CHAPTER LXXVI

COMPOUND FRACTURES OF THE EXTREMITIES

PRE-OPERATIVE TREATMENT

A COMPOUND fracture is a most urgent surgical emergency; immediate operation is as imperative for this condition as for early perforated appendicitis.

First Aid.—Treatment of a compound fracture should commence at the place of the accident. A sterile dressing is applied to the wound, and, as a rule, a suitable dose of morphine is injected intravenously, but splintage alone sometimes ameliorates the pain adequately. Exceptionally, there is considerable hæmorrhage from the wound; even so, the application of a tourniquet is unnecessary and harmful. What is required is a pad with a firm bandage over the wound. The limb should be splinted before the patient is transported to the nearest hospital; there is no better method of immobilizing the lower limb than by means of a Thomas's splint. Great care must be taken to ensure that the limb is not moved unnecessarily. First-aid workers should receive specific instructions on these fundamental points.

Prophylactic Therapy.—As soon as possible 500,000 units of penicillin and 0·5 G. of streptomycin are injected in order to combat common pyogenic infections. In addition it is imperative to inject intramuscularly 1500 international units of antitetanic serum, whether or not the patient has been inoculated with toxoid previously. Admittedly early excision of the wound is by far the most important means of prophylaxis against gas gangrene, but the additional precaution of injecting the contents of an ampoule (22,500 I.U.) of antigas-gangrene serum intramuscularly is worth while. In this connexion attention is drawn to the convenience of compound tetanus–gas-gangrene antitoxin (combined),[1] which ensures that neither of these safeguards is forgotten.

Treatment of Shock.—While loss of blood and shock, often due mainly to other injuries, sometimes necessitate postponement of operative treatment, in the majority of instances a compound fracture *per se* is not accompanied by profound shock, so that the sooner the patient is conveyed to the operating theatre the better. However, it should be the unwavering rule to take a sample of the patient's blood for grouping and cross-matching so that blood transfusion can be given without undue delay in necessary cases. This accomplished, a slow continuous intravenous infusion of a blood substitute is commenced in the ward: at any time during or after the operation, if the signs so dictate, the rate of flow can be increased. In this way delayed shock will probably be circumvented.

Regarding the need for blood transfusion, R. Clarke et al. found that the average blood-loss was:—

Tibia and fibula (some compound) ..	1·5 l.
Femur (closed)	1·0 l.

In all patients the pre-operative loss, if more than 2 pints (1·15 litres) and the operative loss (fairly accurately determined by swab weighing) should be replaced.

Radiography.—Radiographs of the entire length of the broken bone in two planes are highly desirable: they should be taken with a portable machine, either in the ward or in the operating theatre.

Obtaining Permission for Amputation.—As it is most inadvisable to examine the wound before it is uncovered in the operating theatre, when the radiograph reveals comminution or there is reason to believe that mutilation of the soft parts is extensive, or indeed when the extent of the damage is as yet unknown, it is highly important to obtain permission for amputation in writing before commencing to operate. Explain to the patient and relatives that every effort will be made to save the limb.

[1] Parke Davis & Co. Ltd., Hounslow, Middlesex.

OPERATIVE TREATMENT

Anæsthesia.—Full general anæsthesia is necessary.

The Question of the Advisability of Immediate Amputation arises.—A pulped limb with multiple contaminated compound fractures must be treated by suitable amputation. In cases of comminuted compound fractures or compound fractures complicated by extensive injury of soft parts, the decision whether or not to amputate sometimes can only be made after the wound has been opened in the manner to be described ; the demonstration of an intact main arterial trunk can be the deciding factor in favour of conservatism. The fact that the general condition of the patient will not withstand a prolonged operation sometimes weighs heavily in favour of a quick amputation. In cases of real doubt, if a second opinion can be obtained without delay, so much the better. In the case of a foot that has been crushed producing multiple compound fractures of the tarsal and metatarsal bones, or where a contaminated compound fracture involving the ankle-joint is present, so often, when amputation is considered but not performed, it transpires that after weeks of suffering the patient has to have an amputation after all. Therefore in the case of the foot, especially a dirty foot, if the question of amputation arises, carry out amputation somewhat more readily than in similar circumstances in other situations. After a well-planned amputation there is a definite period of convalescence, at the end of which an artificial foot can be fitted to the stump.

DETAILS OF AN OPERATION FOR A COMPOUND FRACTURE

In compound fractures of the lower limb the operation should, if possible, be carried out on an orthopædic table or with the aid of a traction appliance. Either of these expedients will support the limb during excision of the wound, provide traction to overcome shortening, and leave the limb free for the application of a plaster cast.

The Böhler Screw-traction Apparatus for the leg consists of a rectangular tubular steel frame with uprights carrying crossbars (*Fig.* 1213). The proximal crossbar is placed under

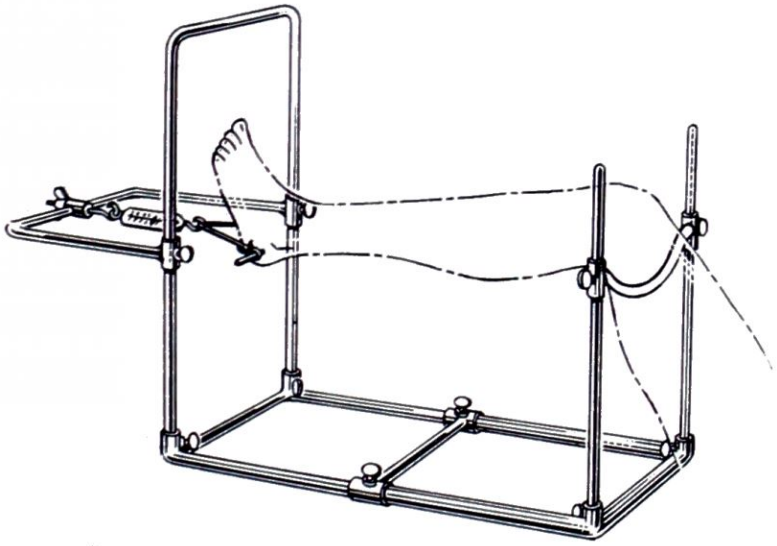


Fig. 1213.—Böhler's screw-traction apparatus for the leg.

the flexed knee ; the distal crossbar carries a screw with a winged nut. To the screw is attached a hook, and to the hook is attached the stirrup of a Steinmann or other pin by means of copper wire with a spring-balance intervening. By tightening the nut, increasing tension can be exerted on the leg and registered on the spring-balance. A third detachable upright (not shown) can be used to support the lower third of the leg, which is hung from it by a bandage.

This frame can be combined with adjustable supports for the thighs and the sound leg ; it is then used in conjunction with an ordinary pelvic rest. In this way the whole limb can be kept extended while traction is applied (*Fig.* 1214). This is most valuable for reducing the fragments in a compound fracture of the femur, and for applying a hip spica plaster cast at the conclusion of the operation.

When such apparatus is lacking the surgeon should reflect that, desirable as is mechanical traction in many cases, a greater number of comparable compound fractures have been operated upon and reduced successfully with the aid of manual traction alone than all those where the surgeon has had the advantage of an orthopædic table or a traction apparatus.

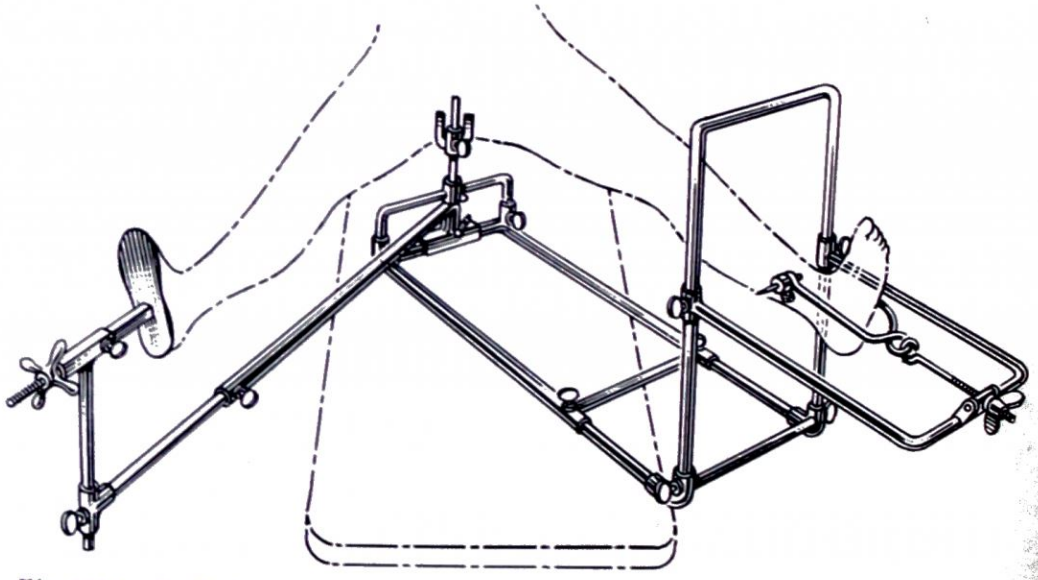


Fig. 1214.—Böhler's screw-traction apparatus with a fitting for the sound limb, making it comparable to an orthopædic table. The apparatus is used in conjunction with a pelvic rest.

He will therefore appoint an assistant whose sole duties are to hold the limb and apply traction when requested to do so. For the upper limb manual traction in all types of fracture is the method of choice.

Before commencing the operation, compare the site of the wound with the radiological demonstration of the fracture, for an open wound near a fracture is not always connected with the site of bony injury. Because the wound is small—a mere puncture—it does not imply that there should be a departure from the accepted principles of wound excision. The practice of sousing the wound with an antiseptic, and then treating the compound fracture as a closed fracture is archaic and reprehensible.

Ablution of the Surrounding Skin.—A mop of gauze is held over the wound so that the skin can be cleansed up to the wound margin without further contamination of the wound itself. The skin is shaved, and washed with 1 per cent cetavlon or soap and water, using large gauze mops. Ether is used to remove grease. Hair should be shaved with a sterile razor. The tendency at the present time is not to paint the skin with any antiseptic; this, however, is a matter of personal preference, but if a skin antiseptic is employed it should be colourless (alcohol or the colourless variety of metaphen) so as to avoid vitiating the distinctive features of non-viable skin.

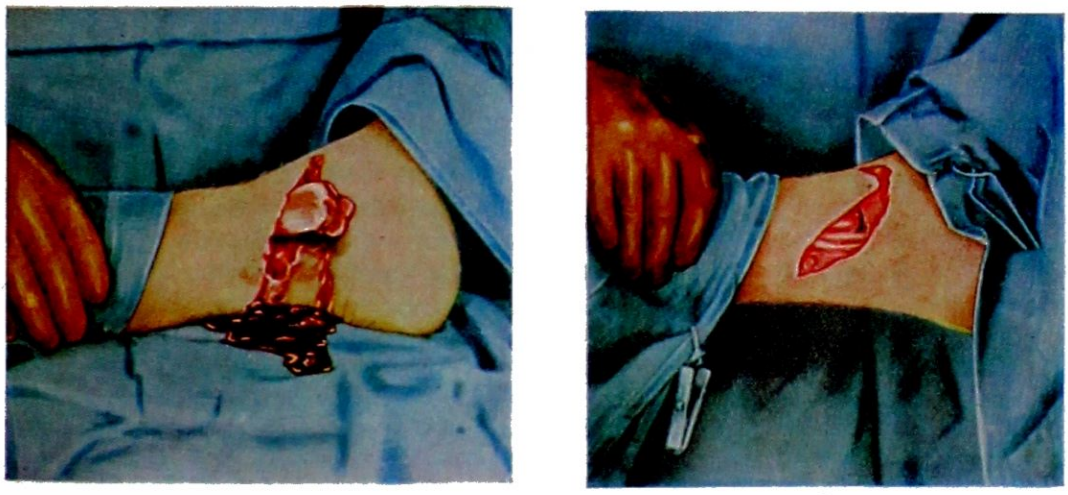
Bone is protruding from the Wound.—A comparatively thin, spiked fragment of bone should be cut off with heavy bone forceps flush with the wound, as a first step. If the protruding fragment includes the whole, or a large part, of the circumference of the shaft (*Fig.* 1215), it should be cleansed with gauze well moistened with saline solution, but not dripping wet, after which the excess of moisture is absorbed by dry gauze. Every precaution must be taken to see that fluid does not trickle from the bone into the wound. Tags of torn periosteum are excised and particles (usually silicon or carbon from road dirt) ingrained in the periosteum or the bone must be removed, a dental excavator being particularly useful for this work. On no account attempt to replace the bone until the wound has been excised. Rarely, in cases of separation of an epiphysis the end of the diaphysis is forced out of the wound, when it is treated in the same manner.

Excision of the Wound.—The more promptly and thoroughly excision of the wound is carried out, the less is the probability of infection, with its attendant train of suppuration, osteomyelitis, and non-union of the fracture. In the case of injury of under 6 hours' duration, excision of the wound is carried out in precisely the same manner as described on p. 134. Here, only points in special relation to excision of a wound in the presence of a compound fracture will be considered.

The wound is often more or less transverse. While the wound must be enlarged to give ample access to the bone ends and to be enabled to carry out adequate débridement, never enlarge the wound transversely, and never enlarge it longitudinally in such a way as to convert a transverse wound into a +. The incisions to extend a transverse wound must be so placed as to make a step-like opening, viz., ⅃. This type of incision is particularly advantageous in an area where the skin is normally tight, such as over the anterior surface of the tibia. All recesses must be opened widely. Those in relation to the bone are often deep, necessitating considerable enlargement of the skin incision.

Small, completely detached fragments of bone found in the course of dissection are removed. Fragments that have any soft-tissue attachment whatsoever should be preserved carefully. Larger loose fragments are removed and placed in a bowl of warm saline solution pro tem.

Attending to the Bone Ends.—Unless it was unavoidable, only after the débridement of the soft parts has been completed are the fractured ends of the bone touched, even with



A B

Fig. 1215.—A, Compound fracture of the tibia with the upper fragment protruding from the wound. B, Wound excised and fracture reduced.

dissecting forceps. Before directing attention to the bone lesion, the surgeon covers the wound with a pack and removes the towels clipped to the wound edges. The surgeon, his assistant, and the instrument nurse change their gloves and, if time permits, their gowns also. A fresh set of instruments is put out, and the wound is redraped. By suitably retracting the bone the fractured surfaces can be seen, and this is highly desirable, for foreign matter, and particularly muscle, may be imprisoned between the surfaces. It is better not to attempt to cleanse the bone ends with gauze swabs—so often this results in the tearing of some of the cotton fibres, which are liable to become entangled in the spicules of bone.

Débridement being concluded, the wound is irrigated with normal saline solution delivered from a douche-can and tube. Usually a gallon (4·5 litres) or more will be required ; it is advisable to irrigate too plentifully rather than too little, the stream being directed into every portion of the wound. Irrigation being completed, the wound is mopped dry, and again a search is made for foreign material or devitalized tissue that has become apparent as a result of the irrigation. Particularly a search is made for loose tags of periosteum, which are snipped off. In cases where larger loose fragments of bone were removed temporarily, these are cleansed mechanically if they are obviously soiled, and replaced as accurately as possible. There is a definite risk of non-union if a gap is left between the ends of the bone. Provided the fragment or fragments are clean, they often act as a bone-graft. Should the wound become seriously infected, they still lead to some formation of new bone before being cast off as sequestra.

Reduction of the Fracture.—The fragments of the bone must be placed and held in adequate apposition and alinement. Satisfactory apposition of the fragments not only favours union of the fracture with minimum deformity, but aids in the prevention of infection of the wound. An infected fracture is usually an incompletely reduced fracture. With the fragments held in anatomical alinement, dead space in which contaminated blood-clot and

exudate can collect is minimized, and pressure of one or both ends of the fractured b against the deep surface of the skin, that might cause tissue necrosis, cannot occur. these ways accurate reduction inhibits wound infection.

Reduction of a fracture is accomplished more easily in an open than a closed frac because the fragments are under visual control and muscle that was trapped between fragments has been excised. To avoid further injury of the periosteum, as far as possi manipulation of the bone ends within the wound should be eschewed, reduction being effe mainly by the use of traction and external lateral pressure. No effort should be sp to obtain good alinement, for re-manipulation of a compound fracture within 14 day its infliction must not be countenanced : the danger of spreading strictly localized infec is too great. When mechanical distraction is used to reduce the fracture, care mus exercised not to overdo the distracting force : non-union of the fracture is sometimes penalty of too much traction ; Volkmann's ischæmia can also arise from this cause. A reduction of the fracture the wound is irrigated and dried once more, swab-sticks are inse into the various parts of the wound and sent for culture to determine what organi are present, and their antibiotic sensitivity. Ideally the report should read, 'Cul sterile.'

Difficulty in maintaining the Fragments in Good Alinement.—If the lower fragm cannot be maintained in good position without the aid of traction, and a Steinmann's other pin has not been inserted already, the best site (*see Figs.* on p. 881) below fracture is chosen and, after gloves have been changed, a pin is driven through the bo When, in addition, the upper fragment cannot be stabilized, a pin be inserted through the upper fragment 3 in. (7·5 cm.) proximal to wound—a distance that will ensure that the bone through which it pa is sufficiently removed from the infected or potentially infected a The pin or pins are later incorporated in the plaster-of-Paris cast.

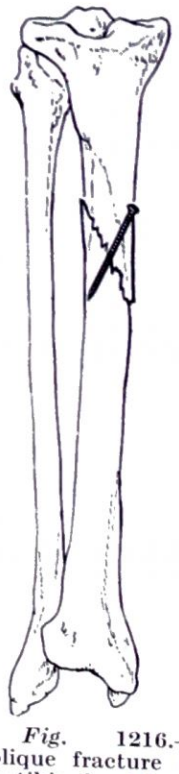


Fig. 1216.—Oblique fracture of the tibia fixed by a single screw.

Internal Fixation.—While some orthopædic surgeons emplo bone-plate or an intra-medullary nail to maintain apposition of fragments in difficult cases (provided, of course, the case is an early and débridement has been carried out meticulously), it would be n

Fig. 1217.—Bone screw of vitallium or stainless steel. Its tip is so shaped as to make it self-tapping.

inadvisable for anyone without considerable experience in the o reduction and fixation of fractures to attempt such procedures, with th ever-present danger of incurring, or increasing the extent of, ost myelitis. To place an encircling wire around an oblique fracture t tends to slip has on many occasions served me well : the wire has b removed when the fracture has united. Circumferential wiring recommended by Böhler, but is condemned by Sir Reginald Wats Jones because it deprives the bone of some of its blood-supply. S comes about that if circumferential wiring is not to be used, fixat by means of a bone-screw (*Fig.* 1216), or at the most two bone-scre is the only procedure that can be advised in these circumstances. T vitallium machine type of screw with a self-tapping point (*Fig.* 12 should be employed whenever possible. These screws are usually $\frac{9}{64}$ in. in diameter, a before use a drill-hole with a $\frac{7}{64}$-in. drill is required. A screw of the correct length is selec after measuring the drill-hole. It is better to employ a screw that is too long than that is too short, and the screw should be turned until it is inserted fully ; thereafter it not tightened.

Concomitant Severed Tendons and Nerves.—No definite instructions can be given to whether or not severed tendons and nerves should be sutured. If reduction of the fract was difficult, if the wound was considerably contaminated, if the general condition of t patient is not all that could be desired, and if there are several tendons and nerves to rep it is better to postpone a time-consuming apposition of these structures until at leas fortnight after the wound has healed soundly.

Should the Skin Wound be Closed by Sutures? Many surgeons believe that all compound fractures should be left open, that the limb should be immobilized, and the wound permitted to heal by granulation. A growing number have found that in civilian cases of under 8 hours' duration where débridement has been carried out meticulously, primary closure is possible for most wounds; indeed, in many cases of compound fracture the wound can be closed safely if operated upon within 12 hours after injury, provided there is absolutely no tension on the suture line. It should be noted most carefully that the wound must never be closed in layers, but the skin and subcutaneous tissue are brought together in one layer by rather deeply placed skin sutures, preferably of stainless-steel wire, tied not tightly. If there is even a suggestion of tension when a trial is made to bring the skin edges together, unilateral or bilateral releasing incisions can be made, but they must be at least $1\frac{1}{2}$ in. (3·8 cm.) from the corresponding wound edge. This enables the skin edges to be approximated without any tension whatsoever, and it has the additional advantage of providing drainage without leaving the bone exposed (*Fig.* 1218). It has been said by some of those who advocate leaving the wound open in every case that the only objective of primary closure is to obtain a linear scar. This is far from the truth. Skin is the best covering for any clean wound; by suturing a clean wound secondary infection is prevented and scar tissue, in which tendons, in particular, can be encased, is minimized. It is unwise to attempt to close the wound by split skin-grafts at the time of the débridement; in these circumstances skin-grafts do not survive regularly, and dead epithelium is a good medium for the growth of bacteria. Very occasionally it is an excellent practice to cover exposed bone and tendons by cutting and transposing a suitable pedicle-flap of skin with a broad base.

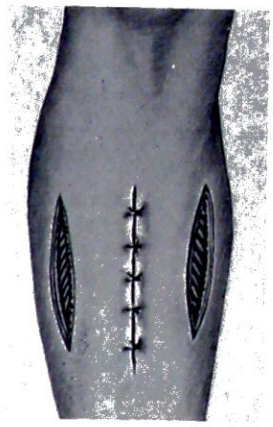


Fig. 1218.—The use of lateral incisions to prevent tension on the suture line. If the skin between the incision and the wound is dissected up, lateral incisions provide drainage without leaving the bone exposed.

When the interior of the wound was contaminated with road or agricultural dirt, when the surgeon has any doubt concerning the effectiveness of the débridement, when the skin cannot be brought together without tension, unquestionably the wound should be left completely unsutured.

When it has been decided to leave the Wound Unsutured.—The wound is packed to the surface level with fine-mesh dry or petroleum-jelly gauze 'with a firmness you would hold a lady's hand on greeting her'.

Dressings and the Application of a Plaster Cast.—Whether or not the wound has been left open, the subsequent steps are the same. The wound and surrounding skin are covered with a single layer of petroleum-jelly gauze. Upon this is superimposed a thin layer of dry gauze. The limb is then bandaged with gauze, followed by a thin layer of wool. Usually a plaster[1] cast is applied, and if it is, include the joint below and the joint above the fracture. The plaster cast is split before it has dried; this is a wise routine measure to prevent the occasional, but disastrous, occurrence of ischæmia. When the patient has been returned to bed the limb is elevated, and kept elevated for about a week.

A well-applied plaster cast immobilizes the limb more completely than any other form of splint, even when combined with efficient traction. With the limb, including the joint above and the joint below, encased, both movement of these joints and their activating muscles is prevented. It is muscle contraction, and particularly joint movement above and below the wound, that squeeze infection into the lymphatic network. Another advantage of plaster is that it readily absorbs exudates, rendering dressing of the wound unnecessary. Its one disadvantage is, should an anaerobic infection supervene, the wound is hidden from view—careful watch must therefore be kept for the development of general signs that point to this complication, rare as it is in civilian practice. If gas gangrene is suspected a radiograph (*see* p. 131) frequently shows gas in the tissues, even through a plaster cast.

Leaving the Wound alone.—In the absence of untoward symptoms, the plaster cast should not be changed for 3 or 4 weeks. Antibiotic therapy is continued throughout this

[1] A plaster slab wide enough to encircle threequarters of the diameter of the limb, and kept in place by a few turns of plaster bandage, is a good alternative. Should it be necessary to split the plaster, it can be done with a pair of scissors.

period. Should the bacteriological report reveal that a penicillin-resistant organism is present, the appropriate antibiotic is substituted for the penicillin. When the cast has been removed the wound is inspected in the operating theatre, with full aseptic precautions. The gauze is removed, and either fresh petroleum-jelly gauze inserted or, if thought advisable, secondary closure of the skin can be undertaken. The cast is then re-applied until firm bony union has occurred. Should the wound have been closed primarily, the cast is removed at the end of 4 weeks, the stitches are removed, and the plaster is re-applied.

Evidence of Infection.—The first evidence of serious infection is pain. When the infection is due to gas gangrene, the pain is sometimes excruciating and is accompanied by elevation of temperature and a disproportionate increase in the pulse-rate. The fingers or the toes may become swollen or cyanotic. If any of these symptoms develop, remove the plaster, reopen the wound if necessary, and change or insert petroleum-jelly gauze. If the infection is not due to gas gangrene, the plaster cast is re-applied and should penicillin and streptomycin have proved ineffective, these antibiotics are changed in favour of one of the tetracycline group.

TREATMENT OF AN INFECTED COMPOUND FRACTURE WITHOUT GAS GANGRENE

Cases of compound fracture not admitted until more than 12 hours after the accident are not common in civil practice, but cases where, for one or other reason, infection becomes manifest after admission are less unusual. In each instance the treatment is similar. Enlargement of the wound, as necessary, to provide unhampered drainage is the order of the day. Major pockets are opened up, but tissue is not excised. Loose bone fragments, unless large, are removed, as also, of course, is any foreign material that can be found. Specimens of the exudate are sent for bacteriological examination, culture and antibiotic sensitivity tests ; needless to say, great trust is placed in correct antibiotic therapy. Should it be absolutely necessary to employ a transfixion pin, the transfixion should be as far away from the infected wound as possible. The wound is packed very lightly with petroleum-jelly gauze, dressings similar to those described already are applied, and the limb is immobilized in a plaster-of-Paris cast. The plaster should not be changed until the odour makes it compelling, unless there is pain, pyrexia, increased pulse-rate, toxæmia, or progressive anæmia ; a combination of all or of some of these untoward symptoms indicates progressive invasion of the tissues.

In cases falling into the latter category the closed plaster technique must be abandoned, at any rate for the time being, in favour of a splint with extension and moist dressings of the wound. Carrel-Dakin intermittent irrigation (*see* p. 139) was designed for such cases, and, carried out faithfully, is extremely effective.

Carrel-Dakin Treatment of an Infected Compound Fracture.—Unless the sister in charge has had special experience in the method, every detail of the treatment should be supervised by the surgeon or his deputy. The skin around the wound must be protected from the commencement, or it soon becomes inflamed by the irritating action of Dakin's solution. Tulle gras is the best material for protecting the skin. The distributing tubes are inserted into the wound with care and thought ; one is tucked beneath the bone and one is placed in the superior end of the wound ; it is exceptional for more to be required unless there are pockets present, which, after an efficient operation, should not be the case. The tubes are kept in place by gauze soaked in Dakin's solution. *No bandage is used.* A large piece of Gamgee tissue lined by four layers of gauze is made to encircle the limb, and kept in place by safety-pins. The distributing tubes are brought out at convenient places, slots being cut in the Gamgee tissue to accommodate them ; they are anchored by small safety-pins which do not penetrate any part of the tube.

In cases where a good deal of slough is present in the wound, irrigations with streptokinase and streptodornase (*see* p. 140) can be employed with advantage. In grave infections the advantages of timely amputation must be weighed carefully.

Treatment of Gas Gangrene.—*See* p. 130.

Pyogenic Skin Infection.—In cases of even mild infection of the wound where, on removal of the plaster, the skin is found to be covered with purulent follicles—a not uncommon finding—it is wise to employ a splint and dry dressings to the area until the superficial infection has abated.

SKELETAL TRACTION BY PINNING

Skeletal traction pins should not be employed promiscuously, for in a high percentage of cases a low-grade infection of the track occurs. If the pin track is close to the synovial and capsular reflexion of the joint, the degree of inflammatory change is sufficient to give rise to intra-articular adhesions.

Supracondylar Skeletal Traction is particularly liable to result in a stiffened knee-joint, and should be avoided if there is an alternative. To insert the pin, a point is chosen on the inner side of the thigh two finger-breadths above the adductor tubercle (*Fig.* 1219).

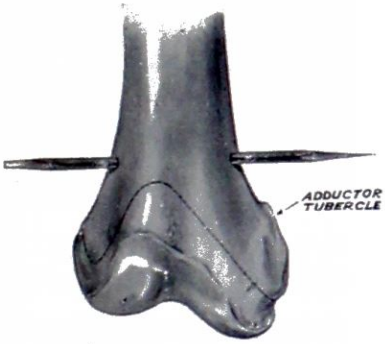


Fig. 1219.—Transfixion of the lower end of the femur.

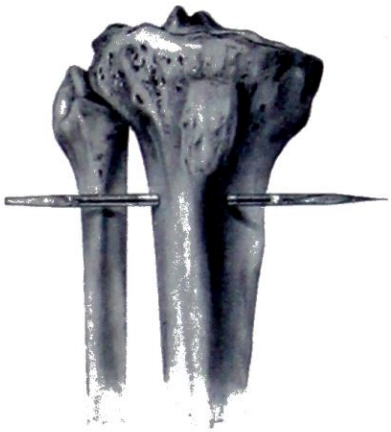


Fig. 1220.—Transfixion of the upper end of the tibia.

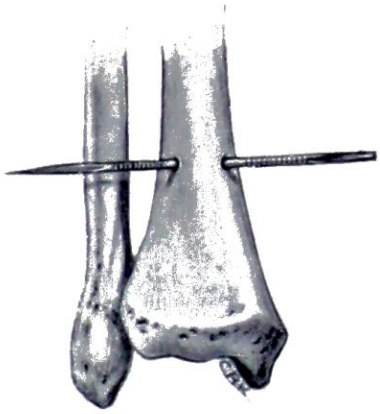


Fig. 1221.—Transfixion of the lower end of the tibia.

Tibial Traction at the Level of the Tuberosity of the Tibia (*Fig.* 1220) is relatively safe because, even if slight infection does occur, it is too remote from the knee-joint to cause adhesions. The pin is inserted just below the tibial tubercle and about two finger-breadths lateral to it. The fibula is not penetrated (*Fig.* 1220). This site should not be used in children below the age of 14, because of late ossification of the nearby epiphysis.

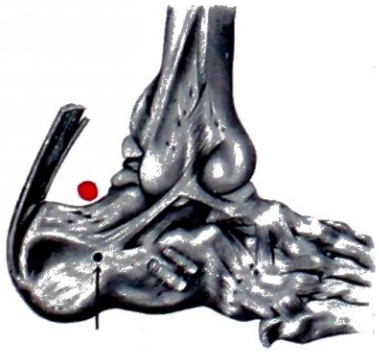


Fig. 1222.—Transfixion of the os calcis, and (red) supra-calcanean transfixion.

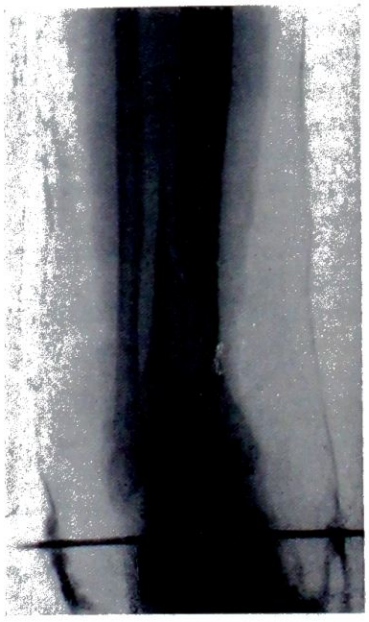


Fig. 1223.—Supracalcanean traction pin in use. (Dr. S. Movsas.)

Tibial Traction of the Lower Shaft 2 in. (5 cm.) above the Ankle (*Fig.* 1221) is an excellent site free from joint complications. The pin is applied from within, outward. The point of exit should be slightly anterior to the point of entrance, in order to avoid the fibula, which is not penetrated. This site can be used in children, for the epiphysis lies below the point of transfixion.

Calcaneal Traction (*Fig.* 1222) is rather often required, because there is no alternative. It should not be used for longer than the bare minimum, because the ensuing mild infection is liable to involve the synovial reflexions of the subastragaloid joint and cause permanent limitation of inversion and eversion of the foot. Instead of inserting the pin through the os calcis, it may be inserted immediately above it (*see Fig.* 1222, red dot). This has the

advantage that if infection does occur, it will not be an osteomyelitis of the calcaneum (Dr. S. Movsas). A radiograph in which the latter method was employed is reproduced (*Fig.* 1223).

Olecranon Traction is the most unsafe, the elbow-joint being particularly susceptible to the formation of adhesions ; moreover, it is hardly ever necessary.

Steinmann's Pins are made of stainless steel, and vary in diameter from 2 mm. to 4 mm. One end is pointed sharply and the other is squared for the reception of a handle (*Fig.* 1224). The pin can be hammered through a cancellous bone like the calcaneus, but in most situations it is better to drill the bone first with a small wood twist drill of smaller diameter than the pin, and then insert the pin through this hole. This gives accurate control over the direction of the pin. The pin is held in a stirrup by a screw and a collar (*Fig.* 1225) that permits the stirrup to rotate without rotating the pin ; a rotating pin is a common cause of infection of the pin-hole.

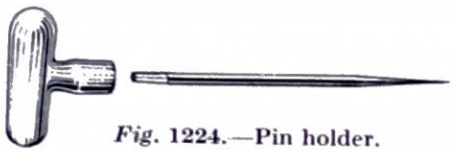


Fig. 1224.—Pin holder.

Fig. 1225. — Böhler's swivel stirrup affixed to a Steinmann's pin.

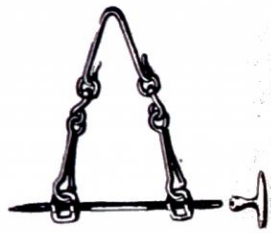


Fig. 1226.—Whitchurch Howell's pin.

Whitchurch Howell's Pin (*Fig.* 1226) is extremely satisfactory ; it is easy to maintain necessary extension by the ' dog-chain ' clips.

A CONSIDERATION OF INDIVIDUAL BONES

The treatment of *compound* fractures is dealt with in this chapter : the treatment of fractures, as such, is beyond the scope of this work, and the reader is referred to one of the standard works devoted to the subject. It is, however, necessary to give some instructions concerning problems such as the immobilization of individual bones involved in a compound fracture. As has been emphasized, a plaster-of-Paris cast including the joint above and the joint below the broken bone is the method of election in nearly all cases. The plaster should not be provided with a window, which causes œdema of the fenestrated area and invites secondary infection when the wound is dressed. Plaster, being porous, absorbs exudates seeping from the wound. A plaster-of-Paris cast immobilizes a fractured bone and the joints related to it more completely than can be achieved by a splint combined with traction. Nevertheless a plaster cast is not always the best method to employ in a given case.

Absolute contra-indications to the application of a plaster cast are :—

1. When there are any signs of impaired circulation in the distal part of the affected limb.

2. Where there are reasons to fear that the supervention of gas-gangrene is not improbable.

Tibia.—This is the commonest site for a compound fracture, and compound fractures of this bone lend themselves to the closed plaster method. The foot as far as the toes should be included, and the cast should extend to the upper third of the thigh. In cases where a plaster cast is contra-indicated, immobilization on a Braun's splint with pin traction via the calcaneus (so that the transfixion is removed as far as possible from the injured area) is recommended.

Femur.—Pin extension is nearly always necessary, and as a general rule the upper end of the tibia should be employed for this purpose. Alternatively, the lower end of the femur is transfixed ; this site should only be used if there is some definite contra-indication to the foregoing. Another possible alternative, when the wound is small and not situated laterally or medially in the lower half of the thigh, is skin traction by means of extension strapping, but in this instance immobilization in a Thomas's splint is a *sine qua non*.

While a hip spica plaster cast extending from the base of the toes, with the transfixion pin incorporated in the plaster, is the best method of immobilizing the limb, there are often formidable difficulties barring the way to its application. First and foremost, except in a

child, it is difficult to keep the fragments in good alinement while the plaster is being applied, unless the surgeon has the advantage of an orthopædic table, or comparable apparatus. Another important consideration is that a compound fracture of the femur is more likely to be accompanied by severe shock than is a compound fracture of any other bone of an extremity, and the application of a hip plaster consumes a considerable amount of time. Another disadvantage of a plaster cast in this area is that in the elderly or undernourished, unless the padding is perfect, a bed-sore is liable to ensue. For these reasons a Thomas's splint with efficient skeletal or skin traction is usually the method of choice.

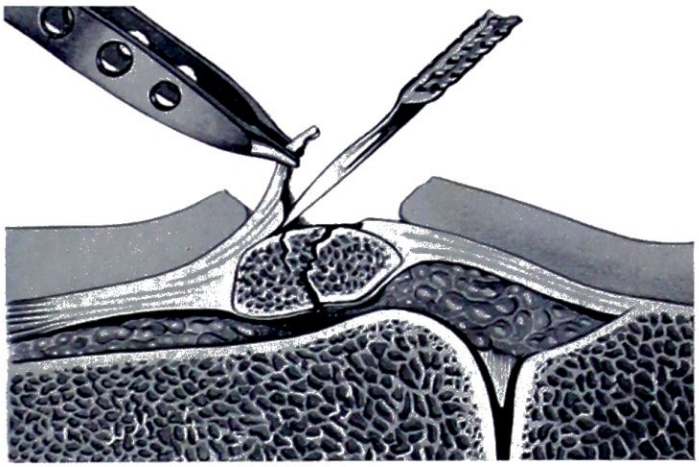


Fig. 1227.—Excision of the patella. The lateral expansion must be preserved carefully.

Patella.—When the patella is involved in a compound fracture, and the bone is comminuted, or the knee-joint is opened, or the wound is severely contaminated, if the case is an early one the patella should be excised. Keeping close to the bone, the patella is cut out of the central tendon (*Fig.* 1227). The lateral expansion must be united carefully. In most cases the wound can be closed without drainage. The limb is immobilized in a plaster-of-Paris back slab.

In comparatively clean transverse fractures not involving the knee-joint, the fracture can be united with two wire or catgut sutures.

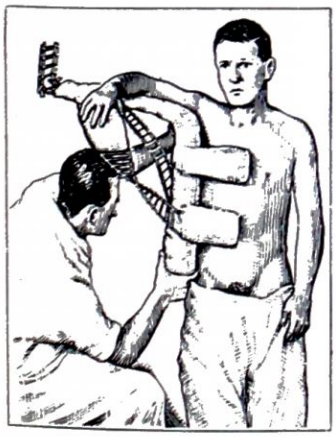


Fig. 1228. — Aeroplane splint constructed from Cramer wire and padded well. It should fit well up into the axilla. (*After L. Bohler.*)

Humerus.—An efficient method of immobilizing the humerus is to construct an abduction splint (*Fig.* 1228) from Cramer wire and to pad it well. The splint is fixed to the body, not with calico bandages, but with a few plaster-of-Paris bandages. If desired, plaster-of-Paris bandages can be applied over the splint and the humerus, thus combining the advantages of the lightness of the splint with the closed-plaster technique.

Fig. 1229.—Athoracobrachial plaster applied; note the optimal position (45° abduction). (*After D. W. Jolly.*)

Many surgeons with experience of compound fractures of the humerus in war have found that the immobilization afforded by the aeroplane splint is insufficient and much inferior to that obtained with a thoracobrachial plaster. The difficulty of applying the latter to an unconscious patient is circumvented by using an aeroplane splint as a temporary expedient. When the patient has sufficiently recovered, usually a matter of two or three days, after a preliminary sedative and the injection of procaine solution into the brachial plexus (*see* p. 936), a thoracobrachial plaster (*Fig.* 1229) is applied with the patient sitting on a low stool. The surgeon sits facing the patient and the assistant sits behind the patient. A second assistant holds the arm in the desired position. The optimal position for immobilization is one of 45° abduction.

Radius and Ulna.—When an oblique fracture of the radius or ulna is difficult to control, one of the forms of internal fixation described on p. 878 is often advantageous. Compound fractures of these bones are well suited to the closed-plaster technique.

* * * * * * *

In the case of an upper limb, intelligent conservatism should be the guiding principle whenever possible.

As an example of what can be achieved in this direction the following case is cited :—

E. H., aged 7, was brought to hospital having been knocked down by a car. The left arm was hanging by a pedicle of the brachial artery and the nerves. The pedicle had undergone axial rotation, and the casualty officer contemplated severing the pedicle there and then. Mr. Trevor Berrill, my house surgeon, was called into consultation, and he untwisted the pedicle and noted that the radial artery could be felt at the wrist. He therefore brought the patient straight to the operating theatre. The muscles and bone were covered in road dirt. What was so remarkable was the fact that there was no muscular continuity between the upper and lower segments. I

Fig. 1230.—Eleven years previously this patient's left arm was hanging by a pedicle consisting of blood-vessels and nerves.

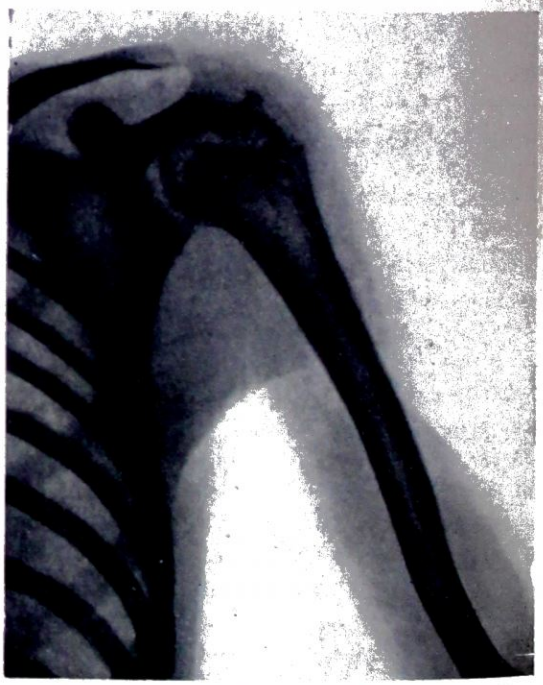


Fig. 1231.—Radiograph three years after operation. The bone-graft has been largely absorbed and remarkable regeneration has occurred.

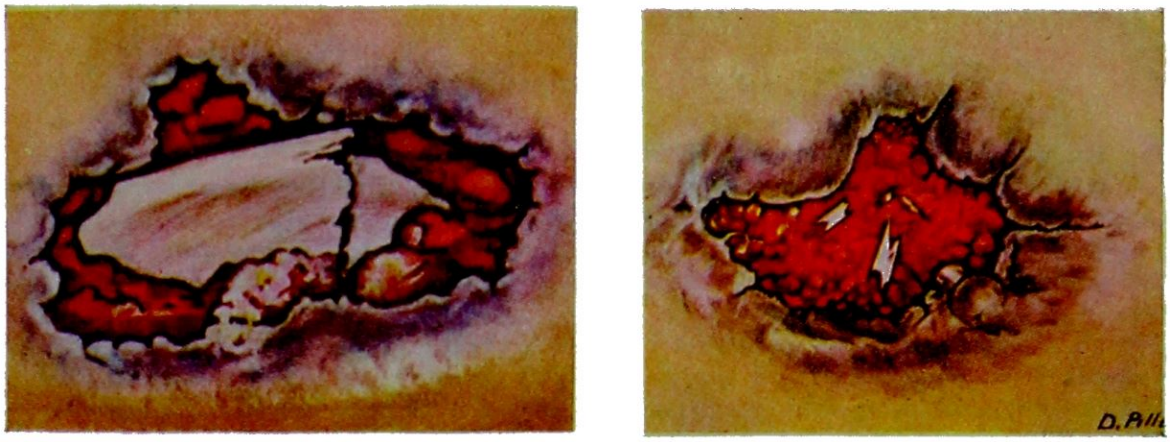
carried out débridement of the wound, and made an attempt to fashion a spike in the lower fragment and drive it into the medulla of the upper fragment. The triceps behind and the biceps and coracobrachialis in front were drawn together with sutures and the skin closed partially. The limb was placed on an aeroplane splint. Considerable suppuration followed and later a sequestrum, which consisted mainly of the spike referred to, was removed. Eventually the wound healed, but there was non-union of the fracture.

In due course the middle third of the fibula was removed subperiosteally and, utilizing this as a bone-graft, it was driven down the medulla from above, so that the two fragments were bridged. *Fig.* 1230 shows the patient eleven years later. The function of the arm is unimpaired and a radiograph three years after operation showed remarkable bone regeneration (*Fig.* 1231).

CHRONIC INFECTION

When the bone is the seat of chronic osteomyelitis secondary to a compound fracture, Winnett Orr's method combined with antibiotic therapy is unsurpassed. The wound is excised thoroughly. The diseased bone (*Fig.* 1232 A) is chiselled away so as to leave a funnel-shaped cavity. Bleeding is controlled by packing with dry gauze, and after hæmostasis is satisfactory the wound is swabbed out with saline solution and packed with petroleum-jelly gauze. The cavity is packed with this material until the whole wound is filled. The remaining steps do not differ from those of the closed plaster technique for compound fracture described earlier in the chapter. Discharges ooze through the plaster, which often becomes malodorous, and is the main disadvantage of this method. The objectionable smell is bearable if the patient can be nursed on a balcony. In other circumstances putting the cast in a cellophane bag containing charcoal can be tried. Whenever feasible, provided the general condition remains satisfactory and the patient is not in pain, the plaster is not removed ; it can remain unchanged for upwards of eight weeks (*Fig.* 1233). When

eventually it is removed, in most cases the gauze will be found to have been extruded on to the surface, and the wound itself will appear as a flat area of granulation tissue beneath



A B

Fig. 1232.—Chronic osteomyelitis secondary to a compound fracture of the tibia. A, Condition of the wound before Winnett Orr treatment; B, Eight weeks later. (*Hey Groves.*)

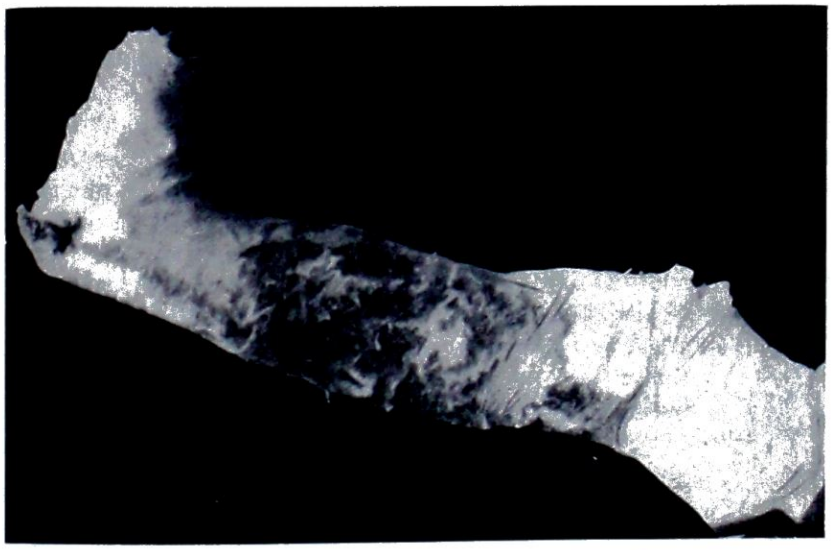


Fig. 1233.—The limb in plaster, which was not changed for eight weeks.

which the united fracture is buried. The clean wound (*Fig.* 1232 B) and radiographs showing the united fracture are a joy to behold.

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CHAPTER LXXVII

ACUTE OSTEOMYELITIS

THE blood-supply of a bone is derived from two principal sources :—

a. The nutrient artery supplies the medulla, the endosteum, and the deep aspect of the cortex.

b. Periosteal vessels supply the periosteum and the superficial aspect of the cortex. The anastomosis between these two sets of vessels is such that if one alone is cut off, the bone, including the medulla, can survive. On this knowledge rest the elements of treatment. The aim is to preserve the periosteal blood-supply because the nutrient artery so often becomes thrombosed early in the disease. Effective as is the antibiotic treatment of acute osteomyelitis, circulating antibiotic is powerless to act *on the lesion* unless an adequate blood-supply to the involved bone can be maintained.

Bacteriology.—In about 90 per cent of cases the causative organism is a *Staphylococcus aureus*, but in a small but increasing percentage this staphylococcus proves to be penicillin-resistant. In approximately 4 per cent the *Streptococcus hæmolyticus* is responsible. In the remainder *Staphylococcus albus*, *Pneumococcus*, *Salm. typhi*, *Salm. paratyphi*, *Salm. choleraesius*, or *Brucella abortus* is disclosed by the bacteriologist, usually to the astonishment of the clinician.

Pathogenesis.—

a. During the period of growth the weakest part of the long bone is the diaphysial side of the epiphysial line (the metaphysis). It is here that delicate blood-vessels penetrate the epiphysial cartilage, and even a slight jar is liable to rupture one or more of them, thereby causing a hæmatoma. If, before the hæmatoma resolves, bacteria circulating in the blood from a distant focus settle in the clot, lively inflammation is likely to follow. The resulting purulent exudate does not, as might be expected, often extend along the medulla, but interosseous pressure is relieved by necrosis of bone absorption of the thinner metaphysis permitting pus to escape under the periosteum (*Fig.* 1234). Thus the periosteal vessels become interrupted, and deprive the affected part of the bone of its only remaining blood-supply for, as has been stated, in acute osteomyelitis, thrombosis of the nutrient artery frequently occurs, probably before the clinical signs of the disease are manifest.

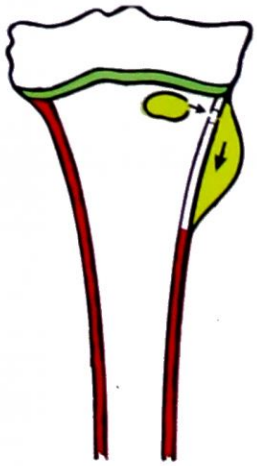

Fig. 1234.—Mode of formation of a subperiosteal abscess.

That portion of bone deprived of its blood-supply forms a medium in which bacterial fission proceeds apace, and by reason of its avascularity it is impossible for a circulating antibiotic to come into contact with these rapidly multiplying bacteria. Consequently, if the patient survives, which with antibiotic therapy is usual, the portion of bone so affected ultimately separates from the living bone as a sequestrum.

b. In cases of septicæmia, as opposed to bacteræmia, acute osteomyelitis can occur in the absence of any kind of trauma by an infected embolus lodging in an artery supplying the epiphysis. In such cases occasionally osteomyelitis of more than one bone can occur almost simultaneously, and the diagnosis becomes correspondingly complicated.

In cases of acute osteomyelitis that remain untreated for many days, provided the resistance of the patient is sufficiently good to withstand the blood infection, the whole diaphysis may become a sequestrum by pus under pressure stripping up the periosteum on all sides. At other times, in similar circumstances, the pus bursts through the periosteum, and depending on the location, tracks among the muscles or becomes subcutaneous.

Owing to the firm attachment of the periosteum to the epiphysis and the inherent resistance of cartilage, subperiosteal pus is unlikely to invade a neighbouring joint, unless the epiphysial line is intra-articular, as is the case in the head of the femur, the upper end

of the humerus, the external malleolus, and the olecranon process. The most dangerous, as well as the most frequent, site for concomitant purulent arthritis is the hip-joint.

DISTRIBUTION OF THE LESION

	per cent		per cent		per cent
Tibia	35	Ulna	3	Metacarpals	1
Femur	25	Metatarsals	3	Frontal bone	1
Fibula	8	Ilium	1	Maxilla	1
Humerus	8	Pubis	1	Scapula	1
Calcaneus	5	Vertebræ	1	Clavicle	1
Radius	3	Patella	1	Ribs and Sternum	1

Clinical Features.—The incidence of acute osteomyelitis has diminished during the last decade. Probably this is due to the frequency with which antibiotics are used to treat respiratory and cutaneous infections, both of which are known precursors of osteomyelitis.

Age.—Eighty per cent of the patients are between the ages of 2 and 17 years; the highest incidence being between the ages of 10 and 11 years. Fifteen per cent occur in adults, and 5 per cent in infants under 2 years.

Seasonal Variation.—Acute osteomyelitis has a seasonal tendency. Cases due to *Staph. aureus* are more frequent in August and September than at other times of the year.

Period of Quiescence.—For an unknown period, estimated at under 12 hours, there is no pain; pain is not experienced until the periosteum becomes involved.

'Classical' Signs.—Following a boil or other infected cutaneous lesion, which may have escaped the mother's notice, the child exhibits general malaise, shivering, and severe pain situated in that part of a long bone that lies near a joint. Sometimes a history of trauma, usually minor, is forthcoming. On examination the temperature is raised above 100° F. (37·8° C.), (often to 102–103° F.), there is extreme tenderness over the affected metaphysis, and the nearby joint is sometimes the seat of an effusion. The intensity of the local signs varies inversely with the depth at which the inflamed bone is from the surface. Occasionally the general condition of the patient is so poor that the local signs are masked; nevertheless, unless the lesion is very deep-seated, tenderness can be elicited during a meticulous examination.

Fulminating cases with profound toxæmia, which in days gone by were common enough, especially in children dwelling in slum areas, are becoming less frequent owing to better nutrition and hygiene of the children of the working classes, as well as to early antibiotic therapy.

Summarizing: A febrile patient with pain and localized tenderness of a bone near a joint should be presumed to have acute osteomyelitis until it is proved otherwise.

Differential Diagnosis.—

1. *Acute Primary Suppurative Arthritis.*—While in this condition the maximum tenderness is over the joint—not close to it—it is sometimes extremely difficult to differentiate acute primary infected arthritis from osteomyelitis with secondary invasion of the joint.

A presumptive diagnosis of primary infected arthritis can be made when the pain and swelling is limited to the joint, and there is almost complete limitation of movement of the joint in question. The diagnosis may seem substantiated by aspiration of purulent fluid, and positive culture. However, too often it subsequently transpires that radiography shows typical changes of osteomyelitis in the metaphysial area of the bone. Pathological fracture is not an uncommon sequel in such cases if weight-bearing without a plaster cast is permitted. If doubt exists as to whether there is a primary lesion in the bone, it is far better to perform an exploratory operation.

2. *Rheumatic Fever.*—Although the pain of rheumatic fever usually flits from joint to joint, in a few cases it remains stationary in one joint. The cases that are especially difficult to differentiate from rheumatic fever are the ones when the patient has septicæmia, and more than one metaphysis is attacked. Aspiration of the joint in rheumatic fever yields a turbid fluid which has a high cell-count but will produce no growth on culture. There may be no detectable cardiac changes, but if acute rheumatism cannot be ruled out, electrocardiography is advisable.

3. *Tuberculous Osteitis* can closely resemble mild acute osteomyelitis. By the time the patient is brought for advice, X-ray changes in the bone are likely to be obvious, and a radiograph of the thorax may reveal a pulmonary lesion. Excision and biopsy of an enlarged regional lymph-node sometimes shows tuberculous inflammation, while a Mantoux or a Heaf's reaction is likely to be positive if the lesion is tuberculous.

4. *Syphilitic Periostitis.*—The commonest site is the anterior aspect of the upper third of the tibia, where visible and palpable swelling will be found. In contrast to acute osteomyelitis, radiographic changes will be evident at the time of the clinical onset of the disease.

5. *Acute Anterior Poliomyelitis.*—The overall picture is rather similar—an ill child with pain and loss of function of a limb. In anterior poliomyelitis the pain and tenderness is spread throughout the main muscular mass, whereas in osteomyelitis the tenderness is greatest on direct pressure or percussion of the bone.

6. *Malignant Neoplasm.*—This is often the greatest problem of all, for sarcoma and osteomyelitis can remain indistinguishable for a considerable time. In both conditions, if one waits long enough, there are destructive changes of the bone detected by radiography. Often the only certain proof of the diagnosis is an incision (which reveals an absence of pus) and biopsy.

Radiography shows no abnormality in early acute osteomyelitis. None the less, radiographs should be taken when the patient is first seen, for negative radiographs are valuable in assessing subsequent changes. In acute osteomyelitis correctly treated, the first radiographic changes are seen in approximately 21 days. The exception to the rule is in neonatal infections where radiographic changes occur rapidly (*see* p. 894).

Pathological Investigations.—

Blood Culture.—A specimen for blood culture should be taken before antibiotic therapy is commenced. The fact that some patients have been given antibiotic therapy already swells the number of negative cultures to about 60 per cent. In all cases a request is made for testing the sensitivity of the organism, if present, to antibiotics. If the blood culture is positive it should be repeated on alternate days, until negative. Usually, as a result of antibiotic therapy, this is attained in three days.

Leucocyte Count is usually raised, but shows such great variations that it is of little diagnostic assistance at the time it is required (J. Trueta).

Erythrocyte Count.—While often normal in the early stages of the disease, in severe cases it becomes reduced by the end of the first week. It should therefore be repeated in cases of septicæmia, for when reduced, blood-transfusion is beneficial.

Erythrocytic Sedimentation Rate.—This is elevated almost constantly in acute osteomyelitis, and serial tests are of signal value in estimating the progress of the case.

Sensitivity to Antibiotics (usually three days is required for the result).—If the organism is found to be a penicillin-resistant staphylococcus, or another penicillin-resistant organism, the antibiotic will, of course, be changed from penicillin to one to which the organism has been found to be sensitive.

TREATMENT

On Admission.—The patient is examined by the surgeon in charge of the case, and the site and the extent of the tenderness is noted with extreme care. At least 10 ml. of blood are removed by venepuncture for (*a*) culture ; (*b*) erythrocyte count ; (*c*) leucocyte count ; (*d*) sedimentation rate test. The affected part is immobilized with a splint that will permit re-examination without disturbing the patient.

Immobilization.—During the phase of acute inflammation perfect immobilization is required. For each limb, and for every joint, there is a position of optimum rest, viz. :—

Positions of Optimum Rest

Joint	Position	Joint	Position
Shoulder	Abduction 45° ; flexion 30° ; external rotation 15°	Hip	No abduction or adduction ; rotation nil ; flexion 20°
Elbow	Extended to about 100°	Knee	Flexion 15°
Forearm	Mid-prone-supine position	Ankle	Right angle or, in woman, a degree or so below
Wrist	Extension 15–20°		
Digits	All joints flexed about 25°. Thumb abducted and opposed moderately	Tarsal	Neutral as to inversion or eversion
		Toes	Maintain flexion of metatarsophalangeal joints and extension of interphalangeal joints
Spine	Normal curves maintained		

(*N. Capener*)

The splintage recommended at this stage is :—

For the tibia and fibula, or calcaneus a padded splint with foot-piece ; the splint should extend above the knee-joint.

For the bones of the forearm a padded splint extending from the palm to the upper third of the upper arm is adequate.

For the femur and for the humerus a Thomas's splint with moderate extension by means of an adhesive plaster stirrup cannot be bettered.

There is no contra-indication to the use of plaster-of-Paris splints, provided they are split to enable examination of the limb. In many instances these are preferable, because of the better immobilization they afford.

If feasible, the part is elevated.

Antibiotic Therapy.—Penicillin treatment, 500,000 units 12-hourly is commenced. In view of the increasing incidence of penicillin-resistant organisms, it is expedient to administer a second antibiotic (streptomycin, aureomycin or erythromycin) until the sensitivity of the organism becomes known ; usually this takes three days.

Restoration of Fluid Balance.—A high fluid intake must be assured. The aim is to ensure a moist mouth and skin, and an adequate output of urine of normal specific gravity and free from urates. If the general condition is good, the patient is encouraged to drink barley-water and water flavoured with fruit juice ; in toxic patients continuous intravenous dextrose-saline solution is administered slowly. A pint (475 ml.) of plasma given early during the first 24 hours is recommended as part of the fluid intake. Blood transfusion is indicated only if the blood examination shows a low hæmoglobin content or low red cell count.

Sedation.—Barbiturates are valuable for controlling anxiety. Pain is alleviated by morphine gr. $\frac{1}{6}$ (10 mg.), repeated if necessary in 6 hours, if the patient is a youth or an adult, while in children nepenthe, 1 minim for each year of age, is the narcotic of choice.

