35 Vascular surgery

35.1 Varicose veins

ANATOMY AND PHYSIOLOGY
There are four categories of leg vein, and they all have valves which stop blood flowing downwards away from the heart.
(1) **Long and short saphenous veins** run superior to the deep fascia, and are usually deep to the fibrous layer of the superficial fascia (35-1). They have numerous valves, the most important of which is the femoral valve, in the long saphenous vein, just before it penetrates the deep fascia to join the femoral vein. The femoral valve prevents blood from the femoral vein flowing back into the saphenous vein.
(2) **Superficial collecting veins** are tributaries of the saphenous veins. They lie between the skin and the fibrous layer of the superficial fascia. These have valves, but they are poorly supported by connective tissue.
(3) **Deep veins** accompany the arteries, and run among the muscles deep inside the leg. These have important valves.
(4) **Perforating veins** pass through the deep fascia, joining the superficial collecting veins to the deep veins. Their valves direct blood into the leg. The most important of these perforating veins are just behind the medial border of the tibia.
Standing at rest, the superficial veins on the dorsum of the foot support a column of blood that reaches to the right heart. While the leg muscles are relaxed, this blood flows through the perforating veins, into the deep veins inside the leg. On walking, the contractions of the leg muscles squeeze the blood from the deep veins up towards the heart. This cycle of contraction and relaxation reduces the pressure in the superficial veins, and prevents varicosities.
However, if the valves of the deep perforating veins are incompetent, blood from inside the leg is pushed out at high pressure into the unsupported superficial collecting veins. This distends them, and makes them varicose. The increase in venous pressure makes capillary pressure increase, which results in tissue oedema, and leakage of fluid into the tissues, hence tissue oedema. This fluid is rich in albumin and so infection is a real risk, especially as the nutrition of overlying skin becomes impaired.
If the valves which guard the long and short saphenous veins are incompetent, the blood in the femoral and popliteal veins can flow downwards, into the saphenous veins, and make them varicose.
The aim of surgery is to stop blood flowing backwards through veins with incompetent valves.

Varicose veins are the result of failure of the valves in the venous system, which takes 2 forms:
(1) Primary: the valves of the saphenous system fail, while the deep veins of the legs remain normal; the symptoms are usually mild, and the legs rarely ulcerate.
(2) Secondary (post-thrombotic): the deep veins, or the communicating veins between the superficial and deep systems, have had their valves destroyed by thrombosis; ulceration is more common, and treatment more difficult.

Varicose veins are generally associated with Western lifestyles; obesity and low-fibre diets play a role. They are unsightly and cause aching and cramps, a scaly, itchy, varicose eczema, swelling of the legs, and ulceration; occasionally they bleed. Symptoms may bear little relationship to their size and extent. If they are primary, the swelling usually only involves the feet and ankles, and resolves completely overnight. If they are secondary, the lower legs may be swollen all the time.

Make sure the pain is due to the varicose veins (relieved on lying down, worse at the end of a day's standing), and not due to (invisible) ischaemia, arthritis of the hip or knee, a prolapsed intervertebral disc, or *meralgia paraesthetica* (32.17) which can be there at the same time as the (visible) varicose veins. Swelling of the legs may co-exist with varicose veins, but is usually due to another cause, *e.g.* heart failure or lymphoedema.

Very occasionally varicose veins are the result of an **arterio-venous fistula**: you should be able to hear a bruit and feel a thrill over the fistula. The veins may be enormous. Occlusion of the fistula by pressure will, however, make them disappear.

VARICOSE VEINS

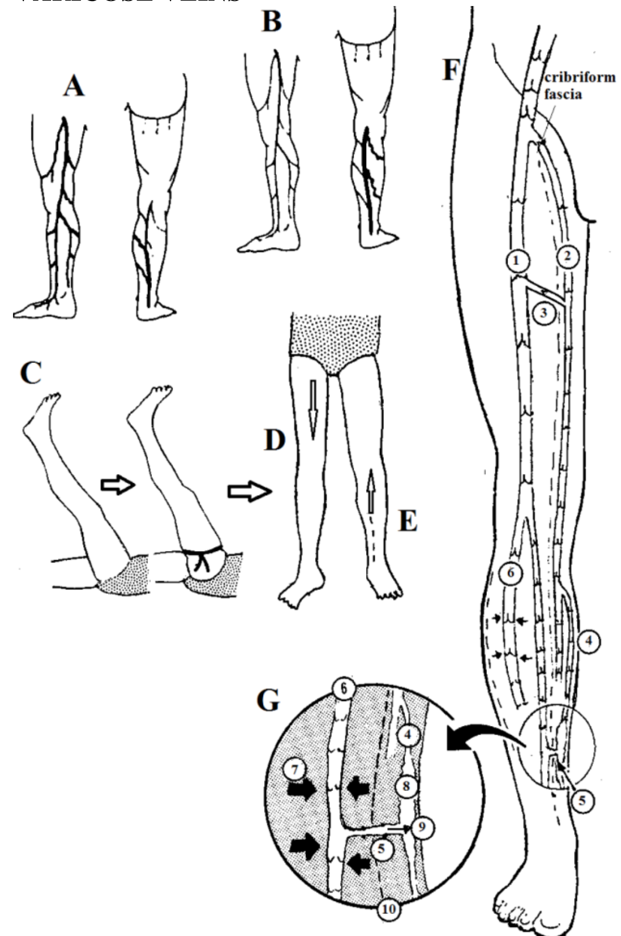

Fig. 35-1 VARICOSE VEINS: ANATOMY.
A, varicosities of the long saphenous system. B, varicosities of the short saphenous system. C, Trendelenburg test for the long saphenous vein: lay the leg supine and then raise it. Apply a venous tourniquet just below the saphenous opening. Stand the patient up and release the tourniquet. D, if the femoral valve is incompetent, the veins fill immediately from above. E, if it is normally competent, they fill slowly from below. F, anatomy of the leg veins; the long saphenous enters the femoral vein through the cribriform (deep) fascia. G, close-up view of a varicosity, and an incompetent perforating vein connecting it with the deep venous system. (1) femoral vein. (2) long saphenous vein, passing through the cribriform fascia. (3) mid-thigh perforating vein. (4) superficial collecting vein. (5) perforating vein with its valves destroyed. (6) deep veins of the leg. (7) muscular forces compressing the deep veins. (8) varix in a superficial collecting vein. (9) blood forced through a perforating vein with an incompetent valve. (10) superficial fascia.
After Ellis H, Calne RY. Lecture Notes on General Surgery, Blackwell Science, 10th ed 2002 p.93 Fig 12.1, with kind permission.

BE SURE THAT THE VALVES
OF THE DEEP VEINS ARE COMPETENT
BEFORE YOU TIE THE SUPERFICIAL VEINS

ANATOMY OF VARICOSE VEINS

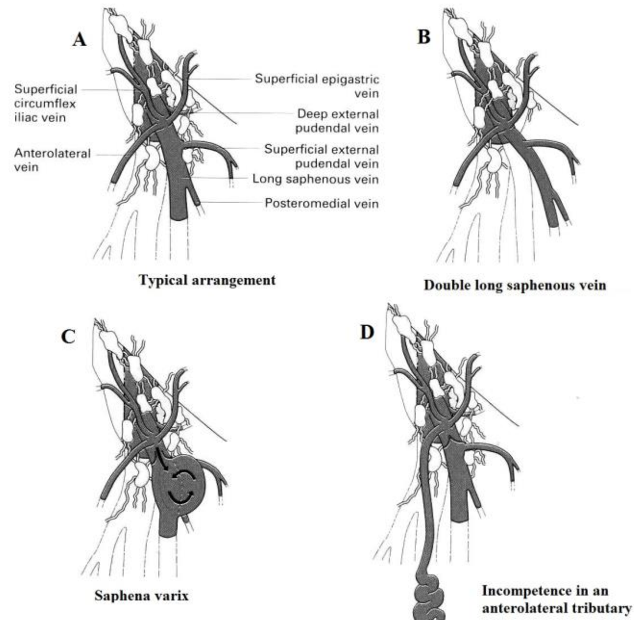

Fig. 35-2 VARICOSE VEINS: GROIN ANATOMY.
Variations in the anatomy: A, typical arrangement. B, double long saphenous vein. C, saphena varix. D, incompetence in an anterolateral tributary.
After Morris, PJ, Malt RA. Oxford Textbook of Surgery, OUP, 1994 p.550 Figs 51a-c.

