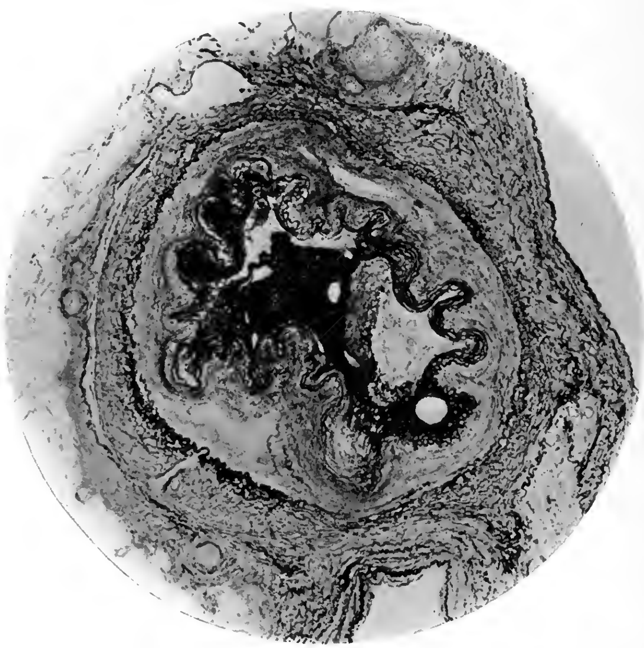


Fig. 503.—Occlusion in arteriosclerosis; on left of lumen new formed elastic tissue almost closing vessel; small light area on right of lumen is so-called Keystone Thrombus. (Buerger in Archives of Diagnosis.)

this process and arteriosclerosis. Thus, the region of the organized clot is almost completely free from elastic tissue. The small amount which is present is concentrically disposed about the new formed vessels (Fig. 502). The abundant elastic tissue formation in the arteriosclerotic plaques is well seen in Fig. 503.

Still more suggestive and instructive is the finding of various stages of the disease in different members of the same vessel sheath. Thus, in Fig. 504 a large artery affords a view of the old lesion, as well as one of its venæ comites. Another accompanying vein, however, is in the "acute" stage of the disease, a smaller venule or satellite being in the

Fig. 504.—Various stages of occlusion in thrombo-angiitis obliterans; above, a vein; just below it, artery in healed fibrotic stage of occlusion; below, two veins; the larger recently occluded (acute stage) and the smaller satellite in the intermediate thrombotic stage with giant cells. (Buerger in Archives of Diagnosis.)

intermediary stage, where certain "miliary giant-cell foci" make their appearance. Such pictures not only reveal the thrombotic nature of the disease, but also present an argument in favor of the following two assumptions: that the disease begins with an inflammatory lesion attended with occlusive thrombosis, and that it affects the arteries and veins in a sort of relapsing fashion, very much in the same manner as in the veins in migrating phlebitis.

The termination of the occluding tissue in arteries and veins is often seen in the form of a rounded, convex projection looking upward (cephalad), and lying in practically healthy vessel wall (Fig. 505). At other times, the old occluding tissue is capped by an additional clot which rises in pyramidal fashion ending in a long tapering extremity.

2. *The Acute or Specific Lesion.*—The early lesions are so characteristic histologically that their appearances are practically specific for thrombo-angiitis obliterans and may permit the pathologist to make a diagnosis of the disease. They are rarely to be seen in the deep vessels, for the reason that patients do not allow amputation until the disease has lasted for months or years. However, they can be well studied when these are the seat of the typical migrating phlebitis, and have been shown by Buerger to be identical with the acute lesions in the deep vessels.

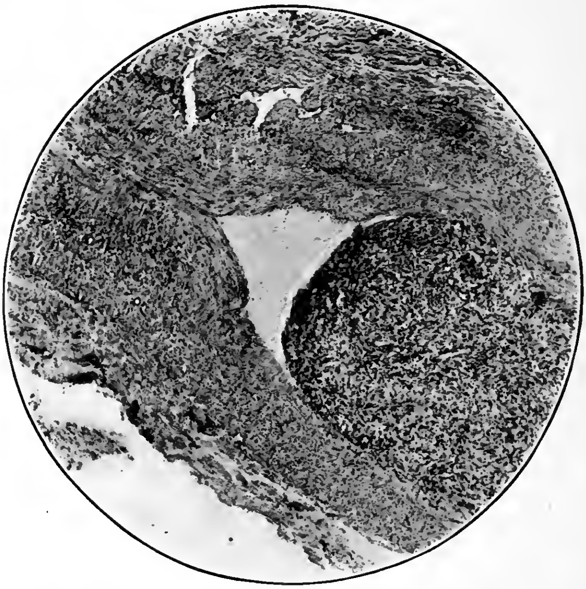


FIG. 505.—Termination of an organized thrombus in practically normal vessel in thrombo-angiitis obliterans; on the right, the vessel is collapsed so that intima is against intima (longitudinal section.)

The earliest changes appear to be the usual evidences of an acute inflammatory process involving all the coats of the vessel. The media, adventitia and perivascular tissues are infiltrated with polynuclear leukocytes and the lumen of the vessel is completely filled with red clot. In the peripheral portions of the clot, larger or smaller foci of leukocytes (purulent foci) being to form, whose growth occurs by virtue of immigration of leukocytes (Fig. 506). The certain peculiar giant-cell foci develop (Figs. 507 and 508), which are characteristic. They contain giant cells, endothelioid or angioblasts and numerous broken-down leukocytes. These foci then undergo connective-tissue replacement. The giant cells gradually disappear, numerous small vessels are formed, the final product being a fibrous nodule containing vessels and some pigment. In the rest of the occluding clot, the organizing

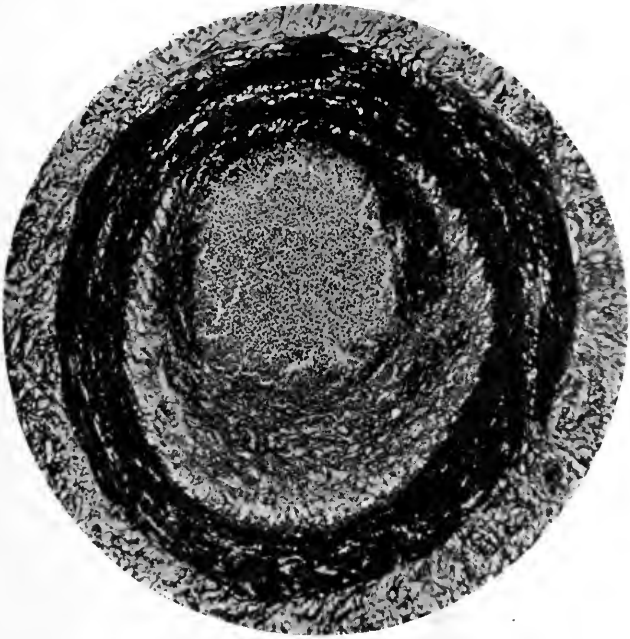


FIG. 506.—Acute stage of thrombo-angiitis obliterans in superficial vein (Giemsa stain); purulent focus occupies upper portion of obturating clot.

FIG. 507.—High power appearance of characteristic "miliary giant cell" focus in thrombo-angiitis obliterans.

process is somewhat different, resembling that which characterizes the organization of blood clot in other thromboses.

In short, the lesions in thrombo-angiitis obliterans are in chronological order, (1) an acute inflammatory lesion with occlusive thrombosis, the formation of miliary giant-cell foci; (2) the stage of organization or healing, with the disappearance of the miliary giant-cell foci, the organization and canalization of the clot, the disappearance of the inflammatory products, and the development of fibrotic tissue in the adventitia that binds together the artery, vein and nerves.

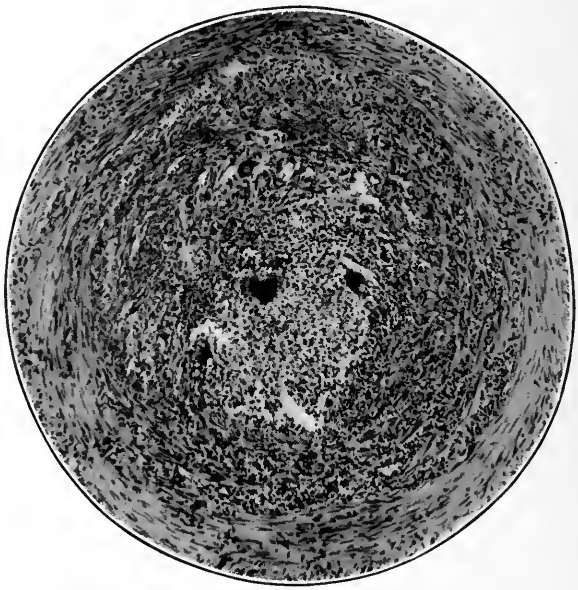


Fig. 508.—Acute stage of thrombo-angiitis obliterans in superficial vein, showing infiltration of all coats of vein with leukocytes, also giant cells.

Diagnosis.—Thrombo-angiitis obliterans must be diagnosticated from (1) lesions of other organic vascular diseases of the extremities; (2) cases of neuropathic or neurogenic vascular disorder of the extremities. In the first group belong athero- and arteriosclerotic gangrene, endarteritis obliterans, embolic and thrombotic gangrene. In the second group belong Raynaud's disease, erythromelalgia, acro-paresthesia, multiple neurotic gangrene, scleroderma, sclerodactyly, and chronic acro-asphyxia. A careful clinical study of thrombo-angiitis obliterans will dissipate all doubt as to the possibility of separating this disease as a clinical entity from the other types of organic vascular disease, as well as from all those neurogenic varieties of vasomotor and trophic disorders that may be clinically confounded with it.

Characteristic for thrombo-angiitis obliterans are the following groups of symptoms: (1) the disappearance of the pulses, particularly the dorsalis pedis, posterior tibial and popliteal, more rarely the femoral, radial and ulnar; (2) the development of typical manifestations of impaired circulation, to wit: blanching of the lower extremities when these are elevated above the horizontal, hyperemia (rubor or erythromelia) or reddening of the foot in the dependent position during certain stages of the disease, and trophic disturbances such as impaired growth of the toe nails, slightly atrophic condition of the skin, ulcers, and gangrene; (3) true vasomotor phenomena of transitory nature, such as alternating syncope, rubor, coldness apparently independent of those chronic changes that have been cited above, and that are distinctly traceable to the occluded condition of the arteries and veins; (4) the symptoms of pain, either in the form of intermittent claudication (pain in the calf of the leg or in the foot on walking with cessation when the limb is at rest) or the severe pain that is associated with the advent of trophic disturbances, especially with ulcers and patches of gangrene; (5) the slow course of the disease, symptoms of intermittent claudication or pain, preceding the development of trophic disturbances for months and years; (6) the fact that about 99 per cent. of the cases occur in Polish, Galician or Russian Hebrews, and that almost always young males between the ages of twenty and thirty are taken with this disease; (7) the onset of symptoms in the lower extremities, one of the legs being first affected; (8) the comparative infrequency of involvement of the upper extremities; (9) the association of a peculiar type of migrating phlebitis in the territory of the external or internal saphenous, less frequently in the larger veins of the upper extremities, characteristic in about 20 per cent. of the cases; (10) the slow but steadily progressive course, leading in a large majority of the cases to amputation of at least one limb, not infrequently of both lower extremities, and in rarer instances to amputation of one of the upper extremities as well.

For the *clinical diagnosis of thrombo-angiitis* we must depend upon (1) the racial (Hebrew) and sex (male) predilection; (2) the early involvement of the lower extremities; (3) the early symptoms of pain or intermittent claudication; (4) the presence of migrating phlebitis; (5) the evidence of pulseless vessels; (6) the presence of blanching of the extremity in the elevated position; (7) the existence of rubor in the dependent position; (8) the relation of the hyperemic phenomena to posture; (9) the absence of simultaneous, symmetrical involvement; and (10) the slow, progressive, chronic course terminating in gangrene.

Differential diagnosis between thrombo-angiitis obliterans and the vasomotor neuroses. Were it not for the fact that certain symptoms, closely resembling typical vasomotor phenomena may persist for weeks and years in this disease, confusion with the true neurogenic vasomotor process would scarcely ever arise. The chronic condition of redness in thrombo-angiitis obliterans can be explained as due to dilatation of the superficial capillaries, this being a compensatory phenomenon making for an adjustment of the impaired circulation. This chronic redness or rubor may be mistaken for erythromelalgia, or for the rubor of Raynaud's disease. The fact that it is associated with other evidences of closed vessels and the other characteristic features above mentioned, together with the circumstance that the redness disappears at once upon elevating the extremity, will make the recognition of its nature possible.

In addition to this more or less chronic or permanent sign of deranged vasoconstriction, other phenomena which are truly vasomotor in nature may frequently be associated in thrombo-angiitis, and it is these that must be differentiated from similar phenomena accompanying Raynaud's disease, erythromelalgia, scleroderma, sclerodactyly and acrocyanosis.

In order that a differential diagnosis may be clearly presented, let us briefly recapitulate the typical course of a case of Raynaud's disease. *Raynaud's disease* is an affection whose pathology has not as yet been definitely determined, the lesion doubtless residing somewhere in the central nervous system. Its clinical characteristics may thus be summed up. Somewhere in the peripheral portions of the body (so-called acra) there occurs more or less severe pain not confined to distinct nerve territory, usually affecting symmetrical parts, attacks of vasomotor disturbance being part of the syndrome. These latter are (1) syncope, asphyxia, or local rubor, and (2) severe trophic disturbances, usually in the form of gangrene of the parts first affected with symptoms. The course is an intermittent one, for there may be completely free intervals; but in some instances, evidences of disturbed vasomotility may persist. The disease may consume itself in one attack or several attacks may occur in succession. Objectively, sensory disturbances are usually absent, as well as paralysis, although other evidences of disturbed vasomotor innervation, such as aphasia, hemoglobinuria, arthropathy may occur. Usually neuropathic individuals are affected. The organic vascular changes, as well as the lesions of the nervous system, reported occurring in some of the cases, have doubtless no causative relation with the disease.

It is true that there are still some who cling tenaciously to the theory that some lesions of the peripheral arteries may account for the symptoms of Raynaud's disease. In support of this view certain anatomical findings have been cited as strong arguments by those who believe that a definite anatomical lesion in the peripheral vessels is irresistible testimony against pure hypothesis. A careful analysis of the cases in question, as made by Cassirer, shows that reported organic alterations in the vessels will not suffice to explain the symptoms any more satisfactorily than the theory of a central nerve affection of the sympathetic system. Whereas in thrombo-angiitis obliterans the territory manifesting symptoms corresponds to that containing the diseased vessels, we find that no such relation exists where vascular lesions are associated with Raynaud's disease.

In Raynaud's disease we will note the following features: A sudden onset of the first stage of local syncope or regional ischemia involving usually the fingers, more rarely the toes, and occasionally the margins of the ears or the tip of the nose with coldness and blanching; associated sensory phenomena, paresthesia and pain; a comparatively short duration of the vasomotor and sensory manifestations, their intermittent character with return to normal between the attacks; the symptoms of local asphyxia attended with local depression of tempera-

Fig. 509.—Disappearance of terminal phalanges in x-ray picture of hand in Raynaud's disease.

ture and swelling of the parts involved; the disappearance of the asphyxia with substitution of reactive hyperemia and a third stage of dry gangrene. Characteristic for this disease as well as for the cases of scleroderma and sclerodactyly is the striking atrophy of the ends of the distal phalanges (Fig. 509). The changes in the bones can be well demonstrated by roentgen-ray examination, atrophy and disappearance of large portions of the end-phalanges being distinctive and diagnostic features. In our own experience the alterations in the bones could be detected early in the disease, probably developing simultaneously with the other trophic disturbances.

The differentiation of true scleroderma from thrombo-angiitis will be rarely difficult to make. In scleroderma and sclerodactyly the first stage with hard edema is characteristic and never simulated by cases of organic vascular disease. The second indurative stage may, however, be almost exactly reproduced by other affections. The form of scleroderma known as "sclerodactyly" because of attendant alterations in the deeper tissues may not be unlike thrombo-angiitis. Roentgen-ray examination of the hand in sclerodactyly offers the most valuable means of differentiating the two diseases. The phalanges will very early show atrophic changes and disappearance of the terminal portions in scleroderma, sclerodactyly and Raynaud's disease, while the bones, although somewhat rarefied, will be seen to conserve their outlines throughout the course of the disease, thrombo-angiitis obliterans, until they are disturbed by the effects of gangrene.

So far as our experience permits us to judge, symptoms of scleroderma occur only late in thrombo-angiitis when other signs of vascular occlusion have already become well developed. The recognition of the condition will then depend upon the absence of pulsation in the larger peripheral vessels, the presence of gangrene (or the history of such a condition) and of the other typical signs of obliterated arteries and veins.

It is most probable that in Raynaud's disease and the related affections the seat of the pathological process is to be sought in the vegetative system, that is, somewhere in the vasomotor apparatus. Nor are we likely to be rewarded in a search for any organic change. The frequent return to a normal condition, observed clinically, also speaks against the likelihood of morphological or chemical alterations in the nervous system.

Whereas in thrombo-angiitis obliterans a definite and specific morphological change in the arteries and veins is responsible for the varied phenomena in the superficial capillaries, in Raynaud's and allied disease, the vasomotor and trophic disturbances are the outcome of irritative and exhaustive processes of the sympathetic nervous system.

Treatment.—The treatment will vary according to the stage of the disease, the presence of migrating phlebitis, trophic disorders and gangrene.

Prophylactic Treatment.—The same general rules laid down for the arteriosclerotic and diabetic cases regarding walking, cold, traumatism, cleanliness, etc., should be followed in the cases of thrombo-angiitis obliterans.

Conservative Treatment.—When the disease is well developed, distinct intermittent claudication being present and fairly marked pain with or without trophic disorders, it is advisable that the patient remain in bed for several weeks or even longer, or at least that walking and standing on the feet be completely interdicted. Therapeutic measures should be directed toward the conservation of warmth, enhancing the circulation, the prevention of traumatism and the treatment of local conditions, trophic disorders or gangrene when these supervene.

A. *Methods of Enhancing the Circulation.*—1. *Buerger's Postural Method.*—Buerger has suggested that certain passive exercises may be of value in inducing hyperemia or rubor in the affected limb, and therefore, therapeutically beneficial in increasing the blood supply.

This method is the logical therapeutic outcome of Buerger's method of diagnosticating impairment of circulation of the lower extremities, in that it uses the phenomenon of *induced rubor,* or *induced hyperemia* (see section on Diagnosis) in a therapeutic way. If the method be carried out daily for a sufficiently long period, it is of greater value in improving the circulatory conditions and in increasing the blood supply, than any of the other mechanical or thermal means that are at our disposal.

The procedure is as follows: The affected limb is elevated with the patient lying in bed, to from 60° or 90° above the horizontal, being allowed to rest upon a support for thirty seconds to three minutes, the period of time being the *minimum* amount of time necessary to produce blanching or ischemia. As soon as blanching is established, the patient allows the foot to hang down over the edge of the bed for from two to five minutes, until reactionary hyperemia or rubor sets in, the total period of time being about one minute longer than that necessary to establish a good red color. The limb is then placed in the horizontal position for about three to five minutes, during which time an electric heating pad or a hot water bag is applied, care being taken to prevent the occurrence of a burn. The placing of the limb in these three successive positions constitutes a cycle, the duration of which is usually from six to ten minutes. These cycles are repeated over a period of about one hour, some 6 to 7 cycles constituting a seance.

It is well to begin with about three seances daily, that is, three treatments daily, gradually increasing the number of séances until the patient allows the séances to occupy at least six or seven hours a day, that is every alternate hour during the daytime. During the hours of rest, heat is applied continuously in the form of an electric pad, hot water bag, hot air apparatus or electric lamp.

In the opinion of the author, this method does far more to improve the circulation than either the application of superheated air (so-called baking treatment), or the diathermic treatment.

The length of time of its application may in some cases depend upon the pain which may be induced by elevation of the foot. In some cases the symptoms may necessitate a diminution in the period of elevation.

2. *Heat.*—For the cases of thrombo-angiitis obliterans, as well as arteriosclerosis, it is best to exclude the foot from the hot-air treatment, when it is the seat of trophic disorders or gangrene. Heat may be applied either by means of an electric thermophore, by a hot-air appa-

ratus, or an incandescent apparatus containing one or more incandescent lamps, or a single strong electric lamp with reflector. The temperature should not be raised higher than 120° F. at the first treatment, and gradually increased to 150° or 180°, but never more than 200° F. Heat is applied as high as the middle of the thigh for about one-half hour. In the presence of migrating phlebitis this treatment is not well borne. Whenever gangrene is present, the gangrenous part is left covered with dressing, but not included in the apparatus. The treatment may be given once or twice a day, depending upon how well it is borne, and upon its effects upon the progress of the disease.

3. *Diathermic Treatment.*—This is an excellent method of obtaining the effects of heat upon the deeper parts, and is particularly applicable to the early cases, especially those in which intermittent claudication is the most marked symptom, and in those patients in whom ambulatory treatment must be carried out. In the presence of inflammation, migrating phlebitis, ulcers or gangrene, it does not seem to be well borne or beneficial. The séances should last from twenty to twenty-five minutes. The best apparatuses are those made by Reiniger, Gebbert and Schall (Berlin) and the Wappler Electric Manufacturing Company (New York).

The patient will feel the development of the heat in the region of the ankle, where the effects of warmth can be demonstrated by the touch. Subjectively, there is in addition to the feeling of heat, a dull ache which should not be allowed to become marked. Pain is a sign for diminishing the strength of the current.

Certain observers claim success in the treatment of thrombo-angiitis obliterans by the diathermic method, which H. Wolf employs as follows: The feet and legs are bared, each foot being immersed in a tray half filled with salt water. Each tray is connected with one of the poles of the diathermic apparatus. About 600 milliampères of current are used, the exact amount of current applicable in each case depending upon the amount of heat generated and the way this is borne by the patient. Three treatments are given per week, each séance lasting ten minutes.

B. *Subcutaneous Saline Solutions.*—Koga[1] believes that the circulatory conditions can be improved by reducing the viscosity of the blood with subcutaneous injections of Ringer's or saline solution. Although clinical reports of a number of observers have tended to confirm the improvement reported by this author in some of the cases, this theory cannot be accepted without challenge, for he believes that the lessened viscosity of the blood permits of more rapid flow through the narrowed arteries. Histological studies show that the arteries are not narrowed but completely closed. However, the method may be given a trial, since it improves the condition of the patient when this is reduced by starvation, lack of sleep and lack of food. Willy Meyer has observed marked benefit from this method of treatment.

[1] Deut. Ztschr. f. Chir., 1913, p. 371.

Internal Medication.—Mercury may be given in some cases in smaller injections when syphilis is suspected, although it does not seem to have any material effect upon the disease. Nitroglycerin and iodides may be administered under certain circumstances, although their effects are questionable.

Local Treatment.—Trophic ulcers must be treated on general surgical principles, the combating of the severe pain attending these being the most difficult part of the treatment. An ointment containing 4 or 5 per cent. novocaine, and 5 to 10 per cent. orthoform or anesthesin in lanolin and glycerin is sometimes beneficial in allaying local pain due to trophic disorders. The continuous saline bath or repeated baths alternating with the postural exercises are a valuable adjuvant in aiding healing.

Operative Treatment.—*Ligation of the Femoral Vein.*—Lilienthal has suggested the ligation of the femoral vein as of some value in enhancing the circulation. He claims that in some cases of sudden gangrene healing may take place after conservative treatment, such as removal of a toe alone, and that a lower amputation will succeed more frequently after ligation of a vein than without it.

Arterio-venous Anastomosis.—This has been suggested by Wieting with a view to reversing the circulation, the femoral artery and femoral vein being anastomosed in such a manner that the vein will receive the arterial blood. Wieting and others have reported successful results, cures of impending gangrene and restoration of circulation. Experimental work, however (Stetten), would tend to show that it is practically impossible to transform the veins into arteries by anastomosis, and clinical reports do not justify us in recommending this method either in the presence of gangrene, or in threatened gangrene. Involvement of the veins in thrombo-angiitis obliterans, both superficial and deep, with obliteration in a larger percentage of the cases, makes it unlikely that improvement of circulation could occur by deflecting the arterial current into the vein.

Limited Amputation.—After-amputation of a toe alone is unsuccessful for healing will not take place. In some instances, however, conservative treatment such as described above, together with ablation of a toe alone, or several toes if necessary, may be followed by good results. In the majority of cases, amputation at a point higher up will be necessary.

Radical Amputation.—In the majority of cases amputation of at least a portion of the leg will become necessary. The Gritti-Stokes amputation is the ideal procedure in these cases, although lower amputations are occasionally successful. Buerger found that in a series of 40 amputations according to the Gritti-Stokes method primary union was obtained in all instances.[1] When amputation is performed lower

[1] It must be noted that one case died on the eighth day trom embolism, and another succumbed to mesenteric thrombosis early in the second week after operation. In both, however, the wounds were clean and would have healed by first intention had the patient survived.

down, healing may take place, but in many instances sloughing of the flaps occurs, and secondary amputation becomes necessary. Inasmuch as the disease occurs for the most part in poor working people, it seems that the Gritti-Stokes amputation is preferable to those methods which are dubious in their outcome and require many months for the accomplishment of their purpose. Methods or tests for estimating the point at which amputation should be done are all unreliable.

Endarteritis (Syphilitic, etc.).—Although lues is held responsible for much of the endarteritis that occurs in the cerebral vessels, and is doubtless the cause of the frequent endarterial and mesarterial lesions of the aorta, it rarely affects the larger arteries of the extremities sufficiently to produce gangrene.

The smaller peripheral arteries, however, seem to be involved often enough to furnish circulatory conditions favorable for the development of gangrene, whenever other factors such as severe general infection, traumatism, debility and exposure to cold supervene. In such cases it is difficult or even impossible to correctly estimate the relative importance of the syphilitic endarteritis, and the other causative factors in the production of the gangrene. Pathological studies have been insufficient to warrant any definite conclusions as to the incidence of gangrene due to true luetic endarterial disease.

Gangrene Due to Embolism and Thrombosis.—Embolism and thrombosis may be considered together, since they are frequently associated in the pathology of gangrene, and since it is often difficult to make a differential diagnosis, or to distinguish between the effects of the pure embolic process and the result of occlusion by thrombosis. In the veins we find that only extensive thrombosis over large territories is effective in producing gangrene of an extremity or portions of an extremity, whereas, in the case of the arteries, either process, embolism or thrombosis may lead to gangrene.

Emboli may lodge at the bifurcation of arteries, particularly in the popliteal or in the aorta at the division into the iliacs. The source of an embolus must be sought in a portion of the circulatory system, situated proximally to the obstructed vessel, in the left heart and rarely in the right heart, when the foramen ovale is patent. Emboli may be dislodged from the ulcerative lesions of atherosclerosis, from syphilitic arteries, from an aneurysm, from arteriosclerotic, injured or infectious vessels. A heart that is the seat of myocarditis and endocarditis or bacterial endocarditis, or that is altered in consequence of previous infectious diseases, such as typhus, variola, scarlet fever and bacteriemia (so-called pyogenic infection) may be the source of emboli. When the emboli contain organism, they are called *infectious emboli,* and may give rise to metastatic abscesses.

Classification.—The cases may be divided into (1) thrombosis and embolism after infectious diseases, including pneumonia; (2) cases secondary to cardiac disease; (3) cases following operations, especially abdominal and complicating pregnancy, in both of which the exact mechanism is not well understood; (4) *peripheral thrombotic gangrene*[1] *or thrombotic gangrene* in healthy or but slightly diseased vessels; (5) embolism and thrombosis complicating arteriosclerosis.

1. **Embolic and Thrombotic Gangrene after Infectious Diseases.**—Gangrene complicating pneumonia may be described as a good example of this type. Sudden thrombosis of the femoral or popliteal artery may occur within a few days (four to eight) or much later (three to four weeks) after the onset of pneumonia. The character of the symptoms, and the extent of the gangrene will depend upon the site of the embolus or limits of the thrombosis; and the general symptoms will be determined rather by the general condition and disease which gave rise to the thrombotic process, than by the gangrene itself, subsequent emboli often causing sudden death.

As early as six to eight days after the onset of pneumonia, or at a much later period, the patient will experience numbness of the foot, coldness, cyanosis, weakness, followed by loss of active motion, and then cyanosis of the distal part. On examination the dorsalis pedis, posterior tibial and popliteal may be found pulseless. Gangrene rapidly ensues, and, if amputation is done, the femoral artery and vein are usually found filled with red clot.

It is often difficult in these cases to determine just where the thrombus began, or just where the embolus became lodged. If amputation is done after the lapse of a week or more, beginning organization of the clot can be demonstrated.

In other cases, thrombosis may occur as late as three to six weeks after the onset of pneumonia, beginning with sudden onset of pain in one limb, coldness and blanching followed by cyanosis, the peripheral arteries being pulseless.

Clinical Course.—Either during the course of the pneumonia, or as a sequel, embolism or thrombosis of the iliacs, femorals or popliteals may occur. Symptoms of thrombosis or embolism may begin with sudden pain or numbness and coldness in one foot, which rapidly becomes blanched, later cyanotic, the dorsalis pedis, posterior tibial and popliteal arteries pulseless. The typical signs of gangrene then develop, associated with distinct aggravation of the general condition. Where the condition of the patient has allowed it, amputation was done in many of the reported cases. The mortality, however, has been exceedingly high, the patient often becoming delirious then stuporous shortly after operation, or even before amputation was done. The prognosis is grave, either because of the extent of the thrombotic process, and the development of other emboli, or because of the menace of pulmonary edema and heart failure. In some instances, where amputation was postponed for weeks or more, the amputated limbs revealed extensive organizing thrombosis of all the larger arteries and veins.

[1] First described by author, no reference to this type having been found in the literature. However, clinical and pathological investigations have demonstrated the existence of other forms to the author. (Studies in the Pathological Department of Mount Sinai Hospital, New York.) (See p. 822, 4. Thrombotic Gangrene in Healthy or but Slightly Diseased Vessels.)

Post-pneumonic Gangrene.—A young man, aged thirty years, with the history of pneumonia, and with consolidation at the right base, was treated at the hospital in April and May, 1914, having been discharged on May 11. He was again admitted on July 13, because of shortness of breath, palpitation, hacking cough with sputum. On July 25, there was *sudden pain* in the *left leg*, the leg being found cold and cyanotic, with pulses in the femoral, and distal to this artery being absent.

Tenderness along the vessels could be elicited. About this time the patient's mental condition changed, being frequently irrational.

July 28, the entire left foot was markedly discolored, having a purplish mottled appearance, the whole leg being cold.

August 7. Patient mentally confused but rational. From now on the left leg passed through the various stages of gangrene.

August 24. Amputation at junction of upper and middle third of left thigh.

August 27. Very irrational, having marked hallucinations.

September 1. Some sloughing of the skin flaps. Patient removed to Bellevue Hospital because of mental condition.[1]

When the edema is absent and the veins remain patent sufficiently long, then the characteristic picture of *dry gangrene* results. The initial coldness and pallor are also followed by blueness or bluish-purple discoloration. Gradually the peripheral parts are depleted of their water content, and the tips of the toes and outer border of the foot dry up rapidly, gaining the characteristic appearance of the desiccated dissecting room corpse. The color soon changes from the dried beef appearance to a blackish-brown, as the process extends up for a variable distance, usually almost to the ankle, rarely much above.

When the condition of *moist gangrene* develops, because of more extensive thrombosis in the femoral vein, and possibly earlier thrombosis in the veins than in the arteries, the following picture of the local condition is typical, but may also be characteristic of embolic and thrombotic gangrene due to other causes.

First Stage.—After a preliminary blanching which rapidly follows the onset of the embolism or thrombosis, the limb becomes intensely cold and soon develops bluish patches that give the limb a mottled appearance (ischemia and cyanosis). The cyanosis becomes intense, spreads rapidly replacing the areas of pallor; the limb becomes livid and dusky, save for patches of vermilion red scattered here and there.

Second Stage of Subepidermal Exudation.—The foot sometimes becomes edematous, the calf brawny and hard, and extremely tender; the soles are livid or they show a striking vermilion red. Over the dorsum of the foot, large blebs or bullæ form, which contain bloody serum, and some of the toes may become intensely red, because of the separation of the epidermis, the weeping cutis vera shining through. The red condition of the foot extends up for a variable distance to the

[1] The pathological findings will be found under the paragraph on Pathology, page 818.

ankle, or even higher, giving the limb an angry red appearance, characteristic of the second stage of moist gangrene. When edema precedes the gangrene, the brawny and swollen condition of the limb may be intense.

Third Stage of Intense Lividity.—As the gangrenous process becomes more advanced, the bullæ become larger; the epidermis hangs in folds, breaks and allows the serum to escape. The color of the skin changes to a deep purple, except for places where the weeping cutis vera still shines through. The general color is often a grayish-purple, because the combination of the dead epidermis and the bluish-red cutis vera. Associated with these typical signs of moist gangrene there may be patches of dry gangrene. Higher up, at the periphery of the gangrenous process, where demarcation begins to take place, there are usually areas of hemorrhage, or ecchymosis. The limb above this line is indurated, tender, and usually much enlarged. Sometimes the external popliteal vein can be felt as a hard cord. The popliteal and the femoral arteries are frequently pulseless.

Fourth—the final stage of disintegration has been previously described.

Gangrene occasionally follows *diphtheria.* Rolleston[1] reported a case in which a lower extremity was affected. He could find but one reported instance in which an upper limb was involved.

Embolic gangrene complicating *chorea* was observed by Chodak.[2]

V. H., aged twelve years, was admitted into the Royal Free Hospital on December 7, 1918, suffering from chorea of a week's duration. This was a first attack, and there was no previous history of rheumatism; no history of shock or overwork. Two years previously she had had diphtheria, with a bad attack of tonsillitis during convalescence. The mother had had rheumatism and one sister has had chorea. On admission, the patient, a thin slip of a girl, was found to be suffering from a moderately-severe attack of chorea, all parts of the body being affected. There was very little loss of strength on the left side, but the right hand grip was poor and feebly sustained. All reflexes were exaggerated.

Ten days after admission the right hand began to go white, the finger-nails blue, though the hand did not actually feel cold to the touch. The onset may be described as rapid rather than sudden, and it was fully a week before gangrene of the finger-tips and ball of the thumb had definitely set in. During this time the pallor spread up the forearm. There was no pulse at the wrist, but the brachial could be felt pulsating about half-way down the upper arm, and after a time there was distinct pulsation of the superior profunda artery.

The temperature throughout never rose above 99° F., and was rarely as high as that. Later still, the brachial pulse slowly disappeared, and the brachial artery could be felt like a thick cord along the arm. The little finger recovered and lines of demarcation gradually formed on the remaining fingers. The ball of the thumb appeared at first to have

[1] Royal Soc. Med., 1911, iv (section on Diseases of Children).

[2] Ibid., 1918–1919, vol. xii (section on Diseases of Children, p. 8).

escaped as the discolored skin peeled away from it, but there must have been considerable damage to the muscle, followed by contraction of the scar tissue, which has led to considerable deformity of the thumb.

Pathology.—On dissection of such a limb the vessels are found matted together by intense edema and infiltration. The posterior tibial and femoral arteries are filled with red clot, decolorized in places, but nowhere showing advanced organization, even when the limb is removed eighteen to twenty days after the onset of the thrombosis. Histological examination of such vessels shows a bland clot undergoing early stages of organization. The peripheral layers of the muscle, of the media and the adventitia show extensive infiltration with mononuclear cells. No definite data as to the cause of the thrombosis can be learned from the study of the vessels, unless they can be obtained within a few hours after embolism or thrombosis has occurred. In the later stages, the usual signs of organization are present, the organizing process being often older in the veins in the cases of moist gangrene.

In the case of post-pneumonic gangrene described above (under *Clinical Course*) the examination of the amputated leg and of the vessels by the author (August 22, 1914) revealed the following: The large vessels (femoral and popliteal) were matted in their sheaths surrounded by considerable edema everywhere filled with red clots. Some of these were found decolorized in places, but nowhere were they firm, nor did they suggest the picture of thrombo-angiitis. The femoral, popliteal and posterior tibial showed these changes. Recent thrombosis was found in other vessels situated distally. Macroscopically one could have concluded that here was a case of either thrombotic or embolic gangrene with the vascular occlusive lesion probably beginning in the femoral or possibly in the external iliac artery, with thrombosis extending rapidly downward.