At the End of 24 hours.—The same surgeon re-examines the patient, noting particularly the 4-hourly temperature chart, the pulse-rate, and the result of the blood examination, in so far as the results are available. He then examines the tender area,[1] and unless the tenderness has decreased considerably in both extent and intensity from that of the previous examination (allowance being made for any narcotic that has been administered within 6 hours) the patient is prepared for operation under general anæsthesia.

Operation.—Wherever possible the use of a pneumatic tourniquet is advised. An incision is made over the area of maximum tenderness. The method of exposing each of the more commonly affected sites is described on p. 890. The periosteum is divided and the subperiosteal abscess is evacuated by suction, or mopped with dry swabs, not forgetting to collect a specimen of pus for bacteriological investigation.

Metaphysial Decompression.—To relieve the intramedullary tension three to four drill-holes through the cortex are made in the following way. The drills (three should be available) should be approximately $\frac{3}{16}$ in. (4·5 mm.) in diameter. If pus is encountered, the drill should be changed before another hole is made. If pus wells from the first drill-hole, which is made just below the metaphysis, a second drill-hole is made about $\frac{1}{2}$ in. (1·3 cm.) lower ; this is repeated until a site is reached where blood and not pus is encountered (*Fig.* 1235). If blood exudes from both the first and the second drill-holes, it is unlikely that pus will be located at a greater distance from the metaphysis. The tourniquet is then removed, bleeding vessels are ligated, and oozing points in the soft tissues are coagulated with a diathermy ; skin only is sutured without drainage. Drainage is not only unnecessary, but may be harmful by permitting secondary infection. The limb is then re-immobilized.

After Treatment.—Penicillin treatment[2] is continued for three weeks, unless the organism is penicillin-resistant, in which case the most suitable antibiotic, as revealed by sensitivity tests, is given for a like period. Five days later the wound is re-examined in the operating theatre, and a hæmatoma, if present, is aspirated. The stitches are removed on the tenth day, and unless there is some contra-indication, a complete plaster cast is applied. The

[1] In under 10 per cent of cases do the symptoms abate sufficiently to justify continuing with non-operative treatment. In a proportion of these cases recurrence of tenderness occurs ; it is therefore necessary to examine the patient twice a day for at least three further days.

[2] The return of the E.S.R. to a normal level is a useful indication as to when to conclude penicillin therapy.

cast is necessary because if, as is hoped, the operation succeeds in preventing involucrum formation, the bone is liable to fracture when weight-bearing is permitted.

The first positive radiograph is usually obtained about three weeks after the onset of the disease. Radiographic examinations are made at intervals, and on the findings it is judged when it is safe to discard the plaster cast.

By combining antibiotic therapy and early conservative operation, Professor Trueta has been enabled to report a series of 150 cases without mortality, without joint involvement,

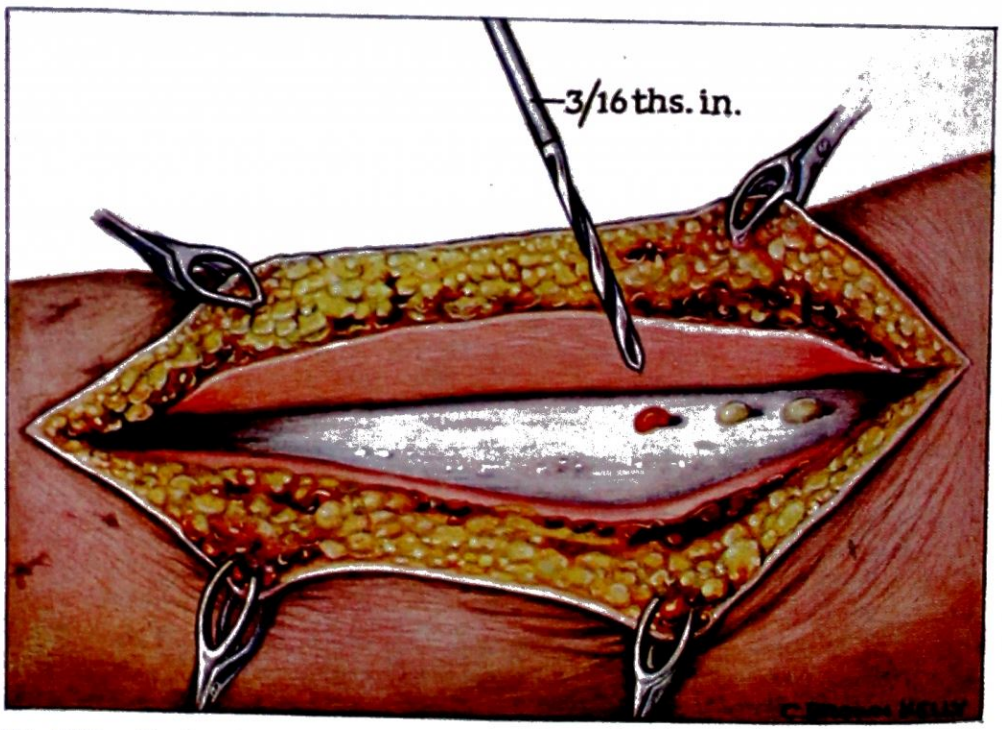

Fig. 1235.—Pus has been evacuated from beneath the periosteum. In this case deep pus is revealed by the first and second drill-holes, but blood only is exuding from the third drill-hole (i.e., the one farthest away from the metaphysis). (*After J. Trueta.*)

and with sequestrum formation in only 17. Twelve of the latter, though classified as sequestra, were merely periosteal fragments of dead bone that were removed easily.

Many cases treated by penicillin therapy and evacuation of pus without drilling the bone, after a certain period of quiescence show a recurrence of infection (Chigot and Polony).

METHODS OF DISPLAYING INDIVIDUAL BONES

Femur.—

Upper End.—The incision, about 8 in. long (20 cm.) commences above the upper third of the greater trochanter, and passes vertically down the lateral aspect of the thigh. The tensor fasciæ latæ is divided in the length of the incision. The plane of cleavage between

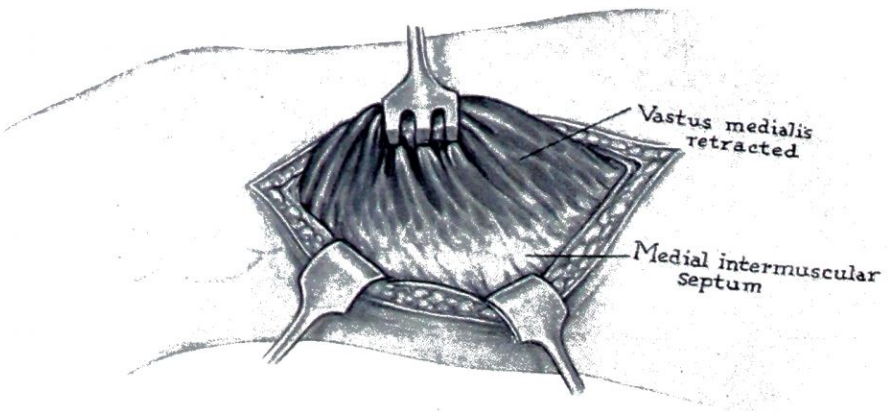

Fig. 1236.—Exposing the lower end of the femur from the medial aspect. (*After Banks and Laufman.*)

the rectus femoris and the vastus lateralis is found, and very few muscle-fibres need be cut to separate these two muscles and expose the bone.

The first drill-hole is made over the greater trochanter, and should be directed towards the head of the femur. After it has been made, if no pus exudes it is advisable to pass a probe through the cancellous bone towards the head. In one instance an appreciable amount of pus was evacuated by this expedient.

Lower End.—

Medial approach : The medial condyle is located and an incision passes straight upwards for 5 in. (12·5 cm.). The deep fascia is incised to expose the vastus medialis muscle. The medial edge of this muscle is freed by sharp dissection from the intermuscular septum. (*Fig.* 1236). The muscle can then be retracted laterally, exposing the periosteum. This exposure is simple and safe.

Lateral approach : A vertical incision is made immediately in front of the tendon of the biceps. Care must be taken not to open the suprapatellar pouch, which communicates with the knee-joint.

Tibia.—

Upper End.—An incision over the middle of the subcutaneous portion of the bone must be avoided rigorously, for it invites an adherent scar that is liable to interfere with the revascularization of the bone. A curved incision that slightly overlaps the crest of the tibia (*Fig.* 1237) affords ample exposure, and leaves a scar that cannot become adherent to the bone.

Lower End.—A similar incision is made overlapping the crest of the tibia.

Fibula.—The upper part or the lower part of the bone, as the case may be, is exposed through a lateral incision with retraction of the peronei anteriorly. One must be careful to preserve the integrity of the external popliteal nerve as it winds around the neck of the fibula when exposing the uppermost part of the bone.

Tarsal Bones.—With the exception of the os calcis, it is usually impossible to be sure which bone is affected. Guided by local tenderness, a dorsal incision is made pursuing a course between the extensor tendons ; this gives the best approach.

Os Calcis.—The os calcis, on the other hand, can be exposed readily through a medial or lateral incision, as the site of maximum tenderness dictates.

Clavicle.—The clavicle is displayed easily by an incision along its subcutaneous border.

The Scapula.—Make an incision over the spinous process, enlarging it downwards or upwards by an extension following the vertebral border, if necessary. In two cases where this bone was affected, pus was discovered under the periosteum in the infraspinous fossa.

Fig. 1237.—Incision for exposing the upper part of the tibia.

Humerus.—It is necessary to bear in mind the relationships of the radial nerve, and preserve this nerve at all costs. Whichever part of the bone is to be exposed, the skin incision follows the line between the tip of the coracoid process to the middle of the fold of the elbow. The patient lies with his arm by his side, supported by the operating table.

Upper End.—The incision commences at the tip of the coracoid process and extends downwards between the pectoralis major and the deltoid muscle for a distance of 5 in. (12·5 cm.). Much of the upper half of the shaft can be displayed by retracting these muscles. If the head of the humerus is to be uncovered, retraction of the deltoid is insufficient. A thin slice off the clavicle, removed with a hammer and chisel, will detach the origin of the deltoid and give full exposure (*Fig.* 1238 B).

Lower End.—The incision is made along a line connecting the middle of the antecubital fossa with the coracoid process ; it need only be 4 in. (10 cm.) long. Divide the deep fascia in the line of the incision. Identify the outer edge of the biceps. Split the brachialis longitudinally a finger-breadth from the outer edge of the biceps (*Fig.* 1238 A). *Instruct the assistant to flex the elbow*, and the humerus is readily accessible. The radial nerve is not seen.

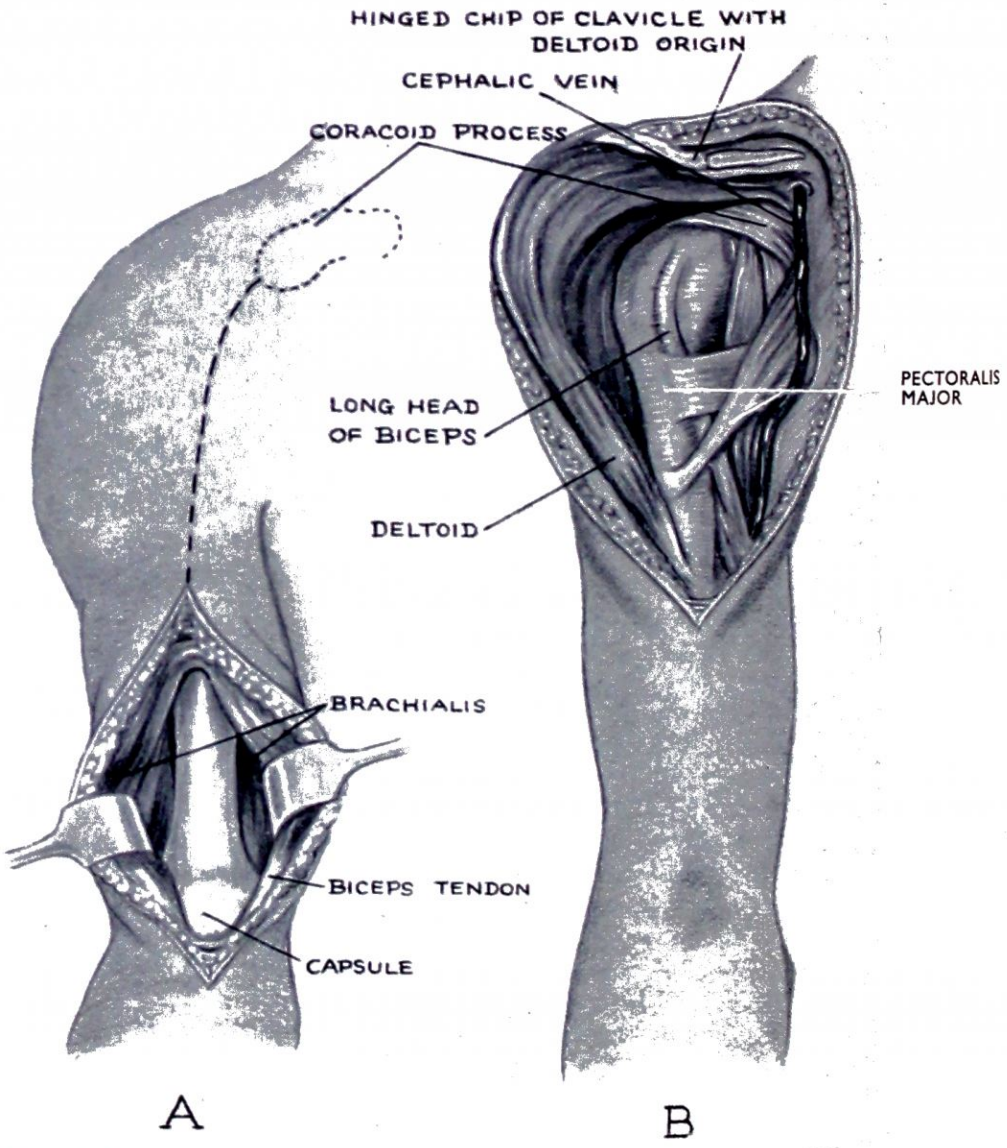

Fig. 1238.—A, Incision for exposing the lower end of the humerus by splitting the brachialis in the manner described. B, Incision for exposing the upper end. The head of the bone has been uncovered by removing a thin slice off the clavicle, from which the deltoid arises.

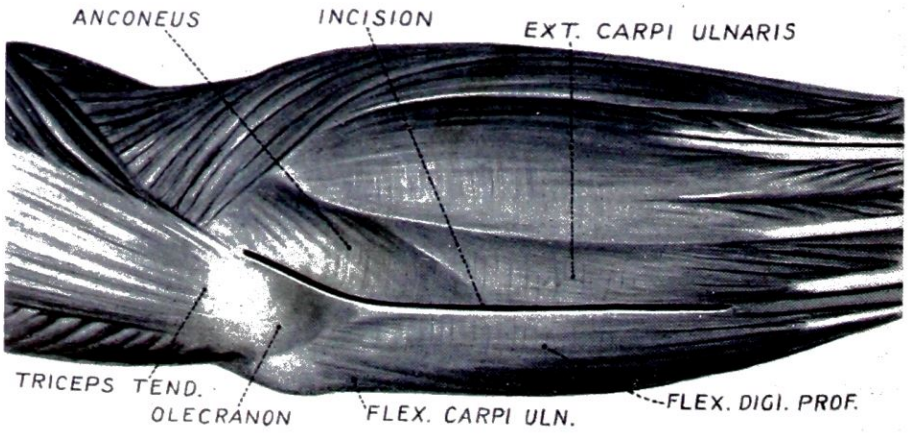

Fig. 1239.—Exposure of the upper end of the radius. Showing the line of the skin incision and the plane through which the ulna is reached. (*After H. B. Boyd.*)

Radius.—

The Upper End of the radius, on account of its thick muscular clothing, is comparatively inaccessible. This, however, is a minor difficulty. It is the possibility of injuring the posterior interosseus (deep branch of the radial) nerve which is the bugbear of the operation. H. B. Boyd explains that this nerve enters the forearm between the superficial and deep planes of the supinator muscle, and if the supinator is detached from its origin and elevated from the bone, the nerve is protected. The incision commences 1 in. above the tip of the olecranon on the lateral side of the triceps. It passes downwards, as shown in *Fig.* 1239, for about

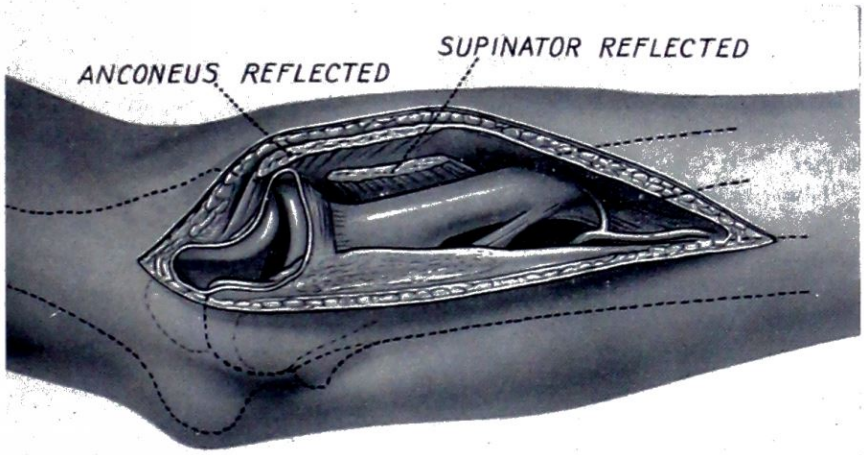

Fig. 1240.—The supinator having been detached from the ulna and swept aside, both the radio-humeral articulation and the upper part of the radius are displayed. If further room is necessary, the dorsal interosseous artery must be divided between ligatures. (*After H. B. Boyd.*)

7 in. (17·5 cm.). The incision is deepened on to the dorsal surface of the ulna and the muscles are elevated subperiosteally—a process which can be accomplished with ease. The supinator can now be identified and its deep fibres are divided as close as possible to the ulna. This muscle can now be peeled off the radius and when the muscles on each

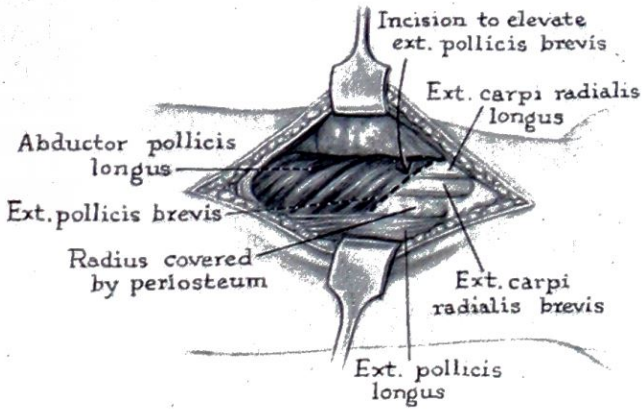

Fig. 1241.—Exposure of the distal fourth of the radius. (*After Banks and Laufman.*)

side are retracted, the radio-humeral articulation, the head of the radius, and the upper third of the shaft of the radius are in view (*Fig.* 1240). If further exposure of the radius is desired, the dorsal interosseous artery must be ligated and the muscular flaps reflected from farther down the bone.

The Lower End of the bone is the part usually diseased. To expose the lower end, a vertical incision is made over the dorsal aspect of the middle of the radius, commencing at the level of the wrist-joint and extending upwards for about 4 in. (10 cm.). The skin-flaps are undermined, and the deep fascia is incised, displaying the bellies of the abductor pollicis

longus and extensor pollicis brevis wrapped over the extensores carpi radialis longus and brevis. The incision is made through the fascia, as shown in *Fig.* 1241. After the bellies of the former muscles are separated from the latter tendons, the bellies are retracted upwards. This, combined with retraction of the tendons laterally, gives good access to the lower third of the radius.

Ulna.—The ulna, like the tibia, has a subcutaneous surface throughout its length. Consequently it is technically a simple bone to display.

Carpal Bones.—These are approached through a dorsal incision, and the extensor tendons are retracted suitably.

Frontal Bone.—(*See* p. 1072.)

SPECIAL FORMS OF ACUTE OSTEOMYELITIS

Acute Osteomyelitis in Early Infancy runs a rapid course. Too often the correct diagnosis is made late, after irreparable damage to the epiphysis and the neighbouring joint has occurred. The upper end of the femur is the bone most often attacked, and the hip-joint then becomes infected early. A normal temperature and the absence of a general reaction are often misleading; the infant shows so little systemic disturbance in spite of advanced local disease that over and over again the diagnosis of acute osteomyelitis is not entertained. The disease should be suspected if the infant is irritable and there is swelling and loss of function of an extremity; these are the outstanding symptoms, which are often confused with those of scurvy (D. W. Blanche).

The phalanges are not uncommonly affected, whereas in older children this is rare.

There is one facet which simplifies the diagnosis of acute osteomyelitis in the newborn. Radiographic changes occur rapidly, and are usually evident by the time surgical advice is sought.

Acute osteomyelitis in the newborn appears to be on the increase. In no less than 80 per cent of cases the causal organism is a penicillin-resistant staphylococcus.

Treatment.—While the administration of chlortetracycline (aureomycin) controls the toxæmia, the exhibition of this drug, or other broad-spectra antibiotics, in the newborn infant is liable to be followed by staphylococcal enterocolitis. On this account achromycin is recommended in these cases, but whatever antibiotic is employed, it should be discontinued as soon as the blood infection is controlled. Early operation is imperative. In cases of acute osteomyelitis affecting the upper end of the femur, splinting is important; full extension and abduction should be applied.

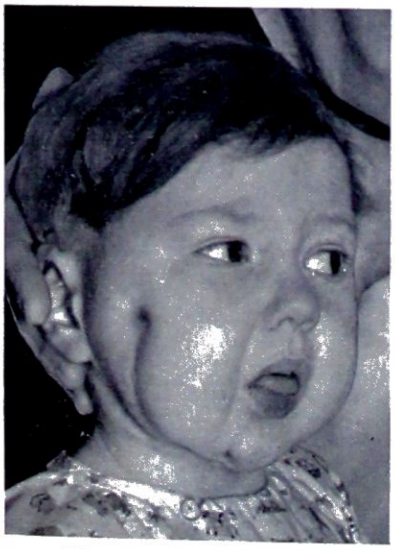

Fig. 1242.—Scars resulting from *not* draining acute osteomyelitis of the maxilla early into the mouth.

Acute Osteomyelitis of the Maxilla in Sucklings and Infants is an infection probably arising from a tooth follicle. The infection may proceed from the mother's breast, an attendant's fingers, or a feeding bottle, and the highest incidence is during the third week of life. Infection of the maxillary antrum, if it occurs, is secondary. The condition is essentially an acute inflammation of the maxilla with thrombosis of its nutrient vessels, followed ultimately by sequestration of necrotic bone and tooth follicles. Rarely does early antibiotic therapy prevent sequestration.

The first sign is the appearance of redness and swelling below the inner canthus. At this time the differential diagnosis between dacrocystitis and orbital cellulitis is difficult. Radiological investigation is of no value at this stage. The inflammation progresses until it reaches the alveolar margin. Before the infection has advanced so far, no time should be lost in incising the mucous membrane and the periosteum into the mouth, using an incision in no way differing from that of the Caldwell-Luc operation (*see* p. 1074); this will prevent visible scarring (*Fig.* 1242).

The second stage consists of multiple discharging sinuses into the mouth or, if not drained therein, on the cheek. This stage persists until sequestra are extruded or removed by operation. The final sequestrum is usually from the inferior orbital margin. In a number

of cases the causative organism is a penicillin-resistant *Staph. aureus*. Consequently treatment by a penicillin-streptomycin preparation, as advocated for osteomyelitis in the newborn, is also strongly recommended in this instance.

While the superior maxilla is most frequently attacked, the disease occurs occasionally in the mandible.

Acute Osteomyelitis of the Maxilla in Children and Adults.—The blood-supply of this bone is derived almost entirely from the internal maxillary artery, the branches of which form anastomosing loops. As a consequence, sequestra can form within one or more of these arterial arcades. However, if the internal maxillary artery itself becomes thrombosed, the entire upper jaw sequestrates, and bony regeneration is almost entirely absent. By vigorous treatment with antibiotics very early in the disease, sometimes operation can be avoided entirely, for resolution without sequestrum formation occurs. More usually a comparatively early incision above the alveolar margin through the periosteum is imperative. If left untreated, septicæmia, cavernous sinus thrombosis, or other intracranial complications are liable to ensue.

Osteomyelitis can occur from an extension of an alveolar abscess (*see* p. 829) in either the maxilla or the mandible.

Typhoid Osteomyelitis occurs nearer the centre of a long bone than the usual place (the metaphysis). Other bones frequently affected are the sternum and the ribs.

Paratyphoid Osteomyelitis attacks the lumbar spine in about 70 per cent of cases (R. Rozansky et al.).

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I have to thank Mr. Dennis Walker for many valuable suggestions connected with the revision of this chapter.

CHAPTER LXXVIII

JOINTS

SPRAINS

THE function of a ligament associated with a joint is to check excessive movement of that joint until the appropriate muscles come into action. A joint ligament is torn only when the violence is so sudden that the muscles cannot contract until it is too late to spare the ligament.

A sprain is a *partial* tear of a joint ligament. It is diagnosed by the complaint of pain, local swelling, and the elicitation of tenderness in the line of the ligament; sometimes bruising appears. X-ray examination to exclude bony damage is a wise precaution.

The commonest site for a sprain is the external lateral ligament of the ankle-joint. Lesions of this ligament will be described, and when necessary the principles involved can be applied to other joints. First of all it is highly important to determine that the injury *is* a sprain, and not a complete tear of the ligament. In the case of the external lateral ligament of the ankle-joint a complete tear always takes the form of avulsion of the ligament from its attachment to the fibula. In every relevant case the following test should be carried out, otherwise an avulsion of the lateral ligament is liable to be overlooked. The ankle is passively inverted, a manipulation which, if carried out slowly, does not cause much pain. If the ligament is avulsed tilting of the talus will become evident on the anterolateral aspect of the joint. In doubtful cases this finding can be confirmed or disproved by an X-ray examination while the surgeon holds the ankle in full inversion (Sir Reginald Watson-Jones). Avulsion of this ligament should not be classified as a sprain; it is treated as a fracture—indeed it is sometimes associated with a chip fracture of the external malleolus.

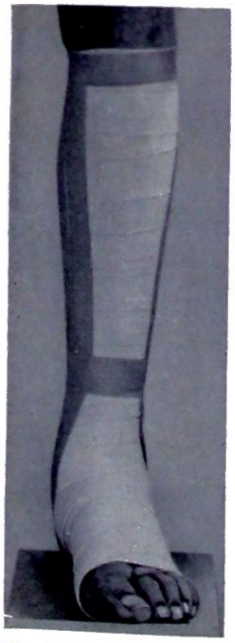

Fig. 1243.—Strapping a sprained ankle.

Treatment of a sprain depends upon the severity of the soft-tissue damage as assessed by a clinical examination.

Severe Cases.—If gross swelling and bruising are present, the limb should be elevated and a crêpe bandage applied firmly from the toes to the knee: the bandage is removed twice a day for massage. When the swelling has subsided a toe-to-knee plaster cast is applied, in which the patient is encouraged to walk. After three weeks the cast is removed, and a course of remedial exercises is given.

Less Severe Cases.—A toe-to-knee (including the heel) flexible adhesive bandage is applied, supplemented by zinc oxide adhesive strapping bands as shown in *Fig.* 1243; this support is retained for two weeks. The bands relieve the lateral ligaments of strain, and contribute greatly to the relief of pain. Weight-bearing is insisted upon from the commencement of this treatment, and the patient must be instructed to walk correctly: the surgeon is responsible for seeing that he does so, for a limp is liable to become a habit very difficult to eradicate. A course of exercises designed to use every muscle that activates the joint is embarked upon forthwith. These measures will prevent or reduce œdema which, if allowed to persist, so often results in periarticular adhesions. If this treatment is adopted there is very seldom need for manipulation of the joint under an anæsthetic.

Depending upon the severity of the injury, the bandages are dispensed with in two to three weeks.

In comparatively minor ligamentous tears the infiltration of 1 per cent procaine has been advocated so that activity can be resumed at once. Unfortunately, after 24 hours the pain often recurs with increased severity, and withal the practice is dangerous, for the pain is a warning that damage has been done and that further activity will result in increase of the injury (P. Lewin).

JOINT EFFUSIONS

An excess of fluid in a joint demands urgent treatment on diagnostic and therapeutic grounds. It is only by aspiration that a certain knowledge is obtained of the nature of the effusion and, as it is not uncommon for effusions to be temporary, if aspiration is not carried out when the opportunity presents, a cardinal diagnostic aid is thrown away. The presence of an excess of fluid in a joint is harmful because it stretches the ligaments, and if stretching is permitted to continue for even a few days, laxity of the ligaments will persist for a long time. Furthermore, if the effusion is of blood an irritative reaction of the joint occurs ; this is followed by synovial thickening, which frequently gives rise to prolonged and even permanent stiffness of the joint. Trauma to a joint frequently causes an effusion of blood or synovial fluid in excess, depending upon the degree of violence. In cases of a fracture involving a joint, frequently the fluid aspirated contains globules of fat which can be seen floating on the blood if it is placed in a shallow dish. A hæmarthrosis in the absence of trauma suggests general disease such as purpura or hæmophilia, and calls for scrutiny of the skin for purpuric spots and special laboratory examination of the blood (*see* p. 68). On the other hand, an excess of synovial fluid without trauma is particularly suggestive of tuberculous infection, and in such cases the pathologist should be asked to culture the specimen for tubercle bacilli, or perform a guinea-pig test.

Seropurulent or frankly purulent effusions occur in suppurative arthritis (*see* p. 904), and if pus is aspirated the diagnosis cannot be in doubt.

Aspiration of a Joint should always be carried out in the operating theatre with full aseptic precautions after preparation of the skin as for arthrotomy. Local anæsthesia is satisfactory in all cases except the hip-joint. It is possible to aspirate the hip-joint under local anæsthesia, but it is easier under general anæsthesia because of the depth of the joint from the surface and the consequent extensive area that requires infiltration. In all instances it is essential to render every layer of tissue, from the skin down to and including the synovial membrane, insensitive. Failure to do this may result in sudden muscular contraction as a result of pain with, possibly, fracture of the needle deep in the tissues, or even in the joint. To minimize this accident, after raising the preliminary intradermal weal, a large-bore intramuscular needle should be employed for the infiltration and a proper aspirating needle for the actual entry into the joint.

When introducing a hollow needle into a joint it will be found to be satisfactory to rely on a hollow needle alone, rather than a needle connected to an aspirating syringe. The needle by itself can be manipulated with greater delicacy. When the joint has been entered the intra-articular pressure is usually sufficient to force the fluid through the stem of the needle ; sometimes it takes a moment for thick pus to well up. When satisfactory entry is assured the aspirating syringe is connected with the needle.

After the aspiration the needle puncture is sealed with mastisol or collodion on a pledget of wool.

TECHNIQUE OF ASPIRATING VARIOUS JOINTS

(*Fig.* 1244)

Wrist-joint.—The radial styloid is palpated—this gives the line of the joint. The needle is entered between the tendons of the extensor pollicis longus and the extensor indicis, which are felt readily. The needle is directed forwards in an ulnar direction, and 45° in a proximal direction.

Elbow-joint.—Flex the elbow to a right angle. Ascertain the position of the head of the radius. Insert the needle from the posterolateral aspect above the head of the radius, which serves as a guide. Alternatively when the joint is much distended it can be entered on either side of the olecranon.

Shoulder-joint.—The coracoid process is palpated readily in the delto-pectoral interval below the clavicle. The needle is entered ½ in. (12 mm.) below and ½ in. medial to the tip of the coracoid, and directed backwards with a lateral inclination of 30°. It will then enter the inferior part of the shoulder-joint, where there is a loose pouch of synovia and capsule.

Ankle-joint.—The line of the joint is ascertained by palpation and, when possible, by movement of the foot on the tibia. Choosing a point on this line just medial to the lateral malleolus, the needle is directed backwards and slightly downwards, so as to strike the interval between the tibia and the talus.

TECHNIQUE OF ASPIRATING VARIOUS JOINTS

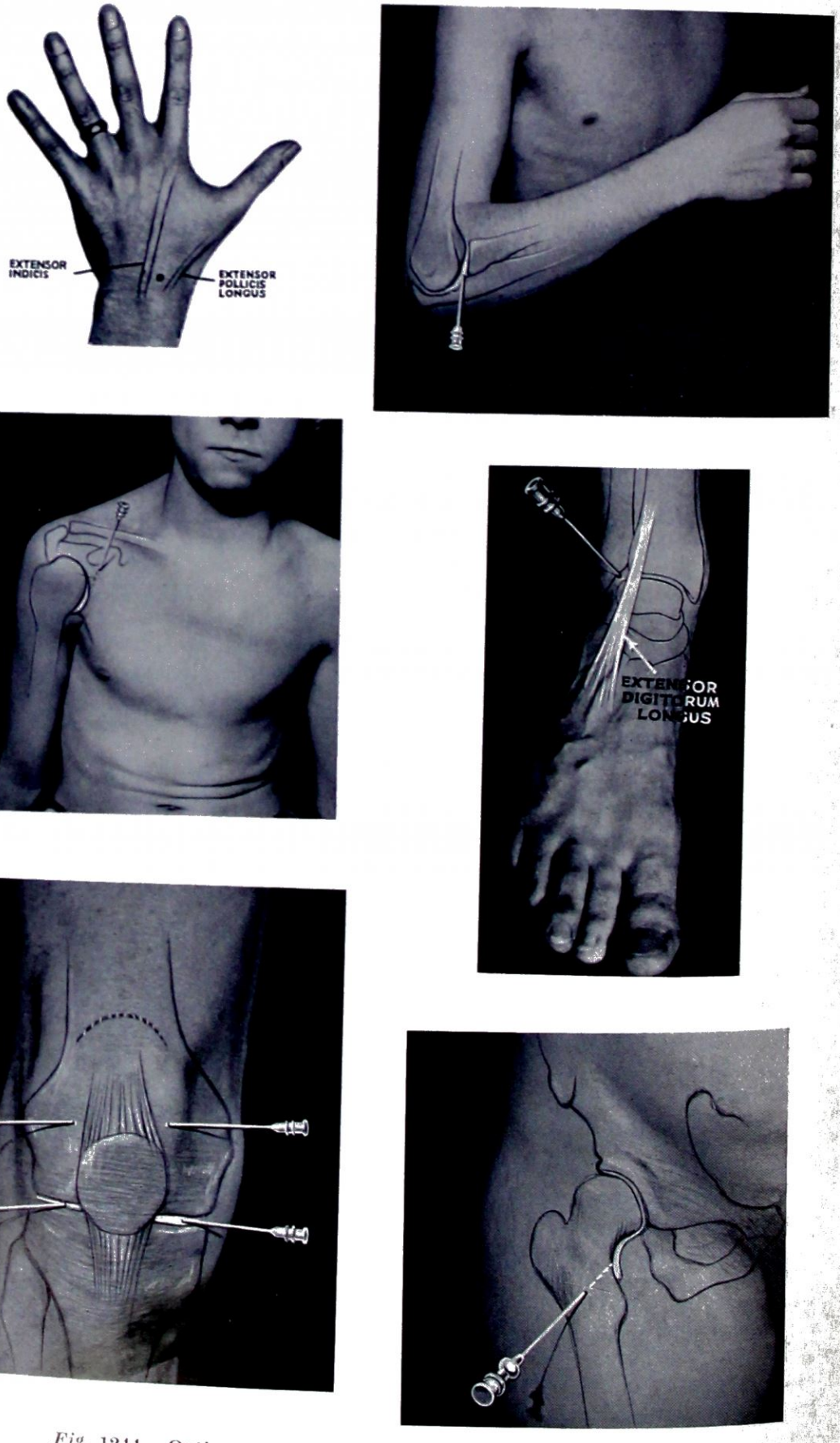

Fig. 1244.—Optimum site of puncture for aspirating certain joints.

Knee-joint.—When, as is frequently the case, the effusion into the suprapatellar pouch is evident, the needle can be introduced just medial or just lateral to the upper border of the patella. Entry into the suprapatellar pouch is easy and safe. The alternative route, directing the needle into the joint on one or other side of the lower pole of the patella, is more difficult and is capable of causing damage to the articular cartilage.

Hip-joint.—The hip-joint is the most difficult joint into which to insert a needle. A lumbar puncture needle is the best type of needle to employ. Palpate the greater trochanter and refer to the anteroposterior radiograph in order to ascertain the line of the neck of the femur. The needle is inserted into the anterolateral aspect of the thigh opposite the lower edge of the base of the neck of the femur. The needle is directed inwards, slightly upwards, and parallel with the lower aspect of the femoral neck. It may be necessary to manipulate the point of the needle several times before a satisfactory entry is assured.

Alternative Method.—The femoral artery is palpated 1 in. (2·5 cm.) below the inguinal ligament, and the needle is inserted directly backwards lateral to the artery. When the femoral artery is impalpable, a point 1 in. below and 1 in. lateral to the mid-inguinal point is chosen. The needle is pushed through the capsule into the cartilage of the femoral head. To prove that this is the case, the thigh should be rotated externally slightly, whereupon the hilt of the needle will move medially. Very slight withdrawal of the needle, to allow the bevel to emerge from the cartilage, will permit aspiration or injection of fluid into the joint.

DISLOCATIONS

For a dislocation to occur, considerable violence is required ; the capsule and at least one of the ligaments of the joint must be torn before the articular surfaces can come apart. If this extensive damage is borne in mind, the folly of allowing free movement after reduction is apparent. A period of rest for the joint is essential to allow these torn structures to heal and to unite at the correct tension.

At the time of the first examination, a careful search must be made for an associated fracture, a nerve injury, or a vascular lesion. Their absence must be recorded, and the presence of one or more of them not only be recorded, but also should be brought to the patient's notice at once. Failure to heed this injunction may result in the surgeon being held responsible for the occurrence of one or other of these complications, which it is alleged occurred at the time of the reduction of the dislocation.

When facilities are available the diagnosis should be checked radiologically, but when this diagnostic aid can be obtained only after considerable delay, the dislocation should be reduced and X-ray confirmation of reduction sought afterwards. This advice is based firstly on the fact that the injury is a very painful one, and secondly on the belief that the sooner the soft parts are returned to their proper position, the more rapid and complete is the return of function. If pre-operative X-rays are dispensed with, the reason for this step must be explained to the patient.

After reduction a further examination is made to determine the presence or absence of any nervous or vascular lesion, and these findings are again recorded.

Anæsthesia is not always necessary, particularly in the case of the shoulder. When anæsthesia is employed, it should be preceded by appropriate premedication, and carried out as though a major surgical procedure was contemplated, with due regard to the time of the last meal. The ' whiff of gas ' and kindred light anæsthetics are dangerous. Either full anæsthesia or none at all must be insisted upon.

SHOULDER-JOINT

(*Fig.* 1245)

Anterior Dislocation.—Usually anæsthesia is not required. If properly employed, Kocher's method of reduction is excellent. It depends upon tiring out the contracted subscapularis until that muscle relaxes and permits the other muscles which activate the shoulder-joint to reduce the dislocation. The patient lies on a couch, and he is told that no violent manipulation is contemplated. By talking to him sympathetically a considerable degree of relaxation is obtained. This relieves pain, and allows further relaxation. The elbow on the affected side is then grasped and gentle, strong, and steady traction is applied in the axis of the humerus (*Fig.* 1246 A). This brings the head of the humerus down to or below the level of the glenoid. With his other hand the surgeon grasps the wrist of

the affected limb, and very slowly rotates the arm externally (*Fig.* 1246 B). This movement must be performed very slowly and gently, and must not evoke the slightest wince from the patient. It may take five minutes. Usually as the limit of external rotation is reached the head of the humerus glides into position, and such should be the surgeon's control that the patient is unaware of the precise moment of reduction. If reduction does not occur at this stage of the manipulation, the elbow is carried towards the patient's umbilicus and the humerus is rotated internally by placing the patient's hand on his opposite shoulder (*Fig.* 1246 C); this additional manœuvre frequently accomplishes reduction.

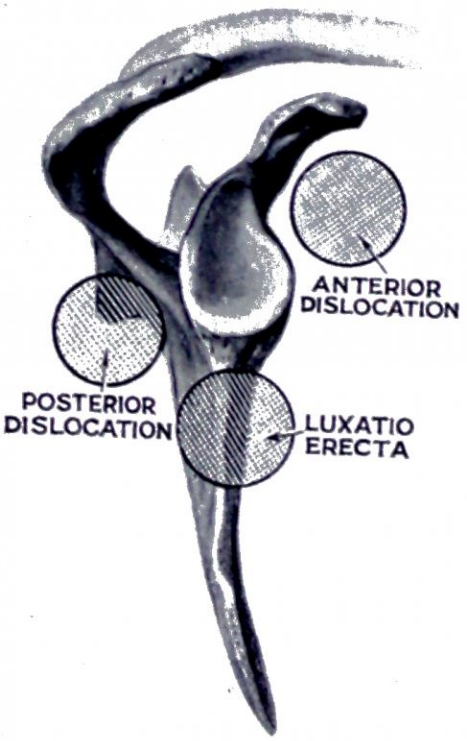

Fig. 1245.—Dislocation of the shoulder-joint.

The Method of Hippocrates.—If Kocher's manœuvre fails to reduce the dislocation at the first attempt, and the dislocation is recent, the following method is bound to succeed. With the patient lying on his back, the surgeon removes his own right shoe for the right shoulder and his left shoe for the left shoulder. He then grasps the wrist with both hands, and places his stockinged foot against the ribs close to the axilla. The patient's arm is carried slightly inwards, so that the surgeon's foot abuts the head of the humerus, which is levered outwards, and is thus guided into the glenoid fossa. While traction and leverage are being maintained, the limb is rotated externally. Performed as here described, nerve or arterial injury cannot occur.

Complications of a Dislocated Shoulder-joint.—Regarding nerve injuries, these are much more likely to occur as a result of the dislocation than from skilful manipulations to reduce the dislocation. Before reduction is attempted, 7 per cent of patients with a dislocated shoulder have a nerve lesion, usually of the circumflex nerve. By laying one hand upon the deltoid, and asking the patient to attempt abduction against the resistance of the surgeon's other hand placed over the patient's elbow, the integrity of the deltoid can be tested without the patient moving his arm.

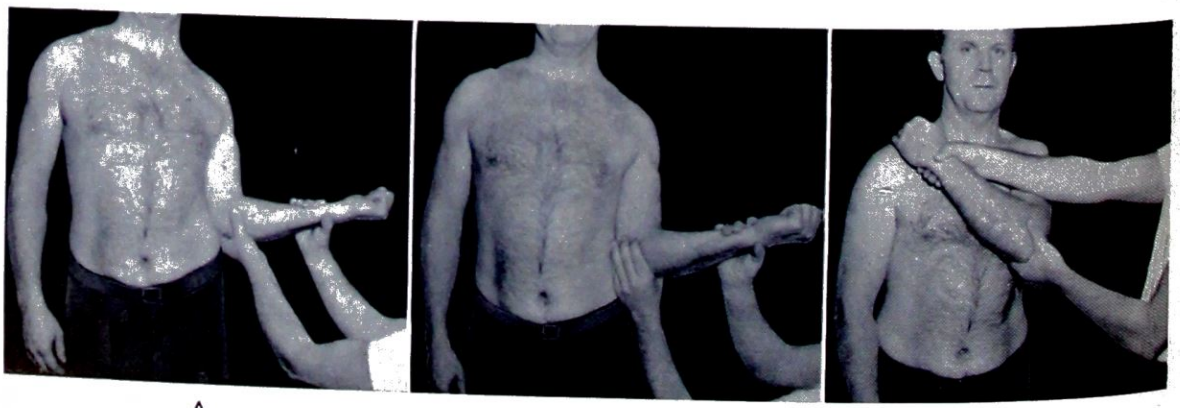

Fig. 1246.—Kocher's method for reduction of a dislocated shoulder. (*Mr. F. P. Fitzgerald.*)

When reducing a dislocated shoulder the utmost gentleness is essential, for it is possible to fracture the shaft of the humerus by rotation in Kocher's method.

The late George Stephen encountered a case where an arteriosclerotic artery was torn during reduction of a dislocated shoulder.

After reduction, the integrity of the supraspinatus tendon is demonstrated by asking the patient to abduct his arm about 45°. Having demonstrated the integrity of this muscle, a collar-and-cuff sling is applied, a sheet of wool placed between the arm and the trunk,

and the limb bound to the side for three weeks. The hand and wrist are exercised frequently, but the limb must not be rotated externally. At the end of this period active exercises are employed until full movements of the shoulder-joint are regained.

If the complication of ruptured supraspinatus tendon is recognized immediately and the limb is immobilized in an abducted, externally rotated position on a frame, recovery is usually secured without operation.

Posterior Dislocation is uncommon, easily overlooked, and is prone to occur in elderly persons. One sign which helps in diagnosis is unusual prominence of the coracoid. In this injury the posterior part of the capsule is torn. Reduction is carried out by traction and external rotation (as in Kocher's method), but after reduction the limb must be immobilized for three weeks in a plaster spica with 45° abduction and full external rotation at the shoulder.

Luxatio Erecta.—This very rare injury is reduced by upward traction on the limb, which is afterwards immobilized in a collar-and-cuff sling, as for an anterior dislocation.

ELBOW-JOINT

The common dislocation consists in a backward displacement of the forearm bones, and may be accompanied by avulsion of the medial epicondyle with lesions of either or of both the median and ulnar nerves. Obstruction of the brachial artery may also occur. Whether one or more of these complications is present must be ascertained before reduction of the dislocation. An anæsthetic is required and gentle, sustained traction is applied to the forearm in the position in which it lies. As the forearm bones are frequently displaced laterally as well as backwards, local pressure is applied in a medial direction. The dislocation is reduced without difficulty. Post-operative radiographs should be taken to confirm reduction and to show the position of the medial epicondyle. This has its own centre of ossification which appears at the age of 7 years and fuses with the humeral shaft at the age of 17 years. Between these ages the medial epicondyle may be avulsed, and during reduction it is possible for the detached epicondyle to become entrapped within the joint, from whence it can be withdrawn often only by operative means. Special regard should be paid to the radiograph to be sure that the medial epicondyle lies in its correct anatomical position. A collar-and-cuff sling is then applied (*Fig.* 1247) and retained for three weeks, after which movement is regained by active exercises. Myositis ossificans need not be feared in recent dislocations if a three weeks' period of rest in a collar-and-cuff sling is insisted upon.

Fig. 1247.—Arm in a collar-and-cuff sling. This is made of green flannel bandage, and is sewn closely around the wrist, so that the hand cannot slip out.

METACARPO-PHALANGEAL JOINT OF THE THUMB

Gently hyper-extend the thumb and push the base of the proximal phalanx over the head of the metacarpal. After reduction a plaster cast is applied to immobilize the joint for three weeks. On rare occasions reduction is impossible because of interposition of a portion of the capsule, or the short thumb muscles. Open reduction is then necessary.

HIP-JOINT

(*Fig.* 1248)

Lay the fully anæsthetized patient on blankets on the floor and instruct an assistant to fix the pelvis by downward pressure of both anterior superior iliac spines. Grasp the affected limb and lift it by the knee, so that the long axis of the femur points towards the ceiling. Flex the knee to a right angle and correct any rotational deformity present. Then, with the fingers interlocked beneath the lower half of the popliteal space, apply upward traction on the thigh (*Fig.* 1249); the essence of reduction lies in the vertical lifting of

the femur. It should be noted that this method applies equally to anterior and posterior dislocations, for flexing the thigh and placing it in neutral rotation results in the head of the femur passing to the postero-inferior aspect of the acetabulum. A forward thrust is then all that is required to effect reduction.

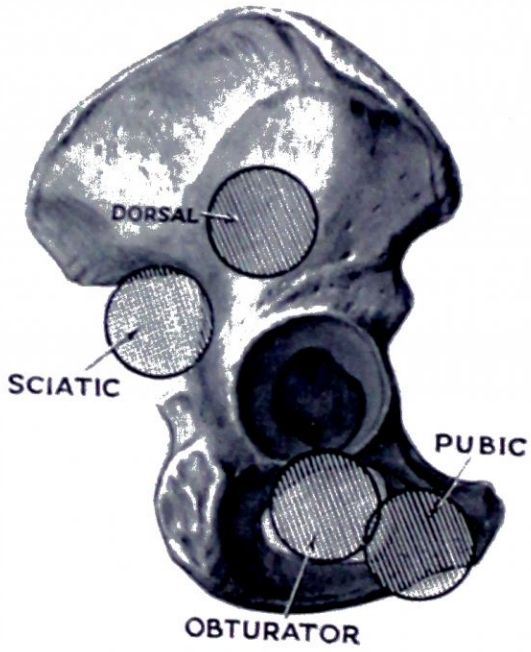

Fig. 1248.—Dislocations of the hip-joint.

Occasionally, when reduction has been accomplished, redislocation occurs as soon as the thigh is extended. The reason for this is that in addition to the dislocation a large fragment of the rim of the acetabulum was detached at the time of the accident. Sometimes redislocation can be prevented by maintaining traction while the limb is extended, and continuing to exert traction until a hip spica has been applied. When this expedient fails, the only effective treatment is to perform, in due course, open reduction with internal fixation of the fragment to its bed.

In every case of dislocation of the hip-joint radiographs should be taken after reduction, not only to confirm reduction, but to exclude fracture of the rim of the acetabulum.

Immediate After-treatment.—The joint is immobilized by applying a plaster hip spica.

Although the hip-joint would appear to be an inherently stable joint, this is not the case, and immobilization for ten weeks is required to enable torn capsule to heal and overstretched muscle to recover. If the rule of ten weeks' immobilization in a plaster cast is adhered to, the complication of myositis ossificans is extremely rare.

Remote After-treatment.—After the plaster cast has been removed, movement of the joints is regained by active exercises. Weight-bearing is permitted only when the

Fig. 1249.—Method of reducing a dislocation of the hip.

muscles that activate the joint, especially the abductor group, have become plump and firm.

In about 10 per cent of cases avascular necrosis of the head of the femur is inevitable, owing to tearing of the ligamentum teres and the anastomotic branches that nourish the head. Osteo-arthritis is a common sequel.

THE KNEE-JOINT

While dislocation is rare, subluxation due to rupture of one or both cruciate ligaments is common. When seen early, the diagnosis is obvious. A little later effusion renders immediate recognition more difficult. When needed, preliminary aspiration of the joint is advised.

Reduction is effected by extension with traction and direct pressure on the bones. The joint should be immobilized in a plaster cast in slight flexion for three months, followed by appropriate remedial exercises. Instability due to failure of one or both crucial ligaments to unite is not uncommon.

Manipulation of a Locked Knee (Displaced Meniscus).—Full anæsthesia is recommended, when frequently the displaced fragment of cartilage goes back into position at the first movement of the knee. When this is not the case, the surgeon manipulates the knee in an endeavour to open the medial aspect of the joint, which gives an opportunity for the displaced fragment to be released from its entrapment between the medial condyle and the tibia. When this manœuvre is not followed by the characteristic ' snap ' followed by a free range of movement of the joint, operation in due course is indicated.

PENETRATING WOUNDS OF JOINTS

Operation in the case of a penetrating wound of a joint is very urgent ; only by early operation as well as by antibiotic therapy can suppurative arthritis and its crippling aftermaths be prevented or minimized. The exception to this rule is a recent puncture by a fine, comparatively clean object, such as a needle. In such a case the object, if still present, is removed, the joint is immobilized in the position of rest, and systemic penicillin is administered. As a rule a transitory effusion occurs, which subsides in two or three days. Should this not be the case, the directions for the conservative treatment of suppurative arthritis (*see* p. 906) are followed.

Diagnosis.—Any wound in the vicinity of a joint should be presumed to communicate with that joint until the contrary has been proved. Certain dislocations, e.g., of an interphalangeal joint, are at times associated with tearing of the skin as well as the joint capsule. Compound fracture-dislocations are fairly common at the ankle. If penetration of a joint is present, or is suspected, the patient should be informed, and warned of the possibility of some permanent reduction in the range of movement in the joint. An X-ray examination is valuable, even if only to exclude the presence of radio-opaque foreign bodies.

First-aid Treatment.—The wound should be covered with a sterile dressing or a clean cloth, and the part splinted.

Pre-operative Treatment.—The patient should receive antitetanic serum 1500 units, and penicillin, 500,000 units intramuscularly, together with pre-operative medication. When necessary, operation is delayed until shock has been treated adequately. In view of the limited exposure it allows, local anæsthesia should be avoided. Brachial block anæsthesia (*see* p. 936) is acceptable in the upper limb, but general anæsthesia is to be preferred in all cases. However trivial the wound appears, if there is a possibility of penetration of the joint, preparation should be made for a major operation.

Operation.—The directions for obtaining swabs of the interior of the wound for bacteriological examination, culture, and sensitivity to antibiotics, the preparation of the skin, and the excision of the wound, do not differ from those described on p. 134, except in the following particulars : the sterile towels are so arranged and fixed with towel clips that the joint can be put through its full range of movement without uncovering unsterile parts. Having excised each layer of the wound, when the joint capsule is displayed the fact that it has been penetrated can be confirmed. The damaged capsule and synovial membrane are excised. When retraction of the superficial tissues and the muscles does not give a sufficiently clear view of the joint, the wound must be enlarged suitably. Gross fragments of dirt and other foreign matter are picked out of the joint with dissecting forceps.

Should foreign matter be embedded in bone or cartilage, it is disimpacted gently with a curette. All visible foreign matter having been removed, the interior of the joint is irrigated with saline solution. A most useful method of being enabled to direct a fine stream of the solution into every nook and cranny of the joint is to inject the fluid with a Higginson's syringe to which has been fitted a Eustachian catheter, instead of the usual nozzle. After thorough irrigation the synovial membrane is closed with fine interrupted catgut stitches. If the capsule can be brought together without undue tension, and the case is an early one, the capsule is included in these stitches. Closure of the joint being completed, 1,000,000 units of penicillin are injected into the joint cavity. If the capacity of the joint is too small to take the whole of this dose, sufficient of it to fill the joint is injected. The remaining steps of the operation depend upon the interval between the time of wounding and the time of operation :—

Less than 6 *hours* : The skin should be sutured. If the skin deficiency is considerable, proceed as described on p. 138.

More than 6 *hours* : The skin must not be sutured. The wound is packed lightly with sterile petroleum-jelly gauze.

In all cases splintage is essential. A plaster cast, which is split completely to permit swelling of the part, is usually the most convenient form of splint.

After-treatment.—Penicillin therapy in doses of 500,000 units 12-hourly is continued until the wound has healed. If organisms that are insensitive to penicillin are recovered, appropriate change to another antibiotic is made. On no account should the wound be inspected in the ward, where every dressing is a potential source of infection or reinfection: all such inspections must be carried out in the operating theatre. When the wound has been closed and there are no untoward signs to indicate that all is not well with the wound, the first inspection is on the tenth day when the stitches are removed. When the wound has been left unsutured it is examined on the fifth day, and if it is clean, delayed closure is carried out. When the wound is found to be infected it is lightly repacked, and is re-examined after a further interval of 5 days, when a decision is made whether to continue with packing or to undertake secondary closure. Splintage is retained until the skin wound has healed. When the joint is painless and the overlying skin feels cool, the splint is removed for a short period and movements are permitted. If no reaction in the joint follows, the splint is discarded and movements are regained with the help of active exercise.

Should infection of the joint supervene, it is treated as described in the section on acute suppurative arthritis that follows.

ACUTE SUPPURATIVE ARTHRITIS

Usually a purulent exudation into the cavity of a joint is caused by a hæmolytic staphylococcus or a hæmolytic streptococcus ; less frequently a pneumococcus is responsible, and rarely the meningococcus or another organism. Infection occurs in one of three ways :—

1. Via the blood-stream.
2. By direct introduction of infection through a punctured or lacerated wound.
3. By invasion from a purulent compound fracture or from osteomyelitis of a bone contiguous with the joint.

Local Signs and Symptoms of acute suppurative arthritis include pain in the joint, which increases in severity as the joint capsule becomes distended, limitation of movement, swelling, and redness of the overlying skin. Most of the joints of the body (the hip-joint being a notable exception) are sufficiently superficial to allow local signs to be detected fairly easily. When a joint becomes acutely inflamed it takes up the position of greatest ease, which is, in fact, the position of greatest joint capacity. The position of greatest ease is in sharp contrast to the position that is most useful should ankylosis supervene.

The general signs, especially in cases of blood-borne infections, are typically those of severe toxæmia with a swinging temperature reaching to 102° F. (38·9° C.) or more. There are, however, numerous exceptions, especially in old age and in infancy. For instance, D. W. Rose reviewed 18 cases of acute suppurative arthritis of the hip-joint in newborn infants. In 5 of these, all premature infants, the diagnosis remained unrecognized until a swelling of the buttock or thigh, or both, appeared. A high temperature was present in only 2 of these patients. At any time of life, when infected arthritis complicates septicæmia the profundity of the toxæmia may overshadow the early local manifestations in the affected joint.

Joint	Position of Ease	Site of Maximum Swelling	Position for Ankylosis
Wrist	Slight flexion	Under extensor and flexor tendons	Dorsiflexed to allow a firm grasp
Elbow	Flexed at a right angle and pronated	On either side of triceps tendon	90° of extension semi-pronated. If both sides involved, position of one side modified according to occupation
Shoulder	Adducted	Under the deltoid, along the tendon of the biceps, and in the axilla	45° of abduction, and just anterior to the coronal plane, and hand in front of mouth
Hip	Flexed, abducted, and externally rotated	Upper part of Scarpa's triangle	20° to 30° of flexion to allow sitting, and in neutral position as regards abduction
Knee	Flexed	Suprapatellar pouch, and either side of patellar tendon	5° to 10° of flexion to allow foot to clear ground
Ankle	Slightly extended and inverted	Anteriorly and on either side of the tendo Achillis	At a right angle, with slight inversion to discourage flat-foot

Differential Diagnosis.—

Acute Osteomyelitis is sometimes difficult to distinguish from acute suppurative arthritis; moreover, acute suppurative arthritis is not an uncommon complication of acute osteomyelitis of the upper end of the femur. This subject is discussed fully on p. 887.

Acute Arthritis accompanying Bacillary Dysentery is especially liable to follow infection by the Shiga bacillus, and usually the larger joints such as the ankle or the knee are attacked. The comparatively late onset of the arthritis distinguishes it from a serum reaction, if serum has been employed. Fluid aspirated from a distended joint will agglutinate the dysentery bacillus. With aspiration, if necessary repeated, complete resolution usually occurs, but in severe cases some degree of fibrous ankylosis is liable to result.

Reiter's Disease (non-specific urethritis with arthritis and often conjunctivitis).—Multiple arthritis is a usual feature of this syndrome. The joints most commonly involved, in order of decreasing frequency, are the knees, ankles, wrists, shoulders, spine, and hips. The joints are hot, swollen, tender, and acutely painful, especially when moved; the overlying skin often becomes reddened. Occasionally a pneumococcal-like organism has been isolated from the synovial fluid. This infection is resistant to all antibiotics.

Gonococcal Arthritis.—The usual form of arthritis following gonorrhœa is identical with that following non-specific urethritis. When the gonococcus cannot be found in the urethral discharge, a positive complement-fixation test of the serum or the joint fluid clinches the diagnosis. A response to systemic penicillin is usually complete and prompt. In the occasional penicillin-resistant case, combined aureomycin and streptomycin has proved successful.

Rheumatic Fever.—The most characteristic feature of this arthritis is that the pain flits from joint to joint, and the arthritis is always multiple. The disease involves the larger joints. Signs of cardiac involvement are usually manifest.