(a) Examination. Examine the patient standing in a good light. Feel the veins. If he is obese, percuss the course of the saphenous veins. Examine the peripheral pulses. Feel for a thrill in the vein above as you tap it below, and listen for a bruit of a (rare) arterio-venous fistula.

If there is ulceration, thick induration, and marked hyperpigmentation, the valves of the deep veins are almost certainly incompetent, and the varicose veins are secondary. Otherwise they are probably primary.

Perform the Trendelenberg test:

To test the competence of the perforating veins and the valves of the greater saphenous system, lay the patient supine, raise the leg, and massage the veins proximally to empty them. On the upper thigh apply a rubber tourniquet, tight enough to compress the veins. Then ask him to stand and move the forefoot up and down, so as to actuate the calf muscle pump. Inspect the varices for 30secs, and then remove the tourniquet (35-1C,D,E).

If the veins gradually fill from below on standing, and continue to fill gradually from below when the tourniquet is released, *the valves in the veins of the legs are normal*.

If the veins fill rapidly from below, the varices are being filled from the deep veins, and *the valves of the perforating veins are incompetent*.

If blood flows rapidly into the long saphenous vein from above, after removing the tourniquet, the *long saphenous valve is incompetent*.

If finger pressure on the upper part of a thigh varicosity controls blood flow, the *anterolateral tributary is incompetent, bypassing the main long saphenous valve* (35-2D).

To test the competence of the valves of the short saphenous vein, lie the patient flat and apply 2 tourniquets, one above the knee to occlude the long saphenous vein and another just below the popliteal fossa to occlude the short saphenous vein. Ask the patient to stand up, leave the upper tourniquet on, and remove the lower one. If the blood flows immediately into the short saphenous vein from above, the *short saphenous valve is incompetent.*

To find the sites of major incompetent perforating veins:
(1) Look for visible and palpable ‘blowouts’ of subcutaneous veins.
(2) Feel for circular gaps in the deep fascia below the visible or palpable ‘blowouts’.
(3) Repeat the tourniquet test at each level above a ‘blowout’, to see if this prevents the ‘blowout’ appearing.

(b) Special tests. Doppler ultrasound is easy: pressure on the vein above causing a rush flow below indicates incompetence. *N.B. Don’t perform a venogram with contrast*: you may cause the thrombosis you want to avoid!

(c) Diagnosis
Suggesting primary varicose veins: usually start at 15-25yrs. No incompetence of the perforators shown by the test above. Incompetence demonstrated by back-flow on release of the upper thigh tourniquet (long saphenous), or just below the popliteal fossa (short saphenous).

Suggesting secondary varicose veins: obesity, multiple pregnancies, or a pelvic tumour; a history of venous thrombosis, an older age, less obvious veins partly hidden by eczema, fat necrosis, or ulceration.

(d) Non-operative treatment
INDICATIONS
(1) Minor symptoms.
(2) Uncertainty whether symptoms are really due to varicose veins.
(3) Untreated HIV disease.

METHOD
Encourage weight loss if appropriate, frequent walking, avoiding prolonged standing and sitting, and raising the leg when seated. Try to fit graduated compression stockings from the distal metatarsals to thigh or calf (depending on whether the long or short saphenous system is affected).

CAUTION! Make sure that the stockings are not too tight to give a tourniquet effect: however, *they are no use if too loose!* Ordinary elastic bandaging is not as good but better than nothing.

N.B. They are uncomfortable in hot climates though!

SCLEROTHERAPY OF VARICOSE VEINS

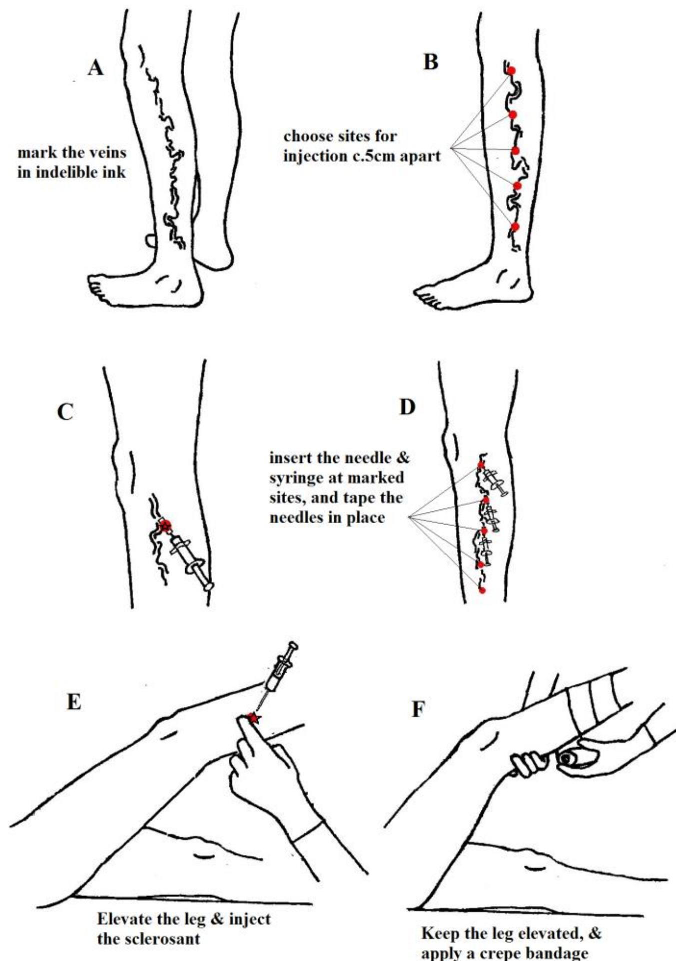

Fig. 35-3 SCLEROTHERAPY.
A, mark the visible varicose veins. B, choose maximum 5 injection sites c.5cm apart: mark these in a different colour ink. C, insert a needle and syringe and check that the needle is correctly in the vein by withdrawing a spot of blood, then tape needle and syringe to the skin. D, tape further needles and syringes to the skin. E, elevate the leg and inject the sclerosant, starting from the site nearest the foot, and apply pressure. F, apply crepe bandage up to last injection site, and continue the injections.
Kindly contributed by George Poulton.

(e) Sclerotherapy (GRADE 1.2)

INDICATIONS
(1) The cosmetic treatment of small primary varicose veins.
(2) Incompetent perforating veins without an obvious incompetent major valve.
(3) Varicose veins which persist or recur after stripping.

CONTRAINDICATIONS
(1) An incompetent major valve.
(2) Large varicosities.
(3) Gross obesity (it is difficult to maintain compression).
(4) Deep venous thrombosis.

EQUIPMENT. 5 small syringes fitted with fine needles and filled with 0·5ml of 3% sodium tetradecyl sulphate, 5% ethanolamine oleate, or 0.5-2% polidocanol (especially as a foam). 2 different colour marking pens, strapping, gauze, crepe bandages and graduated compression stockings.