Histological examination of the femoral and popliteal arteries showed the following lesions: The lumina of the arteries were filled with clots. The adventitia and media were infiltrated with mononuclear cells interspersed here and there by a moderate invasion with migrated leukocytes. The veins, too, revealed similar changes with some organization of the clots.

All these changes could be regarded as being secondary to, rather than as responsible for, the occlusive thrombosis, for the site of the initial lesion cannot be determined in the limited vascular territory obtained by amputation.

2. **Embolic Gangrene with Cardiac Disease.**—When this occurs in young and middle-aged individuals, the source of the embolus is usually the left heart. Autopsy not infrequently reveals thrombi in the left auricle as the probable source, or chronic endocarditis with valvular lesions, particularly mitral stenosis. In the older individuals, particularly the senile cases, with intense athero- and arteriosclerosis and ulcerations of the aorta, a lesion proximal to the site of the embolism may furnish one causative factor of the embolic process.

The clinical history in cardiac cases is typical and striking. There may be *a fulminating course,* terminating in death within a few hours or a few days (less than a week) after the onset, or a more *protracted course,* in which case the mortifying process in one or both lower extremities or even upper extremities may have progressed so far that demarcation has set in, allowing amputation to be done. Even here, the mortality is exceedingly high, death usually following within a short time after operation.

A typical course of a *fulminating case* is the following: With a distinct antecedent history of cardiac disease, the patient suddenly experiences pain in one or both lower extremities, or pain in the abdomen or back, followed by coldness of one foot or leg, loss of sensation, paresthesia and loss of active motion. On examination the affected limb will be found to be blanched, soon after the onset, cold, flaccid, and somewhat tender above the zone of frigidity. The toes soon become livid, purplish or cyanotic, or the ischemic condition of the foot gives way to a mottling, patches of bluish-purple appearing over the foot and lower part of the leg. The muscles of the calf of the leg, or the thigh frequently manifest fibrillary twitching. After forty-eight hours, this mottling gives way to a diffusely livid color, here and there scarlet patches shining through. The zone of coldness and of discoloration correspond fairly well in extent, the upper portion of the discolored area showing extensive ecchymoses. Death may occur within twenty-four hours, or within a week, the patient becoming delirious, then stuporous, cardiac failure or cerebral emboli leading to sudden exitus.

In protracted cases dry gangrene often develops; rapid evaporation takes place and the distal parts are the first to become mummified. A type of gangrene which in its objective manifestations can be compared to the desiccating process seen in the drying parts in the dissecting room is not uncommon. This form of gangrene, when it involves a considerable portion of the foot, or the whole foot, is *almost always due to embolism.*

Where there is a more chronic course over a period of weeks or more than a month, the history may be as follows: With the story of an old cardiac complaint, there suddenly develop shortness of breath, precordial distress, possibly palpitation with or without vertigo and fainting. This is followed by pain in one or both lower extremities, loss of motion and loss of sensation. One or both limbs become rapidly cyanotic, the extent of the discoloration depending upon the situation of the thrombus. On physical examination, the dorsalis pedis, posterior tibial and popliteal arteries are regularly found pulseless. The femoral may or may not pulsate. Then the typical changes incident upon the development of dry gangrene ensue. The general condition of the patient will depend particularly upon the cardiac condition, and upon the presence or absence of infection. Usually there is more or less cyanosis due to the impaired cardiac action and evidences of a cardiac murmur.

Such cases may last for a variable time (six weeks or more) before amputation is done. Although the operation of amputation through the thigh may be temporarily well borne, the mortality is exceedingly high. The patients may suddenly become stuporous. Evidences of cerebral embolus may appear, death occurring within a few hours or several days after amputation.

Diagnosis.—The recognition of embolic or thrombotic gangrene must be based upon the following facts: the existence of the proper etiologic factor (cardiac disease, aneurysm, etc.), the suddenness of the onset with the distribution of the gangrene, the affected territory corresponding to sudden obliteration of one of the larger arterial trunks, popliteal, femoral and iliacs. The differential diagnosis between embolism and thrombosis can rarely be made, for the gangrene is often due to extensive secondary thrombosis, rather than to the primary lodgment of an embolus in a larger vessel. For, the mere closure of an artery alone would not account for the extent of the gangrenous process in many instances. Furthermore, the pathological examination of the amputated limb will usually corroborate the view that secondary thrombosis is responsible for the extent of the lesion. Nor, is it always possible to locate exactly the site of the embolism or thrombosis. Although *simultaneous involvement of both lower extremities* with feeble pulse in the femorals suggests a saddle-shaped thrombus in the iliac, a similar picture may be due to simultaneous lodgment of emboli in both popliteals with secondary thrombosis extending up to the femoral artery. The study of clinical cases, however, together with pathological findings has demonstrated that even where we strongly suspect saddle-shaped embolism at the bifurcation of the aorta, this portion of the vessel may be found free at autopsy. In such cases it may be assumed, with some justification, that the saddle-shaped embolus was broken up and dislodged, and thrown into both femorals or popliteals.

When the femoral pulse is lost in both legs, the presence of a saddle-shaped thrombus is almost certain. When there are symptoms in both extremities, and the femoral pulse absent in one, present in the other, a saddle-shaped embolus may or may not be present. If it is, it occludes one iliac more thoroughly than the other. The femoral artery may be felt as a hard cord usually due to secondary thrombosis. The clinical picture may be complicated by sudden exacerbation in the limb which was at first but slightly affected, an argument in favor of the view that another embolus had been cast off in the corresponding vessel. Occasionally embolism or thrombosis of the external iliacs will give the symptoms of ischemia, which will be soon followed by improvement due to the establishment of collateral circulation through the internal iliac arteries.

3. **Postoperative Embolic or Thrombotic Gangrene.**—We are concerned here not with the pulmonary emboli and thrombosis, but merely with the lodgment of emboli in the peripheral arteries, where they may produce gangrene. Surgical operations seem to be a very common cause, or at least seem to provoke in some way or other, the detachment of

emboli in the formation of thrombi in veins and in arteries. Schenk[1] found that of the cases of thrombosis and embolism following operations, 58 per cent. occurred after the removal of large pelvic tumors. In 3204 myoma operations, 96, or 3 per cent., were followed by thrombosis. McLean[2] in his studies of a series of 1310 laparotomies found 26, or about 1.9 per cent., complicated by thrombosis or embolism.

The production of gangrene of this type is not thoroughly understood. Doubtless traumatism to the iliac vessels or pressure on the popliteal in the Trendelenburg posture may explain some of the cases; or a complicating cardiac lesion may be the source of an embolus in others. There still remains a fairly large number in which no satisfactory interpretation of the pathogenesis has as yet been offered.

Similarly in the cases of gangrene complicating pregnancy (so-called *Puerperal Gangrene*), the causal factors have not been adequately clarified. Most of the reported cases have occurred after confinement, a very few during pregnancy and after abortion.

Perhaps even more instructive than a discursive exposition of this form of gangrene will be the citation of the following clinical observation:

In a young man operated upon for gangrenous appendicitis by a colleague (February 14, 1920), the right forearm suddenly became cold, cyanotic and motionless early in the morning of the third day after the operation. The brachial artery did not pulsate below its upper fifth.

February 17, some three and one-half hours after the onset of symptoms, the author exposed the upper portion of the brachial artery at the site of the thrombus, under novocain anesthesia, and by arteriotomy removed a clot about 2 cm. in length, closing the artery by suture according to Carrel technic. There was excellent pulsation in the brachial below the site of the clot and no leakage after completion of the suture. In spite of this demonstrable patency of the brachial artery below the site of the embolism and thrombosis, no pulsation could be detected in the radial artery. It was, therefore, believed that secondary clots had previously become detached and lodged in the peripheral vessels.

Clinical Course.—February 18, in spite of the reëstablishment of the circulation in the lower brachial artery, the right hand was somewhat cold, but there was definite evidence of *marked improvement in its circulation.* On February 19 the color of the thumb looked doubtful, being somewhat cyanotic and cold. Furthermore, there were signs of muscular palsy and some tendency to contracture of the fingers in the flexed position. Extension of the hand seemed impossible, although motion of the fingers was excellent.

On February 20, after the application of dry heat in an electric baking apparatus in which a contact burn could have taken place, *trophic disturbances* became manifest over the posterior surface of the

[1] New York Med. Jour., September 6, 1902. Trans. Am. Gyn. Soc., 1913.
[2] Jour. Am. Med. Assn., August 29, 1914.

forearm. A long whitish area suggesting dead skin, with loss of sensation over at least 3 inches by 1½ inches appeared. There was another similar smaller area over the posterior aspect of the wrist and the skin just above. Later in the day, the central portions of these areas showed blebs.

February 25, the fact that a certain amount of gangrene would develop was well established since the following lesions could be demonstrated. (1) *The Trophic Lesions.* (2) *Evidences of Gangrene.* (3) *Circulatory Disturbances.*

The Trophic Lesions.—The areas of circulatory insufficiency were well demarcated on February 25, there being an elongated area some 3 x 1½ inches surrounded by a well defined narrow line of deep red, as if a red chalk mark had been drawn around it. Within this there was a distinctly white zone less than 1 cm. in diameter enclosing a central purplish space, in which the typical blebs of gangrene were to be seen.

Evidences of Gangrene.—The thumb showed a deep purplish color; was somewhat withered, evidently in the early stage of a dry gangrene.

Circulatory Changes.—Although the postero-external aspect of the forearm was fairly warm, the internal aspect changed color so that one was in doubt as to its future. Between the thumb and the dorsal trophic disturbance, over the thenar eminence and thereabout on the posterior surface, there was a peculiar ham-colored red with diminished temperature suggesting marked circulatory disturbances. The four fingers, however, were in fairly good condition, the patient could move them, and they had fairly good color.

Outcome.—During March, 1920, the gangrenous process became delimited, the necrotic patches of skin became sequestrated and detached, while dry gangreme of the thumb led merely to the loss of the terminal phalanx of the thumb. The nerve involvement lasted for about four weeks and then gradually disappeared.

4. **Thrombotic Gangrene in Healthy or but Slightly Diseased Vessels.** (*Peripheral Thrombotic Gangrene.*)—There is still another class of cases in which the etiology of the thrombus formation is not clear, and in which pathological studies have revealed a bland thrombosis of the peripheral vessels, in the territory of the dorsalis pedis and plantar arteries, that is undoubtedly the immediate cause of the gangrene. It may occur in elderly individuals, who have slightly or moderately atherosclerotic vessels, or may occur in vessels that are practically normal save for plaques of thickened intima. These must be distinguished from the cases of thrombo-angeitis obliterans because the specific and characteristic lesion of thrombo-angiitis obliterans is absent, and since the thrombotic process is less extensive, coming on suddenly, without the long history so characteristic in thrombo-angiitis obliterans. The author was unable to find a description of this type of gangrene in the literature.

Clinically there is the history of exposure to cold or other insult or trauma. Or, without a cause, one of the toes, usually the big toe, becomes cyanotic; the distal portion of the foot shows areas of pallor.

The big toe, or the other toes, may show marked ischemia on elevation, or the cyanosis may be so marked as to mask the blanching. *Sometimes pain is altogether absent,* another distinguishing feature from thrombo-angiitis obliterans, as well as from the cases of acro-asphyxia. There may or may not be slight erythromelia or reactionary erythromelia. Both lower extremities may be affected, although not simultaneously as in Raynaud's disease. There may be a history of gangrene of one limb, presumably following a mechanical or thermal trauma. Or, no such history may be obtainable. Thus, the first symptom to be noticed may be the appearance of bluish or cyanotic spots or areas at the tips of one or more toes, usually the big toe or the big and adjoining toe. Rather significant, too, is the absence of pain in some of the cases.

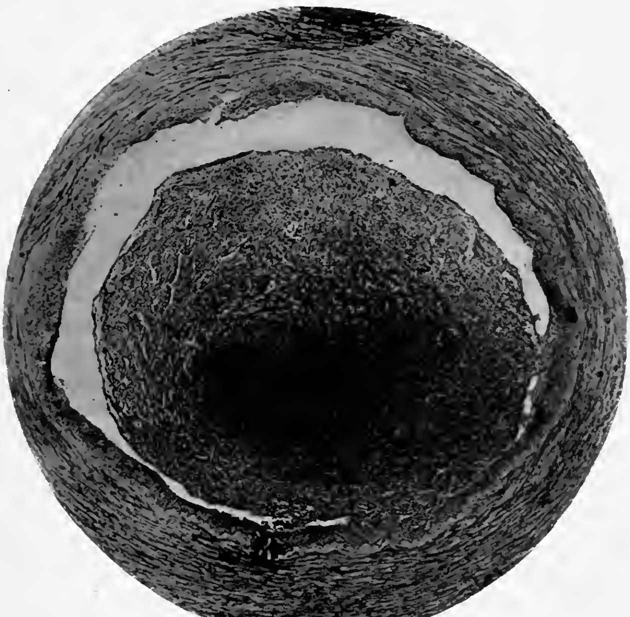


Fig. 510.—Bland thrombosis in slightly diseased vessel in case of thrombosis in peripheral vessels. (Buerger in Archives of Diagnosis.)

Low amputation may not suffice and reamputation may have to be resorted to in some cases, as at the knee or higher.

Pathological studies (Buerger) have revealed that the vessels are practically negative, except near the site of gangrene. Bland organizing thrombi are found in the territory of the dorsalis pedis and plantar vessels (Fig. 510). In such cases a differential diagnosis between chronic acro-asphyxia to which thrombosis has been added, and slight arteriosclerosis with superadded thrombosis in the distal vessels cannot be made.

From the *diagnostic standpoint,* the cases are interesting because they may be confounded not only with chronic acro-asphyxia, but with thrombo-angiitis obliterans and arteriosclerosis. The suddenness of the onset, the sudden disappearance of the pulses, and the rapid development of symptoms, the absence of pain in some instances, the absence of evidences of marked arteriosclerosis in spite of the age of the patient are rather characteristic; in thrombo-angiitis obliterans there is a long prodromal period in much more youthful individuals.

5. **Embolism and Thrombosis Complicating Arteriosclerosis.**—Embolism may occur when the larger arteries (particularly the aorta) are markedly diseased. Small thrombi attached to ulceration may become detached and lodged in the more peripheral parts of the circulatory system. In such cases, the symptoms are similar to those described as secondary to cardiac disease. This type may coincide with post-operative embolic gangrene after operations on individuals with the arterial lesions referred to.

Thrombosis in the peripheral vessels complicating arteriosclerosis has been described under the section on arteriosclerotic gangrene. The most characteristic cases are those in which the symptoms of threatening gangrene occur.

Treatment of Embolic and Thrombotic Gangrene.—The following operative methods have been proposed for dealing with thrombosis and embolism of arteries: (1) Ligation; (2) arterio-venous anastomosis; (3) arteriotomy; (4) arterial resection; (5) arterial catheterization.

1. *Ligation* has been suggested with a view to avoiding the dangers of embolism. However, Stewart[1] contends that when the diagnosis is certain, thrombosis is usually occlusive and the danger of embolism is usually past, and therefore does not recommend ligation. We are concerned here with the role of thrombosis and embolism in the production of gangrene, and certainly ligation can in no way improve the circulatory condition.

2. *Arterio-venous anastomosis* at the present stage of our knowledge seems to be theoretical rather than practical. Stewart believes that in most of the cases reported favorable, even if the arterio-venous fistula remains patent, the blood deflected from the artery into the vein does no more than hinder the return of blood in those veins, producing a sort of passive hyperemia. Stetten[2] from his experimental studies, concludes that the operation is dangerous, and the results have been most unsatisfactory, except in a very small percentage of cases, and that even if the anastomosis functionates, which it rarely does, there is no possibility of circulatory improvement, and that the usefulness of the operation is restricted to an inappreciable minimum.

3. *Arteriotomy* is an operation which must be seriously considered if the diagnosis be made sufficiently early, and if operation be permitted before the effects of occlusion of the vessels have set in, namely, advanced gangrene. Success can only be obtained if the arterial wall is still undamaged at the site of the embolism, and before the secondary extensive thrombosis has occurred. The operation was first proposed by Sabanajew in 1896. Stewart reported a successful case in May,

[1] Ann. Surg., 1915, p. 519.
[2] Surg., Gynec. and Obst., April, 1915, 381.

1907, in a man aged sixty-one years, in whom thirty-six hours after the onset of pain, the femoral was opened, and an embolus extracted and the artery sutured. Pulsation immediately appeared in the femoral below the point of suture, and also in the popliteal, but not in the tibial. Forty-two days later, the leg was amputated below the tubercle of the tibia, and evidences of good circulation were obtained at operation.

Mosny and Dumont[1] were able to save a limb by the removal of an embolus five hours after its lodgment in the femoral artery. Murphy[2] removed a clot from the iliac and femoral in a case after gangrene had already set in, making an incision in the superficial femoral. By means of a spoon or scoop and catheter, the clot was dislodged, the catheter passed up into the aorta, a good flow of blood obtained and the artery sutured. He believes that in cases of aseptic embolism, immediate removal by division of the artery in the line of embolism or below should be resorted to. Although in his case he used a spoon and catheter for probing and dislodging the clot, he believes that aspiration through a catheter is a better means of removing the plug. If the catheter be divided on the slant, its open end can be easily introduced into the artery, and unless the embolism is hard, it can be sucked or drawn into the catheter. He does not advise incision into the artery at the site of the embolism because this region is already roughened, and the tendency to subsequent thrombosis is favored.

Bauer[3] has reported a successful case of removal of embolism from the aorta just above the bifurcation through an incision into the artery made by the transperitoneal route. The embolus was about 3 cm. long, had the form of a molar tooth with two short roots, these lying in the iliac arteries. The symptoms referable to the lower extremities promptly disappeared, except for some pains in the left foot and calf. This operation, performed three hours after the onset, was followed by recovery, the patient leaving his bed on the twenty-fifth day.

Buerger in a case of embolism in the upper portion of the right brachial artery, employed the following technic.

Under novocain anesthesia and sharp dissection, the artery both at the site of the thrombus as well as for some two centimeters above and below, was exposed, kept moistened with saline and lubricated with liquid vaseline. The extent of the thrombus could then be easily determined both visually and by palpation. After the application of a *serrefine* or arterial compressor above, a site for arteriotomy was selected at the very upper end of the clot. Using the very finest Kirby needle and lubricated doubled China silk, incision into the artery was facilitated and made safe by transfixion of about 7 mm. of the presenting arterial wall longitudinally with a silk suture, the two emerging ends serving as guy sutures to hold up the arterial wall and simplify incision. This accomplished, the upper end of a clot presented itself. To avoid injury of the intima, the thrombus was milked up and out-

[1] Bull. de l'Acad. de méd. de Paris, lxxv, No. 43.
[2] Jour. Am. Med. Assn., 1909, lii, 1661.
[3] Zentralbl. f. Chir., December 20, 1913.

ward by merely compressing the artery from below upward, beginning in the distal empty portion of the artery. In this way a thrombus almost 2 cm. in length was dislodged. Its surface seemed roughened, its texture friable. Washing of the artery with saline and longitudinal suture of the artery in Carrel fashion, completed the operation. No leakage followed the removal of the arterial clamp above, and pulsation could be immediately detected in the brachial artery below.

III. NEUROPATHIC GANGRENE.

Only Raynaud's disease and multiple neurotic gangrene will be discussed here, since the differential points of diagnosis in acro-asphyxia, scleroderma, sclerodactyly, erythromelalgia have been already given elsewhere.

Raynaud's Disease (*Symmetrical Gangrène Asphyxie Locale Symmétrique*).—Symmetrical gangrene is an affection which may appear independently of other disease, or in the course of other nervous diseases such as hysteria, traumatic neurosis, tabes dorsalis, epilepsy and Basedow's disease. It seems to be associated as a rule with a neuropathic habitus, and anemia or other debilitating conditions may predispose to it. As a rule, it affects youthful individuals, particularly of the female sex. Emotions such as sudden fright or other striking nerve impulses may be regarded as contributing causes. Some authors regard the infectious diseases, such as typhoid, influenza, erysipelas pneumonia, also nephritis and pericarditis as influential in bringing about a predisposition.

Pathology.—Although a number of authors have claimed to have found changes in the peripheral arteries, such as endarteritis, endophlebitis, it seems highly improbable that organic changes of the arteries are responsible for the vasomotor symptoms and the gangrene. It is more likely, according to Oppenheim,[1] that a number of different causes initiated by infections, intoxications, etc., may produce a lesion in the spinal cord, which is responsible for the symptom-complex. Cassirer[2] believes that the vasomotor paths and centers may be considered to be in a condition of increased irritability, either because of congenital *anlage* or because of repeated injurious impulses, such as cold, infection, intoxication, etc.

Symptoms.—The disease is practically always paroxysmal in its manifestations. Beginning with paresthesia, a feeling of formication, or a "dead" feeling, the fingers or toes soon become cold and white and sometimes cadaveric or waxy white in appearance. This is regarded as the stage of *local syncope,* or of *ischemia.* Severe pain which involves not only the fingers or other peripheral parts, but also the whole extremity, may even precede the attack, and reach its greatest intensity with the complete development of the attack. The local syncope may disappear completely or give way within a short

[1] Lehrbuch der Nervenkranheiten (Karger, 1908, ii).
[2] Vasomotor u. troph. Neurosen, 1912 (Berlin, S. Karger.)

time, a few minutes or a few hours to the stage of regional cyanosis or local asphyxia.

The stage of *local asphyxia* may be the first one, in some of the cases, and be unattended with syncope. When it is well developed we see symmetrical portions of the hands or feet, fingers or toes, usually the end phalanges, become bluish-red, the cyanotic color deepening, becoming finally almost black. The pains become more and more intense. Finally, the epidermis may be lifted off by accumulation of serum under it, or by subcutaneous hemorrhage.

Following cyanosis, *gangrene* may occur, or the bluish-black discoloration may give way to a stage of rubor or redness. Gangrene usually begins with the appearance of a blackish spot at the tip of the phalanges, or with a bleb filled with bloody serum. In some cases an ulcer is left after the separation of the gangrenous patch, healing occurring very slowly. More rarely the gangrene may extend into the deeper parts, so that a whole phalanx or more may become completely mummified. It is rare to find extensive gangrene, and spontaneous demarcation is the rule. During the attacks, sensation in the affected part seems to be diminished, and motion of the part seems also to be inhibited.

Gangrene usually affects the end phalanges of the fingers or toes in symmetrical fashion, and only rarely are all the fingers or toes affected. Asymmetrical development, that is, unilateral, seems to be very rare and probably some of the reported cases do not belong to true Raynaud's disease. The disease may also involve other parts of the body such as the tip of the nose, the nates, or ears, etc. The disease may be self-limited after a period of a few months (two to four months), particularly after one complete attack. Or, a number of succeeding attacks with intermission may extend over a period of years. In some of the cases there is a more chronic course, the affection passing over into a condition of scleroderma.

Buerger's observations favor the view that the arteries are patent in most of the cases, and that organic disease of the vessels cannot be held responsible for the symptom-complex.

Diagnosis.—The disease will be confused most frequently with thrombo-angiitis obliterans, from which it can be readily differentiated according to the characteristics described under this disease.

In *chronic acro-asphyxia* (also known as acro-cyanosis) there is a progressive, slowly developing asphyxia of the ends of the extremities without paroxysmal attacks, associated often with hypesthesia. In a second group of cases of acro-asphyxia there are associated trophic disturbances which may still further lead to confusion.

Raynaud's disease must also be differentiated from erythromelalgia, syringomyelia, acroparesthesiæ (Schultze), congenital cyanosis of the fingers, various forms of gangrene due to cardiac and arterial disease, including athero- and arteriosclerotic gangrene, the so-called intermittent claudication of Erb, ergotism, etc.

From *athero- and arteriosclerotic affections* it must be distinguished by its paroxysmal nature, symmetrical development, pulsation of the arteries, and the absence of the characteristic phenomena of arterial occlusion, namely, ischemia on elevation, compensatory rubor on depressing the limb, and other characteristics already described.

From *erythromelalgia* it can be differentiated if the true characteristics of erythromelalgia, namely, the red color, attacks of pain, slight extent of trophic disorders, tendency to elevation of temperature of the part, etc., are properly considered. In Raynaud's disease the color soon becomes cyanotic, analgesia may be present, the trophic disorders become marked, the temperature of the part becomes low.

In *syringomyelia* the onset is slow, the course extends over many years, and the symptoms appear first in one limb, usually as a painless felon. There is dissociation of the sensory phenomena, atrophy of muscles, tendency to the formation of perforating ulcers, and ulcers in general, necrosis and caries of bone.

In *congenital cyanosis* of the fingers, the end phalanges become tumefied, while in Raynaud's disease they have a tendency to become reduced in size. Also, in congenital cyanosis there are associated cyanosis of other parts of the body, and labored breathing.

Intermittent claudication described by Erb, which by some authors has been confused with the Atypical Vasomotor Neuroses, is incorrectly regarded by many as an entity, but should be considered as a symptom of a number of diseases, being present in thrombo-angiitis obliterans, arteriosclerotic gangrene, and whenever the arteries of the extremities are narrowed or obliterated from whatever cause.

The differentiation from *ergotism* is discussed under gangrene due to ergot.

Treatment.—In order to combat the neuropathic diathesis which doubtless contributes toward the Raynaud complex, attention should be paid toward strengthening and improving the general physical condition of the patient. In the way of prophylaxis, all thermic injurious influences should be avoided. Since the symptoms are most marked in winter, cold should be avoided. Galvanic hand or foot baths with one broad electrode (cathode) at the nape of the neck, the other electrode (anode) in the water are of value. One or both hands or the feet are placed in the bath, the current being strong enough to arouse a sensation of formication or prickling, the duration of treatment being about ten minutes. Arsenic given internally, either in pill form or in Fowler's solution, or as sodium cacodylate, is the most valuable drug. When gangrene sets in, the usual surgical principles must be followed.

Multiple Neurotic Gangrene of the Skin.—There are rare cases in which multiple patches of gangrene of the skin occur, which cannot be attributed either to diseases of vessels, the general condition, or to infection with bacteria. It seems to affect mostly young people, usually women, and is almost always associated with a marked nervous habitus.

Symptoms.—Characteristic is the appearance of numerous small necrotic foci in the skin, without anything in the general condition or local condition to account for their development, being thus distinguished from the so-called multiple cachectic gangrene. Peculiar burning or pricking sensation in the skin precedes the appearance of gangrene, while vasomotor symptoms are less regularly present. Finally mortification takes place, the dead area having been variously described either as yellowish white, brown or gray, greenish, parchment-like spots which represent death of tissue involving either the superficial layers of the skin, or reaching down to the subcutaneous layers. The skin separates, an ulcer being formed, the duration of sequestration varying from a few days to several weeks (five to fifteen days up to four to six weeks.)

Prognosis.—The prognosis is good as far as life is concerned, although the duration of disease may be a long one, and recurrences may take place.

Cassirer believes that in the majority of cases some nerve lesion must be the cause of the multiple necroses. Multiple neurotic gangrene must not be considered as an entity, but rather as a symptom-complex that can arise from a number of different causes. Multiple neurotic gangrene may be associated with gliosis spinalis, with tabes, peripheral neuritis, and herpes zoster, or it may follow severe urticaria (urticaria gangrenosa) or angioneurotic edema.

ULCERS.

By EMIL G. BECK, M.D., F.A.C.S.

Definition.—The term ulcer is applied to a large variety of defects in the skin and mucous membrane, usually of an infectious character. It is defined as a slow disintegration of the skin or mucous membranes with little or no tendency to healing. Destruction takes place by liquefaction or breaking down of the parts affected. It has many characteristics of the abscess in its formation. In the latter, however, the detritus accumulates within a closed space and forms a walled-off cavity, which by overdistention will open spontaneously, if not opened by surgical intervention, to allow the escape of the pus. In the open ulcer the detritus discharges freely from the ulcerating surface.

Classification and Etiology.—Ulcers vary in their character, their pathology, their appearance, their virulence and location. They may be classified according to any of these characteristics. Classifying them from their etiology, we have the following varieties to deal with:

(*a*) Ulcers due to infectious diseases such as syphilis, tuberculosis, leprosy, actinomycosis, etc.

(*b*) Ulceration due to malignant growths.

(*c*) Ulcers due to constitutional diseases such as diabetes, Raynaud's disease, gout, arteriosclerosis, etc.

(*d*) Ulcers due to injuries which have become infected, and in which the circulation and repair is poor; also due to frost bites, burns or corrosive substances, such as acids or caustic alkalies.

(*e*) Ulcers due to trophic conditions, injuries of nerves, or diseases of the central nervous system.

(*f*) Ulcers from impaired circulation due to varicose veins, thrombosis, or to pressure or irritation, especially of the aged, or invalids confined to bed (decubitus).

The variety of terms applied to ulcers is most confusing. Some are named according to their pathology; others according to their locations, or their behavior; thus we hear of the irritable or painful ulcer, the sloughing ulcer, the indolent, the fungus, the hemorrhagic, the rodent, the indurated, the excavated, the fistulous, the serpiginous, etc.

It is useless to describe each of these in detail since some of them represent certain phases or stages of the same case, and some of the names are now obsolete and discarded. There are, however, distinct and well differentiated types of ulcer, which may be described under the different heads:

The principal ones of these are:

(*a*) Varicose ulcer (ulcer of the leg, acute or chronic).
(*b*) Rodent ulcer.
(*c*) Mal perforans (perforating), trophic ulcer.
(*d*) Peptic ulcer.
(*e*) Syphilitic ulcer.
(*f*) Phagedenic ulcer.
(*g*) Senile ulcer.

Since the pathology of each of these differs, the treatment, of necessity, must differ also. Thus, varicose ulcer, for instance, would require different treatment from epithelioma or the syphilitic ulcer. Treatment of acute cases will also differ from that of the chronic. It will, therefore, be necessary to discuss the treatment of each variety separately, although some fundamental principles will apply to all varieties. Cleanliness of the ulcer and rest of the affected limb are the most essential of these principles. In other respects the treatment may differ in each type. As the leg is the most common site for ulcer and represents the average type to be treated, a description of its pathology, symptoms and treatment in this chapter, may be a guide for treating other types of ulcers.

ULCER OF THE LEG (VARICOSE ULCER).

This term implies that the varicose veins are the cause of the ulceration. The presence of the most extensive varicosity, may, however, not cause the ulceration; but the combination of the two is so common that we cannot help but attribute the ulcer in a large measure to the varicosity of the leg.

Symptoms.—The imperfect return of the venous blood through the varicose veins of the leg causes stagnation of blood in the lower part near the ankle, produces an edema and consequently poor nutrition of the skin and the underlying tissues. An infiltration soon takes place which gives the skin a leathery appearance, usually of a purple or a bluish discoloration. In time there appears a deposit of pigment in the skin, and even if the ulcer has healed, a large area including the scar will retain this brownish color.

The congestion and induration may persist for years without causing the actual breaking down of the tissues, an exciting cause is sometimes necessary to start the ulcer, such as a slight injury, rubbing of a hard edge of a shoe against the inflamed part or a slight bruise which when infected may become the starting-point for a prolonged ulceration.

Weeping eczema will often precede a gradual disintegration of the skin, which may progress in all directions, so that in time it may encircle the entire lower limb; in other cases an inflammation of the veins (phlebitis), whether calcified or thrombosed, may lead to their rupture, cause profuse hemorrhage, and from this point the ulcer may develop.

The ulcer itself is usually dark red with small necrotic areas which resemble gangrenous ragged connective tissue. The edges may have crusts, underneath which there is some pus, or they may be smooth and glistening, indicating an effort of nature for healing. An attempt to detach these crusts may cause slight bleeding. Fig. 511 illustrates an extensive and neglected case of ulcer of the leg.

The destruction of the tissues is not always confined to the skin. In the more virulent forms, it may penetrate deeply, destroy the muscles and may even affect the bone itself. In the latter type the ulcer is of a grayish, dirty appearance, and the granulations present a flushy character and bleed easily with slight abrasion or cleaning. The condition may be so severe as to resemble true erysipelas.

Fig. 511.—Extensive chronic ulcer of the leg.

The secretion varies according to the activity and the type of the ulceration. In some cases, it is profuse and creamy; in others it is very liquid, dirty looking and of an offensive odor. It consists principally of detritus from broken-down cellular tissues, a serous exudate of a large number of pus cells and a variety of microörganisms. In the more acute cases the streptococcus is present.

Ulcer of the leg is usually a chronic condition. Cases are frequently met with which have existed thirty or even forty years. During this time there occurred periods of several years when the ulcer remained healed; but broke open again and again. It is at times very painful without causing constitutional symptoms. The patient tires very easily on walking or with strenuous work. The unpleasant part is the odor which is especially noticeable when the bandages are not changed frequently; they become soaked with the secretions and when the same are dried up, they will retain their most offensive odor.

Pathology.—Inasmuch as the causes are not the same in all cases of ulcer, the pathogenesis will necessarily vary; but certain characteristics are rather common in most ulcers.

The ulcer has always an infiltration process of either an acute or chronic character with a gradual destruction of the skin or mucous membrane, and sometimes underlying structures. The molecular death of the part causes a sloughing of tissues, leaving an unhealthy granulating surface. There is little tendency for repair and this distinguishes it from a healthy granulation. This lack of reconstruction is due either to infection which is the etiological factor or the local condition of nutrition—a local edema—due to obliteration of small bloodvessels or of thickening of their walls (endarteritis obliterans).

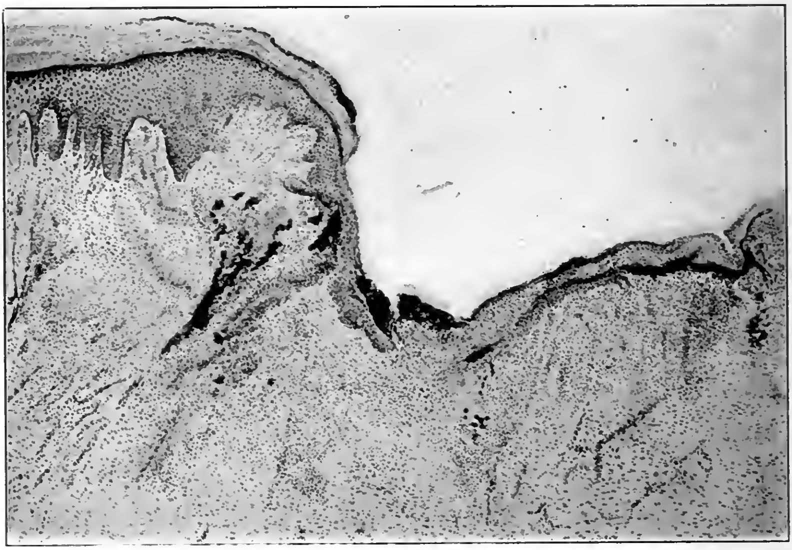


Fig. 512.—Ulceration showing destruction of the skin. (Warren.)

Histological Changes.—Beneath the debris, which consists of broken-down cellular structures, is a layer of granulation tissue consisting of large deposit of leukocytes rich in capillaries with a small quantity of intracellular substance; beneath this layer the connective tissue becomes more predominant and cellular, and infiltration less pronounced, and still deeper, a distinct layer of connective fibrous tissue forms a dense wall of the ulcer. At the margin of the ulcer we note the epithelial structure of the epidermis bordering on the granulation tissue. The epithelial cells are sometimes detached and partially destroyed, indicating the corroding action upon the epidermis. One may observe the changes in the epithelial cells nearest the ulcer border to be less distinct in outline and partially broken down (Fig. 512).

Treatment of Chronic Ulcer.—The treatment may be divided into palliative and curative. In some cases a cure is impossible. To this group belong the very extensive ulcers, involving the entire circumference of the lower part of the leg, in which the degenerative change below the ulcer are so extensive, that superficial circulation cannot be restored. This is particularly the case in very old people where the extensive operations are contraindicated. In these cases, however, much can be done to palliate the condition. First of all complete rest of the limb and cleanliness of the wound are necessary. Warm, moist boric acid dressings should be applied three times daily or Billroth's solution:

Liqu. plumbi (subacetatis)	25
Alum pulv.	5
Aquæ	1000

Apply once a day.

Elevation of the limb is essential and patient should remain in bed. The ulcer will gradually assume a more healthy appearance; the bad odor will subside, and the swelling of the foot will materially diminish. The ulcer may eventually heal; but unfortunately, it is apt to break out again when the patient resumes walking. The tender scar will become moist and break open if the patient neglects the rules for its prevention.

In younger individuals when the ulcer is not quite so extensive, a complete cure may be expected. The crusts should be gently removed and scrupulous cleanliness observed. Warm moist applications and elevation of the limb should be employed. If the moist dressings produce too much maceration of the tissues, they may be left off for a day or two, when the ulcer may be treated only with dusting powders or some suitable ointment, such as:

Rx. ichthyoli	10
Vaseline	50

Apply externally.