Diagnostic and Therapeutic Aspiration must always be undertaken in the operating theatre. That the synovial fluid is purulent, semipurulent, or hazy clinches the diagnosis of infected arthritis there and then. In these circumstances as much of the synovial fluid as possible is aspirated, and 1,000,000 units of penicillin are injected into the joint. In the case of a small joint this amount could not be accommodated, and the joint is filled to capacity. A generous sample of the aspirated fluid is sent to the bacteriologist with the usual request for isolation of the organism or organisms present, and their sensitivity to antibiotics. What is also highly important is to send a specimen of the patient's blood for culture at the same time.

Splintage.—The joint is splinted in the best position for ankylosis, should it occur. Plaster splints are convenient in many situations. A Thomas's splint is adequate for the knee-joint, and can be used for the hip-joint if skin traction is applied to the leg.

Notwithstanding, the most desirable method of immobilizing the hip-joint is by means of a Robert Jones abduction frame.

General Treatment.—

1. Penicillin, 500,000 units, is given 12-hourly for three weeks, unless the bacteriological report indicates that another antibiotic should be substituted.

2. An adequate fluid intake is essential. If this is not possible orally, dextrose-saline is given intravenously until the patient is able to take sufficient fluid by mouth. In cases of septicæmia blood transfusion or an exchange transfusion is often indicated.

3. Rest is vital, and pain should be relieved by morphine.

Local Treatment.—

1. The joint is aspirated daily and 1,000,000 units of penicillin, or an appropriate dose of such other antibiotic as the culture indicates, is injected.

2. When the joint is infected because of a penetrating wound or an open fracture that communicates with the joint, general surgical principles demand adequate toilet of the wound, and skin cover as soon as the underlying tissues present a healthy appearance.

Radiological Examination.—Periodic radiographs are desirable with a view to demonstrating local bony changes or the development of a pathological dislocation, both of which are to be regarded as evidence of inadequate treatment.

When Therapeutic Aspiration with Antibiotic Therapy bids fair to control the Disease.—In the majority of cases the treatment detailed above brings about a favourable response, as shown by lessening of the toxæmia, a fall in the temperature, and progressive relief of pain in the joint. The effusion decreases in amount, and becomes less obviously purulent. Aspiration of the joint and intra-articular injection of an antibiotic can cease when the effusion is small and is sterile on culture. Parenteral antibiotics are continued for three weeks. When the joint is cool and painless, and there is no pyrexia and no muscle spasm, splintage is discarded. If this does not result in a recrudescence of symptoms, active exercises are commenced to restore joint movement and muscle bulk and tone.

When Therapeutic Aspiration and Antibiotic Therapy prove insufficient to control the Disease.—The problem is an onerous one. The first consideration is to save the patient's life; a secondary matter is, if possible, to preserve the limb, taking into consideration that a varying degree of ankylosis or a flail joint is a foregone conclusion.

What not to do: Experience of the second world war and the Korean war proved, as earlier experience had indicated, that thorough continuous drainage of a joint is not feasible. Incisions for draining a joint serve only as avenues for overflow; the intra-articular suppuration persists, often with continuing proteolytic digestion of articular cartilage. Continuous drainage of fluid from a joint is contra-indicated for other reasons:—

1. An open wound of the joint is liable to become secondarily infected.

2. The nutrition of the articular cartilage is reduced by the continual loss of synovial fluid.

3. Dense intra-articular adhesions are almost inevitable.

4. The antibacterial action of the synovial fluid, if any, is lost.

Modified Arthrectomy.—In post-traumatic suppurative arthritis the nidus of persistent infection is almost always devitalized articular cartilage. It is safe to assume that in cases of acute hæmatogenous infection that show little or no response in four days to therapeutic aspiration combined with local and systemic antibiotic therapy, the articular cartilage is irreparably damaged. Experience, particularly military experience, has proved that excision of devitalized tissue within the joint—usually articular cartilage—followed by closure of the synovia, is the treatment of election in comparatively early cases of suppurative arthritis which fail to respond to therapeutic aspiration with antibiotic therapy, or where therapeutic aspiration is inapplicable. Should the damage be found to be so extensive as to preclude future function, morbidity can be reduced and the best possible function obtained by a more formal resection of the joint.

Whichever technique is employed, the operation should be performed promptly, because the hyaline component of articular cartilage is destroyed rapidly by a proteolytic enzyme present in the purulent exudate.

Amputation.—In grave cases of suppurative arthritis that do not respond to conservative treatment, the advisability of performing timely amputation should receive carefully-weighed consideration. In situations where an artificial limb is highly satisfactory, the responsibilities of advising an amputation that will almost certainly cure the patient, and

cure him quickly, are not great, seeing that the alternative is, at the best, a stiff or partially stiff, and often painful, joint.

EXPOSURE OF JOINTS

Individual joints will be considered in the order of frequency with which the need for operation is likely to be encountered.

Exposure of the Knee-joint.—Timbrell Fisher's incision (*Fig.* 1250) gives good access. The various layers are deepened in the line of the incision until the joint is opened; the patella can then be displaced laterally. The joint is cleansed of pus and exudate. The articular surfaces of the femur and the tibia are inspected carefully; upon their appearance rests the decision as to whether the joint can be saved, or is doomed. Unhealthy cartilage must be excised. If the menisci are softened and dull, they are removed. The articular surface of the patella is inspected. If its cartilage appears dead, the patella is excised—the loss of the patella is a small price to pay for enhancing the chances of preserving the joint. If the patella is not removed, a second incision along the outer border of the patella is often necessary, so as to be enabled to attend to the articular surfaces on the lateral side of the joint. All devitalized cartilage having been removed, the joint is irrigated with normal saline solution. The synovial membrane, and sometimes the capsule, is closed tightly. Penicillin is injected into the joint.

Fig. 1250.—Timbrell Fisher's incision for exposing the interior of the knee-joint.

Modified Resection of the Knee-joint is a last hope of preserving the limb, to be employed only when the cartilage covering the ends of the bones is obviously infected. Timbrell Fisher's incision having been made, flexion of the knee provides exposure of the femoral condyles and the head of the tibia. The patella is excised unless its cartilage is healthy, which is unusual. The tibial articular cartilage, together with a thin margin of bone, is resected. The condyles of the femur are also resected at the level of the anterior border of the articular cartilage. Both these sections are made with a saw, a Gigli's saw being well adapted for this purpose. The joint surfaces are removed, together with the menisci and the cruciate ligaments. The excision being completed, the ends of the bones are approximated to reduce dead space and promote fusion. Because all dead space cannot be eliminated, a soft-rubber drain is inserted. The wound is left open, including the capsule and the synovia, and the superficial part of the wound is packed lightly with petroleum-jelly gauze. Immobilization is provided by a single hip-spica plaster cast extending to the ankle. Five days after the operation the wound is examined under anæsthesia, drains are removed, and the depths of the wound are irrigated thoroughly. Should the appearance of the wound warrant it, delayed closure is carried out. In other circumstances the wound is again repacked and inspected after a further interval of five days, with the same objective in view. Needless to say, antibiotic therapy is continued until the wound has healed.

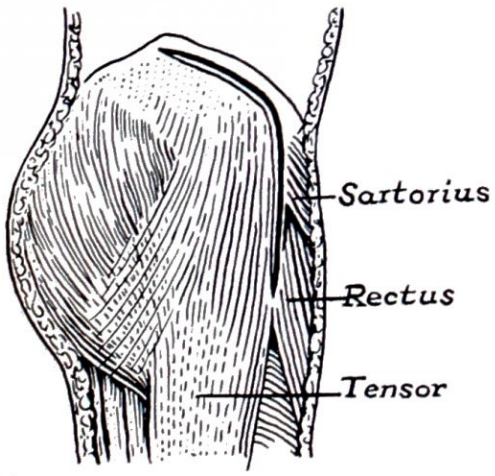

Fig. 1251.—Smith-Petersen's approach to the hip-joint.

Exposure of the Hip-joint.—Although anterior or posterior drainage had been employed in 26 cases of suppurative arthritis of the hip-joint following wounding, control of the infection and healing occurred in only 2 (O. P. Hampton). This, in itself, is evidence that if therapeutic aspiration fails, more radical measures than drainage of the joint are of cardinal importance.

The Anterolateral Approach of Smith-Petersen gives excellent exposure with a minimum loss of blood. The incision passes from just below the middle of the iliac crest to the anterior superior iliac spine, then vertically downwards for 4–5 in. (10–12·5 cm.) (*Fig.* 1251). The superficial and deep fasciæ are divided in the line of the incision, and the origins of the gluteus medius and tensor fascia latæ are erased subperiosteally from the ilium, and reflected downwards. Attention is then directed to the vertical portion of the incision. The interval between the sartorius and rectus femoris anteriorly and the tensor fascia latæ posteriorly is sought, and these groups of muscles are separated by sharp and blunt dissection. This

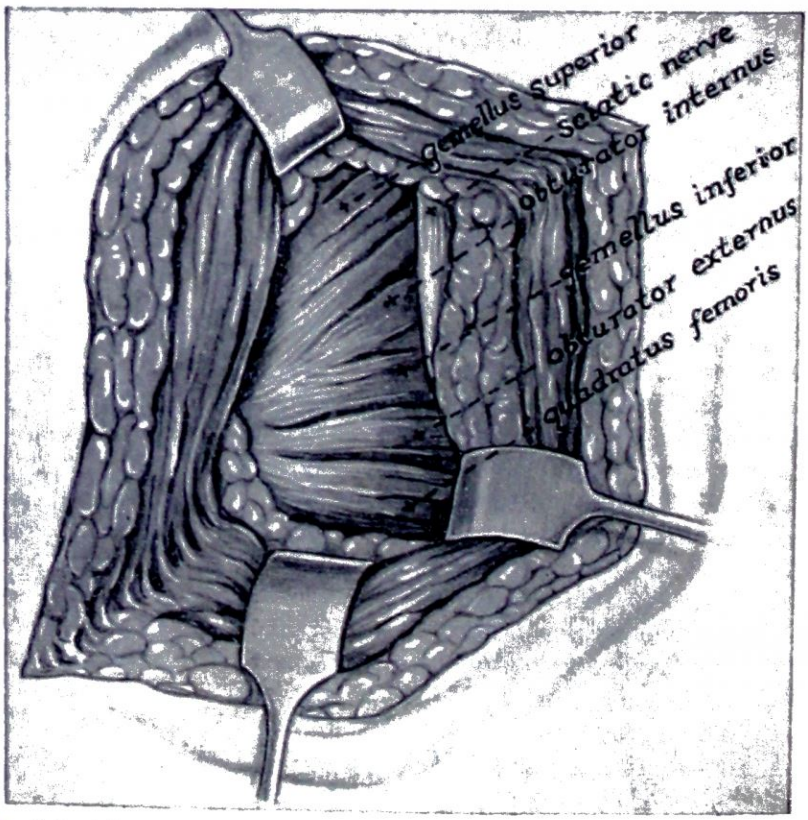

Fig. 1252.—Ober's incision. By separating the gemellus inferior from the obturator internus, the capsule of the hip-joint is exposed. (*After M. J. Hoover, jun.*)

accomplished, retractors are inserted. The ascending branches of the femoral circumflex vessels are divided between ligatures. The joint capsule is now in full view, and is incised vertically. Usually reflexion of the iliacus muscle medially, as in the Smith-Petersen approach for cup arthroplasty, is necessary to obtain proper exposure of the acetabulum.

Ober's Posterior Incision is preferred by many surgeons who have had experience of this operation for suppurative arthritis. The fibres of the gluteus maximus are split longitudinally over the centre of the muscle. The subgluteal fat is opened up and the sciatic nerve is identified; later the nerve is retracted medially. The gemellus inferior is separated from the tendon of the obturator internus (*Fig.* 1252). The posterior aspect of the capsule of the hip-joint is now exposed; it is incised vertically.

The object of the operation is to erase all infected cartilage. Dislocation of the head of the femur is sometimes necessary for this purpose. At the completion of the intra-articular part of the operation, when possible the joint is closed, after which penicillin is instilled into it. In many instances such closure will be found impracticable. In that event posterior drainage is instituted. Closure of the hip-joint is less important than in the case of other joints, because the hip-joint is so well protected from secondary contamination by its complete muscular investment.

A hip plaster cast which extends to the toes is applied, or a half-ring Thomas's splint with skeletal traction and balanced suspension from an overhead Balkan frame can be substituted.

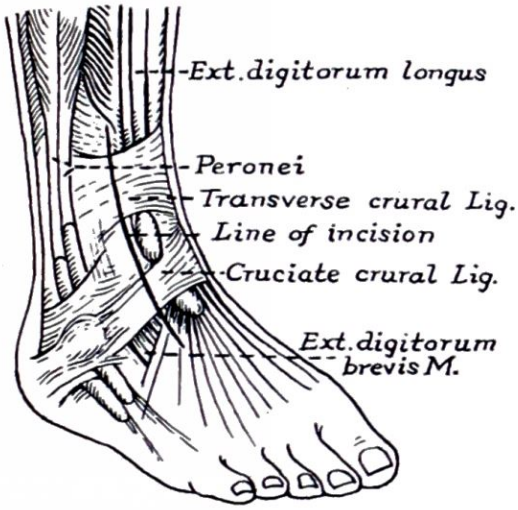

Fig. 1253.—Incision for exposure of the ankle-joint. (*After W. C. Campbell.*)

Fig. 1254.—Incision for Henry's approach to the shoulder-joint.

Exposure of the Ankle-joint.—The anterolateral approach cannot be bettered. The incision commences in front of the fibula 2 in. (5 cm.) above the joint, and is carried downwards between the lateral malleolus and the peroneus tertius, to end at the base of the fourth metatarsal. Both extensor retinacula are divided (*Fig.* 1253).

Fig. 1255.—The joint is reached between the triceps and brachioradialis above and the anconeus and radial extensors below.

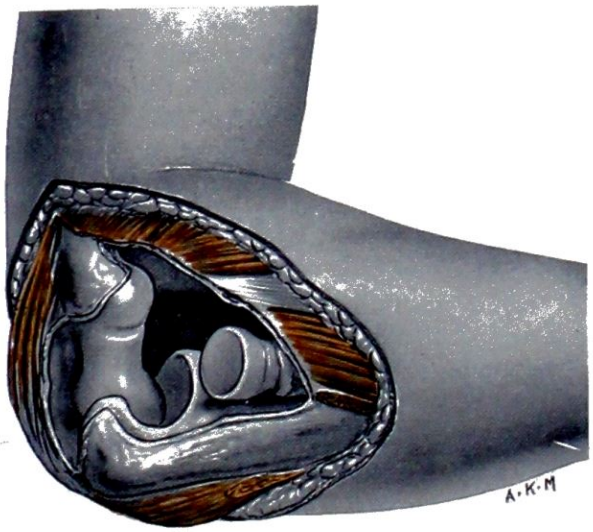

Fig. 1256.—Wonderful exposure without mutilation is afforded by following Kocher's method.

Exposure of the Shoulder-joint.—The patient lies on his back with the shoulder raised slightly by a flat sandbag. The arm should be so wrapped that the limb is freely movable at the joint during the operation. The incision commences behind the highest point of the shoulder over the spine of the scapula, and passes downwards over the medial border of the deltoid as far as its insertion (*Fig.* 1254). The cephalic vein is identified, and avoided by deepening the incision through the medial fibres of the deltoid. The anterior part of the deltoid is detached from the anterior border of the lateral third of the clavicle by severing a thin slice of bone from its border with a chisel. Splendid exposure of the shoulder-joint is thus obtained.

At the close of the operation the slice of bone, with the muscle attached, is replaced, and retained with a single stitch.

Exposure of the Elbow-joint.—Kocher's method is excellent. The incision commences 2 in. (5 cm.) above the lateral epicondyle, and passes downwards to the back of the head of the radius, and then curves medially over the lateral border of the anconeus, to end over the superficial border of the ulna (*Fig.* 1255). The interval between the brachio-radialis and the triceps in the upper part, and the carpal extensors and the anconeus in the lower part, of the incision is defined, and these groups of muscles are separated down to bone. The muscles on each side of the incision are erased subperiosteally. The capsule of the joint is incised and the heads of the radius and ulna can be subluxated laterally, exposing the whole of the interior of the joint (*Fig.* 1256).

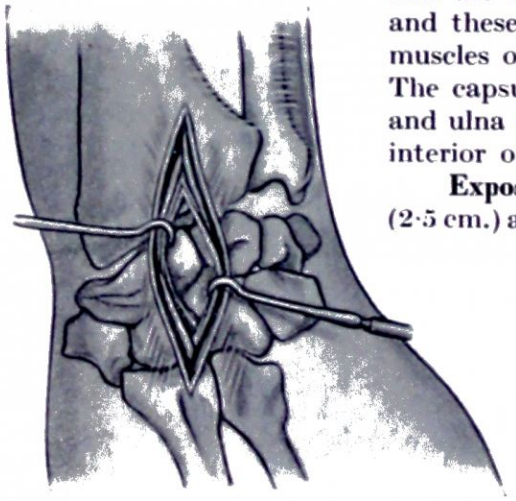

Fig. 1257.—Exposure of the wrist-joint. (*After W. S. Bickhan.*)

Exposure of the Wrist-joint.—The incision is commenced 1 in. (2·5 cm.) above a point midway between the styloid processes of the radius and ulna, and passing along the lateral aspect of the extensor carpi radialis longus is continued downwards vertically to the middle of the base of the second metacarpal. The posterior retinaculum is divided in the line of the incision. The tendon aforesaid and that of the extensor pollicis longus are retracted laterally, and the incision is deepened to the bone. The insertions of these tendons are then detached subperiosteally. The hand is flexed so as to make the wrist-joint more prominent, and the capsules of the joint are incised (*Fig.* 1257).

Exposure of the Interphalangeal and Metacarpophalangeal Joints.—Suppurative arthritis occurring in these joints is usually the result of a lacerated wound on which débridement has not been carried out, or has been carried out incompletely; in some cases the patient has failed to report until the joint is infected. Often the extensor tendon has been severed. Should it have been sutured, the sutures are removed. The wound is excised and all infected cartilage and, if present, infected bone is removed. The wound is closed by a figure-of-8 stitch of stainless steel passing through the tendon and the skin.

When the tendon is intact the joint is approached by a dorsilateral incision; if the exposure thus afforded is insufficient to see the ends of the bone clearly, it is better to sever the tendon partially or completely than to divide a lateral ligament; the tendon can be repaired at the conclusion of the intra-articular portion of the operation.

Healing with good movement is achieved in 50 per cent of cases; in the remainder the discharge ceases, but the digit is stiff, or has very restricted movement. In all cases of modified excision of a joint antibiotic therapy should be continued for fourteen days.

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CHAPTER LXXIX

NERVES AND TENDONS

SEVERED NERVES

REGENERATION of a nerve occurs at the rate of 1 mm. a day; consequently after suture of a severed nerve there is bound to be a long interval before the parts supplied by that nerve will function once more. Obviously, therefore, one would think that if circumstances are favourable it would be advantageous to effect union at the time of the original operation. Another advantage of primary suture is that technically it is less difficult than secondary suture. At a secondary operation the cut ends of the nerve are liable to be encased in fibrous tissue; retraction of the ends has occurred, and a bulbous neuroma requiring resection surmounts each end, and adds to the length of the gap that must be overcome before the freshened ends can be approximated without tension. On the other hand, severed nerves at secondary repair have one advantage: fibrosis having occurred, the ends are firm and the epineurium holds sutures comparatively well.

Massed statistics (mostly war injuries) show that the results of secondary suture are better than those of primary suture (B. Woodhall). What is even more authoritative are the findings of the Nerve Injuries Committee of the Medical Research Council, who recommend that primary suture, even for nerve injuries due to clean incised wounds, be abandoned. In spite of these weighty pronouncements, it must be remembered that they concerned mainly war injuries, and whether or not to employ primary suture in suitable cases in accidents in civil life is still controversial. M. L. Mason, writing subsequently, states that the surgeon dealing with wounds of the hand (and wrist) prefers, when possible, to carry out primary suture, reserving for secondary repair those cases in which contamination or age of the wound contra-indicates suture. Professor Bogdanov, writing in 1955, states that "in the USSR we aim at accurate suturing of damaged nerves at the primary operation".

To suture or not to suture—a compromise: When conditions are favourable for primary suture (i.e., healing of the wound by first intention is anticipated), but for one or other reason it is considered wiser to postpone effecting the anastomosis, it is a good practice to insert one fine tantalum wire suture through the nerve-ends in the manner shown in *Fig.* 1258, and to tie it just tight enough to approximate the cut surfaces. This stitch is not intended as a means of effecting union, but as a temporary expedient to prevent retraction of the nerve-ends, and to enable the site of severance to be identified radiologically before secondary suture is carried out.

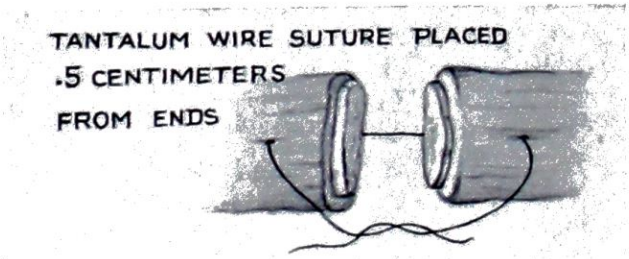

Fig. 1258.—To prevent retraction of the nerve-ends a fine tantalum wire suture is placed 0·5 cm. from the ends. (*After C. E. Troland.*)

Secondary Suture.—When the wound heals by first intention, secondary suture can be carried out twenty to thirty days after injury. If suppuration occurs the operation should not be attempted until at least a month after the wound has healed soundly.

NERVE SUTURE

Materials.—Although advocated by some, wire sutures tend to cut through the epineurium (E. A. Spigel). Catgut provokes an inflammatory reaction, and is condemned by all. Favourable results have accrued from the employment of the finest black silk mounted on eyeless needles, such as are used in blood-vessel surgery. Very fine cotton on a dress-maker's needle also has given satisfactory results. The finest nylon sutures are admirable.

Technique.—Gentleness in the handling of the nerve is essential, and for this reason cotton-wool pledgets held in a hæmostat are preferable to gauze swabs. Nerves must not be allowed to dry. Very moist gauze should overlie the nerve, allowing only such visualization as is absolutely necessary; a pertinent example is, having freed and prepared the upper end, it is covered while the lower end is rendered suitable for anastomosis. When

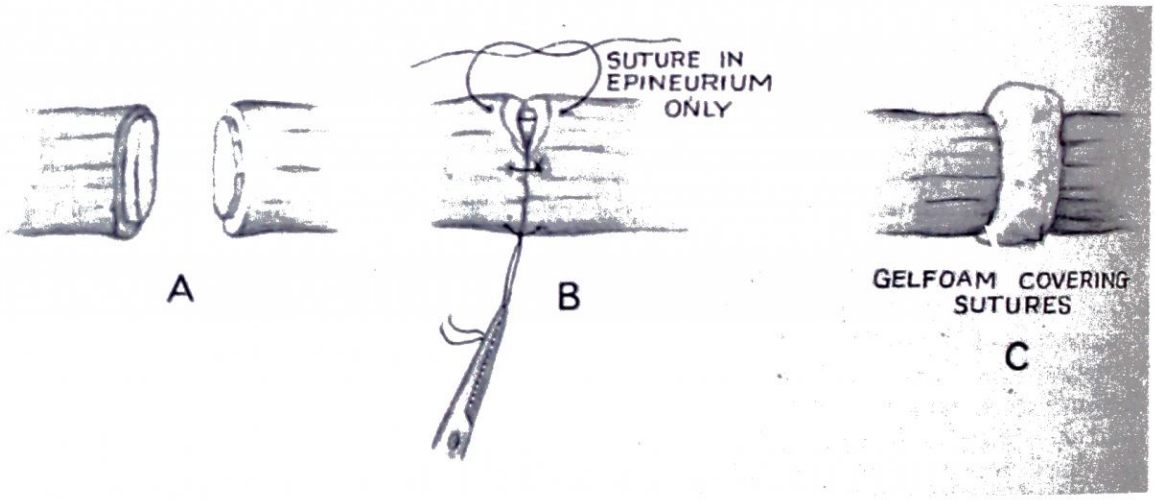

Fig. 1259.—A and B, Sutures are placed through the epineurium only. C, A small strip of gelfoam is placed over the suture line. (*After C. E. Troland.*)

it is necessary to grasp the nerve, this is best accomplished between the finger and thumb; if it is essential to use an instrument for this purpose, fine dissecting forceps should be made to pick up the cut edge of the epineurium and the cut edge only.

In the event of the nerve-ends being too short to be brought together without tension (an unusual event in recent injuries) each segment must be freed by gentle dissection both proximally and distally. To allow more freedom of the main stem, branches arising from the nerve are also dissected carefully. Care and thought should be given before sacrificing even the smallest branch. Slight flexion of the appropriate joint usually permits apposition of the ends without tension. The position of the limb should not be allowed to change during the operation, or during the subsequent application of a plaster cast.

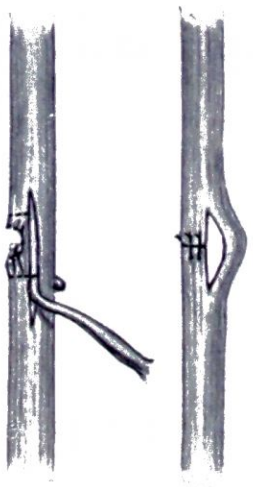

Fig. 1260.—A, Method of separating intact from divided fibres; B, Anastomosis of divided fibres completed.

Trimming the Nerve-ends.—Examine the cut surfaces of the nerve; if they are jagged, place first one and then the other on a piece of moist cotton-wool. Section the nerve with a safety-razor blade held in a hæmostat, or a very sharp scalpel, at right angles to the long axis of the nerve, sacrificing only the minimum to be enabled to approximate clean-cut surfaces. Usually there is some bleeding from the cut end that can be controlled by placing a strip of gelfoam[1] on each cut surface, and leaving it there for a few moments.

The Anastomosis.—The cut ends are then allowed to take up their natural lie, which is noted, the aim being to approximate the nerve-bundles within the epineurium so that each bundle lies in apposition with its pristine counterpart; rotation will disturb regeneration and promote neuroma formation from maldistribution of fibres. The sheath of the divided nerve is approximated with sutures that penetrate the epineurium only (*Fig.* 1259 B). After the epineural sutures have been placed in the superficial aspect, the ends of the sutures, having been left long, are used to rotate the nerve and so expose its under surface where a similar suture or sutures are inserted. Often four sutures placed north, east, south, and west are sufficient. Rarely is the nerve large enough to necessitate more than six sutures: the average median nerve at the wrist requires six interrupted sutures. A small cuff of gelfoam placed over the suture line (*Fig.* 1259 C)

[1] English equivalent—Sterispon, Allen & Hanburys Ltd.

will protect this region, and the expedient seems preferable to other substances that have been used for the purpose.

Partial Division.—If a few drops of saline solution are injected beneath the epineurium with a hypodermic syringe 1 cm. above and 1 cm. below the laceration, it will be found that the divided nerve-bundles are much easier to identify. The severed bundles are trimmed without disturbing the remaining intact fibres. The sheath is then incised longitudinally for a short distance, so that the injured nerve-fibres can be separated gently from those that are intact (*Fig.* 1260 A). The epineurium of the divided bundles is united by end-to-end suture, while the intact part of the nerve remains as a lateral loop (*Fig.* 1260 B).

Epineural and Endoneural Hæmatomata.—After injecting a little saline solution beneath the epineurium in the vicinity of the lesion, the epineurium is split and blood-clot which, if left, would favour neuroma formation. is syringed out with a fine stream of saline solution directed through the needle of a hypodermic syringe. The sheath of the nerve is left unsutured.

EXPOSURE OF INDIVIDUAL NERVES

Median and Ulnar Nerves at the Wrist.—The majority of cases of cut nerves requiring immediate suture are caused by incised wounds in the vicinity of the wrist. The position of the median and ulnar nerves in relation to surrounding tendons is shown in *Fig.* 1276.

While suture of these nerves in this situation presents no particular difficulty, it is essential to obtain wide exposure, so that the nerve-ends can be identified ; although it seems unlikely, a mistake that has often been made is to suture the divided median nerve to the divided palmaris longus tendon.

Digital Nerves are also frequently divided in wounds involving the sides of a finger. Since anæsthesia of a finger is a considerable handicap, these nerves should be sought carefully, and if possible repaired by primary suture. The digital nerves are structures

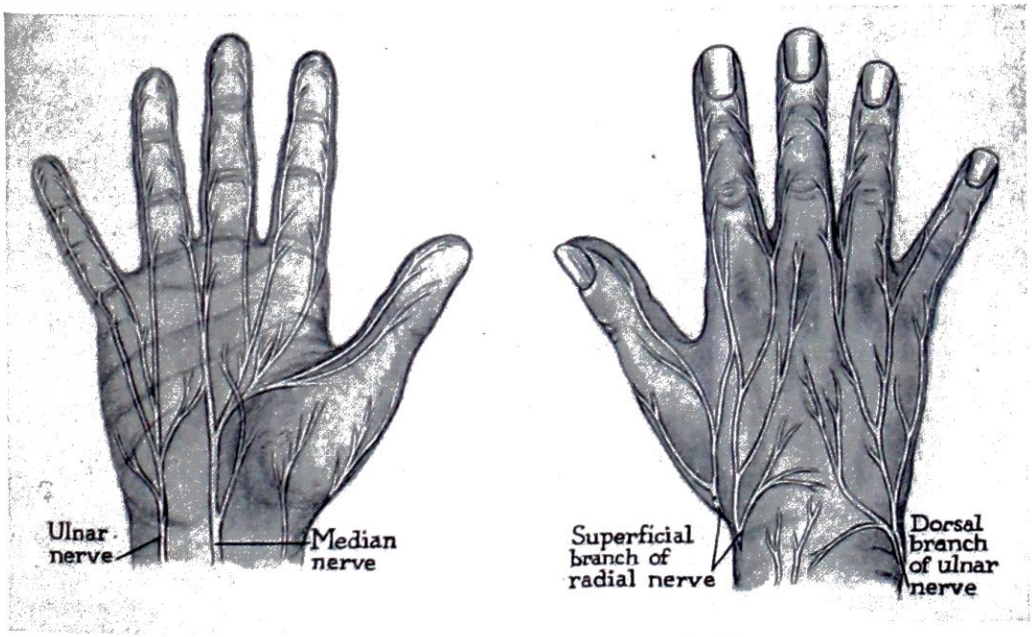

Fig. 1261.—The digital nerves. (*After Phil Thorek.*)

of appreciable size, and their repair is not so difficult as might be supposed, and the results are often particularly gratifying ; the same is true for all the nerves of the hand (*Fig.* 1261).

Having dealt with these common lesions, it is necessary to pass on to some nerve injuries in other situations that require more detailed consideration.

Brachial Plexus.—The entire plexus can be exposed by the incision recommended for displaying the subclavian and axillary arterial trunk (*see* p. 946). The upper portion of the plexus lies behind the scalenus anticus muscle, which must be divided in necessary cases. Wounds of the brachial plexus that require resection of more than 1 in. (2·5 cm.) of the nerve-bundles are almost impossible to treat, because of the difficulty in securing relaxation.

Shortening the divided clavicle is helpful in this respect, and some tension can be relieved by elevating the shoulder and flexing the arm across the chest.

Median Nerve.—Shortly after its origin in the brachial plexus, good exposure of the median nerve can be obtained by an incision passing along the anterior border of the deltoid and along the bicipital groove. A lesion in the middle of the arm is exposed easily by a straight incision along the sulcus between the triceps and biceps (*see Fig.* 1314, p. 948). A double flap incision (*Fig.* 1262) is desirable at the elbow, where the nerve passes between

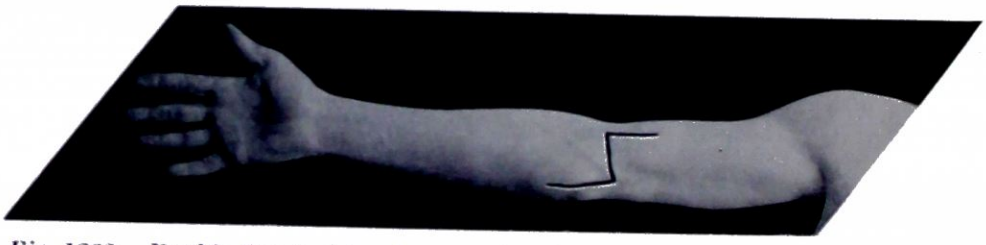

Fig. 1262.—Double flap incision for exposing the median nerve at the elbow. This incision avoids flexion contracture. (*After C. E. Troland.*)

the two heads of the pronator teres. Some relaxation of the nerve can be obtained by dividing one of these muscular bundles. Important motor-fibres to the flexor muscles originate at this site, and great care must be taken to avoid injuring them. Below the elbow the nerve runs a straight course lying on the flexor digitorum profundus and covered by the flexor digitorum sublimis: considerable relaxation of the distal end of the nerve can be obtained by flexion of the wrist.

A lesion of this nerve at the wrist has been considered on p. 913.

Radial Nerve, below and in its Groove.—The arm should be laid across the chest. The hand may be attached to the operating table by a length of bandage. Identify the lateral epicondyle. Above it, by palpating deeply, the supracondylar ridge can be felt. Here arises the brachioradialis. Commence the incision between the origin of the brachioradialis and the brachialis, and carry it upwards in the direction of the spiral groove. Dissect in the interval between the brachioradialis and the brachialis. The radial nerve will be found lying very deeply in this groove, the depth at which it lies differentiating it from the more superficially placed musculocutaneous trunk. The nerve is now traced upwards. Towards its groove it will be found to pass deep to the outer head of the triceps. The outer head of the triceps arises by a flattened tendon from the back of the humerus. By dividing this outer head and the aponeurotic bridge across the spiral groove, an excellent view is obtained. The radial nerve and the profunda brachii artery are displayed (*Fig.* 1263).

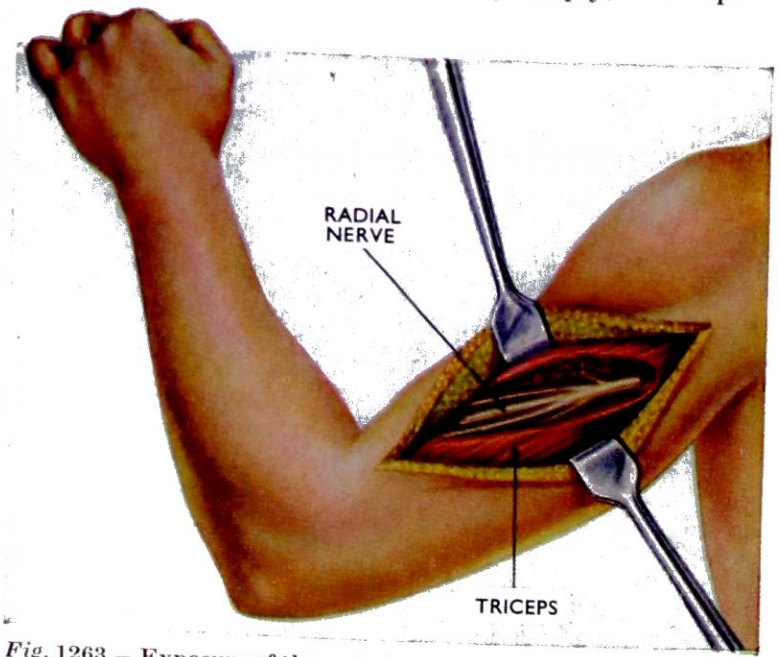

Fig. 1263.—Exposure of the radial nerve in its groove. The triceps has been divided.

Posterior Interosseous Nerve.—The course of this nerve being short, and winding as it does around the lateral aspect of the neck of the radius in the fibres of the supinator muscle, it is well protected. Consequently, it is injured rarely. For this very reason, should a case of injury of this nerve be encountered, the surgeon will be in need of instructions for exposing it. Being a purely motor nerve, its suture yields most satisfactory results.

The arm lies across the patient's chest. Palpate the head of the radius. Commence the incision over the head of the radius and carry it down the shaft rather nearer the posterior than the anterior aspect. Expose clearly the common extensor origin and find the interval

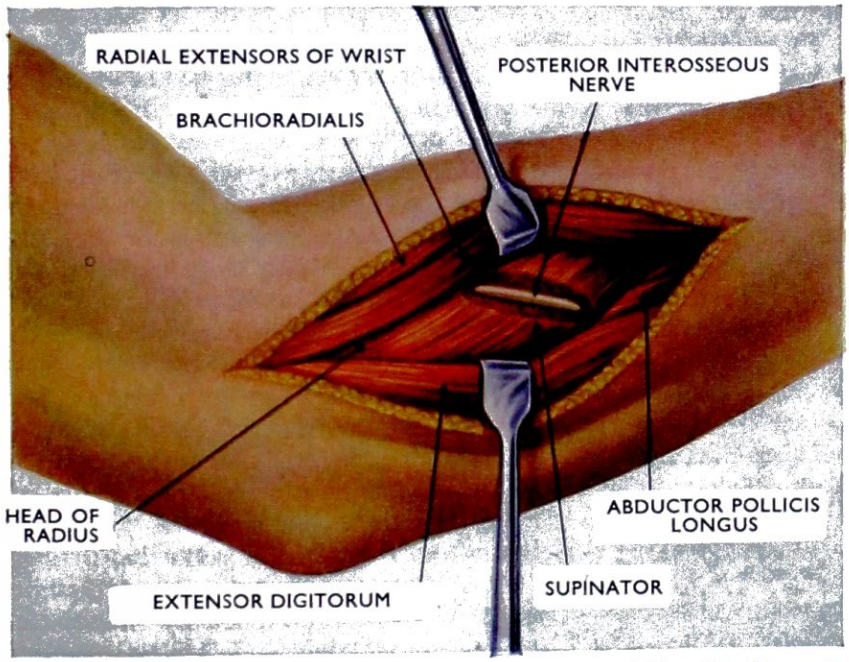

Fig. 1264.—Exposure of the posterior interosseous nerve. (*After Sir Henry Souttar.*)

between the extensors of the wrist laterally and those of the fingers medially. The extensor digitorum is thus separated from the extensor carpi radialis brevis and the supinator comes into view. Palpate this muscle. If the nerve cannot be felt winding around the neck of the radius, it must be sought deliberately. It can be found on the *back* of the radial shaft at a quite definite point—three finger-breadths distal to the head of the radius (A. K. Henry). Incise the muscle and the nerve is exposed (*Fig.* 1264).

Ulnar Nerve.—

In the Upper Arm the ulnar nerve can be exposed by an incision similar to that for the brachial artery (*see* p. 948). As far as the middle of the upper arm the nerve lies in close relationship to the artery. In the lower half of the upper arm it inclines increasingly medial to the artery lying upon the medial belly of the triceps muscle.

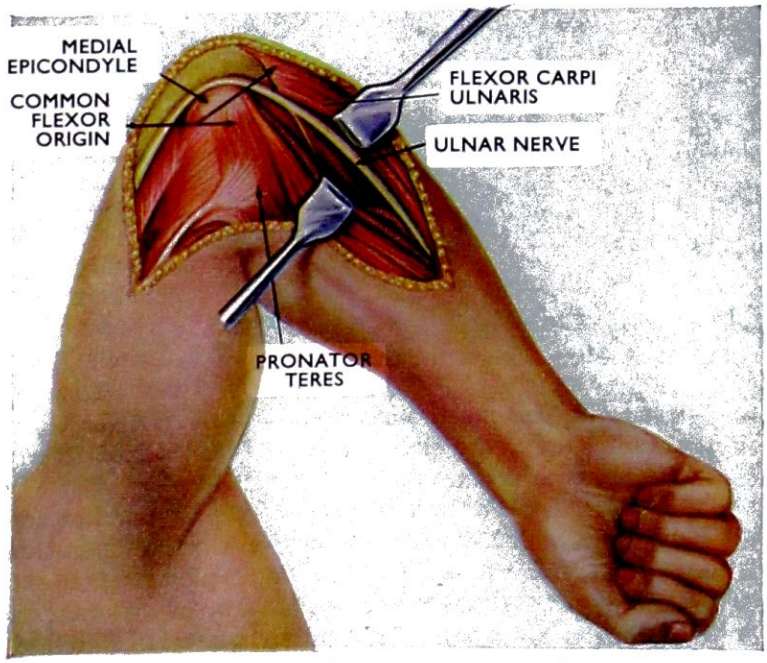

Fig. 1265.—Exposure of the ulnar nerve at the elbow before transplanting it in front of the medial epicondyle.

At the Elbow.—In addition to suture, the nerve should always be transposed in front of the medial epicondyle and a bed made for it in this situation. For this procedure it will be found convenient to have the arm across the patient's chest and to stand facing the forearm—that is, to stand on the side of the sound limb. If the lower part of the forearm and the hand are wrapped in a sterile towel, the hand and forearm can be twisted into various

positions to suit particular circumstances at various stages of the operation. The incision follows the ulnar groove, passing in a straight line from a point 1 in. above the groove to 3 in. below the groove.

The proximal end of the nerve is dissected up with due regard for its muscular branches. Likewise the distal end is followed, freeing it from the fascia which bridges the ulnar groove. Proceeding, the nerve is traced under the fascia covering the common flexor origin—it will be seen to dive under the fibrous arch uniting the heads of the flexor carpi ulnaris. There is no difficulty in following it for some distance, and it can be mobilized readily.

Both ends having been mobilized, twist the forearm so that the front of the epicondyle is visible. Bring the nerve-ends anterior to the epicondyle, and unite them in this anterior position. As the nerve lies loosely on the front of the elbow it is obvious that a bed for it can be made very simply. Make an incision about half an inch deep in the common flexor origin (*Fig.* 1265). Place the nerve into the furrow and bury it neatly by sewing the divided muscle over it. When the operation is completed, bandage the flexed arm to the side.

Sciatic Nerve.—The patient should lie on his face.

In the Buttock the nerve can be exposed by the method described for displaying the superior and inferior gluteal arteries (*see* p. 955).

In the Thigh.—Take a point slightly medial to midway between the greater trochanter and the tuber ischii; this is the surface marking. Commencing just below the gluteal fold, make an incision passing directly downward. Identify the hamstring muscles, and retract them medially. Although deeply placed in the wound, usually the sciatic nerve will be found without difficulty; in muscular subjects the gluteal muscles must be retracted upward

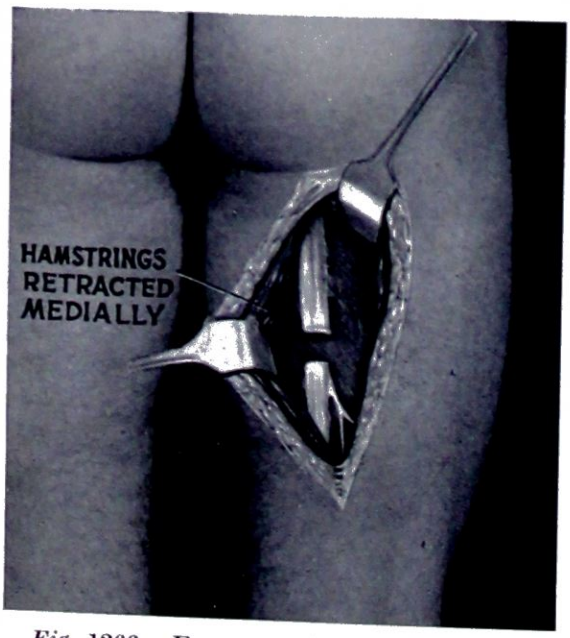

Fig. 1266.—Exposure of the sciatic nerve.

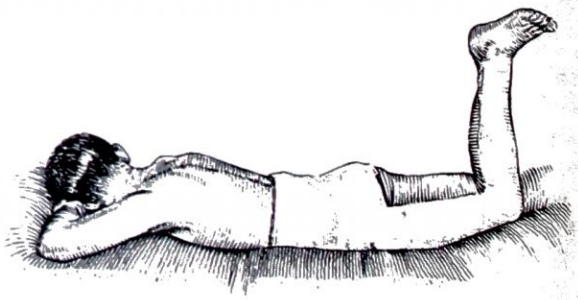

Fig. 1267.—Plaster shell for maintaining the desired position after suture of the sciatic nerve.

(*Fig.* 1266). The bifurcation of the sciatic nerve into its two terminal divisions is not constant; sometimes the nerve divides high in the thigh. As soon as the cut ends of the nerve have been located, the knee-joint should be flexed; this lessens tension considerably. After the nerve has been sutured and the skin wound closed, the limb must be immobilized in a position that will reduce tension on the nerve to a minimum.

Post-operative Position of the Limb.—Hyperextension of the hip and full flexion of the knee must be maintained. When an elective operation is to be performed, this position is best obtained by making a removable plaster shell extending from the upper abdomen to the ankle (*Fig.* 1267). The application of an extensive plaster cast at the conclusion of an operation for repair of the sciatic nerve adds greatly to the shock, therefore this shell should be made some days before operation on the nerve is undertaken. Alternatively, after primary suture, if that be thought desirable, the position can be achieved by bending a Thomas's splint suitably. In either event the patient is nursed prone for 48 hours, and then is turned on to his side. At the end of a fortnight slight flexion of the hip can be permitted; three weeks later gradual extension of the flexed knee is commenced.

The Femoral Nerve.—Unless the nerve is found to be injured above its high division into numerous branches, this is a most difficult nerve to repair, and partial success is all

that can be achieved. The femoral nerve is displayed as for exposure of the upper part of the femoral artery (*see* p. 951).

Medial and Lateral Popliteal Nerves in the Popliteal Space should be exposed by a ⅂ incision to avoid flexion contracture. After completion of the operation a plaster cast is applied with the knee-joint flexed to a right angle.

The Lateral Popliteal Nerve and its Branches.—The patient lies on the sound side, three-quarters prone, with the hip and knee flexed. The incision follows the biceps tendon in the thigh, and extends to in front of the neck of the fibula. When the distal part of the popliteal nerve (anterior tibial nerve) requires freeing, the incision can be prolonged over the upper part of the anterior compartment of the leg. After the deep fascia has been divided the biceps is retracted, and the nerve is displayed easily. Traced downward, the nerve passes beneath the upper part of the peroneus longus, which is divided as necessary. To obtain sufficient relaxation for anastomosis, usually it is necessary to mobilize the sciatic nerve for some distance. Suture is carried out with the knee flexed, and at the conclusion of the operation flexion is maintained by a plaster cast.

The Posterior Tibial Nerve.—The incision is commenced in the popliteal space, and the medial popliteal nerve is traced downward, the various layers of the calf being split as directed on p. 953.

SEVERED TENDONS

In civil life about 90 per cent of cut tendons concern the hand and wrist. The complex nature of the flexor tendons of the hand renders their repair a more difficult problem than that of other tendons. The tremendous importance of tendons of the hand to the earning capacity of the individual makes this a subject worthy of especial study. Accurate and adequate notes on the injury and operative treatment are essential, not only for their own sake, but to refresh the mind during the litigation which so often follows.

First-aid Treatment has a much greater bearing on selecting cases for primary suture and on the prognosis than has been hitherto accredited to it. It should be taught emphatically that the first-aid treatment is :—

Cut flexor tendon : Flex all the joints activated by the cut tendon and immobilize securely.

Cut extensor tendon : Extend all the joints activated by the cut tendon and immobilize securely.

It is the contention of the Russian surgeons that the ill-repute of ' no-man's-land ' is due, not to some factor which is difficult to explain, but to abrasion of the delicate lining of the tendon-sheath when endeavouring to retrieve tendons that have retracted within the sheaths. Correct first-aid treatment, therefore, greatly minimizes post-operative adhesions—the bugbear of tendon suture.

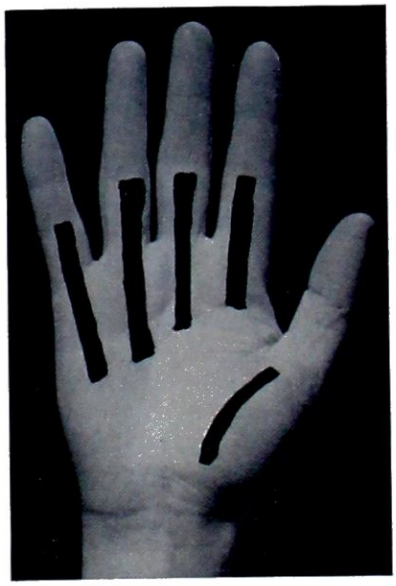

Fig. 1268. — ' No-man's-land '. It extends from the middle palmar crease to the middle crease of each finger.

' No-man's-land '.—The usual poor results of repair of flexor tendons in this zone, so picturesquely described by S. Bunnell, have led many surgeons to abstain from performing primary repair, in favour of secondary repair by means of tendon grafting. The zone extends from the middle palmar crease proximally, to the middle crease of each finger distally (*Fig.* 1268). To this zone G. Pulvertaft has added (for another reason (*see* p. 921)) that part of the sheath of the flexor pollicis longus within the thenar eminence. A growing number of surgeons now maintain that under proper conditions, with certain steps in technique, notably by the employment of a ' pull-out ' suture, the ban in this area can be lifted.

Primary Suture of a Tendon should *not* be attempted :—

1. If more than 6 hours have elapsed since the time of severance.
2. In crushing injuries in which fractures, bursting of tendon-sheaths, and loss of skin have occurred.
3. When necessary débridement is such that a dead space is left, and a tendon, if sutured, would span a cavity.

4. When it has been decided to leave the skin unsutured.

5. When, owing to the extent of other injuries or the poor condition of the patient, there is insufficient time to repair the tendon or tendons meticulously.

Injuries inflicted by the human teeth, and injuries due to the fishmonger's or butcher's knife, should not be subjected to primary tendon suture or primary closure either, for that matter.

REPAIR OF CUT TENDONS

Some General Principles.—Operations for repair of cut tendons should not be carried out in the casualty department; the patient requires admittance, and an operation in the general theatre.

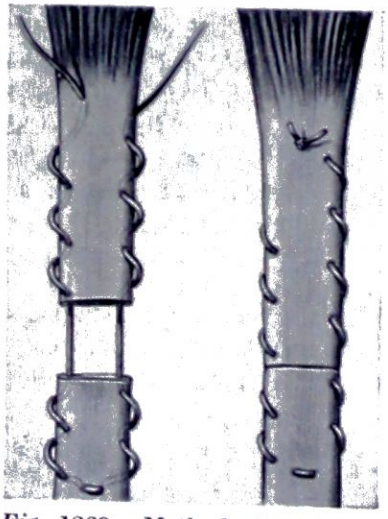

Fig. 1269.—Method of uniting a large flat tendon.

Local anæsthesia is often adequate. Most of the operations for suture of tendons of the hand performed by Russian surgeons are carried out under this form of anæsthesia. The Russian surgeons advise against the use of a tourniquet; in this way hæmatoma formation is prevented. Many European and American surgeons recommend the use of a pneumatic tourniquet, but this is not in accordance with the best technique of débridement (*see* p. 134). Possibly these conflicting instructions have arisen because the Russian surgeons carry out primary suture whenever conditions permit, whereas many other surgeons are concerned mainly, if not entirely, with secondary repair where there is no contra-indication to the use of a tourniquet.

Methods of enlarging the wound for repair of a severed tendon of the hand or a digit are described and illustrated on p. 993.

When the proximal end of the tendon cannot be found in the wound, do not grope for it blindly with a hæmostat; other structures, especially nerves, are liable to be endangered in this way. As a rule it is best to make a transverse incision 2–3 in. (5–7·5 cm.) above the wound, and examine systematically the underlying anatomy. The missing tendon surely will be found. Pass a hæmostat from the first to the second wound, grasp the free end of the tendon, and draw it down.

After-treatment of Sutured Tendons.—The limb must be immobilized in whatever position is best to relieve all pull on the sutured tendon. In the case of the hand or wrist a plaster slab, with the affected joints flexed or extended as the case may be, cannot be bettered. It has been shown fairly conclusively that tendons unite firmly in a period of 2½–3 weeks. Following tendon repair, most surgeons immobilize the area for a period of 3 weeks.

Flat Tendons.—A large flat tendon can be repaired with a stainless-steel wire suture[1] inserted as shown in *Fig.* 1269. After the sutures have been tied the junction is reinforced by a few interrupted stitches of very fine silk.

The Extensor Tendons of the Hand are repaired most satisfactorily by end-to-end anastomosis with interrupted sutures of 000000 silk; in this situation it is best to avoid sutures of wire because of its tendency to bunch the tendon, and in the dorsal surface of the hand there is inadequate soft tissue protection to make the wire knots impalpable. Meticulous end-to-end approximation with 000000 silk on an atraumatic needle with three knots, and the suture cut flush to the last knot, has given the best results (C. E. Nemethi).

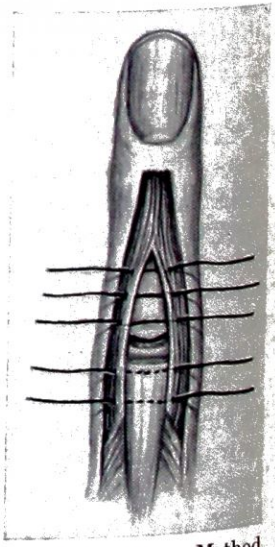

Fig. 1270.—Method of repairing an extensor tendon severed over the proximal phalangeal joint.

The Extensor Tendon over the Proximal Interphalangeal Joint is often difficult to approximate by the usual methods: sutures in the distal part of the central portion of the

[1] As in the case of nerve suture, never use catgut for suturing a tendon, because of the reaction it provokes.

extensor expansion are liable to cut out. The following method is therefore advised. The wound having been enlarged in a ㄣ manner the aponeurosis is dissected, so as to define the lateral bundles. These are approximated by transversely-placed stitches (*Fig.* 1270) with the finger in extension, five to six sutures being used. The stitches include not only the lateral bundles, but also where available the severed middle bundle of the long extensor (Weinstein).

Results of Primary Repair of Extensor Tendons of the Hand are very good indeed. In the best series 92 per cent of the patients have regained full function.

Round Tendons.—

The Bunnell-Mayer Suture.—The standard method of repair is by the Bunnell-Mayer suture. Fine (preferably braided) stainless-steel wire (No. 30–40 S.W.G.) on an atraumatic needle is by far the best suture material, as it invokes so little tissue reaction. The extreme cut end of the tendon is held in a hæmostat ; commencing about 1½ in. (3·8 cm.) away from the cut end, a ' double right angle ' stitch is inserted—usually three twin bites are taken.

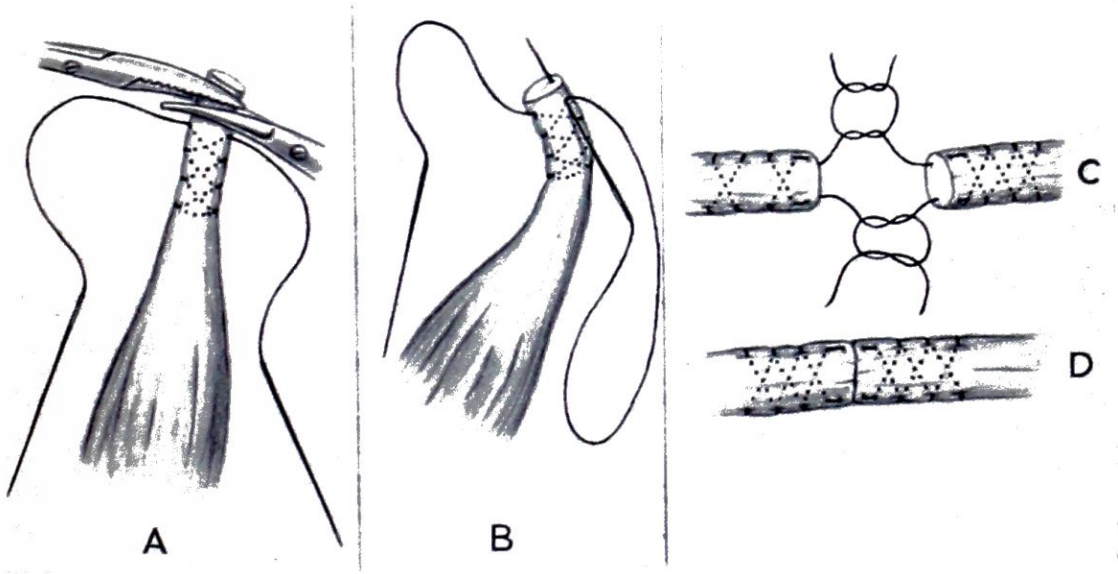

Fig. 1271.—Steps in the Bunnell-Mayer suture for round tendons. Note that the knots are counter-sunk between the divided ends of the tendon.

The end of the tendon is then trimmed with scissors (*Fig.* 1271 A) and the stitches are brought out near the centre of the cut surface of the tendon (*Fig.* 1271 B). An exactly similar stitch is inserted into the other end of the tendon. Each end of the suture is tied to its counterpart (*Fig.* 1271 C) ; thus the knots lie buried between the cut ends of the tendon (*Fig.* 1271 D) so that only a minimum of suture material remains on the surface to interfere with gliding.

The Barb Wire Method of Primary Suture of a Tendon.—If this wire suture is available, it is an admirable method of anastomosing flexor tendons of the palm or fingers, but is applicable to the repair of any tendon. The use of this expedient avoids burdening the tissues with a considerable amount of suture material, does not leave knots between the stumps, and does not strangle tissues. The suture consists of braided tantalum wire with needles affixed, and it should be noted that the barbs point towards the straight needle (*Fig.* 1272 *inset*).

Technique.—The straight needle is threaded through the centre of the proximal segment of the tendon, until the barb is engaged. The same needle is then inserted through the mid-portion of the distal segment, and brought out through the skin. Adequate tension is placed on the distal portion of the suture, thus approximating the severed ends of the tendon (*Fig.* 1272). Tension is maintained by means of a button with a match-stick or lead shot. The proximal portion of the suture is made to emerge through the skin by means of the curved needle ; it is then anchored loosely over a button in the way described for its fellow. After the severed tendon has healed, the suture is cut below the distal button, and removed by a gentle pull on the proximal button. Because of the simplicity and the ease of

application of this suture, it is likely that this will prove a great asset in the repair of tendons, especially those of the hand.

Bunnell's 'pull-out' Tendon Suture was designed for the repair of a flexor tendon within a sheath, on the theory that absence of a suture left the repaired tendon in a better condition and freer from adhesions than would be the case in the presence of any suture. Tension or pull on a tendon suture is from one end only—that to which the muscle is

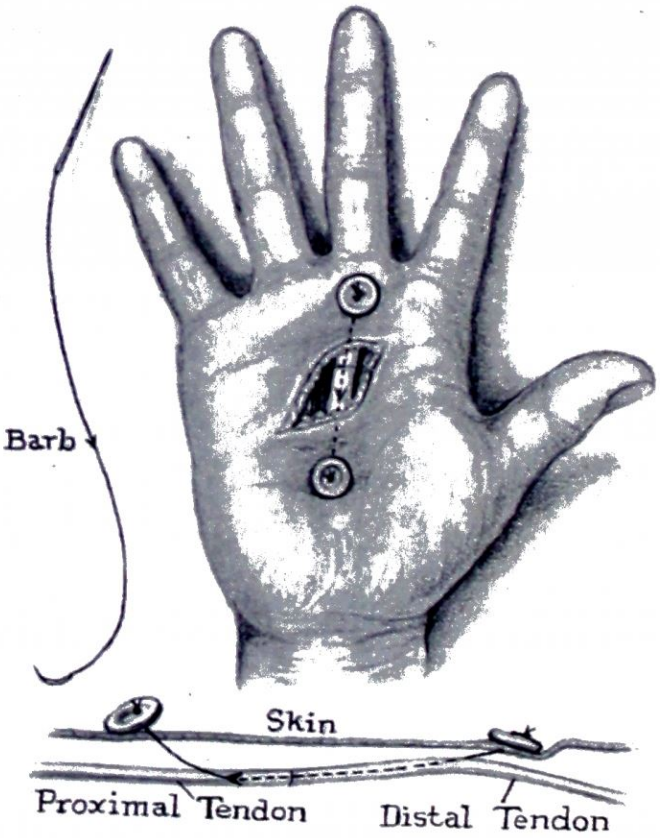

Fig. 1272.—Method of approximating a severed tendon with barb wire. *(E. R. Jennings et al.)*

attached—the other end of the tendon remaining passive; therefore the suture (wire) is spliced to the proximal end only. It is passed down the distal end and made to emerge through the skin, there to be fastened firmly to a button (*Fig.* 1273). The proximal end is thereby held distal-wards against the passive distal tendon end. The suture is rendered removable by threading a piece of wire under the proximal loop of the stitch. Both ends of this wire are threaded on *the same* curved needle and passed through the skin proximal to the junction, and either left there or, more usually, tied very loosely over a button.