CAUTION! Anaphylaxis is rare but may occur, so have hydrocortisone and adrenaline to hand.
The veins must be almost empty when you inject, and be kept empty so that their walls adhere, so careful bandaging is critical. *If you inject sclerosant into an artery, you may cause extensive gangrene, so don't inject around the ankle.*

METHOD
You need an assistant. Ask the patient to stand up; observe, palpate, and percuss the veins; mark them with a permanent marking pen. Then ask him to lie down, elevate the foot, and feel the course of the veins for gaps in the fascia (sites of incompetent communicating veins). Mark these with a pen of a different colour. Press with the tips of your fingers on as many of these gaps as you can, and, still pressing, ask him to stand. Remove your lowermost fingers first. If removing your finger from a gap in the fascia immediately causes the vein to fill, that gap is the site of an incompetent perforating vein. If it does not fill, there was no perforator in it. The sites where pressure controls the filling are the best sites for injection. Inject the lowest sites first.

Ask the patient to sit on a couch with the affected leg over the edge of the bed so that the vein fills, insert the mounted needle at the marked sites c.5cm apart, and aspirate only as far as the transparent hub to be sure you are in the vein, and strap the syringes securely to the skin; then empty the vein by raising the leg above the horizontal. Isolate the segment to be injected by pressing with your fingers above and below it, and inject 0·5ml of sclerosant. Apply a pressure pad over the injection site to keep the vein empty, and apply a crepe bandage up to that site. Then move up to the next site, and repeat the process until all your chosen sites have been injected. *Don't inject >5 sites*. Leave a gap in the bandaging for knee flexion.

N.B. You might find butterfly needles easier.

Apply a graduated compression stocking over the bandage and immediately encourage walking for 1h, and thereafter for 5km daily. Advise elevation of the legs as much as possible. Remove the bandages for a wash after 1wk. Then re-apply the bandages od, with the leg raised, for at least 3wks in order to maintain pressure without interruption. If the bandages become loose, reapply them. Further injections for missed or recurrent veins may be necessary: wait 3 months before doing this.

If there is severe pain after the injections, take off the bandages with the leg elevated and look for skin necrosis or gangrene. Use analgesics and encourage walking if there are no untoward effects.

(f) Long saphenous vein ligation, stripping and avulsions for varicosities (GRADE 2.5)
Determine whether there is long sapheno-femoral or short sapheno-popliteal incompetence. Make sure the deep venous system is patent. Wait till after delivery if the patient is pregnant. If a patient is on oral contraceptives, she should stop them one month before operation.

EQUIPMENT. STRIPPER, for varicose veins, Nabatoff, in sterilizer case, complete with 3 metal olives, cable and handle. (Some strippers have olives that can be attached at either end.)
N.B. A sterilized scooter clutch wire works as well!

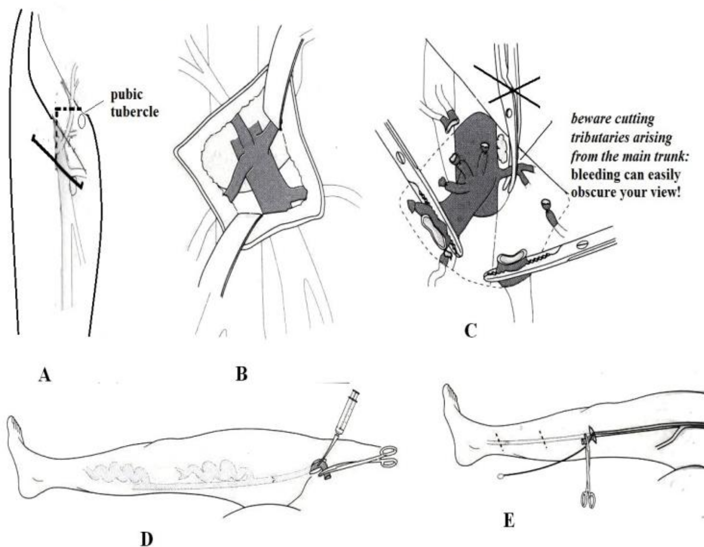

Fig. 35-4 VARICOSE VEINS: LIGATION & STRIPPING.
A, incision 2cm lateral and below pubic tubercle. B, expose the saphenous vein and tributaries (note the medial axis of the long saphenous vein compared to the femoral). C, divide the saphenous vein and tributaries. D, syringe test to prove incompetence. E, pass the stripper through the groin downwards.
After Morris PJ, Malt RA. Oxford Textbook of Surgery. OUP 1994, p.551-2 Figs 51e(i,iii),f(iv,vii),g(ii),h(ii).

PREPARATION
Scrub the groin thoroughly with betadine and make sure the legs are well washed beforehand. With the patient standing, mark the vein to be operated on, and all its tributaries and dilations, using a permanent marking pen. Also find and mark the perforating veins, using the finger-pressure method described above.

FOR THE LONG SAPHENOUS VEIN, lay the patient supine with a 30º head-down tilt with the feet apart. Support the heels on foam cushions.

Make a 5cm oblique incision 1-2cm below and parallel to the inguinal ligament, centred a finger-breadth medial to the pulsating femoral artery (35-4A). Deepen the incision, until you reach the superficial fascia. Proceed carefully using non-toothed dissecting forceps, spreading the fatty tissues gently with scissors to expose the saphenous vein (35-4B).

You may find the superficial external pudendal artery in the way, running over or under the long saphenous vein; make no hesitation in ligating and dividing it if it is in the way. You often come to tributary veins of the saphenous first before the vein itself. Tie and divide all these tributaries (35-4C). Then dissect out the groin end of the saphenous vein and demonstrate the sapheno-femoral junction as the vein dips down through the cribriform fascia (35-1F).

Tie the saphenous vein securely with two ligatures as close to its entry to the femoral vein as you can, making sure no further tributaries enter above your ligature. Clamp the saphenous vein a suitable distance from the femoral vein with haemostats and divide it.
N.B. There may be a ***saphena varix***, a dilated saccule below the incompetent valve; you will need carefully to get above this to ligate the vein satisfactorily.

CAUTION! **If you encounter much bleeding**, *don't clamp blindly with haemostats*, or you may damage the femoral vein, or even the femoral artery. Instead, apply pressure, and raise the foot of the table. Get the suction ready. After 3mins pressure you can usually find the bleeding point and control it, with either a haemostat or a fine silk stitch.

Then mobilize more length of the saphenous vein down the leg; place an untied ligature round it and, holding one edge of the vein carefully with dissecting forceps, release the haemostat. If there is too much bleeding from the open vein (because the patient was not put in head-down tilt), re-apply the haemostat further down the leg. Introduce a wide-bore cannula into the lumen of the vein, and inject 20ml of saline; no resistance should be found, and the varicosities should be shown to bulge (35-4D). If this is the case, introduce the stripper (one with a suitably-sized olive) into the vein and tie the ligature to prevent it falling out (35-4E).
N.B. Make sure you have put the stripper inside the saphenous vein and not the femoral*!*

Release the haemostat, if applied, and manipulate the stripper down the leg, by twisting and turning it. You may guide its passage by external manipulation as well. Try to get it to mid-calf position; *don't try to go as far as the ankle where nerves are close to the vein and may be damaged by avulsion*. Sometimes the stripper gets stuck because of the tortuosity of the varicose vein; in this case you can make a small incision over where the stripper has reached, dissect out the vein and manipulate it further by direct vision. You may have to open the vein between ligatures to do this successfully.

When the stripper has reached its destination, make a 2cm incision over the olive, dissect out the vein, pass looped ligatures underneath the vein at two sites, tie the lower ligature tight and divide the vein. Extract the olive from inside it, and tie the ligatures round the stripper and vein.