Dusting powders such as dermatol, aristol or orthoform, and many others have been used with apparent success.

Professor Unna has devised the following treatment which at one time was used quite extensively:

The ulcer is dried with gauze and painted with an emulsion prepared, as follows:

Dissolve 40 grams of gelatin in 100 grams of water. While the fluid is hot add 40 grams of glycerin and 40 grams of white zinc oxide powder, and stir continually until it cools and becomes semisolid. Melt this paste before using by placing receptacle into a hot water-bath. Paint this emulsion over the entire leg from the ankle to the knee. Wind a layer of fine gauze bandage smoothly over it; then paint the bandage with another coat of this emulsion, and place another layer of gauze bandage, and paint this surface also. This is allowed to dry and forms a smooth dressing over the ulcer and surrounding inflamed tissues. The dressing is kept on for several weeks (four to six). A trap door over the ulcer may be made for cleaning the surface.

Similar dressings such as camphor were recommended by Schulze,[1] of Berlin. The ulcer is first cleansed with soap and water, and a wet dressing of 2 per cent. solution of acetate of aluminum is applied for three days. After the first dressing, the ulcer is covered with a small piece of gauze soaked with spirits of camphor. A piece of rubber dam is placed over this, and the dry gauze dressing snugly applied.

Since the *varicose veins* seem to predispose to the formation of the ulcer, it is natural that a cure of the varicose veins would aid in the healing of the ulcer, and this is actually the fact. Therefore, the surgical treatment in all extensive varicosities is indicated.

The various operations such as ligation or dissection of the veins or the subcutaneous stripping method have been advised by Dr. Charles Mayo. The removal of the veins alone is at times not sufficient. It is often necessary to excise the ulcer itself, leaving healthy borders, and a clean bottom of the ulcer, so that the skin may gradually regenerate from the edges and cover the surface. In order to promote the rapid regeneration of the skin, I have employed for many years adhesive strips along the margins of such ulcers.[2] This method is so effective in these cases, that I desire to give a detailed description of it.

Adhesive Plaster Strips for the Rapid Regeneration of Skin Over Granulating Wounds.—The simplicity of this procedure and its effectiveness are here illustrated. It may be applied in all types of granulating wounds, whether these be due to ulceration, burns, trauma or subsequent to surgical operations.

The technic consists in applying strips of plain or zinc oxide adhesive plaster along the edges of the granulating wound. These strips one-half to three-quarters of an inch in width, must be so adjusted that they overlap both margins, that of the skin and that of the ulcer. This leaves the center of the ulcer exposed for the escape and absorption of the wound secretions by a dry sterile gauze. Twenty-four hours later the dressing and adhesive plaster are carefully removed. It will be found that along the margin of the ulcer, there has now formed a bluish-gray border. This bluish-gray border represents the new growth of epithelial cells.

The wound is now dressed with dry gauze, which is left on for twenty-four hours, followed in the next day by another application of adhesive plaster. This procedure is repeated until the entire granulating surface is covered.

All necrotic tissue must be allowed to slough off or be curetted so that the base of the wound is clean, before we can expect the epithelium to grow. The wound should not be rubbed with gauze, as this would be apt to destroy the new epithelial cells.

Adhesive plaster was used as early as twenty years ago in the treatment of chronic ulcers.

[1] München. med. Wchnschr., March 19, 1901.

[2] Beck: Adhesive Plaster Method for the Rapid Regeneration of Skin over Granulating Wounds, Ann. Surg., March, 1919.

Many substances have been used to stimulate skin regeneration, such as balsam, acacia and paraffin and scarlet red. None, however, fulfilled the requirements as has the adhesive plaster. Its action is largely mechanical, as explained in an article written by Dr. Charles A. Parker in the *Journal of the American Medical Association.*

Explanation of the Rapid Epithelial Growth.—The reason why large granulating surfaces have no tendency to be covered by epithelium until skin grafts are used, is that the granulation tissue grows much faster than the epithelial growth, and thus we find that the granulating mass overlaps at the margin of the wound. In other words, the granulating mass is much higher than the skin level. The epithelial growth stops at this margin because it cannot grow upward over the elevated granulating surface.

In order to overcome this obstacle we must establish a level surface, merging from the skin over the granulating surface, and this is accomplished by pasting adhesive plaster over the margin. It keeps the granulations from rising any higher than the skin and gives the epithelium a chance to regenerate underneath the adhesive plaster. The epithelial cells will grow rapidly under these favorable conditions and cover as much as one-quarter inch in twenty-four hours all around the wound, which is plainly visible by the appearance of a bluish-gray border. The under surface of the adhesive plaster acts as a path for the regeneration of the cells, on the same principle as the vine would grow along a string of wire and cover, within a short period, the entire wall of a building.

This explanation of the growth is not entirely theoretical, it is based upon experimental study on animals and more extensively on the human. The microscopic examination of specimens cut out for this purpose from healing wounds or ulcers, has proved this beyond doubt.

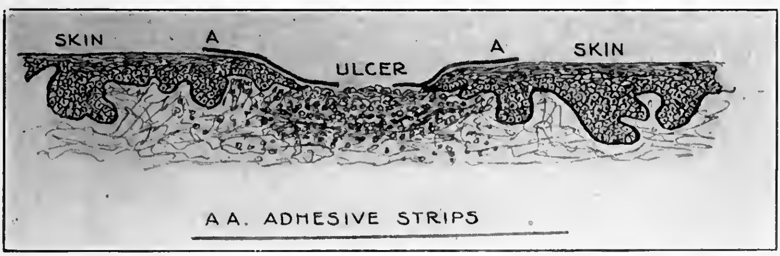


Fig. 513.—Regeneration of epithelium over ulcer.

For illustration I exhibit schematic drawing (Fig. 513) which is self-explanatory.

Technic of the Adhesive Plaster Method.—*Varicose Ulcer of the Leg.*—Fig. 514 illustrates a typical case in which the largest varicose vein and the ulcer in the lower part of the leg had been excised. The clear-cut borders of the ulcer have comparatively healthy skin edges.

During the first four days this wound was carefully packed with plain gauze. On the fifth day a ring of adhesive plaster as illustrated in Fig. 514 was pasted in such manner over the ulcer as to cover completely the rim of the ulcer and overlap the granulation surface, leaving the center exposed. This was repeated every second day until the entire ulcer, was covered with apparently normal skin, as shown in Fig. 515.

Fig. 514.—Excised ulcer before adhesive plaster is applied. (Above, ring of adhesive plaster illustrated.)

Ulcer of Ankle Unresponsive to Skin Graft Treated with Adhesive-plaster Strips.—An ulcer of the ankle in a young man which had existed for some five years, with no tendency to heal (Figs. 516 and 517). Several methods had been tried, nevertheless it persisted. We first dissected an area of about three inches in diameter, clear to the border of the true skin and then made a transplant of skin from

Fig. 515.—Ulcer surface covered with skin.

the thigh. This, however, sloughed out (Fig. 515). We then tried Thiersch grafts; but these also sloughed away. There was no local tendency to nourish any skin graft or transplant. Thereupon we tried the adhesive plaster method and succeeded in regenerating the skin completely within four weeks, as shown in Fig. 517. The skin is perfectly movable over the regenerated surface.

Figs. 518, 519, and 520 illustrate another type of ulcer, namely the postoperative ulceration in tuberculosis-osteomyelitis. Fig. 518 shows the extent and character of the granulating surface after the skin and

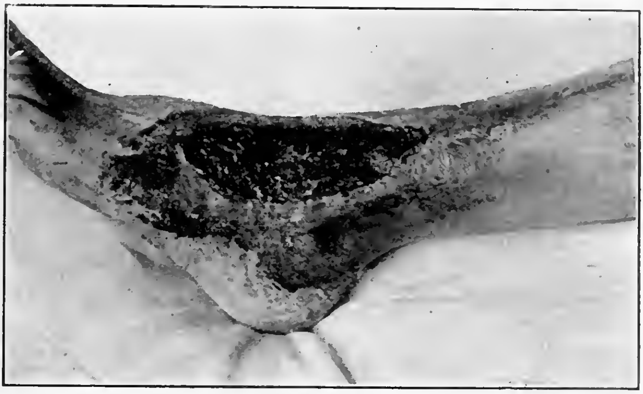


Fig. 516.—Neglected ulcer after sloughing of graft.

diseased costal arch had been removed. Fig. 519 illustrates the method of applying the adhesive strips, and Fig. 520 the final result without the use of skin grafting.

Fig. 517.—Complete healing of adhesive-plaster strips. Skin movable.

Fig. 521 represents a section of a piece of skin removed from a scar three years after its formation by means of the adhesive plaster.

From this newly formed skin I made microscopical sections, which showed distinctly the regeneration of the epithelium very nearly that of normal skin. There is a distinct basement membrane between the connective tissue of the outside and the epithelial layer (Fig. 521), but no sweat glands, or hair follicles. In this respect this newly formed skin differs from the normal. But for practical purposes the skin surfaces so covered are usually dry and fulfil the requirements of

Fig. 518.—Granulating surface remaining after resecting costal arch.

Fig. 519.—Method of application of the adhesive plaster.

Fig. 520.—Entire surface covered by new growth of skin from edges.

normal skin. At any rate, it is the best substitute for normal skin, for it has no tendency to contracture.

Fig. 521.—Microscopic section of newly formed skin removed several months after formation.

MAL PERFORANT.

(Perforating Ulcer of the Foot.)

Definition.—A chronic ulceration usually on the sole of the foot or the heel, of trophoneurotic origin, and progressive in character. The ulcer begins in a callous part of the sole. The borders sometimes overlap the granulating wound, forming a sort of rim of thickened epidermis. Suppuration is not profuse, rather serous in character; but oftimes offensive in odor.

Etiology.—Formerly it was regarded as a result of late syphilis; at present it is attributed to various causes, mainly to such diseases as diabetes, syphilis or alcoholism, and especially locomotor ataxia. The degenerative changes are due to arteriosclerotic and trophoneurotic conditions and consequently poor nutrition. Affections of the spinal cord such as syringomyelia, spina bifida and progressive paralysis are also regarded as causative factors. The exciting factors are pressure of a hard shoe against the callous portion of the foot or some trauma.

Mal perforant ulcer is rare in children, only in cases of spina bifida. It usually occurs in persons between thirty and fifty. The ulcer usually begins as a small abrasion on the calloused part of the sole of the foot or heel; but may develop anywhere that callosity is present. It grows larger and deeper, the calloused skin is perforated and a red, somewhat sensitive granulation is exposed. The ulcer may burrow deeper into the foot until the bone is exposed and excoriated. In advanced cases, osteomyelitis of the metatarsal bones may result.

There is very little tendency to spontaneous healing; in fact it is toward progression, even with the most painstaking treatment.

Treatment.—The underlying cause of the ulcer, such as syphilis, diabetic and spinal diseases must be taken care of if any result is expected. Rest to the foot with frequent bathing in hot water, and when walking a well-fitted shoe, and a felt ring should be worn which will often lead to gradual improvement. The calloused edges of the ulcer should be carefully trimmed and the ulcer itself treated with antiseptics—silver nitrate solution, 20 per cent., applied daily and aristol powder dusted over the ulcer. If the bone is affected, it requires surgical intervention, curetting or removing the bone which is affected, packing the cavity with gauze followed by antiseptic washes or salves. If the ulcer progresses in spite of all of that, and invalidism is threatened, it may be even indicated to amputate the foot. This, however, should be reserved for exceptional cases.

RODENT ULCER.

(Jacob's Ulcer or Epithelioma Ulcer.)

This term applies to the ulcerating stage of epithelioma, occurring most commonly on the face of old people. It originates in center of an old superficial epithelioma and gradually enlarges in circumference as well as in depth. It may assume large proportions and involve destruction of tissues until it may be regarded as malignant growth. It differs from true carcinoma, in that it does not involve the lymphatic glands. The ulcer is excavated and has hard, sharply defined and elevated borders; it is painless and when not very extensive, movable with the skin.

The treatment should be radical since the neglect may lead to extensive destruction, and vital organs may be invaded. The eyelid is not infrequently the seat of this ulceration, causing impairment of the sight or even destruction of the eye.

In the rodent ulceration application of salves and washes are inadequate, especially since we possess more efficient means. The treatment should be either surgical or radiotherapeutic, the method to be chosen to suit the individual case.

Surgical Treatment.—In case of ulcer involving the eyelid, for instance, a plastic operation, is the most advantageous. For illustration a case is here cited.

Fig. 522 illustrates a chronic rodent ulcer of the upper eyelid of a man about forty-five, which had practically destroyed the upper eyelid. The condition was threatening to the eyesight. By a delicate plastic operation performed by Dr. Carl Beck who employed a shifting skin flap from the forehead, he restored the upper eyelid not only in appearance but in function as well. Fig. 523 illustrates the new eyelid about two months after the operation and Figs. 524 and 525 show the patient's ability to open and close the eyelid normally.

When the ulcer is on the cheek or other parts of the body, an excision of the same without an attempt to cover it with skin, is preferable.

Fig. 522.—Chronic rodent ulcer of the eyelid.

Fig. 523.—Plastic reconstruction of upper eyelid by skin transplanted from forehead.

Figs. 524 and 525.—Patient opening and closing eyelid.

The growth should be excised completely and a narrow margin of the normal skin should go with it so that the epithelium may regenerate from the edges of the healthy skin. The denuded surface will soon contract and a small but healthy scar will remain. Skin will not grow over the granulating surface unless the growth has been removed entirely. The application of adhesive plaster as described in this chapter, may be employed to hasten the regeneration of skin.

Radiotherapy has now been recognized as the most efficient in the treatment of rodent ulcer. The literature contains numerous, reliable reports, in which the usefulness of this method is demonstrated. Radiologists have successfully employed the roentgen rays, the Finsen rays and radium, or a combination of these. The technic as well as the results may be found described in the chapter on Radiology. Cauterization or caustic salves are also effective; but radiotherapy has supplanted them.

PEPTIC ULCER.

Peptic ulcer will be described in the chapter on Intestinal Diseases.

SYPHILITIC ULCERS.

Under this heading come the primary sores, as well as the late stages of ulcerations due to syphilis. These will be described in their respective section. The treatment of this class of ulcers is the application of the usual antisyphilitic remedies now in vogue. In addition to this, the general rules for the treatment of ulcer outlined in this section, are applicable.

PHAGEDENIC ULCER.

This class of ulcers comprises the virulent type of inflammation of the skin upon surfaces which have low-grade vitality, so that the ulcer spreads rapidly and destroys the tissues without much attempt on the part of nature for repair. The milder types of ulcers of the leg are apt to assume this intense form by neglect or by secondary infection. The discharge has a foul odor and is irritating to the surrounding tissues. It is of a creamy consistence and often mixed with blood. When the leg is affected, it may destroy the skin all around the limb, so that the muscles or even the bone may be exposed. Fig. 526 illustrates such a condition.

Treatment.—This being an acute infection, vigorous and persistent effort should be made to eliminate the acute process and transform it into a milder form. Moist antiseptic dressings of boracic acid should be first employed, constant bathing and application of Carrel-Dakin solution. Subsequently a cauterization of the unhealthy granulations and disinfection with tincture of iodine may be done.

When the ulcer has assumed a more benign character, it may be treated along the outline for chronic ulcers. The general treatment of this class of cases is of the utmost importance, for the patients are usually run down, and some underlying disease may be contributing to the causes. Iron tonics and exposure of the body to sunlight is very often of great utility.

Fig. 526.—Extensive phagedenic ulcer.

SENILE ULCER.

To this class belong many types of ulcer occurring on the limbs and other parts of the body in old people, due, as a rule, to poor nutrition of the skin and pressure. Invalidism furnishes a number of this class of ulcers.

Treatment.—Treatment of this type of ulcer is practically as described in previous sections, under ulcer of the leg.

FISTULA AND SINUS.

By EMIL G. BECK, M.D., F.A.C.S.

These two terms have been used interchangeably. There is however, a difference in the interpretation of each term.

Fistula may be defined as an abnormal channel existing between hollow organs such as the stomach, the gall-bladder, the rectum, the urinary bladder, etc., or between the skin and these organs; thus we speak of a biliary fistula or a urinary fistula, etc. According to this definition, the term fistula is often misapplied, for instance in referring to a case of rectal fistula, which usually originates in the pararectal connective tissues, and opens into the rectum or around the orifice of the anus. It ought to be called a pararectal sinus. A *fistula* is most commonly a postoperative condition, and has a tendency to self closure. The secretion is usually that of the organ from which it originates—thus a biliary fistula will discharge clear bile, sometimes mixed with mucus or pus. A urinary fistula will discharge urine, a gastric fistula—gastric juice—and a fecal fistula will discharge the intestinal contents which correspond to that part of the bowel which is the seat of the fistula.

A *sinus* is a suppurative channel which has its origin in connective tissue structures, such as bones, joints or in parenchymatous organs such as the liver, the kidneys and other glandular organs. The formation of a sinus takes place in this way: Whenever an infection terminates in an abscess, the pus will burrow in various directions by force of the overdistention of the abscess cavity. It will burrow along the spaces in the direction of least resistance, especially along the tendons or muscle sheaths until it has reached a point near the skin, sometimes quite a distance from the origin of the seat of the disease. There it may open spontaneously or be opened by a surgeon's knife, and the pus allowed to escape. While the pus burrows into various directions, it may lock itself off into a number of compartments, and each of them open on a different region of the body, and thus multiple sinuses will result. Oftentimes the number of these sinuses is large, as many as forty has been found in one case of knee-joint disease, as illustrated here in Fig. 527.

If the focus of the disease is cured or eliminated, there will remain no sinus; but if the disease persists, the sinus will continue to discharge. The abscess walls will gradually shrink to the size of a channel not larger than a lead pencil. Thus we may regard a sinus merely as a shrunken abscess cavity. The walls of the sinuses and their structure differ considerably according to the stage of the disease. The newly formed sinuses have inflamed succulent walls, granular in appearance, while those which have persisted for years develop a well-organized fibrous wall, the channel has a glistening and smooth appearance resembling a serous lining. A sinus is always preceded by an abscess. The chronicity of these sinuses is the most distressing problem in their treatment.

Treatment.—The *treatment* of sinuses is either medicinal, such as the injection of cleansing fluid and salves, or surgical. The irrigation treatment of sinuses had been given up for years; but lately it has been revived since the Carrell-Dakin solution has been employed principally in sinuses resulting from empyema. The treatment could also be tried in other forms of sinuses. The injection of strong disinfectants, such as pure carbolic acid or zinc chloride solution, have been found effective in some cases; but on account of their corrosive action are now rarely used.

Fig. 527.—Multiple sinuses from a tuberculous knee-joint, 40 in number.

Injections of the various liquefied ointments have been found to be very effective, the bismuth paste having been used since 1908, and at the present time it is the one principally employed. A discussion of this treatment is found on page 850. In the cases which do not yield to this method or to the treatment by other similar substances, such as novojodin paste, Bipp paste, etc., surgical treatment is indicated. Indiscriminate curettage is, however, not effective. If a surgical operation is absolutely necessary, it should be preceded by an anatomical diagnosis, which can be best accomplished by stereoroentgenograms of the injected sinus with bismuth paste, or other shadow-producing substances, such as argyrol, collargol, etc.

In many cases the condition is inoperable, such as disease of the spinal column or sacrum, which may be the cause of the persistent sinus discharge, because the focus of the disease is surgically inaccessible. The slitting open of sinuses and curetting without reaching into the very depth and origin of the disease, is useless; every part of the sinus must be reached, otherwise the operation will be a failure. In cases where many sinuses exist from one focus, the indication is to remove that focus, if the same be accessible. Extraction of a sequestrum may effect a cure. In cases of sinuses due to osteomyelitis for instance, the seat of the disease should be exposed, the affected tissues removed, and the wound left wide open, without an

Fig. 528.—Skin sliding operation for sinuses resulting from osteomyelitis of the tibia. (Fourteen years' standing.)

attempt to close the skin by sutures. The cavity should first be swabbed with tincture of iodine, packed with gauze, and left gaping. In some cases, it is advisable to transpose a suitable skin flap from the

Fig. 529.—Same case after closure.

side into the depth of the cavity, from which the skin may regenerate, and transform the space into a skin-lined cavity. One illustration of the procedure is here presented (Fig. 528).

Fig. 528 illustrates the skin-sliding method in the case of an old persistent sinus in the leg which had its origin in osteomyelitis of the tibia. It had been treated previously by incomplete operations, irrigations of antiseptic fluids, as well as the paste, without result. Finally a large part of the tibia was exposed, the diseased tissue eliminated and three skin flaps from the side of the wound shifted into the depth of the cavity, which healed in and thus this skin regenerated the denuded surface, as shown in Fig. 529. The sinus has thus been obliterated.

FIG. 530.—Hip-joint disease; network of sinuses. (Beck.)

BISMUTH PASTE IN THE TREATMENT OF SUPPURATIVE SINUSES, FISTULÆ, EMPYEMA AND INFECTED WOUNDS.

This method of treating suppurative sinuses and fistulæ has been employed since 1907 in hospital and private practice by surgeons of

America and Europe and by many military surgeons in war hospitals. It has been employed for:

1. Diagnostic purposes (tracing sinuses).
2. Therapeutic purposes (healing chronic suppurations).
3. Prophylactic purposes (preventing fistulæ).

The method consists in injecting sinuses and fistulæ or old suppurative empyemata with a mixture of:

℞—Bismuth subnitrate	10 per cent.
Yellow vaseline	90[1] "

The mixture should be sterile and liquefied by heating,[2] so that when injected with moderate pressure it will readily flow and fill all branches of the sinuses. At the body temperature it becomes semisolid within the sinus tracts and thus remains there long enough for taking radiograms. Such radiograms of the injected region will give by the contrast of shadow produced by the paste from other tissues a very clear picture of the extent and ramifications of the sinus tract (Fig. 530) and very often lead us to the original focus of the disease. A study of these radiograms, especially the stereoscopic, will enable us to discriminate operable from inoperable cases and is more reliable than the probe or colored liquids for diagnostic purposes.

In former times the operation itself had to be first performed, to prove the impossibility of eradicating the entire tract. Now the injection is sufficient to decide the question.

Pathology of Sinuses.—In order to carry out the treatment rationally and intelligently, one must be familiar with the pathology of suppurative sinuses and of the manner in which they originate.

Formation.—We must bear in mind that a sinus is nothing more than a contracted abscess cavity. Its formation usually takes place in the following manner: After an abscess has formed, the increasing pressure of pus within the pus cavity will undermine the tissues in various directions, until the abscess has reached a place near the surface of the body or some hollow organ, such as the intestine or bladder, where it will break through and empty its contents. The usual route is along the muscle sheaths or fascia, the abscess opens often at some distance from its origin. In one of my cases a psoas abscess opened above the clavicle, and the resulting sinus was for a time thought to be a broken-down tuberculous gland, until the paste injected into it escaped from a second sinus near the sacrum. This cleared up the diagnosis.

After an abscess has emptied its contents, a shrinkage of the walls takes place so that after a time only a narrow channel, or sinus, remains. Sometimes these channels undermine the tissues to such an extent that a complex network of sinuses results.

[1] Previously we used a 33 per cent. mixture.
[2] See p. 883 for instructions for preparation of paste.

When small abscesses lock themselves off, they empty their contents in different regions. This explains the multiplicity of openings. I have seen as many as forty openings resulting from a knee-joint tuberculosis.

Sinuses frequently open into the bowel or bladder in addition to other openings on the skin, and thus fecal matter or urine may escape from the skin sinuses.

Structure.—The sinus is a hollow channel, irregular in its course and unequal in its dimensions in various parts of its course. In some instances it is widened to such an extent as to practically form a pus pocket, in which it may terminate. Its origin may be in bony structures, such as the spinal vertebra, medullary canal of the long or short bones, in joints of the body, as well as in parenchymatous organs. The openings may be multiple, opening into a hollow viscus, or the skin. The walls may be hard and rigid, or soft, depending on the character of the discharge and also on the chronicity of the case. In cases where the sinus has existed for years, the walls are composed of dense connective tissue, while in recent cases the walls are thin and succulent, more of a granulating character. Microscopic examination of the sinus wall shows it to be composed of fibrous connective tissue, and in the more recent cases somewhat infiltrated with leukocytes. It is lined with flattened connective-tissue cells, resembling the endothelial cell.

Diagnostic Application.—The injection of bismuth for diagnostic purposes in these cases is most helpful and far superior to the probe as a diagnostic instrument in tracing sinuses. The probe in fact is very misleading in ascertaining the depth of sinuses or bone cavities. A glance at one of these radiograms in which the sinuses have been injected will convince us that the use of the probe in ascertaining the course of the tract is not dependable. The tip of the probe may be arrested in the nearest pocket or recess of the tract, and leave us under the impression that we have reached the bottom, whereas, there may exist a network of sinuses into which the probe can never be introduced. In fact, the sinus at times may be many times as long as the probe itself.

The diagnostic value of bismuth may best be illustrated by citing cases, which the reader finds in this chapter. It will be shown that patients who had been operated upon as many as ten or fifteen times, had undergone these operations on account of erroneous diagnoses. The errors were disclosed by the injection of the paste. Cases of psoas abscess, for instance, due to spondylitis, with sinuses opening around the hip so simulated coxitis as to be diagnosed hip disease and were operated upon for it. A tuberculosis of the eleventh dorsal vertebra, resulting in a psoas abscess which had opened near the anus and left a sinus, was mistaken for rectal fistula and operated upon four or five times for rectal fistula. The injection proved the origin of the disease high up in the spine. Such examples are very numerous in a series of several thousand cases and illustrate the extreme helpfulness of this diagnostic aid.

The technic for diagnostic and for therapeutic purposes is identical. This diagnostic method of tracing the fistulæ, or estimating the size of abscess cavities, disclosed also a most efficient therapeutic agent. Many cases which were first injected for diagnosis healed subsequently without surgical intervention.

Therapeutic Application.—In January, 1908, I brought before the ChicagoMedical Society the first 14 cases treated with bismuth paste. Ten of them were then healed. Of these 14 cases, now after a period of ten years, 12 are still entirely well, the remaining 2 having died within the past seven years. Up to 1913, the following reports had appeared:

Name.	Number of cases.	Percentage of cures.
Ochsner, Chicago	20 (tuberculous sinus)	55.0
Ridlong and Blanchard	17 (tuberculosis sinus)	53.0
Beck, E. G., Chicago	192 (collective report)	64.0
Robitschek, Minneapolis	9 (tuberculous sinus)	55.0
Don (Edinburgh)	.. (tuberculous sinus)	17.0
Rosenbach, Berlin	4 (tuberculous sinus)	50.0
Dollinger, Budapest	16 (tuberculous sinus)	12.5
Beck, J. C., Chicago	319 (accessory sinus, no operation)	22.0
Pennington, Chicago	17 (rectal fistulæ)	76.0
Bae, Baltimore	12 (tuberculous sinus)	33.5
Stern, Cleveland	4 (tuberculous sinus)	100.0
Steinman, München	5 (tuberculous sinus)	20.0
Bogardus, U. S. A.	1 (tuberculous sinus)	100.0
Vidakovich, Russia	2 (empyema)	100.0
Nemanoff, St. Petersburg	6 (empyema)	100.0
Ochsner, A. J., Chicago	14 (empyema)	85.0
Beck, E. G., Chicago	11 (empyema)	82.0
Ely, New York	14 (tuberculous sinus)	43.0
Hines, Cincinnati	9 (tuberculous sinus)	89.0
Cuthbertson, Chicago	1 (intestinal fistula)	100.0
Sandor, Sag., Budapest	2 (otologic)	100.0
Heitz, Boyer, Morens, Paris	11 (renal sinuses)	73.0
Zollings, Zurich	25 (tuberculous sinus)	54.0
Schober, Philadelphia	5 (tuberculous sinus)	80.0
Gessner, New Orleans	4 (tuberculous sinus)	50.0
Schmid, Vienna	15 (tuberculous sinus)	30.0
Rivera, Porto Rico	8 (tuberculous sinus)	75.0
Goror, E., Paris	3 (tuberculous empyema)	66.0
Reichelfelfer, Washington	4 (tuberculous empyema)	75.0
Brandes, Kiel	29 (all varieties of sinuses)	76.0
Beck, R., Chicago	58 (alveolar sinuses)	54.0
Beck, R., Chicago	9 (empyema antrum)	66.0
Collective reports from nineteen dental surgeons in U. S. A.	39 (alveolar sinuses)	74.0
	4 (empyema antrum)	100.0

Soon after my first publication in the *Journal of the American Medical Association* and in the *Centralblatt f. Chirurgie*, surgeons from all parts of the world began to report their results with the bismuth paste. Some authors obtained even better results than we did, others only partially succeeded, while a few have failed in the treatment. We must, however, bear in mind that most of the cases in which this method was tried had already been regarded as hopeless, every known method having been tried and failed; thus we must regard even the smallest percentage of cures an actual gain. The reports of the first five years indicate that more than 60 per cent. of all these apparently hopeless cases were finally cured by this simple method, and without any surgical operation.

Statistics on this subject are not easy to compile, since there is only a small fraction of the cases reported. The majority are treated by general practitioners in the country in office practice or in the homes of the patients and therefore not reported in medical literature.

Indications.—The bismuth treatment has been employed in almost all varieties of chronic suppuration. I shall enumerate those most commonly treated.

(*a*) All sinuses resulting from chronic suppurative joint affections, tuberculous as well as non-tuberculous. This includes especially the sinuses after spondylitis and hip-joint diseases.

(*b*) Sinuses after osteomyelitis of long bones and flat bones, including the ribs.

(*c*) Sinuses resulting from suppurative diseases of parenchymatous organs, such as the kidney and other glandular structures in the body, including suppurative tuberculous glands.

(*d*) Post-operative sinuses which sometimes remain after draining infected wounds.

(*e*) Sinuses after empyema of the pleura or from lung abscess.

(*f*) In cases of abscess and suppuration of the mammary glands.

(*g*) In all infected wounds due to crushing injuries.

(*h*) In infected and long suppurating war wounds due to shrapnel or bayonet injury. It has been tested in these and found most effective. The rapid accumulation of this class of cases due to the recent war in Europe will furnish a tremendous amount of material for treatment.

(*i*) In rectal fistula or pararectal abscesses.

(*j*) By otolaryngologists in the treatment of suppurative antrum disease and accessory sinuses, as well as in the after-treatment of mastoid operations.

(*k*) By dentists in suppurative sinuses about the teeth and jaws and in pyorrhea alveolaris.

(*l*) It has also been used by us in chronic endometritis.

(*m*) In the prevention of sinuses by incising the cold abscess and injecting it with a 5 per cent. bismuth paste.

Technic.—For practical purposes the procedure in the average case is here given. Let us take, for example, a case of tuberculous coxitis of long standing, with multiple suppurative sinuses:

1. Preliminary to the treatment, *a set of stereoroentgenograms* of the affected region is taken, to make sure that there are no foreign bodies or sequestrums present. If they were present, they might be overlooked after the bismuth had been injected, because the shadows produced by the bismuth would obliterate the shadow of the foreign body.

2. Bacteriologic examination of the secretion is the next step. Smear preparations, cultures, and, in some instances, inoculation of guinea-pigs is made.

3. The sinus is now ready for injection. No attempt should be made to irrigate the sinuses with antiseptic solutions, nor should any drying-out process be tried. The skin surrounding one of the sinuses is washed with alcohol, and the tip of the glass syringe, which has been filled with the liquefied paste, is placed firmly against it, and *the paste slowly but firmly forced into its channel until it is seen to escape from the nearest opening.* Then the finger is quickly placed against this opening to prevent the escape of the paste, and the injection is continued until the patient begins to complain of some pressure. If there are many openings, an assistant must occlude all of them with his fingers during the injection, in order to be certain that all the branches of the sinuses have been filled.

4. After the injection another set of stereoscopic roentgenograms is taken, which will give a clear picture of the entire network of sinus tracts and sometimes be the means of tracing the path to the focus from which the disease originated.

5. A sterile bandage is then applied and the patient put to bed, for a few hours, or a few days, depending on the severity of the case. In subsequent treatments the patients are usually allowed to walk about immediately after the injection.

6. The first dressing is done the following day. If the discharge, which before injection was creamy or profuse, has changed to a serous consistency, it is to be regarded as a favorable sign, and a microscopic examination will usually prove it to have become sterile. If the discharge is sterile, the sinuses need not be reinjected unless they later become reinfected. It is not intended that the paste remain in the sinuses. It will gradually exude, and within a week only traces may be found by fluoroscopic examination or by roentgenogram.

If the focus from which the sinus originated is reached and disinfected, in practically all instances the sinuses will close up. It is, therefore, essential that when a fistula or sinus is injected with bismuth paste, it must reach the focus of the disease. If, through faulty technic, this is not accomplished, good results cannot be expected.

The first injection ought, therefore, to produce the desired result. If it does not, then we must assume that the paste has not found its way into all portions of the diseased tract, and we must try again and reinject. It is a safe rule to wait at least one week. If the discharge changes its character from purulent to serous, and the microscopic examinations of a slide and culture show that the secretion is sterile, we should not reinject; the sinus will usually close within a very short period. If, however, the discharge continues to be purulent and we find microörganisms in it, then we should reinject at least twice a week.

While the entire technic is quite simple, a few instruments have been found to be of advantage. A glass syringe, with a cone-shaped tip

(Fig. 531*A*) is most commonly used and is suitable for nearly all cases. For rectal cases we employ a metal syringe with a small conical tip (Fig. 531*B*).

It is essential that the tip should block the external opening, so as to prevent the liquid paste from escaping along the nozzle and in order to force the paste into the collapsed sinuses.

Causes of Failure.—We note the unequal results in the hands of surgeons. How can this be explained?

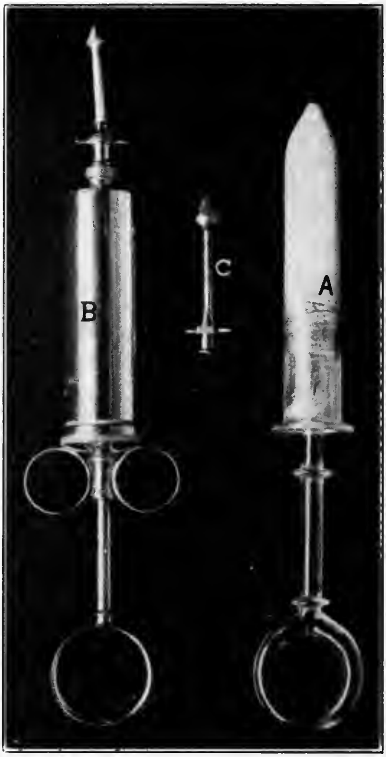


Fig. 531.—Syringes for injections of bismuth paste.

At the North Chicago Hospital, where the method was first employed, we have had the opportunity to study many cases after they had been treated with the paste, without result, and thus could determine the causes of failure. In some instances the sinuses closed after our first injection, while they had been previously injected for months without success. In these, we could not account for the failure. Was it faulty technic, improper material or unsuitable instruments which were responsible? In other cases the causes of failure were quite apparent. Aside from the most common cause, namely, the presence of a sequestrum, we found other foreign bodies. In one case, for example, a metal probe in the humerus; in another, a rubber tube within the medullary canal of the humerus, accidentally left in years before; in another, two rubber tubes within an old cavity. As soon as these foreign bodies were removed, the injections were effective.

The most common cause, however, is faulty technic and lack of knowledge of the rules which have been laid down for the treatment.

Technical Errors Usually Committed.—1. The method is applied indiscriminately, without control by radiograms.

2. The mixture, when injected, is not sufficiently liquefied to fill all the sinuses and suppurating cavities.

3. The bismuth is applied in cases in which either a sequestrum or infected foreign body is at the bottom of the trouble.

4. The injections are often kept up after the wound is sterilized and thus no chance is given for healing.

5. The instruments used are often improvised and unsuitable.

6. The bismuth mixture is very often spoiled by the accidental admixture of a few drops of water. (Syringes should be perfectly dry when used.)

Since the technic varies in different cases, the illustration of a variety of cases will suggest the different points of correct technic.