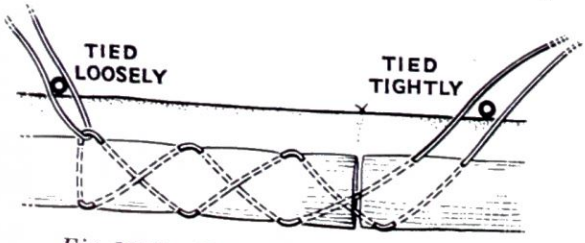

Fig. 1273.—Bunnell's 'pull-out' suture.

Removal.—Three weeks later, after sterilizing the skin under the distal button, the wires are cut at skin level. A small rubber band is then attached to the pull-out wire or its button, the other end of the rubber band is passed over a narrow strip of adhesive plaster, which in turn is stuck to the forearm. Within 24 hours the suture will be out.

DIGITAL FLEXOR TENDON SEVERANCE AT VARIOUS LEVELS, AND THE TREATMENT RECOMMENDED

Anatomical Arrangement of the Tendons.—The sublimis is superficial. The way in which the sublimis bifurcates to permit the profundus to pass through it is shown in *Fig.* 1274. The sublimis is inserted into the sides of the shaft of the middle phalanx. The

profundus is inserted in the base of the terminal phalanx. The function of the sublimis (flexion of the proximal phalanx on the metacarpal and flexion of the proximal interphalangeal joint) can be carried out by the profundus, but full flexion, as in grasping, is less strong.

1. Severed Sublimis only.—Because it is more superficial, when a single flexor tendon of a digit is severed, usually it is the sublimis. This tendon can be sacrificed without serious loss of function ; therefore excise the divided ends as widely as the limits of the wound will permit. As far as the tendon is concerned, that concludes the operation.

2. Severed Profundus only, severed just distal to the Insertion of the Sublimis.—Repair of the profundus in this situation is likely to interfere with the gliding of this tendon through the slips of the sublimis (*see Fig.* 1274). Therefore if suture of the profundus is undertaken, it must be combined with excision of the sublimis, with the risk that if the operation is unsuccessful, loss of flexion of the whole finger will result. The surgeon should therefore ask himself the question, " Will loss of flexion of the distal phalanx be a serious handicap to the patient? " In the majority of cases the advice of Hans May should be followed. Trim the ends of the divided tendon and leave them unsutured. Fix the finger for three weeks in a position of 30° of flexion of the middle interphalangeal joint.

3. Severed Profundus only, severed near its Attachment.—Within ½ in. (1·3 cm.) of its attachment to the base of the terminal phalanx is stipulated, so that the junction of the severed tendon will not, by its roughness at the site of suture, cause interference with free

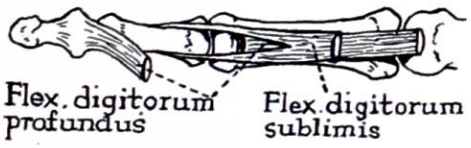

Fig. 1274.—The sublimis separates and the profundus perforates it. (*After Testut.*)

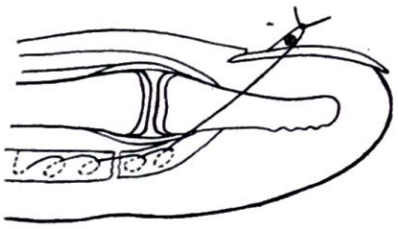

Fig. 1275.—Method of approximating a profundus tendon divided near its insertion. (*After A. B. Watson.*)

gliding between the two slips of the sublimis (*see Fig.* 1274). The cut ends of the tendon are trimmed. A wire suture is inserted on both sides of the tendon, as shown in *Fig.* 1275, and the ends of the suture are made to emerge on either side of the finger-nail. The ends of the sutures are then tied over the nail with a piece of rubber tube intervening. When a tendon has united, no attempt is made to remove all the wire ; it is cut at skin level. Exceptionally, if the wire gives rise to symptoms, it can be removed at a later date under local anæsthesia (A. B. Watson).

4. Both Tendons severed.—There is world-wide agreement that the sublimis should be sacrificed. Therefore the sublimis is excised both proximally and distally as radically as the enlarged wound permits. This obviates adhesions between the two tendons—one potent source of curtailed function. It also results in a relatively commodious tendon-sheath in which the injured profundus can swell, thus reducing the incidence of adhesion of the remaining tendon to the tendon-sheath.

It should be noted that the uniformity of opinion concerning the necessity of excising the sublimis refers only to the frequently encountered cases where both tendons are severed.

As to the repair of the profundus, in the tendon-sheaths distal to the proximal finger crease the tendon can be sutured at the primary operation with every chance of success if the wound is a clean, incised one. Proximal to the middle palmar flexion crease primary suture is usually satisfactory. The sharp differences of opinion as to whether primary suture or a delayed tendon-graft should be performed when the lesion is in ' no-man's-land ' have been discussed on p. 917.

5. Flexor Pollicis Longus.—When the tendon is divided distal to the thenar eminence (the usual situation) primary suture is often attended by an excellent result ; usually the proximal segment must be sought between the heads of the short flexor. When the tendon is severed in the thenar eminence, the proximal end must be sought at the level of the wrist. Pulvertaft has found that in this situation, because of tension, sutures in the distal end tend

to cut out, causing fraying of the tendon. Therefore, when the lesion is in this zone, he recommends secondary tendon-grafting.

Results of Primary Suture of Flexor Tendons.—In the Russian series excellent results accrued in 75 per cent of the cut flexor tendons of the fingers. Taking repair of the tendon

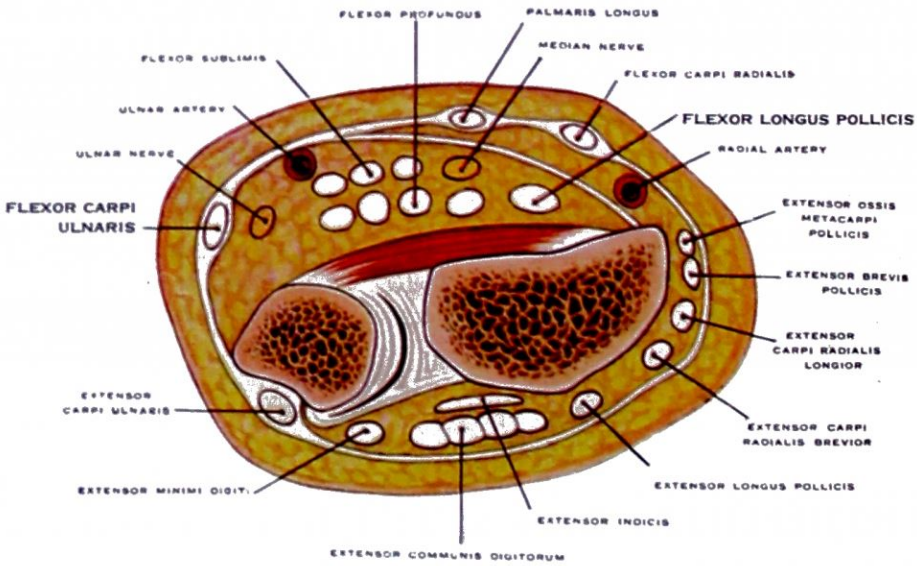

Fig. 1276.—Transverse section through the distal ends of left radius and ulna.

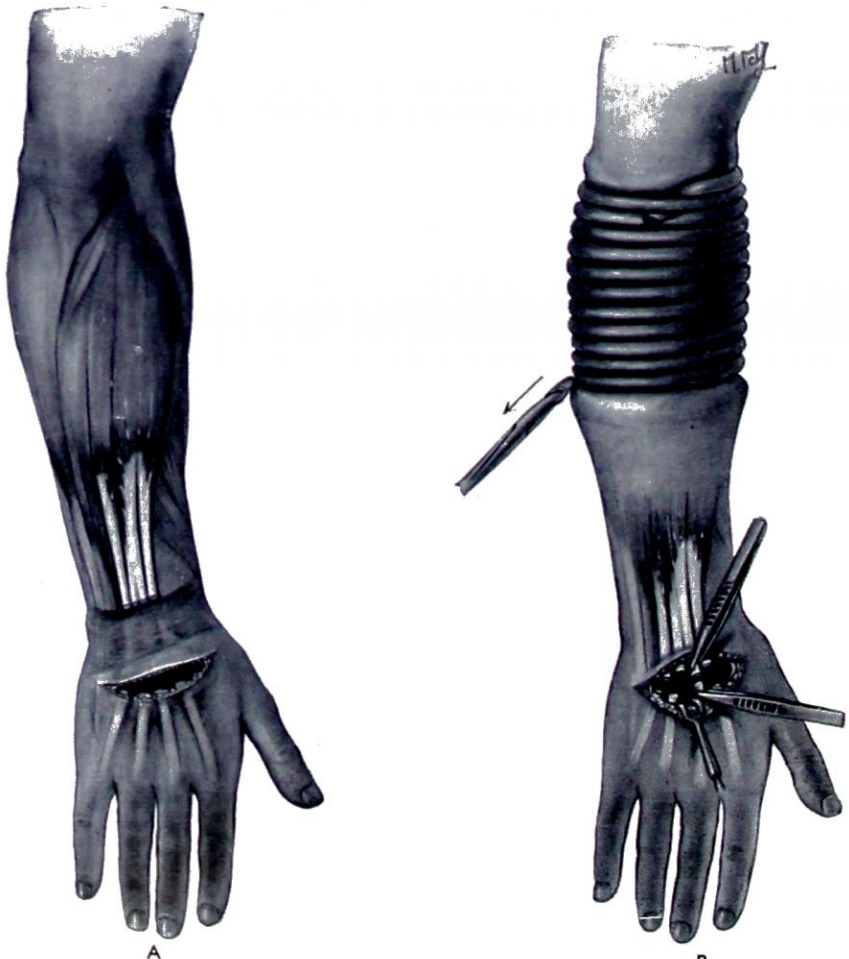

Fig. 1277.—Cut wrist. A piece of rubber tubing has been applied from above downwards in order to make the proximal ends of the tendon accessible. (*After E. W. Rockey.*)

in 'no-man's-land' alone, good results followed in 65 per cent of cases. Usually primary suture of the flexor pollicis longus distal to the thenar eminence is attended by excellent results.

CUT WRIST

Accidental division of tendons at the wrist is encountered frequently and, seeing that secondary repair is very difficult in this situation, if there is no contra-indication (*see* p. 917), primary suture is the goal.

Once again the sublimis tendon or tendons can be sacrificed when the sublimis alone, or the sublimis and profundus, are severed. A cut palmaris longus can also be sacrificed. It is most necessary to be familiar with the anatomical arrangement of nerves and tendons around the wrist, and for refreshing the memory *Fig.* 1276 is helpful. When the proximal ends of either the flexor or the extensor tendons have retracted (*Fig.* 1277 A), after débridement of available structures in the wound, it is most helpful to apply rubber tubing from below the elbow to the lower third of the forearm. By compressing the muscle bellies, the tubing will assist in the search for the proximal divided ends (*Fig.* 1277 B). The rule for the repair of a cut wrist is to attend to blood-vessels first, nerves second, and then proceed to unite tendons. The results of primary suture of tendons in this situation are good: of 5 cases sutured with barb wire, all made a perfect functional recovery (E. R. Jennings).

TENDON-GRAFTING

At any rate as far as the hand and wrist are concerned, at the time of a secondary operation the tendons have retracted so far that reuniting the stumps is impossible, and the only means of effecting repair is by a tendon-graft. Exceptions to this rule are the profundus tendons, which in the middle of the palm are, as a rule, held in fairly close proximity by the attachment of the lumbricals.

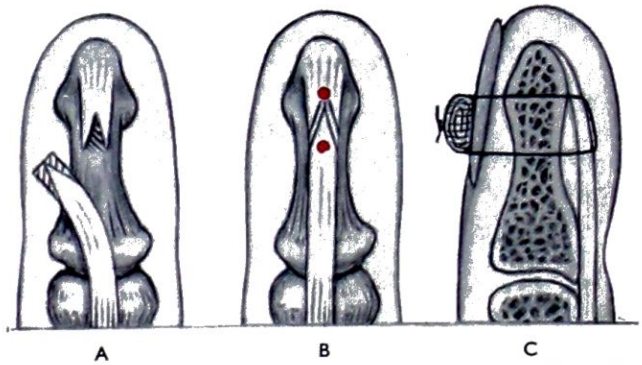

Fig. 1278.—A, A ∧ is cut in the distal end of the tendon and the distal end of the graft is cut so as to fit the ∧. B, With the finest possible awl, two holes are made which perforate the bone to the dorsum. C, The graft is sutured to the bone by a mattress stitch, which is tied over a pad of gauze. (*After R. F. Bogdanov.*)

Grafts that can be used are the tendon of the flexor digitorum sublimis, the tendon of the palmaris longus, and perhaps best of all, the extensor tendons of the 2nd to the 5th toes inclusive. Tendon-grafting is not as difficult as might be supposed. Much patient dissection is often required to free the ends of the tendon. A bloodless field is maintained by the use of a pneumatic tourniquet, released for 5 minutes every 90 minutes. Good exposure is required, and in general the incisions for the hand must follow those depicted in *Figs.* 1379, 1380, p. 993. For a digit the whole length of the finger or thumb is exposed by a midlateral incision. In the case of a flexor tendon of a finger, most authorities advise that empty, contracted portions of the tendon-sheath should be excised: all emphasize the importance of preserving the narrow proximal and distal pulley-like annular ligaments (digital vaginal ligaments). Should either of these ligaments have to be removed because of dense adhesions within the tendon-sheath, later in the course of the operation the pulley must be reconstructed by passing a ligamentous or fascial strip around the bone, or by reconstructing the annular ligament from the residuum of the terminal crura of the sublimis tendon (Koch and Mason). The sublimis tendon is excised, as also is the distal part of the profundus, to within $\frac{1}{2}$ in. (1·3 cm.) of its insertion. The distal end of the profundus is found by making an incision along the proximal palmar or thenar flexion crease. Then comes the tedious dissection of freeing adherent tendon in the blind area between the palmar and digital incisions. The graft is attached to the proximal stump by a Bunnell-Mayer suture. The attached graft is then passed through, to emerge in the digital incision, where it is united to the distal stump (*Fig.* 1278). G. Pulvertaft has found that in this instance the Bunnell-Mayer suture is more satisfactory than the Bunnell 'pull-out' suture. In the case of a

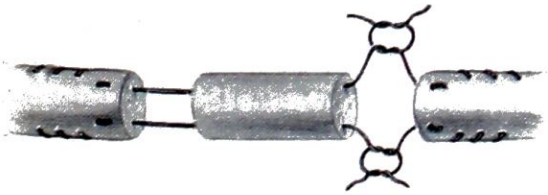

Fig. 1279.—Bunnell's method of bridging a short span with a tendon-graft.

short graft, the expedient depicted in *Fig.* 1279 can be employed. When each graft is fairly long, each end is attached by a Bunnell-Mayer suture.

The same principles are invoked for extensor tendons, but in this instance the absence of tendon-sheath makes the operation less difficult.

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WEINSTEIN, quoted by BOGDANOV. (*Vide supra.*)

CHAPTER LXXX

PHLEBOTHROMBOSIS DECUBITI AND PULMONARY EMBOLISM

POSTURAL or post-operative venous thrombosis still occurs far too often. It is a serious, and not infrequently a tragic, complication, for the patient succumbs to fatal pulmonary embolism. In spite of early rising and respiratory exercises, J. Marks et al. have shown that the number of deaths due to pulmonary embolism has remained stationary over the past decade, and that the great majority of these deaths occur in patients in whom the diagnosis of phlebothrombosis has not been established before the fatal episode. The condition must be anticipated, and it is only *awareness* on the part of the clinician that will reduce the present high incidence.

Prophylactic Measures.—Precautions must be taken before, during, and after operation. In urgent conditions it is not often practicable for adequate instructions in breathing exercises and limb movements to be given prior to surgical intervention. In the operating theatre the calves and heels are protected from pressure on the operating table by thick layers of cotton-wool. A tight abdominal binder is avoided, unless there is a specific indication for its use. Respiratory and limb exercises should be instituted and maintained for as long as the patient is confined to bed. Such treatment should be regular and controlled, preferably by a physiotherapist. No undue immobilization is countenanced. Pillows beneath the knees are prohibited, and if Fowler's position is necessary, it is maintained by one of the methods described on p. 192. Early ambulation is encouraged, but with discretion. Any semblance of infection observed in the post-operative period should be treated promptly by appropriate antibiotic therapy. Dehydration must be prevented or rectified. Finally, it is of paramount importance that it should be regarded as a surgical sin to utilize a vein of the leg for transfusion or infusion when a vein of the arm is available. After any infusion that has been continued for more than eight hours a certain degree of perivenous cellulitis followed by thrombophlebitis is inevitable.

Diagnosis of Established Phlebothrombosis.—It is alertness on the part of the surgeon to the possibility of venous thrombosis that helps materially in the recognition of this menacing complication. Careful scrutiny of the limbs reveals many latent forms, but not all. Being very uncommon in the arms, it is to the lower extremities that attention is directed. Phlebothrombosis decubiti is rare in childhood, the highest incidence occurring between 50 and 60 years of age. Moderate pyrexia, otherwise unexplained, arouses suspicion. Bearing in mind that the condition is prone to occur past the meridian of life, if the patient has undergone an operation about a week previously, the well-trained clinician's thoughts will turn instinctively to the lower extremities. When all those in attendance are alive to the dangers of clotting in the veins of the legs, when the nurse reports slight pain in a calf, and in relevant cases (especially between the third and seventh post-operative days) when the house surgeon undertakes routine investigations for the express purpose of detecting phlebothrombosis, then, and then only, is real progress in the prevention of pulmonary embolism likely to ensue.

Have the bedclothes turned up (not down) and display the whole of the lower extremities (*Fig.* 1280). Examine the limbs for swelling (which may be slight and detectable only by measurement), fullness of the superficial veins, a cyanotic tinge, and palpable temperature changes.

In suspected cases proceed as follows :—

1. Apply finger-tip pressure over each saphenous opening, and with a stroking motion run the finger down the course of each femoral vein, seeking a segment of unilateral localized tenderness.

2. Let the patient draw up the knees and lie quietly, relaxing the muscles. Commence by palpating the feet for tenderness, especially the medial aspect and behind the medial malleolus. Next, squeeze the calves gently, and thirdly, palpate the whole of the thighs systematically, the object being to seek a localized area of muscular rigidity combined with deep tenderness.

3. Palpate deeply in the popliteal spaces, noting if there is tenderness there, after which ask the patient to lower the legs on to the bed.

Fig. 1280.—Diagnosis of phlebothrombosis. Display the whole of both legs and commence by applying finger-tip pressure over the saphenous opening.

4. Homans' sign. With the knee extended, dorsiflex the foot (*Fig.* 1281). Pain experienced in the calf is a positive sign of considerable significance.

Fig. 1281.—Eliciting Homans' sign.

If, as a result of this thorough investigation, the diagnosis of phlebothrombosis is reasonably assured, active therapeutic measures must be instituted forthwith. There are different lines of approach; all of these, having common objectives, show a commendable

tendency on the part of both physicians and surgeons to come to grips with those pressing problems—the prevention of pulmonary embolism and the avoidance of the disabling distal after-effects of widespread venous occlusion.

ANTICOAGULANT THERAPY

Before undertaking this form of treatment, facilities must exist for daily clinical supervision of the patient and full scientific determination of the effect of the drugs. The anticoagulants commonly prescribed are heparin and dicoumarol derivatives. Both are potent agents, each possessing several distinctive features.

Obviously anticoagulants should not be employed when there exists an actual or potential bleeding point, or in those blood disorders with hæmorrhagic tendencies.

Heparin acts powerfully and rapidly in preventing spread of the thrombotic process. Being non-cumulative (it is excreted rapidly by the kidneys), the action of each dose is of comparatively brief duration. Heparin is best given by the intravenous route—either continuously or by intermittent injection at relatively short periods, the effects being recorded by observing the clotting time of the blood. Sufficient heparin should be injected to maintain the clotting time between 15 and 25 minutes. If renal function is poor, the dosage will have to be reduced, sometimes drastically.

In the treatment of post-operative thrombosis heparinization is not likely to be followed by oozing from the incision since thrombosis is not usually recognized clinically before the wound has commenced to heal.

Dicoumarol derivatives differ from heparin in that they are effective when taken by mouth and are more slow-acting. Exerting their action by diminishing prothrombin activity, their administration is governed by accurate daily estimations of the prothrombin time; the necessity for laboratory control cannot be overstated. It is to be remembered that an interval of 24–36 hours is required in which to develop full effects, and the action may be prolonged for a similar period after the last dose.

Contra-indications.—Oral anticoagulants are contra-indicated in hepatic disease and renal failure, as well as in states of vitamin-K deficiency. They should not be given in any type of purpura, in intestinal obstruction with vomiting, or in cases of hypertension and subacute bacterial endocarditis. Other contra-indications are after operations upon the central nervous system and last, but by no means least, in every case where a cutting operation is contemplated in the near future. Hæmorrhage, the important complication of large and unregulated administration, can become so serious as to threaten life.

Heparin Therapy.—Commercial preparations of heparin are put up in international units, but it is much more convenient to translate the dosage into milligrams. For practical purposes 100 i.u. are equivalent to 1 mg. Administration is by intermittent or continuous intravenous injection or, if no vein is available, by intramuscular injection with hyaluronidase 0·1 mg. (*see* p. 36). If the intermittent intravenous route is used Mitchell's self-retaining needle (*Fig.* 1282) will enable the nursing staff to administer the injections and obviate having to call a medical officer day and night for this purpose. Gordh's needle (*Fig.* 1283) is also convenient for withdrawing samples of blood for the determination of the clotting time.

Fig. 1282.—Mitchell's self-retaining, self-sealing needle.

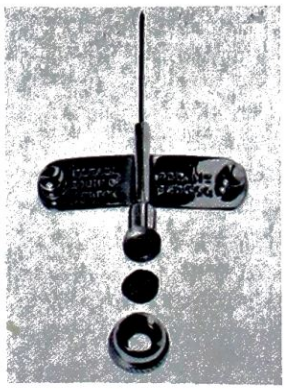

Fig. 1283.—Gordh's needle.

In an average case the following dosage may have to be adjusted to keep the clotting time within the required limits.

First dose 125 mg.

Second dose 4 hours later, 100 mg.

Third dose is given 4–6 hours after the second dose, *only after the clotting time has been ascertained.* It will vary from 50 mg. to 100 mg., depending on the result of the test. If the clotting time is much prolonged, the third dose should be omitted altogether.

Fourth and subsequent doses are given at intervals of 4–8 hours, depending on the response of the clotting time to previous doses.

The total daily dose will usually be between 500 mg. and 800 mg.

The clotting time should be estimated daily.

Treatment should continue until the patient is completely ambulant and has been free of pain and pulmonary embolism for 7–10 days.

Oral Anti-coagulant Therapy.—A veritable host of dicoumarol derivatives are now available, and the later preparations are much safer than the original ones. Their chief indications are in relatively mild cases of phlebothrombosis which have been diagnosed early (as they should be) and in combined oral and intravenous anticoagulant therapy (*see below*). The chief disadvantage of anticoagulants administered orally is that dosage has to be based on daily prothrombin time estimations, which require laboratory facilities. In the absence of full laboratory facilities *oral* anticoagulants should not be given because their actions are erratic, and consequently bleeding from the area of operation may ensue.

At the time of writing the cheapest and best oral anticoagulant is phenylindanedione (dindevan), and treatment with this drug will be described. If another preparation is used the dosage can be ascertained by perusal of the manufacturer's instructions, but the principles are identical.

First dose 200 mg. (of dindevan).

Second dose after 12 hours, 100 mg.

Subsequent doses 50–100 mg. 12-hourly with the object of keeping the prothrombin time between 20–30 per cent of the normal time for the particular patient as estimated by the particular laboratory. Daily estimations should be performed.

Treatment is continued until the patient is completely ambulant and has been free from pain and pulmonary embolism for 7–10 days.

Combined Anticoagulant Therapy.—In practice (except in mild cases) heparin and oral anticoagulant therapy are started simultaneously and the former is discontinued after 24–36 hours when the prothrombin time has been reduced to the requisite level.

Specific Antidotes.—In certain circumstances it becomes imperative to counteract the action of the anticoagulant drugs. In the case of *heparin*, this can be effected in a few minutes by the intravenous injection of 5–10 ml. of a 1 per cent solution of protamine sulphate. If this drug is not available one of the protamine zinc insulin preparations should be utilized (with the administration of sufficient dextrose to counteract the hypoglycæmic action of the insulin).

On the other hand, the action of the *dicoumarol derivatives* is not so easily and rapidly reversed, and it takes several hours and occasionally even days to neutralize the anticoagulant effect of these drugs. Vitamin K_1 (30–50 mg.) should be given intravenously; when this proves unsuccessful in restoring the prothrombin time to normal a transfusion of fresh blood should be given.

Complications of Anticoagulant Therapy.—Slight hæmaturia, mild epistaxis, and even considerable bruising, are not causes for alarm; they are the hall-marks of adequate therapy.

When hæmatoma formation, severe hæmaturia, considerable epistaxis, or hæmothorax occur the dosage of the anticoagulant drug used should be decreased. If blood-loss proves serious the specific antidotes should be given, and in necessary cases blood transfusion should be commenced without delay. Occasionally febrile and anaphylactic[1] reactions occur with these drugs, and indicate the necessity for a change to an alternative preparation.

Bleeding from an unrelated condition such as a duodenal ulcer introduces a problem in priority. In this particular instance sometimes it is wise to abandon anticoagulant therapy in favour of proximal venous ligation (*see below*). On the other hand, when the bleeding can be controlled comparatively easily by a direct attack (e.g., a vesical papilloma or a rectal polyp) this is obviously the course to follow, and as soon as the bleeding has ceased anticoagulant therapy can be resumed. Each case must be dealt with strictly on its merits.

[1] Anaphylaxis following the administration of heparin (*see* p. 79).

Additional Treatment.—As it is impossible to state where aseptic phlebothrombosis ends and infected thrombophlebitis begins, it is logical to treat all these cases as being infected.

The affected leg should be supported by firm crêpe bandaging extending from the toes to the groins, after the application of a kaolin poultice over the painful segment of the vein. Antibiotic therapy is also indicated, and unless there is good reason to prescribe another, penicillin 500,000 units 12-hourly is administered.

PROXIMAL VENOUS LIGATION

The wave of enthusiasm for vein interruption in the prevention and treatment of pulmonary embolism has receded. The reasons for this are fourfold :—

1. As Ian Aird has emphasized, an embolus originates more frequently from a clinically silent area of phlebothrombosis, rather than from an easily apparent patch of thrombophlebitis.

2. Moreover, this silent phlebothrombosis may be situated in the pelvic veins ; so it comes about that the only effective vein interruption is that of the inferior vena cava.

3. The operation of ligation of the inferior vena cava has been shown to have severe late sequelæ. In Shea and Robertson's series of 25 patients, 24 had bilateral œdema of the ankles after the operation, 10 had leg ulceration, 9 were unable to carry out their previous occupations, and only 1 was entirely free from after-effects.

4. Ligation of the inferior vena cava is a formidable procedure, especially in a patient who has very recently suffered a severe pulmonary embolism, and there have been numerous unrecorded fatalities.

INDICATIONS FOR LIGATION OF THE INFERIOR VENA CAVA

1. Occasionally when phlebothrombosis is known to exist at the time of the primary operation.

2. Likewise there are rare occasions when the patient has suffered pulmonary embolism during the pre-operative period.

3. The occurrence of repeated emboli while the patient is undergoing anticoagulant therapy. Although no one can foretell whether small emboli causing no more than transient pain in the chest are not harbingers of a larger embolus, in a given case it may be justifiable to continue with expectant treatment. In such cases, however, it is essential to review the dosage of anticoagulants ; it is possible that the cause of the repeated emboli is inadequate dosage. It should be remembered that anticoagulants can be continued with safety for many weeks, and even months.

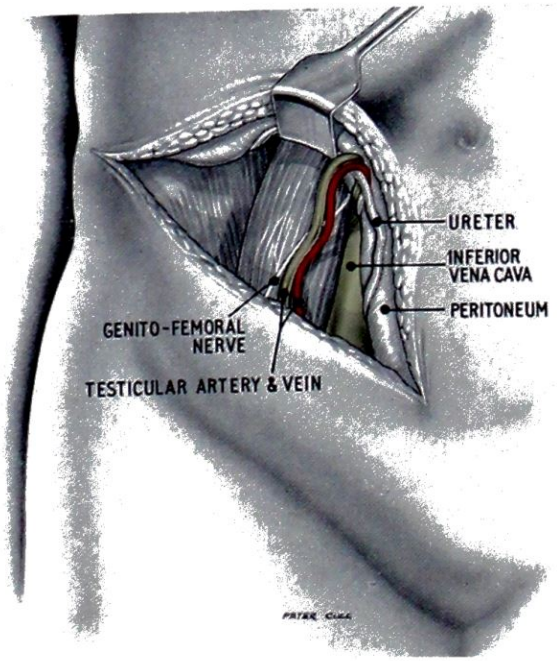

Fig. 1284.—The approach to the inferior vena cava utilizing Morison's incision.

4. Caution must be exercised before undertaking ligation of the inferior vena cava in patients with carcinoma. The extensive deep thrombosis of malignant states has been stressed since the teachings of Trousseau. Less widely known, however, is the fact that thrombotic disease in carcinomatous subjects is prone to be of the migrating type. Therefore, careful examination of all four limbs, and even of the neck, should precede the decision to ligate the inferior vena cava.

Technique of Ligation of the Inferior Vena Cava.—Anticoagulant therapy should be stopped and the particular specific antidote (*see* p. 928) administered.

Local anæsthesia, perhaps combined with small doses of thiopentone if the patie complains of pain, is usually the anæsthetic of choice.

The most convenient approach is an extraperitoneal one through an oblique incision a little lateral to the midpoint between the umbilicus and the anterior superior iliac spine on the right side (Morison's incision). The incision is 4–6 in. (10–15 cm.) long, and after division of the skin and subcutaneous and deep fascia, the external oblique muscle is split and the internal oblique and transverse abdominis divided in the line of the skin incision. The peritoneum is displaced medially, and the ureter usually adheres to the peritoneum, although it sometimes has to be dissected off the psoas muscle. The inferior vena cava now seen lying medial to the psoas muscle (*Fig.* 1284) and is cleared of its surroun connective tissue (the fascia of Zuckerkandl or Gerota) with a Lahey swab (*see Fig.* 12) A non-absorbable ligature (e.g., thread) is passed around the vein on an aneurysm n and tied ; the vein is thus ligated in continuity.

Provided the muscle layers are closed carefully and separately a ventral hernia is unlikely to occur. Drainage is unnecessary.

PHLEGMASIA CERULEA DOLENS

(*See* p. 967)

PULMONARY EMBOLISM

As J. Marks et al. have shown, prophylactic measures, including early rising and the use of anticoagulants, have not reduced the incidence of fatal pulmonary embolism materially. In a 500-bedded General Hospital an average of 10 fatal pulmonary emboli occur yearly. This disappointing state of affairs seems to be due partly to the fact that fatal emboli frequently occur unheralded by the signs of localized phlebothrombosis, and partly to the increasing age and infirmity of patients submitted to operative procedures. So it comes about that the house surgeon is summoned from his bed (for some unexplained reason this catastrophe occurs more frequently at night) only to find when he arrives in the ward tha the patient is already dead.

In an effort to save some of these patients, an emergency stock of heparin clearly labelled, should be kept in the hospital dispensary's refrigerator where it can be found easily by the house surgeon or night sister. Double the usual dose, i.e., 250 mg. of heparin, should be injected intravenously by the first doctor to reach the patient, if he be still alive.

Fortunately this treatment is also of some benefit in the only condition with which pulmonary embolism is frequently confused, to wit, coronary thrombosis.

If the patient survives, anticoagulant therapy is continued as detailed in this chapter.

Heparin has a twofold action in established massive pulmonary embolism :—

1. It prevents further clot formation in the pulmonary arteries, and actually may cause some of the existing clot to become disintegrated.

2. It acts as an antispasmodic and favours the clot being swept from the pulmonary artery into one of its branches.

Trendelenburg's operation, whereby clot was removed from the pulmonary artery, has become obsolete : if a patient survives long enough to be submitted to this formidable operation, there has been adequate opportunity to institute heparin therapy.

See also Chapter XCIII.

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CHAPTER LXXXI

URGENT SURGERY OF BLOOD-VESSELS

THE immediate treatment of a wound of any large artery is to apply pressure to the bleeding point with the left thumb while the right hand seeks the point of vantage to compress the artery above the wound. In the case of the limbs, when the wound is below the axilla or groin, direct compression is quickly changed in favour of some form of tourniquet. Unfortunately for the patient, it is seldom that skilled help can be procured on the scene of the accident. Thus it comes about that the general diffusion of 'first-aid' knowledge among the public is to be encouraged. Sometimes it happens that a little knowledge is a dangerous thing :—

A man was admitted dying from hæmorrhage from a wound in the thigh. Before his transit from an outlying district to hospital, a tourniquet had been applied ineffectively above the wound. The femoral artery was intact, but there was a large opening into the femoral vein.

Firm local pressure usually arrests bleeding. When the pressure is removed a fleeting opportunity is afforded to view the source of the hæmorrhage. Often it is found that it is not the main artery that is bleeding, but a large branch thereof (S. M. Cohen).

Temporary arterial constriction should not last longer than half an hour ; by that time it must be followed by one of the measures to be detailed in this chapter. If facilities are not available for proper exploration of the wound the medical practitioner must secure the bleeding point temporarily, using whatever means are available. This accomplished, the tourniquet is removed.

On the other hand, the emergency surgeon should do all within his power to avoid ligation of 'critical' arteries (axillary, brachial, iliac, femoral, popliteal). H. H. Ziperman found that in the Korean War the proportion of extremities lost, when compared with the results obtained in the Second World War, was reduced from 40 per cent (de Bakey and Simeone) to 20 per cent, by the greater use of conservative operation.

VASCULAR SUTURE

Suture of a wounded blood-vessel is not as difficult as is sometimes assumed. Results in properly selected cases are superior to those of ligation. In the case of a large vein, contrary to what might be thought, sutures hold well. The inferior vena cava and common iliac vein have often been repaired successfully after accidental injury in the course of a surgical operation.

Arterial suture is called for when there has been little or no loss of the arterial wall. Stab wounds involving a vessel often fulfil this criterion. On the other hand, if there has been loss of substance of the vessel wall suture is liable to be followed by such narrowing that thrombosis ensues. Consequently, one of the methods of restoring the continuity of the artery described below should be utilized.

Methods of Temporarily Occluding an Artery.— Before an artery can be sutured it is necessary to occlude it temporarily. The following methods are in use :—

1. *Sol Cohen's Method.*—A strip of corrugated rubber is passed around the artery and held moderately taut by the assistant (*see Figs.* 1287, 1307).

2. *Sir Charles Gordon-Watson's Method* (*Fig.* 1285).—The tape should be soaked in paraffin otherwise it knots jerkily and is liable to damage the artery.

3. *Crile's Arterial Clamp* (*Fig.* 1286).

4. *Blalock's Arterial Clamp* (*see Fig.* 1288).

In the absence of special arterial clamps Method 1 will be found most generally useful. Method 2 is particularly valuable when assistance is limited.

Suture Material.—No. 100 cotton, No. 000 untwisted Chinese silk, or the finest linen thread ; the finest round-bodied needle compatible with the suture material. After sterilizing, lightly anoint the suture with sterile liquid paraffin. Special atraumatic arterial sutures (size 00000) are valuable, if available.

Provision must be made to prevent clotting: The wound is moistened with isotonic sodium citrate solution or ½ per cent heparin.

Instruments.—Fine instruments are preferable for vascular surgery. In an emergency the ophthalmic surgeon's instruments will be found to provide the fine mosquito hæmostats and dissecting forceps necessary. Special arterial clamps (Crile's or Blalock's) are useful,

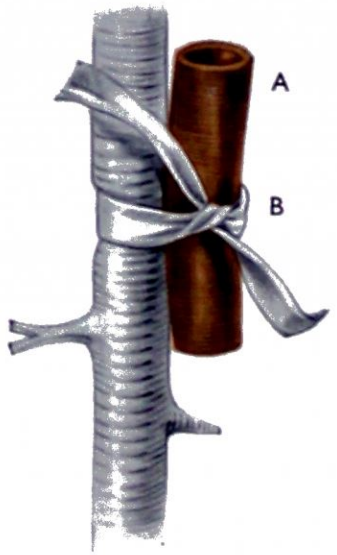

Fig. 1285.—Temporary occlusion of a large artery by Gordon-Watson's method. A, Rubber drainage-tube; B, Tape tied with a single turn.

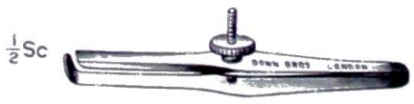

Fig. 1286.—Crile's arterial clamp forceps.

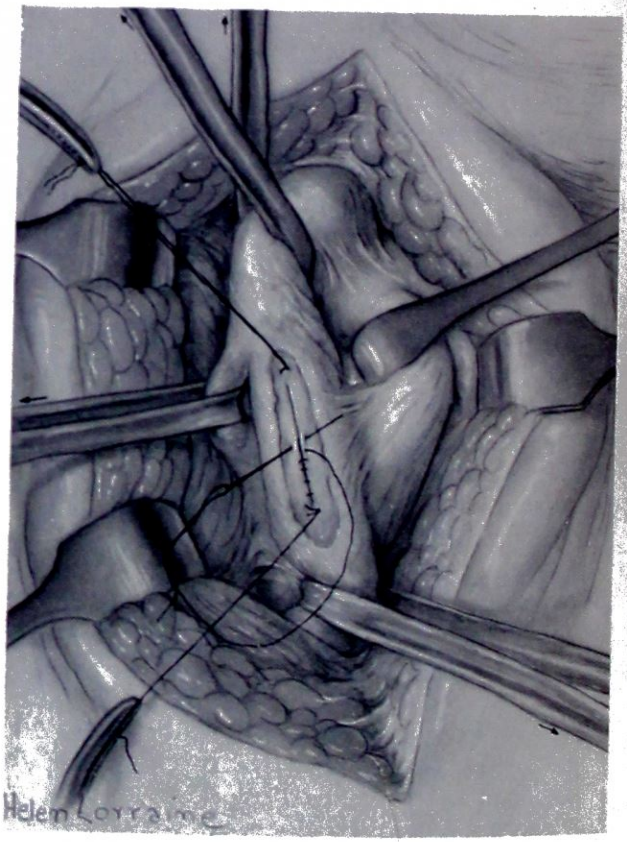

Fig. 1287.—Wound of the femoral artery being repaired by suture.

but not essential. Lahey's swabs (*see Fig.* 12) and Desjardins' forceps (*see Fig.* 1305) are also of great value.

Technique of Suture.—The edges of the wound in the vessel should be cleared of adventitia, but no attempt should be made to excise them. A continuous over-and-over stitch as shown in *Fig.* 1287 can be utilized, and will give excellent results. Interrupted mattress sutures (*see Fig.* 1289) produce better eversion, and are an added refinement. Another method is a continuous mattress suture, but there is little to choose in the results of all three methods.

When the clamps are released, there may be a little leakage at one or two points, necessitating additional interrupted sutures.

END-TO-END ARTERIAL ANASTOMOSIS

This is the method of choice when a vessel has been divided completely, or when a lateral wound has caused such loss of substance that simple suture would be followed by narrowing. Its use is, of necessity, limited to the loss of a relatively short segment, but it is permissible to mobilize the damaged vessel extensively (provided no large branch is sacrificed). At the same time it must be known that in anastomosis of blood-vessels moderate tension is an advantage. It is also permissible to flex a limb to enable the vessel ends to be brought together.

Temporary clamps are applied as before. The ends of the arteries are trimmed, any excess of adventitia being cut away. This is followed by irrigation of the interior of the ends of the vessel with citrate or heparin (*see above*). Three stay sutures are passed at equidistant points so that when they are pulled taut a triangle is formed (*Fig.* 1288). The

portions A–B, B–C, and C–A shown in the inset are sewn separately, using a mattress suture to evert the edges (*Fig.* 1289). This eversion forms an ideal junction, endothelium being apposed accurately to endothelium. Particularly with a small vessel, it is often an advantage to employ only two stay sutures. When the anastomosis is completed the stay sutures are removed.

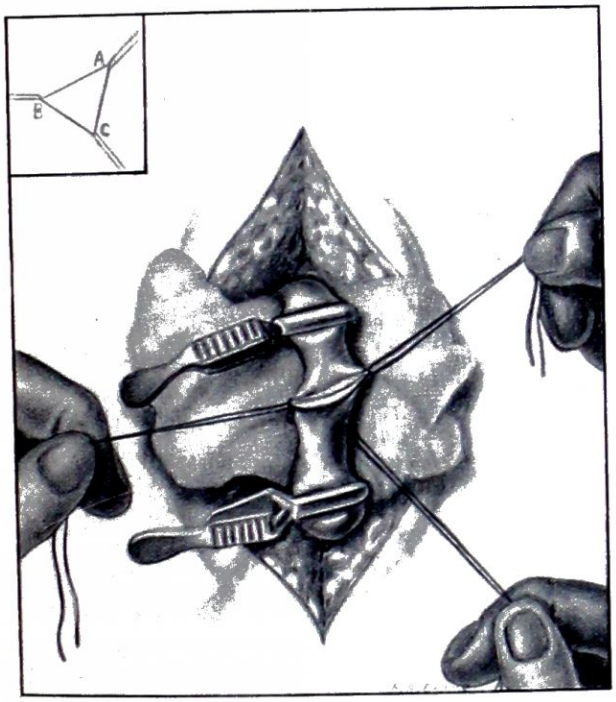

Fig. 1288.—End-to-end arterial suture. Three stay-sutures have been inserted. Blalock's clamps are being used.

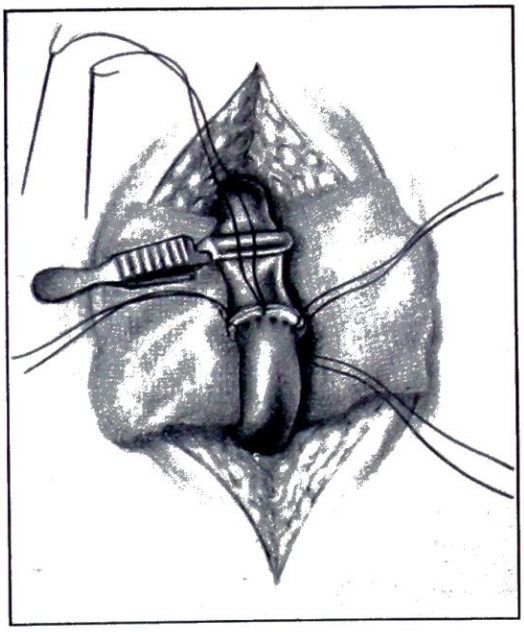

Fig. 1289.—End-to-end arterial suture. The edges of the artery have been approximated by mattress sutures.

ARTERIAL GRAFTING

Various methods of arterial grafting used in the treatment of obliterative arterial disease have led to a decrease in the amputation rate (*see* Ziperman's statistics, p. 931). In average hospital practice, and certainly under the conditions of warfare, the use of preserved arterial homografts, as popularized by Rob and Eastcott at St. Mary's Hospital, London, is not practicable. During the Korean War it was found that, for lesions of the 'critical' arteries (axillary, brachial, iliac, femoral, popliteal) autogenous vein grafts were as good, and probably better. The long saphenous, external jugular, or cephalic veins can be used, and it is important to remember to reverse the vein in order to avoid obstruction to the flow of blood by any valves present. As an alternative, various impervious plastics such as orlon, nylon, and vinyon-N can be used in an emergency, and a number of workers have shown that a process of 'arteriogenesis' occurs, new fibrous tissue being laid down on the foundation of the plastic cloth tube, which acquires an endothelial lining.

Fig. 1290.—1, Polyvinyl graft; 2, Orlon graft.

Any one of a number of plastic cloths can be utilized, and in an emergency a piece of close-mesh nylon cut from a shirt or other article of clothing can be employed. For a femoral arterial prosthesis two pieces of material 1 in. (2·5 cm.) wide are laid on one another and stitched together with two rows of stitches, using a sewing machine, and giving a diameter of $\frac{1}{2}$ in. (*Fig.* 1290). The prosthesis can be sterilized by boiling, and when used the correct length is calculated and the ends are everted to provide smooth edges for

anastomosis with the artery. After the clamps are released there is always a certain amount of leakage of blood, but this ceases as the blood clots in the interstices of the material.

Recently a new plastic material—polyvinyl-ester sponge[1]—has become available. Introduced by N. E. Shumway et al., thin strips of the material are wrapped around a glass rod the size of the vessel to be replaced, and held in position by an ordinary roller bandage. When sterilized by boiling, the material fuses and becomes flattened and as smooth as the glass on its inner surface, and on cooling down can be made to slide off the mould as a resilient but tough graft which closely resembles an actual artery. In the future it is likely that this material will be easily obtainable.

Technical Points in Arterial Grafting.—

1. A time lag of up to 15 hours will not vitiate success, and the procedure should be attempted even later than this, as the collateral circulation may have kept the limb alive. Nevertheless, the earlier the operation the better the prognosis.

2. Wound débridement (*see* Chapter XIII) should be carried out first, and the classical approaches described in Chapter LXXXII should then be utilized for adequate exposure of the particular artery damaged. In many cases it will be found that the débridement of the wound, with slight extensions, will provide adequate exposure.

3. Jahnke and Seeley have shown that microscopical damage to the arterial wall extends much farther than the apparent macroscopic damage. With the object of preventing subsequent thrombosis due to this occult trauma, a centimetre of each end of the artery should be excised beyond the point of gross damage; once a decision has been reached to use an arterial graft the loss of a further 2 cm. makes no difference.

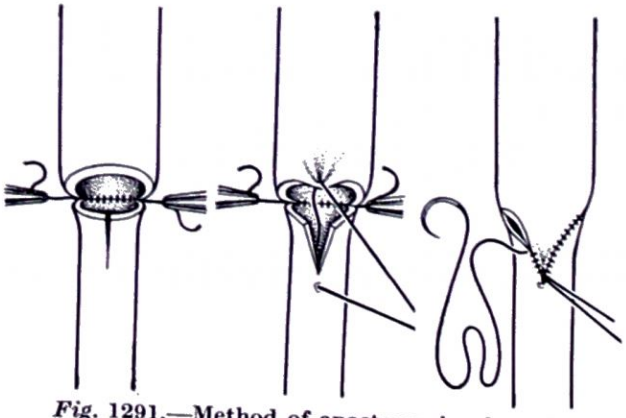

Fig. 1291.—Method of anastomosis when there is a discrepancy in size between the artery and the graft. (*After E. Holman.*)

4. When arterial clamps have been applied proximal and distal to the divided ends of the artery a few ml. of ½ per cent heparin should be injected with a fine hypodermic needle beyond the clamps, to minimize the possibility of thrombosis.

5. If there is a discrepancy between the sizes of the artery and the graft the expedient suggested by E. Holman should be used (*Fig.* 1291).

6. The technique of anastomosis is the same as that described under ARTERIAL ANASTOMOSIS (*see* p. 932).

7. The grafts should be sewn-in under slight tension, otherwise they tend to kink, and later thrombosis occurs.

8. It is convenient to complete the proximal anastomosis first and then release the proximal clamp and seal off any leaks with interrupted sutures. The proximal clamp is then reapplied and the distal anastomosis completed in the same way.

9. The anastomosis and grafts should be covered by muscle or fascia if possible, before skin closure. Should a rotation flap prove necessary for skin closure, the resultant skin defect should be covered by split-skin grafts.

10. Anticoagulant therapy is contra-indicated, as bleeding from the anastomosis would result.

LIGATION

Ligation can be employed without hesitation in the case of the smaller arteries, but its use should be a last resort when interruption of the vessel concerned would carry an appreciable risk of gangrene (*Fig.* 1292). It follows that its application in injuries of 'critical' arteries should be entertained only if circumstances dictate that the methods just described cannot be applied. Catgut should not be employed as ligature material for any artery of appreciable size. A non-absorbable suture (silk, cotton) carries a greatly decreased risk

[1] Ramer Chemical Co., 79, Blackheath Hill, London, S.E.10.

of secondary hæmorrhage. Should the wound become even mildly infected, catgut becomes prematurely digested.

The stay-knot of Ballance is useful in the case of large arteries. Two independent ligatures are placed very close to each other. The first tie concerns each ligature only, the second is made with both ligatures taken together. *Fig.* 1293 makes this procedure clear.

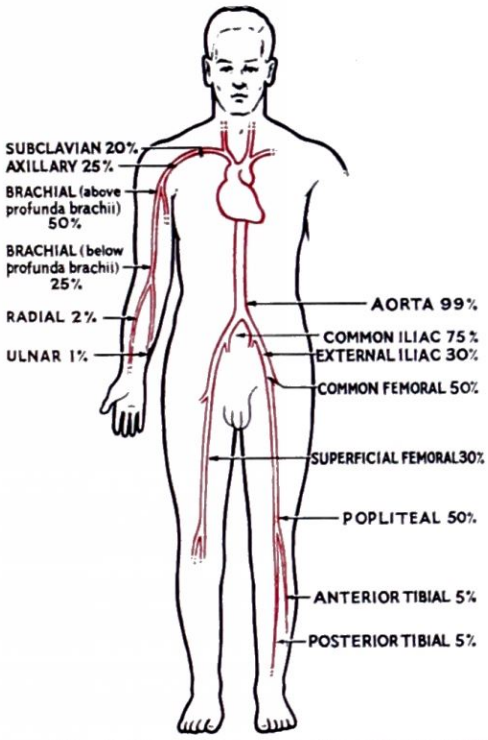

Fig. 1292.—The expectation of gangrene ollowing ligation of a main artery after injury. Based on Heidrich's (World War I) and de Bakey and Simeone's (World War II) statistics.

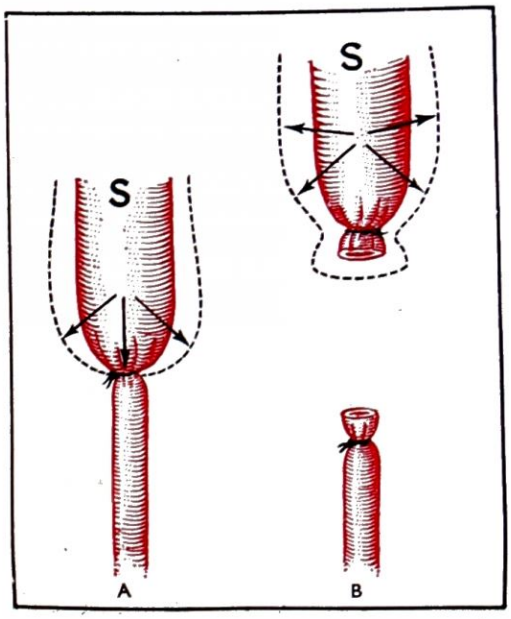

Fig. 1294.—A, Simple ligation. The kicking arterial stump cannot retract. Consequently the force of pulsation is centred on that weakened rim of arterial wall constricted by the ligature. Secondary hæmorrhage invited. B, Division of artery between ligatures. Kicking stump retracts and thus the force of pulsations is dissipated. Secondary hæmorrhage is highly improbable. (*After Emile Holman.*)

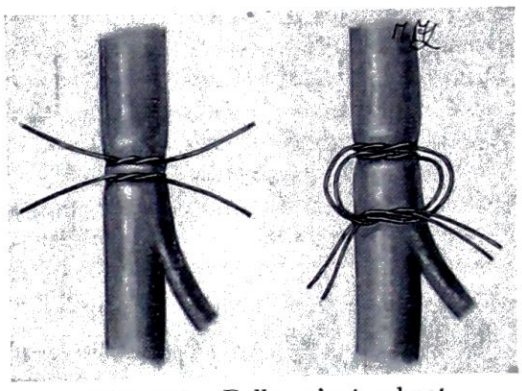

Fig. 1293.—Ballance's stay-knot.

The application of a ligature that controls what would quickly prove fatal hæmorrhage rightly engenders a sense of satisfaction. Nevertheless, simple ligation must not content the surgeon. The artery should be *divided* between ligatures. The reasons for this injunction are well founded. In the first place ligation in continuity is far more likely to be followed by secondary hæmorrhage than division between ligatures. The kicking arterial stump of an artery ligated in continuity cannot retract, consequently the constriction of the ligature

Fig. 1295.—Closing the open mouth of an artery by suture, to avoid ligating two main branches. (Maybury's expedient.)

causes pressure necrosis because the weakest point is subjected to constant battering (*Fig.* 1294 A). When an artery has been divided between ligatures the stump is mobile and retracts; therefore, the force of pulsation is dissipated (*Fig.* 1294 B).

Another important dictum is to ligate an artery as near as possible to the lesion.

Minimizing the Risk of Gangrene.—The following measures have proved helpful:—

Removal of Clot from the Distal End of the Artery.—Before applying the ligature to the distal end of the divided artery the hæmostat should be loosened. If no bleeding occurs, an attempt should be made to clear the interior of the artery of clot. Clot within the lumen of the artery may jeopardize the establishment of a satisfactory collateral circulation.

Closure of the Distal End of the Artery by Suture.—Gangrene is especially liable to follow occlusion between ligatures of an artery just above its bifurcation into two main branches; e.g., the brachial artery in the antecubital fossa, the common femoral just above where it divides into the superficial femoral and the profunda femoris. Ischæmia and gangrene can sometimes be circumvented by adopting the expedient of Maybury. Instead of ligating the dividing limbs of the artery the open end of the arterial fork is closed with a running suture (*Fig.* 1295).

Ligation of the Corresponding Vein.—H. H. Ziperman's conclusions (based on Korean War results) are that this measure is contra-indicated.

Gangrene Inevitable.—Usually there is no reason to hurry to amputate the limb. Treatment as for dry gangrene should be instituted. When the time comes for the operation, refrigeration anæsthesia (*see* p. 968) has much to recommend it in a frail patient.

POST-TRAUMATIC VASCULAR INSUFFICIENCY (VOLKMANN'S ISCHÆMIA)

Volkmann's ischæmia following a closed injury of an extremity may be due to a number of conditions:—

1. Injury to a major artery by a bone fragment.
2. Spasm of a major artery due to trauma.
3. Disruption of arterial muscular branches at the time of injury.
4. Occlusion of arterial branches by local pressure due to a tight plaster-of-Paris cast or bandage.
5. Occlusion of arterial branches by a hæmatoma enlarging beneath the unyielding deep fascia.

It must be appreciated that the blood-pressure in muscular arteries and vasa nervorum is only about half that in the major arteries so that the presence of a radial pulse, for example, does not imply that the muscles and nerves of that arm are receiving an adequate blood-supply. Therefore, after an injury to a limb followed by pain in the hand or foot, the early signs of Volkmann's ischæmia should be sought assiduously; they include pallor or cyanosis, œdema and weakness or paralysis. Pain on passive extension of the fingers is particularly significant. Pulses are not necessarily absent, but if present are often weaker on the affected side.

Treatment.—The first step is to release a tight plaster or bandage, and if the fracture is near the elbow or the knee, the limb should be extended. Adequate reduction of a fracture is required if radiographs suggest that a bone-end is impingeing on the brachial or popliteal artery.

When the above-mentioned measures fail to provide rapid relief, in the case of an arm the next step is the induction of a brachial-plexus block. The aim of this is twofold: firstly, the relief of spasm by cervical sympathetic block, and secondly, to provide anæsthesia should operation prove necessary.

Brachial Plexus Anæsthesia.—The patient lies with the head and neck on a pillow and with the head rotated to the opposite side. In order to depress the clavicle, an assistant exerts traction on the arm at the patient's side, provided the causal injury permits this step. The index finger palpates the subclavian artery above the middle of the clavicle, and with this finger depressing the artery a skin weal is raised immediately above the finger-tip ($\frac{1}{2}$ in. (1·3 cm.) above the clavicle). A fine spinal needle is then passed in the direction of the spinous process of the third thoracic vertebra (downwards, inwards, and backwards). As the needle is inserted it may strike part of the brachial plexus, and cause pain in the arm. This should be the signal for commencing the injection of the local anæsthetic. Alternatively, the needle may reach the first rib at a maximum depth of 2 in. (5 cm.) without causing pain, and injection should then start at this level. In either case, after aspiration of the needle to make certain that it is not in a blood-vessel or the pleura, 40–50 ml. of 1 per cent procaine is injected slowly, the needle being withdrawn gradually while the injection is in progress.

The last resort, if there is still doubt about the circulation, is exploration of the affected artery. This is carried out conveniently under the previously induced brachial-plexus block, supplemented if necessary by local anæsthesia.

Arterial Exploration for Volkmann's Ischæmia.—The particular artery (usually the brachial) is approached as detailed in Chapter LXXXII. After incision of the deep fascia, a hæmatoma, if present, is evacuated. Examples of tense subfascial hæmatomata being the sole obstructing agent have been reported. A hæmatoma within the arterial sheath should be evacuated. J. B. Kinmonth has found that the local application of a 2·5 per cent solution of papaverine sulphate for several minutes is most effective in relaxing spasm. If this measure fails, a periarterial sympathectomy should be performed. In the rare event of a tear of the main artery being found, the continuity of the vessel must be re-established.

Sometimes a segment of artery is found to be thrombosed (W. S. Edwards) and in this event the artery should be opened and the clot removed (*see* TECHNIQUE of EMBOLECTOMY, p. 941). In late cases excision of the thrombosed segment, followed by an arterial graft, may be required.

ACCIDENTAL INTRA-ARTERIAL INJECTION OF DRUGS

As S. M. Cohen remarks in his valuable study of thiopentone cases, this accident can happen to anyone. Contrary to what is usually taught, puncture of the arterial wall is usually painless, but an intra-arterial injection of thiopentone causes severe agonizing pain coming on when about 2 ml. has been injected. Intense transient vasoconstriction usually follows and several of the cases analysed by Cohen showed, besides involvement of the hand and fingers, mottled bluish-green patches in the skin of the forearm, around the elbow-joint, and in the arm well above the site of injection. A striking feature in some patients was extensive œdema of the hand and forearm; this may be evident within 2 hours and well-marked within 5 hours. Massive gangrene of the limb followed extensive thrombosis in the major vessels. The commonest abnormality predisposing to the accident is a superficial ulnar artery (*Fig.* 1296).