Now make 0·5cm-long incisions through the skin over the various tributaries marked in indelible ink. Select prominent remaining varicosities, and by spreading forceps raise a loop of varicose vein by gentle blunt dissection. Follow it as carefully as you can in each direction and when you have exposed as much length of vein as you can, pull it out. Get your assistant to press on the site to stop the bleeding. There is usually no need to tie the vein unless it is large or perforates the deep fascia. Close the small skin incisions with one suture.

N.B. Don't go as far as the ankle with avulsions.

Now raise the leg high and slowly pull the stripper attached to the vein out from the groin. Keep the leg high for a few minutes afterwards to reduce bleeding. Examine the groin wound for bleeding. Examine the avulsed vein for its length to make sure you have extracted it *in toto*; make sure the olive is still attached to the stripper. Close the remaining wounds, and bandage the leg firmly.

(g) Difficulties with stripping varicose veins

If the varicosities don't bulge with the syringe test, incompetence may be in the anterolateral tributary (35-2D): dissect this out, and do the test again. Pass the stripper down this vein.

If the stripper does not pass below the knee, make an incision over the marked route of the varicosed saphenous vein at a suitable point, and introduce another stripper in the same way from below, so that the 2 strippers meet. You can then try to manipulate the proximal stripper upwards, following withdrawal of the first one, or simply pull out each stripper in turn.

If the olive becomes detached, palpate where it has dislodged, and make a 3cm incision over it. Dissect down and remove it; bleeding may be troublesome, so have suction ready.

ANATOMICAL VARIATIONS OF THE SHORT SAPHENOUS

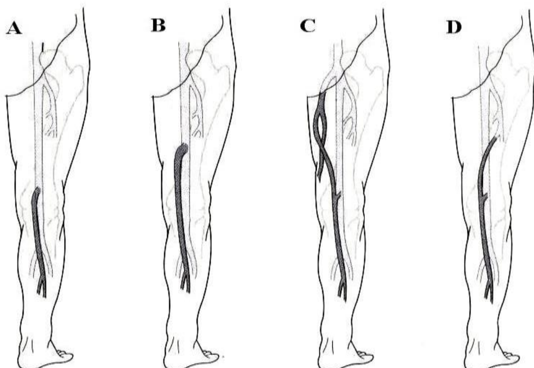

Fig. 35-5 ANATOMICAL VARIATIONS OF THE SHORT SAPHENOUS VEIN.
A, normal level of the sapheno-popliteal junction. B, high level termination. C, upward extension to join the posteromedial tributary of the long saphenous vein. D, upward extension deep to the profunda femoris vein.
After Morris PJ, Malt RA. Oxford Textbook of Surgery, OUP, 1994, p.553 Fig51j.

FOR THE SHORT SAPHENOUS VEIN, you need either spinal anaesthesia or GA and intubation. Use at least 2 assistants to turn the patient by a log roll and lay him prone with the feet apart, and the knees slightly flexed. Put pillows under the chest and pelvis, and make sure the neck is supported, and the abdomen can move freely. It is best to put the arms flexed above the head.

CAUTION! If your team is not familiar with GA in the prone position, don't attempt it!

Make a transverse incision across the middle of the popliteal fossa and deepen it through the deep fascia to expose the short saphenous vein (which lies deep to it). Dissect it out, ligating its tributaries, and trace the knee end down into the popliteal fossa, and doubly ligate it close to its communication with the popliteal vein.

CAUTION! The anatomy of the short sapheno-popliteal junction is notoriously variable (35-5). *Don't attempt to strip the short saphenous vein* as it is closely accompanied by the sural nerve, and avulsion may well result in anaesthesia of the lateral foot and calf. Also, there may be short *and* long saphenous incompetence! However, select prominent remaining *superficial* varicosities outside the deep fascia, dissect these out through 0·5cm incisions, and avulse them.

POST-OPERATIVELY, keep the legs elevated at 30º for 24h. Encourage walking as soon as possible for 1h daily. Leave the pressure bandage applied at operation for 1wk, then remove the sutures. Advise wearing bandages for a further 2wks.

If varicose veins recur, try sclerotherapy if the varicosities are limited. Recurrence may occur when some tributaries of the saphenous vein or a double vein are not ligated; to re-explore the sapheno-femoral junction is quite hazardous because of scarring, though, and mapping of the veins by Doppler is usually necessary.

(h) Complications of varicose veins

(1) VARICOSE ULCERATION

N.B. Most lower leg ulcers in the tropics are chronic tropical ulcers (34.9) and varicose ulcers due to incompetent perforators are less common. If the ulcer is not typically the result of varicose veins, consider alternative causes.

A varicose ulcer is usually on the lower ⅓ of the leg, especially just behind and above the medial malleolus. It may be of any size and shape, its edges are usually brown and eczematous, and it has red granulations under the slough on its base. The patient is usually obese. Progressive fibrous atrophy of the subcutaneous tissues of the lower leg ('inverted bottle leg') and liposclerosis precede ulceration. There are gross varicose veins of many years' standing with incompetent deep perforating veins in 50% of cases.

TREATMENT

Be prepared for a long haul! Insist on bed rest and apply frequent sterile water soaks until the ulcer is clean and oedema has gone. Deslough the wound, and when clean, apply betadine or zinc oxide paste.

Only use antibiotics if there is associated cellulitis (6.22). *Don't use topical antibiotics.*

Advise cleaning the ulcer once or twice daily, and coating the ulcer weekly with platelet-rich fibrin, and sleeping with the foot of the bed raised.

When dressings are no longer cumbersome, apply graduated compression stockings from the base of the toes to the thighs. Recent ulcers (<3 months) will often heal this way, but a graduated compression stocking should be worn for life, despite the discomfort in the heat.

If the ulcer will not heal or recurs, there is no history of deep vein thrombosis and you can be sure of the venous abnormality, check for malignant change (characterized by firm nodules) and take biopsies. Otherwise, treat the varicose veins by operation to reduce orthostatic venous pressure on the skin. Try honey, ghee, pawpaw or banana dressings (2.10). Then think of skin grafting if the ulcer surface is granulating well (34.9).

(2) HAEMORRHAGE

If varicose veins bleed, haemorrhage can be alarming. Elevate the leg and apply pressure to the bleeding vein. If bleeding persists or recurs, take the patient to theatre to expose and isolate the vein and ligate it formally.

(3) SUPERFICIAL THROMBOPHLEBITIS

If an indurated line develops along the course of the vein, advise that it will usually be gone in a month. Use cloxacillin 500mg qds and ibuprofen 400mg tds for 1wk. There is almost no danger of pulmonary embolism.

35.2 Peripheral gangrene

Inadequate blood supply leads to gangrene of the peripheries; strictly speaking, gangrene implies digestion of dead tissue by anaerobic bacteria. This may occur as a primary process in gas gangrene due to *clostridia* (6.24), or more usually secondarily to ischaemia. If there is little subcutaneous fat, and no oedema, the skin becomes cold and waxy, haemoglobin diffuses out of the veins, discolouring the skin purple and then black, and ischaemia results in shrinking of the tissues (mummification or dry gangrene). There results a clear line of demarcation between viable and dead tissue, and the dead part sometimes simply falls off, leaving the stump to heal. At the junction between live and dead tissues, however, organisms do survive, as is the case with the more common scenario of fatty oedematous tissues, particularly found with diabetes mellitus. The result is a mass of infected, necrotic, smelly, partially destroyed tissue, known loosely as wet (or moist) gangrene.

Underlying causes are numerous, and can be:

(1) Sepsis with diabetes mellitus (causing a combination of vasculopathy and neuropathy).

(2) Peripheral ischaemia due to arterial disease (usually because of cigarette smoking), HIV or syphilitic vasculitis, arterial emboli, vascular injury (including injection of barbiturate or sclerosant into an artery, 35.1), and vasospasm due to cold (*e.g.* in trench foot) or, rarely, an accessory cervical rib.