Tuberculous Spondylitis Sparing the Vertebral Bodies.—Fig. 532 represents a case of tuberculous spondylitis in a man of forty-two. It had progressed to the stage of cold abscess. The tumor in the left pelvis was hard and did not fluctuate. For some time it was taken for a sarcoma because the radiograms did not show any destruction of the vertebra. The abscess was incised and injected with 5 per cent. bismuth-vaselin paste. The incision closed in a week and patient gained thirty pounds in two months attending to business. Six months later he fell, injured his back, and shortly after the sinus reopened spontaneously and a serous discharge escaped. A drain-tube was inserted by his house physician, secondary infection took place and general breakdown. A month later we injected a mixture of 33 per cent. bismuth vaselin and obtained picture (Fig. 532) which shows distinctly the focus of the disease and its extent across the entire width of the intervertebral space. There is no deformity present, the sinuses healed after a few injections and no recurrence has taken place to date (six years).

The practical point to be learned from the case is that when a sinus reopens and discharges a serous fluid, it should not be drained with rubber tubing, because secondary infection will surely follow. It should not be injected, unless the secretion contains microörganisms.

A case instructive in many points is the following:

Hip-joint Disease with Coexisting Pulmonary Tuberculosis.—F. B., seventeen years old, had pulmonary tuberculosis when fifteen years old, with rapid decline in her health. To this was added a hip-joint disease. For one year the hip was kept in a case and she was placed in the most favorable surroundings to restore her health. An abscess formed and was allowed to rupture spontaneously. Secondary infection took place, and all she had gained during the past year was lost, her weight reduced from 125 pounds to 89. In this condition she was brought for treatment in 1910. The tuberculosis of her lung was still present.

Findings: Two sinus openings, about three inches apart, in line with Poupart's ligament. Both discharged about two ounces of green pus every twenty-four hours. The injection of the paste and the radiograph (Fig. 533) disclosed that these two sinus openings, while very near to one another, led into two different directions; one to a coil

FIG. 532.—Tuberculous spondylitis with sinuses through disk.

of sinuses within the pelvis underneath the iliac fascia, while the other led into an abscess along the fascia lata. This demonstrated that, no matter how near together two openings of sinuses are, they do not necessarily communicate. Without the radiographic guide one would be tempted to connect these two openings, which, of course, would be of no avail.

The therapeutic result in this case was most unusual. The pus discharge changed into a serous within twenty-four hours and from this time on the patient gained at the rate of from 4 to $11\frac{1}{2}$ pounds each week, until she had gained 48 pounds within two months. Both sinuses closed. She married, was well for four years, then developed an acute pulmonary tuberculosis, to which she succumbed.

It is rare that active pulmonary disease coexists with bone tuberculosis. In my experience of about 650 cases of tuberculous joint diseases but 3 had a coexisting extensive, active pulmonary affection. I have found evidence of a healed tuberculosis of the lung in many of the cases by taking stereoscopic radiograms of their chests, but the active type is rare. In fact, tuberculosis of joints seems to protect one against active pulmonary tuberculosis.

FIG. 533.—*A*, intrapelvic sinuses from hip; *B*, subfascial abscess from hip.

Another point of technic may be illustrated in the following case:

Supposed Hip-joint Disease Proved to be Spondylitis of the Twelfth Dorsal Vertebra.—An Italian woman, aged twenty-five years, was brought to me with supposed hip-joint disease. The diagnosis of hip-joint disease was made by her physician because she had a swollen hip, contracture of the adductors, and was greatly emaciated, and had a discharging sinus near the great trochanter.

As shown in Fig. 534 the injection of the paste passes beneath the adductor muscles, winding anterior in front of hip-joint, upward into the pelvis, then along the iliac and psoas fascia into the region of the kidney. Since the vertebræ appeared normal as far as the first lumbar and the paste did not reach the column, I diagnosed the condition as a pararenal abscess and drained the same through an incision below the twelfth rib. The discharge continued and I suspected that my diagnosis was in error also. I therefore reinjected through the opening in the region of the kidney, preventing, however, the paste from passing downward by occluding with my finger the sinus along the pelvic

A B

FIG. 534.—Supposed renal abscess proved to be a spondylitis.

fascia and thus forced the paste in the opposite direction. To my surprise I found that the paste found its way into the focus in the twelfth dorsal vertebra, passing through the vertebral column and then filling a small abscess cavity on the other side. See Fig. 534*B*. I incised the left lumbar region and found an abscess there.

This illustrates the possibility of error due to the incorrect application of technic.

Hip-joint Disease Causing Perivesical and Rectal Fistula.—Illustrated in Fig. 535. A young man twenty-seven years old, developed at age of fourteen a tuberculous hip-joint disease, which progressed to abscess formation, was incised and drained by rubber tubing. Sinuses kept on discharging pus. Two years later another abscess formed near the rectum which was likewise incised and drained. Thereafter he had four radical operations, without any improvement.

In January, 1912 I saw him first. There were four discharging sinuses around his hip and rectum. These were injected three times at one-week intervals. All closed, and he was able to take up work within two months and remained well for a year. In December, 1913, he felt a pain in the region of the third lumbar vertebra. This

FIG. 535.—*A*, perivesical sinus anterior to bladder; *R*, rectal fistula communicating with above; *C* and *D*, newly formed hip-joint.

pain gradually extended toward the bladder; he urinated frequently, tenesmus after each urination. I found a small abscess around the anal orifice, which I opened and about 14 ounces of pus escaped. I injected 4 ounces of bismuth paste through this anal opening and took a stereoscopic radiogram. This showed that the abscess had gravitated down from the hip-joint toward the rectum and also anterior to the bladder, encircling it, as plainly seen by viewing a stereoscopic radiogram. The pus changed to a serous discharge within twenty-four hours and in three days all the sinuses were closed. He gained 30 pounds within a month and remains perfectly well to date.

Another interesting point is that a new joint formed. While his limb is two and five-eighths inches short, he can flex it practically as well as his other hip. The radiogram shows a new joint from C to D.

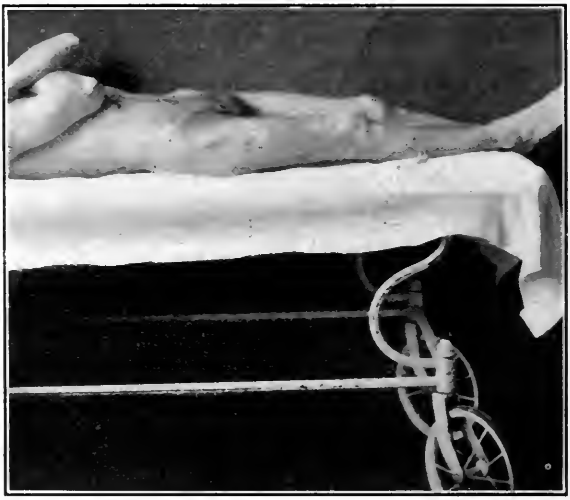


Fig. 536.—Limb extended.

The upper part of the neck has formed a fitting articular surface against the upper part of the acetabulum, and motion is perfect.

Fig. 537.—Limb flexed.

Fig. 536 illustrates complete extension of his limb.
Fig. 537 shows to what degree he can flex it.

Fig. 538 proves that he can support his present body weight (142 pounds) on the tuberculous limb without any support.

Fig. 538.—Supporting his weight on healed tuberculous hip.

Multiple Abscesses of Kidney Communicating with the Bladder.—This illustration (Fig. 539) represents a case of large suppurative kidney in a woman about forty years of age, which had been drained some six years previously. The fistula in the region of the kidney continued discharging and was injected by me with bismuth in January, 1914.

The radiogram shows that the paste filled the pus cavities in the kidney and the excess forced down into the bladder through the ureter. After a few injections with the paste the fistula closed. Pus, which had been present in the urine in large quantities for years, ceased. The patient has had no return to date and is in perfect health.

This case teaches that sinuses resulting from a resection of the kidney or from drainage, may be easily cured by this simple injection, but the technic must be perfect; namely, every suppurating pocket must be filled, otherwise suppuration will recur.

Heitz and Boyer of Paris reported 11 cases of this type which had been suppurating for many years, and were then treated with bismuth injections. Nine of these healed almost immediately and 2 were still under treatment at time of report.[1] In my own experience with this

[1] Annals des maladies des organes urinaires, June 1, 1910.

class of cases, I have on my records 15 cases, all of which have been entirely cured without any secondary surgical intervention.

Bismuth Paste in Dentistry.—Since the bismuth injections have been widely employed by dentists in treating paradental abscesses and sinuses resulting from necrosis of roots and the alveolar processes, I shall cite a typical case for the purpose of illustrating the technic.

Fig. 539.—Network of sinuses in the kidney leading into ureter and thence into the bladder.

Alveolar Sinus.—A girl twenty-five years of age, had a bridge adjusted to her second molar and canine teeth and for years there was a discharging sinus in the lower maxilla near the molar. Patient, a neurasthenic, had undergone three extensive operations: Fixation of the uterus, removal of the appendix, and loosening of adhesions, without any relief. Our suspicions were directed to the symptoms in the teeth. An injection was made into the sinus and the radiogram Fig. 540 shows distinctly that the paste went to the root of the molar tooth, filling the little abscess cavity (*A*). The light zone around the margin of the root indicates the granulating cavity in which the root is embedded (*B*).

The discharge ceased within a few days, the tooth became solid and her general health improved perceptibly; so that we may assume that this constant absorption of pus from the alveolus was the cause of her general neurasthenic condition.

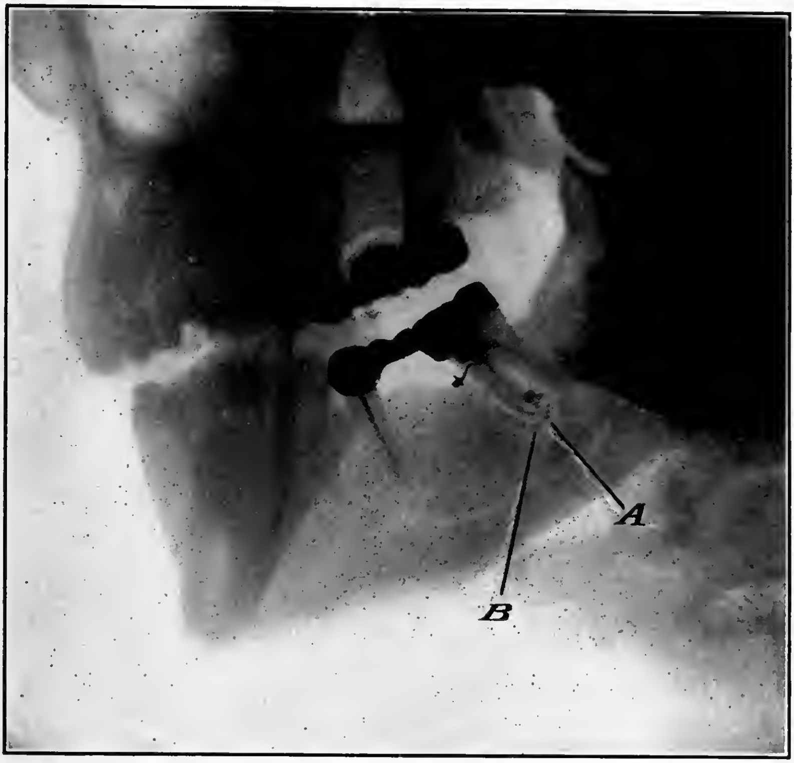


FIG. 540.—*A*, alveolar sinus, bismuth injection; *B*, granulation zone.

Rectal Fistulæ.—In this class of cases the bismuth paste has proved very useful. There are four points I wish to make:

1. A correct anatomical diagnosis of rectal fistula before an operation is undertaken is essential and such can be obtained by stereoscopic radiograms of the injected tracts.

2. That many cases of so-called rectal fistula are inoperable because they originate or extend into inaccessible regions, as for instance, into the sacrum, the hip, or the spine.

3. That a correct anatomical diagnosis will keep us from attempting impossibilities and thus save the patients from useless operation.

4. That operable as well as inoperable fistulæ around the anus can be cured by the injection of the bismuth paste.

In our experience we have noted that many cases which were diagnosed as rectal fistula were simply sinuses which have originated either from tuberculosis of the spine, sacrum, or sacro-iliac joint, hip-joint, or intra-pelvic suppuration, in which the abscess happened to gravitate toward the rectum and opened in this region, leaving a sinus. Both conditions are illustrated below. In one case the disease originated in the twelfth dorsal vertebra and in the other in the hip-joint. Both of the cases had previously been treated a long time for rectal fistula.

Supposed Rectal Fistula, Repeatedly Operated, Causing Incontinence, Discovered to be Tuberculosis of the Eleventh Dorsal Vertebra.—A. H.,

Fig. 541.—Rectal fistula originated in the eleventh dorsal vertebra.

fifty years old, was first seen by me in June, 1913, at his home in Canada. He stated that four years previously he had been treated for pararectal abscess, after he had suffered for nearly eight years with what was thought to be rheumatism of the back. The operation resulted in a fistula, fever, and emaciation began from that time. He was confined to his bed nearly all the time. A second and third operation was performed with division of the sphincter, resulting in complete incontinence of feces. Another operation was then performed above the crest of the ileum and two more sinuses added. He was unable to walk, having been confined to bed for the past fourteen months. July 12, 1913, he was brought to Chicago. The injection of paste as shown in Fig. 541 revealed the true diagnosis. The sinuses with several side tracks extended from the rectum into the eleventh and twelfth dorsal vertebræ, where the disease originated. The injection not only cleared up the diagnosis but had a marked therapeutic effect. The rectal sinus closed, and the man gained 20 pounds in six weeks, and was able to walk about five miles each day.

Fig. 542.—Supposed rectal fistula being a sinus from the hip-joint.

Hip-joint Disease Causing Anal Fistula.—E. D., age eleven years, developed hip-joint disease with abscesses at age of ten, two near the hip and one between the scrotum and anus. These kept on discharging profusely until I saw him in October, 1911. He was in an emaciated condition, hardly able to turn in bed, weighing only 53 pounds. The accompanying illustration, the radiogram of the injected sinuses (Fig. 542) gives more information than any description. This represents a very acute form of tuberculous and mixed infection, which, as a rule, is fatal. This case, however, improved from the very first injection. He gained in weight at the rate of 3 pounds a week; sinuses closed.

From these two cases we may learn that the operative treatment of these pararectal abscesses is sometimes a very treacherous one. The surgeon who attempts to resect such a sinus may in view of these radiograms realize the inadequacy of surgical treatment. Both cases have proved that this apparently incurable condition may be cured by the simple injection of bismuth.

Fig. 543.—Tuberculous spondylitis of great extent, causing such deformity as to prevent erect posture. Injection of bismuth paste at age of eight.

Fig. 544.—Four years after treatment.

Fig. 545.—Flexion and extension almost perfect.

Tuberculous Spondylitis.—Technic of Injecting Multiple Sinuses.—N. O., eight years old, developed tuberculous spondylitis when two years old. Double psoas abscess and a number of smaller abscesses in the region of the sacrum resulted. All were opened and drained and persisted

Fig. 546.—Drainage in six places.

in discharging very profusely for six years. The child never learned to walk and when eight years old could only creep like a baby.

The bismuth injections were started in November, 1913 (Fig. 543) and for a long time there was no appreciable improvement. Within a year all except the sinus along Poupart's ligament, and one near the sacrum, were healed. These remained open discharging small

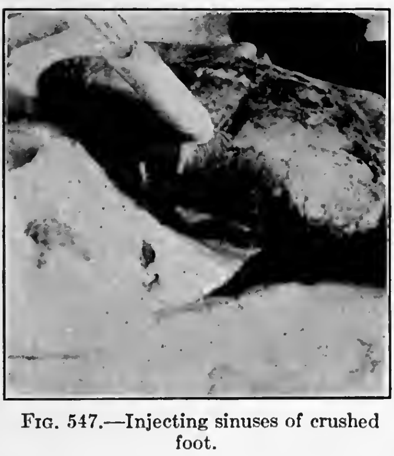


Fig. 547.—Injecting sinuses of crushed foot.

Fig. 548.—Sinus closed after injection.

quantities of serum. The boy regained perfect health and gradually was able to stand erect. Since then he has developed an unexpected agility. He can stand perfectly erect, as shown in Fig. 544, rotate as well as bend his spine, and even jump a rope (see Fig. 545).

Crushing Injury of Foot, Treated with Bismuth Paste.—E. P., a man of twenty-two, while riding a motorcycle was run over by a motortruck. The right foot was crushed completely by the heavy wheel (see **Fig.** 546). The heel having been torn away, it was replaced and gauze

FIG. 549.—Final result (extension.)

FIG. 550.—Final result (flexion).

FIG. 551.—Crushed infected foot. *A*, one of the sinus openings; *B*, bismuth paste.

drains introduced. On account of the virulent type of infection, his condition grew worse, the fever rose to 105°, so that an amputation was contemplated. Gradual improvement, however, took place and a profuse chronic suppuration from six different sinuses resulted, persisting for two months.

Injection of bismuth paste was then resorted to, as shown in radiogram (Fig. 546). Within three days the purulent discharge became serous in character. From then on the condition improved rapidly and the sinuses began to close (Fig. 548). Within two months the limb was entirely healed and gradually assumed normal shape. Patient is now able to walk without the use of a crutch and is able to flex and extend his foot (Figs. 549 and 550). The radiogram (Fig. 551) shows the channels of injected paste reaching the big toe.

Prevention of Sinuses.—The method has also been used for the prevention of sinuses. We know that a fistula or sinus is the result of a preëxisting abscess. It is in our power to prevent the sinus by proper treatment of the abscess. *A cold abscess should never be drained by means of rubber or gauze drainage.* Various modifying fluids such as Calot's mixture or formalin solution, etc., have been used after the abscess is incised, to prevent secondary infection. We have employed the following method:

The cold abscess should be incised under local anesthesia on the most fluctuating point (incision half inch long). The contents should be evacuated, by gentle pressure. Undue pressure or squeezing should be avoided. Then a quantity, not more than 100 grams, of a 10 per cent. bismuth paste is injected and sterile gauze and a bandage snugly applied (no closure of opening is advised). The abscess cavity will remain sterile and the paste and secretion will gradually escape. Twenty-four hours later the first dressing is made with most scrupulous precaution against infection. The discharge will usually remain serous and in one week to ten days the opening will heal. We have treated more than 150 cases with this method and have experienced a secondary infection in only 3 cases. None was fatal.

Bismuth Paste in Persistent Sinuses of Empyema and Lung Abscess.—When an empyema or lung abscess continues to suppurate after it has been drained for a reasonable length of time the problem becomes a difficult one.

The flushing of empyema cavities with disinfecting fluids was extensively used until about fifteen years ago. A weak solution of permanganate of potash or iodin or boric acid were the favorite fluids employed. This practice was discontinued until recent years when Dr. Carrel renewed the interest of the profession in this form of treatment by showing good results from flushing infected wounds and pus cavities with what is now known as the Carrel-Dakin solution. Judging from the reports in the literature, the results will justify its employment in the future. For technic in its use the reader is referred to the description by the Empyema Commission.[1] One of the advantages of the use of Dakin's solution which I have observed was its solvent action on fibrinous adhesions of the lung, thereby liberating pus cavities, locked off by fibrinous adhesions.

[1] Jour. Amer. Med. Assn., August 3, 1918, 372.

The bismuth treatment is the most conservative and at the same time very effective in chronic discharging sinuses of the chest. After ten years of its use in surgery it has retained its place and is now employed very extensively. The reports in the literature indicate that at least 4 out of 5 cases of the very old neglected suppurative empyemata or lung abscesses may be cured by this simple procedure. Ochsner of Chicago reported to the American Surgical Association on June 4, 1909, 14 cases of empyema, all of which have been operated on (2 by Estlander's operation) with sinuses in all cases persisting nevertheless. He applied the bismuth paste in each of these cases, with the result that 12 cases healed completely and 2 were still under treatment at the time and very much improved. Others have reported equally good results. In my own series of 150 cases, approximately 80 per cent. were cured by the bismuth injection treatment alone.

The failures may in a measure be accounted for in the lack of knowledge in the technic. The injection of the empyema or lung abscess serves *diagnostic* as well as *therapeutic* purposes.

The various shapes of these empyema cavities can be best visualized by filling them with a 10 *per cent. mixture of bismuth paste* and then taking a set of stereoroentgenograms. These will give nearly exact information of the size, location, and depth of these cavities. One can define with accuracy the boundaries and anatomical relations of the cavity and thus plan the treatment accordingly. In some cases there exists a long sinus leading into a pus pocket not larger than a crabapple (Fig. 552). In other instances radiograms will show a channel from the skin opening leading directly into a bronchus, which indicates that the preëxisting cavity had shrivelled into a narrow sinus which did not close on account of its communication with the bronchus.

A communication between the sinus and a bronchus is best proved by the injection of bismuth paste. As soon as the existing cavity or sinus has been completely filled, the overflow will penetrate into the bronchus and the patient will cough out some of the paste. In such cases the injection should be done very slowly and the patient asked not to inhale during this injection, so that he may not aspirate some of the mixture into the other lung. The paste should be liquefied, in order to prevent clogging of the trachea, the lumen of which is very narrow. It is possible to clog the lumen by a column of thick paste and cause suffocation. When there is an accumulation of pus in the abscess cavity, the paste mixture will force the pus into the bronchus and the patient will cough up a quantity of pus before any paste will appear in the expectoration.

Prior to the treatment it is necessary to ascertain the character and quantity of the discharge. In some cases it is a green, foul-smelling pus, in others a serous, semipurulent fluid resembling dirty dishwater; in others a pinkish or chocolate-colored thick pus. The color of the pus depends very often upon the substances which have been used in treatment. Irrigations of permanganate or silver nitrate, especially, change the character and color of the secretion. Invariably a culture and smear of the pus is taken and whenever it seems necessary one or two guinea-pigs are injected with a 10 per cent. solution of this pus. The tubercle bacillus is rarely found in the secretion, even in the cases in which the empyema is known to be of tuberculous origin.

Fig. 552.—Long sinus leading into a small cavity in the apex.

We have, however, made the observation that in the cases known to be of tuberculous origin in which the tubercle bacilli could not be found in the secretions, the same would appear in large numbers within twenty-four hours after injecting the cavity with bismuth paste. This surprising finding was verified in a number of cases during the past ten years. These tubercle bacilli however differ somewhat in their appearance, they are beaded and stain much darker than usual. The number of these bacilli gradually diminishes and within two or three weeks the secretion may be free from them.

My explanation for the appearance of these bacilli after the injection is the following: The tubercle bacilli live within the walls of the sinuses or the abscess wall and not in the secretions. It requires a local leukocytosis to provoke their exit. The injection of a substance like bismuth subnitrate produces a leukocytosis within the walls and by this means the bacilli are carried out in the discharge.

Points of Technic in Chest Cases.—A set of stereoroentgenograms of the entire chest (plate: size 14 x 17) should first be taken in order to visualize if possible the retracted lung, adhesions, thickened pleura, or

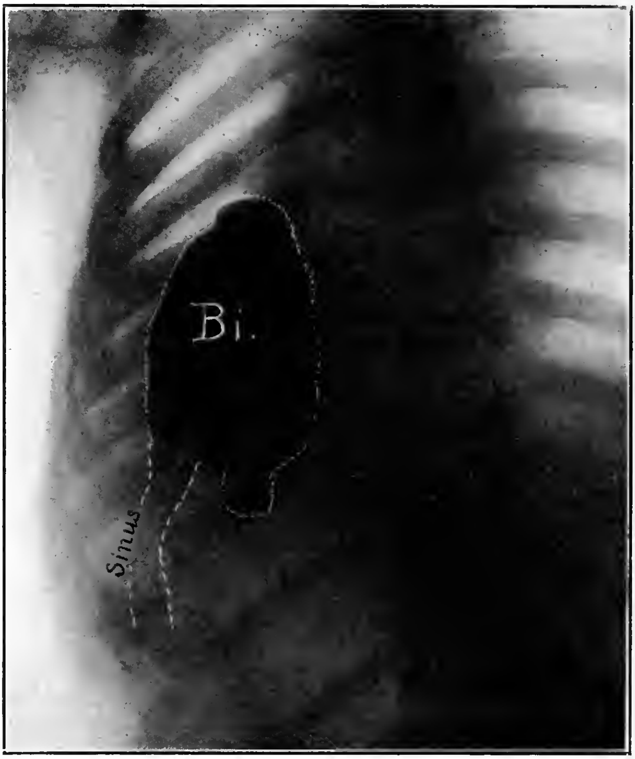


Fig. 553.—Short sinus leading into a large cavity.

locate foreign bodies if such be present. The cavity is then filled with a 10 per cent. bismuth-vaseline paste and another set of stereoroentgenograms is taken. The second set of roentgenograms shows that the cavity is entirely filled with bismuth and usually marks the inner boundary formed by thickened pleura. The sizes and shapes of these cavities vary so much that there are no two alike. Figs. 553, 554 and 555 illustrate the various shapes of abscess cavities.

The paste is not supposed to be retained in the cavity and allowed to remain there for absorption. Many have the idea that the paste serves as a filling substance to obliterate dead space. This is an error which might lead to serious complications, especially bismuth intoxication. The paste is to remain about two to five days and if it does not spontaneously escape it should be drawn out by means of a catheter attached to a suction syringe.

The treatment should be controlled by repeated bacteriological examination of the secretions. No attempt should be made to irrigate the cavity before the injection. The patient should be placed in such a recumbent position, that the sinus opening is on the highest level. This will allow the air to escape while the bismuth is being injected. A two-ounce syringe is filled with the liquefied paste, the long nozzle

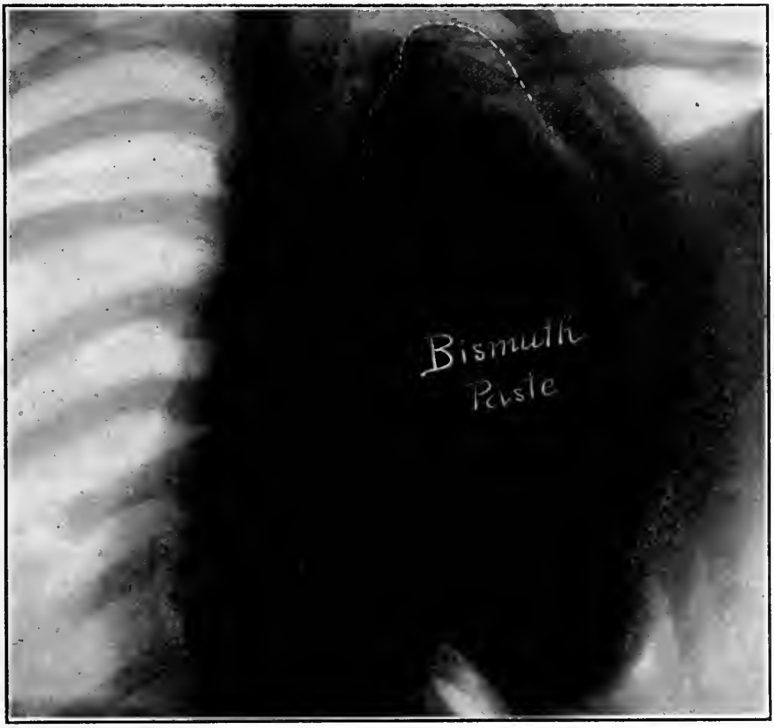


FIG. 554.—Empyema cavity occupying upper half of the left chest. Well defined with injection of bismuth paste.

of this syringe as shown in Fig. 556 is introduced into the sinus and the paste slowly injected into the cavity. Upon withdrawal of the syringe some bubbles of air will escape. A second syringeful is introduced in the same manner and as a rule this will fill most of the smaller cavities, which is indicated by the overflowing of the mixture from the sinus. At times, however, it requires ten to twelve ounces or even more to fill an empyema. No attempt is made to plug the opening for the retention of the paste. A simple sterile dressing, with a snugly fitting bandage is applied. A great part of the paste will escape within twenty-four hours.

FIG. 555.—Irregular-shaped cavity due to adhesions. Outlined with the injection of bismuth paste.

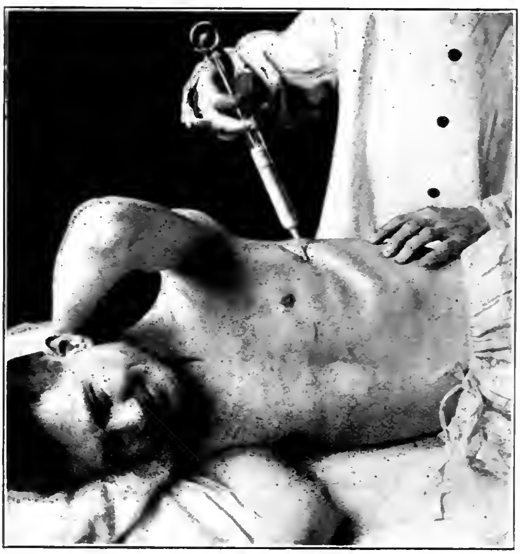


FIG. 556.—Position of patient best adapted for the injection of bismuth paste into an empyema.

The first injection does not always produce permanent healing. It requires at times repeated injections during several months. But whenever the discharge changes from pus to a serous fluid, the injections should be stopped, because healing will usually follow. Only when the discharge continues to be purulent for months should we consider a more radical procedure. Some cases will close shortly after the injection and remain so for a year or two and the patient be in good health, often gaining as much as 30 pounds, and then the sinus will reopen. The injections are then to be repeated. Closure usually follows for another year or two with another relapse. The patient often prefers to keep up treatment in this way, not being much inconvenienced and perfectly well in the intervals.

Causes of Persistence of Discharge.—On analysis of a large number of chronic discharging sinuses of the chest, the following causes have been found to be the principal factors:

1. The retracted and infiltrated lung tissue cannot expand sufficiently to fill the dead space. Nature tries to diminish this space by contracting the chest wall, so that the ribs almost overlap, often obliterating the intercostal spaces, except at the insertion of the ribs at the spine. The diaphragm is drawn upward two or three inches in its attempt to obliterate the space; the thickened pleura also diminishes to a certain degree this space. Nevertheless there often remains a cavity holding two or three hundred cubic centimeters of fluid.

2. The pleura often contains microörganisms which cannot be reached by flushing and thus the secretion of pus continues indefinitely.

3. At times there are foreign bodies present, such as rubber tubing, which has slipped in unknown to the surgeon, keeping up the suppuration.

4. In cases of abscess of the lung, the tendency to non-closure is greater because there is usually a communication with a bronchus, which after drainage keeps up the suppuration.

5. Abscesses are often multiple, and when one or two are opened the drainage and suppuration persist from many small recesses communicating with the main cavity.

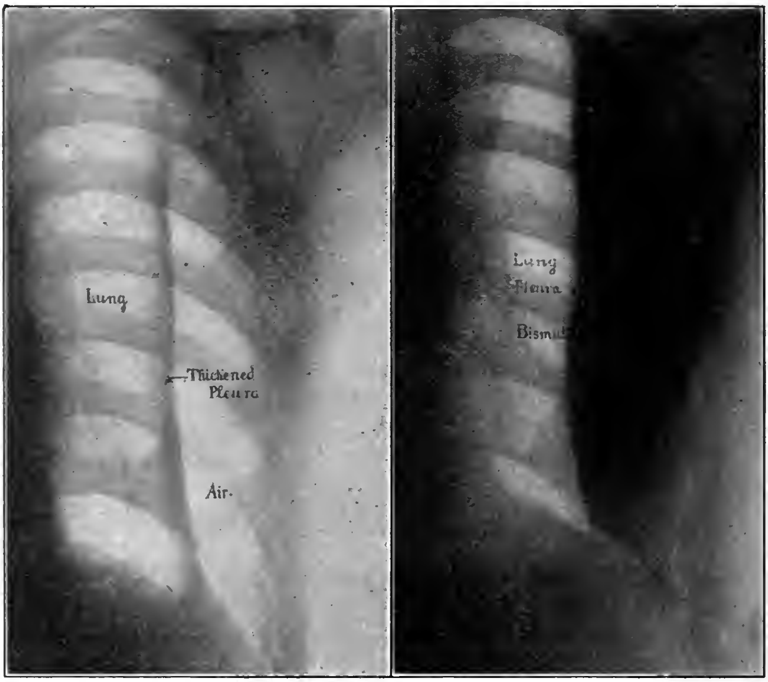
6. In abscesses due to tuberculosis of the lung, the reason for non-closure is apparent when we consider the pathology of the tuberculous lobe.

Bearing in mind these various causes for non-closure, the treatment in each case will naturally consist in removal of the cause, if this be possible. If the cause is not removable, as for instance the extreme size of the pus cavity, we are faced with a most difficult situation. The patient then has the choice of either enduring his trouble and be satisfied with daily dressings, or take the risk of an extensive operation.

During the past seven years I have employed a method of obliterating these very large cavities, or those which persist in discharging on account of communication with a bronchus, which I believe is simpler and less dangerous than the extensive Estlander or Schede or decortication of the lung operations. The same is described in the April, 1919, number of *Surgery, Gynecology and Obstetrics,* p. 259, under the title of "Skin Sliding Operation for Chronic Empyema."

For illustration of the bismuth-paste treatment I shall cite only a few cases.

CASE I.—*Tuberculous Empyema; Closure with Bismuth Treatment.*—Arthur C., aged nineteen years, perfectly well up to one year ago when he developed what was thought to be pneumonia, which was followed by empyema and drainage. Two weeks later the rubber tube dropped into the empyema cavity and this required a subsequent larger operation. Profuse discharge, with constant loss of weight continued for one year. During this time the cavity was injected with peroxide of hydrogen and a weak solution of silver nitrate, without benefit.



A B

FIG. 557.—*A*, empyema cavity before filling, showing the retracted lung with its margin of thickened pleura; *B*, same cavity after injection. Bismuth paste fills entire cavity. Note margin of thickened pleura.

I saw him first March 6, 1916. Examination: Patient 6 feet tall, weight 145 pounds. Right chest retracted, right scapula protruding. In the midaxillary line is a drainage opening surrounded by a large area of eczema. Cultures taken showed streptococci and staphylococci but no tubercle bacilli.

Stereoroentgenograms without the bismuth injection produce a characteristic picture of retraction of the lung toward the center with a thickened pleural wall covering the retracted lung, see Fig. 557*A*.

The cavity was injected with 300 c.c. of bismuth paste, which filled it completely, as shown in Fig. 557*B*. The second radiogram illustrates with absolute certainty that the entire cavity has been filled, as the thickened pleural margins are visible all around the injected paste.

Within twenty-four hours the secretion became less purulent but it contained *numerous tubercle bacilli*, at least twenty in each field. The cavity was reinjected once a week for three months, the discharge gradually diminished; the tubercle bacilli and other microörganisms disappeared. The sinus closed, patient gained gradually in general health and is now apparently well.

Case II.—*Post Influenzal Empyema; Closure.*—Miss. M. S., aged forty-one years. For the past ten years has had a bronchial cough. Had paralysis of her face twice during the past seven years. Four years ago had a nervous breakdown. During the epidemic in August, 1917, she developed a typical case of influenza and pneumonia, which resulted in an empyema. Her chest was tapped several times and two weeks later one rib resected and two rubber tubes were introduced for drainage. Patient was seen in November, 1918, emaciated, with a

Fig. 558.—Resected rib from old empyema. Note bony ring around the drainage opening.

high temperature, and a profuse discharge from the sinus in the chest. The sinus was injected with bismuth paste and revealed the size and shape of the cavity. Injections were repeated every three days, the paste escaping from the cavity during this period. Within two months the patient gained 30 pounds in weight, the cavity was gradually reduced in size and finally closed without any recurrence to date.

At times it is difficult to inject the paste on account of the very narrow channel leading into the empyema. This narrow channel is due to a growth of bone which takes place around the resected rib. A bony ring will usually form around the rubber drain and only a very small opening will remain, through which the pus may not find its escape. The granulations in this opening further diminish its size, so that a catheter may be introduced only by the use of considerable force. In such cases it is not advisable to inject large quantities of the paste, because it would be difficult to remove it. Under these circumstances it is advisable to resect that part of the rib and produce a good drainage opening before the paste is introduced.

Such bony growth as is illustrated in Fig. 558, which is a specimen from a case in which drainage had persisted three years after the rib had been resected.

CASE III.—*Bilateral Empyema; Post-influenzal, During Pregnancy.*—Mrs. A. S., aged thirty-five years, while in good health and eight months pregnant, developed a severe type of influenza during the epidemic in August, 1918. Complications were bilateral pneumonia and empyema. She gave birth to a normal child during the height of the pneumonia. The right chest was drained by a small rubber tube by her house physician but drainage seemed inefficient and her condition did not improve. For two months she lingered.