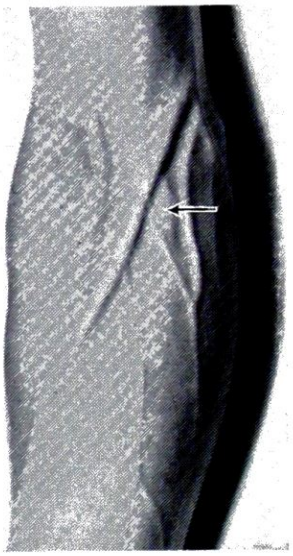

Fig. 1296. — Veins distended with a rubber band. Arrow indicates superficial ulnar artery. Gliding of the needle to enter the median basilic vein may lead to puncture of the artery. (*S. M. Cohen.*) (*By kind permission of* '*The Lancet*'.)

When this accident occurs the needle should be left in situ and 10 ml. of 1 per cent procaine injected into the artery, in an effort to release vasoconstriction. Provided the circulation in the limb is quite satisfactory after this measure (it is frequently effective), the operation is carried out as planned. On the other hand, if there is any sign of impaired circulation in the affected limb, the operation, unless imperative, should be postponed and immediate heparinization (*see* p. 927) carried out, provided there are no fractures present from which bleeding would occur.

If after 4–6 hours the circulation has not returned to the arm, the operative measures detailed under Volkmann's ischæmia (*see* p. 936) are indicated.

ARTERIAL OCCLUSION BY AN EMBOLUS

The restoration of the circulation by the removal of an embolus was a notable advance in urgent surgery. However, during the past few years, with the development of anticoagulant therapy, there has been a gradual narrowing of its indications (*see* p. 939). In England the possibilities and urgency of treatment are not yet fully appreciated (*Fig.* 1297).

Usually an embolus lodges where an artery divides. The bifurcations of the aorta, common iliac, femoral, and the popliteal arteries are favourite sites (*Fig.* 1298). In the upper limb, embolism is relatively uncommon. The axillary artery, at the point where its subscapular branch is given off, and the brachial artery, at its bifurcation, are the usual sites of arrest (*Fig.* 1299).

Diagnosis and Localization of the Site of the Embolus.—Localization of the site of the embolus is more difficult than the diagnosis of its presence. Suddenly there is 'cramp' in the limb. The pain may be severe, but more often it is less than one would expect, the patient's main complaint being numbness and loss of use of the member.

On Examination.—The limb is blanched and paralysed, and below the occlusion pulsations have ceased. Here the prick of a needle fails to bleed. Proximal to the embolus the artery is beating as in an amputation stump ; below it is empty, contracted, and still.

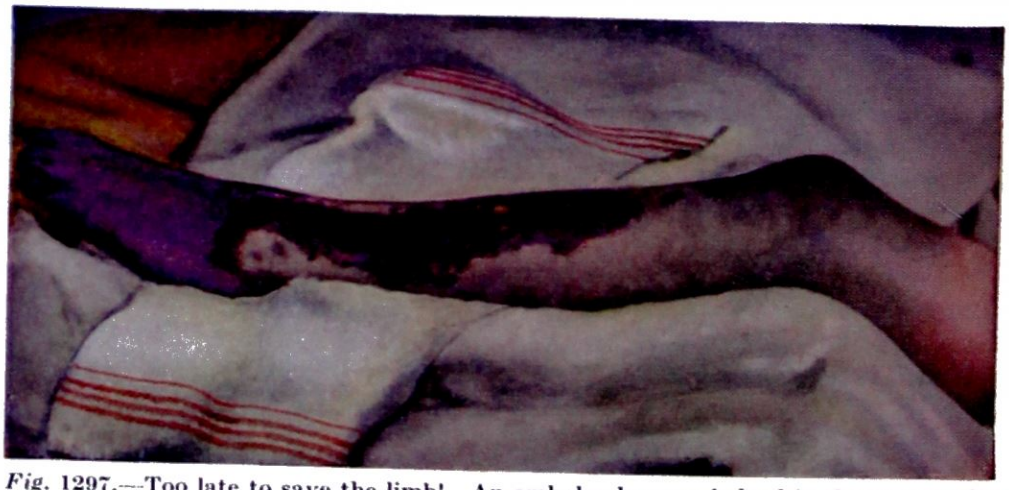

Fig. 1297.—Too late to save the limb! An embolus became lodged in the common femoral artery forty-eight hours before the patient's admission to hospital. The patient was a young woman with mitral stenosis.

When pain is present, unfortunately the site of maximum pain is not necessarily the site of the embolus ; for instance, when an embolus is arrested at the bifurcation of the femoral artery symptoms are often referred to the knee. The collateral circulation also helps to beguile us. What we need in cases of doubt is quick, definite proof of the exact location of the embolus. In the absence of the facilities for arteriography the following test may prove helpful.

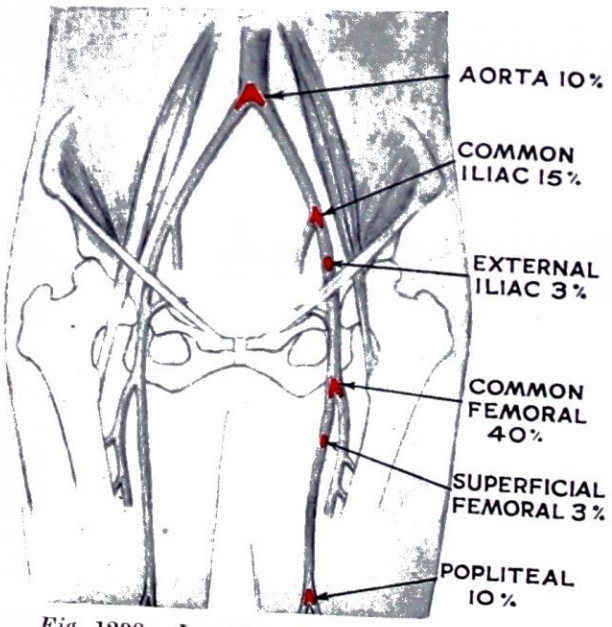

Fig. 1298.—Location of peripheral emboli in the lower extremity.

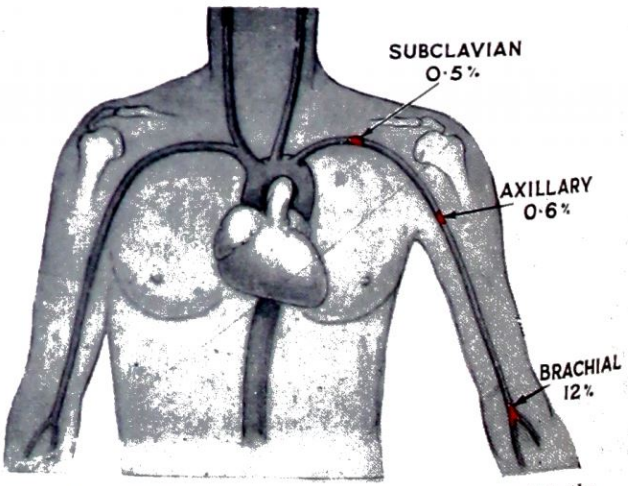

Fig. 1299.—Location of peripheral emboli in the upper extremity.

(*Figs.* 1298, 1299 founded on 335 cases collected by R. E. Pearse.)

The Ausculatory Test : Temporarily occlude the femoral (or brachial) artery at the root of the limb with the pressure of a sphygmomanometer cuff. Alternatively, instruct an assistant to compress the artery with his thumb. A stethoscope is applied at various points along the course of the artery from above downwards. After releasing pressure the booming of the returning arterial flow will be heard until the site of the embolus is reached, when there is an abrupt cessation of sound (R. J. Last).

Percutaneous Disimpaction of the Embolus (S. M. Cohen) is a valuable measure if the clot lies in an artery which is relatively superficial. In suitable cases this should be attempted as soon as the patient has been heparinized. The artery is palpated carefully for the site of arrest of pulsation, and is then gently but firmly massaged from above, downwards. The

vessel may be felt to leap into pulsation as the clot glides onwards to become arrested distally in a less important part of the artery, or in one of its branches.

Embolism of the Upper Limb.—If the embolus has lodged in the upper limb further diagnostic refinement is a matter of interest only, as the correct treatment is heparinization (*see* p. 927), which should be immediate, high doses being used. With this régime it is rarely, if ever, necessary to resort to embolectomy, but the limb should be watched carefully for the first 6–8 hours. Morphine is administered, and warming of the limb avoided.

Mrs. M. A., aged 68, was admitted having experienced transient lower abdominal pain three days previously. This was followed by coldness, blueness, and paralysis of both legs, and it was obvious that an aortic saddle embolus had disintegrated, the fragments lodging in the femoral arteries, probably at the profunda femoris origin. The lower limbs were gangrenous and beyond hope. Her general practitioner had requested admission because, some 12 hours previously, the

Fig. 1300.—Method of percutaneous femoral arteriography if a special limb-length cassette is available.

right lower arm had become weak and cold! The right radial pulse was absent, and the hand was cold and blue from the mid-palm distally. The cause of the embolism was auricular fibrillation.

Heparinization was followed in a few hours by return of normal colour and movements to the right hand. The patient refused amputation of the lower limbs, and died three days later. Post-mortem examination confirmed the sites of lodgement of the emboli, which had been postulated.

Embolism of the Lower Limb.—When an embolus is arrested below the bifurcation of the aorta the interests of the patient are best served by varying the treatment in accordance with the length of time that has elapsed since the time of lodgement.

Indications for Heparinization and for Embolectomy.—

1. **Early Cases** (those of up to 8 hours' duration).—Six to eight hours after lodgement of the embolus can be spent in endeavouring to restore the circulation by means of heparin (*see* p. 927). If, after this period, the colour of the affected limb remains unchanged and the temperature unaltered, embolectomy is called for. While the operating theatre is being prepared and the necessary instruments assembled, the specific antidote (*see* p. 928) is administered.

2. **Intermediate Cases** (8–18 hours' duration).—Embolectomy, without delay, offers the patient the best chance of saving the limb.

3. **Late Cases** (over 18 hours' duration).—By this time probably irreversible thrombosis has occurred in the arterial wall distal to the embolus, and in a very high percentage of cases gangrene of at least a part of the limb is inevitable. A futile attempt at embolectomy only decreases the chance of saving at least part of the limb, as heparinization must be postponed for at least 12 hours after operation, because of the risk of hæmorrhage.

These patients, many of whom are poor surgical risks because of auricular fibrillation, and prone to further showers of emboli, are best treated by heparinization while awaiting a line of demarcation. Before amputation, the specific antidote must be administered.

Five hours after its lodgement, an embolus was removed successfully from the common femoral artery of a woman of 62 suffering from auricular fibrillation. An attempt at post-operative heparinization led to bleeding, and was discontinued. Two days later she died of a cerebral embolus. In retrospect, her chances would have been better with immediate heparinization.

Fig. 1301.—Method of utilizing a 17 × 14 in. (42·5 × 35 cm.) cassette

Fig. 1302.—Showing complete occlusion of an arteriosclerotic femoral artery in the lower third of the thigh. Note calcification in the walls of the unobstructed segment.

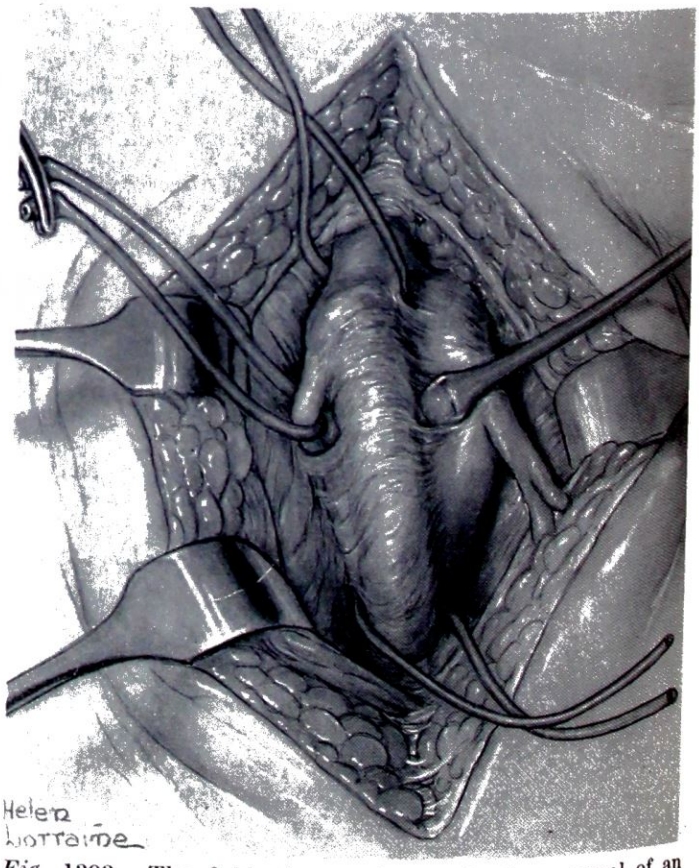

Fig. 1303.—The field of operation ready for removal of an embolus from the femoral artery.

Once a decision to operate is reached there may be some doubt as to the exact site of the embolus.

Femoral Arteriography is often a useful preliminary to operation if the common femoral artery is pulsating, showing that the embolus has impacted distally. The X-ray films are placed as shown in *Figs.* 1300 and 1301. Of 35 per cent diodone (or a similar opaque

medium) 18 ml. is drawn up into a 20-ml. syringe, and with a large-bore angled needle the femoral artery is entered obliquely percutaneously. There will be no doubt when the artery is punctured ; blood will spurt back into the syringe forcibly. The medium is injected as rapidly as possible, and the radiograph taken when 15 ml. have been introduced. On withdrawing the needle, while the film is being developed, firm pressure with gauze at the site of puncture prevents leakage of blood. The site of obstruction being thus displayed pictorially (*Fig.* 1302), the operation is planned according to radiological findings.

If difficulty is experienced with the percutaneous method, a vertical incision just below the inguinal ligament will enable arteriography to be carried out under direct vision, and in many cases the incision, if prolonged, can be utilized for the subsequent embolectomy.

Armamentarium.—Suture materials and instruments, as described under VASCULAR SUTURE (*see* p. 931), are necessary.

If a sucker is available a Eustachian catheter fitted to its tubing, or a glass tube of similar calibre with a blunt end, is most desirable. In the absence of a sucker one of the foregoing end-pieces connected by a piece of rubber tubing to a well-fitting syringe allows clot to be sucked out of the artery.

Anæsthesia.—As a general rule the operation should be performed under local anæsthesia. In a number of reported successful cases spinal anæsthesia has been used. Vasodilatation following a spinal anæsthetic sometimes results in the embolus passing distally (R. Daley). For this reason, after administering a spinal anæsthetic, it is prudent to wait for a quarter of an hour, and then to reassess the level of pulsation before commencing the operation.

Technique of Embolectomy.—Often the embolus is situated in the common femoral or in the superficial femoral artery, either of which can be approached through the femoral triangle (*see* p. 951). Less frequently an incision will be required above the inguinal ligament for access to the common or external iliac arteries (*see* p. 950) or in the popliteal fossa for removal of an embolus at the popliteal bifurcation (*see* p. 952). Careful clinical examination of the pulses, together with arteriography in doubtful cases, should enable the surgeon to site his incision correctly.

Exposing the Common Femoral Artery.—Procaine solution is injected into the skin in the line of the artery, and an ample incision is made downwards from the inguinal ligament, bearing in mind that the origin of the profunda femoris is more distal than one is inclined to imagine. More procaine solution is injected, and by suitable dissection and retraction the artery is displayed. If the diagnosis is correct, and that part of the artery containing the embolus is under vision, the artery will be found to be in spasm but slightly swollen and darker in colour in the region of the embolus (*Fig.* 1303).

Before proceeding further, arterial clamps or slings are placed in the positions shown in *Fig.* 1303, in order to prevent migration of the embolus and to control hæmorrhage.

Separation of the Adventitia.—A longitudinal incision is made through the adventitia about $\frac{3}{4}$ in. (2 cm.) long, and each edge of the adventitia is grasped in a hæmostat. Using a Watson-Cheyne dissector, or a Lahey's swab (*see Fig.* 12), the adventitia is separated from the media (*Fig.* 1304). This step facilitates subsequent arterial suture.

Opening the Artery.—The wound is moistened with sodium citrate solution.

The best site for extraction of the embolus is at the origin of the profunda femoris artery, as often a part of the embolus is in this important branch and cannot be removed except under direct vision. The artery is incised longitudinally : the opening should be small in the first instance ($\frac{1}{2}$ in.).

Extraction of the Embolus.—Sometimes the clot is extruded spontaneously, or some of it remains to be picked out with a Desjardins gall-stone forceps (*Fig.* 1305). It is important to remove as much clot as possible from the distal portion of the artery before traction to the distal sling, or an arterial clamp is re-applied. When the distal part of the artery is freed from clot, some bleeding from it is observed with pleasure. When no more clot can be extracted traction is re-exerted to the distal sling. With due caution, tension on the proximal sling is momentarily released. If blood spurts we have achieved our objective of clearing the lumen of clot. All slings are kept tight until the artery is sutured. If a free flow of blood is not obtained from both the proximal and the distal ends of the artery, further clot must be sought. Suction (*Fig.* 1306) is of value in evacuating distant clot, but great care must be exercised lest the intima be further damaged and late thrombosis results.

Closing the Artery.—An interrupted suture is inserted at each extreme end of the incision—these sutures are held by the assistant, while the incision in the artery is closed. If the arterial wall is elastic a running suture can be used (*Fig.* 1307). Only if the suture

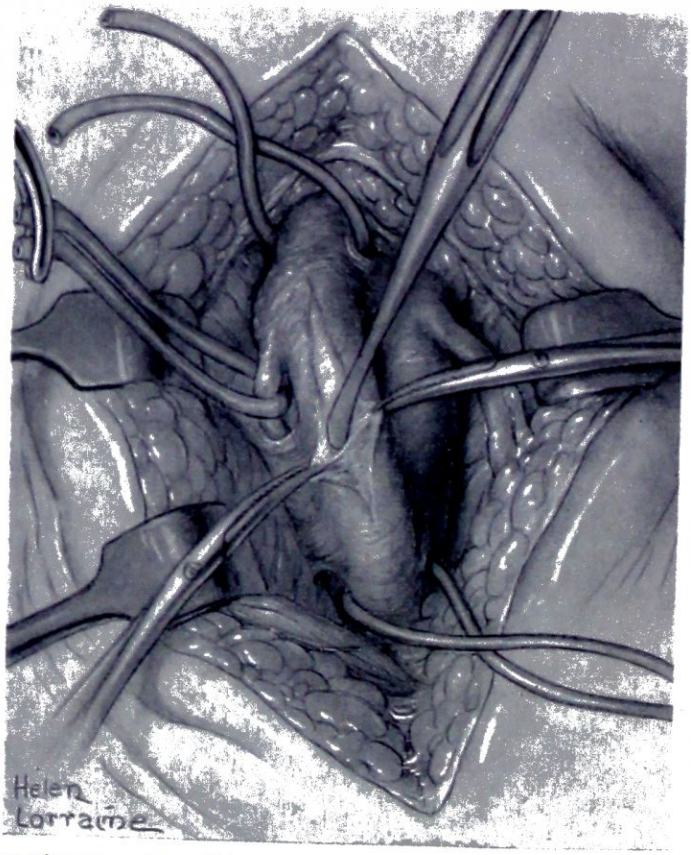

Fig. 1304.—Separating the adventitia over the area of the proposed line of incision into the artery.

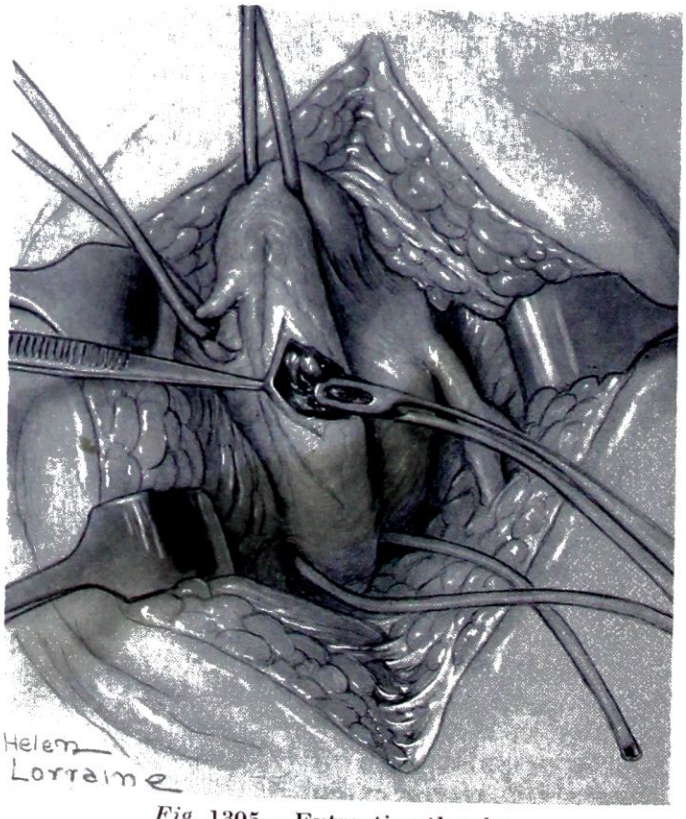

Fig. 1305.—Extracting the clot.

line proves sound are the slings removed. It may be necessary to reinforce the line of suture with an interrupted stitch or two. The adventitia is left unsutured.

When the circulation has been restored the blanched toes assume a pink hue, and a few minutes later hyperæmia of the limb is evident.

E. L., aged 40, a patient in a medical ward, experienced cramp in his left leg at 1.40 p.m. At 1.50 p.m. there was severe pain in the limb. The house physician was summoned and found the leg pale and cold below the knee. He diagnosed popliteal embolism. Further examination showed that no pulsation could be felt in the femoral artery. At 3.45 p.m., under local analgesia the common femoral artery was exposed. Above the origin of the profunda the artery was full and pulsating. Below the bifurcation both the profunda and the femoral arteries were empty and pulseless. The artery was opened in the manner described on p. 941. There was a three-limbed clot (*Fig.* 1308) situated at the bifurcation. The profunda clot and the lower femoral clot extruded themselves spontaneously; these vessels then bled slightly, but without pulsation. The proximal femoral clot was withdrawn with Desjardins's forceps. This was followed by a gush of blood, controlled at will by the sling. The incision in the artery was closed. The suture line was reinforced in two places by an interrupted stitch. Hæmostasis proved satisfactory. The distal femoral artery and the profunda remained contracted but pulsated. The wound was closed. The patient recovered.

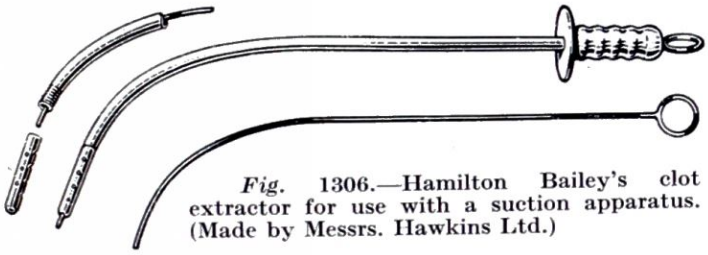

Fig. 1306.—Hamilton Bailey's clot extractor for use with a suction apparatus. (Made by Messrs. Hawkins Ltd.)

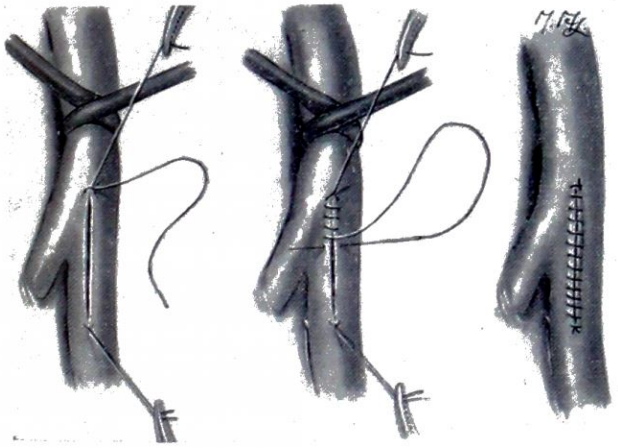

Fig. 1307.—Closing the incision in the artery.

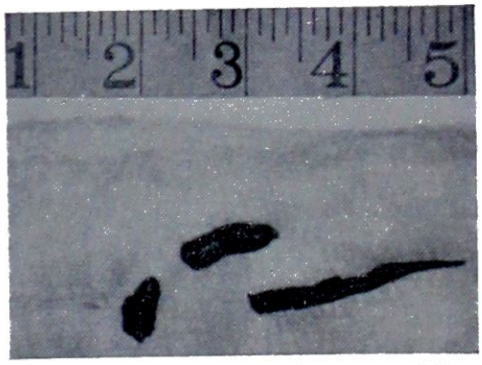

Fig. 1308.—The embolus removed from the bifurcation of the femoral artery in the case of E.L. consisted of three fragments, one in the main trunk and one in each of the branches.

FAILED LOWER LIMB EMBOLECTOMY

The usual cause of failure is that the operation has been attempted too late and thrombosis has occurred beyond the site of impaction of the embolus. It may be possible to remove clot for a distance of several inches beyond the incision into the artery, but if this is not rewarded by a gush of blood from the distal end of the artery, perseverance is useless; blood has clotted in the distal arterial tree and the limb is doomed. Small as it may be, the patient admitted late (more than 18 hours after the onset of symptoms) has a better chance of restoration of the circulation of the limb when treated by heparinization than when embolectomy is attempted. Unfortunately both the methods cannot be used simultaneously; to close the incision and commence heparin therapy immediately will result in severe bleeding. By the time the wound has sealed sufficiently for heparinization (say, 12 hours) the situation will have become correspondingly more hopeless. So it comes about that a decision to attempt embolectomy is, in a sense, a burning of one's boats.

AORTIC EMBOLISM

Saddle embolus of the aortic bifurcation is the exception to the rule that anticoagulant therapy is indicated in cases of under 6 and over 18 hours' duration. The chief reason for this is that the heparinization, if it is going to benefit the patient, must lead to breaking up

of the clot into fragments which will lodge distally in less important branches of the affected artery. In the case of the aortic saddle embolus this would be disastrous; emboli would lodge in both external iliac, femoral, or popliteal arteries, necessitating bilateral operations. Moreover embolectomy on the aorta—an artery with a large diameter—is more likely to be successful than when the operation is performed on an artery of a smaller calibre. An embolus in this situation is amenable to surgical removal for a much longer period than more peripherally situated emboli. L. N. Atlas recorded successes up to 60 hours.

In spite of these favourable facets, the prognosis is poor. Most patients in whom an embolus becomes arrested at the aortic bifurcation are suffering from either congestive cardiac failure due to auricular fibrillation or recent coronary thrombosis, and it is on this account that if unreported failures are taken into consideration, the success rate probably is not more than 10–20 per cent.

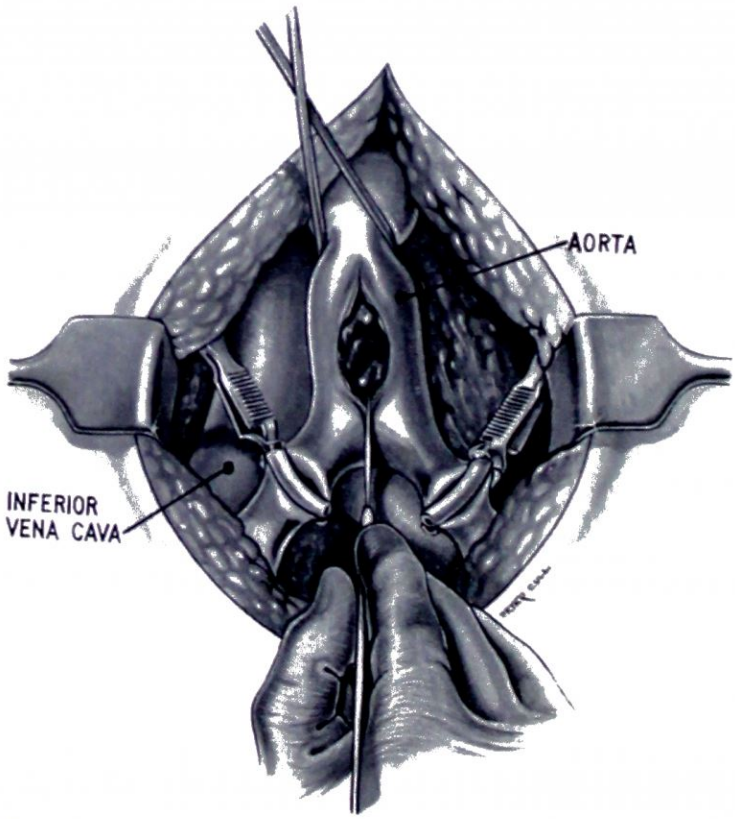

Fig. 1309.—Aortic embolectomy in progress. The aortic wall is being incised after the application of arterial clamps.

Diagnosis.—The condition should be suspected strongly if a patient with one of the above-mentioned antecedents complains of sudden acute lower abdominal or back pain with paralysis of the legs. The diagnosis is certain if the legs are cold and anæsthetic below the knees and both femoral pulses are absent. Cyanosis is often present instead of pallor, but even in these cases, the legs are frequently painless.

Aortic Embolectomy.—General or spinal anæsthesia is essential. The latter is preferable as the better relaxation allows the intestines to be packed out of the field of operation more easily. A left paramedian incision allows the best access to the lower aorta and its branches (J. L. Madden) and the transperitoneal approach is quicker. After tilting the patient into the Trendelenburg position, the intestines are packed out of the way and the posterior peritoneum overlying the aorta and the common iliac arteries is incised. The surrounding areolar tissue is separated by blunt dissection, and at this point it is essential to occlude the common iliac arteries distally by whatever means are available (*see* p. 931) to prevent distal migration of the embolus, which might necessitate a further incision.

Lastly, the aorta is occluded proximally before incising it vertically for a distance of about 1 in. (2·5 cm.) above its bifurcation (*Fig.* 1309). After this the steps of the operation are the same as detailed under TECHNIQUE OF EMBOLECTOMY (*see* p. 941).

In the early post-operative period, anticoagulant therapy is unwise because of the risk of hæmorrhage, but a few days after operation long-continued oral anticoagulant treatment should be commenced to prevent further embolic episodes (J. W. Lord). This applies to all successful embolectomies.

ACUTE ARTERIAL THROMBOSIS

Sudden arterial insufficiency occurring in the absence of the usual causes of peripheral embolism (auricular fibrillation; recent coronary thrombosis) should lead to the suspicion of local arterial thrombosis at a point beyond the most distal palpable pulsation. The signs of ischæmia vary from mild to very severe, with a cold, pale, anæsthetic limb and intense pain. Easily palpable arteriosclerotic arteries elsewhere support the diagnosis.

An exact diagnosis is of academic interest only, as the treatment is by heparinization (*see* p. 927). Removal of the clot by operation has no place in this condition because, if attempted, it will be followed by further, and more extensive, intravascular clotting.

RUPTURED AORTIC ANEURYSM

Surgical treatment of this condition, formerly invariably fatal, now offers hope. A number of cases have been reported where the ruptured aneurysm has been excised and the continuity of the aorta restored by a plastic prosthesis.

	No. of Cases	*Survivals*
Javid et al.	4	2
Gerbode	1	1
Cooley and deBakey	18	11
Shumacker and King	5	2
Total	28	16

A surgeon who has the facilities and the ability should, therefore, attempt to save these otherwise doomed patients.

The essential points in the technique are :—

1. Early operation with a midline incision extending from the xiphisternum to the pubis.
2. Large blood transfusions.
3. As soon as the aorta has been clamped above the aneurysm, and the common iliac arteries below, heparin should be injected into the arteries below the distal clamps. Even so, as the circulation of the lower limbs will be considerably curtailed for several hours, widespread intra-arterial clotting is very prone to occur.

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CHAPTER LXXXII

THE EXPOSURE OF THE BLOOD-VESSELS OF THE EXTREMITIES

THE SUBCLAVIAN AND AXILLARY ARTERIAL TRUNK

Exposure:—

Position of the Patient.—The patient lies with his shoulder projecting over the edge of the table. A small, narrow sandbag is placed under the upper thoracic spines. An assistant supports the arm held at right angles to the body.

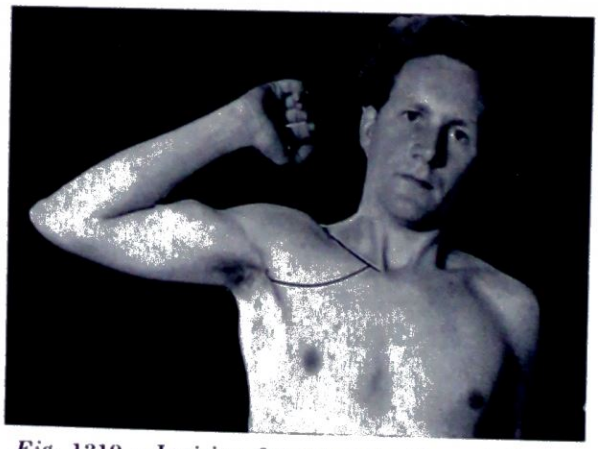

Fig. 1310.—Incision for exposing the subclavian and axillary arterial trunk.

Incision.—The incision is made through skin only, and consists of two distinct cuts. The first is parallel to and ½ in. (1·3 cm.) above the upper border of the clavicle. Secondly, the axillary extension of the incision is made; begin 1 in. (2·5 cm.) outside the inner end of the supraclavicular incision, and pass downwards towards the insertion of the pectoralis major (*Fig.* 1310).

Division of Muscles.—The pectoralis major is divided completely from the clavicle downwards. By slightly abducting the arm this muscle is put on the stretch and is severed with a few touches of the scalpel. The pectoralis minor is hooked up on the finger, as in complete amputation of the breast; this muscle, too, is divided completely. The fascia is incised from the clavicle downwards, and branches of the acromiothoracic

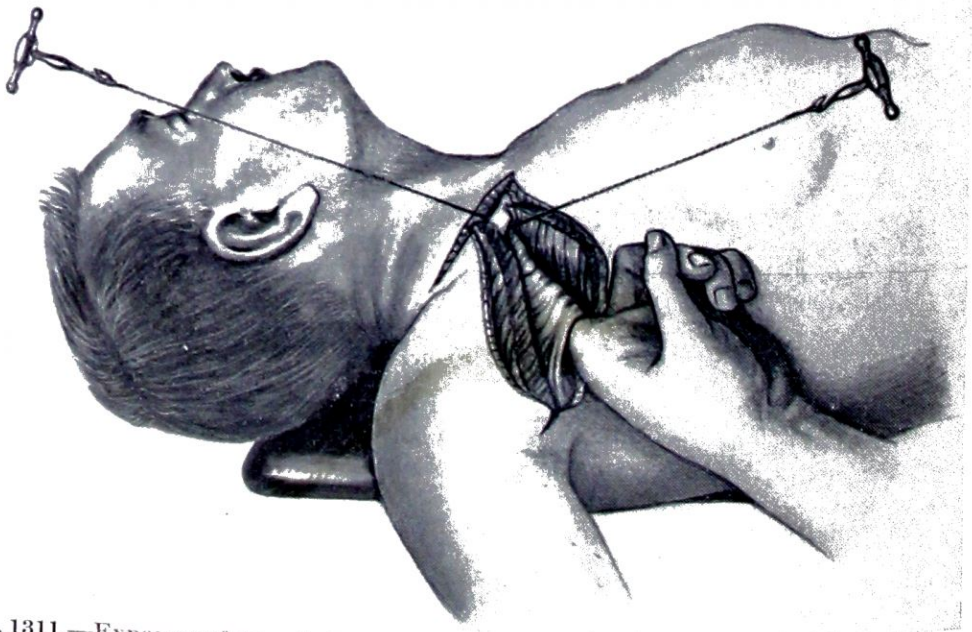

Fig. 1311.—Exposure of the subclavian and axillary arterial trunk. Dividing the pectoralis minor and the clavicle. (*After Fiolle and Delmas.*)

artery are secured as necessary. It is highly important to ensure that the pectoralis major has been severed completely right up to the clavicle.

Section of the Clavicle.—The clavicle is divided as near as possible to its inner extremity ; the point of division should be abutting the clavicular head of the sternomastoid (*Fig.* 1311). Clear this point with a periosteal elevator. Slip a retractor under this portion of the clavicle and bore two holes through the bone from below upwards about $\frac{3}{4}$ in. (2 cm.) apart. Then divide the clavicle between the two holes with a Gigli's saw or chisel. If the chisel is used, keep the retractor protecting the subclavian vessels.

Fig. 1312.—Exposure of the subclavian vessels and the brachial plexus. (*After Fiolle and Delmas.*)

At this stage, if the entire pectoralis major has been divided, the axillary space opens like a book under the mere weight of the arm (*Fig.* 1312). A few fibres of the subclavius alone need division to give the most perfect exposure of an otherwise inaccessible region.

Reconstruction.—While the assistant raises the shoulder, the clavicle is united with steel wire. The pectoralis minor is approximated with a running suture. The pectoralis major is drawn together by three or four deep mattress sutures tied moderately tightly. If drainage is necessary, a stab is made in the axilla for the tube.

THE THIRD PART OF THE AXILLARY AND THE BRACHIAL ARTERY

Exposure.—

Position of the Patient.—The arm should be supported at right angles to the body by an assistant. To rest the patient's forearm upon a small table (*Fig.* 1313) is convenient,

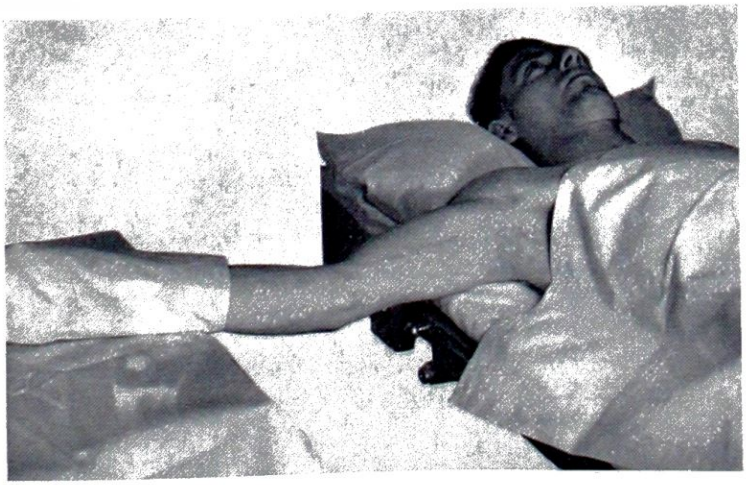

Fig. 1313.—Position of patient for exposure of the brachial artery. Note that the upper arm is unsupported.

and prevents fatigue of the assistant. The arm between the axilla and elbow must not be supported. The surgeon may be seated facing the inner side of the arm.

Incision.—An ample incision is made in the line of the artery between biceps and triceps, but hugging the inner border of the biceps.

The fascia having been divided, the overlapping innermost fibres of the biceps are drawn upwards with a retractor. The median nerve is isolated and kept out of the way

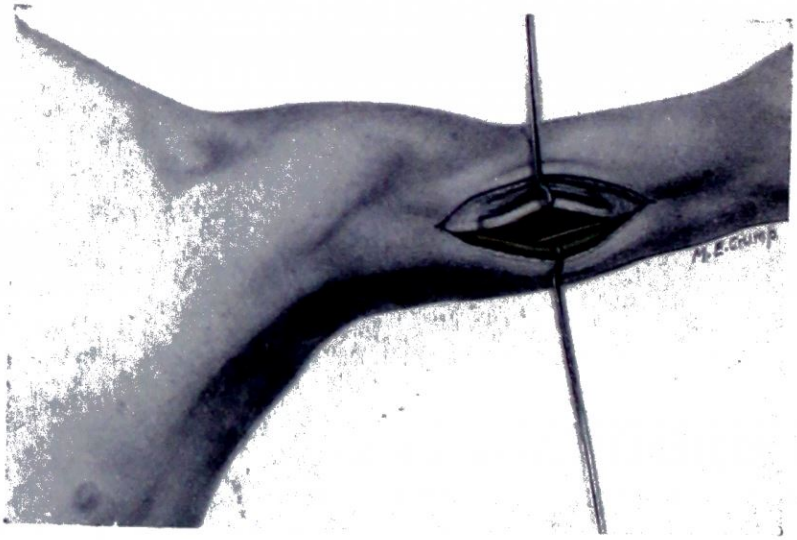

Fig. 1314.—Exposure of the brachial artery. The median nerve has been hooked upwards.

(*Fig.* 1314). The brachial artery with its two venæ comites is exposed. The artery may be much smaller than expected. It is sometimes duplicated, as I found in one case. Other anomalies may be present. The artery should be isolated from the venæ comites if it has been decided that ligation is necessary.

THE BRACHIAL ARTERY IN THE CUBITAL FOSSA

The arm is held or supported on a table. The operator stands or sits on the medial side of the arm. An incision is made along the inner border of the tendon of the biceps. The median basilic vein is pushed aside and the bicipital aponeurosis divided. *Now partially flex the elbow.* On the brachialis is the brachial artery with the median nerve lying to its inner side. If the bleeding point is inaccessible, the incision can be prolonged in a downward direction, in the manner about to be described.

The Termination of the Brachial Artery; the Radial, Ulnar, and Interosseous Arteries in the Upper Third of the Forearm.—In wounds of the upper third of the forearm it is impossible to determine whether the termination of the brachial, the radial, the ulnar, or the common interosseous artery is the source of severe arterial hæmorrhage. It is obviously desirable to expose all the vessels, which can be done as follows.

Position of the Patient and Incision.—The arm is placed on a table in the manner described already, or it is held away from the trunk by an assistant. The operator stands on the outer side of the limb. The incision begins 1 in. (2·5 cm.) above the fold of the elbow, medial to the biceps. Proceeding distally, it is carried to the fold of the elbow and from thence in a ⌙ manner towards the middle third of the radius, where it ends (*Fig.* 1315).

The incision is deepened and the median basilic vein ligated. The bicipital aponeurosis is divided, and the median nerve comes into view. The pronator teres is retracted, and on the outer side of the median nerve the brachial artery will be seen. Place a second retractor under the brachioradialis. With the finger break through the extremely loose cellular tissues between these two muscles. The bifurcation of the brachial artery is clearly demonstrable. The radial artery under cover of the brachioradialis is readily exposed. The ulnar artery, the larger vessel, lies more deeply. *Pronate the forearm strongly.* Under these conditions strong retraction of the pronator teres opens up the area marvellously (*Fig.* 1316). With a little dissection the ulnar artery can be followed as it lies on the flexor digitorum profundus for 5 or 6 in. (12·5–15 cm.). Near the bifurcation one can see the commencement of the common interosseous artery for a short distance.

Reconstruction.—As nothing of importance has been divided, it is only necessary to unite the fascia and the skin.

Fig. 1315.—Position of patient and incision for exposing the termination of the brachial artery, the radial, the ulnar, and the common interosseous arteries in the upper third of the forearm.

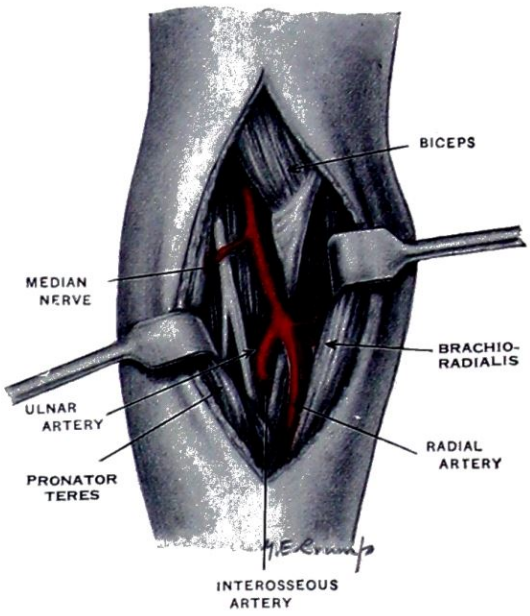

Fig. 1316.—Exposure of the termination of the brachial artery. The radial, the ulnar, and the common interosseous arteries are displayed by suitably retracting the pronator teres and the brachioradialis. (*After Fiolle and Delmas.*)

THE RADIAL AND ULNAR ARTERIES IN THE LOWER TWO-THIRDS OF THE FOREARM

(*Fig.* 1317)

The arm should be supinated fully and supported on a table.

Ulnar Artery.—The pisiform bone is palpated, and the incision is commenced along the radial side of the flexor carpi ulnaris. After the wrist has been flexed, the flexor carpi ulnaris is drawn to the ulnar side, the other muscles being retracted to the radial side. Splendid exposure of the ulnar artery and nerve is thereby obtained.

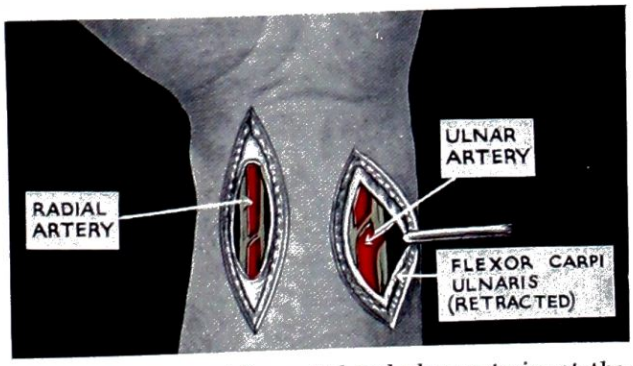

Fig. 1317.—Exposure of the radial and ulnar arteries at the wrist.

Radial Artery.—This part of the radial artery is readily exposed in the line of the pulse—that is, between the brachioradialis and the flexor carpi radialis.

THE ARTERIES OF THE PALM

A bleeding artery in the palm should be sought after a pneumatic tourniquet has been placed on the upper arm ; the tourniquet can be released as necessary to help to identify the bleeding point. In the rare event of hæmorrhage from the palm being uncontrollable,

it is the brachial artery that should be exposed and ligated. Ligation of the radial and ulnar arteries at the wrist may prove insufficient, as the following case exemplifies.

Fig. 1318.—A case of fungating sarcoma of the first metacarpal bone in which ligature of the radial and ulnar arteries at the wrist failed to stop hæmorrhage.

The patient had a sarcoma of the first metacarpal. A piece was removed for section, and severe hæmorrhage occurred. The radial and the ulnar arteries were tied, and the patient was transferred to another hospital some miles distant. On arrival the dressings were soaked in blood, and the patient by this time was severely oligæmic. After blood transfusion the arm was amputated. *Fig.* 1318 shows the condition of the hand. The incisions for ligation of the radial and ulnar arteries can be seen.

THE EXTERNAL ILIAC ARTERY

An incision is made $\frac{1}{2}$ in. (1·3 cm.) above the inguinal ligament. It is a long incision, and is comparable to that for femoral herniotomy by Lotheissen's method, but in this case the incision curves upwards somewhat towards the anterior superior iliac spine (*Fig.* 1319). The aponeurosis of the external oblique is exposed and divided in the length of the incision. The conjoint tendon is defined. Those fibres of the internal oblique attached to the inguinal ligament are made taut by retraction and divided close to the inguinal ligament. This exposes the fascia transversalis. The inferior epigastric vessels may be avoided, but it is usually best to divide them between ligatures. The division of these vessels opens up the plane between the fascia transversalis and the peritoneum. After working in this plane with the finger the fascia transversalis is divided. The remainder of the exposure is performed entirely with the fingers. The peritoneum is lifted up and gently eased until the external iliac vessels are in full view (*Fig.* 1320).

Fig. 1319.—The incision for ligating the external iliac artery.

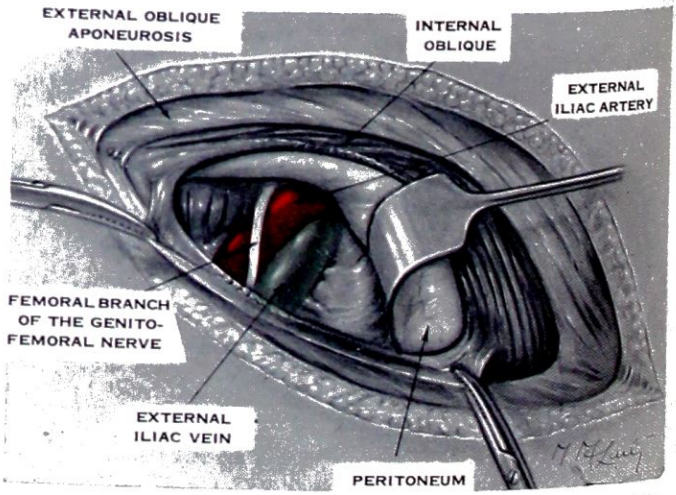

Fig. 1320.—Exposure of the external iliac artery. The peritoneum has now to be peeled off the external iliac vessels with the finger.

Ligation of the external iliac artery is required only exceptionally. It is not a reliable method of stopping bleeding from a wound of the thigh, for often anastomotic circulation allows renewed hæmorrhage; wounds of the common femoral should be attacked directly. Ligation of the external iliac artery should be reserved for secondary hæmorrhage from an infected wound high up in the femoral triangle, or for malignant ulceration involving the main vessel in this situation.

A. W., aged 51, had an indurated ulcerating mass in the groin (*see Fig.* 1319). No primary focus could be discovered. Two days after admission a violent arterial hæmorrhage occurred.

A tight bandage over a dressing partially controlled the hæmorrhage. The external iliac artery was ligated and the hæmorrhage ceased. The patient was treated with deep X-ray therapy, without much benefit.

THE FEMORAL ARTERY

The Upper Two-thirds.—Exposure of the upper two-thirds of the femoral artery presents no difficulty. The surface marking is from a point midway between the symphysis pubis and the anterior superior iliac spine to the adductor tubercle, the limb being slightly flexed at the knee and rotated externally. An incision is made on this line. After incising the fascia the sartorius is identified, mobilized with the finger, and then retracted. With a little dissection the femoral artery and vein are identified easily, and can be traced upwards or downwards as circumstances demand (*Fig.* 1321). Ligation of the *common* femoral artery should be avoided whenever possible. If practicable, this artery should always be repaired.

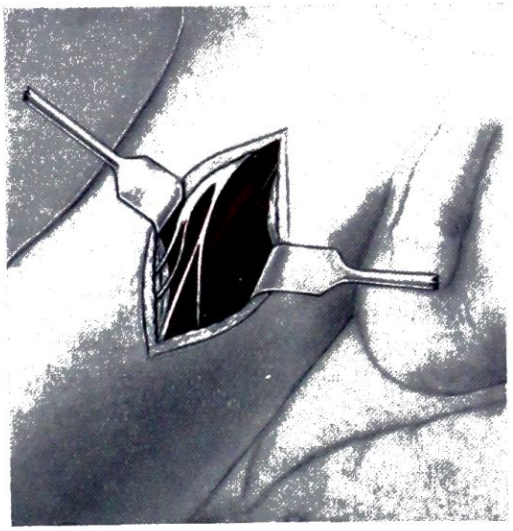

Fig. 1321.—Exposure of the upper third of the femoral vessels.

I was called to see a girl of 13 who had had an operation for osteomyelitis of the lower third of the femur fourteen days earlier. Twelve hours previously considerable hæmorrhage had occurred from the wound, but this had been controlled by packing. An hour previously violent hæmorrhage had occurred, and a tourniquet was in place around the thigh. She was very blanched, and the pulse was 140 and poor. The tourniquet was loosened, and as no arterial hæmorrhage occurred we decided to perform blood transfusion first. As soon as compatible blood had been procured, the tourniquet was reapplied and the transfusion carried out. The patient was then anæsthetized and the femoral artery exposed

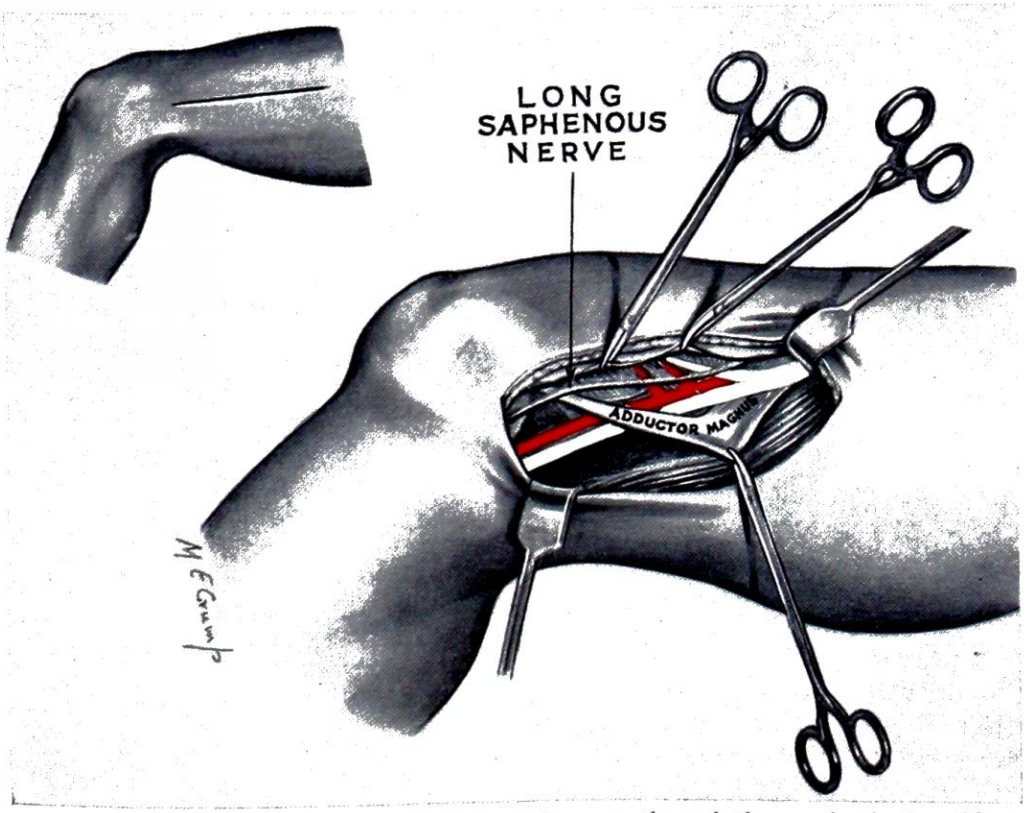

Fig. 1322.—Exposure of the femoral artery as it passes through the opening in the adductor magnus. A large part of the popliteal artery is also available. The tendinous expansion of the adductor magnus has been drawn towards the operator, while the aponeurotic roof of the adductor (Hunter's) canal has been drawn away to expose the femoral vessels. (*After Fiolle and Delmas.*)

in the middle third of the thigh. The profunda femoris was ligated above the first perforating artery. Probably as the result of the blood transfusion, the convalescence of the patient, which had been slow, was much enhanced.

The Lower Third of the Femoral Artery and the Upper Half of the Popliteal Artery.—The following method is designed to expose the femoral artery where it passes through the opening in the adductor magnus. Incidentally, it gives good exposure of the upper half of the popliteal artery.

Position of the Patient.—This is most important. The buttocks are placed as near as possible to the edge of the table. The assistant grasps the lower leg and foot, flexes the knee, and abducts and at the same time externally rotates the thigh. The surgeon stands on the inner side of the manually supported limb facing the region to be explored. The only necessary landmark is the tendon of the adductor magnus.

Incision.—Palpate the upper edge of the medial femoral condyle, feel the tendinous insertion of the adductor magnus, trace the tendon upwards along this line. Commencing at the insertion, make an incision 6 in. (15 cm.) long.

In the upper part of the incision the sartorius will be seen. Mobilize this muscle with the finger. Run the finger upwards and downwards on the under surface of the tendon of the adductor magnus, cleaning it within the limits of the incision. When the muscle

Fig. 1323.—Incision for exposing the popliteal artery and the commencement of its terminal branches—namely, the anterior tibial, the posterior tibial, and the peroneal arteries.

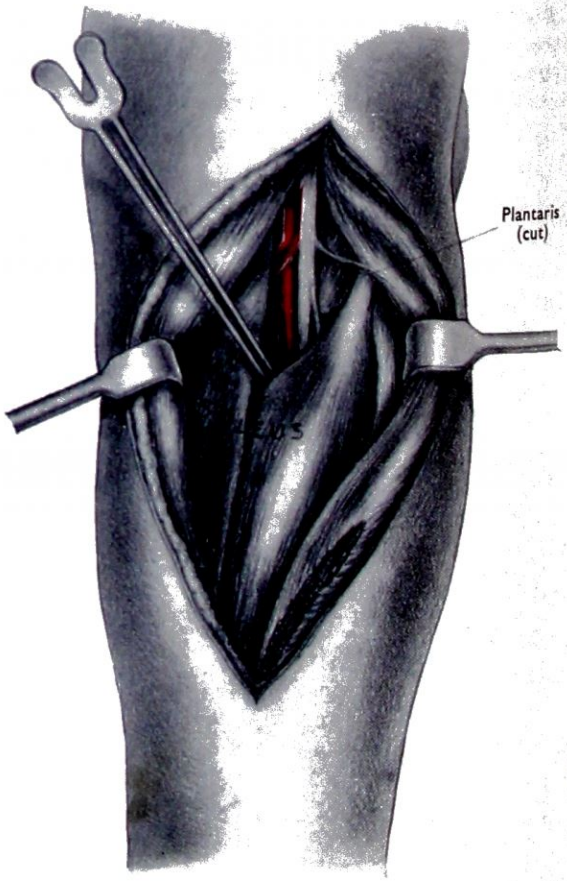

Fig. 1324.—Exposure of the lower part of the popliteal artery and the origins of its posterior tibial, anterior tibial, and peroneal terminals. The soleus muscle is about to be split on a director. (*After Fiolle and Delmas.*)

is clearly defined, with the scalpel open the aponeurotic roof of the adductor (Hunter's) canal close to the upper and external border of the adductor magnus tendon. Place two hæmostats on the edge of the tendon and draw it towards you. Then place two more hæmostats on the divided aponeurotic roof of the adductor canal, and give them to an assistant to retract away from you. With blunt dissection the femoral vessels can be traced from the adductor canal through the opening in the adductor magnus, right on into the depths of the popliteal space (*Fig.* 1322). It will be noted that the only guide is the

THE ANTERIOR TIBIAL ARTERY

Incision.—Palpate the head of the fibula, then the crest of the tibia, at the same level. In the intervening space between these bony points lie two muscular masses—a large inner, the tibialis anterior, and a smaller outer, the extensor digitorum longus. The incision commences in the depression between these two muscles at the level of the head of the tibia. It proceeds downwards to the lower part of the middle third of the tibia, almost imperceptibly approaching the tibial crest as it does so.

Commencing towards the lower end of the wound, identify the two muscles. Dissect them apart, then, with the finger below, aided by a few touches of the scalpel, separate them completely in the whole length of the incision. Retract these muscles strongly, and the anterior tibial vessels and nerves are in full view (*Fig.* 1328).

SUBGLUTEAL HÆMATOMA

Exposure of the Superior Gluteal, Inferior Gluteal, and possibly Internal Pudendal Arteries.—In wounds of the buttock with a large subgluteal hæmatoma it is impossible

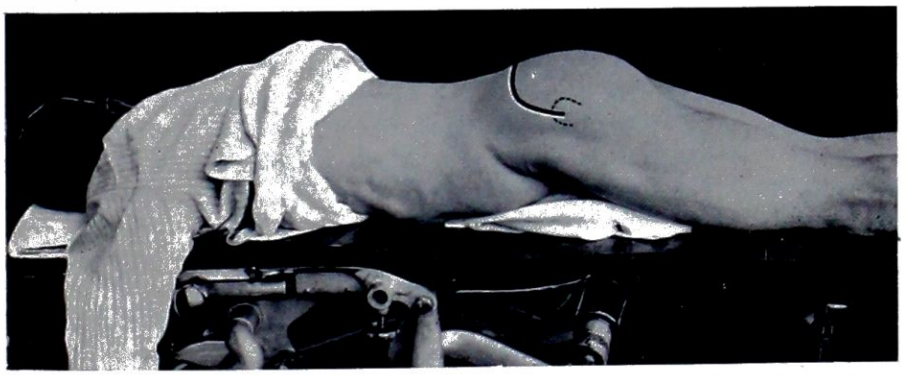

Fig. 1329.—Incision for exposing the vessels concerned in a subgluteal hæmatoma.