(3) Compartment syndrome due to burns, crush injury, snake bite especially with inappropriate tourniquet use, too tight plaster of Paris, fibrous stricture (*e.g.* ainhum, auto-amputation of the 5th toe) or an acute venous thrombosis.

(4) Septicaemia (from any cause) resulting in simultaneous venous and arterial thrombosis, especially in neonates, HIV+ve patients, and the malnourished.

(5) Necrotizing fasciitis (6.23) or gas gangrene (6.24): these produce a toxic combination of (3) and (4).

(6) Multi-organ failure.

(a) Examination

The diagnosis of gangrene is usually obvious; unfortunately many patients present when gangrene is already established and all you can do is amputate. You therefore need to know where and how to do so.

Make sure ischaemia is established: you may still save toes, feet, fingers or arms if you release an eschar, decompress a compartment syndrome, or simply *slowly* warm up a cold periphery.

Make sure you document all the peripheral pulses (including thrills and bruits), examine for capillary return on the toes or fingers (should be <1sec) and for sensation, and check a random blood glucose and HIV screen (and also VDRL if available). Look for xanthelasmata at the inner canthus of the eyes, indicating hyperlipidaemia, as well as the tell-tale signs of nicotine-stained fingers.

Measure the ratio of the ankle to the brachial systolic pressure (significant occlusion exists if it is <0·85) but this may be unreliable if arteries are calcified as in diabetes or renal failure. If you have a Doppler ultrasound probe, this gives greater sensitivity than the finger and can give very useful objective information about flow rates. However, you may not be able to tell where the occlusion lies, and if there is a stenosis, whether there is a more significant stenosis more proximally placed.

Similarly if you compare the p_aO_2 taken with a pulse oximeter at the big toe and the thumb, you can get an idea of the degree of relative hypoxia: this is significant if the ratio is <0·6; a reading of <20mm Hg in the lower leg demonstrates significant ischaemia.

(b) Vascular reconstruction
It is, sadly, often too late with many patients to consider this. However, with minor areas of gangrene or ischaemia, a patient will do better if you can arrange a successful revascularization of the limb and perform a minor amputation, rather than a major amputation *without any improvement in vascular supply*.

If you see a patient with claudication at <200m, or rest pain, try to refer him before gangrene sets in. You can relieve much pain (and peripheral inflow) with epidural analgesia.

35.3 Amputations in general

(a) Introduction

The decision to amputate is always a drastic one. There is, obviously, no going back, so think about remaining function. This will depend on many factors: the patient's determination, cultural obligations, residual pain, the presence of continuing infection, the healing of the stump, the level of the amputation, the prostheses and the physiotherapy available. Generally speaking, a disarticulation away from sepsis is less likely to become infected than amputation through the bone.

Some prostheses may be of little use in the patient's particular circumstances, and a simple hook or peg leg may be preferable to a sophisticated gadget even if he does get one.

The rule in the arm is to maintain as much length as possible: every cm is useful. For the leg, the crucial element is walking or, failing that, crawling. If the heel is preserved, a patient should be able to use the foot to walk.

In a perfect stump:
(1) The scar is not exposed to pressure.
(2) The skin slides easily over the bone.
(3) The skin is not infolded.
(4) There is no redundant soft tissue.
(5) There is no protruding spur of bone.
(6) The stump is painless.
(7) The wound has healed by first intention.
(8) The skin has good sensation.
(9) The shape of most should be conical.

So try if possible to make sure:
(1) you divide the bone where its cross-sectional area is greatest and so gives broad support,
(2) the whole surface of the cut bone is capable of weight-bearing,
(3) the skin of the stump is centred on the stump, firmly attached, and adapted to weight-bearing,
(4) the stump end is bulbous so the prosthesis does not slide off.

Deciding where to amputate can be difficult. Mention where, why, and how you plan to amputate. Make sure you have properly counselled the patient, the family or any relevant decision-maker and obtained consent for amputation. This may be a decision that is taken after considerable discussion in the family or clan; *don't force them into agreement against their own judgement*, otherwise they will not cooperate.

Mention the possibility of a higher amputation if complications ensue, and mobilize well post-operatively. If the patient is going to take a long time to recover, say so. Discuss any alternatives. Mention the stages of the road to rehabilitation. If you focus on this (going back to work, or walking), you are much more likely to engender enthusiasm about the future. Think of what position the patient is likely to find himself in 12 months' time. Get help from peer groups of amputees.

If you have to operate in an emergency, and you cannot obtain consent because the patient is unconscious and there are no family members present, but you think the amputation is life-saving, get a second opinion, a witness to document this, and take a photo of the limb to be amputated.

AN AMPUTATION IS THE START OF A LIFELONG TREATMENT

N.B. There may be elaborate rules for burying the amputated limb.

An emergency amputation for sepsis or crushed limb may save someone from the jaws of death!

(b) Considerations in leg amputations

You will need to amputate a leg much more frequently than an arm. The lower in the leg you amputate, the greater the chance that the patient will walk again afterwards, especially in the elderly. The longer the bone stump, the less effort is required when walking. Energy expenditure and oxygen consumption increase as the level of amputation rises in the limb: for an above-knee amputation, 65% extra work is needed.

However, the lower in the leg you amputate, the greater the chance that the tissue through which you cut will not be viable. So, feel the pulses carefully and take measurements to assess the degree of ischaemia (35.2): *don't perform a below-knee amputation if you cannot feel a popliteal pulse.* If the tissues have poor bleeding and the muscle is purple at operation, abandon this level and cut more proximally.

The leg must have a prosthesis which will bear weight. There are a limited number of these, and the stumps for them are standardized. So always perform one of the standard leg amputations. There are three technological grades of prosthesis; of these, the third is not necessarily the worst.

WHERE TO AMPUTATE

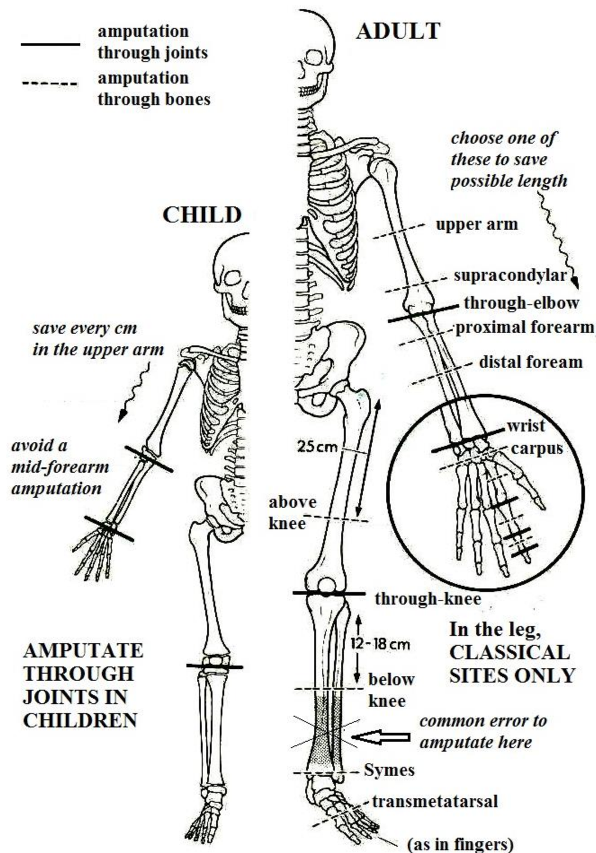

Fig. 35-6 AMPUTATION SITES.
In the arm, save every centimetre in the child's upper arm, and at the joints so as not to affect growth; choose the longest feasible amputation in the adult arm; in the leg, amputate at the classical sites only.