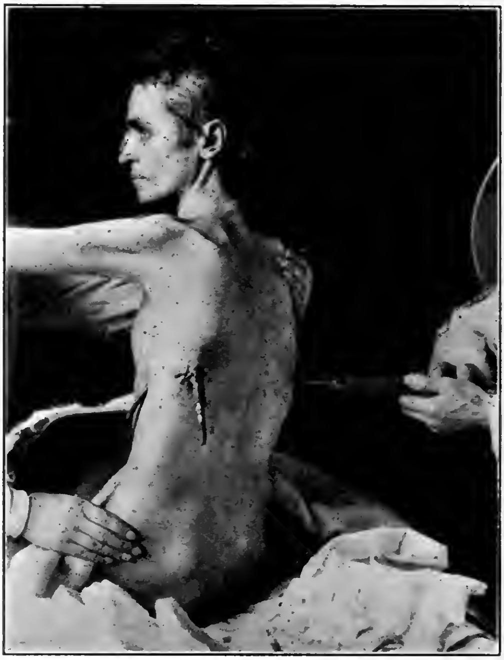


FIG. 559.—Bilateral empyema. Patient in sitting posture. Right side, pleural cavity half filled with pus. Pneumothorax above pus level. Left side, multiple abscesses, intralobar and perilobar.

On December 21, 1918, an examination by stereoroentgenograms showed a large empyema on the right side and several locked-off abscesses in the left pleura (Fig. 560). Under local anesthesia a catheter was introduced in the eighth intercostal space in the axillary line on the right side. Another operation with resection of a rib followed on January 11th on the same side. On January 14th the patient became very cyanotic, had a temperature of 101°, respiration 40, pulse 150, due to retention of pus on the left side and pneumothorax on the right.

It was decided to operate also on the left side. Under local anesthesia a portion of the seventh rib posteriorly was resected and two

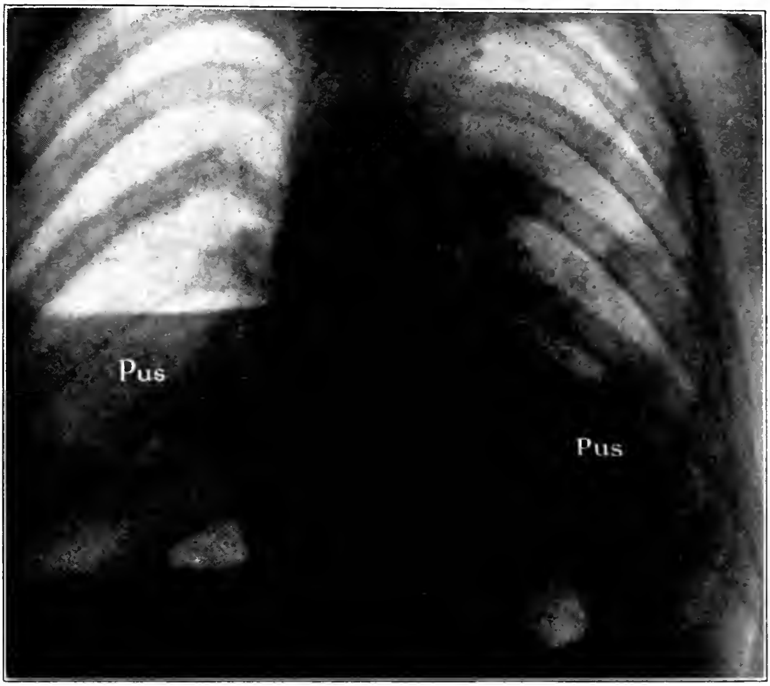


FIG. 560.—Bilateral empyema seen draining on right side. Cavity being injected with bismuth paste. Counterdrain on left side. Not yet ready for bismuth treatment.

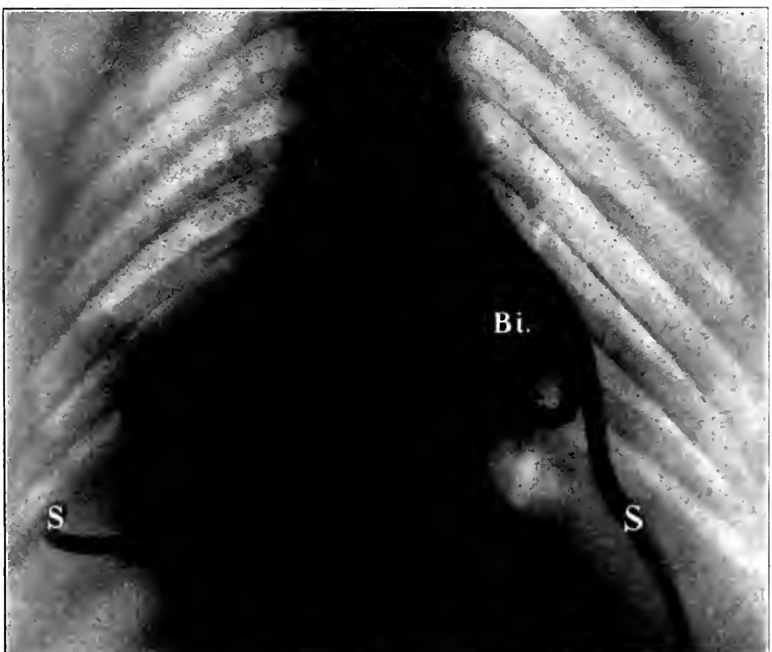


FIG. 561.—Roentgenogram illustrating bilateral empyema. Still draining but lungs reëxpanded, finally closure, complete recovery.

cavities of pus emptied. A counterdrain was inserted through an anterior incision, as shown in Fig. 559. After one month's drainage of both sides of the chest in the usual way, all cavities were filled with bismuth paste. Gradual improvement in the patient's condition followed, with cessation of discharge and fever.

At present there is a small cavity in the region of the hilus of the right lung and a very small sinus between with the two drainage openings in the right side of the chest. The lungs on both sides have sufficiently reëxpanded to give normal breathing capacity (Fig. 561).

The following observations are made in this treatment:

(*a*) That in practically all cases we could prevent a secondary infection.

(*b*) That the creamy pus upon opening the cold abscess was changed into a straw-colored clear fluid within three or four days after injection.

(*c*) That 90 per cent. of all cases closed within three weeks after incision and injection.

The preference for bismuth over other modifying substances was given for the following reasons:

1. The paste is injected through a small incision instead of using a trocar, and thus the possibility of missing the abscess is eliminated.

2. By discarding the aspirating needle the danger of injuring underlying vital organs or entering bloodvessels is avoided.

3. Through an incision it is possible to evacuate the larger clumps of the tuberculous débris, which could not pass through the aspirating needle.

4. The thick paste within the cavity will allow the escape of secretions along the walls of the abscess, but will not permit the entrance of infectious material; thus secondary infection is prevented.

5. Injections of other modifying fluids must, as a rule, be repeated, while with the paste the first injection usually attains the desired result.

6. The injection of bismuth paste is not painful or irritating. It is injected in a warm, semiliquid state, and remains long enough in contact with the diseased tissues to produce its therapeutic effect. The vehicle (vaselin) does not macerate the walls of the abscess. Toxic effects from bismuth subnitrate can easily be prevented.

Dangers and Complications.—The only danger which has been noted is the possibility of bismuth poisoning. My brothers and myself are fortunate in not having had a single fatal case in our series of 2000 cases treated. We observed the symptoms in one of the first cases of empyema and were able to check the progress and save the patient. This case was reported by me in the *Journal of the American Medical Association,* January 8, 1909, and is the first case on record. I then warned the profession against the careless use of the paste. This has put on guard those who thought that bismuth was an entirely innocuous substance. My warning must have had a very salutary effect, because nearly all the cases of poisoning occurred in the first two years, 1908 and 1909, and during the past year only 1 case was reported, although the bismuth paste is now employed by many American surgeons, and, to a large extent, abroad. It is gratifying to know that the poisoning can be prevented, and if it accidentally occurs and is discovered, it can be checked before it causes irreparable damage, by observing the following rules:

1. Do not allow more than 100 grams of the paste to remain in the body for longer than a week.
2. Do not use any larger percentage than 33 per cent. of bismuth and 66 per cent. of vaseline.
3. If symptoms of poisoning arise, act at once. Wash out the bismuth by injecting warm olive oil, retaining it in the cavity for twenty-four hours.
4. Scraping the cavity with a scoop is a dangerous procedure. It will expose fresh surfaces to absorption of the metallic bismuth.

Small quantities of glycerin by mouth are of benefit. Teaspoonful every two hours. A gargle with weak thymol solution is advisable. Alcoholics are forbidden.

PREPARATION OF BISMUTH PASTE.

Apparatus.—

1. Bismuth subnitrate C. P.
2. Yellow vaseline (best grade).
3. Large porcelain mixing bowl.
4. Large enamel jar with cover for storing paste.
5. Several small enamel jars with covers for liquefying paste at time of use.
6. Water bath for heating paste.

Bismuth paste is a 10 per cent. mixture, one part of bismuth subnitrate to nine parts of vaseline. The mixing bowls, jars and spoon are sterilized. The vaseline is sterilized for twenty minutes in the original container in the autoclave. The bismuth subnitrate is sterile in original containers. The mixing bowls and jars must be absolutely dry, as the slightest amount of water produces a curdling of the paste and it is then useless.

The bismuth subnitrate is poured into the mixing bowl and all lumps smoothed out with the spoon. A sufficient amount of vaseline, which is still in a liquefied condition from the sterilizing, is slowly poured into the bismuth, to make a stiff paste. This mixture is then stirred for an hour until it is a smooth, bright yellow, homogeneous paste. This is the most important step in the process and if not carried out carefully the paste will not be homogeneous.

From time to time small amounts of this paste (8 to 10 oz.) are transferred to small jars in which the paste is liquefied and from which it is used. These jars should not be more than half full and great care should be taken not to get any water into the paste while heating it.

Summary.

To insure success in employing bismuth paste the essential points are summarized as follows:

1. One should make a correct diagnosis by all methods at our disposal and corroborate the same with stereoscopic radiograms before an injection is made.
2. Before attempting to employ this method, one should acquaint himself thoroughly with the technic.
3. The proper instruments should be employed in order to carry out the technic correctly.
4. The patient should be kept under constant observation to prevent bismuth intoxication.
5. Examine the secretions from the sinus before the first injection, by slide and culture, and often by the inoculation of guinea-pigs; then three days later test the sterilizing effect of the injection.
6. As long as the sinus contains microörganisms it should be reinjected, but if it is found sterile, it should not be reinjected.
7. It is good practice to wait at least one week after the first injection before repeating it.
8. A stereoscopic radiogram of the parts affected should always precede the first injection, in order to detect the presence of sequestra or foreign bodies. The shadow of the paste might make their presence obscure.
9. Following the injection, a second set of stereoscopic radiograms should be taken in order to make a correct anatomical diagnosis.
10. In case a foreign body or sequestrum is present, the injection is useless, operation is necessary.
11. Acute suppurative processes should not be treated with bismuth paste, only chronic suppurations, both tuberculous and non-tuberculous.
12. Bismuth poisoning may easily be prevented by using only small quantities, or when large quantities are required they should not be retained longer than ten days, and patient should be carefully watched.
13. Fecal fistulæ and other postoperative sinuses are very favorably affected by bismuth paste treatment.
14. A 5 per cent. or a 10 per cent. bismuth-vaseline may be used in cold abscess. In practically all instances secondary infection can be prevented, providing the technic is carefully observed.

TRAUMATIC INSANITY.

By JOHN CHALMERS Da COSTA, M.D., LL.D.

It has been known for centuries that mental disorder and other brain disease may follow injury, especially head injury.

Literature, ancient and modern, abounds with cases. Some of the cases are accurately reported. Some of the reports, especially the older ones, give evidence of containing what Junius called "false facts." Nevertheless, it is known that insanity and other evidences of brain disturbance may follow an injury; although genuine insanity so caused is extremely rare.

It may arise after a traumatism to any part, induced in any way. For instance: crushes of the extremities, gunshot wounds, stabs, falls from heights, electric shocks, surgical operations, etc., but is most common after railroad injuries and especially after injuries of the head.

Railroad accidents are apt to produce great psychic shock. Head injuries may damage the brain directly and grossly or may do so by the induction of nutritive alterations and perversions.

It is so well known that insanity may follow surgical operations that we use the term "Postoperative Insanity" to describe such cases. In all supposed cases of traumatic insanity we must consider the possible influence of psychic shock and of physical shock. We must seek for evidence that there has been hereditary or acquired predisposition to insanity. If evidence of such predisposition is found due importance must be attached to it.

A careful study of the history of every case is necessary to reach an accurate conclusion. If a study is made of a number of cases of insanity following trauma, we will discover that in some of the cases the attack was impending when the accident happened and the accident only served, so to speak, to topple a crumbling tower a bit before its time. The attack may have been impending because of hereditary predisposition or because of acquired predisposition.

In some of the cases I have studied, the histories indicated great instability of the nervous system. Such cases had predisposition to insanity and would probably have gone insane sooner or later if no accident had happened. The accident only precipitated events. In the words of Maudsley—it was casual and not causal. The traumatism at most was but an exciting cause.

It is claimed by some that there are cases due purely to psychic shock caused by injury to some part other than the head, in which the history shows no suggestion of predisposition, hereditary or acquired, a statement I am unable to accept. If such cases do exist they are seldom seen by the surgeon.

It cannot be insisted upon too strongly that the surgeon is not a fit person to finally diagnosticate and treat mental diseases. He should know something of them in order that he may promptly recognize them, and that he may coöperate helpfully with an alienist. The moment the condition is suspected an alienist must be called. In deciding as to the advisability of operative treatment the surgeon and the alienist must study, confer and decide together.

We will take up for consideration:

1. Postoperative insanity.
2. Traumatic insanity following head injury.

POSTOPERATIVE INSANITY.

Various states of mental disturbance may become manifest after a surgical operation. For instance: hysterical excitement, delirium, amnesia, confusion, impulses, hypochondria, mental depression, obsessions, especially morbid fears, illusions, hallucinations or actual insanity. Real insanity is rare.

It has been estimated that out of one thousand abdominal operations four will go insane. If we except from consideration operations upon the ovaries, insanity is no more frequent after abdominal than after other operations.

If we except removal of the ovaries, castration and other operations on the genito-urinary organs and brain operations, there is no especial causal influence in any particular operation. Of course, a brain operation frequently and often greatly injures the brain and yet only seldom does insanity ensue.

It is well known that the menopause is a danger to the mind, and it is, therefore, not surprising that removal of the ovaries, which induces a sudden menopause, is dangerous to the nervous system. It is quite probable that the insanity which sometimes follows removal of the ovaries and that which may follow castration in the male is due to removal of organs which furnish valuable internal secretions. Women more than men, and adults more than children, are liable to become victims of postoperative insanity.

The risk to the mind bears no relation to the magnitude of an operation. The condition may follow a trifling operation as well as a dreadful mutilation. It is common to find that surgical patients have worried a great deal before an operation. Many have been the victims of pain and sleeplessness, many have been exhausted, some may have been in a condition of panic fear.

The anesthetic has a certain depressing influence; in fact, it may actually seem to poison a person. The operation produces shock and loss of blood. The brilliant investigations of Crile, of Cleveland, have shown how brain cells suffer from the influence of shock and how subconscious causes of brain exhaustion are actually at work even when consciousness is abolished by ether or chloroform. After an operation a patient may suffer from pain, sleeplessness, worry, fear of death or deformity and from homesickness. Cases of postoperative insanity, except those due to head injury, have possessed predisposition, hereditary or acquired. The surgical operation is an exciting cause acting upon an unstable nervous system. Such patients were predisposed to insanity. Any of the ordinary troubles and worries of life probably would have caused it to arise. In insanity arising after a head injury, such predisposition may or may not have existed.

Some years ago, in a paper on the diagnosis of postoperative insanity,[1] I made the following statement:

"The normal, stable, healthy brain will probably never go insane after an operation, unless that operation touched the brain, removed the testicles, or removed the ovaries."

The insanity may come on at once after an operation. In such a case the surgeon is apt to regard the anesthetic as causal. According to Savage, of London, in such a case the patient is insane on waking up from the anesthetic. I have seen no such case. The usual period of the onset of insanity is from three to ten days after the operation. Acute insanities are apt to come on in a day or two. Certain insane conditions, for instance, states of fixed and limited delusions, may come on much later, even as late as two or three weeks after an operation.

If a person has ever had an attack of insanity, an operation is undoubtedly a danger. It exposes him to decided peril of another attack, and should be performed only when there is imperative necessity. After a surgical operation of any sort upon a lunatic the patient may become worse, may remain unchanged or may become better mentally. There is no way before the operation of deciding what effect, if any, the operation will have upon the insanity. Is there any special form of mental trouble characteristic of postoperative insanity? I do not believe so. A person may have mania, manic-depressive insanity, stupor or a delusional condition. Undoubtedly acute confusion is the commonest condition met with. Acute confusion is a condition in which there is delirium usually accompanied by illusions and hallucinations, flitting fragmentary and changing delusions, confusion of thought and incoherence of speech. A state of revery is common and there is often a tendency to stupor. In some cases, however, there is the genuine exaltation of mania or the emotional depression of melancholia; the delusions being conflicting, changing, attenuated, unstable as dream images, and Grasset named them "Dream Delusions."

The two most active exciting elements of postoperative insanity are undoubtedly fear and worry. Those who know the powerful influence and far-reaching effects of fear should study the writings of Prof. Crile, of Cleveland, and Prof. Mosso, of Turin. The immense power of fear in causing physical trouble and mental disaster is well known. Fear may be responsible for miscarriage, paralysis agitans, syncope, grayness of the hair, jaundice, diabetes, epilepsy and other conditions.

It is well known that it can sober a drunken man, make a mother's

[1] Surg., Gynec. and Obst., December, 1910.

milk a poison to her baby, induce catalepsy, aphasia, amnesia, and various other things.

It need scarcely be a matter of surprise that fear may cause insanity. As I have said, "An anti-operation fear may become a postoperative phobia."[1]

I do not believe, however, that fear or that the sudden and violent manifestation of fear, we call fright, is very often responsible for postoperative insanity.

Of course, most people when they are badly frightened refuse to be operated on. I have found in my surgical experience that people usually come to the operation with calmness and courage, and some of them with actual satisfaction that the moment has come to rid them of pain, or a danger to life, or a harassing disease.

I believe worry is the most common exciting factor. Many surgical cases are terribly worried for a long period before an operation. Worry brought with it apprehension and depression, which hung upon them until they finally decided to have the operation done. Now and then a person will come to an operation expecting to die. Such prophets of evil are always bad patients. Many who, before operation expect to have terrible pain and suffering, morbidly magnify the prospect. We all know the serious condition worry may induce, how it spoils the appetite, impairs the digestion; interferes with sleep; lessens the resisting power; causes loss of flesh and frequently an actual hysterical condition. People thus worried are irritable, highly suspicious and difficult to deal with, and not unusually are very homesick. Morbid worry is a real cause of insanity. It occurs in those predisposed to insanity. In a morbidly worried subject toxemia, shock, hemorrhage, pain, insomnia, are badly borne and act strongly in inducing insanity. A person who is worried before operation but whose worry is not morbid, that is to say, is not a manifestation of predisposition, usually becomes perfectly healthy in his mental condition after the operation. The depression of his brain passes away entirely and his worry is gone. In a predisposed individual there may be no mental reaction whatever after operation, and the mental depression may pass into actual morbid depression, or confusion, or morbid exaltation or some other form of insanity.

I believe it is a correct statement to say that postoperative insanity and puerperal insanity are identical conditions, both being caused in practically the same way.

Various conditions may be mistaken for postoperative insanity; for instance, febrile delirium. The mental condition of febrile delirium is the same as the mental condition of a person with postoperative confusion. Postoperative confusion is usually without fever, but is sometimes accompanied by fever for a very brief period. Mental confusion may last but a few days but is usually of a much longer duration. In febrile delirium the fever always precedes the delirium.

[1] Surg., Gynec. and Obst., December, 1910,

We must be careful not to confuse delirium tremens with postoperative insanity. The distinction is indicated by the history and the manner of onset, the physical condition and great tremor, and the brief period of time during which the trouble lasts. An opium habitué deprived of his drug may have delirium with tremor. In some subjects a dose of morphin given after operation will induce a temporary delirium.

Cocain causes delirium in subjects predisposed to this drug. The absorption of iodoform may cause delirium and is particularly apt to do so in elderly subjects. The delirium comes on suddenly two days or three days after the operation. It is usually a febrile condition. The conjunctivæ are yellow and the eyes are watery, the nose runs and the patient looks as though he had a bad cold. He complains of a metallic taste in the mouth; suffers from nausea and has a yellow skin. The odor of iodoform can be detected in the breath and iodoform is found in the urine. The mental condition is usually a hallucinatory delirium. In some cases of poisoning by iodoform the patient is morose, irritable and depressed, and develops unsystematized delusions of persecution. There may or may not be fever. If there is a fatality in iodoform poisoning the patient is apt to die in coma.

What we surgeons have called delirium nervosum or traumatic delirium is in most cases a condition in which confusion, revery with a tendency to stupor, accompanied by hallucinations, illusions and delusions, comes on suddenly a day, two days or a few days after an operation. It lasts a few days and disappears as quickly as it came. Most of these cases are instances of real postoperative insanity of brief duration. Now and then the condition becomes acute delirious mania and the victim dies. It is a question if the term "delirium nervosum" is justified. Most cases when analyzed will be found to be hysteria, uremia, acetonuria, sepsis, iodoform poisoning, morphinism or genuine insanity.

In the aged delirium is not uncommon and it usually means that the patient is in a condition of or is bordering upon early senile dementia.

We know how irritable, suspicious, talkative and difficult to get along with, many aged people are and how poorly some of them sleep. Nocturnal delirium after an operation is quite common in aged persons. There may be some elevation of temperature or the temperature may be normal. In the morning the patient may be perfectly clear mentally; as evening comes on he may again wander. In such a delirium he may not know where he is; he may be noisy, confused, incoherent and is frequently very tremulous. He is particularly apt to get out of bed, to wander out of his room or his ward, and may try to escape from the house. A man in such a condition may attempt to kill himself. He commonly suffers from auditory hallucinations. Sometimes he is erotic. Such delirium may soon pass away and the man return to his usual condition, but he may rapidly go down hill and collapse into a mental wreck. After an operation hysterical delirium may occur. It is not necessary to describe it here.

We must also be on the lookout for acetonemia, which, for a few hours before the onset of coma, may present a surprising likeness to postoperative confusion. Uremia may cause delirium, and in some cases the delirium lasts for many days or even for weeks. In the delirium of uremia the patient is heavy, drowsy, restless, perhaps lapses into coma and may develop convulsions.

In the previously quoted article I mentioned the following other conditions which may be mixed up with postoperative insanity:

Delirium of starvation (which is sometimes seen in cancer of the stomach or esophagus).

Delirium of fatigue.

Delirium of collapse (as after a fever).

Mental conditions due to brain lesions (tumor, meningitis, etc.).

Night terrors of children.

Nostalgia.

Epileptic mania.

Delirium after thyroidectomy (thyroid poisoning).

Delirium of exophthalmic goiter (hyperthyroidism).

Belladonna delirium and the condition induced by the administration of large doses of bromide.

It is of immense importance that the surgeon should make a diagnosis of postoperative mental disturbance early. If we assume that a case of diabetic coma is a postoperative insanity the case may be lost by delay.

We must not be satisfied because delirium is associated with elevated temperature that the condition is certainly febrile delirium.

The treatment of postoperative insanity is to be directed entirely by the alienist. In certain cases we find the patient has been sick for a sufficient length of time to convince us that the attack of insanity is not going to be a very brief one, and we must decide whether or not to commit him to an institution for the insane. It is not possible to care properly for such cases in a general hospital. We must never make the mistake of sending someone to an institution for the insane when the attack is very temporary, because we wrong a man and injure all his prospects to let him have the repute of having been a patient in a hospital for the insane, no matter how brief the time he remained there. But a prolonged attack necessitates care in a hospital for the insane.

TRAUMATIC INSANITY FOLLOWING HEAD INJURY.

All sorts of mental disorder or brain disturbance may become manifest after head injury. Such conditions may be manifested by obsessions, predominant ideas, lessened resistance to alcohol, to heat and to the direct rays of the sun; lack of emotional control, neurasthenia, hysteria, aphasia (sensory or motor), amnesia, insomnia, persistent headache, mental dulness, change of character and true insanity. Any of these conditions may be associated for a long or short time with polyuria, albuminuria or saccharin diabetes.

Head injury is not a common cause of insanity. How often it is suspected and how often it should be suspected are matters of dispute. The older writers assign a much larger percentage of cases to this category than do modern authors. Kiernan found 45 traumatic cases among 2200 lunatics. Schleger estimated 8 per cent. as the approximate number of such cases. I have reached the conclusion that traumatism is causal in not over 2 per cent. of cases.

The laity believe head injury to be a common cause of insanity. Traumatism is a popular explanation among the members of a lunatic's family. There is a widespread belief that insanity is a disgrace to the family, impugning the purity of its blood and indicting the morals and mentality of its ancestry.

It is a difficult matter to make persons realize that insanity is no more disgraceful than pneumonia or gout. The feeling of disgrace is much modified if head injury can be assigned as the cause. It is generally felt that such a catastrophe might happen to anyone, no matter how fine the stock and how pure the blood, hence the members of the family wish the insanity to be regarded as traumatic. They remember some antecedent accident, or try to believe that they do remember one. Most people have had falls, many have struck or been struck upon the head. Some have scars more or less pronounced. It is very easy for a relative to persuade himself that the injury caused the insanity. Not unusually members of a family bring imagination to the aid of memory and even replace memory by imagination in discovering an accident or magnifying its gravity.

A traumatism to the head may act in two ways: One way is by what we may call psychic trauma: that is, by exactly such influences as are causal of ordinary postoperative insanity.

The general element in psychic traumatism is fear, with resultant worry, insomnia, pain, anxiety, etc. The cases that are of the most importance are those due to physical trauma, in which some actual injury has been inflicted upon the brain. The injury may have been of a gross nature. For instance: a hemorrhage, a laceration or damage associated with fracture of the skull. The injury may have been of the nature of a concussion, perhaps with minute multiple hemorrhages or of a concussion in which, without gross lesion, there has been interference and perversion of the subtle chemistry of the nerve cells.

In the cases in which psychic traumatism is the influential cause, the patient really develops a neurosis, and a psychosis is contracted on this basis. Such cases are not uncommon after railroad accidents in which there may have been some physical injury, but certainly has been much mental shock.

In such patients there is neurasthenia and often hysteria. There may be a development of confusion, mania, manic-depressive insanity, stupor, hypochondria or dementia.

Careful investigation will show that members of this group of cases were predisposed to insanity, the predisposition having been hereditary or acquired, and no operation upon the head is to be thought of.

When there has been a definite head injury, insanity may arise even if a patient is not definitely predisposed, although often such cases show that many of the victims were predisposed. In these cases we are dealing with conditions of which Dr. A. B. Richardson said the injury is "the direct and sufficient" exciting cause.

In some cases insanity begins almost immediately after the injury or soon after. In most cases it is not definitely manifested until weeks or even months have passed.

Many causal lesions have been described as responsible for traumatic insanity of this sort:

Fracture of the skull with depression;

Fracture of the skull without depression;

Exostosis from the inner surface of a cranial bone;

Sclerosis of the cerebral cortex;

Cerebral softening;

Edema of the brain;

Cyst of the brain;

Edema of the membranes;

Cyst from localized meningitis;

Gluing of the membranes to the skull or to the brain;

Great thickening of the membranes;

Chronic inflammation of a membrane;

Progressive and widespread interference with the nutrition of the brain.

If the insanity appears almost immediately after the accident or very soon after it, we are justified in blaming the accident for the occurrence.

If the symptoms of insanity do not appear for a considerable time after the accident (many weeks or months) we will decide on study that the accident is to be blamed for some cases and not for others. A highly important fact in reaching a conclusion is to note if between the time of the accident and the time of the recognition of the insanity there has been a change of character, disposition or temperament in the individual. In the cases which I have seen such change has been remarked invariably. As Prof. Horatio Wood[1] has said: "Changes in the intellectual or emotional nature so subtle or hidden as not to be readily perceived register themselves with astounding clearness on the dial plate of character."

When a change of character or disposition occurs it is never a change for the better but always one for the worse. The individual usually becomes extremely irritable and is often subject to violent outbreaks of rage at trivial things.

Many of the subjects, having been of previously well-ordered lives, become victims of alcohol and perhaps the slaves of immorality. Most of them neglect business, and some of them seem to have enitirely forgotten family obligations. All of them show great sensitiveness to alcohol, even a little of it serving to make them turbulent, disorderly

[1] Nervous Diseases and Their Diagnosis.

and often uncontrollable. Practically all of them are very sensitive to heat, especially the direct rays of the sun. Such subjects often sleep badly, are liable to headache and perhaps have epileptic fits.

If an individual has not been insane, say for a year after an accident, and has not presented between the accident and the insanity some such change of character, I would regard it as highly doubtful that the injury was responsible for the insanity.

Many persons who have shown such changes have never gone actually insane, but have remained for life altered, changed, perverted, spoiled for usefulness and barred from happiness or contentment.

Such change of character is extremely common after head injuries, particularly if the injury caused prolonged unconsciousness. I have noted it after fracture of the skull and after meningeal hemorrhage. It is not unusually associated with epilepsy.

When a person goes insane after such changes of character have existed we should count the head injury as causing it. Almost any form of insanity may follow a head injury. Some authors believe that a definite type of insanity is apt to follow it.

Dr. Clouston[1] always taught that what he called a typical case of traumatic insanity suffered from headache, from definite hallucinations and motor symptoms; for instance, some disorder of speech, convulsions and perhaps hemiplegia. He was further of the opinion that the mental condition "is marked by irritability and impulsiveness with a definite dementia or fixed delusions." I am convinced that various forms of insanity may be caused by injury.

There may be mania with marked hallucinations and great violence. There may be melancholia with great depression, with stupor or with agitation. There may be confusion. There may be fixed and limited delusions. There may be an organic dementia. Every now and then in an elderly person, but sometimes in a middle-aged or even in a young person, a head injury is followed by a condition which mentally seems identical with senile dementia.

Some authors maintain that traumatism may induce a condition which strikingly resembles paresis. Cases of traumatic insanity after head injury offer a poor prognosis. It is true that some recover after operation. It is also true that some recover without any operation. Many fail to get well in spite of operation.

Operation may disclose a causal lesion, the removal of which may result in the patient's recovery; but, on the other hand, such removal may be without result.

Some cases have recovered after simple trephining, when nothing whatever was found. I had a conspicuous instance of this in my own practice. Now and then a remarkable recovery is obtained by elevating a depressed fracture.

When simple trephining is followed by cure, it looks as if the cure was a mere coincidence or was due to the effect of shock.

[1] Surgery of Idiocy and Insanity, Jour. Ment. Dis., June, 1904.

We should operate on an insane man if the insanity has quickly followed the head injury; if the site of the injury is indicated by a scar, by a depression, by a fixed point of pain or a localized tenderness, or by some localizing symptom, motor or sensory.[1]

If insanity has come on a considerable time after an accident and in the intervening time the patient has exhibited changes of character and disposition, and there exists a definite site of injury, an operation should certainly be performed.

If in the interval between the accident and the insanity there has not been change of character, we should not regard the injury as causal and should not operate unless there is a striking local indication.

We should not feel justified in performing a surgical operation because there is a doubtful record of a blow, or a dubious history of a fall, unless the record or history be reinforced by some definite local sign or symptom.

In any case in which there are obvious evidences of intracerebral pressure we are justified in decompressing.

[1] Jour. Ment. Dis., June, 1904.

THE PRINCIPLES OF SURGICAL TUBERCULOSIS.

By OSCAR E. NADEAU, B.S., M.D.

The treatment of tuberculous lesions by surgical means is one of the most difficult problems in the field of surgery. The very fact of its great tendency to chronicity and to the fact that it is as a rule a self-limiting disease makes it exceedingly difficult to tell whether in a given case one should use hygienic measures and depend on time alone to produce results, or use surgical methods and hope for a speeding up of the cure, thereby saving the individual a great amount of time. The financial condition of the patient is also often a factor to be considered in selecting the treatment.

Tuberculosis is a chronic granulomatous disease due to the tubercle bacillus of either the bovine or human type. The bovine bacillus is that causing tuberculosis in cattle and which, transmitted by means of milk, is the chief cause of lesions in the intestines, lymph glands, and in the bones. The true human type of bacillus is that which causes tuberculosis of the lungs and generalized or miliary tuberculosis. The usual modes of entrance of bacilli are through the mouth and nose from inhalation of tuberculous infected air, or from the drinking or eating of infected food.

Bovine Type.—From a surgical standpoint it is well to remember that since bovine tuberculosis is the usual cause of surgical conditions, the milk supply is a factor to be looked into most rigidly. Infected milk may cause lesions in various ways. The bacilli may lodge in the laryngeal or faucial tonsillar crypts, when, providing the natural resistive powers of the individual are not high, a local process results, then by the process of extension through the lymphatics, lesions may be formed in other parts of the body such as the lymph glands of the neck and mediastinum. Again, infected milk when ingested into the stomach and intestines may cause lesions in the intestinal wall, usually in the last coils of the ileum, and produce ulcers in this bowel or may perforate the bowel and produce lesions in the peritoneum.

The invasion may also be by means of the blood stream from any of these points and distant lesions be produced such as in the bones and joints. Occasionally, although more rarely, lesions of the genital tracts may be produced by direct contact. In Edinburgh an examination of the tuberculous material from cervical glands in 72 cases resulted in a discovery that in 65 of these (or 90 per cent.) the bovine bacillus was present. Lowered resistance, either general or local, is favorable to the production of this disease. The recent great epidemic of influenza has brought us a large number of cases of tuberculosis, not only of the lungs, but also of the so-called surgical types.

A local injury, whether due to mechanical means, or to toxic or mechanical agents, is conducive to the formation of a local tuberculous lesion providing, of course, that tubercle bacteremia is present.

Tests for Tuberculosis.—While it is always desirable to have positive tests in doubtful cases of tuberculosis, still it is not always best to subject the patient to the danger of dissemination. It is a well-known fact that the giving of tuberculin subcutaneously may cause an old, well encapsulated focus to increase its virulence and start up anew, and so destroy the products of resistance that have been formed about this focus.

One of the best tests for the positive determination of tuberculosis is that of an injection into the peritoneum of a guinea-pig of some of the material that has been removed.

PATHOLOGY OF TUBERCULOSIS.

The characteristic lesion is the tubercle. Single tubercles, however, are rarely seen as they do not cause symptoms. The growth of a tubercle is ordinarily a very slow and chronic process, and very often has attained a marked degree of development before being discovered. The tubercles eventually coalesce, forming larger giant-cell masses and later abscesses. There are two main kinds of these granulomatous processes—in one it is surrounded by hyperemic granulomatous tissue in an active stage and in which there are many lymphocytes found in the wall. The second kind is that surrounded by fibrous tissue and fibroblasts which indicates its greater chronicity, slower growth and better resistance on the part of the individual.

The course of the disease varies with the virulence of the germs and the resistance of the patient. The great tendency of a tuberculous process is to cure itself by the formation of fibroblasts and later fibrous tissue, which finally becomes a permanent wall about the process. This fact alone is of the greatest importance in dealing with the treatment of the condition.

The caseation that is seen in tuberculosis is due to the fact that the fibrous wall does not allow bloodvessels to enter to its lumen. Besides this mechanical obstruction due to the fibrous tissue, there is always present an endarteritis which helps to shut off circulation to the part. This obstruction of circulation causes, first, degeneration and, later, the characteristic coagulation necrosis. The older the condition is the less vascular does the wall of a chronic granuloma become. Conglomeration of tubercles forms the typical chronic tuberculous abscess which is found in the bones, joints, lymphatic structures and other organs. In old abscesses the bacilli can rarely be found either by staining or inoculation, so that unless one is able to recognize the condition grossly as seen in the tissues it may be difficult to be able to prove that a granulomatous process is that of tuberculosis.

Secondary Infection.—A chronic tuberculous abscess is of itself practically harmless as a rule, but when infected with other organisms such as the staphylococci, streptococci, colon bacilli, etc., it then becomes a source of great danger due to the fact that these abscesses are often hidden in remote portions of the body, and also that the caseous material is a very fertile medium for inoculation. The tuberculous abscess secondarily infected has all of the evidences of the usual acute abscess and a protective wall may be easily broken down, due to the fulminating character of this new process.