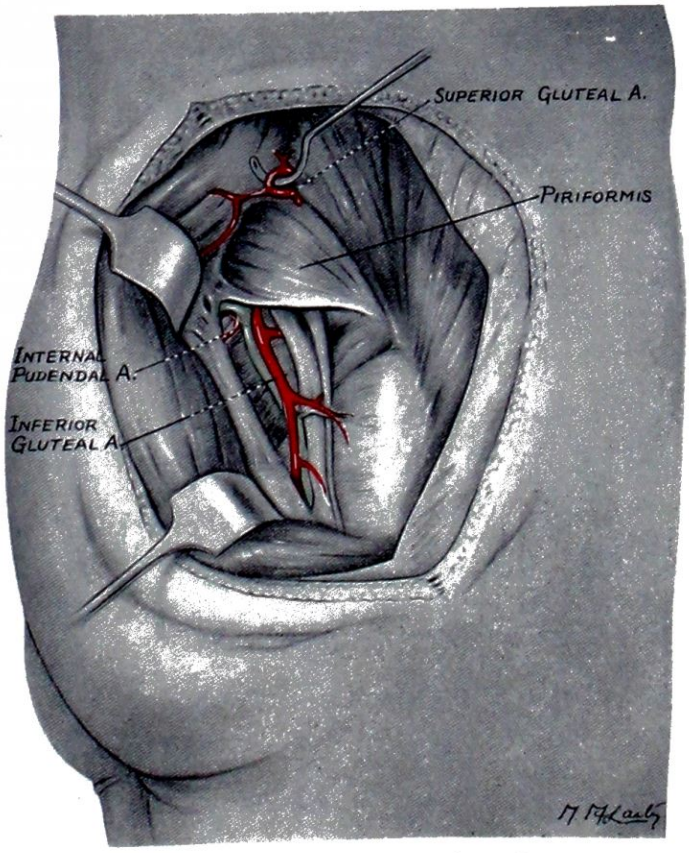

Fig. 1330.—Exposure of the superior and inferior gluteal arteries. The underlying structures seen on retraction of the gluteus maximus. (*After Fiolle and Delmas.*)

Fig. 1326.—Exposure of the posterior tibial artery. Splitting the gastrocnemius.

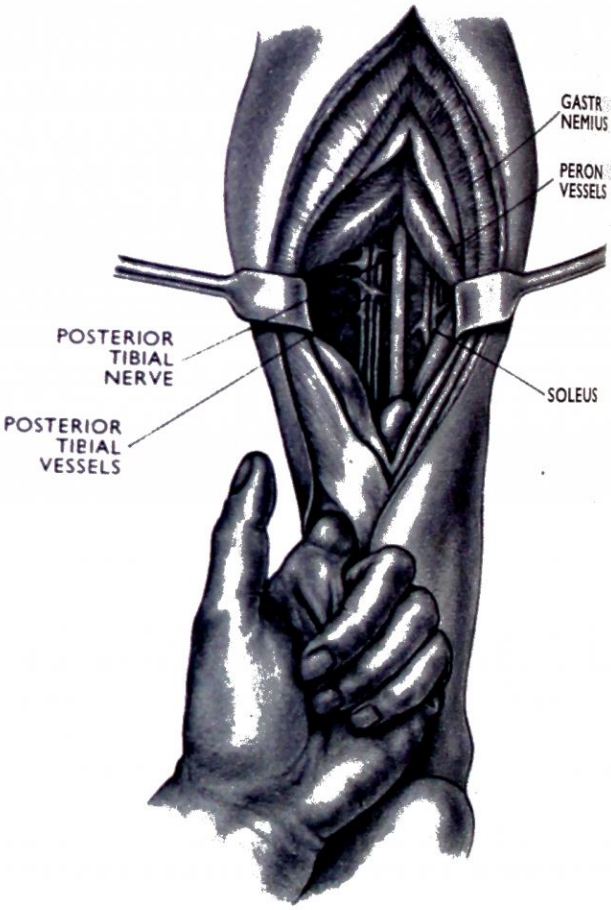

Fig. 1327.—Exposure of the posterior tibial vessels and nerve, and the peroneal vessels. The gastrocnemius and the soleus have been split. (*After Fiolle and Delmas.*)

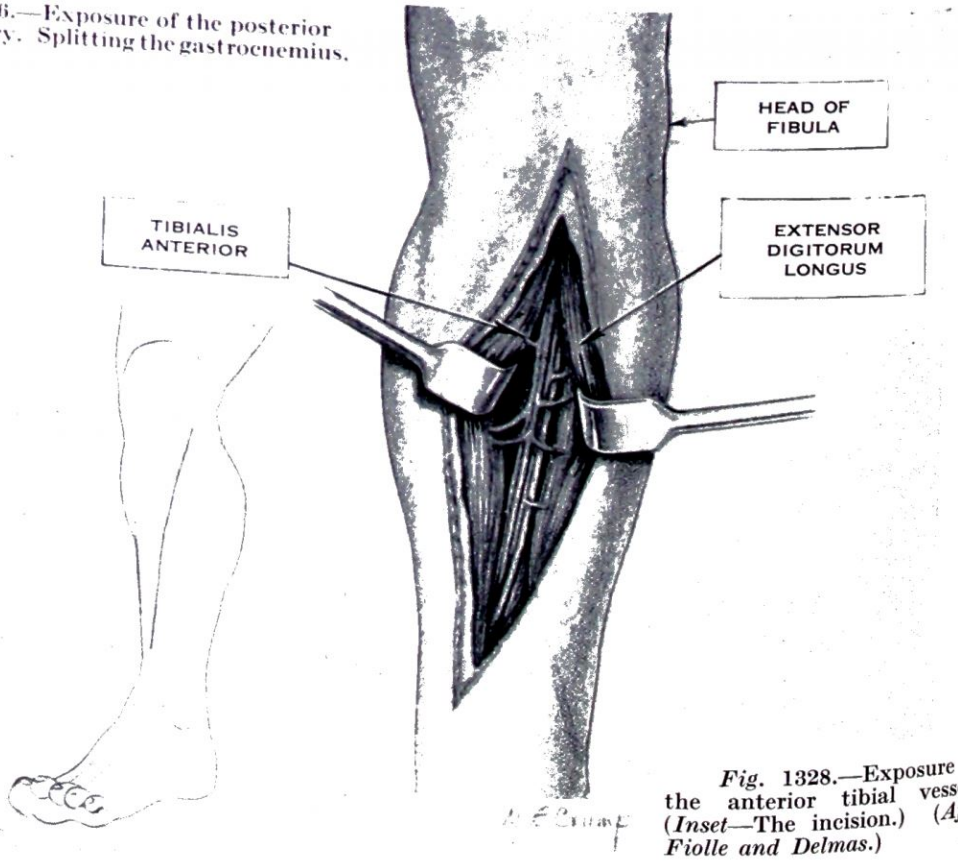

Fig. 1328.—Exposure of the anterior tibial vessels. (*Inset*—The incision.) (*After Fiolle and Delmas.*)

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Incision.—Palpate the head of the fibula, then the crest of the tibia, at the same level. In the intervening space between these bony points lie two muscular masses—a large inner, the tibialis anterior, and a smaller outer, the extensor digitorum longus. The incision commences in the depression between these two muscles at the level of the head of the tibia. It proceeds downwards to the lower part of the middle third of the tibia, almost imperceptibly approaching the tibial crest as it does so.

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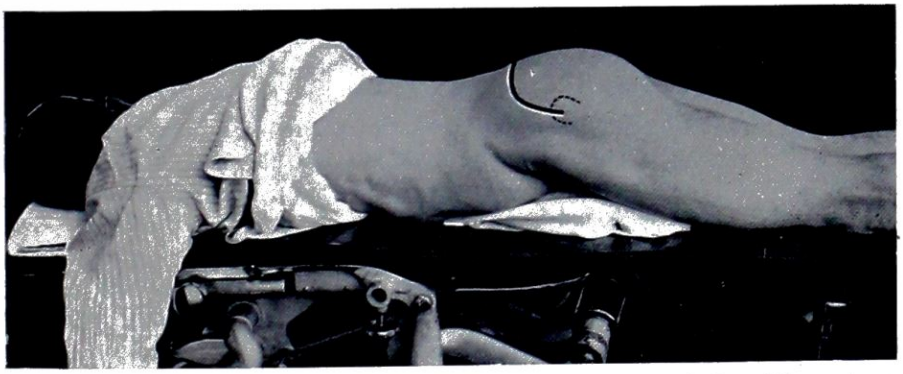

Fig. 1329.—Incision for exposing the vessels concerned in a subgluteal hæmatoma.

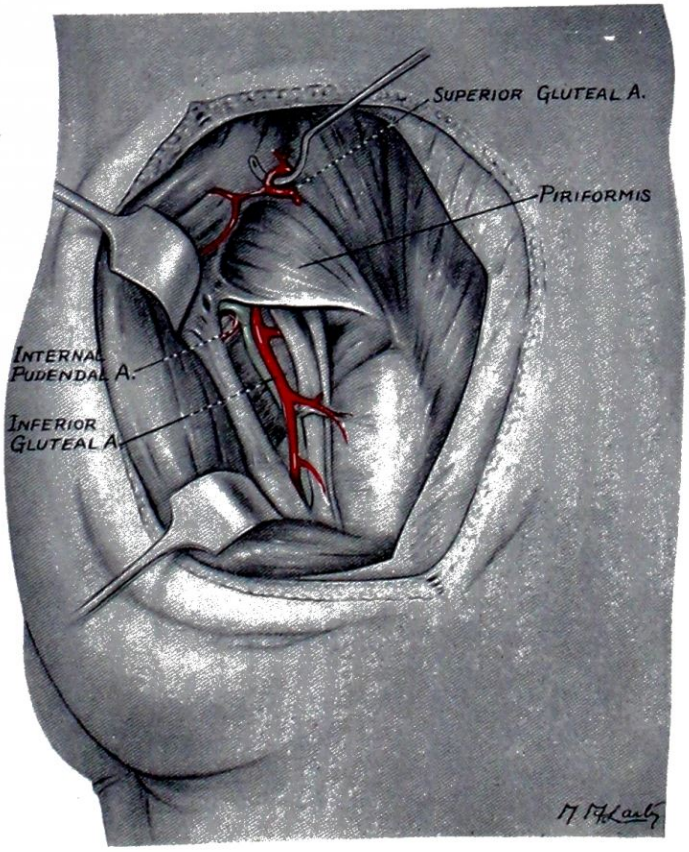

Fig. 1330.—Exposure of the superior and inferior gluteal arteries. The underlying structures seen on retraction of the gluteus maximus. (*After Fiolle and Delmas.*)

to tell which of these arteries is bleeding. Consequently, a wide exposure which the anatomy of the region is necessary.

Position of Patient.—The patient is prone, and a flat pillow is placed under the on the affected side. An assistant slips one hand under the knee, and with the other ho the foot. By externally rotating the thigh he is able to relax the gluteal muscles.

Incision.—*Fig.* 1329 shows the incision. It commences over the middle of the trochanter, sweeps upwards, and then passes in a curved manner to the posterior su iliac spine.

After fat has been cleared away, the fibres of the gluteus maximus will appear upper part of the wound, while in the region of the great trochanter very white, to will be observed. Concentrate on this fascia. Incise it vertically over the great In so doing a bursa is often opened. Pass the finger under the fascia, and it will large potential space beneath the gluteus maximus. Aided by the finger beneath, the gluteus maximus with scissors, cutting as near as possible to the iliac crest muscle is mainly aponeurotic. Once the gluteus maximus is detached and drawn with a large retractor, the underlying structures are accessible (*Fig.* 1330). piriformis muscle. With a little blunt dissection the superior gluteal artery can passing to the deep surface of the gluteus maximus. If the superior edge of the medius is lifted up with a retractor, the deep division of the artery will be fo tracing the deep division the main trunk, issuing from the sacro-sciatic notch, will become apparent. The main trunk can be ligatured here when necessary. Eme below the piriformis is the inferior gluteal artery. Deeply placed, winding aro spine of the ischium, is the internal pudendal artery with the pudendal nerve and to the obturator internus. For a very short part of its course the internal pudendal is available from this aspect.

REFERENCE

FIOLLE, J., and DELMAS, J., *Surgical Exposure of the Deep-seated Blood-vessels*, 1921.

CHAPTER LXXXIII

GANGRENE OF THE EXTREMITIES

The higher the amputation, the higher the mortality. (R. R. Lynn.)

In the comparatively early, painful stage the ischæmic foot is nearly always pink, the skin being shiny and atrophic as though it was stretched tightly over underlying structures (W. Oakley). At a later stage of dry gangrene the foot is white and its skin dry and scaly ; in these circumstances there is little or no pain, and gangrene, if present, is likely to advance more rapidly. Ninety-nine per cent of cases of gangrene of the toes and the lower extremity are the result of arrest of the arterial flow ; only 1 per cent are due to venous obstruction.

Therefore of cardinal importance is feeling the pulses. To palpate the popliteal artery the patient must be prone. Some time should be spent in endeavouring to locate the dorsalis pedis artery, or if this pulse is absent, the posterior tibial or the peroneal arteries should be sought. The latter, if present, will be found $\frac{1}{2}$ in. (1·3 cm.) anterior to the lateral malleolus. In many instances such examinations, together with testing the urine, will suffice to formulate a conclusion as how best to proceed ; in others further information regarding the arterial supply to the limb will be required.

Plain Radiography.—X-ray examination of the lower limbs for evidence of calcification is too often misleading to be of any real value, advanced calcification being compatible with good pulsation and patency of the artery affected. Radiography of the bones and joints in the vicinity of the gangrene is, however, almost essential. Unsuspected necrosis of bone and effusion (purulent) into associated joints are revealed thereby, and when present call for an earlier, and perhaps a more extensive, operation than would be required otherwise. It is necessary to remind the reader that osteomyelitis is not apparent radiographically in its early stages.

Oscillometry.—The Pâchon oscillometer is an instrument like a sphygmomanometer. The needle of the instrument registers the amplitude of the pulse wave on a dial. The oscillometer is applied at various levels from above down the limb and readings are taken at the mid-thigh, calf, and ankle of *both* lower limbs. A sudden decrease in excursions of the needle is observed when the level of a recent occlusion of a main artery is reached, but as a rule it is the comparisons of readings at the same level on each side that are so important. Except in special clinics, an oscillometer is not often available. The main practical application of this instrument is that when adequate oscillations at the ankle are registered, a conservative operation below this level is likely to prove successful.

Arteriography undoubtedly provides more accurate information than other methods of investigation, and it may reveal the site of the obstruction if this is localized. However, it is often unnecessary, especially in cases with generalized occlusive vascular disease. This examination should be undertaken only if the patient is reasonably fit and when more information about the arterial supply to the limb is of fundamental importance. Before it is undertaken good renal activity must be assured, and in all cases iodine idiosyncrasy should be tested by a controlled patch test on the skin and, if this is negative, 1 ml. of diodone is injected intravenously about four hours later. Only if there is no reaction to both these tests is the arterial injection undertaken. The greatest dangers of arteriography in these cases are detachment of a mural plaque and that a high concentration of diodone may precipitate further thrombosis. The second risk can be guarded against by injecting 40–60 ml. of weak heparin-saline solution at the conclusion of the diodone injection (D. M. Morrissey).

GANGRENE THREATENED

One injection of 50 mg. of priscol[1] intra-arterially sometimes brings about a dramatic change for the better ; within half an hour blue discoloration gives place to a healthy pink, and pain departs. Naturally it is problematical how long the good result will last, but sometimes it is for months or years.

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[1] Ciba Laboratories Ltd., Horsham, Sussex.

GANGRENE INEVITABLE

Preliminary Management.—The problem of former days, as to whether to allow th gangrenous area (if dry) to separate spontaneously or to operate, does not appertain at th present time. Owing to the frequent disasters attendant upon the former method, com paratively early operation—the nature of which will be detailed—is now advocated almos universally in cases of gangren that are more than skin deep. Ho to effect separation of dead an non-viable tissue from the livin with the least danger to the patien is the theme of this chapter. Even in patients classified as having dry gangrene, some infection must be presumed, and it is necessary only to examine a well-defined line of demarcation to discover tiny beads of pus. Therefore early antibiotic therapy is required in all cases. When circumstances allow, no time should be lost in sending a specimen of the discharge to the bacteriological department for the usual investigations. Unless the gangrene has reached a level where a considerable amount of muscle is involved, or is obviously spreading rapidly, sufficient time should be allowed for antibiotics to control the infection before operation. In cases of diabetes the optimum time to operate should be chosen by the physician.

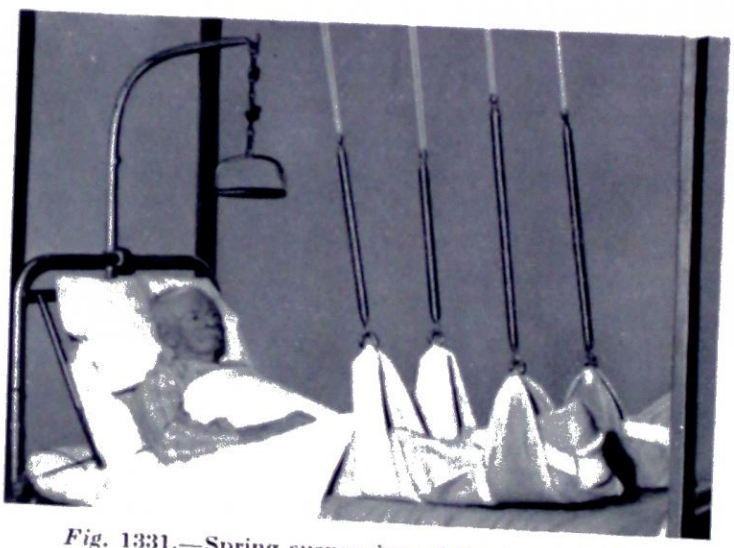

Fig. 1331.—Spring suspension of the lower limbs. (W. Oakley.)

During this waiting period the output of urine must be charted and measures taken to see that it is adequate. A daily blood-urea examination is helpful. If facilities exist, frequent spectroscopic examinations of the urine for myohæmoglobin are desirable.

Protecting the Feet.—Whether the condition is due to ischæmia, neuropathy, or both, there is always the danger that with the patient in the supine position pressure on the heels will cause blistering, ulceration, or gangrene. The best method of preventing these complications is to swing each limb just clear of the mattress by means of two long springs (*Fig.* 1331), such as are used by physiotherapists, the tension of the springs being 30–50 lb. (13·6–22·8 kg.). The slings are made of canvas lined by orthopædic felt. A strap attached to the distal sling is passed around the sole, to prevent the development of equinus deformity (W. Oakley et al.).

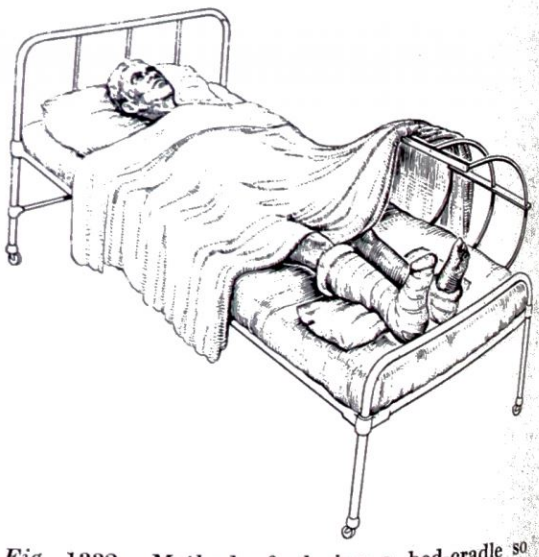

Fig. 1332.—Method of placing a bed-cradle so that the patient cannot injure the toes against it.

If for some reason—there are no contraindications—slinging the legs cannot be undertaken, very special nursing care of the feet is required. After wiping them with spirit, they are wrapped in soft cotton-wool; this is required whether slings are employed or not. A generous pad of wool is placed beneath each heel after it has been smeared with lanoline. The wool is kept in place by a sterile towel fastened with safety-pins. Bandaging is avoided. So often is a bed-cradle the cause of patients injuring their toes on the iron bars that Sol Cohen's method of placing one edge of the cradle under the side (*Fig.* 1332) or foot of the mattress should always be employed. Thus the bedclothes are kept lifted. The feet are kept encased in wool for another reason—to conserve warmth. The practice of leaving the extremities exposed to the air or lightly covered is condemned; it causes vasoconstriction

of the cutaneous vessels and oxyhæmoglobin dissociates poorly at low temperatures. The recent practice of nursing the patient with the heart higher than the feet is also condemned; this causes retardation of venous return, and consequently resistance to the already enfeebled arterial inflow; it also favours peripheral œdema and venous thrombosis. The bed and the lower limbs should be kept horizontal.

Analgesics and Hypnotics.—The pain of ischæmia is sometimes intense; at others, especially in cases of diabetic gangrene, it is slight. In many patients alcohol is effective in relieving severe discomfort, assisting vasodilatation, and promoting sleep. For intense pain morphine should be given, and repeated as necessary. In less severe cases chlorpromazine is a suitable alternative. When necessary, sleep must be induced; omnopon gr. $\frac{1}{3}$ (22 mg.) and nembutal gr. 3 (0·2 g.) often prove a useful combination.

Vasodilator Drugs.—Except, possibly, the one dose referred to on p. 957, in cases of *threatened* gangrene vasodilator drugs are best avoided altogether. They can have little or no action on a limb which is the seat of advanced arteriosclerosis. When the arteries are capable of dilatation these drugs induce general vasodilatation that causes a fall of blood-pressure which is likely to impair the collateral circulation, and may precipitate cardiac incompetence.

Anticoagulant Therapy (heparin) is of distinct value in many patients. If operation becomes necessary the heparin should not be stopped on this account. If during the operation hæmorrhage appears to be excessive an injection of 50 ml. of 1 per cent protamine sulphate[1] solution diluted with an equal volume of normal saline solution given very slowly intravenously restores the original coagulation time of the blood in a few minutes. Excessive bleeding at operation is not usual if anticoagulants other than heparin have been employed, but as there is available such an effective, quick-acting antidote to heparin, it is best to confine pre-operative anticoagulant therapy to this one drug in these cases.

Lumbar Sympathetic Nerve-block sometimes proves helpful in cases where the supplying arteries are not bereft of all elasticity.

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Before leaving the subject of the pre-operative management of gangrene of a part of an extremity, it is necessary to urge once again that attention be paid to the sound side, lest it, too, become involved: likewise to care for it tenderly while the patient is on the operating table, and subsequently. As to the side of the lesion, in every case of gangrene it is still necessary to stress the evil of each and all of *the deadly triad of Boyd*, to wit: (1) Elevation of the limb; (2) The application of heat to the limb; (3) Keeping dry gangrene dry. Above all, one should strive constantly to eradicate the deep-rooted idea that the cold feet of a patient with impaired circulation require added heat in the form of hot-water bottles, etc.

Gauze soaked in equal parts of glycerin and spirit is a dressing *par excellence* for a dry gangrenous area.

ARTERIOSCLEROTIC GANGRENE (SENILE GANGRENE)

The incidence of arteriosclerosis obliterans is increasing in all European countries: it is tending to appear at an earlier age than formerly, and because of the increased expectancy of life, a larger proportion of the population reaches an age when sclerotic arterial changes occur. Arteriosclerosis is the commonest cause of gangrene; of 211 consecutive cases, 107 were due to arteriosclerosis (Lynn and Modlin). The contralateral foot may become involved simultaneously or consecutively.

Diagnosis.—The gangrene frequently commences as a blister containing blood-stained fluid, or as chronic paronychia. Men are much more frequently affected than women, and 80 per cent of the patients admitted with major gangrene give a history of many years of progressive ischæmia. In some of the remainder there is a sudden onset suggesting that the lesion is due to thrombosis of the femoral or popliteal artery. In severity the pain is midway between the agony, interfering with sleep, of gangrene due to thrombo-angiitis obliterans and the slight pain of diabetic gangrene. Usually the gangrene commences in

[1] Boots Pure Drug Co. Ltd., Nottingham.

the great toe, and spreads gradually towards the heel (*Fig.* 1333) and then with greater rapidity towards the calf. Like diabetic gangrene, it often follows a slight injury. The arteries are palpable as hard, pulseless cords, although there may be pulsation of the femoral artery. The tendency is for the gangrene to become arrested temporarily at a larger joint. Usually the dorsal surface of the foot is more affected than the plantar surface.

Arteriographic studies show that gangrene limited to a toe is commonly due to a major arterial block high in the limb, the superficial femoral artery being the most frequent site. In about 10 per cent of cases the block is in the iliac arteries. The block can also occur in the popliteal artery at the level of the knee-joint, in which case it spreads down to the bifurcation. In the aged, multiple blocks are a common finding.

Prognosis.—If the thrombosis is confined to the tibial arteries it is possible that the gangrene will not spread above the metatarsophalangeal joint. If, as is common, the thrombosis involves the popliteal artery, eventually gangrene will extend above the knee. In the spreading type with a poorly-formed line of demarcation, unless early above-knee amputation is performed the patient will die of toxæmia from absorption of metabolites of dying muscle, or infection. In view of the fact that many of these patients are in a parlous condition from other causes, notably cardiac impairment and chronic bronchitis, it cannot be wondered at that the outlook is not encouraging. Of 105 consecutive cases of senile gangrene occurring in patients of over 65 years of age, P. F. McGoey reported that 50 were moribund on admission, and no operation was performed; 31 died as a result of a major amputation; 2 after a minor amputation. Of the remainder, but few lived more than a matter of months, and only 1 patient walked well with an artificial limb; there are very few patients over 70 years of age who can use an artificial leg following an above-knee amputation. In patients below the age of 65, the prognosis is less gloomy.

Fig. 1333.—Arteriosclerotic gangrene with a well-defined line of demarcation.

Treatment.—When the gangrene is limited to one toe there is fairly uniform agreement that this toe should be amputated and left unsutured. In a large percentage of cases healing occurs, and at any rate for some months the patient is spared a major amputation. In other circumstances the right course to take is less stereotyped. Many surgeons prefer to amputate through the middle third of the thigh, because of the greater certainty of primary healing. Others, deploring the not inconsiderable mortality inseparable from this operation in the aged, and the indisputable fact that these patients very seldom can use an above-knee prosthesis, are not deterred by the prospect of having to reamputate in a proportion of cases, and practise more conservative methods. When gangrene is limited to the toes, transmetatarsal amputation is now popular, and in some series 60 per cent have healed. If gangrene is too advanced for a transmetatarsal operation and there is a palpable popliteal pulse, a below-knee amputation should be performed. In doubtful cases it is worth while performing preliminary section 4 in. (10 cm.) below the knee in order to determine the permeability of the tibial arteries. More often than not these vessels are found to be almost or completely occluded, when amputation through the thigh must follow immediately, but in a proportion of cases the blood-supply below the knee proves adequate.

ARTERIAL RECONSTRUCTION IN CASES OF GANGRENE, WITH SPECIAL REFERENCE TO ARTERIOSCLEROTIC GANGRENE

In selected cases, where the block has been proved by arteriography to be localized, a reconstructive operation has been performed with a small, but increasing, measure of success. If the patient is fit enough for a major amputation, he is fit enough for an arterial

reconstruction operation (C. G. Rob). Before a reconstruction operation can be entertained the essential proviso is that the patient's arteriogram shows an adequate arterial system below the occlusion. The best results have been obtained in patients with aortic or iliac occlusions, but many successes have been recorded when the occlusion was in the femoral artery.

An artery can be reconstructed in several ways, but in cases of gangrene more success has followed thrombo-endarterectomy than any other method. This is because wound infection is by no means uncommon when there is a gangrenous lesion of the foot. Such infection causes little trouble when no foreign matter has been introduced (thrombo-endarterectomy). If a homologous arterial graft has been employed, such infection is liable to cause secondary hæmorrhage. When it is not possible to perform thrombo-endarterectomy a by-pass procedure, using either a homologous arterial graft or an autogenous vein graft (*see below*), gives good results. In this condition plastic prostheses are unsatisfactory, even if only one end has to pass below the inguinal ligament, although these materials have been employed with success to reconstruct the aorta and iliac arteries in cases of gangrene of the lower extremity.

Thrombo-endarterectomy.—The obstructed segment is exposed fully and incised in its long axis to the extent of the thrombus. The thrombus is excised together with the intima and the medial coat, taking advantage of the line of cleavage which is present within the external elastic lamina. The artery is then repaired.

By-pass Procedure (de Bakey).—Comparatively short incisions are placed to expose the artery above and below the occlusion. Reference to the arteriogram in the operating theatre is essential for the proper placing of these incisions, an example of which is shown in *Fig.* 1334 A. Following exposure of the artery, clamps are placed on either side of that portion chosen for the anastomosis (*Fig.* 1334 B) and a longitudinal incision is made through the arterial wall of a length corresponding to the diameter of the homograft or vein-graft that is to be inserted. A small elliptical piece of the arterial wall is removed with fine scissors. An end-to-side anastomosis is then performed between the end of the graft, which has been slightly bevelled, and the artery, using the technique described on p. 932. After the first anastomosis has been completed, a subcutaneous tunnel connecting the two incisions is started by burrowing with the index finger of each hand. A long varicose vein probe is used to complete the tunnel, unless a long hæmostat will suffice, which is often the case if the distance between the incisions is not great. The free end of the graft is attached to the instrument, and in this way the graft is drawn along the tunnel, being careful not to twist the graft. A second anastomosis is performed in the same way as the first. The lumen of the graft is filled with normal saline solution or heparin solution and clamped 1 in. (2·5 cm.) beyond its free end : this is a most necessary precaution to obviate air embolism. The clamps are removed, and bleeding from the suture line is controlled by gauze pressure and, if necessary, the application of absorbable gauze. The wounds are closed.

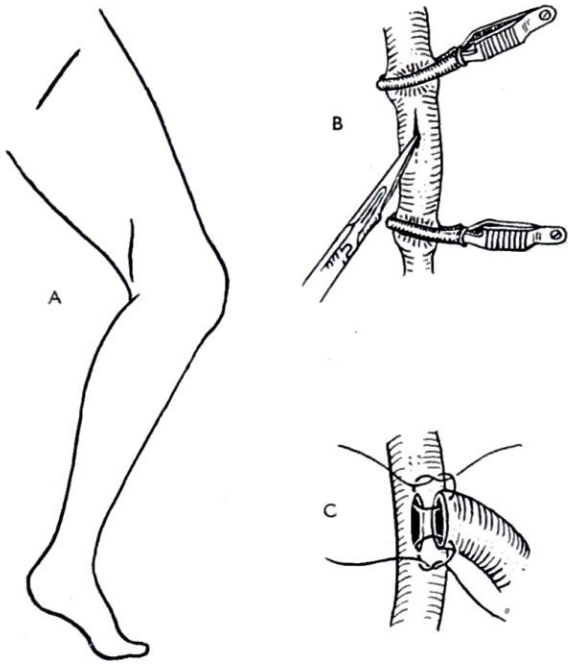

Fig. 1334.—By-pass procedure for early gangrene following thrombosis of the deep femoral artery. A, Incisions ; B, Incising the artery ; C, Commencing the anastomosis—the stay sutures. (*After Crawford and de Bakey.*)

Using this method the occlusion was by-passed successfully in 37 out of 40 cases operated upon by Crawford and de Bakey. In essence, the operation adds a collateral vessel about the size of the main artery without interfering with those collateral vessels functioning at the time of the intervention.

Management of the Patient after a Reparative Operation.—After a reparative operation the patient should take dindevan[1] by mouth throughout the remainder of life, as regularly

[1] Evans Medical Supply Ltd., Liverpool, 19.

as a diabetic takes insulin (C. G. Rob). In this way the incidence of thrombosis in the reconstructed arterial segment and in other arteries is reduced. Should arterial reconstruction restore a palpable pulse distal to the occlusion, amputation of any kind should be postponed for at least six weeks. Only by then will there be a very definite line of demarcation, perhaps more distal than was thought possible. In some cases the gangrene will prove to be only skin deep, and the gangrenous portion will peel off, revealing healthy skin beneath.

THROMBO-ANGIITIS OBLITERANS (BUERGER'S DISEASE)

The patient is most often in the 20–40 age group, and is frequently Polish, Russian, Jewish, or Japanese ; however, to a lesser extent all races are affected. The condition commences as an arteritis involving the intima and then the media. The inflammatory process causes soft red thrombi to occlude the lumen of the vessel. In about 50 per cent of cases there is fleeting phlebitis in the affected limb or limbs, which often heralds a fresh arterial thrombotic attack.

Diagnosis.—The disease is confined almost exclusively to males ; in a series of 500 cases reported by L. Buerger there were only 3 women. In less than 2 per cent does the disease attack the upper extremities. The condition progresses by exacerbations and remissions, the exacerbations usually occurring during the cold weather. The disease commences with attacks of pallor and cyanosis (Raynaud's phenomenon) of the toes. Because the arterial thrombosis commences peripherally and extends proximally, ischæmia of the toes occurs early ; therefore in this condition digital gangrene often appears before claudication. Fungus infection of the toes (athlete's foot) is common in this condition. Radiographs do not show calcification of the arteries.

Treatment.—When gangrene affects a toe, amputation of that toe can be carried out, but when this does not relieve the pain, and particularly if lumbar sympathectomy has been undertaken previously, or when the gangrene affects more than one toe or the foot, amputation through the leg 4 in. (10 cm.) below the knee is indicated. In thrombo-angiitis obliterans amputation through the leg is better than a transmetatarsal operation, and in a young or comparatively young person it is also preferable to one through the thigh, because an artificial limb is easier to control if the knee remains. Even after careful oscillometry it is sometimes extremely difficult to decide whether or not tissues below the knee have sufficient blood-supply to ensure good healing. Often the question can be answered only when the surgeon has made an incision and has examined the blood-supply of the skin and cut muscles. When an exploratory incision reveals that the tissues do not bleed freely, amputation through the lower third of the thigh must be carried out.

When gangrene is confined to the tips of the toes and the block is in the lower femoral or popliteal artery, a reconstructive operation of excising the affected arterial segment and substituting a vein-graft (long saphenous) is sometimes most successful. The absence of pipe-stem arteries permits a satisfactory anastomosis to be made with no particular difficulty. It is important to reverse the excised saphenous vein, so that in its new situation the valves will be incompetent. The after-treatment recommended by C. G. Rob, described on pp. 561, 562, is essential for success.

In the upper extremity tissue loss never extends proximal to the metacarpophalangeal joint.

DIABETIC GANGRENE

While arteriosclerosis is common in diabetes, and it often occurs at an earlier age than in non-diabetics, it has been assumed too readily that gangrene of the foot in diabetes is due to peripheral arterial disease alone, or combined with a lowered resistance to staphylococcal infection. Careful examination shows that the great majority of diabetic patients have quite an adequate peripheral blood-supply, the common defect being diabetic neuropathy. Peripheral nerve involvement, although occurring in diabetics of all ages, is encountered more frequently in the elderly : the chief manifestations are sensory, the outstanding one being impairment of the appreciation of pain. Motor lesions also play a part—the cock-up deformity of the toes frequently encountered in diabetics predisposes to a perforating ulcer over the plantar surface of one or more of the heads of the metatarsal bones. Appreciation of these facts, more particularly that the diabetic, even if the main artery supplying the limb is arteriosclerotic, usually has an excellent collateral

circulation, explains why conservative methods and local operations, which would be doomed to failure in an arteriosclerotic non-diabetic, often prove successful in the treatment of diabetic gangrene.

Usually the gangrene (*Fig.* 1335) follows minor trauma ; improper cutting of toe-nails, corns, and callosities is a very frequent cause. Pressure of a tight shoe (the pain engendered is not appreciated) is also common. Interdigital fungus infection should be looked for.

The early presenting lesion is nearly always one of the following :—

1. Gangrene of a toe. In early cases this is almost always limited to the distal two-thirds, and dry in appearance.

2. Perforating ulcer over the head of one of the metatarsal bones. The cock-up deformity of toes referred to above is often present in these cases.

3. A gangrenous patch on the heel, originating in a fissuring of the thick skin in the ambulatory, and to pressure necrosis in those confined to bed.

4. Web space infection following fungus infection of the interdigital clefts.

Principles in General Treatment.—

1. The patient should be admitted forthwith and a physician requested to undertake the treatment of the diabetes. Effective and early control of the diabetes is obtained more easily in the elderly than in cases of primarily infected gangrene in a young diabetic.

2. Antibiotic therapy is given ; penicillin to commence with. If an opportunity to secure a specimen of pus presents, culture and sensitivity tests are arranged.

3. *Both* legs are suspended as described on p. 958.

4. Operative treatment is postponed until infection is controlled by antibiotic therapy, and until the physician pronounces that the patient is fit for a general anæsthetic. Only in cases of spreading gangrene, especially above the ankle, is there need to curtail preparatory measures to the absolute minimum, in which case the advisability of employing refrigeration anæsthesia should be considered.

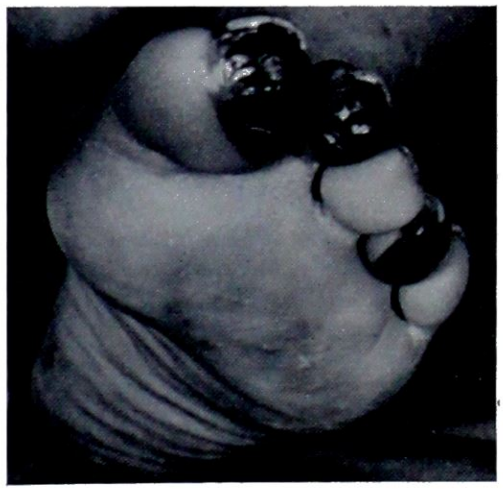

Fig. 1335.—Gangrene of toes occurring in a diabetic after contact with a moderately hot hot-water bottle. (*W. L. Lowrie.*)

The Local Treatment of Various Lesions.—

An area of superficial necrosis can appear with remarkable suddenness, but provided further pressure is avoided and bed-rest is insisted upon, usually these lesions heal uneventfully under purely conservative treatment. The foot is wrapped in a loose sterile dressing, which is removed twice a day for a 15-minute foot-bath, to which soft soap has been added. Foot-baths promote drainage and allow necrotic tissue which is separating to be removed with forceps and scissors ; viable tissues must not be touched during this procedure. The control of infection is a desirable, if not an essential, pre-requisite to any local operation, and while antidiabetic and antibiotic therapy is in progress, the above local treatment greatly enhances the success of a conservative operation.

Gangrene of a toe: As long as there is minimum infection there is little discomfort. Severe pain is suggestive of bone necrosis or purulent arthritis. It is usually wise to remove a single gangrenous toe by disarticulation and excision of the head of the metatarsal bone. Disarticulation *per se* has a tendency to impair the blood-supply to the adjacent toes ; moreover the exposed articular cartilage undergoes necrosis and healing is delayed (J. Grunberg et al.). As a rule the wound is left open and allowed to granulate. Primary suture is undertaken only if hæmorrhage is free and if the skin edges can be approximated without tension. Amputation of the fifth toe with the head of its metatarsal bone leaves a raw area for which it is impossible to provide adequate skin cover. Consequently, when this toe is involved or more than one digit is gangrenous, transmetatarsal amputation should be undertaken. When healing by secondary intention is awaited, the skin edges are held loosely in apposition by petroleum-jelly gauze and covered by an ample dressing of fluffed gauze.

Lesions of the sole: Once a perforating ulcer has occurred, operation is essential. The object of the operation is to remove necrotic tissue and the underlying bone pressure point, and to obtain skin cover without tension. When the toes are not involved, the gangrenous tissue is excised and the underlying pressure point, viz., the head of the metatarsal, is removed. Closure of the wound is permissible only when there is ample skin cover and an adequate blood-supply, as judged by hæmorrhage at operation. As a rule the wound is not closed, but is allowed to granulate, healing being expedited by delayed pinch skin-grafts.

If it is necessary to remove more than one metatarsal head, usually a transmetatarsal amputation is advisable.

Gangrene of the heel usually responds to local excision with or without subsequent skin-grafting. Radical excision of the heel tissues often involves removal of most of the fat pad of the heel. When bare bone lies at the bottom of the wound all presenting *cortical* bone of the calcaneus is chiselled away, leaving a flat cancellous bony surface which, by virtue of its rich capillary bed, provides an adequate granulating surface for the application of delayed pinch skin-grafts. The patient should be confined to bed and the limb suspended until healing is well advanced. Provided weight is directed to the forefoot during ambulation, the scar remains healed.

Summarizing: In most early cases, as soon as the diabetes is under control the local lesion is excised or unroofed. The resulting wound is, as a rule, treated by delayed closure, or when infected tissue cannot be excluded from the operative field, healing by granulation is awaited. In such cases sloughs can often be eliminated by moist dressings of streptokinase and streptodornase. When indicated, pinch grafting is employed to cover the granulating areas. Sometimes the associated vascular impairment is such that clinical judgement dictates that the above extremely conservative operations are unlikely to succeed. At others the gangrene has passed the limits which make them possible. When the associated arterial deficiency is moderate, the fate of the limb after excision and drainage of gangrenous tissue will hang in the balance.

The presence of a palpable dorsalis pedis or posterior tibial pulse is a fairly certain sign of a favourable outcome, but the amount of bleeding at the time of operation remains the most important demonstration that local excision will suffice.

Mid-leg amputation in diabetics: The number of failures of below-knee amputation is sufficiently small to justify its almost routine use, and re-amputation through the thigh can be performed on the few failures—4·7 per cent (S. Silbert). The advantages of below-knee amputation are :—

1. A lower mortality—above the knee 27 per cent, below the knee 9 per cent.
2. Better prospect of fitting and using a prosthesis.
3. Less pain in the stump.

The only contra-indication is absence of a femoral pulse at the groin.

RARER FORMS OF GANGRENE

Threatened and Actual Gangrene from Injury.—The limb has been injured ; typically, a wheel of a vehicle has passed over it, and there may or may not be a fracture. There is an effusion in the region of the injury which is impeding the circulation. The foot is cold and mottled. If the circulation is not restored within an hour it should be assumed that the effusion is compressing a main artery and steps should be taken accordingly. A long incision through the deep fascia (*Fig.* 1336) by releasing tension may allow the artery to function again. Referring to crushing injuries of the foot, blood extravasated beneath the anterior annular ligament sometimes produces sufficient tension to jeopardize the blood-supply to more distal parts. If reduction of a concomitant fracture does not release the tension, an incision with division of the anterior annular ligament is indicated (H. M. Childress). In cases where no improvement follows these conservative operations, amputation becomes necessary.

An 11-year-old boy was brought to hospital, a wheel of a motor-car having passed over the middle third of his left leg. There was some bruising of the skin, which was intact. Radiographs showed that there was no fracture, and he was allowed to go home. Four-and-a-half days later he returned. The foot was quite cold and the great toe was assuming a black tinge. The foot was lifeless. Amputation at the modern seat of election was performed. On dissecting the specimen

it was found that the posterior tibial artery had been torn across, and there was a hæmatoma in the neighbourhood of the anterior tibial artery. With these exceptions there was no gross damage.

Gangrene following Fractures of the Extremities.—Exceptionally the main artery is compressed or lacerated by a supracondylar fracture, or separation of the epiphysis at the

Fig. 1336.—Incision in the case of a run-over accident with œdema threatening the circulation of the foot. Timely incision through the swollen tissues may avert amputation.

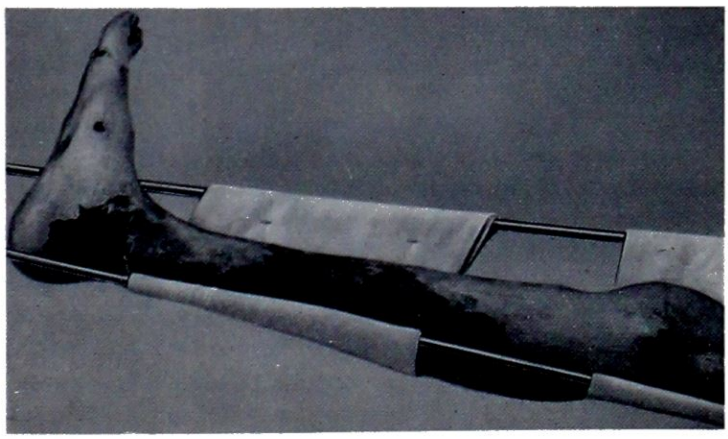

Fig. 1337.—Gangrene following strapping extension. (*D. S. Miller.*)

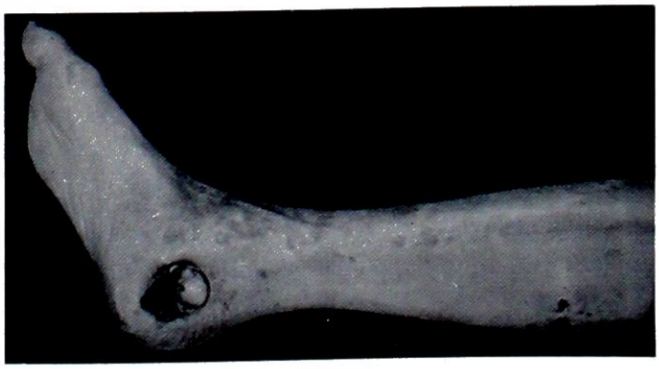

Fig. 1338.—Gangrene originating alongside the track of a Steinmann's pin. (*D. S. Miller.*)

lower end of the humerus or femur. More commonly gangrene occurs in aged patients with fractures, particularly of the neck of the femur. Usually the cause of the gangrene is due to: (1) Traction applied at the time of the reduction of the fracture. (2) Strapping extension, in which case the gangrene commences in the stretched skin (*Fig.* 1337). (3) Pressure sores from a plaster cast. (4) Osteomyelitis via the track of a Steinmann or other pin (*Fig.* 1338).

As D. S. Miller and A. J. Harris, who reported 39 personal cases, state, this complication cannot be rare, but is seldom reported. It might be thought that it could be avoided by treating the fracture by internal fixation, but gangrene occurs from time to time even after this form of treatment. In many of the cases high amputation becomes necessary, and the mortality is very high; 22 out of 39 patients died in Miller and Harris's series, while of 5 cases reported by McGoey, all succumbed.

Frost-bite.—Rubbing with snow is a procedure as dangerous as it is painful. On no account should the frost-bitten limb be pinched or massaged, and to rub it with a coarse towel, as has been recommended by some, is most inadvisable. Thawing should be as slow as possible.

First-aid Treatment.—If freezing has taken place for only a few minutes, the part should be covered with a warm hand or placed inside one's own clothing (R. Greene). Dabbing turpentine on the frozen parts has been found useful in minimizing the risk of gangrene. The trappers in Northern Canada used this remedy long before it was adopted as treatment in the hospitals of Canada (P. Berbrayer).

Course.—As a frozen hand or foot thaws, the pain, swelling, and hyperæmia are intensified if the tissue is still viable. It is impossible to determine the extent of tissue damage without

Fig. 1339.—Gangrene developing after frost-bite in a farm labourer.

prolonged observation. If there is complete loss of viability a line of demarcation (*Fig.* 1339) usually develops within a few days.

Treatment.—During the Korean War, when frost-bite casualties were found within four days after injury they were given an intravenous solution containing 250 ml. of 5 per cent dextrose, 12 ml. of alcohol, and 250 mg. of procaine; provided there were no concomitant battle wounds that might have bled, the solution given also contained heparin (*see* p. 927). This infusion was administered every 6 hours for 48 hours.

In otherwise young and healthy individuals, a conservative programme should be instituted. The affected part is wrapped lightly in sterile gauze and covered with a sterile towel, put to rest, and antibiotic therapy instituted. It has been observed that the contraction of black necrotic eschar frequently results in ischæmic necrosis of a digit. To prevent this the eschar should be bivalved as soon as possible. If it is hard and thick, it can be softened by immersion in sterile lukewarm water containing liquid soap. The majority of black eschars exfoliate and leave healthy, sensitive skin. Nails often exfoliate, and are replaced by new nails.

In the case of a leg: After demarcation is complete, amputation is carried out through the chosen adjacent normal-appearing tissues, provided the clinical tests suggest an adequate blood-supply at this level. A breakdown of the primary suture line often occurred in cases treated in this way by Canty and Sharf. An average of five operations was required in order to achieve a satisfactory stump. If further sacrifice of a length of bone was undesirable, a primary split skin-graft was often applied to cover the tissue defect. In 67 per cent of cases a major portion of the foot was preserved.

In the case of a hand the attitude should be especially conservative, for often mummified fingers gradually exfoliate, leaving normal digits. Consequently no-one can determine whether amputation will be required or not until after a period of three months has elapsed.

Immersion Hand or Foot is a separate entity and must be differentiated clearly from frost-bite. After rescue the immersed extremity passes through two, and sometimes three, stages :—

Stage 1 lasts for a few hours to several days. As a result of anoxia, the permeability of capillaries is increased. The affected part is cold, swollen, often cyanotic, and pulsation in neighbouring arteries is weak.

Stage 2 continues for six to ten weeks. The part becomes dark red, and definitely more swollen. The pain is usually worse at night and in severe cases blebs, containing serous or hæmorrhagic fluid, appear. Owing to the release of histamine-like substances, there is general malaise, slight elevation of temperature, and sometimes albuminuria. Even if the entire hand or foot, and all the digits, are discoloured, it is unusual for even one digit to be lost, particularly in the hand. If gangrene develops it is usually superficial, and with general systemic care will separate naturally.

Treatment.—The patient should not be allowed to use affected hands, or to walk if the feet are involved. After his wet clothing has been removed, he should be wrapped in warm blankets, but on no account must artificial heat be applied. If œdema is much in evidence ice-bags around the area relieve pain and paræsthesia. Intravenous heparin is given in doses as necessary (*see* p. 927) every 4 hours for 48 hours, to prevent thrombosis in the peripheral vessels.

Vesicles and blebs should not be opened. Unless quite detached, the pulling-off of dead or sloughing tissue should be forbidden. On the other hand, the application of moist dressings of streptokinase-streptodornase to remove dead tissue is most desirable. When the œdema and swelling have disappeared passive exercises and warm whirlpool baths are helpful.

Stage 3 does not always occur. When it does, it often lasts for weeks or months, and consists of hyperæsthesia, smooth, shiny, hairless skin, telangiectases, and wasted and pointed digits with stiff joints.

Non-occlusive Symmetrical Gangrene.—In many of these cases the arterial pulses feel normal. In most instances the cardiac output is low. The condition has also occurred in cholera and in carbon-monoxide poisoning.

Fig. 1340.—Gangrene due to Raynaud's disease.

In most cases bilateral below-knee amputation has become necessary.

Occasional Causes of Gangrene of the Fingers.—Raynaud's disease is sometimes responsible (*Fig.* 1340). The usual course recommended is to perform sympathectomy, and when the line of demarcation is clearly defined, to amputate in accordance with the principles set out on p. 971. In the case of gangrene due to cervical rib the index finger, or part thereof, is amputated after clear definition of non-viable tissue has occurred, preferably following scalenotomy.

Gangrene in Infants.—Spontaneous peripheral arterial occlusion during infancy is rare ; most cases occur within fifteen days of birth. The aetiology is often a matter for speculation. However, J. Bret reported 3 cases of gangrene in a lower extremity of the newborn ; in each case the infant had received nikethamide (coramine) through the umbilical vein. The vasoconstrictor action of this drug is therefore a proven danger. The better collateral circulation in an infant, as compared with an adult, provides some protection against extensive loss of tissue. It would seem, therefore, that therapy should err on the side of conservatism, and that measures to increase collateral blood-flow be utilized. Operation should be performed only after clear demarcation between viable and non-viable parts. The initial treatment consists in supportive therapy, antibiotics, and a rigid sterile technique in dressing. A sympathetic procaine block was used in 3 cases reported by Stokes and Shumacker and gangrene that threatened a much larger area became limited to a toe or toes.

Phlegmasia Cerulea Dolens.—Although it is usually due to impairment of the arterial supply, gangrene occasionally results from occlusive venous disease. Phlegmasia cerulea

dolens is characterized by severe pain in a limb (nearly always a leg), very considerable swelling, and rapidly developing cyanosis of the limb. The condition appears to be due to thrombophlebitis of the iliac and femoral veins associated with unexplained spasm of the femoral artery. Many of the reported cases occurred in female patients recently delivered; in a minority the possibility of puerperal origin of the thrombus did not appertain—indeed, in not a few instances the patient was a male. In non-pregnant cases the patient is often debilitated by another disease, e.g., ulcerative colitis (C. G. Rob), but cases have occurred following the injection of sclerosing agents for varicose veins. Many more cases of phlegmasia cerulea dolens occur than are reported, the main reason being that the patients are not observed carefully in the early stages, when the true nature of the pathology can be recognized, but only in the end stage of gangrene.

Measures that should be avoided: Because of the shock, and the fact that they do not act selectively, antispasmodic drugs should be avoided, for they would assuredly lower the blood-pressure. Paravertebral sympathetic block would seem to be contra-indicated because it increases congestion in an extremity the venous return of which is compromised.

Treatment.—As the condition is often associated with shock, the first consideration should be to administer dextran or plasma. Unless there is an obvious contra-indication,

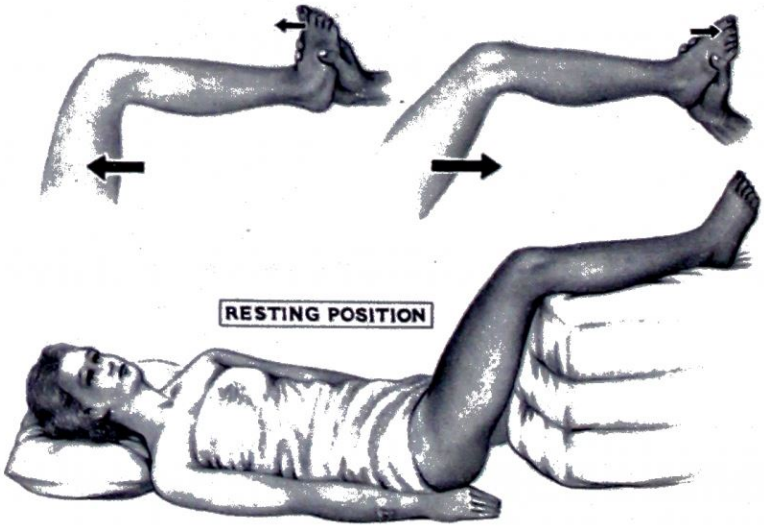

Fig. 1341.—Method of high elevation and leg exercises in early cases of phlegmasia cerulea dolens. (*After J. R. Veal.*)

such as very early delivery, anticoagulant therapy should be given. Contrary to threatened or established gangrene of arterial origin, where to elevate the limb is a misdemeanour, high elevation of the limb so as to aid the return of venous blood by subsidiary channels, and frequent exercises of the foot and leg as shown in *Fig.* 1341, is the treatment J. R. Veal and others have found very successful in early cases. In some cases gangrene ensues, when amputation through healthy tissue above the line of demarcation must be carried out without delay.

In the arm the condition has been attributed to intravenous infusion or injection, but some cases have occurred spontaneously. Gangrene, when it occurs, is practically confined to the digits.

As in all cases of phlebothrombosis, pulmonary embolism is a rather frequent complication of phlegmasia cerulea dolens.

REFRIGERATION ANÆSTHESIA

When the services of an experienced anæsthetist are not available, or in a very poor-risk subject, refrigeration anæsthesia, although somewhat troublesome, and in many instances resulting in a wet bed, is entirely satisfactory. Furthermore, it is the safest of all forms of anæsthesia. The maxim that a tourniquet must not be applied to an arteriosclerotic limb or in cases of diabetes is countered when the limb is to be refrigerated, for without a

tourniquet refrigeration anæsthesia is incomplete, and the advantages of refrigeration anæsthesia often outweigh the dangers of the application of a tourniquet.

Step 1.—Ice-bags are applied about the proposed site of amputation, and left in place for about half an hour.

Step 2.—A tourniquet is applied at least 3 in. (7·5 cm.) above the proposed saw line. With the parts chilled, this can be done without supreme discomfort. During the application of the tourniquet pinching a fold of skin must be avoided studiously.

Step 3.—When amputation of a toe or a transmetatarsal operation is to be performed and the patient is strong enough, refrigeration is simple (*Fig.* 1342). More usually a rubber

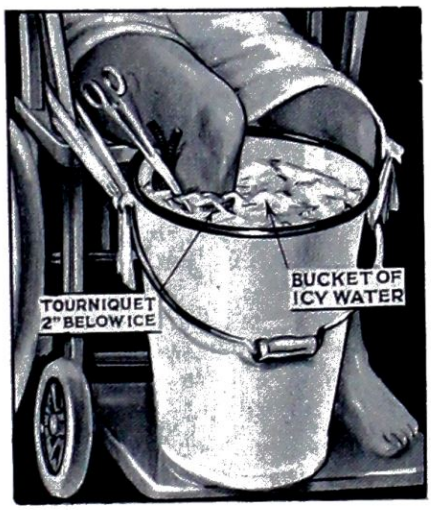

Fig. 1342.—Refrigeration for amputation of the toes when the patient is able to sit in a wheel chair. (*After F. M. Allen.*)

sheet must envelop the extremity and within it cracked ice is packed around the whole limb, including 3 in. (7·5 cm.) above the tourniquet (*Fig.* 1343). If the head of the bed is elevated, the water can be made to drain into a pail. Two-and-a-half hours of this freezing process, which is quite painless, are necessary. A needle introduced into a main nerve will indicate if anæsthesia is complete.

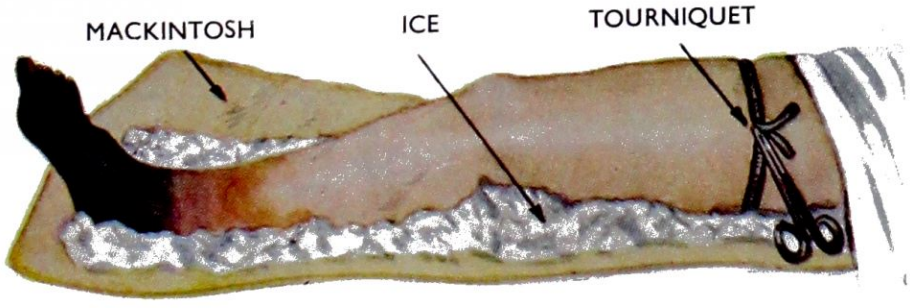

Fig. 1343.—Method of refrigeration for amputation through the thigh. (*After F. M. Allen.*)

Step 4.—The patient, with the ice-bag still in position, is moved to the operating theatre. The temperature of the theatre must be as low as can be obtained conveniently by shutting off heat and opening windows. The whole theatre staff must be completely ready for the operation. There is no need for undue haste, but there must be no waste of time. The tourniquet is unsterile and towels must be so arranged for its removal at the appropriate time during the operation. Unless the temperature of the operating theatre is high, anæsthesia can be expected to last for one hour. At any rate, there is plenty of time to perform a fairly expeditious amputation, and amputation by equilateral flaps is recommended.