A patient might have:
(1) A sophisticated modern prosthesis costing >US$300.
(2) A simpler modern prosthesis costing US$30, such as the Jaipur foot (35-23A) developed by the BMVSS organization, which a mechanic can mend (www.jaipurfoot.org).
(3) A traditional prosthesis, such as a pylon, a peg leg (35-23B) or elephant boot.

Don't despise the last; when well made, they last longer than any of the others, and are better than a modern prosthesis for working in the fields. Remember that the patient may be used to sitting on the floor rather than on a chair, and so his prosthesis must take this into account. To this end, the Jaipur prosthesis is most suitable. It does not require any shoe: amputees can walk barefoot, or use a shoe. It is made of waterproof material, so that amputees can walk in wet and muddy fields. It permits enough foot dorsiflexion and other movements necessary to walk on uneven surfaces.

A leg prosthesis can:
(1) have a cup to bear weight on the sides of the stump, in which case the scar should be at the end.
(2) bear weight on the end of the stump, in which case the scar should be posterior.
(3) have a modern total contact socket in which the position of the scar is unimportant.

Limb-fitting centres vary in their scope and preferences, so visit your local one and find out what they like. A good prosthetist can fit any well-constructed stump with a prosthesis.

Work in good collaboration with your physiotherapist and prosthetic supplier.

CONSERVE EVERY CENTIMETRE IN THE ARM; DO A STANDARD AMPUTATION IN THE LEG

(c) Considerations in children

The epiphyses play pivotal roles in growing limbs, so try to preserve them. Disarticulation, especially at the knee, will preserve the epiphyses. But aim for a below-knee amputation whenever possible. Children´s skin is much more elastic and it tolerates more tension to close a stump. You might even tolerate skin defects of a stump, as they heal quicker the younger the child is. Amputating through the mid-thigh or foream causes the bone to stop growing, but below-knee and above-elbow amputations produce excessive growth, needing revision later.
The technique of periostal flap cover over the shaft stump might prevent stump bony overgrowth.
If there is no good follow-up, amputate through a joint and avoid complications of bony overgrowth.

(d) Considerations in upper limb amputations

Save as much of the length of the arm as you can, because the patient will probably get no prosthesis. If possible, disarticulate the elbow.
If you can leave a reasonable length of humerus, it can be used to hold things by gripping them against the chest. If you have to amputate very high up, even a very short stump will preserve the outline of the shoulder.
N.B. In some cultures, amputation of the right hand makes you a social outcast!

AMPUTATION EQUIPMENT

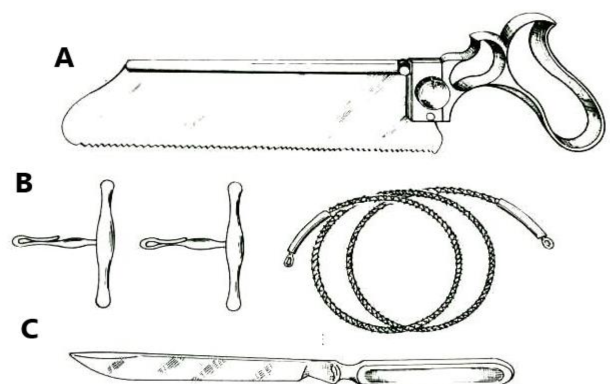

Fig. 35-7 EQUIPMENT FOR AMPUTATION.
A, hand saw. B, Gigli wire and holders. C, sharp long amputation knife. ***N.B. If necessary, you can use any sterilizable saw or domestic knife.***

SAW, amputation, with hinged back, 230mm, with spare blades. The back of the saw stiffens it during the early part of the cut, but can be hinged back later to let the saw pass through.
SAW, Gigli, with a pair of handles and 30cm blades. A Gigli bone saw is a piece of wire with sharp teeth on it which you pull to and fro between two handles. Use it to cut bone in awkward places.
KNIFE, amputation, Liston 180mm. If you don't have an amputation knife, sharpen a long kitchen knife and use that.
N.B. An electric saw is a luxury: keeping strict sterility is difficult.

(e) Indications

(1) Gangrene
(2) Chronically infected limb with osteomyelitis
(3) Advanced soft tissue or bone malignancy
(4) A useless limb, such as affected by severe contractures or polio
(5) A gross congenital malformation
(6) An irretrievably damaged limb (60.1).

(f) Methods for amputations

(1) ANAESTHESIA
Relaxation is unnecessary. Ketamine is the preferred anaesthetic. You can use spinal anaesthesia in a haemodynamically stable patient. Spinal and plexus anaesthesia seem to prevent post-operative phantom pain, and are preferable in ischaemia. If a patient is conscious, premedicate him heavily so he cannot hear his bones being sawed through!

(2) TOURNIQUET
Use a tourniquet and exsanguinate a limb by elevating it and applying an elastic bandage from the distal to the proximal end, *except when you are amputating for ischaemia. Don't exsanguinate a limb if there is sepsis or malignancy in it!*
N.B. You may have difficulty identifying viable muscle if the tourniquet remains in place.

(3) TECHNIQUES OF AMPUTATION
FLAPS FOR AMPUTATIONS
When you perform an amputation, you are making 2 myoplastic flaps. The classical 'fish mouth' flaps must be long enough to cover the bony stump, but not too long that their blood supply is inadequate or they make a lumpy end. If the flaps are equal, the resulting scar will sit at the end of the stump, but if one is slightly longer than the other, the scar will be on the front (if the posterior flap is longer) or the back (if it is shorter). Aim to place the scar where it is not going to be pressed on. In the leg, its site depends on the kind of prosthesis envisaged: end-bearing, side-bearing, or total contact. In the lower arm and leg, transverse scars are better than antero-posterior because they don't get drawn up between the two bones. In the hand and the foot, place it dorsally. Higher up the arm the scar can be anywhere.
A 'dog ear' at the corner of a wound usually resolves.

The long posterior flap technique is the standard for the below-knee amputation (35-24A) especially in ischaemia. *Equal anterior and posterior, or lateral flaps are liable to fail.*
The skew flap is also good, but more difficult (35-24C).

N.B. The guillotine amputation has no flaps; use it only in special circumstances (60.4).

Decide where you are going to saw the bone (the point of section) and plan the flaps in relation to that point. Place the angle of the fish mouth at the site of bone section. Mark the flaps out carefully with a permanent marker.