A tuberculous abscess, when left to itself, does not necessarily come to the surface. It often has a tendency to burrow deeply into the body. Occasionally one meets with a mass of dry putty-like consistency lying along the spine in the body of a patient who has been clinically cured of spinal disease; this is, of course, the desiccated remains of a chronic tuberculous abscess, the fluid portion having been absorbed and the solid elements left behind and perhaps infiltrated with lime salts. Such debris can become the seat of recurrent inflammatory mischief years later when suppuration may suddenly occur and give rise to what is known as a residual abscess. In these chronic cavities large amounts of cholesterin are found indicative of a very slow cystic process. These abscesses are in themselves often harmless, but when they are in such a position as to cause discomfort either from pressure upon nerves or from a location between the bone and the surface, it is best simply to tap the cavity and close it at once.

Diffusion.—One of the chief dangers of tuberculous disease is the great tendency to diffusion which is sometimes lighted up by injudiciously vigorous operative interference. It may occur (*a*) locally, by direct continuity of tissue; *e. g.*, from the testis by way of the vas deferens to the prostate and seminal vesicles, or by extension along neighboring lymphatics or bloodvessels; or (*b*) distant viscera or organs may become infected by embolic dissemination in the blood stream. Thus, phthisis is a not uncommon sequence of a similar affection of bones, joints, or lymphatic glands, while meningeal tuberculosis is more frequently associated with tuberculous affections of the genital organs. (*c*) Moreover any tuberculous lesion may lead to acute general tuberculosis in which the disease is scattered widely throughout the body, giving rise to rapid emaciation, high fever of the intermittent type, and severe diarrhea, dyspnea and delirium or coma, death ensuing in a few weeks.

The pathology as seen in the various organs will be described under treatment of the special tissues, bones, lymph glands, etc.

TREATMENT OF TUBERCULOSIS.

After studying the pathology of tuberculosis one is apt to believe, as Koch did when he studied the subject so intensively, that tuberculous foci should be eradicated by surgical means, and some authorities even went so far as to suggest that every bit of tuberculous tissue be completely excised with as much care as is necessary in the extirpation of cancer.

Many disastrous results became the rule, therefore, in the early days of the treatment of tuberculosis. Gradually, however, less and less operative interference has been used until at present the pendulum has swung far back, so that instead of surgery we are relying more and more on the natural powers of repair inherent in the patient, and are endeavoring to maintain and increase these in every way by suitable general and local treatment. Operative measures are reserved for the comparatively small class of cases which resist such treatment, or for the larger class to which conservative treatment for various reasons, most often financial, cannot be given.

In other words, tuberculosis of practically all tissues can be satisfactorily cured providing general and hygienic treatment can be given over a sufficiently long period of time. For instance, a man has a tuberculous ankle-joint, he has a large family to support, his work requires that he be on his feet, he is poor, and he wishes very strongly to get back to work quickly. He is told that it will require possibly one year to cure his ankle. It then becomes a question as to whether one should amputate in these cases. In former years amputation was performed much more commonly than it is done now, but nowadays we believe that an amputation is very rarely needed. It is then the duty of the surgeon to try to arrange for the patient's welfare, and that of his family, so that he can take the required amount of time for the treatment of his lesion. For this reason it is sometimes difficult to hold these patients because they easily become discouraged and will go elsewhere and demand amputation.

Hygienic Treatment.—General treatment, both before and after surgical treatment, is of the greatest importance in treating this disease and should never be lost sight of throughout its course. This treatment is well known to everyone at present, consisting essentially of fresh air, plenty of sunlight, pure and wholesome food free from infection (and this is essentially true in the milk supply) and a change of residence if this be found advisable. The weight should be watched carefully and exercise be advised judiciously. Treatment by the use of the various forms of tuberculin has in the main been disappointing, and its use must never supersede the hygienic and surgical measures required in the treatment of the disease.

Focus of Infection.—Wherever it seems that there may be a source from which the infection is gaining entrance into the body, this source should first be eradicated. If it is in the milk supply, that should be attended to; if the tonsils are diseased, they should be removed, and the teeth and mouth should be carefully treated for any septic lesions. It is generally possible to place these patients under preliminary hygienic, dietetic, and often under climatic treatment for the cure of pulmonary tuberculosis before they are subjected to surgical operations.

Many surgeons have noted the fact that patients suffering simultaneously from a mild form of pulmonary tuberculosis improve rapidly after operations removing extremities containing the tuberculous joints; as, for instance, an amputation of the hand in case of tuberculosis of the wrist, or amputation through the lower third of the thigh in case of tuberculosis of the knee. On the other hand, they found that similar cases became rapidly worse and resulted fatally in those in which an attempt at excision of the joint was practised. Later on when these latter operations were performed under antiseptic precautions and the wounds healed primarily, the pulmonary conditions improved rapidly, while if suppuration was present the opposite was true.

The following explanation of this fact has been given by Beck and others: In every patient suffering from tuberculosis there is an attempt by nature to provide a sufficient amount of antitoxin, so that the tuberculous tissue, removed by the amputation, leaves more of the substance in the blood to combat the disease in the lungs and elsewhere, and that for this reason healing occurs. On the other hand, if the organism is burdened by any additional task, as, for instance, the combating of a mixed infection, the course changes in favor of the disease, and the patient succumbs to pulmonary tuberculosis. The shock of a long-continued bloody operation undoubtedly has the same effect.

In patients suffering from tuberculosis it is well known that an operation is usually well borne if it removes tuberculous tissue. If this is not removed by the operation, the presence of tuberculosis is a contra-indication to operation. E. A. Gray has shown that in patients suffering from pulmonary tuberculosis, long-continued operations are contra-indicated chiefly because the disease in the lungs is likely to make progress during the time that the patient is recovering from the depressing effects of the operation. Ether anesthesia is in most instances contra-indicated in all cases in which consumption is present.

Indications for Operation.—Obviously, extirpation of the tuberculous focus of practicable is the ideal treatment in all cases, and for most conditions no other treatment need be considered. For instance, in superficial lymphatic glands in the neck, excision is the best treatment whenever progress to recovery is delayed or absent. The chief indications for operative interference are probably about as follows: (*a*) When general and hygienic measures of treatment fail to check the growth of the process; (*b*) when an abscess has formed; (*c*) when the process is becoming more extensive or is progressing more rapidly; (*d*) when it seems as though the natural process of repair by the individual does not safely inhibit the action of the process. Other factors also involved, and which must be considered in the treatment, are; (1) the stage of the disease; (2) its position; (3) its character, whether chronic, stationary, or acute; (4) the probable hygienic conditions surrounding the patient after the operation, for all the benefits to be hoped from an operation may be completely destroyed by not being able to take care of the patient's general condition after his operation.

The Social Service Centers now doing such efficient work in all centers of population in this country and in others, are aiding a great deal in this problem by coöperating with the patient and with the physician in handling the general condition of the patient both before and after operations. For this reason it has been found safer to do more surgical operations for tuberculosis during the past few years than it was possible before the Social Service System came into effect.

CHRONIC TUBERCULOUS ABSCESS.

A tuberculous abscess is a collection of pus caused by the tubercle bacillus that does not show signs of inflammation and has been growing for a long period of time. It is the result of disease in bone, joint, or lymphatic tissue, and tends to spread along fascial planes or along lines of loose areolar tissue. The pus is of a special character, being a necrotic, caseous, curdy material. Bacteria are rarely found, although the pus may cause infection in guinea-pigs after injection into the peritoneal cavity. The wall is made up of loose granulation tissue.

One of the most frequent sites for chronic tuberculous abscess is in the lumbar region or in the groin as a result of tuberculous disease of the spine. It is also seen as a fluctuating mass in the iliac fossa as a result of disease of the ileum and more rarely as a chronic retropharyngeal abscess arising from disease of the upper cervical vertebræ.

Treatment.—When it is found necessary to open an abscess it should be treated by most scrupulously aseptic and antiseptic methods. The field overlying the mass should be very thoroughly cleaned with soap and water and then tincture of iodine painted over it. The operator should wear gloves, and the entire procedure looked upon as a very serious and major type of operation. The contents may then be evacuated through a small incision and as much of the fluid allowed to escape as is possible and without using undue massage. If any loose sequestra of bone are found, they may be removed. The cavity should then be filled with either a 10 per cent. solution of iodoform in glycerin or with Beck's bismuth paste which consists of 20 per cent. bismuth subnitrate in sterile yellow petrolatum. The wound is then closed tightly and a careful dressing applied. If such a wound were to become infected, it is probable that the result would be much worse than the original condition. Hence the rigid asepsis that must be employed in treating this condition. A chronic abscess thus treated may slowly reform, especially when the primary cause cannot be removed.

TUBERCULOUS SINUS AND FISTULA.

Abscesses that have opened spontaneously or that have been opened with resultant secondary infection are the cause of chronic sinuses developing. These sinuses are exceedingly difficult to treat, not only because of the fact that they lead to a tuberculous process deeply situated, but also because the tubercle bacilli form a tuberculous process all along the track of the sinus. Hence, the reason for preventing secondary infection or continued drainage as mentioned above. In the treatment of tuberculous sinuses one should always attempt to remove the offending tissue if possible. Where possible, also, it is best to excise the entire tract of the fistula, although this can rarely be expected.

Treatment.—A form of treatment that has been used to a large extent in the past few years is that introduced by Dr. Emil Beck which he describes on page 850. He injects a paste made of 20 per cent. subnitrate in yellow petrolatum which has been warmed and placed in a glass syringe. The paste should be just warm enough to remain melted while being injected, but not hot enough to cause necrosis of tissue. It is then slowly injected without using undue force. Injections of this paste should be administered about once a week until the process is arrested. The danger from bismuth poisoning is practically nil, and if a chemically pure bismuth salt be used, there should be no untoward effects.

At best the treatment must be long continued and a great deal of patience must be exercised by both the physician and the patient.

TUBERCULOUS LYMPHADENITIS.

This condition is usually seen in children who have lived under impure hygienic surroundings, bad food, and have been subject to some predisposing cause such as tonsillitis and septic mouth. The condition is usually seen in the glands of the neck beneath the sterno-cleidomastoid muscle, although it may also be found, though rarely, in the axilla or in the groin. The cause is practically always due either to a tuberculous focus in the tonsil or to tuberculosis of the lungs. When due to a condition in the tonsils, it is advisable first to remove the tonsils and so prevent further inoculation, then the usual hygienic measures should be instituted. When this plan of treatment is carried out, it often follows that the disease in the lymph glands subsides and no other surgical procedures are necessary. When, however, the process goes into abscess formation it is then necessary to make complete excision of the lymphatics as extensively as possible. Surgical measures, however, are contra-indicated when an active lung disease is present.

TUBERCULOSIS OF BONE.

Varieties.—Watson Cheyne has described the varieties of tuberculous disease of bone under ten great headings, and his classification will be used here as it is one of the best obtainable.

1. *Miliary Tubercle.*—This condition is very rarely found in bone disease.

2. *Caseous Foci.*—Usually situated toward the end of bones and near the surface. The following shows the structure from within outward: (*a*) a mass of caseous material occupies the center, this represents the

first seat of the disease, the cells of which have died and undergone fatty degeneration; (*b*) granulation tissue, containing tubercles in which all bony trabeculæ have been absorbed; (*c*) the zone of sclerosis containing small round cells instead of fatty tissue; (*d*) a zone of rarefying osteitis at some distance from the deposit.

3. *Necrosis with Sequestrum Formation.*—This also occurs chiefly in the ends of long bones. The sequestra vary in size and are often wedge-shaped with the base of the wedge toward the joint. The formation of caseous foci and of sequestra often occur at the same time and location, and the sequestra remain attached for a long time to the living bone at one spot.

4. *Superficial Caries.*—This occurs beneath the cartilage of a bone or the periosteum of the shaft. The surface is covered by caseous debris, beneath this is more or less osteosclerosis. At a little further distance a zone of osteoporosis. It very seldom extends deeper than $\frac{1}{4}$ of an inch from the surface.

5. *Tuberculous Periosteitis.*—Found most commonly in ribs and vertebræ and produces caries of the underlying bone together with chronic abscesses spreading along the bones and tracking to a distance.

6. *Osteomyelitis and Epiphysitis* that is most often seen in phalangeal, tarsal, and carpal bones.

7. *Caries Sicca.*—This is very rare, except in the shoulder-joint. Instead of soft tuberculous granulation tissue, firm fibrous tissue forms on the surface and the bone steadily atrophies. It is accompanied by ankylosis with muscular atrophy.

8. *Diffuse Osteosclerosis.*—This occurs for some distance along the shaft of a bone in the neighborhood of an old tuberculous process. The bone becomes dense and thick.

9. *Diffuse Softening.*—This is the rarest of all bone changes and is only seen in rapid cases where the disease spreads from one bone to another. There is a great enlargement of the medullary cavity and increase of the red marrow with general absorption of the hard bone.

10. *Chronic Deep Abscess.*—Usually situated near the epiphyseal line. It is lined by a thick pyogenic membrane and surrounded by a thickened mass of sclerosed bone. This thickening often extends up the shaft.

The bones most commonly affected are the vertebræ, long bones, the ribs, pelvis and the carpal, tarsal and phalangeal bones. The os calcis, astragalus, scaphoid or one phalanx, may be separately diseased, but usually more than one bone or joint is affected.

Treatment.—Here, as in all other cases of tuberculosis, the primary and most important treatment is constitutional and hygienic. If possible, the part should be put at rest by means of splints or carefully applied plaster-of-Paris casts, because in that way can be obviated the effect of pulling of muscles upon periosteum and bone.

Operative treatment may be instituted when general measures have completely failed for a sufficient length of time and the presence of tuberculosis in the bone seems to be possible of eradication. When an abscess has occurred in the bone, it should be opened and all disease grnaulations curetted away, sequestra removed and the cavity packed with some substance such as iodoform—glycerin mixture or bismuth paste. The wound is then closed preferably without draining.

As has previously been mentioned, the question of amputation of a limb because of tuberculosis in a bone occasionally comes up. This practice, however, cannot be recommended for reasons that have previously been given, except in cases in which a joint such as the ankle-joint has been so completely destroyed that it will be impossible to produce a usable foot.

In the surgical treatment of long bones particularly, one must always be exceedingly careful not to transmit the disease to a neighboring joint. Therefore, when treating a case such as a lesion in the lower end of the femur, the chisel should always be directed away from the joint as soon as the operator is in that immediate vicinity.

TUBERCULOUS ARTHRITIS.

Infection of a joint with tubercle bacilli is always a serious condition, not alone from the gravity of the lesion, but more particularly from the tendency to chronicity. The disease primarily affects either the synovial membrane or the ends of the bone, the cartilages and ligaments being affected only secondarily. The synovial changes are, as a rule, so marked and infiltration so thorough that complete eradication of the disease is thereby made very difficult. The ultimate results of joint disease may be one of the following: (1) Complete recovery, possibly only when the original disease has been limited to the bone or when a synovial infection has been arrested or excised in a very early stage. (2) Fibrous fixation of the joint resulting from destruction of synovial membrane and cartilage, these being replaced by granulations which later revert to fibrous tissue. (3) Bony ankylosis; this results from a more or less complete destruction of the articular cartilages followed by a union of apposed granulating surfaces of diseased bone. The united granulations then become ossified.

The prognosis of a tuberculous joint is, as a rule, good. It is bad when treatment cannot be efficiently carried out, in people over fifty, in the presence of tuberculosis elsewhere and, finally, when there is secondary invasion with other organisms.

Treatment.—General hygienic and constitutional measures, of course, come first in the treatment of any tuberculous joint. The next most important principle is that of rest as complete as can be obtained in order not to aggravate the disease. Complete immobilization must be maintained until all pain and tenderness have disappeared; this usually requires from four months to one year. A tuberculous joint under proper treatment usually recovers in from eight months to two years.

Due to muscle spasm that is always present about a tuberculous joint, there often occur deformities such as contractures which must be corrected in order to obtain proper function.

This should be done very gradually by using weight and pulley extension or gravity methods. In the correction one should aim to place the joint in its most useful position, should ankylosis occur, such as a 45 degree flexion of the elbow and a very slight flexion of the knee. A joint such as the hip or knee can be conveniently put at rest and the muscular contractions about it relaxed by means of a Buck's extension with adhesive straps applied to each side of the leg and weights applied by means of a cord and pulley in order to overcome the muscular spasm. This treatment also prevents a possible dislocation of the joint following treatment.

The treatment of joints by injection with substances such as iodoform in glycerin is not always satisfactory, but is worth while trying in joints such as the knee. A useful procedure is to tap the joint, allowing most of the fluid to escape, then to inject 1 ounce of a mixture of 10 parts of iodoform in 100 parts of glycerin. This mixture occasionally clears up the infection in remarkably short time. It may be repeated once every two or three weeks during a period of several months.

Arthrectomy during the active stage of tuberculosis is an operation of very doubtful utility and is not to be recommended. Complete excision of a joint and removal of a wedge of bone may be performed after the condition has healed and there is a bony ankylosis with deformity that cannot be corrected by non-operative methods.

CHRONIC PLEURAL EFFUSION.

This condition is practically always caused by tuberculosis. Its treatment consists in aspiration through the sixth or seventh intercostal space in the posterior axillary line. The fluid should be withdrawn slowly so as not to cause dyspnea. As soon as bleeding or coughing results, the needle should be withdrawn as it is an indication that the lung is in contact with the point of the needle. For this reason it is best to use a blunt needle rather than a sharp one. This procedure may be repeated as often as fluid reaccumulates. Of course, there is a great danger of secondary infection which should be guarded against most rigidly.

TUBERCULOUS PERITONITIS.

This affection is frequently found in children. It may arise from a diseased appendix, ileum or cecum, or from a uterine appendage. Rigid constitutional measures should be employed as in all other cases of tuberculosis, since this condition occasionally clears up by proper medicinal treatment alone. The treatment is that of laparotomy with eradication of the focus whether it be appendix, salpinx or mesentery glands, and closure of the wound without drainage and without irrigation. About 75 per cent. of all cases may be cured by this means. An attempt should never be made to insert drains in these cases as it is almost certain to lead to secondary infection.

TUBERCULOSIS OF THE KIDNEY.

In tuberculous disease of the kidney general measures are seldom of much avail, and surgery must usually be resorted to. Before surgery is attempted, however, there should always be made a functional test of the opposite kidney in order to determine that the disease does not occur in this kidney and also that it is capable of carrying on the functions of both. The question of the kind of operation may come up. As a rule, nephrectomy and ureterectomy is the best procedure. In cases in which there is pyonephrosis and where the condition of the other kidney is uncertain, a nephrotomy is safer. Partial nephrectomy is practically of no avail because it is practically impossible to determine that the condition is located in only one portion of the kidney.

THE DIAGNOSIS AND TREATMENT OF SYPHILIS.

By WILLIAM ALLEN PUSEY, A.M., M.D.

We have now exact laboratory methods for the diagnosis of syphilis. Unfortunately, as a result of this, we have the same tendency that is seen with other diseases in which laboratory methods of diagnosis are available, to neglect the importance of clinical knowledge, not only in the diagnosis but in the treatment of syphilis. This is a retrogression in practice which should be checked. Until recently we were compelled to rely upon clinical knowledge for the diagnosis of syphilis; and with it alone a definite diagnosis was usually possible. This clinical knowledge is still useful in the diagnosis and management of syphilis. In most cases it should make the diagnosis independently of the laboratory. It should always confirm it, or challenge it. It prevents the practical application of inaccurate laboratory findings. It discovers a considerable number of cases which may escape the laboratory. And, most important of all, it is of imperative use in estimating the progress of syphilitic patients and in guiding their treatment. If, therefore, much is said in what follows of the laboratory methods used in the management of syphilis, it should not be assumed that these methods can safely be substituted for clinical knowledge of the disease.

The laboratory methods used in the diagnosis of syphilis are chiefly the demonstration of the Spirocheta pallida and the serum-complement reaction, known as the Wassermann reaction. The cutaneous reaction, the luetin test, is so likely to be inaccurate or misleading that its practical value is very slight, and it has not come into general use.

THE SPIROCHETA PALLIDA.

The demonstration of the Spirocheta pallida is of chief importance in making a diagnosis of the chancre before the Wassermann test becomes positive. Here it is of very great practical importance. It is also useful in showing the syphilitic character of mucous patches and other moist lesions during the course of early systemic syphilis. It is of little or no importance in late syphilis, because of the scarcity of the spirochetæ in the late lesions of syphilis, and the very extreme difficulty, if not impossibility, of demonstrating them in such lesions.

Examination for Spirochetæ Pallidæ.—The Spirocheta pallida is most abundant in the lymph of early active syphilitic lesions, especially in the chancre and mucous patches. To obtain this lymph the lesion should be wiped clean with pledgets wet with normal saline solution until a clean moist surface is exposed. In the case of a dry chancre it may be necessary to curette it lightly, or rub it vigorously with a wet cotton applicator, in order to get a supply of lymph, but bleeding should be avoided, and the serum to be examined should be free from gross mixture with blood. Squeezing of the chancre between the finger and thumb (protected with rubber cots) may be necessary to get a free flow of lymph. A drop of lymph from the surface can be transferred to a glass slide by applying its surface to the drop, but a much better method is to collect the lymph in a capillary glass pipette, from which it is later transferred to the slide for examination. By sealing the pipette and preserving the specimen on ice, the spirochetæ may be kept for several hours before examination, but their viability and their motility rapidly diminish with time, and the reliability of findings from preserved specimens is impaired. The examination, if possible, should be made promptly.

Serum for examination for spirochetæ can also be collected by aspirating the base of the chancre or adjacent enlarged glands. In the case of a gland, it is fixed between the thumb and finger, and a hypodermic needle attached to a small syringe stuck into it. That the end of the needle is in the gland will be shown by the movement of the gland with the movement of the needle. After introduction into the gland the needle point should be moved about to produce slight injury. Aspiration then brings into the barrel of the syringe two or three drops of lymph in which, if the case is syphilis, the Spirochetæ pallidæ are usually abundant. This method is only slightly painful, and it has the advantage of furnishing lymph which is free from contamination with other organisms, so that the danger of mistaking other spirochetæ for the Spirocheta pallida is avoided.

The most convenient and satisfactory method of demonstrating spirochetæ is by examination with a dark-field apparatus. The morphological features of the Spirocheta pallida are characteristic, and suffice for the definite recognition of the organism by an experienced worker. In the hands of an expert a diagnosis by demonstration of the Spirocheta pallida may be accepted as conclusive. Where the diagnosis of syphilis, however, rests upon the recognition of the Spirocheta pallida alone, this demonstration should not be undertaken by one who is inexperienced in this work.

THE WASSERMANN REACTION.

After syphilis becomes systemic the Wassermann reaction is the important laboratory method of diagnosis. It has been proved to be a reaction which can be depended upon, but it has certain limitations which should not be forgotten. It is not always positive in the presence of syphilis. It is not positive during the early days of the chancre, usually not until the chancre is about ten days old.

It is nearly always positive during the florid early systemic course of syphilis, the so-called secondary period. As secondary syphilis becomes older—after the first few months have passed—the Wassermann is less certainly positive, and it may become negative without any assurance that the disease is cured. In late syphilis, so-called tertiary syphilis, the Wassermann reaction may be negative, even in the presence of known active syphilitic lesions. There has been a strong effort to make the Wassermann so sensitive that it will prove positive in all cases of active syphilis, but this has not been found possible in late syphilis without making it so sensitive that it will at times give positive reactions in the absence of syphilis, and thus become unreliable. With experienced careful workers doing a reliable Wassermann, the reaction is positive in 80 to 90 per cent. of cases of late syphilis.

There are certain technical limitations in the Wassermann reaction which must not be forgotten. When properly made, with proper controls carefully carried out, the reaction, when it is positive, is dependable—experience has fully justified confidence in it—but it is unfortunately true that many inaccurate Wassermanns are made, and that many deplorable mistakes occur from reliance upon such Wassermanns. Mistakes also occur among competent Wassermann workers when the endeavor is made, by special technic, to increase the sensitiveness above that of the orthodox Wassermann technic. With such technic unreliable positive reactions sometimes occur. Inaccurate reactions may also occur from changes in blood after it is withdrawn, particularly from its being infected and undergoing decomposition from preservation for some time, as in shipment, at ordinary temperature. The blood for Wassermann tests should be drawn under aseptic conditions into sterile tubes, and should immediately be put into the ice-box if possible. If it is to be shipped it should be sealed in a sterile container.

The Wassermann as a Guide to Treatment.—The use of the Wassermann reaction as an index of the progress of treatment is a debatable subject and one upon which it is not justifiable to dogmatize. It has been generally held, and apparently upon good ground, that the presence of a reliable positive Wassermann means that the patient has active syphilis. It certainly means that the patient has had syphilis, but it is not established beyond question that, whenever there is a positive Wassermann, vigorous treatment must be continued or instituted with a view to making it negative. Long clinical experience has shown that innumerable Wassermann-positive but symptom-free patients live out a healthy existence, and recent experience shows that in old cases of syphilis it may be impossible, even by treatment which passes the bounds of safety, to make the Wassermann permanently negative.

In early syphilis vigorous efforts should be made by treatment not only to render the patient symptom-free of syphilis, but to give him a permanently negative Wassermann. In old syphilis wisdom seems to indicate that this effort should be tempered with discretion; that as a guide to treatment the patient's physical condition should be given full consideration; and that it is a doubtful course, in an effort to make the Wassermann negative in symptom-free patients, to push treatment to the point where the treatment produces ill effects upon their physical well-being.

There are also pitfalls in relying too much upon a negative Wassermann as an index of the effects of treatment. The negative Wassermann may not mean freedom from active syphilis; until this is the case, it will not be safe to rely too fully upon negative Wassermanns as evidence that the treatment of syphilis may be shortened below what long clinical experience has shown to give the best results.

THE CHANCRE.

During the period of incubation, and for about ten days after the appearance of the chancre, syphilis is a local disease, confined to the initial lesion and to contiguous structures. There are no symptoms except those arising directly from the chancre; the Wassermann is negative; a general infection has not yet occurred. If the chancre is recognized during this time—that is during the first week or ten days of its existence and before the Wassermann has become positive—vigorous treatment instituted at once will in many cases abort the disease and prevent a general infection. It thus becomes excessively important to recognize the chancres at this opportune time. This can be done definitely by the demonstration of the Spirocheta pallida, and by this method alone. Recent experience has shown that the supposedly characteristic clinical features of the chancre are often lacking, and that these cannot be depended upon for diagnosis. Indolence in the lesion is the most constant of its clinical characteristics, and any lesion, particularly if it is indolent, should be examined for Spirochetæ pallidæ, if there is any possibility of its being chancre. This applies to extragenital as well as to genital lesions that are open to any suspicion.

The chancroid presents a particularly difficult problem as respects the determination of syphilis. In a great many of them—in more than 50 per cent.—there is also a syphilitic infection. The two infections occur at the same time, but the chancroid appears in a few days, while the chancre does not develop for two or three weeks; and this fact along with the virulence of the chancroidal ulcer is likely to mask or conceal the accompanying chancre. Every chancroid should be regarded as probably concealing a syphilitic infection and should be repeatedly examined for Spirochetæ pallidæ. But Spirochetæ pallidæ are difficult to demonstrate in such cases, and if their demonstration fails, the possibility of the presence of a syphilic infection of chancroidal cases should not be ruled out until negative Wassermanns repeated over several weeks have been made, and until sufficient time has elapsed to enable one definitely to exclude syphilis.

In very early chancres the spirochetæ are abundant, and their demonstration in such chancres, which have not been treated, is easy. As the chancre grows older their number in the serum obtained from the surface of the chancre becomes fewer, so that after ten days to two weeks the demonstration is more difficult. But even in these older chancres persistent examination is usually successful in finding the organism. The demonstration may be difficult or impossible in chancres treated with antiseptics, particularly mercurial antiseptics; and for this reason no antiseptics should be used upon genital sores, or other sores which may be suspected of being syphilis, before conclusive examinations for spirochetæ have been made. Mercurial applications are the worst, but all antiseptics make the demonstration more difficult, and their use, before syphilis is excluded, in lesions which may be chancres is a cardinal mistake.

If antiseptics have been used on a suspicious lesion before it comes to examination, the lesion should be thoroughly washed with normal saline solution, and a wet dressing of this solution applied for twelve to twenty-four hours, and daily examinations for spirochetæ then begun.

When, in suspicious cases the demonstration of the Spirocheta pallida fails, Wassermann reactions should be repeatedly made at intervals of not more than a week until the possibility of the development of syphilis can be excluded by time; that is for at least six weeks after the appearance of the suspicious lesion.

Treatment.—Until a positive diagnosis has been made the chancre should not have any treatment, except measures to keep it clean. It should simply be washed with water or normal saline solution. As soon as systemic treatment of syphilis is begun, the chancre, which might otherwise persist as an indolent lesion for several weeks, will promptly heal; so that for the chancre itself there is little need of local treatment. For the purpose, however, of reducing the amount of infection in the original focus, vigorous treatment of the chancre is indicated. To this end the most useful procedure theoretically should be excision of the chancre or its destruction by the actual cautery, and, when it is so situated that it can be destroyed without leaving a deforming scar, excision or destruction by the cautery is a good procedure. The most that this can do, however, is to reduce the quantity of infection in its original focus, and it should never be undertaken with the expectation of aborting syphilis. Even at the time of the appearance of the chancre the spirochetæ have gotten too far beyond the original site of infection to be eradicated by any surgical procedure. The next best method, if not an equally good one for destroying spirochetæ in the chancre, is the inunction of calomel ointment. If the chancre is not excised it should have an inunction of 30 per cent. calomel ointment twice daily, and it should be dressed with calomel ointment or some bland dressing.

SYSTEMIC SYPHILIS.

From about the tenth day after the appearance of the chancre syphilis becomes generalized. It first spreads by the lymphatics, but when it becomes systemic its distribution also occurs through the blood stream. During its early course there is a syphilitic septicemia. In its late course it again becomes a local disease in various tissues. Its early spread is first manifested by enlargement of the lymphatic nodes adjacent to the chancre, and the first clinical evidence that it has become systemic is a general adenopathy, which can be recognized most easily in the epitrochlear and posterior superficial cervical glands. This is quickly followed by the appearance of one of the secondary eruptions of syphilis, usually a maculopapular eruption, which is likely to occur in the mouth in the form of mucous patches.

The evolution of secondary syphilis is of striking regularity, and this evolution should be given careful consideration in diagnosis. The chancre itself nearly always appears from two to three weeks after infection, usually about the eighteenth day. Great variations in this incubation period are reported, but, if they occur, they are so rare that any great variation from this regular incubation period is a weighty factor against a diagnosis of chancre. The chancre usually persists from four to six weeks, if the patient is not given specific treatment. By the time it heals—that is usually about six weeks after its appearance—the cutaneous eruption appears. Usually from a week to ten days after the appearance of the chancre the adjacent lymphatic nodes show painless enlargement and, three to four weeks after the appearance of the chancre, as a rule, and a week or two before the appearance of the eruption, the epitrochlear and posterior superficial cervical glands show a similar enlargement. In the absence of this sequence of symptoms, from the appearance of the chancre to the appearance of the eruption, a diagnosis of syphilis should be made with very great caution. This evolution is even more characteristic than the occurrence of the eruption. The eruption may not occur, or it may be so faint as totally to escape recognition. If present, it is not nondescript. It may closely resemble other eruptions—toxic erythemas, pityriasis rosea, and occasionally some other dermatoses—but it has characteristics that allow, as a rule, of a definite diagnosis. It is not true that any sort of eruption may be syphilis.

In the presence of symptoms or facts suggesting secondary syphilis the Wassermann reaction is of the greatest importances. In early secondary syphilis it is practically always positive, and in the face of repeated reliable negative Wassermanns a positive diagnosis of early systemic syphilis will not stand. As the first months of systemic syphilis pass, the Wassermann is less invariably positive, even in untreated cases, but throughout the course of secondary syphilis a positive Wassermann is usually obtainable, unless treatment has made it negative.

Treatment.—Specific treatment of primary or secondary syphilis should never be started before a definitely positive diagnosis has been made. If this precaution is not observed, treatment may so obscure the situation that a diagnosis cannot be made. And the questions, as respects the present and future treatment and the course to be followed in very serious affairs of life, hinging upon the primary diagnosis of syphilis are too important to warrant one in doing anything irrevocable that may interfere with their determination.

As soon, however, as a definite diagnosis of syphilis has been made treatment should begin. It is well established that in early syphilis the sooner this treatment begins the better are the chances of curing the patients. If the diagnosis can be made and treatment instituted before the Wassermann becomes positive, the prospects are excellent that the case can be cured by one series of treatments with mercury and arsphenamine. The prospect of prompt cure, or of prompt eradication of all evidence of the disease, diminishes rapidly with the first few weeks after it becomes generalized; the longer the disease persists before specific treatment is begun, the less favorable become the prospects of cure, and the more necessary is prolonged treatment.

Specific Drugs.—The three drugs of specific value in syphilis are arsphenamine, mercury, and the iodides. Their properties may be briefly summarized as follows:

Arsphenamine is the most efficient in destroying the organisms of syphilis, but its administration may interfere with the development of the patient's resistance to syphilis and is at least not followed by any evidence that it helps to develop resistance.

Mercury destroys the organisms, but is a less efficient spirocheticide than arsphenamine. It has, however, the great advantage of not only not interfering with the development of the patient's resistance to the infection, but probably of increasing it.

Potassium iodide does not destroy the organisms of syphilis, but causes the disappearance of syphilitic infiltrations. It is of great value therefore in curing the late lesions of syphilis, and it may at times be of great aid to mercury and arsphenamine in causing solution of syphilitic infiltrations, and thus uncovering the spirochetæ to the action of the other drugs.

In the specific treatment of systemic syphilis mercury and arsphenamine are both needed—not arsphenamine alone. When the disease is detected before evidences of systemic syphilis have appeared, arsphenamine and mercury should be started at once on successive days. If the disease is not recognized until systemic syphilis is present, there is no prospect of eradicating the disease by a quick hard attack with arsphenamine, and it is better, in order to avoid the dangers of temporary cerebral symptoms from arsphenamine (a Herxheimer's reaction), to give mercury vigorously alone for one or two weeks before beginning arsphenamine.

Preliminary Survey of Patient.—Before beginning treatment a physical survey of the patient's condition should be made. The current intensive methods of specific treatment, particularly with arsphenamine, throw a considerable burden on the patient's physicial resistance, and, in order that this should not overtax him, his points of lowered resistance should be found at the outset.

Mercury attacks chiefly the teeth and the gastro-intestinal tract. Bad teeth and a foul mouth in particular interfere with the efficient use of mercury; and bad conditions of the mouth especially should be corrected as far as possible at the beginning of treatment. The patient should be instructed in the care of the teeth and mouth, and carious teeth should be treated, but never without notifying the dentist of the situation, in order that he may protect himself. While taking treatment it is well for the patient to use an oxidizing mouth wash, such as potassium chlorate solution or hydrogen peroxid. Soft bleeding gums can be improved by having the patient paint them twice daily with tincture of myrrh.

Both mercury and arsphenamine throw a burden on the kidneys, which may be manifested by nephritis. Whenever patients are being vigorously treated with arsphenamine and mercury careful watch should be made of the kidneys, and the urine should be examined at weekly intervals.

In general, arsphenamine should be given with caution to patients who show evidence of gross disease, other than syphilitic processes, particularly of the liver, the kidneys, or the vascular system.

Methods of Treatment.—The specific treatment of syphilis is best carried out by courses of treatment of eight to ten weeks' duration, between which there are intervals of rest of one to three months. These courses should consist of both mercury and arsphenamine given in conjunction, but the methods of administering the two drugs may for clearness be considered separately.

Mercury.—A course of mercury should consist of eight to ten weeks' treatment. The most efficient methods of administering mercury, omitting intravenous injections, which have not come into common use here, are by inunctions or by intramuscular injections. Either of these methods is efficient if well carried out.

Inunctions.—For inunctions mercurial ointment should be used. Less disagreeable substitutes have been suggested, but their value has not been established. A course should consist of from 30 to 50 inunctions. An inunction should be given daily and at each inunction 4 to 8 grams, (1 to 2 drams) of mercurial ointment should be rubbed in. Inunctions to be effective should be carefully administered, and it is very difficult to have a patient administer them satisfactorily to himself. Before the inunction the area to be used should be washed with alcohol or with soap and water. The ointment should be rubbed in gently with the palm, using a gentle rotary motion, and the rubbing should continue for 20 to 30 minutes in order to get absorption of the ointment. The ointment remaining after the inunction should be left upon the surface and allowed to get into the underclothes. These should not be changed more than once or twice a week during the course. After six inunctions the patient should take a bath, and take one day's rest from inunctions.