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CHAPTER LXXXIV

URGENT AMPUTATIONS

In works on operative surgery, especially those designed to meet the needs of the examination room, much space is devoted to classical amputations. Only a few stereotyped amputations are necessary in emergency surgery.

Urgent amputations may be called for: (1) In crushing accidents; (2) In spreading gangrene of the limb; (3) In a grave infection of the limb threatening life, after antibiotics have had a just trial.

The first thought is to save the patient's life. The second should be to plan an amputation suitable for an artificial limb. These objectives must be before us in all amputations.

GENERAL CONSIDERATIONS

Prophylaxis against Gas Gangrene.—The skin in the neighbourhood of the anus is contaminated with intestinal bacteria to a greater distance than is generally supposed; these bacteria include the *Aerobacter aerogenes*, the spores of which are not destroyed by ordinary methods of skin disinfection (L. P. Garrod). It should be recognized more widely that amputations either for obliterative arterial disease or through the upper part of the thigh—and particularly when both factors exist—involve an exceptional risk of gas gangrene. Such operations afford one of the few imperative indications for full penicillin cover, and possibly if the prophylactic value of anti-gas-gangrene is allowed, a prophylactic dose of this serum, also.

Anæsthesia.—In diabetic and arteriosclerotic patients anæsthesia is usually a problem. Spinal anæsthesia has been the choice of many surgeons: nevertheless, as spinal anæsthesia tends to diminish the blood-flow through the extremities, it is possible that it favours intra-arterial thrombosis in the opposite extremity. For this reason in the aged, in those with peripheral arterial disease, and in diabetic persons, nitrous oxide and oxygen or cyclopropane with a relaxant is to be preferred. Referring to the diabetic patient, Chew Smith says there is no anæsthetic of choice—it must be chosen as best suiting the patient, combined with the capabilities of the available anæsthetist. Refrigeration anæsthesia is advocated by some, especially in infected cases, but it has never become popular.

Site of Amputation (*Fig.* 1344).—In deciding the level of a lower limb amputation one must remember that if there is a choice of sites, particularly in an elderly person, the lower the level of amputation, the greater the prospect of ambulation. Nevertheless, before deciding to amputate below the knee in an arteriosclerotic patient the following factors should be taken into consideration: If simple amputation of a toe is carried out, 50 per cent of the patients require re-amputation at a higher level within three months (Reeves and Quattlebaum). The frequency with which supracondylar amputation becomes necessary after below-the-knee amputation in arteriosclerotic patients varies so widely in different series that the incidence is problematical, but it is clear that it occurs sufficiently often to make it essential to weigh carefully all data relating to the probable viability of tissues at the proposed site of amputation. If, after deliberation, amputation through the leg below the knee is decided upon, should the cut muscles appear dusky and ooze but little, one must be prepared to abandon amputation at this level in favour of an above-the-knee amputation. Amputation must be performed through indubitably viable muscle, as evidenced by a beefy red colour and a goodly capillary ooze.

In the upper limb, it is of the highest importance to preserve the elbow-joint, if that be possible; a prosthesis can be fitted to a stump if only $1\frac{1}{2}$ in. (3·8 cm.) beyond the insertion of the biceps muscle can be retained.

Control of Hæmorrhage.—At the present time the tendency is to avoid using a tourniquet, unless it is obvious that the patient's arteries are in a youthful elastic condition. Sometimes in infected cases, by reason of œdema of the upper part of the limb, both the use of a tourniquet and external digital compression are rendered ineffectual; in these

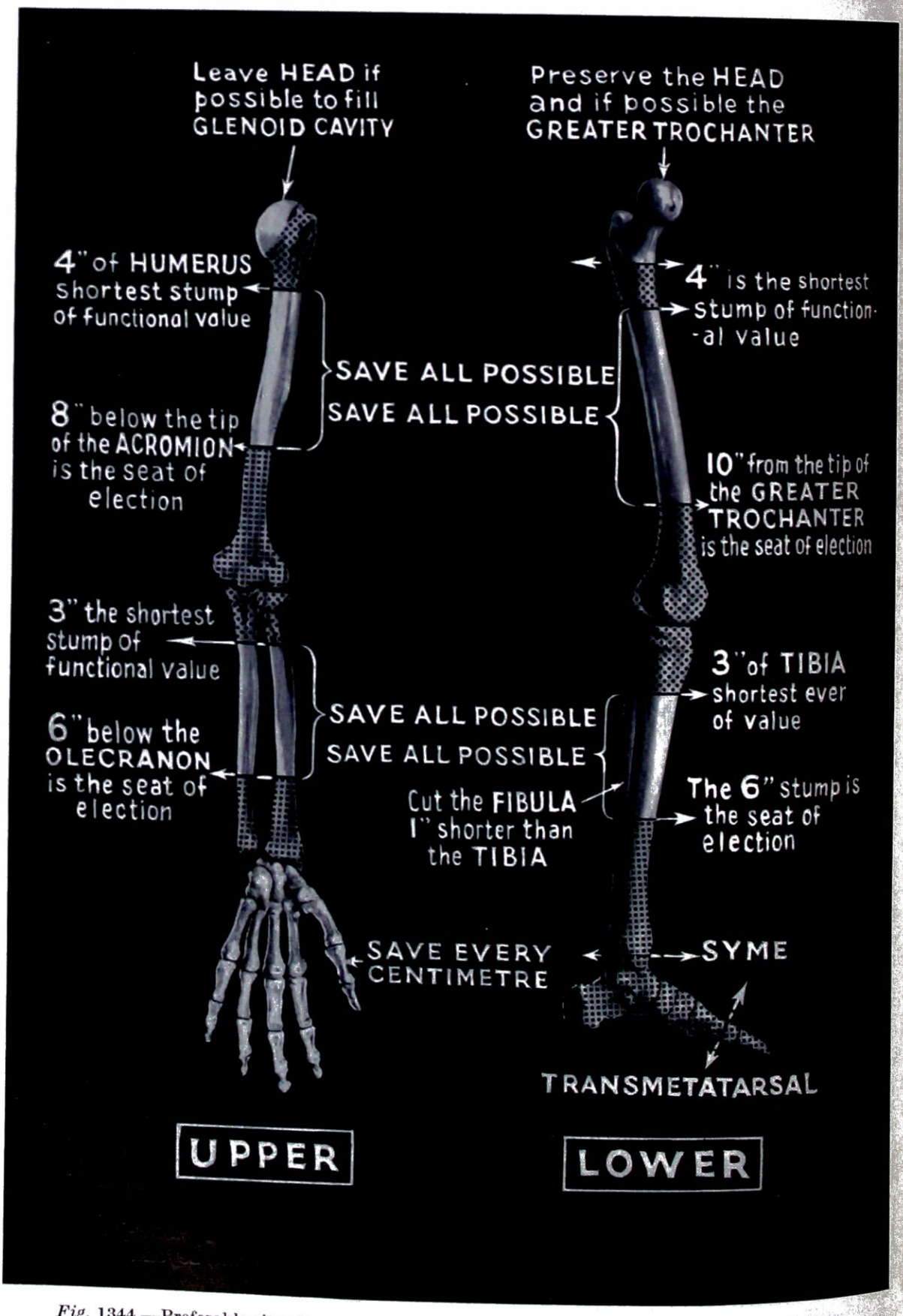


Fig. 1344.—Preferable sites for amputation from the point of view of fitting an artificial limb.

circumstances the correct procedure is, first, to expose the main vessels at the usual site of compression; then, as the surgeon commences to amputate, a gloved and gowned assistant compresses the vessels between the finger and thumb for as long as is necessary.

External Digital Compression in the line of the main artery is most often called for in the lower limb. Progressive gangrene of the foot due to obliterative arterial disease is a common indication for amputation, and it is precisely in these circumstances that the evil effects of a tourniquet reach their zenith. Not only is the main artery liable to direct an undue injury, but damage to the smaller arteries often results in thrombosis and occlusion of the very vessels upon which the nutrition of the stump depends. Hence, for the control of hæmorrhage in arteriosclerotic subjects, digital compression, because it minimizes these risks, is the only method that should be employed. If he is not fully acquainted with the technique, the assistant should be instructed where and how to compress the femoral artery before the operation is commenced.

The Application of a Tourniquet.—When it is considered that the application of a tourniquet will do no harm, the limb should be elevated *for two minutes* in order to allow the blood to gravitate. A tourniquet is then applied with no greater pressure than is required to control the bleeding. It is important not to keep the limb elevated too long, for under these conditions vasoconstriction occurs, and when the limb is lowered and the vasoconstriction passes off, the tourniquet may prove ineffective.

For the upper limb a sphygmomanometer cuff is the ideal tourniquet. For the lower limb the type of tourniquet is a matter for individual preference. A length of new ½-in. (1·3-cm.) rubber tubing retained by a strong hæmostat is second to none. Whenever a tourniquet has been employed, be vigilant in seeing that it is removed as soon as it has served its purpose.

Fashioning Flaps.—With very few exceptions flaps should be cut from without, inwards. The scalpel, which should not be small, is held in a manner that gives perfect control of the blade (*Fig.* 1345). All the flaps should be fashioned somewhat longer than is necessary: they can never be lengthened, but it is a simple matter to trim them appropriately at the end of the operation. While making this final adjustment, it should be borne in mind that the shorter the flap the better its nutrition.

Severing the Soft Parts.—Except for leaving a little muscle at the base of the flaps, in most instances all the soft parts are cut at the level of the proposed section of the bone and a 'tour de maître' is the technique recommended (*Figs.* 1346, 1347). For this purpose a Syme's knife (*Fig.* 1348) is desirable.

Retracting the Musculature.—An efficient muscle retractor, so essential for amputations, can be made from a piece of stout calico. For use in the case of the femur and humerus one slit is made (*Fig.* 1349 A). For amputations of the forearm and the leg below the knee a double slit is necessary (*Fig.* 1349 B), so that the tongue of material can be passed between the radius and ulna or the tibia and fibula. It is advisable to have the edges of the slit hemmed. The cloth retractor is sterilized by boiling with the rest of the instruments. To an assistant is delegated the sole duty of seeing that every portion of muscle is completely covered by the cloth, which is well and evenly retracted with both hands (*see Fig.* 1357).

Dealing with the Periosteum.—The ends of the bone should be denuded of periosteum for about ½ in. (1·3 cm.) above the line of section. Using a periosteal elevator, this erasion can be done before or after section of the bone. Removal of the periosteum helps in preventing thickening of the end of the bone and spur formation.

Section of the Bone.—The saw-cut is commenced by steadying the instrument against the thumb. By drawing the saw[1] towards one with a few light strokes, a groove is cut in the bone. Vigorous sawing is then commenced. This process is greatly enhanced by having a stream of saline solution injected from a syringe on to the line of bone division, otherwise bone dust tends to collect and clog the cutting edge of the saw. The assistant must be told to hold the limb steadily, exerting slight, perfectly horizontal traction. He must understand that elevation will result in locking of the saw blade, and depression will probably cause the bone to splinter. If time permits, the bone end should be smoothed with a file. Any spikes can be cut away with bone forceps. It is most important to bevel protuberant edges such as the crest of the tibia.

[1] Alternatively, a Gigli's saw can be used with certain advantages (*see* APPENDIX, p. 1135).

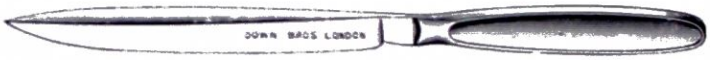


Fig. 1348.—Syme's amputation knife. The blade is 3½ in. (9 cm.) long.

Fig. 1345.—Method of holding the scalpel while cutting amputation flaps.

Fig. 1346.—Usual method of holding Syme's knife while cutting the soft parts.

Fig. 1347.—The 'tour de maître'.

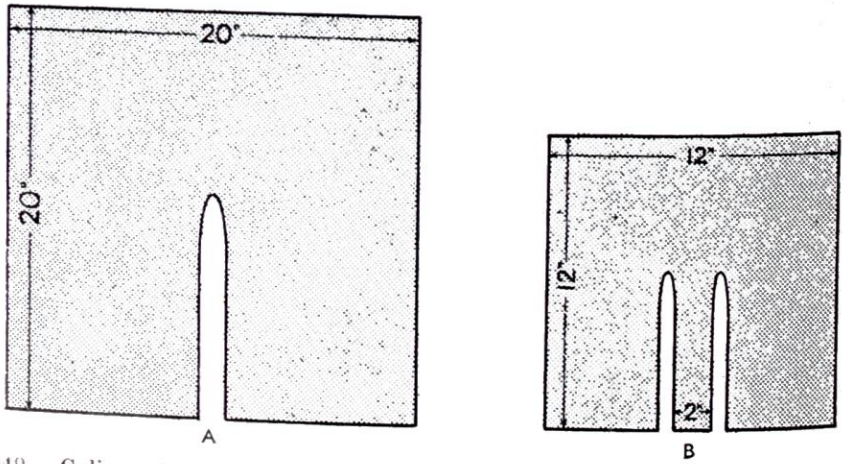


Fig. 1349.—Calico retractors. A, For the humerus and femur. B, For the forearm, or leg below the knee; the tongue of material is passed between the radius and ulna or the tibia and fibula, as the case may be.

Ligation of Divided Vessels.—As many vessels as possible are picked up and ligated before compression of the main vessels is relaxed. A double ligature in the form of Ballance's stay knot (*see* p. 935) is recommended for the principal artery. After compression of the main artery has been released small bleeding vessels will be seen and secured.

Attending to Nerves.—Due largely to the use now made of *lateral*-bearing appliances, in recent years there have been radical changes in the level of division of nerves during amputation. Unless an *end*-bearing prosthesis is to be fitted, nerve-trunks should not be expressly sought, drawn down, and shortened, as was formerly considered advisable. They are merely divided along with the muscles, with the result that amputation neuromata are less common.

Closure.—The skin is approximated loosely with interrupted sutures, but correct apposition is important. 'Dog-ears' should never be allowed to remain. If such appear at the ends of the line of skin approximation, they should be snipped off with scissors and the resulting defect[1] brought together with a stitch. As a rule, if bleeding points have been attended to meticulously, drainage of the wound is unnecessary: the presence of a drain may interfere with the healing of the skin-flaps; it is also a possible source of infection. However, when oozing is troublesome a piece of corrugated rubber should be placed in one or both corners of the wound for 24–48 hours.

Unless there is some special reason for so doing, the stump should not be uncovered for fourteen days, when the stitches are removed. Often it is advisable to leave a few stitches in place for a further period.

SPECIAL EMERGENCY MEASURES

When it is essential to provide Free Drainage (i.e., infection is present).—

The guillotine amputation is not recommended; the only justifiable site for this procedure is in the lower third of the tibia, for here re-amputation at the seat of election (*see* p. 972) will be necessary in any case.

The usurper of the guillotine operation is the short, equilateral flap operation.

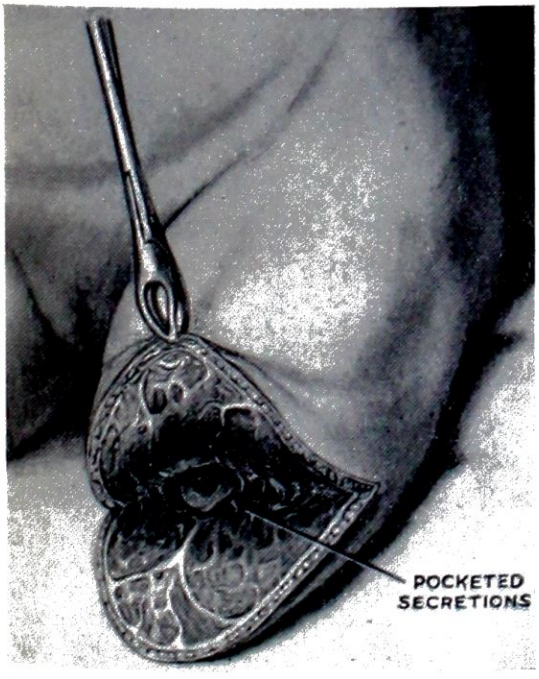


Fig. 1350.—When anteroposterior flaps are used, pocketing is encouraged.

Fig. 1351.—Equilateral flaps afford the wound perfect drainage. (*After W. A. Steel.*)

The wound is left partially or completely open. In the case of the femur or the humerus far better than anteroposterior flaps (*Fig.* 1350) are lateral equilateral flaps (*Fig.* 1351), which afford dependent drainage of the wound. In the case of the leg below the knee, and

[1] It is convenient to use one or both of the defects for the insertion of a drain, if that be considered necessary.

the forearm, lateral flaps are better avoided, for the anteroposterior scar becomes drawn up between the ends of the bones. In these situations anteroposterior flaps are preferable. In either case, having obtained good hæmostasis, the wound is packed lightly with petroleum-jelly gauze. In favourable cases, about the tenth day the flaps are drawn together with adhesive plaster or secondary suture is undertaken.

In the meantime skin traction should be applied (*see Fig.* 1374, p. 989). If this is not done, when the time arrives for the wound to be closed, it will be found that the flaps and soft parts have retracted.

AMPUTATIONS OF THE LOWER LIMB

Disarticulation at the Hip-joint.—Amputation at the hip-joint is very rarely necessary in emergency surgery. I have performed the operation but twice as an urgent measure.

Position of the Patient.—The patient lies supine, but slightly turned towards the sound side. The pelvis rests on the end of the table and the sound limb is secured to a leaf of the table (*see Fig.* 1354).

Stand on the outer side of the limb. The assistant supporting the leg must be fully acquainted with the meaning of the terms 'adduction' and 'abduction' and be able to execute these movements deftly when the order is given.

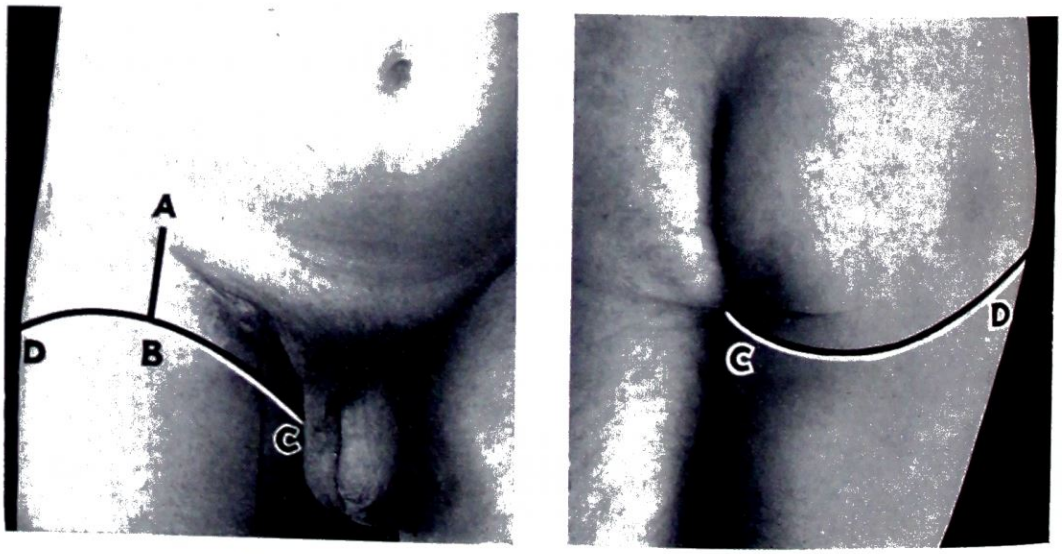


Fig. 1352.—Incision for amputation at the hip-joint.

Preliminary Ligation of the Femoral Vessels.—Make a vertical incision A–B (*Fig.* 1352) 3 in. (7·5 cm.) in length in the line of the femoral artery. Ligate the femoral artery and vein.

Completing the Incision.—From the lower extremity of the vertical incision, sweep inwards along the line B–C to a point 4 in. (10 cm.) below the perineum. Then make the incision B–D, which runs below the base of the greater trochanter. Carry the incision along the line C–D across the back of the thigh.

Dissect up the whole circumference of the skin and fascia.

Division of Muscles.—Direct attention to the outer side of the thigh. Divide the muscles right down to the bone. Tie the lateral circumflex artery. *Ask the assistant to elevate the limb.* Divide the insertion of the gluteus maximus and the muscles on the postero-internal surface. Try to find and ligate the medial circumflex femoral artery.

Tell the assistant to lower the limb to the horizontal plane and to *adduct and rotate inwards.* Divide all muscles attached to the greater trochanter. Tell the assistant to *abduct and rotate outwards.* Divide any remaining muscles.

The capsule of the hip-joint is now in full view. Open the capsule anteriorly with the amputation knife. Dislocate the head of the femur. Divide the remaining part of the capsule and the ligament of the head of the femur with strong curved scissors. The limb can now be removed. Proceed to unite the skin-flaps: it is surprising how readily

the posterior flap can be brought forwards. Drain the wound. *Fig.* 1353 shows the end-result in a patient who had the operation performed.

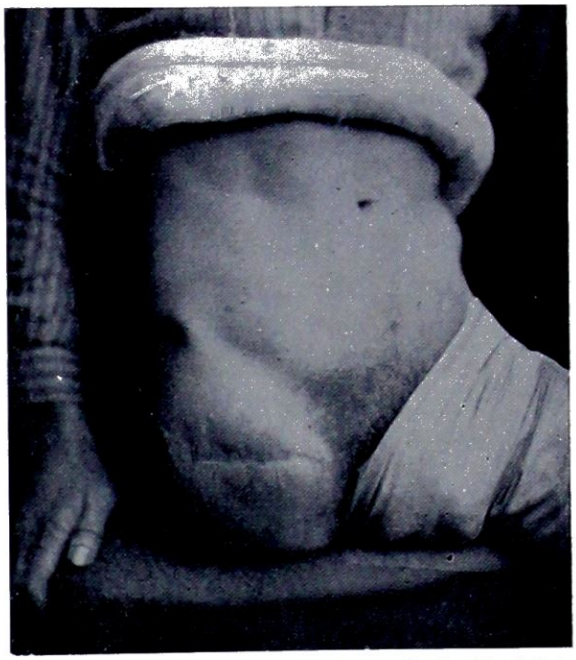


Fig. 1353.—Amputation through the hip-joint. The patient had a virulent osteomyelitis of the femur with infective arthritis of the knee in a limb deformed by old-standing infantile paralysis.

Amputation through the Thigh.—'Through the thigh' is an amputation often called for.

Before the patient is taken to the operating theatre, order the limb to be bandaged securely. Say to the nurse: "Make a parcel of this limb up to such-and-such a level, and make certain that the parcel will not come undone." In this way the infected area is isolated from the field of operation, which is shaved and otherwise prepared in the usual manner.

Making Ready for the Amputation.—If the end of the table has a leaf, let it down. Have the patient's buttocks brought right down to the edge of the table. Bandage the sound limb firmly to the leaf or leg of the table (*Fig.* 1354).

If there is no contra-indication to so doing, elevate the limb and apply a tourniquet as far up as possible. In other circumstances an assistant is relegated to the sole duty of applying digital pressure to the femoral artery or, if an assistant capable of performing this duty is not available, there is no particular difficulty in modifying the operation so that when the flap has been raised the femoral vessels are unroofed, triply ligated, and

Fig. 1354.—Amputation through the thigh. The sound leg must be secured to the table. A and B show the small guiding transverse incisions referred to in the text and in *Fig.* 1355.

divided between the lower two ligatures which have been applied sufficiently far apart for that purpose. Having draped the area surrounding the field of operation with sterile

towels,[1] stand on the inner side in the case of the left leg, and on the outer side in the case of the right. Ask the assistant supporting the limb to raise the leg. Make a small transverse cut in the skin on the *back* of the thigh at the level at which it is desired to divide the bone (*Fig.* 1355 B). Have the limb lowered until it is in a straight line with the body. Make another small cut in the skin on the *front* of the thigh six or eight inches lower than the first (*Fig.* 1355 A).

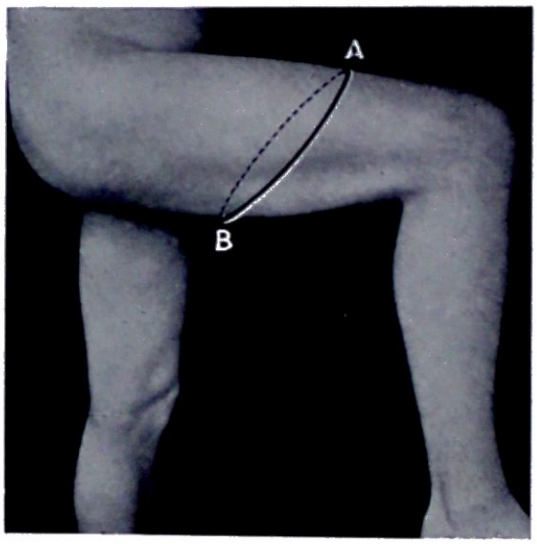


Fig. 1355.—Incision for amputation of the thigh. A small transverse cut is made on the back of the thigh at B, which is the level at which it is proposed to section the bone. A small transverse cut is then made at A in front of the thigh, which is to be the extremity of the flap. A and B are now joined by an elliptical incision.

The Amputation.—Using an ordinary scalpel, describe an ellipse joining the two cuts just made. This incision is through skin and fascia only. Apply a Lane's forceps to the proximal side of the cut edge of the front of the thigh, and commence to dissect up the flap. Proceed to raise the skin and fascia only, for a distance of about 3 in. (7·5 cm.). Now substitute the Syme's knife for the scalpel. Still raising the flap, cut obliquely through the muscles of the front of the thigh in such a way that the flap contains more and more muscle. In this manner proceed for another 3–4 in. (7·5–10·0 cm.) until the level of the original skin mark on the back of the thigh is reached. With a stroke or two of the scalpel dissect up the skin for ¾ in. (2 cm.) on the back of the thigh. Clasping the Syme's knife with the blade looking towards one and the arm passed under the limb, describe a 'tour de maître' right down to bone. Make certain that all structures are divided (*Fig.* 1356): particularly is this necessary in the neighbourhood of the linea aspera. Take a broad periosteal elevator and rapidly bare the bone as high up as can be reached with convenience. So firmly is muscle attached to the linea aspera that it is often necessary to exchange the periosteal elevator for a scalpel in this situation.

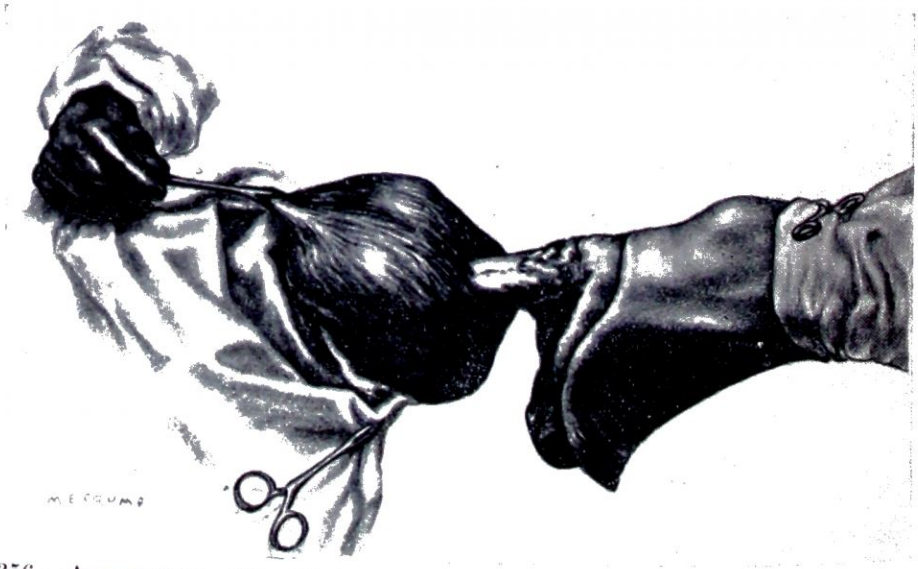


Fig. 1356.—Amputation of the thigh by Kocher's method. The anterior flap has been turned up and the muscles at the back of the thigh have been divided.

Apply the cloth muscle retractor. See that the assistant has got a firm grip of the retractor with both hands, and is exerting sufficient traction to reveal the bone at

[1] A large sheet with a slit in the centre is convenient for draping the upper part of the thigh and the trunk. The foot is passed through the slit and the sheet is carried up above the knee to the desired level, when the edges of the slit are clipped to the skin.

the level at which it is to be sectioned (*Fig.* 1357). With a Butcher's saw, divide the bone in a strictly transverse plane. The leg being amputated, the second assistant dispenses with the muscle retractor, grasps the stump, and holds it in such a way as

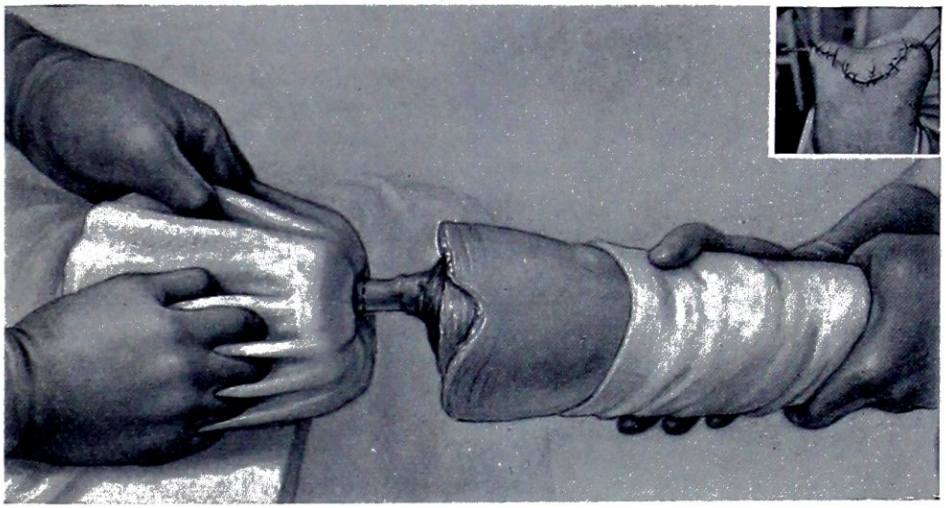


Fig. 1357.—Amputation through the thigh. The retractor in position ready for the division of the bone. *Inset.*—The appearance of the stump at the completion of the operation.

to make the cut surface look upward. Doubly ligate the femoral vessels. Now ask the assistant to loosen the tourniquet or release pressure on the femoral artery. Pick up bleeding vessels and ligate them, not forgetting there is sometimes an artery within the sheath of the sciatic nerve. Unite accurately the deep fascia as a separate layer,

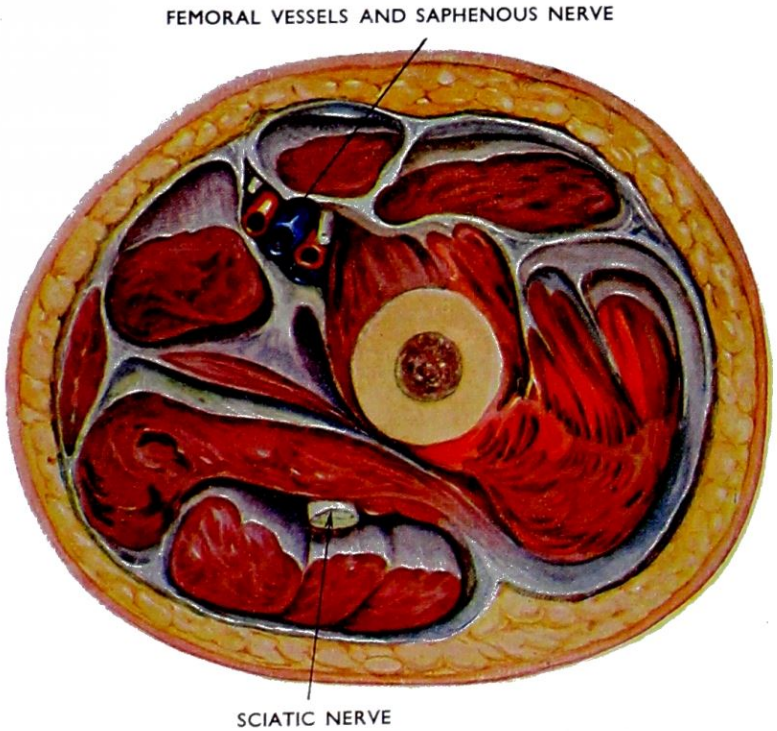


Fig. 1358.—Transverse section through the middle third of the left thigh.

and then approximate the skin margins with interrupted stitches. Insert a strip of corrugated rubber only if hæmatoma formation seems probable. A light dressing is applied and held in place with adhesive plaster, which is not applied tightly. Bandaging has been abandoned because it tends to interfere with the circulation, often impaired already. No splint or traction is applied.

This amputation gives a well-covered stump with a posterior scar (*Fig.* 1359).

Disarticulation at the Knee.—It is surprising that this amputation is not performed more often. Neither muscle nor bone is transected, therefore the risk of spread of infection is minimized. There is less atrophy of the muscles of the stump than after amputations at a higher level; consequently earlier fitting of a prosthesis (six weeks after healing) is possible. A prosthesis for this stump is comparatively easy to construct and to fit. Gangrene of the foot spreading to the leg is a major indication for this operation, the only proviso being that sufficient viable skin must be available to close the stump. In short, disarticulation at the knee is a quick, safe, easily performed, non-traumatizing operation eminently suited to the bad-risk patient.

Fig. 1359.—Amputation through the middle third of the thigh by Kocher's method. The stump.

Technique.—When not contra-indicated, a tourniquet is employed. A long broad anterior flap, measuring approximately one diameter of the knee at the level of the lower border of the patella, and a short posterior flap one-half of this diameter, are fashioned, with the limits of the incision at the level of the condyles of the tibia (*Fig.* 1360). The anterior incision is deepened through the deep fascia to the bone, and this flap is dissected from the tibia and adjacent muscles, the insertion of the ligamentum patellæ and its medial and lateral retinaculæ being included in the flap. The knee-joint having been opened, the medial and lateral ligaments are divided close to the tibia. The cruciate ligaments are severed close to the tibia, as also is the posterior capsule of the joint. The medial popliteal nerve is identified, and hooked forward on the finger: it is divided a few bundles at a time, so as to be enabled to identify and secure the accompanying artery. The popliteal vessels are doubly ligated and divided in the manner described on p. 935. The biceps tendon is severed. The posterior flap is then

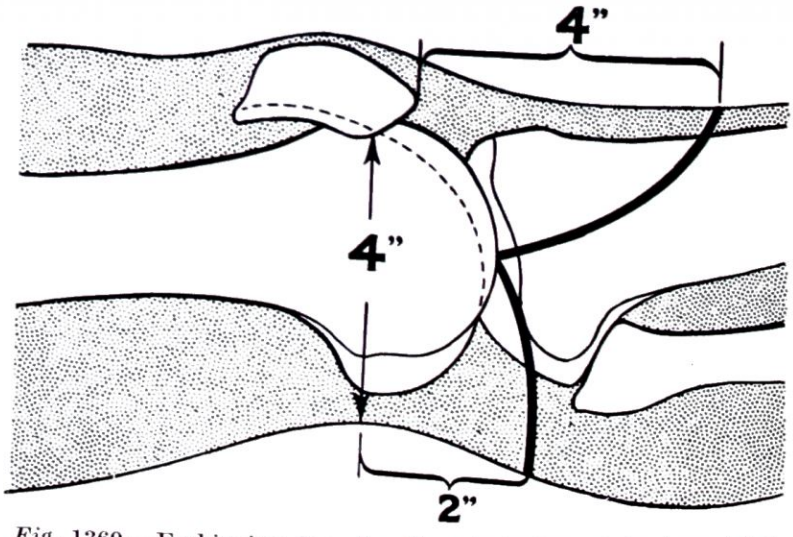


Fig. 1360.—Fashioning flaps for disarticulation of the knee-joint.

dissected up. The gastrocnemius, plantaris, and popliteus muscles are transected at a convenient high level. The disarticulation is now complete. Neither the patella, nor the cartilage of the condyles or of the patella, is removed.

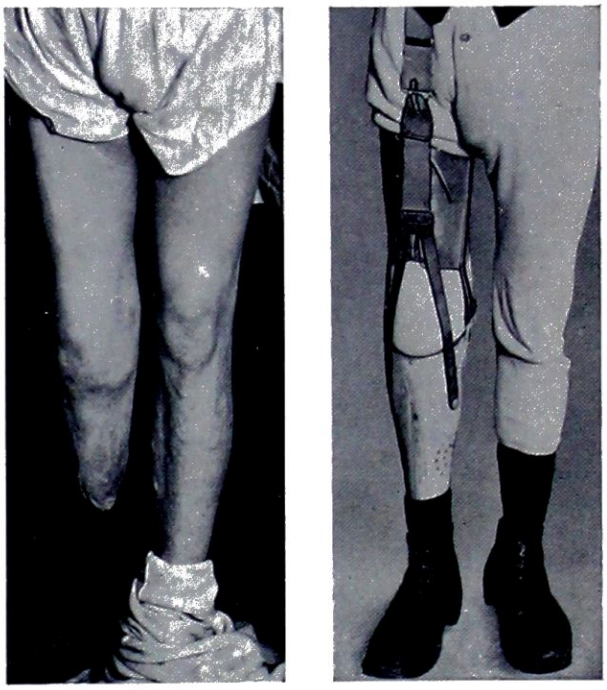
The tourniquet is released, and bleeding vessels are secured and ligated. The ligamentum patellæ is stitched securely to the cruciate ligaments and the remnants of the gastrocnemius muscle are also sutured to structures in the intercondylar notch. Corrugated rubber drains, which are usually necessary, are placed in the corners of the wound.

The deep fascia and subcutaneous tissues of the anterior and posterior flaps are approximated with fine interrupted sutures. The skin is approximated, stainless-steel wire sutures being preferred by Colonel Batch and his colleagues, who have performed the operation twenty-six times.

Amputation of the Leg: the 6-in. (15-cm.) Stump (the modern 'seat of election').—When contemplating a permanent stump, amputation through the *lower third* of the leg must be condemned wholeheartedly. The resulting stump is poorly nourished: it often becomes the seat of chilblains and it atrophies as age advances. The only justification for its employment is as a temporary measure in severe sepsis.

On the other hand, amputation just below the middle of the leg is free from these objections, and is, moreover, excellent from a functional point of view (*Fig.* 1361). One should aim at leaving 6 in. (15 cm.) of the tibia and slightly less of the fibula. The 6-in. stump is so satisfactory from an artificial limb point of view that this is indeed the modern 'seat of election'.

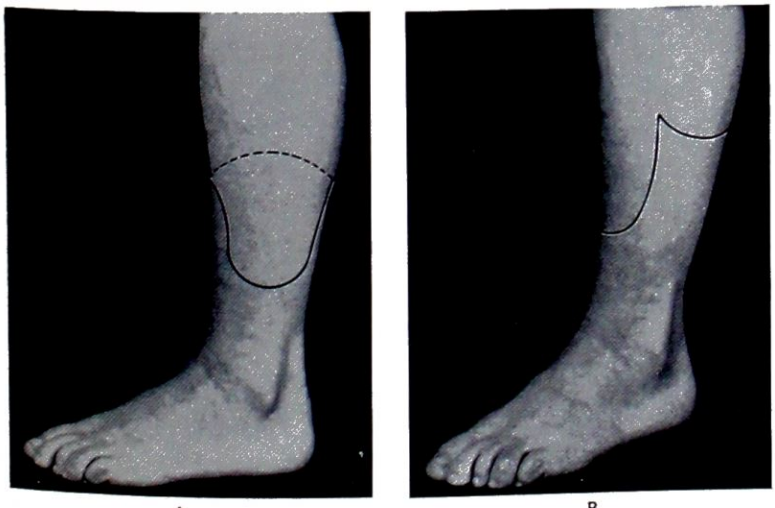
In urgent surgery amputation through the leg is most often required for crushing injuries. Attention has been directed to the advisability of resorting to primary amputation in cases of comminuted, compound, contaminated fractures communicating with the ankle-joint (p. 875).



A B

Fig. 1361.—A, Amputation through the leg. The 6-in. stump. Undertaken for a crushed foot with involvement of the ankle-joint. B, The patient with an artificial limb fitted. Two years later the patient wrote: "I hardly ever use a stick, and just walk with a slight limp as a man would with a corn."

Technique.—Before the patient is taken to the operating theatre the foot is wrapped securely in a sterile towel. As soon as he is anæsthetized the area of operation is shaved, washed, and painted, and a tourniquet is placed around the thigh unless there is some contra-indication to so doing, in which case digital pressure is applied to the femoral artery. Flexing the knee and taking the inferior border of the patella as the guide, 6 in. (15 cm.) of tibia is marked off by a scratch on the skin.



A B

Fig. 1362.—Flaps for amputation of the leg. A, One long flap; B, A long anterior and a short posterior flap.

The Flaps.—Flaps can be fashioned from any healthy skin available, perhaps the best being equal anterior and posterior flaps. If one long flap can be fashioned from the antero-external aspect (*Fig.* 1362 A), it answers the purpose well. A long anterior and a short posterior flap can also be recommended (*Fig.* 1362 B). When a single flap is used, care should be taken not to make it too broad, otherwise when it is sewn into place a ridge will form in the centre of the flap. To prevent other ridges forming, the corners of the flap should be rounded.

A good method of ascertaining just how much flap is necessary is to encircle the limb tightly with a length of suture material at the proposed point of section: this will register the circumference of the limb. With a little ingenuity it can be laid on the skin in such a way as to give an approximate idea of the size of the flap required. It is best to err on the side of having too much; it can always be trimmed with scissors before being sutured into place. Dissect up the flap—skin and fascia alone are required, though a little muscle may with advantage be included in the base of the flap.

Bear in mind that in this amputation there is always a tendency to sever the bones too high; therefore dissect up the flap until the base lies just distal to the scratch on the skin which marks the 6-in. level. Having pulled the flap upwards, perform a 'tour de maître' with a Syme's knife just a millimetre or two below the scratch on the skin. Cut right through the muscular masses at right angles until the bone is reached. Drive a long hæmostat through the interosseous membrane (*Fig.* 1363), and by its means bring the centre tail of the three-tailed calico retractor between the bones. The muscles are now held out of the way (*Fig.* 1364).

Division of the Bones.—The fibula is divided 1 in. (2·5 cm.) higher than the tibia. A frame saw may be used for the former or a pair of Exner's rib shears. The interosseous membrane should not be destroyed above the level of the division of the fibula, otherwise the end of the fibula tends to project forwards. The tibia is divided with a saw, after which the sharp cut end of the crest is sawn off obliquely (*Fig.* 1364—inset). Alternatively, many maintain that it is easier to make the bevel cut first.

The tourniquet is now removed or the assistant releases digital pressure on the main vessel, and all bleeding points are ligated. The flap is then sutured accurately into place, taking particular care to see that the deep fascia is united as a separate layer, using interrupted sutures; only when considered necessary on account of questionable subfascial hæmostasis is the wound drained with a strip of corrugated rubber.

Leg stumps should always be nursed on a back splint.

Below-the-Knee Amputation for Gangrene in a Diabetic.—There is weighty evidence to negative the teaching that an amputation through the thigh is essential in a diabetic patient with gangrene of the foot. For twenty-five years Chew Smith has advised a below-the-knee amputation, performed by the very special technique detailed below.

The foot and leg are prepared in the manner described: shaving must be conducted carefully, as skin cuts often become infected in these patients. Before the foot is done up into a parcel tinct. iodine is poured (not brushed) over the infected area.

Operation.[1]—Commencing 4–6 in. (10–15 cm.) below the tuberosity of the tibia, a straight incision is made down the middle of the subcutaneous border of the tibia for 4–6 in. The skin on either side of the incision is dissected up. At no time during the operation are forceps of any kind applied to the skin; if the skin is grasped by any instrument, areas of necrosis follow almost inevitably. The fascia on each side of the exposed tibia is incised, and with the finger or a periosteal elevator the investing muscles are freed from the tibia along the entire length of the wound. The interosseus membrane is pierced with a sharp periosteal elevator, and this also is separated from the tibia. Thus the tibia has been separated from all surrounding soft parts without entering the muscles. A Gigli's saw is passed beneath the tibia at the *upper* end of the wound. The soft parts are protected from the saw by abdominal retractors. The tibia is divided as water drips upon the bone. The lower divided portion of the tibia is drawn out of the wound. The most difficult step in the procedure follows—namely, division of the fibula. The bone is seated deeply when approached through this incision, and is surrounded by large muscle bellies laterally. It is more superficial in the lower part of the wound, where it is exposed by gentle retraction of muscles. The periosteum is incised and a short distance of the bone is cleared of periosteum, care being taken to avoid injury to the peroneal vessels posteromedially. The fibula is divided well below the tibia with the bone-cutting forceps, an endeavour being made not to splinter the bone. Both bones having been sectioned, the foot and lower leg are brought to a right angle with the upper part of the leg. The tibia has been freed from soft parts already, but the fibula must be denuded of its attached muscle with curved scissors directed towards the periosteum.

[1] During the operation the contralateral heel must be freed from all pressure, preferably by a foam-rubber pillow placed behind the tendo Achillis; otherwise the risk of gangrene of this heel is considerable.

Care must be taken not to sever the periosteum, as this protects the peroneal vessels. Both bones, now divested of soft parts, protrude from the wound. With the lower fragments held at right angles to the upper fragments, a circular incision is made around the

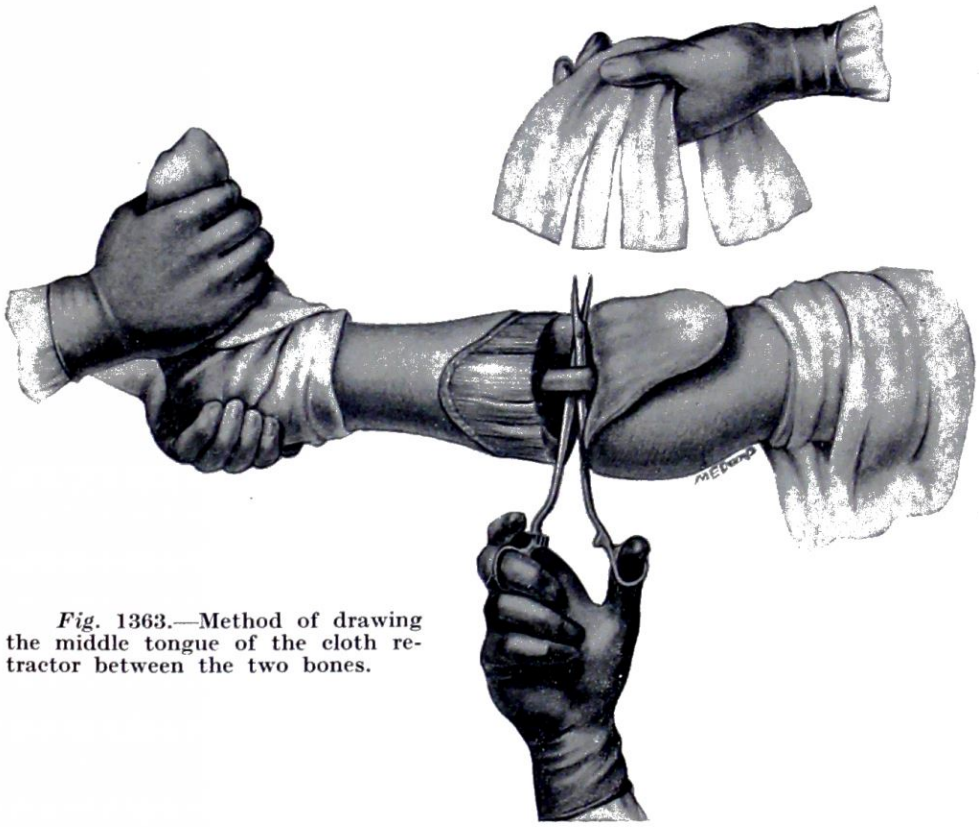


Fig. 1363.—Method of drawing the middle tongue of the cloth retractor between the two bones.

Fig. 1364.—The 6-in. (15 cm.) stump. Dividing the tibia. *Inset.*—Method of bevelling the crest of the tibia.

limb at the level of the *lower* end of the longitudinal skin incision, through skin, subcutaneous tissue, and the deep fascia in one layer. Veins are ligated, and the skin and fascia are dissected up as a flap from the muscles in an avascular plane for 1 in. (2·5 cm.).

A towel is placed on the upper skin-flap, everting and protecting it and exposing the underlying muscle : the assistant's hand keeping it in place acts as a tourniquet. Traction is exerted on the foot held at right angles to the leg. A long amputation knife is placed posteriorly just below the skin-flap, and all the muscles are divided at right angles. Vessels are secured and ligated : the cut end of the posterior tibial nerve should be examined, for sometimes there is a bleeding artery within its sheath. The protruding end of the fibula is grasped and its investing muscles are detached from the periosteum with scissors still further, again taking care to avoid the peroneal vessels. The fibula is re-amputated ½–1 in. above the tibia.

The sharp anterior edge of the tibia is bevelled ; the wound is irrigated with 1–2 quarts (1–2 l.) of sterile saline solution. If hæmostasis is found not to be complete, a corrugated rubber drain is placed in the posterior end of the wound. Through the drain is placed a safety-pin, and to this is attached a silk ligature, so that the drain can be removed without disturbing the dressing. The wound is closed by interrupted stitches passed through the deep fascia. The closure of the skin is important ; it is not touched with dissecting forceps, but grasped in gauze as the skin sutures are inserted. Petroleum-jelly gauze is placed over the wound and at the back of the leg, which is covered with fluffed gauze and then wrapped with wide gauze from a roll. Strapping extension is then applied to the skin of the thigh—a broad piece posteriorly and a narrow piece medially and laterally. These extend to 4 in. (10 cm.) below the dressing. Strips of adhesive plaster then encircle the dressing and the strapping extension. The entire dressing is encased in a sterile towel, kept in place by safety-pins.

When the patient is back in bed, the strapping extension is attached to a cord and a pulley screwed on to the bed-rail ; 2 lb. (900 G.) of extension is applied. This steadies the limb, relieves muscle spasm, and keeps the knee extended. If drainage has been used, the drain is pulled out of the wound without disturbing the dressing by means of the silk ligature described already. The stitches are removed on the tenth to the fourteenth day. As soon as the patient's condition warrants it, he sits in a chair without the traction, which is re-applied when he returns to bed.

Amputation through the Lower Third of the Leg.—A true guillotine amputation through the lower third of the leg is a very useful and often a life-saving procedure. It is seldom performed, but frequently indicated, in infected cases, particularly in the presence of a fulminating infection in an uncontrolled diabetic. A quick guillotine procedure removes the infected area, and facilitates control of the diabetes. It is a temporary expedient, and in successful cases must be followed later by an amputation at the modern seat of election.

Syme's Amputation is a good amputation for a man employed in heavy labour. After a Syme's operation many patients walk about the house without the prosthesis, and suffer no discomfort. J. H. Shelswell, in a review of 305 Syme's amputations, many of which were for war injury, came to the conclusion that the Syme's amputee can do anything of which the below-knee amputee is capable, and possesses certain benefits that the latter does not possess. It is doubtful if its performance is justifiable in a female, for the prosthesis is inseparable from a conspicuously ugly ankle. Another disadvantage is that in some cases ulceration of the stump occurs after 10–15 years, if not earlier. However, patients prefer to have ' ground sensation ', even if it is only for a limited number of years. The results of this operation in children are especially good.

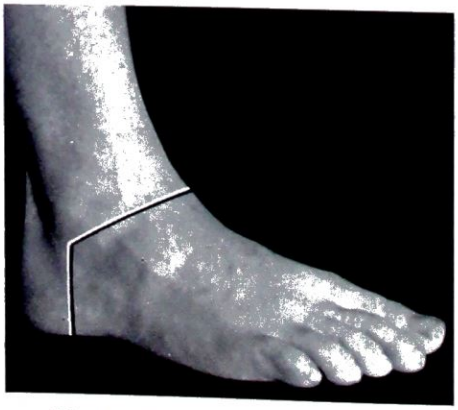


Fig. 1365.—Incision for Syme's amputation.

A specific indication for a Syme's amputation is if the other leg has to be amputated for trauma.

Technique.—The surgeon stands at the end of the operating table, facing the foot. If there is no contra-indication to so doing, a tourniquet is applied to the thigh. The foot projects over the end of the table.

First incision : The scalpel is entered below the tip of the lateral malleolus and carried downward, sloping somewhat towards the heel, across the sole, to end ½ in. (1·3 cm.) below the medial malleolus. Divide all structures down to bone.

Second incision: The two ends of the first incision are joined by the shortest route across the front of the ankle-joint. Divide all structures down to bone, and open the ankle-joint.

Fashioning the flap: Divide the lateral and medial ligaments from their attachments to the malleoli. Dislocate the talus forwards by strongly depressing the foot. With a Syme's knife used with a sawing movement, cut the calcaneus out of the heel-flap from above (*Fig.* 1366) by working round the convexity of the heel in order to meet the U-shape incision on the sole. During this all-important manœuvre the watchword is—*keep close to the bone*, otherwise the blood-supply to the flap will be imperilled.

The amputated foot is now removed, and with a few cuts of the knife the base of the flap is dissected free from the back of the tibia and fibula.

Division of the tibia and fibula: The flaps are retracted. Make a circular incision through the periosteum at the level of the highest part of the articular surfaces of the tibia. The bones are sawn through at this point, making sure that the cut surface is horizontal. "Unless a small portion of the articular surface of the tibia remains, the

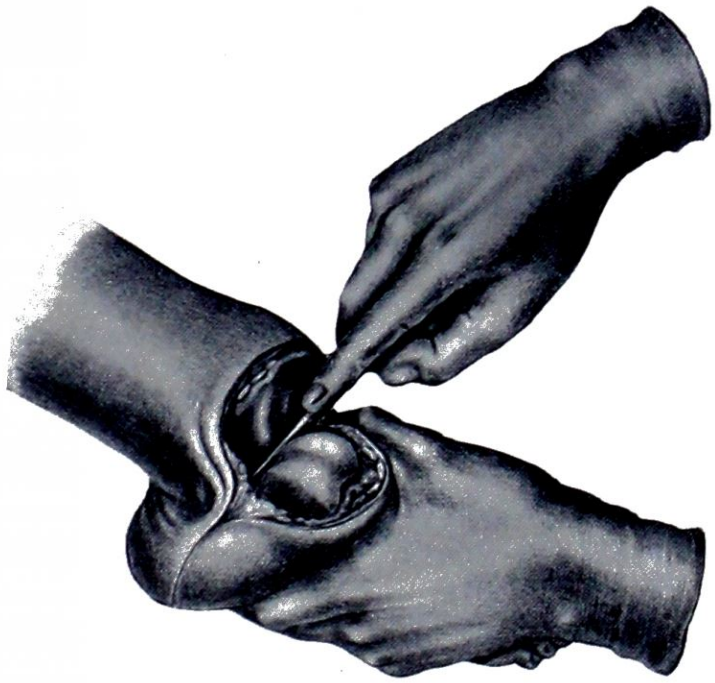


Fig. 1366.—Syme's amputation.

section has been made too high" (G. Perkins). Remove with a saw any projecting portions of bone so as to render the cut surface smooth. As a rule a small portion of the edge of the fibula requires excision.

Vessels, nerves, and tendons: Ligate the anterior tibial vessels and the plantar vessels. As the stump is to be end-bearing, particular attention must be paid to nerves. Shorten the posterior tibial nerve, the anterior tibial nerve, the long and short saphenous nerves, and, if possible, the two divisions of the musculocutaneous nerve. The tendons are also pulled down and shortened. The tourniquet is now removed, and all bleeding points are ligated.

Bring forward the flap, which should form a complete cap over the ends of the bones, and suture it into place accurately. If there are any 'dog ears' at the points where the original incisions met, these should be removed with scissors. If necessary, drain the wound posteriorly on the outer side. Dressings having been applied, a length of flexible adhesive plaster is affixed in the form of a U passing down the sides of the leg. This keeps the heel-flap in contact with the bone. It should be reapplied as necessary for three weeks. The limb is placed on a back splint of sufficient length to fix the knee and to allow the end of the stump to project beyond it for a few inches until the wound has healed.

Syme's amputation in two stages: A number of surgeons speak highly of Syme's amputation performed in two stages. The first stage consists of the operation as described

above, up to the point when the foot has been disarticulated, blood-vessels ligated, and nerves and tendons shortened. The wound is then filled with petroleum-jelly gauze. The second stage is carried out when the danger of spreading infection has passed; it consists of sawing off the malleoli and suturing the flap into position.

Transmetatarsal Amputation.—This has been found to give satisfactory results in selected cases of gangrene limited to the toes. Its main advantage, especially in the elderly, is that the patient can get about reasonably well with only the small alteration of filling the tip of the shoe with lamb's wool, to lessen the tendency of the shortened foot to slip forwards.

Fig. 1367.—Transmetatarsal amputation. The dorsal and plantar incisions.

Absence of palpable pulsation below the femoral artery is not a contra-indication to the operation, provided the skin of the dorsum of the foot is warm and well nourished. Infection must be controlled (*see* p. 958) before the operation is undertaken.

Removal of a toe, especially the great toe, so alters weight-bearing as to increase the vulnerability of the remaining toes. Bearing this in mind, the main indication for transmetatarsal amputation is gangrene of all or part of one or more toes. The operation is also indicated in crushing injuries involving the toes where primary or delayed closure can be accomplished at this level.

The level of the amputation is just proximal to the heads of the metatarsals, and at the conclusion of the amputation for practical purposes there is only bone between the dorsal and plantar layers of the skin and subcutaneous tissue.

Technique.—The dorsal incision commences midway between the dorsal and plantar surface of one side of the foot, and with one bold incision down to the bone, it is continued in a straight line across the dorsum to the midpoint on the opposite side. The plantar incision commences at one end of the dorsal incision and runs parallel but 1 cm. proximal to the proximal crease of the toes (*Fig.* 1367). This incision, likewise, must be made directly down to bone. The comparatively long plantar flap thus obtained is dissected back to the level of the proposed bone section. The heads of the metatarsal bones, commencing with the first, are then removed with a saw. The saw blade is allowed to rest against the previously cut metatarsal, which serves as a guide, so an even stump is obtained. The plantar tendons and sesamoid bones are transected at bone level. Vessels having been ligated, closure (*Fig.* 1368) is effected with non-absorbable sutures. The amputation should be conducted as atraumatically as possible. At no time should the skin edges be touched with forceps. The flap is handled lightly with the fingers after it has been covered with moist gauze. 'Dog ears' must be excised, as these will slough. A bulky dressing is applied to the foot and ankle, being careful to pad the skin over the malleoli and the base of the fifth metatarsal: the dressing is kept in place by adhesive plaster, being careful to avoid pressure. After the operation strict bed rest is maintained until the wound has healed, the head of the bed being elevated slightly. At least half of the sutures must remain in place for two weeks, after which exercises of the leg are commenced.

Fig. 1368.—Transmetatarsal amputation completed. (*After G. H. Pratt.*)

A patch of gangrene of the skin, commencing particularly near the dorsal skin edge, is a rather frequent complication. As a rule the area is small and separates spontaneously, resulting in a granulating area which is likely to heal without skin-grafting. Exceptionally, progressive gangrene requiring re-amputation above the knee occurs.

Amputation of Toes.—In general, the principles set out in amputation of fingers (*see* p. 999) can be followed, with two important exceptions. (1) No effort should be spared

to save the head of the first metatarsal (*Fig.* 1369); this structure is of the greatest importance in the weight-bearing function of the foot. (2) When it is necessary to amputate a toe for gangrene, the digit is removed by a racket-shaped incision. The long arm of the racket should be on the sole instead of the dorsum, so as to ensure dependent drainage. In order that there should be no pocket, this incision on the sole (*Fig.* 1370) extends some distance towards the heel. According to circumstances the incision is closed, or filled with petroleum-jelly gauze followed by secondary closure.