THE GEOMETRY OF 'FISH MOUTH' FLAPS

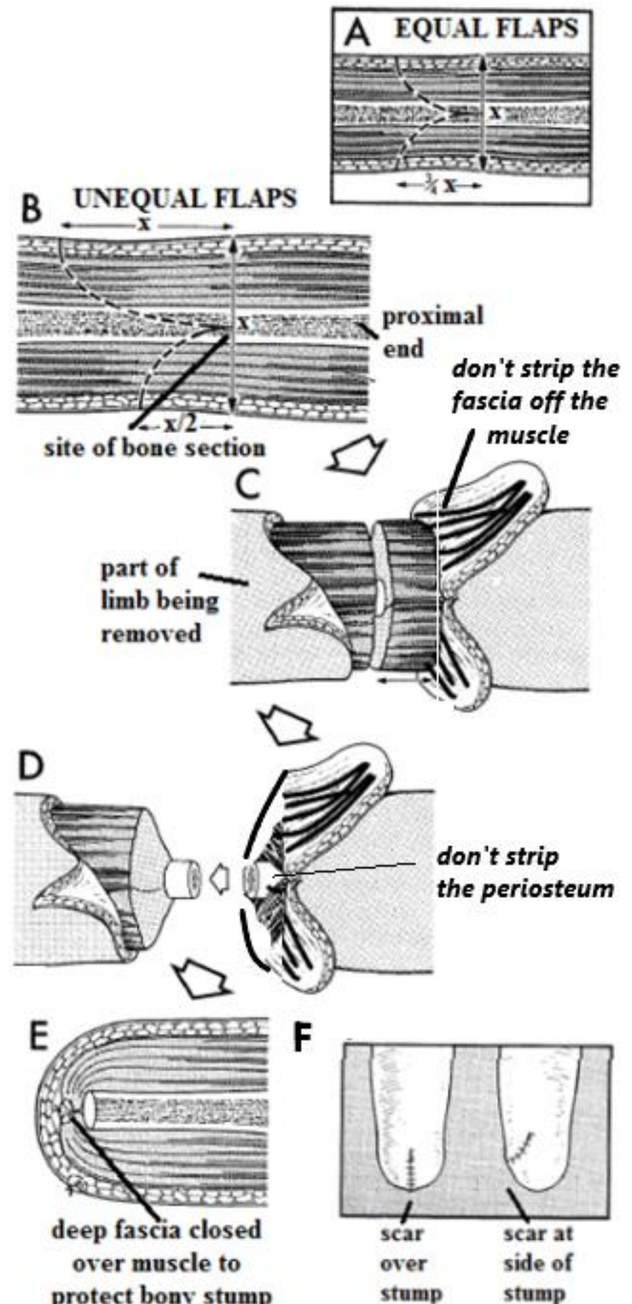

Fig. 35-8 'FISH MOUTH' FLAPS.
Together, the flaps should be 1½ x the diameter of the limb. A, either make them as 2 equal flaps, each ¾ of the diameter of the limb, or B, make 1 flap equal to the whole diameter and the other flap equal to ½ of it. C, reflect the skin with the deep fascia and muscle a little distal to the bone section. D, reflect the periosteum only 1-2cm so you can saw the bone cleanly: ***don't strip the periosteum off the bone.*** **E, close the deep fascia over the bony stump, protecting it with muscle. F, position the scar depending on the type of flap you use.**
Kindly contributed by Peter Bewes.

For equal flaps, make the length of each flap equal to ¾ of the diameter of the limb (35-8A), or ½ the circumference.
For unequal flaps, make the longer flap equal to the diameter of the limb, and the shorter one equal to ½ its diameter (35-8B).

N.B. As a general rule, the combined length of both flaps should equal 1½ times the diameter of the limb at the site of the bone section.

CAUTION!
(1) Start by making fish mouth flaps long. You can always trim them if they are too long later, *but you cannot lengthen them if they are too short*.
(2) Cut them round, *not pointed*.
(3) *Make sure the scar is not at the end of the stump if the limb will carry the pressure of a prosthesis.*

Cut the flaps as far distally as you can, so that you can refashion them later. Cut through the skin down to the deep fascia, and reflect this up with the skin as part of the flap. The flaps will need to be of enough length to meet over the end of the stump (35-8E). Minimize trauma to the flaps: handle them with stay sutures rather than with forceps, particularly in diabetics.

CUTTING MUSCLES DURING AN AMPUTATION
Muscles always contract after you have cut them. So cut them transversely c.8cm distal to the site of bone section (35-8C). Leave them a little longer if you are using delayed primary closure, because they will shrink.
Use a long sharp amputation knife or kitchen knife to cut the muscles straight down to the bone. *Don't use a scalpel* which makes many small cuts and leaves shreds of injured muscle.
Make sure you have released the tourniquet when checking the muscles.

If the muscles look unhealthy when you cut them, abandon the operation at that site, and amputate more proximally. Healthy muscle is a nice bright red, and has a good capillary ooze. Ischaemic muscle is a dark bluish red, bleeds little or not at all, and contracts feebly.

If the cut ends of the muscles bleed furiously, apply packs for 5mins and a tourniquet. If the amputation is very high, you may have to expose the main artery higher up.

CONTROLLING BLEEDING DURING AN AMPUTATION
Early in the operation, find the major arteries and veins. Tie them separately with double transfixion ligatures (3.2). Then cut the vessels between these ligatures. Later, after you have released the tourniquet and removed the limb, tie the remaining smaller vessels. *Don't use diathermy.*

CAUTION! Don't rely on digital pressure over the main vessels to control bleeding.
Bleeding and muscular contraction are useful signs that the muscle is not ischaemic: if these do not happen on cutting muscle, amputate more proximally. *Don't use bone wax.*

CAUTION!
(1) If you don't use a tourniquet, try to find and tie the major vessels *before* you cut them.
(2) *Don't use a clamp:* if it slips, there will be massive bleeding.
(3) Careful haemostasis of the stump is essential. If a clot forms, it is easily infected.

CUTTING NERVES DURING AN AMPUTATION
Don't crush, ligate or inject nerves: a painful neuroma will result, especially in the fingers. Instead, very gently pull each nerve into the wound, cut it cleanly with a knife, then let it retract above the amputation site. The sciatic nerve is accompanied by an artery which may bleed profusely, so tie the artery off carefully, separately from the nerve.

SAWING BONES DURING AN AMPUTATION
Reflect the myoplastic flap proximally for 1-2cm on a limb to expose bare bone. For large bones, use a sharp saw with well-set teeth, or a Gigli wire saw (35-7). Steady it and draw it across the bone a few times to start with. When it has made a good groove in the bone, saw steadily, cooling the bone with water.

Ask an assistant to hold the limb to steady it, and maintain a steady smooth movement to prevent the saw locking in the bone and splitting it. Finally, remove any spikes with bone forceps, and bevel any protruding edges with a coarse rasp.

N.B. Use a bone cutter for phalanges.

CAUTION!
(1) *Only reflect the periosteum proximally a very short distance* (35-8D), because the bone under it will die, and a ring sequestrum will form.
(2) *Don't damage the surrounding muscle with the saw*. Retract the muscle well out of the way with a towel wrapped round the limb (35-9), then saw.
(3) Bone dust from the saw acts as a foreign body, so wash it away.

COVERING THE STUMP WHILE YOU SAW

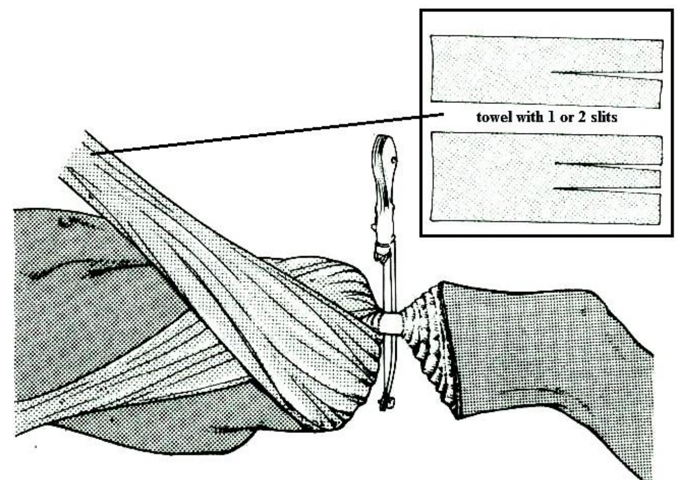

Fig. 35-9 COVER THE STUMP WHILE YOU SAW.
The towel with 2 slits in it is for the forearm and lower leg. The central flap goes between the bones.

DEALING WITH FAT DURING AN AMPUTATION
If the limb is very fat, cautiously remove as much subcutaneous fat as is necessary. *Don't remove too much, especially near the edges of the flap*, or it may necrose. Learn to design flaps so that they come together accurately without dog ears; if they do form, leave them, they will soon disappear. *Don't excise them,* otherwise you may end up with a wound that is too tight to close!