In order to avoid dermatitis, surfaces free from hair should be chosen for inunctions. Flexures of joints should also be avoided, because the skin of these is too delicate to withstand the irritation. The best surfaces are the sides of the back, the sides of the abdomen and chest, and the front surfaces of the thighs.

Injections.—Both soluble and insoluble salts of mercury are used for injections.

The insoluble salts have hitherto been favored as furnishing the most vigorous form of treatment. This preference is disappearing and the soluble salts are gaining in favor. The insoluble salts have the advantage of convenience in that they require administration only at intervals of about a week. They have the objection that they become encysted in the muscles at the site of injection, so that the rate of absorption from them is very uncertain. This makes serious mercurial intoxication a rare but occasional accident from their administration. But the most important objection to the insoluble salts is that because of the uncertain rate of absorption from the insoluble deposits the dose of mercury which the patient receives is unknown. This is the chief reason for the shifting of preference from the insoluble to the soluble salts.

Insoluble Salts. The insoluble forms of mercury which are commonly used are the salicylate, calomel and metallic mercury. They are all given in suspensions in oil. The usual strength is 20 grams (weight) of either salicylate, calomel, or metallic mercury in enough oil to make 100 c.c. (volume). The salicylate or calomel is mixed with sterile olive oil or other sterile fatty oils. Metallic mercury is usually administered in the form of gray oil, a good formula for which is: Redistilled mercury, 20 grams; chlorbutanol, 2 grams; anhydrous lanolin, 30 c.c.; olive oil to make 100 c.c. The average intermuscular dose of each of these forms of mercury is 1 grain; the average dose, therefore, of each of these preparations is 5 minims. This may be cautiously and gradually increased to 2 grains—10 minims.

Soluble Salts.—Various soluble salts of mercury are recommended as having different advantages. The three most commonly used are mercuric chloride, mercuric benzoate, and mercuric succinimid. The chloride and succinimid are given in a 1 or 2 per cent. solution with 1 per cent. sodium chloride in water; the benzoate in 2 per cent. solution with 2.5 per cent. sodium chloride. The doses of the three salts are the same, the average dose $\frac{1}{4}$ grain (12 minims of 2 per cent. solution or 25 minims of 1 per cent. solution), every second day. This can be increased to $\frac{1}{4}$ grain daily in emergencies. Of these three preparations my preference is for the bichloride solution. I have found no advantages in comfort or otherwise in the less familiar salts.

The objection to soluble salts is the frequency with which they must be administered, and also the fact that they are somewhat more painful. The pain from them, however, is usually slight—not more than an aching discomfort for an hour or so. Very rarely is a patient found in whom the pain from the soluble salts, or the induration from the insoluble salts, is so troublesome that injections have to be abandoned. The advantages of the soluble injections are the promptness of their absorption and the certainty of the dose. They give a certain, vigorous means of attacking syphilis with mercury unequalled, in my opinion, by any other method, with the possible exception of intravenous injections.

Technic of Injections.—For all intramuscular injections a Luer type of glass hypodermic syringe should be used with a $1\frac{1}{2}$ inch, 20 or 22 gauge needle. The syringe should be sterilized at the time of using, and if oil suspensions are used, must be dried, either by heat, or by washing with alcohol. The skin at the point of injection should be sterilized by painting with iodine. The best sites for the injections are in the upper outer quadrant of either buttock. The outer half of the upper inner quadrants may also be used. In making injections care should be taken to avoid the neighborhood of the sciatic nerve or of the hip-joint. The injection must be made into the muscle, not into the skin or subcutaneous tissue. The needle, attached to the empty syringe, should be sharply driven into the buttocks for its full length; the empty syringe then detached, and filled with the preparation to be injected. Detaching the syringe gives an opportunity to see if blood wells up into the needle; if this should occur it would indicate that a vein had been entered, and that injection at this point is dangerous. If the needle remains clear, the syringe is attached and the injection slowly made.

Arsphenamine (Salvarsan, 606).—Arsphenamine has shown itself a remedy which must be used with caution in order to avoid its dangers. As a rule it is given now in moderate doses at intervals which allow of the excretion of nearly all of the previous dose before the next dose is administered. It should be given in doses of 1 decigram to each 25 or 30 pounds of the patient's body weight, and at intervals of five to seven days. The usual practice is to give it at intervals of a week. The average course of treatment is 6 doses, after which the patient is given a few weeks rest before the course is repeated. Some authorities of large experience urge its use in greater doses, and at shorter intervals. When syphilis is discovered before the Wassermann becomes positive, the prospect of aborting the disease is good enough to warrant giving the drug at intervals of four to five days, and, with care, in somewhat larger doses.

The number of courses of arsphenamine a patient should take varies greatly in different cases. If, in cases gotten before the Wassermann becomes positive, no symptoms of syphilis other than the chancre develop, and if the Wassermann remains negative in repeated subsequent Wassermann examinations, it may not be necessary to repeat the course of arsphenamine at all. But such cases should be watched for at least two years, with Wassermanns at the intervals of three or four months. And it is the safest course to give them at leats two or three subsequent courses of mercury with intervals of rest of three or four months each.

In early cases in which the Wassermann has become positive before treatment is begun, but becomes negative with the first course of arsphenamine and mercury, the patients should be watched for at least two years, with Wassermanns at intervals of two or three months, and shonld have at least two or three subsequent courses of mercury at intervals of three or four months.

In cases in which a positive Wassermann or other evidence of syphilis persists, or recurs, treatment with mercury and arsphenamine should be repeated with intervals of rest of two months during the first year, and, with somewhat longer intervals of rest during the second year. It is doubtful if anything is gained by continuing periodic arsphenamine treatment beyond two years in these cases with persistently positive Wassermanns, but at least two courses of mercury a year for two years more should be given. There are authorities who hold that in such cases the effort should not be given up to render the Wassermann permanently negative by the use of arsphenamine. It is the experience of other authorities, however, that this effort is not likely to be successful in these intractable cases, and that the excessive persistence in the use of the drug proves a heavy burden on the patient's health.

NEOARSPHENAMINE.—There is some difference of opinion as to the relative value of arsphenamine and neoarsphenamine in syphilis, but, if there is any difference in the action of the two drugs, it is not sufficiently distinct to mean any practical difference in their effectiveness. The chief objections to neoarsphenamine are that it is more unstable and is more likely to contain poisonous byproducts, and, thus, is more frequently followed by toxic symptoms; but with improvement in its manufacture this latter objection is rapidly disappearing. Neoarsphenamine has the great practical advantage that its administration is much simpler. It can be given with safety intravenously in 15 c.c. to 25 c.c. of water for a full dose, which makes its intravenous injection a very simple procedure. It also simply requires solution in water; for its solution does not need neutralization as does that of arsphenamine. The equivalent dose is 50 per cent. larger, so that its dose is $1\frac{1}{2}$ decigrams to each 25 or 30 pounds of patient's weight. The courses and intervals of treatment are the same.

Technic of Arsphenamine and Neoarsphenamine Administration.—General management. A certain amount of care with patients will prevent many reactions from arsphenamine. They bear the drug better when the gastro-intestinal tract is relatively empty. It is desirable to move the bowels freely with a cathartic in the morning before administration, and no food should be taken for at least four hours before, and four hours after it. If it is given in the morning, the patient should omit breakfast and luncheon; if, in the afternoon, luncheon and dinner. After the dose the patient should rest in a recumbent position for at least half an hour. It perhaps is better that he should go to bed until the next morning. This, however, is rather an excess of caution, for experience has shown that the administration of arsphenamine to ambulatory patients is about as safe as to patients confined to bed, providing the precautions suggested above are carried out.

Intravenous Injections.—Of course any procedure that involves injection into a vein should not be undertaken except under strict aseptic conditions. The fact that the administration of arsphenamine is so common and seems so trivial an operation should make it no exception. It should not be given unless it can be done with safety in this respect. The apparatus and instruments should be boiled for at least twenty minutes. The water for the solution should be freshly distilled to avoid reactions, which are well demonstrated to be more frequent when this precaution is neglected. Toxic effects are not very likely to occur if the drug is well diluted, and if the injection is given slowly. The solution should be made with 20 c.c. to 30 c.c. of water for each decigram of the drug. Before the ampoule in which the drug is contained is opened it should be examined for defects. A defect in the ampoule, such as a crack, likely means the admission of air which would cause dangerous oxidation of the drug. The ampoule should be sterilized in a strong antiseptic solution, such as 1 to 1000 mercuric chloride solution. It should then be dipped in alcohol, both to free it from the other antiseptic and as a further test to see that it is not defective. It should be wiped dry with sterile gauze before breaking. Mercuric chloride causes decomposition of arsphenamine, and its solution in particular should be carefully wiped off before the ampoule is broken. High temperature decomposes arsphenamine, and on no account should the ampoule be sterilized by heating, either by boiling or dry heat.

The arsphenamine should be shaken from the ampoule into the container in which the solution is to be made, preferably a mixing cylinder. About 50 c.c. of water should then be added, and solution encouraged by a rotatory motion of the container. In order to avoid admixture with air there should be as little of a shaking motion as possible. The preparation of the Dermatological Research Laboratory, known as arsenobenzol, requires that the water be heated to get solution of arsphenamine, and with this preparation the water can be safely brought to the boiling point for a moment in making the solution. The other preparations of arsphenamine dissolve at room temperature, and are decomposed by heat, and must not be dissolved in water of high temperature. The primary solution of arsphenamine is acid, and it must be neutralized before administration. This is done by the addition of a few drops of a fresh 15 per cent. solution of sodium hydroxide. This should be added drop by drop. It immediately precipitates the arsphenamine. As soon, however, as the solution becomes in very slight degree alkaline a sodium salt of the drug is formed, which at once redissolves. The addition of the alkali should be stopped as soon as resolution has occurred. If in the subsequent further dilution of the solution a precipitation occurs, this is overcome by the addition of a very few drops of sodium hydroxide solution. If caution is used to add the sodium hydroxide solution only a drop at a time, the moment when complete solution of the previously precipitated arsphenamine occurs is a sufficiently accurate gauge of the proper alkalinity of the solution, and makes the technic outlined above a safe one. But it is only safe when neutralization is cautiously done, as described above, and not when an uncertain excess of alkali is thrown into the solution.

A word of caution should be sounded as to the danger of inadvertently failing to neutralize the solution and injecting the primary acid solution. There is no difference in the appearance of the two solutions, and this mistake can occur. It may cause no trouble, but the acid solution is much more toxic than the slightly alkaline and is dangerous. Because of the possibility of this mistake one who is preparing the solution should not be interrupted in the work until he has finished.

After the arsphenamine is redissolved, and the solution is clear, it should be filtered through wet sterile cotton in a small funnel into the container from which it is to be administered. Then water at a temperature to bring the entire solution up to body heat, should be added to make the dilution up to 100 c.c. to 180 c.c. of water for ordinary doses. The rubber tube connecting the container with the needle may be previously filled with normal saline solution, or the arsphenamine solution may be allowed to fill the tube. Care must be exercised that all air bubbles are gotten out of the tube, so that no air is left to be injected into the vein. If the vein to be used is one difficult to enter, or if the injection must be made into a small vein, an ordinary hypodermic needle is satisfactory for the injection. Ordinarily a somewhat larger hypodermic needle—one of about 18 guage—is used. The most convenient needle is the Schreiber needle with a thumb guard.

The drug should be given with the patient lying down. The veins usually used are the large veins of the flexor aspect of the elbow, but when these are not available for any reason, other veins may be used. It has been suggested in difficult cases to make the injection into varicose veins when these are present. As varicose veins are already vulnerable, it would seem to be an unwise practice. The skin should be sterilized by washing with soap and water and painting with iodine. When the elbow is used the vein is distended by a tourniquet around the middle of the upper arm. The needle is pushed through the skin in the line of the vein either directly over it or to the side of it, and then is pushed into the vein. Entry into the vein is suggested by a feeling of entering a cavity, and is demonstrated by a free flow of blood from the needle. Immediately the vein is entered care should be taken not to push the needle further in order to avoid the danger of wounding or going through the wall of the vein. As soon as the needle is in the vein the tourniquet should be loosened. Only after the tourniquet is loosened, is the tube attached to the needle and the injection begun. The reservoir should be held about two feet above the level of the vein, and the rate of flow should be so regulated by its elevation that not less than five minutes is consumed in the administration of the dose. Before the last of the solution has flowed out of the tube the injection should be stopped by lowering the container below the level of the site of injection. This aspirates blood back through the needle, and prevents the leaving of an irritating drop of solution in the tissues upon the withdrawal of the needle.

Technic of Administration of Neo-arsphenamine.—Neo-arsphenamine is dissolved in water at slightly above body temperature, and the primary solution without neutralization is administered. Neo-arsphenamine is safely administered in concentrated solution; 15 c.c. to 25 c.c. of water is a safe dilution. This quantity is conveniently administered intravenously by means of an all-glass syringe of the Luer type. The injection should be made slowly, but because of the small quantity of solution is quickly completed.

Accidents in the Administration of Arsphenamine.—Injection of Air.—Injection of air in any quantity will result in air embolism. It is a distressing and dangerous accident which may be fatal. It is avoided by being sure, before the injection begins, that all air in the tube has been gotten out after the solution is poured into the reservoir.

Infiltration of Tissues.—Arsphenamine or neo-arsphenamine solution is irritating, and, if it escapes into the tissues outside the bloodvessels, produces inflammatory reaction. When it is going into the blood stream there is no pain. The occurrence of sharp discomfort at the site of injection is evidence that escape into the tissues is occurring. If this amounts to only a few drops it will cause a trivial reaction; but if a considerable amount of the solution is injected into the tissues, thrombosis of the vein will occur and a violent inflammatory induration will form. This may go on to sloughing with the occurrence of an ulcer, which heals very slowly. These accidents are extremely rare when proper care in the administration is observed. When such an accident occurs the lesion should be treated by complete rest of the part and application of hot fomentations until the active symptoms subside.

Reactions from Arsphenamine.—As a rule there are no symptoms following the administration of this drug. In rare instances, however, symptoms of poisoning occur. These vary from slight temporary distress to fatal poisoning in excessively rare cases. Some of these reactions can be accounted for by careless technic; by the use of water that is not freshly distilled and that contains dead organic matter; by excessive alkalinity of the solution; by too concentrated solution; by too rapid administration. Perhaps some of them, also, are due to hypersensitiveness of certain patients to the drug. But after all of these factors are eliminated there remain a considerable number which arise from the drug itself, probably from impurities due to defect in manufacture. Every once in a while a bad lot of arsphenamine is found, and when there is a severe reaction one should use other doses from the same lot of the preparation with very great caution.

The reactions can be divided into early and late, the early reactions occurring within a few hours after injection, and the late reactions from a day to three or four weeks after injection. The early reactions are characterized by symptoms of acute poisoning; the late by symptoms of organic disturbances that are the result of the slow action of poisons.

Early Reactions.—(1) *Nausea.*—The most frequent reaction is nausea and malaise occurring five to seven hours after the injection. This is usually accompanied by more or less vomiting, and there may be a chill and slight fever. These symptoms are much more likely to occur when the bowels have not been cleared out, or when the drug is taken with food in the stomach. These symptoms disappear in a few hours, and require no treatment. This slight disturbance is not a contra-indication to the further cautious use of the drug.

2. *Febrile Reaction.*—Occasionally a reaction occurs of the same sort as described above, but much more intense, with a sharp chill and temperature of 101° to 104° F., headache, pains in the legs and back, nausea, vomiting and diarrhea. In these reactions there is not infrequently also an accompanying urticaria or an erythematous eruption. The symptoms usually subside in one or two days. The patient should be kept in bed, given plenty of water, and put on a liquid diet until the reaction is past. The further use of arsphenamine in these cases should be cautious.

3. *Immediate Acute Reaction.—Nitroid Reaction.*—Occasionally an alarming, acute reaction immediately follows the administration of the drug. In such cases symptoms usually begin before the injection is completed. This is the so-called anaphylactoid reaction, but it probably has nothing whatever to do with anaphylaxis. A much better name which has been applied to it is nitroid, from the resemblance to nitroglycerine and other nitrogen-compound poisoning which its symptoms closely resemble. This immediate arsphenamine reaction is that of acute poisoning, producing intense congestion from vasomotor dilation. The patient suddenly shows symptoms of distress. Preliminary to this he may have a queer taste, such as a metallic taste, or one of garlic or ether. Congestion appears on the neck and spreads rapidly over the face. Congestion and swelling of the face become intense and edema of the glottis may occur, which, however, is not likely to be fatal. The pulse is rapid and weak. The respiration is labored, and the patient complains of tightness in the chest and precordial distress. The condition may become apparently very grave with failure of the pulse at the wrist, cyanosis, and syncope. Even the most severe of these cases usually quickly pass through the crisis and rapidly recover.

The treatment is the injection of epinephrin to counteract the vasomotor dilation. The effect of the injection of 1 c.c. of a 1 to 1000 solution is usually immediate. This may be repeated at intervals of fifteen to thirty minutes, as long as necessary to control the symptoms. As a precaution against this emergency there should always be present when arsphenamine is administered a hypodermic syringe containing 1 c.c. of this solution ready for immediate injection if necessary. Epinephrin solution is not immediately damaged by boiling, so that it may be sterilized by boiling if it is to be used promptly thereafter.

This reaction is a toxic reaction due in most cases either to decomposition of the arsphenamine or to impurities from its manufacture. At times it is perhaps due to personal idiosyncrasy. Its occurrence indicates the necessity for a careful checking up of the technic of administration and an examination into the quality of the product being used. It does not contra-indicate the further use of the drug in the patient, but its further use should be cautious.

Late Reactions.—(1) *Deterioration of Health.*—One of the best evidences that a patient is doing well on specific treatment for syphilis is the fact that his general health is improving, or at least not deteriorating. Occasionally under arsphenamine patients show a lowering of the general health without evidence of organic disturbance. Their vigor is diminished; they sleep badly; the appetite is poor; and they lose weight. Such cases need consideration. If these symptoms persist under the use of the drug it should be stopped temporarily. They should have abundant rest, liberal diet, tonics, and measures to improve elimination, Such cases are likely to be helped by iron and mercury.

2. *Exfoliative Dermatitis.*—Occasionally as a result of arsphenamine, patients develop exfoliative dermatitis. It begins usually as a faint, more or less extensive, scarlatiniform erythema. If the drug is not persisted in and the patient has had little of it, it disappears in a few days. It may begin twelve to twenty-four hours after administration, or several days later. If, in spite of the warning of such an eruption, the drug is continued, an intense universal exfoliative dermatitis is apt to develop. These eruptions are arsenical eruptions which occasionally follow the administration of other forms of arsenic. They are accompanied by more or less illness, and may or may not be accompanied by nephritis. They are serious complications, and the appearance of any erythema after the administration of arsphenamine is a warning to stop the drug.

3. *Albuminuria and Nephritis.*—A trace of albumin with a few casts is frequently found in the urine the morning after an injection of arsphenamine. This usually disappears in the course of a day. If it is transitory, and the casts are few, it is not a contra-indication to the further administration of the drug.

True nephritis may occur from arsphenamine. It is occasionally associated with exfoliative dermatitis, but more frequently without such association. It is a serious complication. It may permanently damage the kidneys, and be followed by all the sequelæ of severe nephritis. The occurrence of nephritis in the course of administration of arsphenamine is a complication which should stop the further administration of the drug, until the patient is entirely recovered, and then it should be given with great caution.

Syphilis at times itself causes nephritis. Such a nephritis is benefited by mercury, and perhaps would be by arsphenamine. The development of nephritis during the administration of arsphenamine and mercury is a strong indication that it is not a syphilitic nephritis, but one due to the drugs, probably to the arsphenamine.

4. *Jaundice and Hepatitis.*—The appearance of jaundice after a course of arsphenamine has occurred not infrequently in the experience of some expert syphilographers. Others report it as very rare. It develops late, usually two or three weeks after a course of treatment. The patients become jaundiced; are ill, but not alarmingly so; and often show enlargement of the liver. As a rule they recover completely in two or three weeks. The condition is due to a hepatitis of arsenical

origin, such as is known to occur from poisoning by arsenic in other forms. It is a complication that should cause the further use of arsphenamine to be very guarded.

5. *Hemorrhagic Encephalitis.*—Hemorrhagic encephalitis is one of the rarest, as it is, perhaps, the most serious accident from arsphenamine. The symptoms appear two to three or four days after administration. There is first severe headache, dulness, and mental confusion, which may be followed quickly by convulsions, coma, and death in the course of a few days. Some of the cases may not go on to the gravest symptoms, and recovery may take place; but the condition is a very grave one, and almost invariably fatal. It is apt to be complicated by nephritis and hepatitis. It is an arsenical poisoning. The case should be treated by stimulating elimination as fully as possible, including, perhaps, bleeding and intravenous administration of normal saline solution.

Complications after Arsphenamine not Due to the Drug Itself. Herxheimer Reaction.—The administration of arsphenamine causes a temporary engorgement and swelling of syphilitic lesions, presumably from the liberation of toxins caused by the destruction of the spirochetæ. With syphilitic lesions located in structures where swelling may cause impairment of function, this reaction may produce serious and even grave symptoms. These symptoms are most likely to arise from interference with brain functions by a Herxheimer reaction in meningeal lesions in early syphilis. The symptoms are those of acute brain pressure. There may be paralysis, confusion and dulness, or coma. Even in the apparently gravest cases recovery usually occurs. In late syphilis dangerous complications may be produced by this reaction occurring in syphilitic lesions of the viscera or of the circulatory system, particularly of the heart and the aorta.

The possibility of this reaction occurring in the brain in patients who have not been treated until they have florid secondary syphilis, should make one somewhat cautious in beginning its administration in these cases, especially if the patients have shown, by having syphilitic headache, that they have meningeal irritation. It can be guarded against by giving these patients mercury and iodides for one or two weeks before beginning arsphenamine, and by beginning the use of this drug with small doses, going up to the full dose at the second or third injection. The danger of this reaction is an indication also for caution in beginning the use of arsphenamine in late lesions of the viscera and the bloodvessels. Here it can be guarded against by a preliminary course of mercury and iodides.

Neurorecurrences.—Experience has definitely shown that so-called tertiary or late syphilitic lesions—gummata—are apt to occur earlier and more frequently than usual in patients who have been treated with arsphenamine in the early course of the disease, but short of cure. This is the greatest defect in this new addition to our therapy of syphilis. These early recurrent lesions of syphilis may develop in any tissue, but they have been most observed as recurrences in nervous tissue. They have been most frequent in the auditory and optic nerves. They produce partial or complete destruction of the tissue in which they occur, as do other gummata, and their symptoms are those arising from impairment of function of the involved structure. Partial or complete deafness, usually in one ear, has been most frequently observed. Blindness is very rare.

These neurorecurrences and other early recurrences are not due to arsenic or arsphenamine poisoning. They are syphilitic lesions and they demand for their treatment vigorous use of arsphenamine along with the iodides and mercury.

In the early days of arsphenamine blindness from arsenical neuroretinitis, as it occurs from some of the other synthetic arsenic salts, was greatly feared. This has not proved to be one of its real dangers.

LATE SYPHILIS.

Syphilis passes through its course as a systemic disease in a relatively short time. After the first few months it is usually localized, and after a year or two it comes definitely to be a disease localized in certain structures. Various structures may be involved, and many or few. It is most likely in its late course to affect the skin, the bones, the nervous system, and the vascular system. Its presence often produces no symptoms. When localized in the skin or bones it produces characteristic clinical pictures. In the skin the lesions are so characteristic that they are unmistakable to the expert. In the nervous system tabes and paresis are characteristic syphilitic diseases. These syphilitic involvements of the nervous system show symptoms dependent upon the structures whose function is impaired or destroyed. Aortic aneurysm is a characteristic syphilitic affection of the vascular system. Syphilis of the liver is one of its common visceral manifestations. Late syphilis indeed may affect any structure and tissue, producing symptoms or not according to its extent and the structure affected.

When situated in obscure locations no characteristic symptoms occur. There may be symptoms of an infection or symptoms of impairment of structure or of function in the affected tissue. In these obscure cases of late syphilis reliance must be partly upon the Wassermann, but by no means upon it alone, for the Wassermann may be negative in such cases. It thus becomes highly important to search out all facts which may throw any light upon the previous syphilis. Although the Wassermann may be negative in these cases it is positive in 80 per cent. of them. This makes the taking of a Wassermann a procedure which should be routine in obscure cases that may by any possibility be syphilitic, and requires that Wassermanns should be made repeatedly, when negative, in cases in which there is good ground to suspect syphilis.

Treatment.—The treatment of the late lesions of syphilis is carried out by the use of mercury, the iodides, and arsphenamine in the manner already outlined. One course of the sort already recommended is usually sufficient to remove any gummatous lesions. Indeed the use of mercury and iodide of potassium, without arsphenamine, will usually remove such lesions readily.

In these late cases the use of potassium iodide is of the highest importance. For lesions outside the nervous system it does not seem to be very important whether the dose is large or small. Small doses of iodides, say 10 grains, three times a day, will cure gummatous lesions in the skin with all the promptness of large doses. In syphilitic lesions of the nervous system, however, large doses of the iodides are necessary—up to an ounce or more daily. A method of giving the iodides without difficulty is their administration in large quantities of water. A moderate dose should be administered in 14 to 16 ounces of water to be taken after eating. When very large doses are given, they should be dissolved in as much water as the patient can drink in twenty-four hours, and taken as he drinks water.

In certain structures, notably in the central nervous system and the vascular system, syphilis produces at times a diffuse sclerosis. This produces the late lesions of syphilis which cannot be effectually reached by treatment. When their manifestations become apparent they have already produced impairment of structure which cannot be removed, even if the infiltration itself can be removed. But unfortunately it is excessively difficult to affect by treatment these sclerotic infiltrations of syphilis. Their treatment should be by the most vigorous use of mercury, iodides, and arsphenamine. Arsphenamine has proved a useful addition to our means of attack upon these manifestations of syphilis.

The results of treatment in tabes and paresis, as well as the methods, are *sub judice.* Definite, regular benefit in these cases cannot be promised. There are enthusiastic advocates of intraspinous administration of arsphenamine by various special technics in these cases. The intraspinous administration of arsphenamine, even in the hands of those expert in the technic of its administration, is not free from deplorable accidents arising from injury to the cord, and this method of administration should only be undertaken by men trained in it. Another method of trying to get arsphenamine into the cerebrospinal fluid is first to give an intravenous injection of arsphenamine, and then within a few hours to withdraw by spinal puncture a safe quantity of spinal fluid (20 c.c. to 30 c.c.), with the expectation that in the restoration of this spinal fluid from the blood, carrying arsphenamine at the time, a certain amount of arsphenamine will be carried into the cerebrospinal fluid.

ESTIMATING THE EFFECTS OF TREATMENT ON SYPHILIS.

In estimating the effect of treatment on syphilis, weight should be given more to the effect upon the general health and upon the symptoms of the disease than to the effect upon the Wassermann reaction. Patients with early syphilis who are run down by the disease rapidly improve in general health under proper specific treatment. They gain in weight and increase in vigor; their sense of well-being improves. If these things do not happen, careful survey should be made of the patient, and the treatment checked up likewise. It is unfortunately true that many patients do not get along so fortunately under the intensive methods of treatment now in vogue, and, when they do not, there is reason to challenge the method of treatment. The patient's inherent capacity to resist syphilis has been shown by long experience to be capable of controlling the disease to a greater or less degree—to a very great degree in many cases—and it is not safe to undermine this by pushing specific treatment to the point of unfavorably affecting the general health.

How much weight is to be attached to the Wassermann reaction, as a guide to the effect of treatment on syphilis, is a question which is not as definitely settled as we are in the habit of assuming. It is desirable that the Wassermann reaction should become negative, as it is that all other symptoms of syphilis should disappear; but the mere fact that the Wassermann is negative is no more evidence that the disease is cured than the fact that the patient is otherwise free from symptoms of syphilis. All pertinent factors of the disease, and of the patient's general health should be taken into account in estimating the effects of any given course of treatment.

In syphilis gotten for treatment before the Wassermann becomes positive the persistence of a repeated negative Wassermann is the all-important evidence of cure. In these cases the Wassermann should be repeated at intervals of a month or two for at least a year.

In patients with early syphilis with a positive Wassermann, the Wassermann should be repeated from month to month, and efforts should be made to maintain a negative Wassermann.

In late syphilis there is strong room for doubt whether anything is gained by undertaking to get a permanently negative Wassermann. It is very doubtful if this can be done. In the attempt there is danger of damage to the patient, and, were it possible to make the Wassermann negative, we would be in no position to say, even then, that the patient was definitely freed from further danger of syphilis.

Spinal puncture, and findings, negative for syphilis, in the spinal fluid are advocated by many as a prerequisite for discharge from treatment for syphilis. A provocative injection of arsphenamine with a subsequent Wassermann is also commonly advocated. There is room for discretion in deciding as to a final spinal puncture in these cases. And there is good ground for believing that the so-called provocative injection of arsphenamine is of no influence in provoking a positive Wassermann in latent cases, and that it has some dangers.

DETERMINATION OF CURE OF SYPHILIS.

The wonderful additions to our knowledge of syphilis during the last few years have, unfortunately, not enabled us to dogmatize upon the evidence of cure of syphilis. If syphilis is treated before the Wassermann becomes positive, and if repeated examinations during the course of the ensuing year always give negative Wassermanns, it is a fair assumption that such patients have been cured of the disease. In patients in whom treatment is begun after the disease becomes systemic, the answer is much more difficult. Such patients may become Wassermann negative and symptom-free after the first few months of treatment. That many such patients have been cured has been shown by the repeated reinfection of the persons who have gone through this experience. On the other hand, enough of these patients revert subsequently to positive, and have recurrence of the symptoms of syphilis to indicate that a great many of them are not cured. In the face of such situations the only safe course to pursue seems to be that taught us by our old experience with syphilis; and that has borne in upon us the fact that these patients should be treated for at least three years with mercury. Periodic treatment with mercury can be extended over this long time without damage to the patient, and it is a safe course to pursue.

THE PREVENTION OF SYPHILIS.

Before concluding the subject of the treatment of syphilis a word should be said on the subject of its prevention. Metchnikoff and Roux's experiments established that a 33 per cent. calomel ointment, which they suggested, provided an efficient means of preventing syphilis after exposure to infection. An extensive experience, notably the experience of the American army, has confirmed its effectiveness. The original ointment recommended by Metchnikoff and Roux was calomel, 33; vaseline, 10; anhydrous lanolin, 57. The ointment used by the American army, which has demonstrated in practice its efficacy, is as follows: Calomel, 30 parts; benzoinated lard, 65 parts; white wax, 5 parts. After exposure to syphilis the exposed area should be thoroughly rubbed with this ointment, using it, if the exposure has been a genital one, over the penis, scrotum, and adjacent skin, and rubbing it with particular care into the folds and fissures. The inunction of the ointment should be continued for ten minutes. After this the parts should be covered with oil silk or wax paper for several hours before washing. The earlier the treatment is applied the more likely it is to be effective. It is usually effective up to eight hours, but after eight hours its efficacy rapidly diminishes.

This method of prophylaxis of syphilis is especially applicable to the prevention of hand infections in those exposed to syphilis in the care of cases, and its use should never be overlooked after dangerous professional contact with such cases.

THE DIAGNOSIS AND TREATMENT OF CHANCROID (SOFT CHANCRE).

By WILLIAM ALLEN PUSEY, A.M., M.D.

Diagnosis.—The diagnosis of chancroid, unlike that of chancre, is made upon the clinical findings. Its characteristics, as distinguished from the chancre, may be summarized briefly as follows:

The chancroid has a short incubation period, from twelve to thirty-six hours, like other acute purulent infections. It quickly develops into an ulcer, with a granulating floor covered by a necrotic pellicle, with undermined irregular border, and with a definite tendency to spread. The base has the soft infiltration of an acute inflammatory process. There is a free purulent discharge and the pus is auto-inoculable; multiple chancroids, therefore, are common. It is more or less painful, and after a few days, painful unilateral adenitis of adjacent glands often develops.

It is thus easy on the clinical symptoms alone to differentiate the chancroid from the chancre. But when the diagnosis of chancroid is made nothing has been done toward excluding an accompanying syphilitic infection, for it is never possible to say that a chancroid is not masking a primary infection with syphilis. For this reason one should never rest content with a diagnosis of chancroid, but should spare no effort to discover if syphilis also is present in the case. The necessity of examining for the Spirochetæ pallidæ and of repeated Wassermanns has been emphasized in considering the diagnosis of chancre. In searching for the Spirochetæ pallidæ in chancroids the ulcer should be thoroughly cleaned of pus and debris by washing with normal saline solution or water, and wiped dry with dry gauze or cotton. Serum then should be collected and examined in the usual way. A positive decision that syphilis is not present should not be made until negative Wassermanns, repeated weekly, have been made for two months.

Both chancroid and chancre may be confused with ulcerating gumma, and with epithelioma of the penis. These are both sluggish, comparatively painless lesions without inflammatory involvement of the adjacent glands. With gumma the patients are usually Wassermann positive, and the lesion heals under specific treatment. With epithelioma a microscopical examination will establish the diagnosis.

Treatment.—*General Treatment.*—Chancroid is a disease for the most part of the dirty, and extensive chancroids rarely occur except in those of lowered resistance. In these cases attention should be paid to the general condition of the patient. Such cases do best with rest, preferably in bed, and, if the patients are not vigorous, under a full nourishing diet.

Local Treatment.—No local treatment beyond simple cleansing should be undertaken in chancroid until the search for Spirocheta pallida has been ended.

Chancroid is not self-limiting and is apt to be long drawn out. For that reason the attempt is frequently made under favorable conditions to abort it. The principle of all methods of abortive treatment is to destroy the infection by complete cauterization, and thus convert the lesion into an aseptic wound, or one at most infected with common pus organisms. The best method of cauterization of the chancroid is with the thermocautery. The dried ulcer is completely seared under general or local anesthesia with the cautery at red heat. The usual method of chemical cauterization is as follows: The ulcer is cleaned by irrigation, and then thoroughly dried. It is anesthetized by the application of a pledget of cotton wet with 5 per cent. to 10 per cent. solution of cocaine hydrochlorate or procaine. The ulcer is then carefully dried with blotting paper. After this, liquid phenol is applied over the entire surface by means of a cotton swab, and the surface again dried; then nitric acid is lightly applied in the same way. Immediately after the application of the nitric acid the ulcer is flushed with water in order to stop the acid's action. The success of either of these methods of cauterization depends upon completeness. The base, the edges, every recess of infection must be destroyed by the caustic, otherwise reinfection immediately takes place. After either method of cauterization the wound should be dressed with bland wet dressings.

This method of treatment is only applicable to selected cases. It should not be used with extensive chancroids, or chancroids in situations, such as the frenum or meatus, where the procedure would cause deforming scars. It is not suitable for lesions with which adenitis already exists, and it is not indicated in chancroids which are already undergoing involution. It should of course never be done until the search for spirochetæ has been completed.

The palliative method of treating chancroids is by the use of measures to keep the lesions clean, to reduce inflammation, and to overcome infection. The most important indication is to keep the lesions free from pus, both to promote healing of the lesion itself and to prevent adenitis. Perhaps the most useful measure is the frequent immersion of the penis in hot water, both for its cleansing and its thermal effect. The penis should be held in hot water for half an hour or more at least three or four times daily. If this cannot be done, the lesion should have copious irrigations with a mild antiseptic solution, such as mercuric chloride, 1 to 10,000, or potassium permanganate, 1 to 3000. After the immersion or irrigation, the ulcer should be dusted with an antiseptic powder, such as iodoform, argyrol crystals, or thymol iodide. Iodoform and argyrol are the best powders. After dusting, the lesions should be dressed with a dressing wet with one of the solutions suggested above. This should be covered by an impervious protection to prevent its drying out. If a wet dressing cannot be applied, the next best procedure is to cover the ulcer after the application of the powder with a gauze dressing freely greased with vaseline. Dry powders alone are objectionable dressings for chancroids because they cake and prevent the escape of pus, and thus increase the danger of lymphangitis and bubo.

When chancroid occurs under a swollen or long prepuce it should be treated by prolonged soaking in the way suggested above, and by careful irrigating of the preputial sac with a long-tipped syringe or through a soft catheter. After this the sac should be irrigated with 10 per cent. argyrol solution or there should be injected a 10 per cent. suspension of iodoform or thymol iodide in glycerine or oil. Even a dorsal slit should not be made in these cases, unless phimosis, danger of sloughing of the prepuce, or some similar complication makes it imperative. No attempt at a clean circumcision should be made, until the infection has entirely disappeared; otherwise the entire area of operation will become infected.

BUBO.