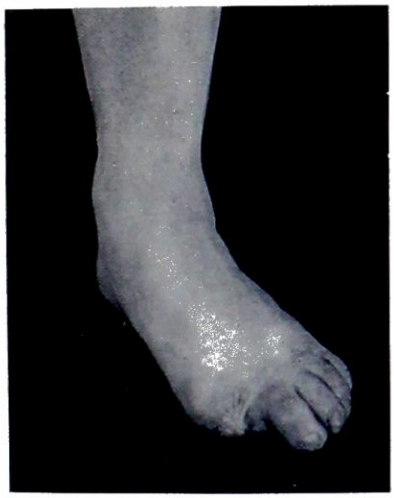


Fig. 1369.—Amputation of the great toe, performed for laceration and crushing following a motor-cycle accident. The head of the metatarsal has been preserved. Two years later the patient, a girl of 20, wrote to say: "The loss of the toe is no inconvenience to me. I dance, etc., as well as ever."

Fig. 1370.—When amputating a gangrenous toe, thought should be given to ensuring dependent drainage.

The skin of the dorsum of the foot is particularly vulnerable; therefore it should never be picked up with dissecting forceps, or any other instrument.

When diabetic gangrene affects more than one toe of the same foot, and is strictly limited to the toes, there is much to be said in favour of amputation of all five toes at one operation. There is little added risk involved, and the patient is often spared a series of operations, each with its attendant dangers (W. Oakley).

AMPUTATIONS OF THE UPPER LIMB

Considerable responsibility rests with the surgeon in advising amputation in the upper limb, for although improved greatly in recent years, the efficacy of an artificial arm[1] compares unfavourably with that of an artificial leg.

Amputation at the Shoulder-joint.—Fortunately disarticulation at the shoulder-joint is rarely required in urgent surgery. Even two inches of the shaft of the humerus provides a stump to which an artificial arm can be fitted, but above this level the artificial limb can be but an ornament. If amputation at the shoulder is inevitable, an effort should be made to leave the head of the humerus in the glenoid cavity. This prevents the subsequent prominence of the acromion, which is unsightly and a nuisance to the patient.

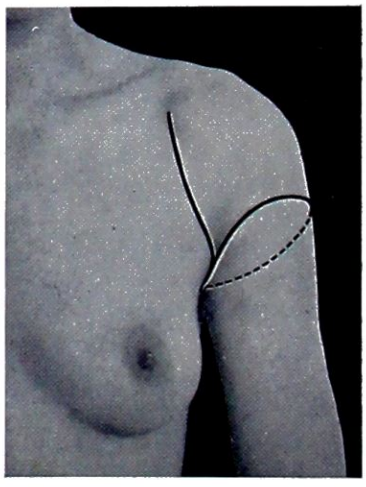


Fig. 1371.—Incision for amputation at the shoulder-joint.

Operation.—Have the arm abducted and rotated outwards. Make an incision commencing at the tip of the coracoid process and passing downwards towards the junction of the pectoralis major with the humerus. The pectorales major and minor are divided, the axillary vessels found and ligated, and the main brachial nerves injected with 2 per cent procaine and divided. The arm is now encircled, as high as possible, by an incision through the skin and fascia (*Fig.* 1371). Flaps are dissected up a short distance, then the muscles divided by the circular method right down to bone. The outer flap which

[1] A mechanical hand with remarkable control has been devised at Roehampton, and many forearm amputees can hold their own with other light manual workers.

contains the deltoid is raised from the humerus with a knife. By rotating the arm in different directions, the muscles attached to the tuberosities can be made tense and divided. If it is absolutely necessary to remove the head of the humerus, the joint is opened. Otherwise the bone is sawn through at the anatomical neck. Modifications in the matter of skin-flaps may have to be devised to meet special circumstances (*Fig.* 1372).

Amputation through the Upper Arm.—The site of election is 7–8 in. (17·5–20 cm.) from the tip of the acromion, or at least 2 in. (5 cm.) above the epicondyle. Small equilateral flaps are fashioned, and unless there is some contra-indication one should be anterior and one posterior, thus producing a transverse terminal scar. It is best to divide the muscles in two layers—first the biceps and triceps, and when these have contracted, to complete the division of the deeper muscles to the bone : if transection of the muscle is not performed in this way the biceps and triceps retract far above the level of the other muscles. In the case of the upper arm, when sectioning the bone very little, if any, retraction of the soft parts is necessary (*Fig.* 1373). After vessels have been ligated, the deep fascia and skin are united as separate layers.

Fig. 1372.—Patient after amputation at the left shoulder-joint by a modified posterior approach.

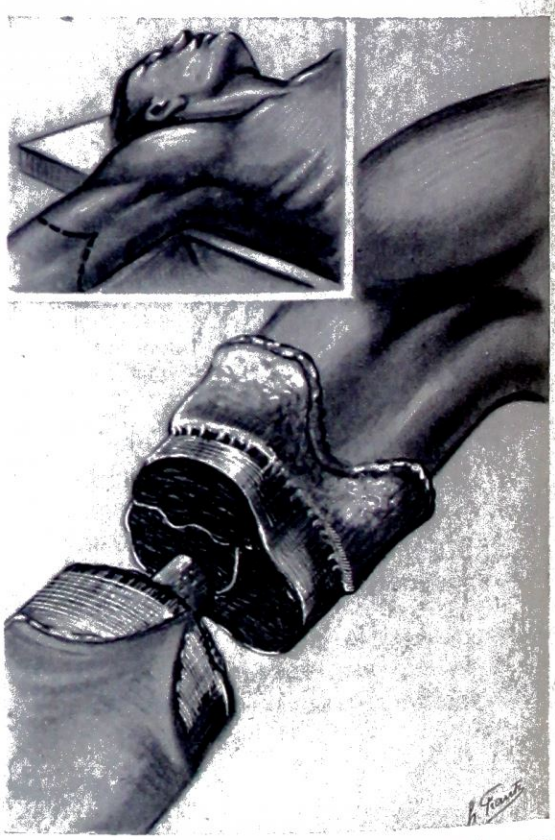


Fig. 1373.—Method of amputating in the upper extremity by equilateral flaps and circular division of soft parts.

Amputation of the Forearm.—The site of election is not less than 6 in. (15 cm.) and not more than 7 in. (17·5 cm.) from the tip of the olecranon. For reasons given on p. 976, the flap should be anteroposterior. Having divided the muscles, the three-tailed cloth retractor is employed, but again comparatively little retraction is necessary.

Amputations of the Fingers and Thumb are described in the next chapter.

AFTER-TREATMENT OF THE STUMP

Especially in the case of an amputation through the thigh, the stump must not be propped with a pillow or a sandbag. Elevating the stump predisposes to permanent flexion deformity—a great disability.

Particularly in the case of the guillotine, but also in other amputation stumps which have been left open, it is necessary to apply extension to the skin in order to aid the eventual healing of the stump. *Fig.* 1374 shows the standard method of applying such extension ; *Fig.* 1375 is a good alternative.

For many weeks after an amputation stump has healed, œdema of the distal part of the stump interferes with the fitting of an artificial limb. The most effective and rapid method of combating œdema in this situation is by skilful crêpe bandaging (*Fig.* 1376).

The care of each stump in this respect is described in the brochure *Rehabilitation following Amputation*, published by the Ministry of Health.

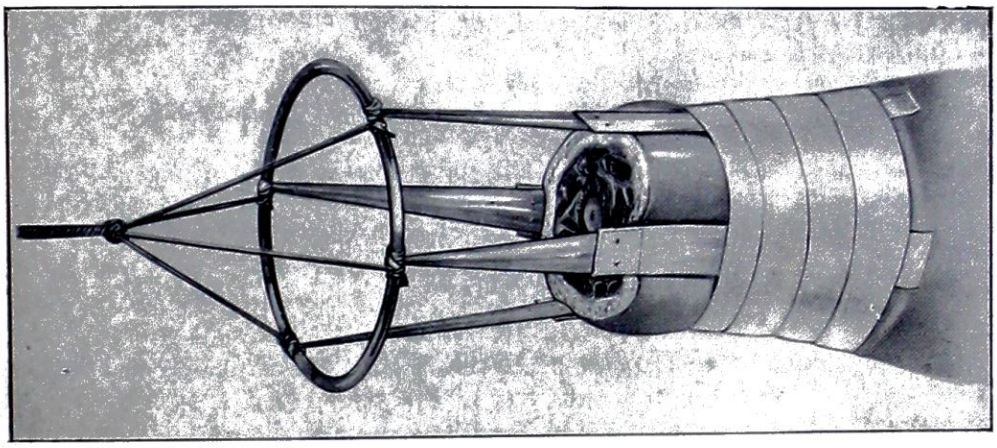


Fig. 1374.—Extension applied to the soft parts of a stump by a metal ring and strapping.

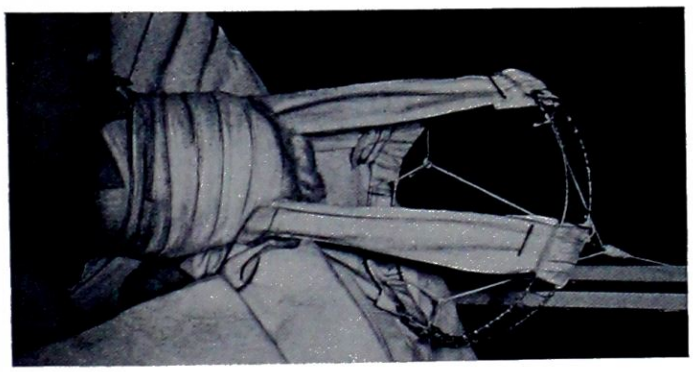


Fig. 1375.—In the absence of a metal ring a hoop of Cramer wire is an excellent substitute.

Fig. 1376.—Method of crêpe bandaging a thigh stump.

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CHAPTER LXXXV

LACERATIONS AND MUTILATIONS OF THE HAND

ONE-THIRD of all compensation cases concern the hand (A. E. Davis), and with the increase in factory employment this proportion is likely to become greater. The social significance of hand injuries is apparent; and equally apparent is the heavy responsibility on those, often with limited experience, called upon to treat these injuries.

The setting up of hand clinics has resulted in improved function after injury, and the good results are indeed good. At the present time the majority of patients with hand injuries do not enjoy the benefits of such expert attention, and this chapter seeks to guide those who treat such cases along the paths laid down by tested surgical principles.

PRINCIPLES OF EMERGENCY TREATMENT

The aim of treatment is first-intention healing whenever possible, followed by an early restoration of function. Of paramount importance is the avoidance of infection, minimizing restriction of movement by scarring and the avoidance of joint stiffness. These principles underlie the procedures advocated below.

First Aid.—First aid should be limited to covering the wound with a clean cloth or sterile dressing. Bleeding rarely needs more than a firm bandage over wool for its control. Antiseptic lotions have no place in treatment—skin cannot be sterilized, and deeper tissues are easily damaged.

In the Casualty Department.—Attention here is limited to a brief appraisal of the nature of the injury. The presence of shock or general disease is noted. A splint is indicated in cases of severe injury. The Casualty Department is not the place for operative treatment—it is the most heavily infected part of the hospital, and it is wrong that the same hands that have just opened an abscess should operate next on a wounded hand. A patient with a lacerated hand should be admitted.

Diagnosis.—As always this rests on a history and clinical examination.

The history is important and the method of wounding must not only be noted, but also recorded. It is sufficient to make a simple note, e.g., 'Whilst using a knife in the course of his work, the blade slipped and struck the back of his left index finger'; or 'Whilst using a grinding wheel at work to sharpen a chisel, the tool slipped and his right hand struck the wheel.' The date of injury must be stated. Not only does the patient's statement assist in diagnosis, but a record is made very shortly after injury that may support or destroy the patient's claims in litigation—which sometimes follows months or even years later. Patients frequently are aware of the presence of a foreign body or sensory loss or tendon injury and their statements assist in the detection of these lesions.

Clinical examination must be local and general. The local examination appraises the nature of the injury, the size and position of wounds, and the type of wound (e.g., incised, bursting). Movement, power, and sensation are tested—and compared with the normal uninjured side if possible. Only thus are partial nerve and partial tendon injuries discovered. It is a good working rule to presume that all structures beneath a wound are damaged until the contrary is proved.

General physical examination is most important not only to determine fitness for anæsthesia but also to detect the presence of disease. A patient with a wounded hand may have syringomyelia, disseminated sclerosis, or diabetes mellitus to mention only three diseases that are often late in being diagnosed. Such diseases predispose to injury, and hinder recovery.

In all cases where a fracture or a retained foreign body is suspected, an X-ray examination of the part, in two planes at right angles to each other, is indicated. In this connexion it should be remembered that certain plastic materials are not opaque to X rays, and that glass is only visualized if it contains lead.

TREATMENT

General Treatment.—This is directed against shock and infection. Shock is combated by the usual methods of relief of pain by morphine and splinting, and by plasma infusion or blood transfusion if required. Infection is dealt with by the routine use of anti-tetanic serum (usually 1500 i.u. in adults, and half that dose in children) and the administration of antibiotics in adequate dosage (e.g., penicillin 500,000 units b.d. by injection).

It is important at this stage to explain to the patient the nature of his injury, the possible sequelæ (as far as is thought desirable), and to secure his permission for possible amputation if there is the slightest chance of this proving necessary.

Local treatment is directed towards the abolition of infection and securing, wherever possible, first-intention healing.

Anæsthesia.—*A general anæsthetic* is usually desirable, for seldom can the skin be cleansed properly without it; without meticulous skin preparation local anæsthesia is dangerous. Another disadvantage of local anæsthesia is that necessary enlargement of the wound is arduous, and, consequently, is inclined to be skimped.

Brachial plexus block is valuable, especially in cases of extensive injury of the hand where a time-consuming operation is anticipated.

Local anæsthesia (1 per cent procaine without adrenaline[1]) is satisfactory when the injury is confined to the distal half of a finger. The base of the digit is infiltrated thoroughly, the hollow needle being introduced from the dorsum (*Fig.* 1377). Be it emphasized that infiltration is performed slowly at the finger *base* so that the analgesic solution can diffuse in the loose interdigital space. No force should be exerted during

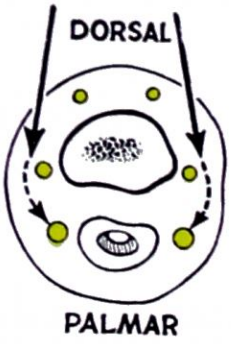

Fig. 1377.—Analgesic solution should always be introduced from the dorsal surface, at the base of a digit, and without undue pressure.

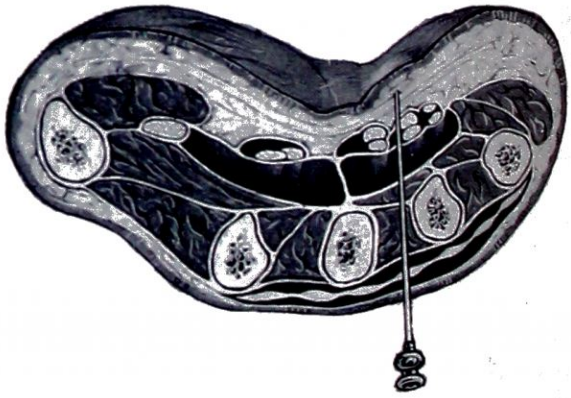

Fig. 1378.—Local anæsthetic being introduced from the dorsum to anæsthetize the palm.

the procedure and never inject with undue pressure on both sides of a phalangeal shaft; gangrene of the finger-tip has followed such injections as the result of excessive fluid accumulation compressing digital vessels between skin and bone. When it is desirable to employ local anæsthesia for a wound of the palm, again the anæsthetic solution must be introduced from the dorsum. Infiltration should be widespread, and it is quite an easy matter to infiltrate the subcutaneous tissues of the palm from the dorsum (*Fig.* 1378).

Preparation of the Part.—Dressings are removed from the wound in the operating theatre, and the surgeon, properly gloved and gowned, cleans the skin. A sterile pad is placed over the wound and the limb cleaned as far as the elbow with 1 per cent cetavlon, in abundant quantity. The limb is then dried and painted with surgical spirit. Neither of these substances should be sluiced over the wound as this carries infected material into it—hence the sterile pad over the wound.

This preparation completed, the surgeon changes at least his gloves, and drapes the parts in sterile towels. Most surgery of the hand is carried out conveniently with the abducted arm resting upon a table at the side of the operating table. This permits the operator to be seated, and allows a more meticulous technique. Good surgery is impossible if the surgeon is uncomfortable.

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[1] The use of adrenaline in the anæsthetic solution often determines the onset of gangrene in cases where the blood-supply is imperilled.

The Importance of Anatomical Exposure.—There need be no hesitation in enlarging wounds provided that certain principles are borne in mind. These are that incisions must not cross skin flexion creases, and that so far as is possible they must lie on skin which undergoes a minimum of movement.

Reference to *Figs.* 1379 and 1380 will indicate the approved incisions and how they may be used in enlarging wounds. It is worth emphasizing that good work can only be done through an adequate incision, and the rate of healing of a wound does not depend on its length. The operator must see clearly what he is doing at every stage in the operation.

In this connexion some advise the routine use of a tourniquet in the shape of a sphygmomanometer cuff around the upper arm ; any other type of tourniquet is liable to damage nerves (or blood-vessels in the elderly) and is unsafe. The disadvantage of a tourniquet is that, owing to the absence of bleeding, it makes the differentiation between dead and living

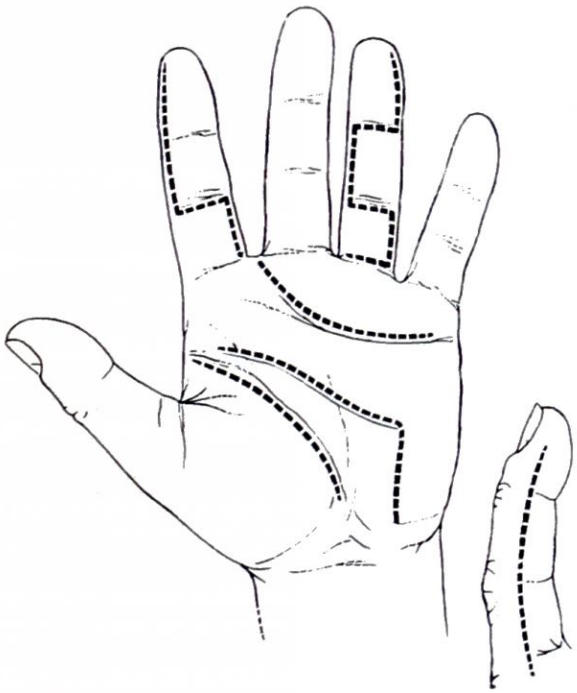


Fig. 1379.—Chart of incisions showing how they are made lateral in the digits, and follow the flexion creases.

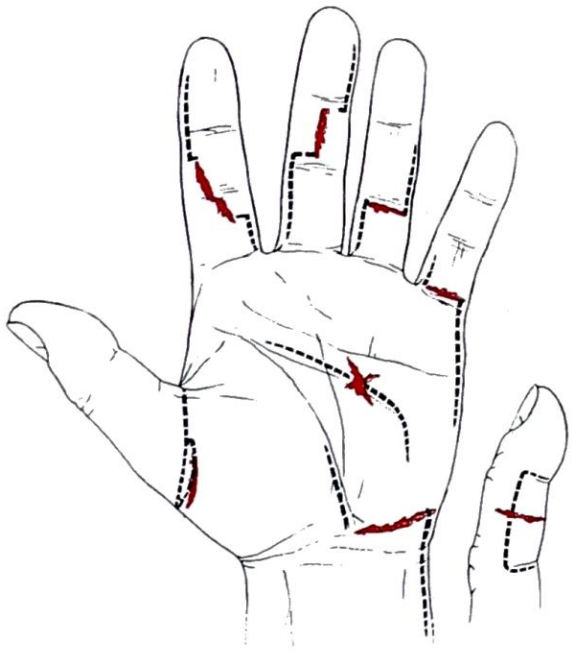


Fig. 1380.—Chart showing how wounds can be extended by using the correct skin incisions.

tissue more difficult ; it also deprives the tissues of oxygen. This deprivation, even for a short time, is liable finally to kill tissue whose hold on life was definite, though precarious. *It is better to avoid using a tourniquet.*

Palmar Hæmorrhage.—*See* p. 949.

Excision and Suture of the Wound.—This is the basic principle in the operative part of treatment. It aims at leaving a wound free of dead tissue and with its walls composed of living tissue adequately supplied with blood. This is based on sound pathology. The removal of dead and damaged tissue deprives saprophytic bacteria of their habitat, and results in a wound having living walls with a good blood-supply. These factors are inimical to the growth of all bacteria, particularly anaerobes.

Technique.—The operation is performed with a scalpel, and requires skill, practice, and a good light. Scissors, unless exceedingly sharp, are apt to crush the tissues they cut, and should be avoided. The layers of the wound, from the skin to its depth, are excised one by one until healthy undamaged tissue that bleeds normally is reached. For the skin a shaving of 1 mm. thick is sufficient, but one should be more ruthless with fat. All damaged muscle must be excised : healthy muscle contracts when cut or pinched, and bleeds freely. Bone implicated in the wound should be scraped gently with a small curette.

Throughout the procedure the utmost gentleness is essential : the objective is to remove dead and dying tissue with minimum trauma to the living tissue to which it is attached. To this end use sharp hooks, not tissue forceps, for retraction ; do not crush

bleeding points with hæmostats and tie them off—use firm pressure with a gauze swab and all but comparatively large vessels will cease to bleed. Large vessels, of course, must be ligated, but strangle as little tissue in the ligature as possible, and cut the ligatures short so as to bury the minimum of foreign material.

If the foregoing instructions are followed meticulously, the wound can be closed by skin sutures without drainage.

Further consideration of these principles will show that the object of the operation is to endeavour to obtain healing of the skin by first intention. As an emergency operation on an open, contaminated wound is not an occasion for extensive operative repair of nerves and tendons, this is deferred to a secondary operation performed after healing is complete.

The exception to this rule is if the wound has been caused by a reasonably clean and sharp implement, and not more than four hours have elapsed since the accident. Then, and then only, can cut tendons be united with (preferably) fine stainless steel wire, and it is helpful to approximate severed nerves by a single stitch, in order to prevent retraction and shortening of their proximal ends (R. G. Pulvertaft).

Splintage.—Splints are not required for fractures only; rest is also essential for the perfect healing of soft parts. Err, therefore, on the side of generosity in splintage, and give these tissues every chance to recover. A plaster-of-Paris cast is the convenient means of affording rest to the hand, but whenever possible the fingers must be free to move. In cases where movement of the fingers is inadvisable, fear of stiffness need not arise if normal joints are immobilized in the position of rest (*Fig.* 1381) or in the position of function (*Fig.* 1382).

Fig. 1381.—The position of rest is the position adopted by the hand when it hangs limply by the side.

Fig. 1382.—The position of function is the position adopted by the hand in reaching out to grasp.

Those who hesitate to apply a plaster cast, and prefer to look at the wound every day or so, should remember that, unless carried out in the operating theatre, each dressing is a potential source of re-infection. If a patient with a wound under a plaster cast has no pain, is afebrile, and has no regional adenitis, then that wound must be progressing well.

When a plaster cast has been applied, after the patient has been returned to his bed, the arm must be elevated. Once consciousness is regained, all parts not immobilized must be moved very frequently. It is the surgeon's duty to see that this is carried out. The more swollen the part, the more vital is the need for active movement. When not being exercised, the splinted hand must never be dependent.

The plaster cast should be taken off about ten days after operation, by which time the wound should be healed, and if so, the sutures are removed.

VARIETIES OF TREATMENT TO SUIT DIFFERENT TYPES AND CONDITIONS OF WOUNDS

1. Late Cases (i.e., more than six hours have elapsed since the accident).—The surgeon who closes a wound more than six hours old runs the risk of incurring severe infection of that wound. The wound must be excised; as a rule the amount of doubtfully viable tissue that must be removed is greater than that necessary in an early case. The wound should be covered with tulle gras and left widely open. If suppuration does not occur, secondary suture can be undertaken in suitable cases.

2. Early Cases (i.e., within six hours of the accident).—

a. Incised Wounds are treated by excision and suture, as detailed already.

b. Contused Wounds.—When the skin edges are bruised, wider excision of them is necessary. Frequently this results in a gap that cannot be approximated without tension, at least towards its centre. Tension (which deprives skin of its full blood-supply) must at all times be avoided. As a rule it is possible to bring the extremities of the wound together without imperilling their blood-supply; if so, this should be done. Covering the exposed area with split (partial-thickness) skin-grafts is not difficult, is safe, and it is fairly certain that the graft will 'take'.

c. Penetrating Wounds.—Often the entry wound is small, but the subcutaneous damage may be great. Very careful clinical examination is necessary to determine the extent of nerve or tendon damage. The writer has seen a number of cases in which the deep branch of the ulnar nerve has been severed, and such damage has not been diagnosed. These wounds must be excised, enlarged as necessary, and explored thoroughly to their depths. Primary suture is then performed, as for incised wounds.

d. Bursting Wounds often go unrecognized as such. When a finger is severely crushed the sides of the digit split, permitting herniation of the pulp. When the terminal portion is involved there is often a subungual hæmatoma. Avulsion of the nail, or Kanavel's operation (*see* p. 1005), releases the hæmatoma, relieves most of the pain, and removes one favourite site for the growth of bacteria. When a finger has been crushed, dead and living tissues are so intermingled that they cannot be distinguished; consequently it is only possible to excise the edges of the skin. The wound is covered with tulle gras, splinted, and allowed to heal by granulation. Provided the blood-supply is unimpaired, the results of this treatment are excellent. On the other hand, as it is impossible to ascertain accurately the extent of the damage to the blood-supply, the unwavering rule should be that *primary closure should not be entertained in cases of crushing injury.*

e. Wound with Loss of Skin.—Making a decision as to the best treatment of these injuries can be exceedingly difficult. The essential points to bear in mind are that the wound must be closed; that the best dressing is skin; and that the prevention of infection and the conservation of what healthy tissue remains is of paramount importance. A surgeon skilled in the transference of skin will know his limitations; for others, the wisest course to pursue is the application of a partial-thickness skin-graft cut with a razor or a knife. A Thiersch graft, which is purely epidermal, should not be used. The partial-thickness graft consists of epidermis and part of the dermis, and will 'take' in a very high proportion of recent wounds, provided it is placed on living fascia or muscle. It will not take on bare cortical bone, tendon, or joint capsule. After it has been applied it is covered with tulle gras and a pressure dressing, and the hand is placed on a splint. This type of graft has the disadvantage that it tends to contract and the area so covered is easily traumatized, although eventually considerable hypertrophy may occur. Its advantages are that it is simple to cut and apply, is of almost universal application, has a high proportion of success, and by providing a covering for the wound, prevents infection. Furthermore, it does not hamper any specialized repair work, if such is needed subsequently.

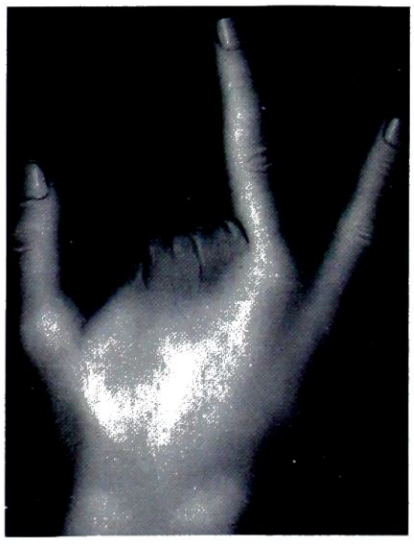
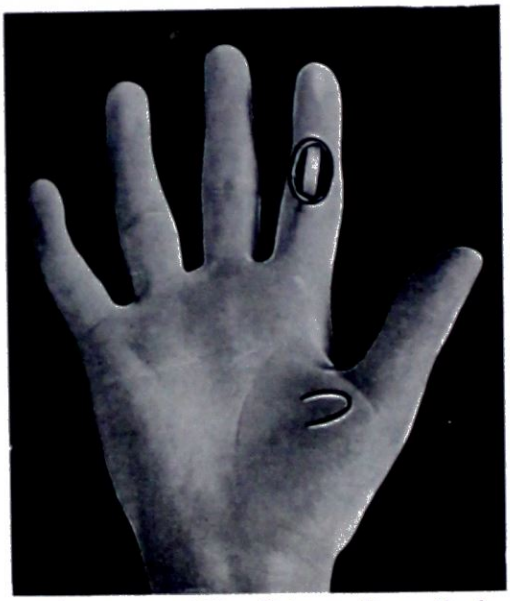


Fig. 1383.—'Deboned' digital flaps were used to cover a skin defect on the dorsum of the hand. (*Mr. T. B. Mouat.*)

When considerable skin loss on the dorsum or the palm is associated with hopelessly crushed digits, the affected digits are disarticulated, but if there is a suitable portion of intact skin with a good blood-supply connected with the digit, it should be preserved and utilized to cover the skin defect on the palm or the dorsum of the hand (*Fig.* 1383).

Gatewood's Method of repairing a Wound with Loss of Substance on the Distal Half of the Flexor Surface of the Finger.—This method may prove useful, and *Figs.* 1384, 1385 make the principle clear. The difficulty of approximating the flap to the finger can be

overcome by inserting all stitches before they are tied. The resulting defect on the thenar eminence can be closed by interrupted sutures, or by split skin grafts (*see also* Chapter XCIII).



Figs. 1384, 1385.—Gatewood's method of repairing a wound with loss of substance on the flexor surface of a finger.

The Degloved Hand.—The patient gets his hand trapped. The skin and nails are torn off—indeed, the skin has been literally ripped off the hand like a glove (*Fig.* 1386), and the muscles, tendons, and perhaps the bone, are laid bare. What is to be done?

When the Skin remains attached.—If there is a grey, lifeless-looking mass of inverted and perhaps dirty skin hanging by a pedicle, it has been taught that the dying mass should be snipped away. C. Beck disparages this teaching, for he has found that if it is cleansed and replaced skilfully, the whole or the greater part of the skin often survives. Therefore, when confronted with such a case, excise lifeless pieces of muscle and fascia, dry the area, and replace the skin. Anchor the skin here and there with sutures. Cover the area with tulle gras and apply a firm bandage. If a portion of the skin sloughs, after the infection has abated the defect must be made good by skin-grafting.

Fig. 1386.—The 'glove' of a degloved hand.

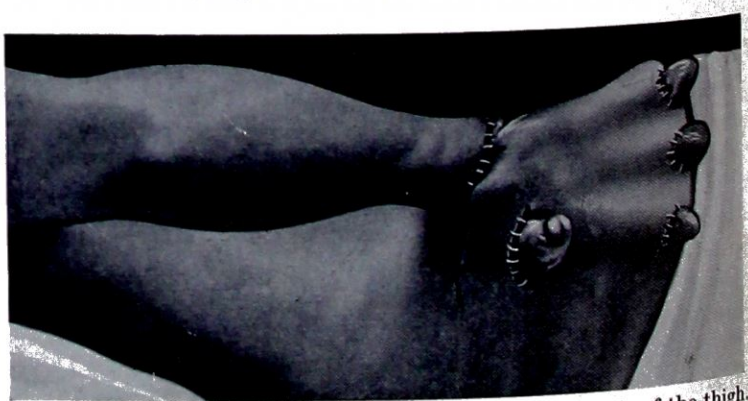


Fig. 1387.—A degloved hand embedded in the subcutis of the thigh. (*After W. E. Schroeder.*)

When the Skin is lost.—After thorough cleansing, immediate implantation of the hand into the subcutaneous tissue of the thigh (*Fig.* 1387) or the abdominal wall may obviate the necessity for immediate or remote amputation. The results of the procedure are encouraging, and hands or portions of hands have been saved which would otherwise have been sacrificed.

The late G. H. Colt's Case.—

A woman of 48 presented herself with a hand entirely denuded of skin on the dorsal aspect, and over the middle three digits and their metacarpal bones on the palmar aspect. Operation

was begun two-and-a-half hours after the accident. The hand was cleansed. A pocket was constructed in the thigh with divergent tunnels for the denuded fingers. Into the pocket was placed the hand, and the three injured fingers were drawn into the subcutaneous tunnels from counter-openings. Drainage was provided at the lower end of each tunnel and under the main flap. After the skin about the wrist had been approximated to the free edge of the flap the hand was firmly bandaged to the thigh. Drains were removed on the third day when it was apparent that there was no gross sepsis. One month after the original operation separation of the flaps was commenced. The fingers were separated one at a time, the hand being completely freed on the 45th day. (*Fig.* 1388.)

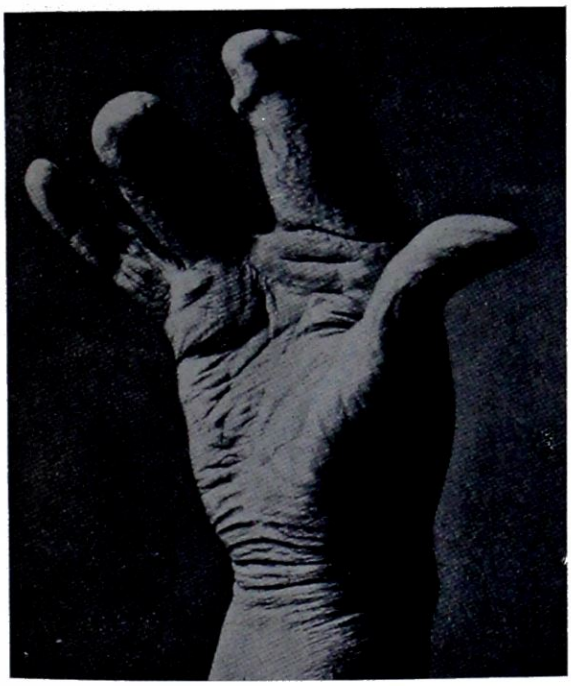


Fig. 1388.—Plastic surgery of the degloved hand. Condition at an early period after operation. (*British Journal of Surgery.*)

Before commencing the implantation, place the injured hand on the prepared thigh so as to make sure that the pocket will be in the right place. Construct diverticula for the fingers as divergently as possible (*Fig.* 1389), so as to yield the maximal amount of skin for each finger. Provide free drainage for the main flap and for each diverticulum.

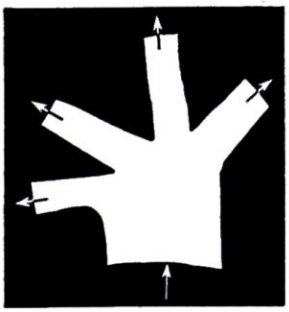


Fig. 1389.—The pattern for a subcutaneous tunnel for a degloved hand. The diverticula for the fingers and thumb should be made as divergent as possible. If there is a fair prospect of saving the remaining digits, the little finger should be amputated.

Replacement of a completely severed portion of a Digit.—The chances of survival of the autograft are inversely proportional to the length of time which elapses between the accident and the replacement of the fragment, and also to the amount of the contamination present. Amazing results have occurred.

T. G. Hamilton's Case.—

A man, using a slicing machine, severed obliquely 1 in. (2·5 cm.) of the tip of his index finger. Profuse bleeding caused much excitement in the shop, and it was fully half an hour before the fragment was discovered with its cut surface against a cooked ham. The fragment was washed in saline solution and replaced. Healing occurred by first intention.

Such a happy result is somewhat infrequent. If after forty-eight hours the fragment is becoming mummified or the suture line shows evidence of infection, the fragment must be cut away and the wound, if infected, treated appropriately.

Avulsion of the Terminal Phalanx with the Flexor Tendon.—

An engineer presented himself at hospital with the terminal phalanx of his thumb wrapped in a handkerchief. He stated that he had caught the thumb in revolving machinery. To the severed phalanx 8 in. (20 cm.) of the flexor pollicis longus was attached (*Fig.* 1390). The head of the proximal phalanx was excised, after which the trimmed ends of the skin could be approximated. A very useful member resulted, for the short flexors of the thumb acted admirably.

Fig. 1390.—Avulsion of flexor pollicis longus.

COMPOUND FRACTURES OF THE FINGERS

The principles involved are the same as for compound fractures elsewhere—that is to say the fracture is converted into a closed one and then immobilized until union is sound.

The wound is first excised and sutured. The fracture is then reduced by a combination of traction and flexion and immobilized on a splint in flexion. The flexed position maintains reduction, and, should stiffness occur, the finger is in a functional position. Beside flexion, the tip of the digit should point towards the base of the thenar eminence, since if the fingers are flexed into the palm individually they will be found to point to this landmark.

For continuous traction in spiral or comminuted fractures, a pulp traction pin (*Fig.* 1391) is effective. If used correctly, it does not cause infection, is not painful, and does not damage the pulp. Traction is maintained by a rubber band or fine rubber tubing, as shown in *Fig.* 1392. The sites at which the pin passes through the finger are sealed with mastisol on wool (collodion does not bond with metal). It should be noted that the pin does not pass through the bone, and that the amount of traction needed is very slight. In the absence of a pulp traction pin, one can be improvised from an intramuscular needle detempered in a flame so that its distal half is bendable (*Fig.* 1393). A plaster cast over wool from the knuckles to the elbow is required for stability. The free digits and the unencased part of the upper limb must be exercised frequently through their full range of movement. After manipulation, the position of the fragments is checked radiologically at once, and at weekly intervals for a fortnight. Splintage is maintained until union is sound, after which active exercises are essential. In these compound fractures it is not uncommon for the tendons to adhere to the site of the fracture with permanent limitation of movement. Perfect reduction minimizes this risk.

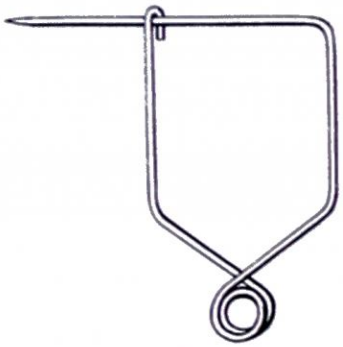


Fig. 1391.—Brock's pulp traction pin.

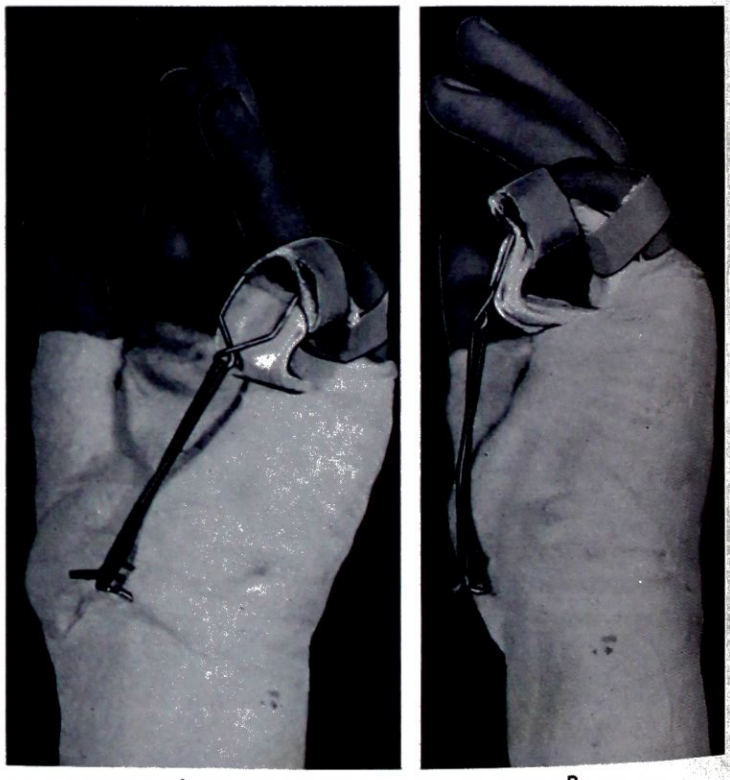


Fig. 1392.—A, The direction of traction is shown. The plaster does not extend beyond the palmar crease so that the metacarpophalangeal joints can be fully flexed. B, Traction in flexion reduces the fracture.

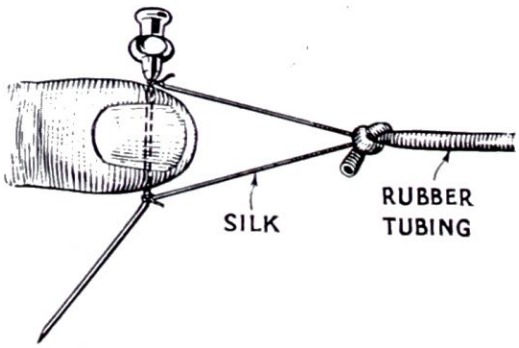


Fig. 1393.—Method of improvising a pulp traction pin from an intramuscular hollow needle.

AMPUTATION OF DIGITS

Every surgeon is aware of the necessity for conserving the hand. Even the stumps of one finger and the thumb are more valuable to their possessor than an artificial hand (*Fig.* 1394).

Amputations of the Thumb.—The importance of the thumb as an integral part of Nature's pincers for grasping objects makes it imperative to conserve every portion

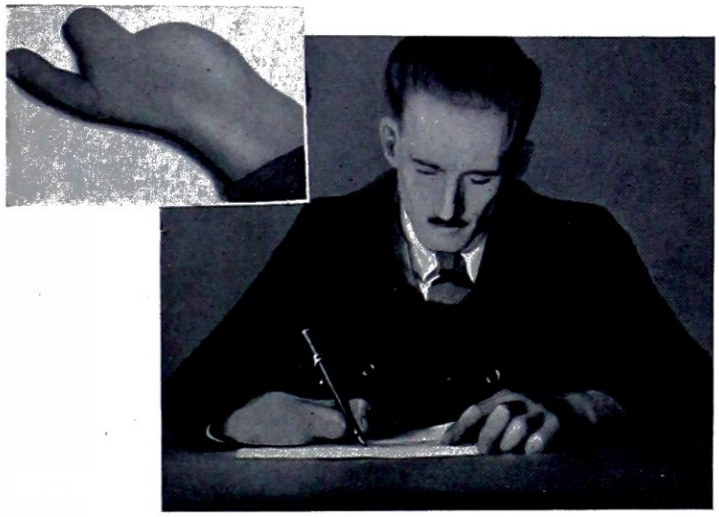


Fig. 1394.—By preserving the thumb and stump of one finger, the patient is left with a useful hand.

possible. Even if we can only save a small part (*Fig.* 1395), we have performed a great service to the patient.

In the endeavour to preserve as much as possible, denuded bone, if not grossly contaminated, may be covered by a flap from the contralateral forearm (*see* Cross-arm Bridge Flap, Chapter XCIII).

To show what conservative surgery will sometimes achieve the following case is quoted :—

T. G. Hamilton's Case.—

Whilst splitting wood a man severed his thumb completely near the base. It was attached only by some skin near the web. The fragments were cleansed, and the divided flexor and extensor tendons were united. Stitches were also placed through the periosteum so as to co-apt the divided bone. The skin was then united by three sutures. After dressings had been applied the hand was encased in a starch bandage. The soft tissues atrophied and remained thus for a long time, but later they recovered, and for years the man has been working at his trade with very little handicap.

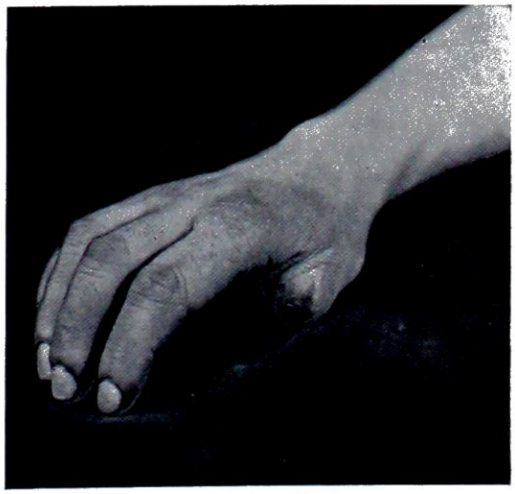


Fig. 1395.—The hand of a patient who severed his thumb in a lathe. The stump, which is only ¾ in. (2 cm.) in length, is of great use.

Amputation of a Finger.—When deciding whether to perform partial or total amputation of the finger the major consideration is the patient's work. For one who earns his living by wielding a pick and shovel, or by comparable heavy manual labour, the head of the metacarpal should be retained, unless there is insufficient flap or flaps to cover the end of the bone. Loss of the head of the metacarpal reduces the effective spread of the palm and the ability to grasp. On the other hand, a stump of a finger is an eyesore to the beholder, while the absence of a finger passes unnoticed. As a well-planned total amputation leaves the patient with a hand which after a little practice is practically unimpaired (except in the matter of sheer strength), amputation of a single finger, together with the head of its metacarpal, is preferable to amputating the greater part of a finger in women (without exception), those who follow the learned professions, business men, clerks, and the majority of highly skilled workmen.

Total Amputation of the Index or Little Finger.—The operation strongly recommended is Farabœuf's—that is, by a lateral flap.

We will consider the index finger. Commence the incision over the dorsal surface of the neck of the metacarpal bone. Sweep round in a curved manner to a point on the palmar surface diametrically opposite the commencement, the flap extending about a third of the way up the proximal phalanx. Dissect down this flap. Encircle the base of the finger with an incision passing through the first interdigital cleft (*Fig.* 1396). Now disarticulate the finger. After securing blood-vessels, clear the neck of the metacarpal bone. Place the hand flat upon a side table and put a pad of gauze beneath the

Fig. 1396.—Incisions for disarticulation at the metacarpo-phalangeal joint.

Fig. 1397.—Showing the method of sectioning the bone in total amputation of a finger. In the cases of the index and the little fingers the bone is severed obliquely. In the middle and ring fingers the metacarpal bone is divided straight through the shaft.

hand. Using a broad chisel, neatly and obliquely remove the head and neck of the bone (*Fig.* 1397). Suture the flap into position accurately. In certain circumstances it may happen that there is rather too much skin, in which case trim the flap before suturing. The result of this amputation is one of the most pleasing in surgery (*Fig.* 1398).

Total Amputation of the Middle or Ring Finger.—A. P. Sherwood's method of reconstructing the interdigital cleft results in a most natural-looking hand. Inspect the webs on either side and select one to be preserved. Have the hand held in the manner shown in *Fig.* 1399. Commence the incision on the doomed finger to one side of the cleft to be preserved (*Fig.* 1400), and sweep down on the dorsal surface to about the middle of the metacarpal bone. Make a corresponding incision on the other side, only this time commence the incision at the base of the sound finger. Now turn the hand over and join the extremities of the incision in the form of a V (*Fig.* 1401). Return to the dorsum. Flex the joint strongly. Cut through the dorsal expansion, open the joint, and disarticulate the finger. Having attended to bleeding points, proceed to clear the upper part of the metacarpal bone, and remove the distal half, or rather more (*see Fig.* 1397), with a chisel and hammer (bone forceps are liable to splinter the bone). The skin edges are now sutured accurately into position. The interdigital cleft is thus brought into its new position. The hand is bound to a plaster slab the same width as the narrowed palm.

An important detail in the operation is the removal of the V-shaped wedge on the palmar aspect (*Figs.* 1401, 1402), which prevents the bulging pad that is so much in evidence after the usual racket removal of a finger. This pad, which is rich in nerve-endings, when subjected to any pressure, calls up a stiff, electrified ghost of the missing finger, a fault which is eradicated by employing Sherwood's technique.

Amputation of a Terminal Phalanx.—When a terminal phalanx is mangled, disarticulation at the distal interphalangeal joint is indicated. The well-known classical method of removing the terminal phalanx by introducing a narrow-bellied finger-knife

Fig. 1398.—Result of amputation of the index finger with excision of the head of the metacarpal. The U-shaped flap was used.

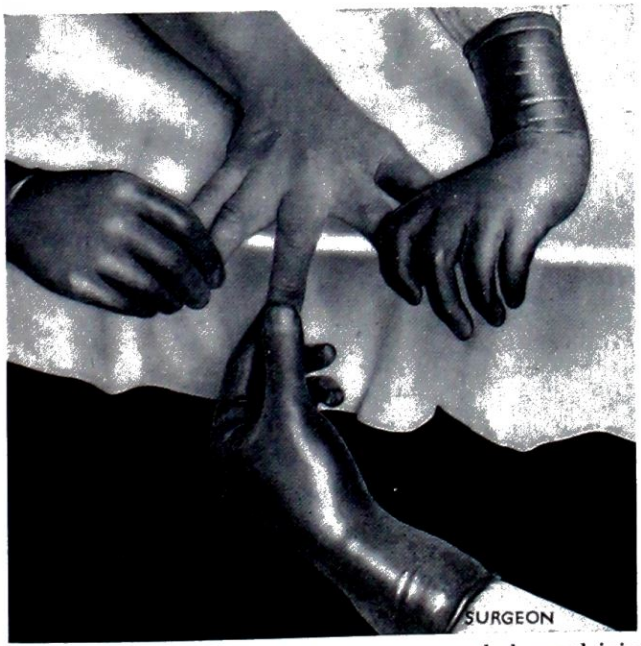
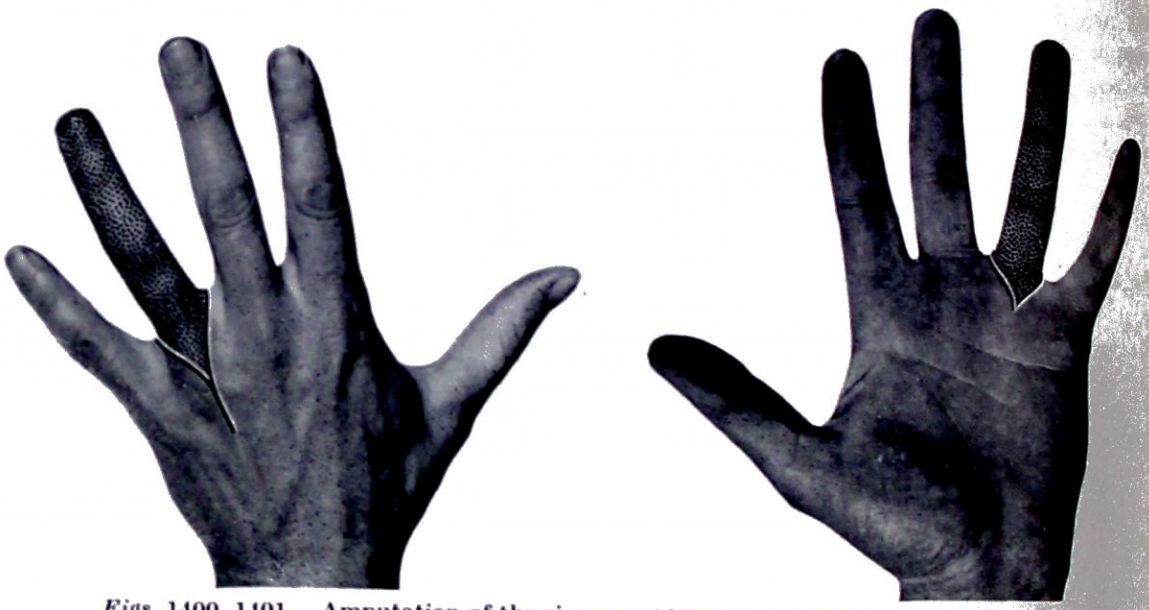


Fig. 1399.—Preparing to amputate at the metacarpo-phalangeal joint. Note that the healthy fingers are held aside by the assistant.

into the joint from the dorsal aspect and cutting so as to form a palmar flap (*Figs.* 1403, 1404) is very seldom applicable, for the pulp of the finger is crushed. On the other hand, small palmar and dorsal flaps of undamaged skin can usually be dissected up. If after disarticulation it is found that the flaps are too short to cover the ends of the bone, the head of the second phalanx can be nipped off with bone forceps.

Amputation at the Proximal Interphalangeal Joint or through the Shaft of the Second Phalanx.—As, invariably, amputation at either of these sites is necessary because of a



Figs. 1400, 1401.—Amputation of the ring or middle finger with reconstruction of the interdigital cleft (Sherwood's method).

Fig. 1402.—End-result of a total amputation of the middle finger. The patient suffers no inconvenience.

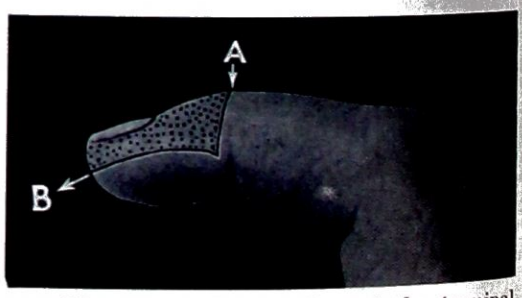


Fig. 1403.—Amputation of the terminal phalanx. An incision is made at A and the joint opened. After turning the knife through a right angle the manœuvre is continued until the blade emerges from B.

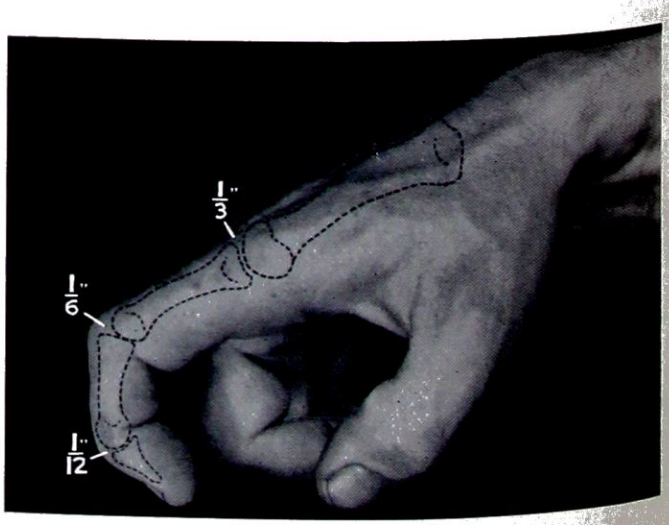


Fig. 1404.—It is important to realize that the joint lies $\frac{1}{3}$, $\frac{1}{6}$, and $\frac{1}{12}$ of an inch (8, 4, and 2 mm.) *distal* to the corresponding eminence or knuckle.

crushing accident, no precise details can be given for cutting flaps. One simply fashions flaps of sufficient dimensions to cover the end of the bone from any available healthy skin. If these prove to be inadequate, a suitable portion of bone must be removed with bone-cutting forceps. Particularly in the cases of the middle and ring fingers, amputation through the interphalangeal joint results in a useful digit for a manual worker.

CLOSED CRUSH INJURIES OF THE HAND

Crushing injuries in which the tissues are infiltrated with blood, and the tissue spaces distended by hæmatoma, are crippling injuries. Much fibrosis occurs, and this limits

Fig. 1405.—The hand is packed with wool, which is used also to separate the adjacent skin surfaces of the digits.

Fig. 1406.—More wool is packed around the hand, and the whole is surrounded by a crêpe bandage and flexible adhesive plaster. The method of suspension is shown.

tendon and joint movement. Such recovery as may occur is often incomplete and the process extends over many months.

Recently, with a view to reducing the fibrosis, the writer tried the following régime: the hand is moulded into the position of function, padded with plenty of wool (*Fig.* 1405) and tightly bound with a crêpe bandage, so that the dressing resembles a boxing glove. The limb is elevated (*Fig.* 1406). From the anti-inflammatory point of view, cortisone therapy is helpful. A good and safe method of administration is prednisone, 40 mg. for 5 days, 30 mg. for 5 days, and then 20 mg. for 5 days, which concludes the course.

In these cases the relief of pain was dramatic, having subsided completely in forty-eight hours, even on passive movement. These patients regained full range and power in all joints of the hand in 4 weeks. The method is worthy of an extended trial.

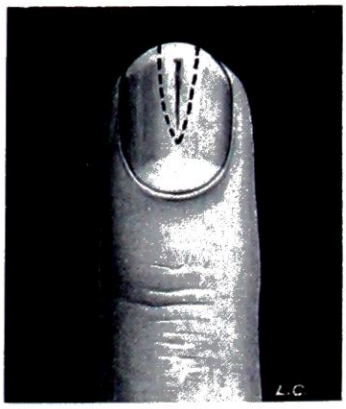


Fig. 1407.—A wedge-shaped piece of nail should be removed to give access to a foreign body beneath the nail.

SPLINTER BENEATH THE NAIL

So often failure to remove the foreign body, or a part of it, results in infection. The following simple and regularly effective measure should be adopted in all cases. The base of the finger is infiltrated with local anæsthetic. A tourniquet applied by winding a catheter firmly around the finger from the distal to the proximal portion, and there

anchoring the catheter by a hæmostat, after which the distal portion is unwound, greatly facilitates the removal of a small foreign body, which does not become obscured by blood. These preliminaries having been completed, a wedge of the nail overlying the splinter is excised (*Fig.* 1407). This permits indisputable access ; not only can the foreign body be removed easily, but the wound can be cleansed and dressed.

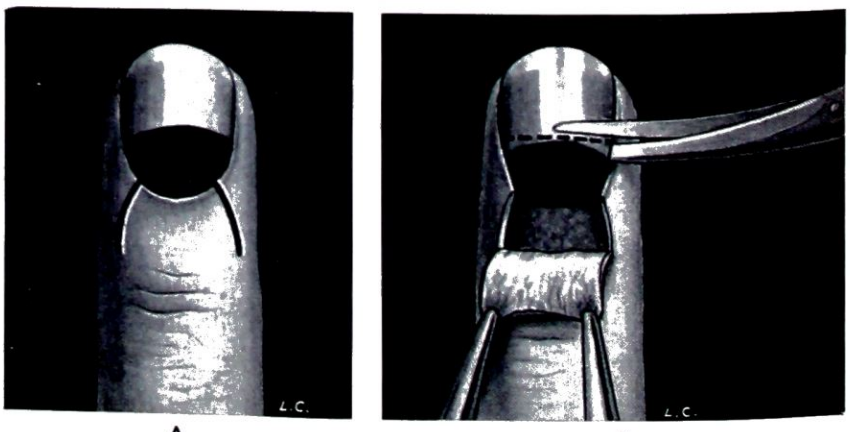
Needle in the Hand.—*See* Chapter LXXXVII, p. 1029.

SUBUNGUAL HÆMATOMA

This common lesion is too often regarded as a triviality, unworthy of surgical attention. There are many reasons why a hæmatoma under the nail should be decompressed and the blood evacuated. Pain is relieved almost immediately, the danger of infection is minimized very considerably, and an unsightly black nail that will be with the patient for many months is prevented.

First of all an X-ray examination is desirable. In one-quarter of cases the terminal phalanx is fractured (M. Iselin). It is a good practice to administer tetanus antitoxin because several cases of tetanus have been reported following this lesion.

Fig. 1408.—Trephining the nail to evacuate a subungual hæmatoma.



A B

Fig. 1409.—A, Incision for evacuating a subungual hæmatoma. B, Excising the base of the nail.

Evacuation of a Subungual Hæmatoma should be undertaken more frequently than is the case.

Method 1 is suitable for early cases without considerable contusion of the nail-bed. In many instances the operation can be undertaken without anæsthesia, but if the finger is very tender it is wise to infiltrate the base of the digit, as described on p. 992. A straight, triangular-pointed needle, as used for stitching skin, or a very fine-pointed narrow scalpel is taken, and with a rotary motion, employing very little pressure, a hole is drilled in the nail just above the quick (*Fig.* 1408). This permits the blood to escape

and by squeezing gently, all the blood can be evacuated. A small piece of gauze followed by flexible adhesive plaster are so applied as to exert moderate pressure.

Method 2.—In later cases, and in those where there is considerable contusion of the nail-bed and the nail will almost certainly be discarded eventually as a natural process, Kanavel's operation (*Fig.* 1409) is admirable.

See also Chapter XCIII.

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