The factors that tend to the prevention of bubo are rest and the prevention of the accumulation of pus in the chancroid. When beginning evidence of bubo appears the efforts to keep the chancroid clean should be increased. The dressings should be changed more frequently and the fact seen to that neither pus crusts nor pus is allowed to accumulate on the ulcer. The patient should have rest in bed and have hot applications made to the bubo. If fluctuation develops the hot applications should be continued until the infected mass is entirely broken down. When a soft fluctuating abscess has developed it should be opened with a short incision, and the pus evacuated. The cavity should then be injected with a 10 per cent. suspension of iodoform in glycerine or oil. Morton recommends that this iodoform suspension should be injected three times; the first two pressed out, and the third left in the cavity. The wound should be dressed with a wet compress. The same treatment should be repeated the next day. After the second treatment, however, if no symptoms of the retention of pus are present, the dressing may be allowed to remain for five or six days, when healing often will be found to have occurred. If, after a week, healing has not occurred, the treatment should be repeated.

In a less fortunate group of cases complete rapid breaking down of the gland, such as outlined above, does not occur; instead the affected mass becomes riddled with suppurating pockets and channels. In these cases free incision is required, after which the necrotic tissue is curetted out and the wound allowed to heal by granulation. If this method of treatment is necessary the cases usually recover only after several weeks.

Formerly it was a common practice, in order to get prompt cure of these cases, to make a clean exsection of early buboes. This practice should not be carried out, because it often fails through reinfection, but more important still, because the destruction of the lymphatics in the area operated upon occasionally results in the development of elephantiasis of the penis and scrotum and inguinal region.

HOSPITAL CONSTRUCTION.

By MEYER J. STURM, B.S.

THE CONSTRUCTION OF SURGICAL HOSPITALS.

An efficient hospital is so absolutely necessary for the carrying on of efficient surgical work that the surgeon himself should carefully study the important features of hospital planning.

It is for this reason that the following section has been introduced.

An efficient hospital reduces the wear and tear and the waste of time of the surgeon. It increases the comforts of the patient and it means an important economy for the community.

Herbert Spencer says, "The wise man must remember that while he is a descendant of the past, he is a parent of the future, and that his thoughts are as children born to him, which he may not carelessly let die." This has become an axiom in the building of hospitals, as it has in practically every human endeavor, but despite this, even today we find hospitals being built as ultimate units and with no thought or preparation for the future. In this country it may be stated, as an almost universal rule, that no hospital should be so planned that does not carry in its conception the right of growth or expansion.

Towns and cities and even villages, especially in our new land, grow with astounding rapidity, and fortunately this is a healthful and logical growth with very rare retrogression in such communities. If, as has been stated by many authorities on the subject, through the fact that there has been an educational propaganda in the hospital field making the hospital a blessed necessity instead of a necessary evil, that the present requirement is one hospital bed to every one hundred of inhabitants, this end is to be not only sought but to be demanded. With our logically increasing population, this would mean that as an average, every three years to three and one-half years every hospital that was fulfilling this requirement at the time it was built, would have to be doubled in its capacity. Necessarily, there is a limit to such expansion, at which time new institutions must come into existence. There should be, however, a minimum of competition in the hospital field in order that the cost of administration and operation may be minimized, it being obvious that one hospital of a legitimate and operable size could be administered very much more economically than two hospitals each of half the size.

The question of cost is one of the most important elements to be considered in this as in every other modern enterprise. No policy aside from the actual service of the hospital should ever actuate the building of such institutions. Hospitals should be built for service and for efficiency to obtain the maximum results for those who need them, always at a minimum cost for the greatest efficiency, but never for mediocre efficiency in order to secure a very low cost. No more should be built at one time than can be afforded, so that all such building may be consistent with given principles. There should be no attempt to obtain service and efficiency and at the same time subserve these to size, capacity, inconsistent cost, or mere policy, and above all, hospitals should be built for the patient.

The tendency in modern hospital planning should be toward privacy for the patient, and more privileges for and visits from friends, and a fee charged in proportion to such service. The trend should be to provide such service, to make the ward unit smaller and smaller consistent with the service to be rendered, and to get as near as possible to the ideal condition, a private room for each patient. Necessarily, such a program has its limitations at the present time, inasmuch as there are those who could not pay for such service. However, it is most urgently brought to the attention of those who are to build hospitals, that thorough consideration be given to the classes of patients with which these institutions must deal.

There are three classes of these patients to be taken into consideration: the poor, the middle class, and the very wealthy. With our present system it is necessary to put the first class into wards where the service to be rendered can be given at a minimum of cost to the hospital, with maximum service to the patient. Although this service is not ideal it is infinitely better than these patients could possibly obtain in their homes. Of the third class little mention need be made at this time, inasmuch as that class can purchase the facilities which are most to their liking, and which service is given the necessary consideration at least to a marked degree in our hospitals in the larger cities, although in many instances these patients are still being accommodated in poorly equipped nursing homes under the impression that the privacy obtained in this manner outweighs the advantage of being cared for in public hospitals which contain all modern facilities.

It is the majority, the so-called middle class, which must primarily be taken into consideration in the planning of new hospitals. Given the alternative of going into a large ward at a minimum cost per day, or going into a smaller ward at a somewhat increased cost, or even into a room with two or three beds at a still more advanced cost, the natural tendency of the majority of patients is invariably to choose, all things being equal, the room or ward in which there is the least number of patients, and the greatest privacy. There is practically no difference in the cost of maintenance of a hospital in which wards contain not more than six or eight beds, and institutions containing larger wards. The main difference, however, is in the enormously increased comfort of the patient in the hospital having the smaller wards. In order to approximate as closely as possible the ideal condition, four beds should constitute a ward. Repeated stress has been laid on the flexibility of hospitals with small wards, but it might be well again to call attention to the fact that a preponderance of one sex over the other in the hospital having the large wards, has resulted in a great loss in revenue and efficiency. Manifestly, in the latter men and women could not be put into the same ward, but there would be no method of alleviating this condition if there was a preponderance of one sex over the other in the number of patients to be admitted. The subject of quietness and better selection and segregation of patients in the small ward has been given very serious attention and need be given no further thought here other than to call attention to it.

The problem of the cost of hospitals when divided into smaller spaces, designated largely as private rooms, necessarily arises at all times. The basic principle, however, of hospital efficiency is not so much in the space required for the housing of patients as in that portion of the institution which is given up to, and necessarily is part of, what is known as the administrative departments. Unless these departments are properly planned and placed, no institution can work at its maximum efficiency with a minimum cost of maintenance. Any hospital can be maintained with a deficit or with large endowments to make up any losses through the fact that they cannot be maintained at the minimum cost, but the ideal hospital is the one which is self-maintaining in every respect.

In all probability the best manner of calling attention to the lack of requirements of such administrative departments would be to ask and honestly answer the question, how many, if any, patients leave our hospitals without memories of cold and unsatisfactory food, sleepless nights made hideous by delirious patients, crying babies, noisy employees, and a general absence of the little niceties and comforts which it has been impossible to accept or demand from tired or overworked nurses? No remedy can be forthcoming without first determining the cause. Every one seems to shift the responsibility. The architect, if he is not an expert hospital designer, says that these are purely faults of administration and management, with which he is not concerned. The superintendent says: "We cannot help that the food is cold; we have no proper means of getting it expeditiously to the diet kitchens; the diet kitchens are so small and so badly located that we can only have a few trays served at a time, and the food spoils; in the meantime the hospital is a bedlam, because there is so much confusion in the carrying out of the ordinary work in the hospital; our service department is not properly planned and cannot be properly equipped; the elevators are so placed that whenever a door is opened or closed, every one in the hospital is aroused." In other words, the hospital is not built for efficiency and quietness.

The nurses say: "We know the food is cold and unsatisfactory, but we do not have the proper facilities for serving it otherwise; we know there is confusion and noise, but what can we do about it; the diet kitchens are next to the wards and are not soundproof or conveniently located, and the night is made hideous by the cracking of ice for icecaps because our refrigerators are not provided with compartments for ice that should come crushed to the diet kitchens; our patients are kept awake because of the lighting system which makes it impossible to keep the remainder of the ward dark when treatment is going on in any one place; there is no isolation or soundproof room in which to put our delirious patients, or those recovering from anesthesia, or where we can place the moribund patients; we cannot give the attention we should because of inconvenience; our long wards mean miles of steps to accomplish the most trivial of results; it is the wrong expenditure of energy; our call system is poor; we do not know half the time what patient has called because no thought has been given to the proper installation of a call system."

While these statements are essentially true, a short analysis might be given of them. First, if the patient leaves the hospital with all these hideous memories, it is probably due to the fact that the hospital has not been properly planned to minimize drudgery or to make proper provision for the work to be done by the nurses. The man who is planning your hospital should be so well versed in the requirements of a hospital, both in its plan and its operation, that he should be able to give to you a 100 per cent. efficient machine in all departments.

Primarily, there are two reasons why so many hospitals are built without the essential factors: (1) Ignorance ordinarily on the part of those who are planning them of the real requirements, not to mention the nice little essentials which go to make up the perfect institution; (2) The lack of consideration of the vital fact that there are two ways in which a hospital problem, or rather the construction of a hospital, can be solved; namely, that if there is an allotted sum of money to be expended, that either a complete hospital should be built commensurate with the means, providing for the maximum number of patients which can be gotten for this amount of money, without the omission of the necessary factors which go to make up such an institution, or to provide the means and build a hospital adequate for the number of patients that it is desired to put into the institution, with all of the necessary requirements included, as stated.

There is little need in a work of this kind, to go into the educational value and necessity for different types of hospitals. There is presented herewith the plans of a hospital which fulfills all of the requirements of a modern institution, for practically a universal service, which contains the facilities desired by most practical surgeons. This institution was erected at a minimum cost. What was particularly evident, however, to the builders of this hospital, was the fact that all provision should be made for its future expansion, in accordance with the principles laid down in the beginning of this chapter.

All of the piping system, electric system, and even the foundations for future wings, where these must necessarily come in contact with or be attached to the present building, were provided when this building was erected so as not to disturb the present building. Despite the addition of these elements with a separate power-house and laundry, with provisions for future expansion, this institution was erected in 1917 during a period of financial depression and of stress probably unheard of before, within the allotted appropriation. We

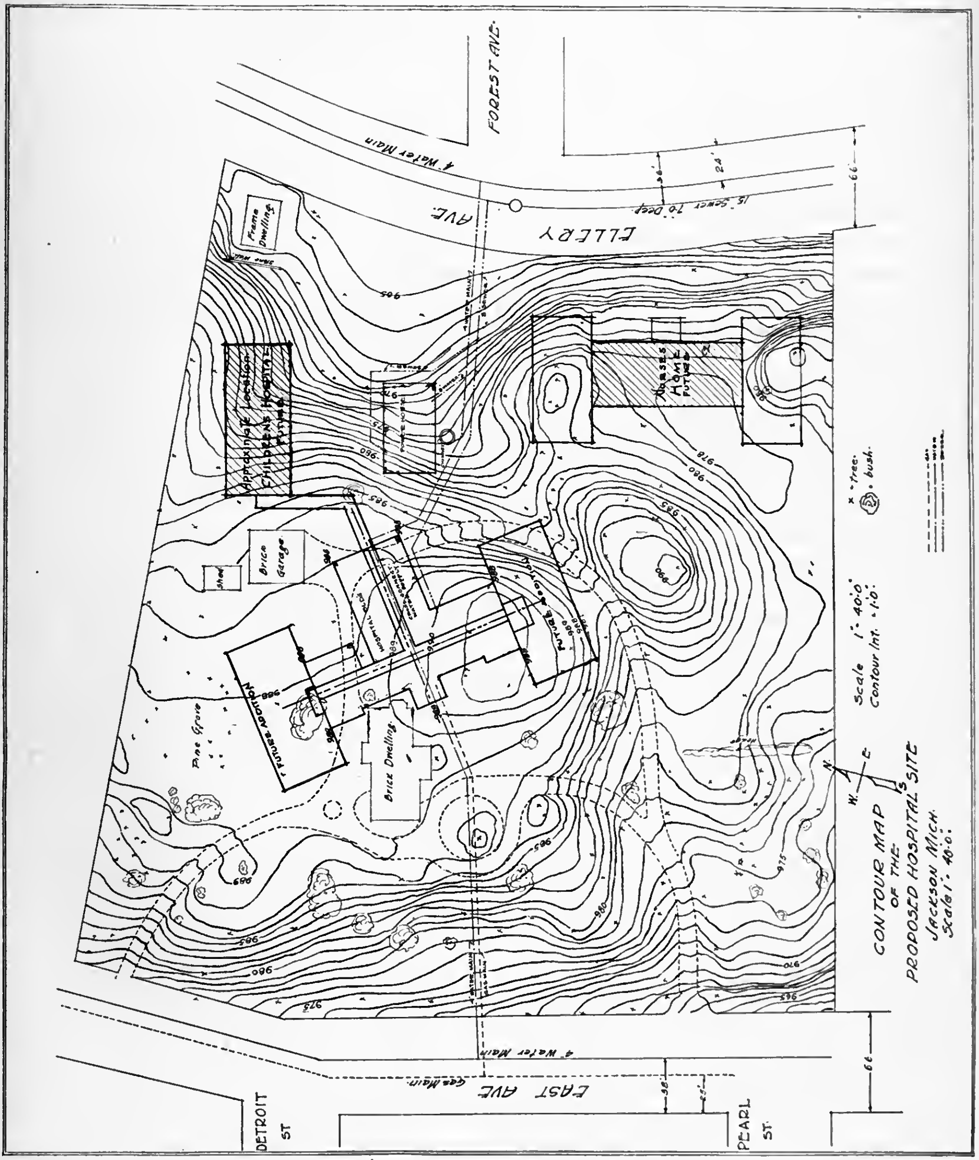


FIG. 562

had been drawn into the world war, and the matter of obtaining labor and material was at its most hazardous period. Despite these handicaps, however, this institution is complete in every detail for the maintenance and care of slightly over one hundred patients, at a cost—

with furnishings and complete equipment included—of approximately \$250,000. This does not include the cost of the grounds. Being a city hospital, there were provided many departments that would not be found in any ordinary hospital, inasmuch as all of the emergency work and outpatient work for the city, including a highly developed and comprehensive social service, must be done in this building.

A description therefore of the plans presented herewith will materially assist in an understanding of what is meant by an efficient hospital. Attention is directed especially to the absolute simplicity with which this hospital has been planned, the main object being to give maximum accommodations to the patients, to bring about at the same time a minimum of maintenance charge, and to create an efficiency throughout that is as high as could be obtained under any conditions.

It might be well here also to state that the site on which this hospital is erected is adequately large for all of the additions and any future expansions which might be made in the institution, including the nurses' home and a contagious disease hospital. The plat plan shows the future additions. Too much stress cannot be laid on the point that sites sufficiently large should be provided so that a comprehensive study can be made for future additions as they will be required. Ultimate capacity for generations to come should actuate the acquirement of such sites.

There is a decided line of demarcation between what is essential and what becomes extravagance in the designing of the exterior and the decoration and beautifying of the interior of a hospital. The hideous exteriors of many hospitals constructed in this country, are as inexcusable as the many prison-like effects obtained in the interiors, especially in rooms and wards. It costs no more to give the hospital a presentable appearance than it does to make it forbidding and inartistic. This applies as well to the interior as to the exterior. It is not necessary to expend money on lavish display, nor should this be tolerated. On the other hand, however, there is a moral obligation to make our hospitals inviting and homelike. There is no more extenuation for the perpetuation of bad taste and inartistic effect, either in over-ornamentation or ugly plainness in our hospitals, than there would be in our homes or hotels. Simply because in a measure an extraordinary service is rendered in the hospital, there is no necessity for sacrificing practical ideals.

Architecture and decoration are secondary, however, compared to the necessity for the builders of hospitals to keep in mind what may be termed the applied arts. Not mural decorations, but a perfect working plumbing system, a perfect working and quiet heating system, and a perfect working and economical electric system with their multitude of devices, fixtures and apparatus are demanded. All of these must be thoroughly understood by the architect that he may give to the hospital in all of their essentials, these systems. This does not necessarily imply that there is anything extraordinary about the mechanical and sanitary systems of such a building, but that the installation and the proper location of such plumbing, heating, and electric work, and the proper facilities for the introduction of everything that is dependent upon these, is vital. As an instance, we may emphasize the apparatus for sterilizing and cooking. The architect should know what is required for each and every piece of apparatus that will be installed, and should graphically show each and every piece of equipment and apparatus with its proper fittings and connections.

The requirements for the kitchen, laundry, storerooms and specialized departments throughout the hospital must be given the attention which they warrant, and which are so necessary to the smooth running of the entire machine. The artistic ability which may be expended on the exterior of a building, or on its interior decoration, goes for naught if the interior is not arranged with the dominant idea that the component part of the hospital must make up a perfect whole. When a machine is built with all of its thousands of parts, and is put into proper position, the machine is capable of doing any amount of work smoothly and with a minimum of friction, merely with the turning of a valve, and in similar manner the hospital should function perfectly.

The matter of the standardization of hospitals has become so important that it has been taken up by many of the organizations identified with hospitals, but a word here may not come amiss. Wherever it is possible to do so, standardized equipment of every character should be used. Special features are costly and are experiments at best. Because some institution has had some special fixture or equipment made for its own particular use to fulfil a hobby, is no reason why some standard fixture of a like character would not fulfil all of the requirements of any hospital, all other things being equal. When repairs or replacements are required, the wisdom of using standard equipment is quickly realized.

Particular care should be exercised in the selection of sites for the hospital so that buildings which are placed upon such sites can be given the proper consideration as to their orientation. In the description of the plan given herewith, a great deal of thought has been given to the maximum amount of sunlight for each and every room and space in the hospital. It will be noted that the buildings are placed somewhat off the direct north and south line, in such manner that even buildings running to some extent in an easterly and westerly direction will get their quota of sunlight for the maximum time each day in the year.

In a description of the plans, it must be stated that for a hospital of this capacity, it is not necessary that it should be planned in the particular form in which this hospital is shown, namely with the T wing extending from the central portion. However, it might be said, in recommendation of such a plan, that it is possible to centralize the administrative department in such manner as to minimize travel to and from any given department. It also has the very manifest advantage of departmental isolation, and still have such departments in working proximity to the administrative department on each floor.

Fig. 563.—Jackson City Hospital, March 22, 1918.

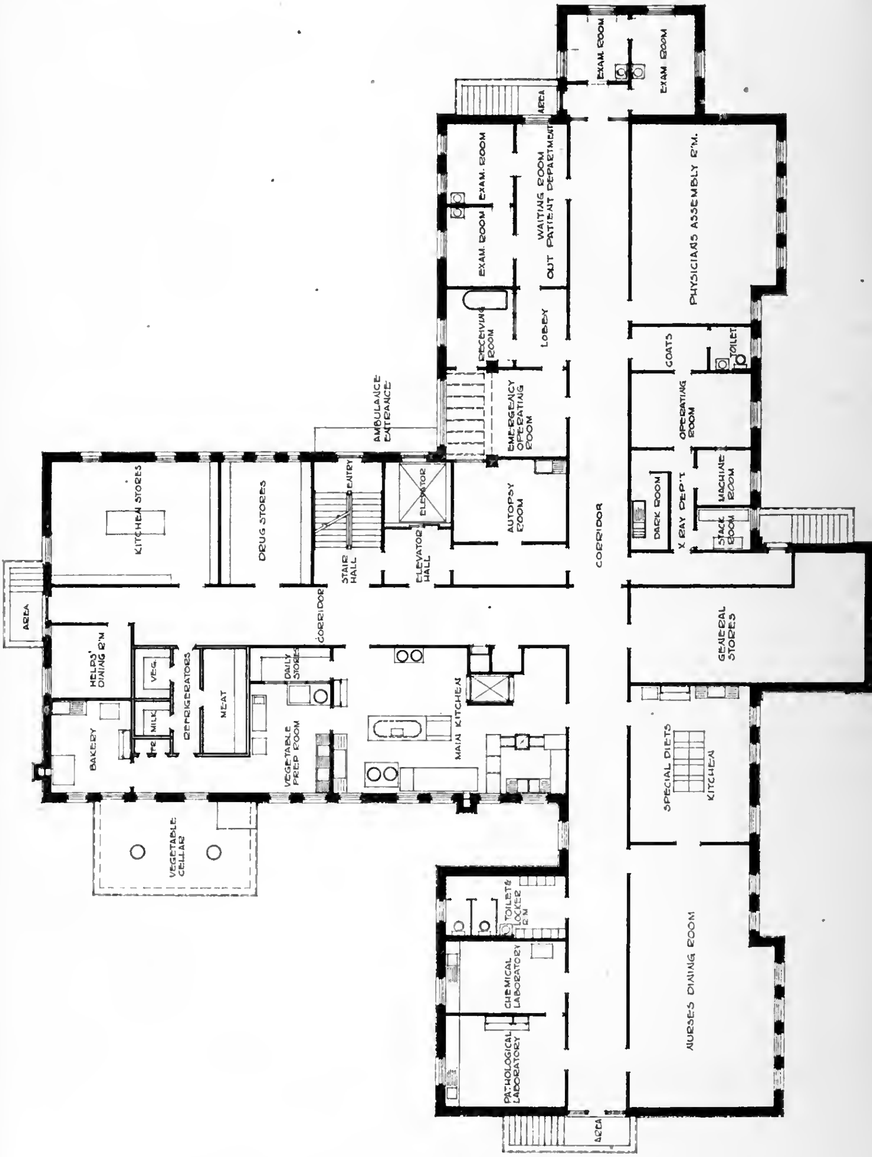
The basement plan in simple form shows the departmental separation of the kitchen from the remainder of the plan. As should be provided for in an institution of this character, the vegetable preparation room and bakery are separated from the main kitchen. It might be well to emphasize the fact that the kitchen department with its storerooms, should be spacious so that the maximum of work can be done with the least noise and friction, and the greatest convenience. All peeling of vegetables and preparation of food should be done in the preparation room for this purpose, and all baking should be done in a separate bakery room. All of the actual cooking, aside from the steaming of vegetables which should be done in the vegetable preparation room, should be done in the kitchen proper. This kitchen should be connected directly, or through a serving room, with the dumb-waiter which goes to all of the diet kitchens on the floors above. A glance at these plans will show the compactness of such a department, and still the spaciousness of it for the ordinary needs of an institution of this size, and to its capacity up to four or five times the size, without having the department too large for present use.

At the right in the basement, with access from the outside, is shown the outpatient department, which department is to be greatly extended when the next wing is added to the institution for its enlargement. The main pathological and chemical laboratories are at the left, and at this side also there is the nurses' dining-room and special diet kitchens, which at the same time serves as a school for dietetics for nurses in training, and also as serving room for the nurses' dining-room. At the right is a physicians' assembly room, which is used in this instance as the meeting place for the local medical society.

On the first floor there is an entrance lobby, to the right of which is the main office in very much the same arrangement that one would find in a first-class hotel. There is a small room at the left of this lobby, which is a parlor or waiting room. Particular attention is called to the fact that visitors and those having business with the hospital, do not have access to the main corridor of the hospital unless they are so directed. At no time does the public come in contact with the working force, except when patients' friends are calling. Adequate stair and elevator service, conveniently located, quickly dispose of visitors by conveying them to the respective floors.

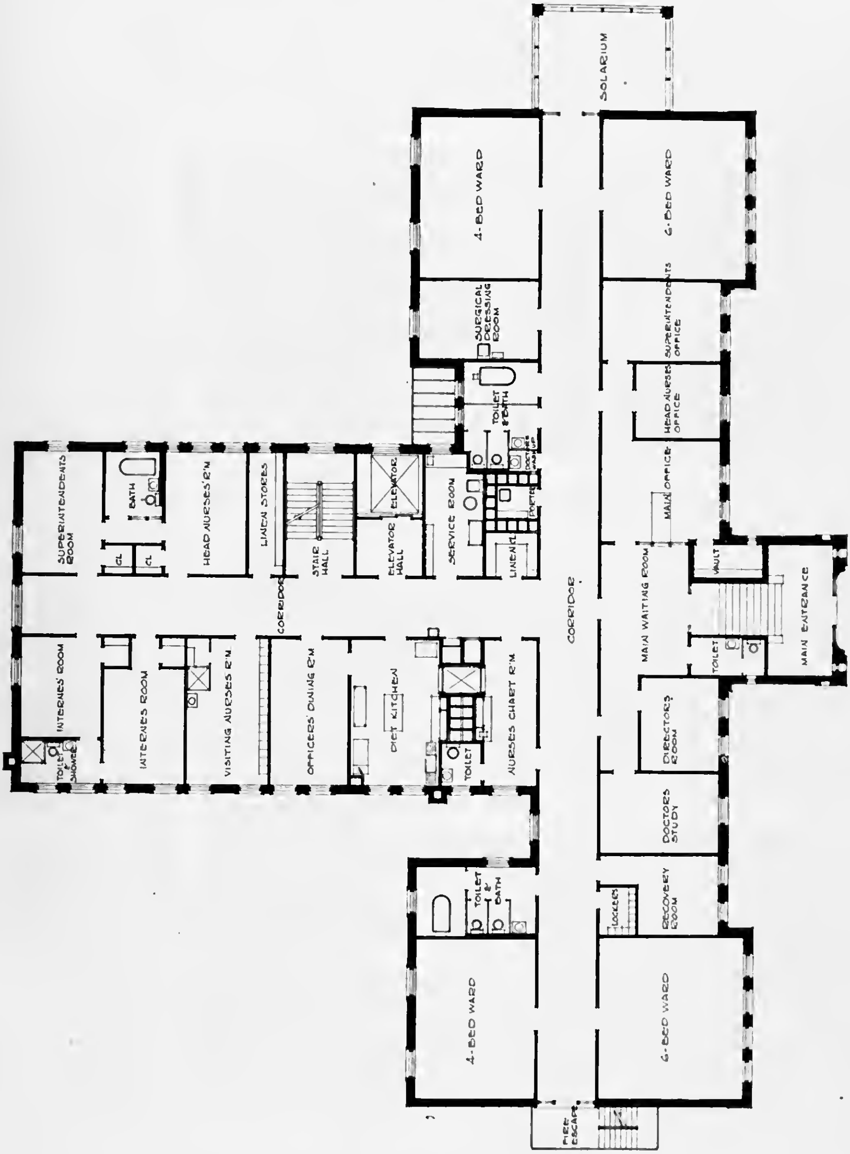
On this and on subsequent floors, attention is called to the centralized administrative department, so that there is, as stated, a minimum of travel either to the left or to the right wing, or to the special departments for a given service. At the most centrally located point is the nurses' chart room with its individual toilet for the nurses. Adjacent to this chart room is the diet kitchen, these two rooms being connected with all other departments by the dumb-waiter which is common to both. The manner of ventilating these two rooms is shown directly back of the dumb-waiter. On the opposite side of the corridor, but still at this central location, is the linen room, the porter's closet, and the service room, and on each floor at this central location is a small doctor's wash-up room. The rear portion of this first floor is given up to administrative living quarters.

It might be well to call attention at this point to the fact that each floor of this hospital is absolutely isolated from every other floor, so that within itself it is a complete unit cut off from the noises and odors from every other floor, and while the hospital, as constructed, is practically fireproof, still any incipient fires which might arise from any floor, would not create any disturbance on any other floor for this reason.



BASEMENT FLOOR PLAN
FIG. 564

One of the most difficult problems to be solved in a hospital is the noise of opening and closing elevator doors and of the shuffling of feet going up and down stairs. A cut-off is put in front of the elevator and also in front of the stairs. This not only makes a practical fireproof stairway from top to bottom, but does away with the possibility of the



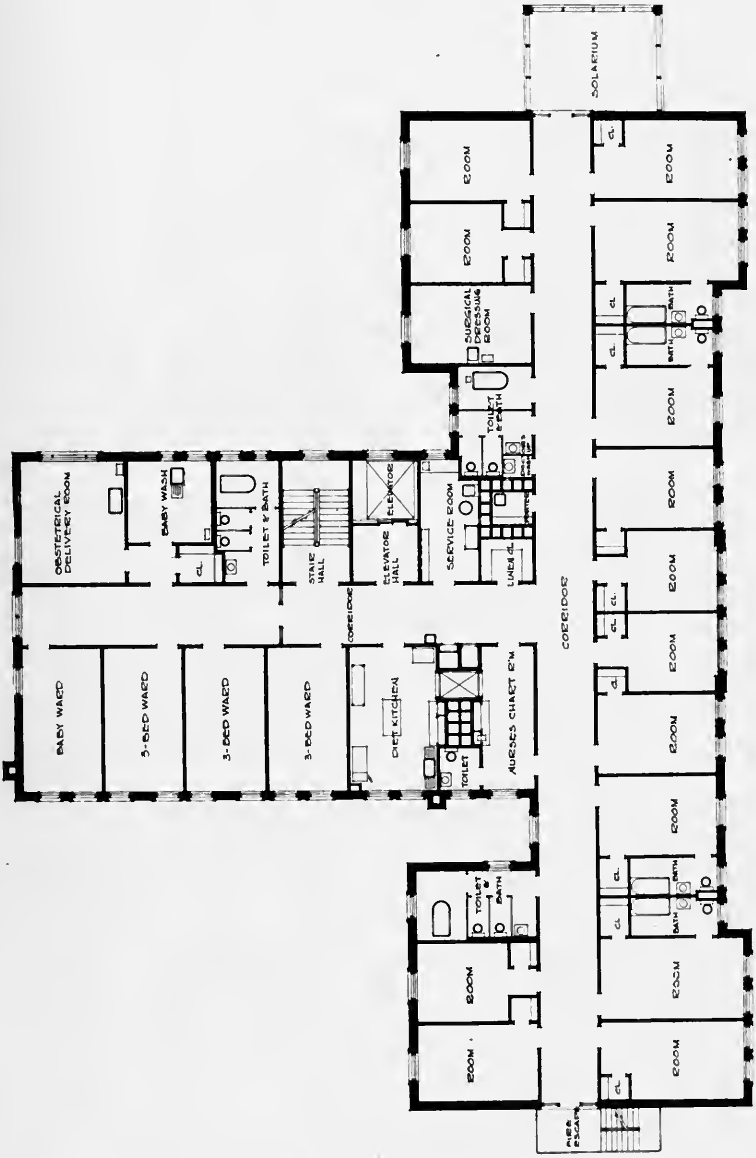
FIRST FLOOR PLAN

Fig. 565

annoyances enumerated. The space directly in front of the elevator cuts off all the noises attendant on the opening and closing of these doors, but particularly makes it possible to take patients out of the main corridors when they are on wheel carts and are to be conveyed to any other floor, a condition which is alike desirable to the patient and to others in the institution. Moreover, this gives a space in which can be placed at all times, a wheel stretcher for immediate use on each floor.

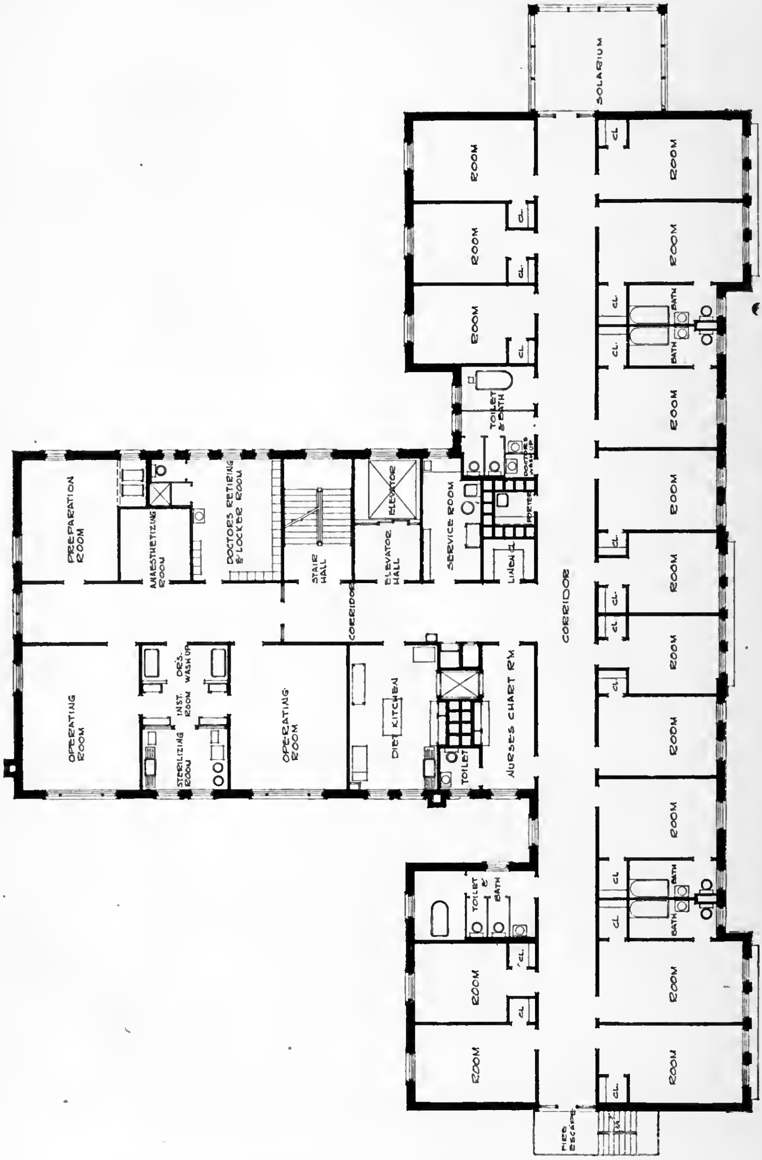
SECOND FLOOR PLAN
FIG. 566

On the second floor the working department is the same as on the first floor, and as described above. The left and right wings of the main building are given over to small and large wards. The rear or transverse wing is cut off by partition and door to exclude all noise and annoyance, this being designated as the Children's department. Additional toilet facilities are provided for this department.



THIRD FLOOR PLAN
FIG. 567

The third floor follows the same plan as the second, except that on this floor to the right and left of the main building, are the private rooms, some with private baths. Directly back of the centralized administrative department in the transverse wing, is the obstetrical department of the hospital. In this department necessarily is the obstetrical delivery room and babies' room, so it is a contained department within itself, with proper toilet facilities.



FOURTH FLOOR PLAN
FIG. 568

On the fourth floor the right and left wings of the main building are like those on the floor below, with private rooms and baths. Directly back of the centralized administrative department in the transverse wing on this floor, is the operating department.

The elevator and stairs run to the roof, and practically the entire roof of the building is given over to roof garden purposes. One portion of the roof is arranged, and all preparation made, so that it will be covered over and glassed in. All of the piping for the radiation has been brought up so that it will be properly heated during the winter. The remainder of the roof is so arranged that it will be an open roof garden. Toilet rooms are now built so that the open roof portion can be used at once. Every hospital should be so planned that the entire roof can be utilized.

The hospital is completely equipped in every detail with necessary mechanical equipment, including a refrigerating plant, which will be sufficiently large for all future additions, and for taking care of the necessary ice for any and all buildings that may be put on the ground, as shown on the plat plan. Both the elevator and the dumb-waiter in the building are automatically operated. All of the apparatus in the kitchen, which requires power, is run electrically. All cooking and all sterilizing, and the heating of all domestic water supply, is done by steam from the central power plant.

The power-plant is a two-story building directly in the rear of the hospital, as shown on the plat plan, and contains an entire equipment and room for future additions for the hospital. In the second story of this building is a complete laundry.

The heating system of the hospital is a modulation system. All steam for the entire operation of the hospital is produced at high pressure and reduced by reducing valves for the different types and kinds of service to required pressures. This simplifies the matter of boiler equipment. All exhaust steam is used during the winter months as auxiliary for the heating, and during the summer months such exhaust steam is used for heating domestic water supply. This is readily accomplished by the proper by-passes and valves.

Every possible economy has been taken into consideration, and methods applied to the end that the maintenance charge will be at a minimum. It might be well here to state that this is not only true of the mechanical equipment of the hospital, but that in the consideration of this phase of the administration of the institution, every effort has been made to eliminate any lost motion, and to get the most perfect and efficient results possible in order to enhance this much to be desired condition. Special care has been given to the method of calling nurses, and every facility has been provided for them so that they can do their work in the most efficient manner, with the least physical effort, and a consequent raising of the standard of service throughout.

"When we build, let us think that we build forever. Let it not be for present delight nor for present use alone. Let it be such work as our descendants will thank us for, and let us think, as we lay stone on stone, that a time is to come when those stones will be held sacred because our hands have touched them, and that men will say as they look upon the labor and wrought substance of them, 'See! This our Fathers did for us.'"

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