CLOSING THE WOUND AFTER AN AMPUTATION
Release the tourniquet, if present, and control all bleeding before you start closing the flaps. Make sure haemostasis is meticulous. *Don't use diathermy.* Check that the flaps meet without tension. *If they don't, cut more bone off.*
Suture the cut ends of the fascia securely together over the cut end of the bone, so that the muscle cushions it, and is well able to move over the stump. Cut the muscle long but *don't leave so much muscle that the stump becomes bulbous.*
Suture the skin and deep fascia separately using interrupted monofilament 3/0 sutures without leaving gaping areas between them, and without tying them tight. Dress the stump firmly, *but not too tightly.* If there is much oozing, insert a closed drain for 24-48h.
Avoid using an open drain, as you risk introducing infection this way. *This may be disastrous in ischaemic tissues.*
Elevate the arm or hand. Plaster of Paris over a leg stump will make it more comfortable and its weight will tend to prevent hip flexion contracture.
Change the wound dressings only if they are smelly or soaked. Remove sutures after 7 days for the hand and arm, and 14 days for the leg.
Plan delayed primary closure on the 5th post-operative day. You may have to shorten the bone so you can close the flaps without any tension.

POST-OPERATIVE CARE AFTER AN AMPUTATION
Elevate the limb after amputation. Make sure the limb or finger is exercised from the 1st day. Provide adequate analgesia. Mobilize the patient early; if you can fit a temporary prosthesis before a definitive one to allow exercises, do so. You will thereby avoid the development of pressure sores (34.16).

As soon as a lower limb stump is healing well, bandage it. For the leg, suture two 15cm crepe bandages end-to-end. For the arm, use one 10cm bandage. Roll the bandage tightly, then wind it round the stump. Apply more tension to the end of the stump than to its base, or it will become bulbous. *Don't use adhesive strapping on the skin*, or you may tear the skin off the stump.

Prepare the leg stump for a prosthesis; use an elastic bandage 8-10cm wide for a below-knee, and 10-15cm wide for an above-knee stump. Wrap the bandage from distal to proximal (knee or groin) with more pressure distally than proximally (35-10A,B). Overlap the layers by ½ the width of the bandage at each turn, keeping it smooth and free of wrinkles. Even if there is a small wound on the stump, start the bandaging, and teach the patient how to use the stump.

This will hasten the change of the stump from a bulky cylinder to a narrow cone, and exercises will strengthen the remaining muscles. After a lower leg amputation, *e.g.* learning to kick a large rubber ball about is very therapeutic. *Don't allow a flexion contracture of the knee or hip to develop.*

If there is already a tendency to flexion, keep the knee in a backslab or cast until full mobilization.

BANDAGING A STUMP

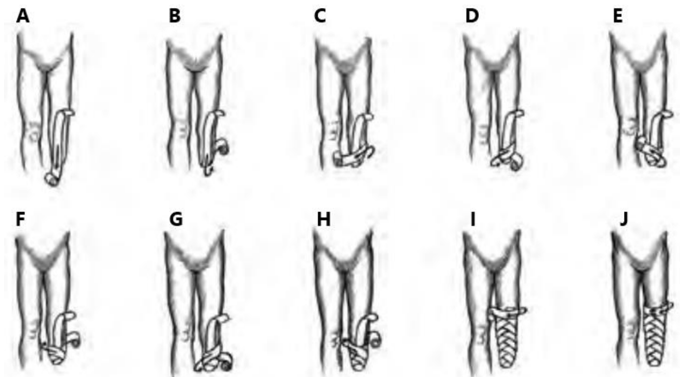

Fig. 35-10 STUMP BANDAGING.
A,B, wrap the bandage from stump to knee (for a BK amputation). C,D, then pass around the tip more tightly than higher up. E-J, make sure the bandage is smooth and causes no wrinkles.
After Giannou C, Baldan M, Molde, Å. War Surgery, ICRC Geneva 2013.

(g) Difficulties with amputations

If the stump bleeds some time after the operation (reactionary haemorrhage), return to theatre, explore the wound, tie the vessels, leave the wound open and close it later when it is clean.

If the stump bleeds some days later (secondary haemorrhage), this is likely to be serious. Apply a tourniquet. Explore the wound to find the bleeding point(s). If you cannot find them, wash the wound with hydrogen peroxide. In desperation, pack the wound with dry gauze, and remove it 48h later.

If the stump becomes infected, open the wound in theatre, irrigate it and debride dead tissue. You may still be able to save the situation if there is no further ischaemia. *Always consider delayed primary suture if there is an increased risk of infection.*

If a persistent sinus develops in the stump, explore it; you may find a piece of necrotic tendon, or an area of osteomyelitis. Another possibility is a stitch sinus. If the offending suture might be securing a vessel, *don't remove it until you have tied the vessel higher up*. Explore the stump, remove all dead and dying tissue, and pack it ready for secondary closure.

If the flaps break down, you probably cut them too short or closed them too tight. Wait until granulation tissue is clean and ready and then apply a skin graft.

The final quality of the skin over the stump will be worse than it would have been if the flaps had survived, and it may break down later. Alternatively, you may have to amputate more proximally.

If a patch of gangrene forms in a flap, be careful, it may hide a larger area of necrosis underneath. Return to theatre. Debride any necrotic tissues; you may need to amputate again more proximally, especially if the limb is ischaemic.

If there is spreading sepsis or gas gangrene, amputate more proximally immediately, through the shoulder or hip if need be, and leave the wound open.

If a prosthesis cannot be fitted, you have probably designed the stump wrong. The reasons include:
(1) bone adherent to the scar,
(2) a spicule of bone sticking out through the skin,
(3) a flexion contracture in a below-knee or above-knee amputation,
(4) too short a stump.
Get advice from your rehab technician as to what is the best way forward.

If the stump is painful:
(1) you may have damaged the nerves or left them too long, allowing a neuroma to form and stick to the scar,
(2) the bone may be too long in relation to the flap,
(3) there is a haematoma or infection in the wound, or
(4) the tissues are ischaemic.

35.4 Arm and hand amputation

(a) Mid-humeral amputation (GRADE 2.5)

If you can provide a prosthesis, *don't amputate through the lower 4cm of the humerus*, because it will be difficult to fit. Remember that the brachial artery lies quite superficially, and is overlapped medially by the biceps.

PREPARATION
Abduct the arm to about 80° on an arm board. Place a block under the arm just proximal to the amputation site. Apply a tourniquet as high as you can. Note the time.

Start proximally at the site of bone section, and mark out equal anterior and posterior skin flaps. Make the length of each flap ¾ of the diameter of the arm at the site of section (35-11). Find, doubly ligate, and cut the brachial artery and vein just above the site of section.

Find, gently pull and cut the radial, medial and ulnar nerves so that their ends retract well above the stump. Cut the anterior muscles 1·5cm distal to the site of section.

Cut the *triceps* 4cm distal to the site of section or free its insertion from the olecranon. Preserve the *triceps* fascia and muscle as a long flap. Retract the periosteum 1-2cm to expose clean bone and saw it cleanly. Rasp the end of the humerus smooth.

Bevel the *triceps* to make a thin flap, reflect it anteriorly over the end of the humerus, and suture it to the anterior muscle and fascia. Release the tourniquet, control bleeding and close the stump (35.3).

(b) Supracondylar amputation

Make equal fish mouth flaps proximal to the site of bone section. Find, clamp, tie, and cut the brachial artery and vein just proximal to the site of section. Cut the median, ulnar, and radial nerves clean at a higher level so their ends retract well above the stump.

Cut the muscles in the anterior compartment of the arm 1.5cm distal to the site of section. Free the insertion of the *triceps* tendon from the olecranon. Preserve the *triceps* fascia and muscle as a long flap.

If there is any hope of an elbow prosthesis, reflect this flap proximally and cut the periosteum all round the humerus at least 4cm above the elbow joint to allow room for the elbow mechanisms of the prosthesis.

If there is no hope of an elbow prosthesis, leave as much bone as you can. Saw across the humerus at the level you choose, and rasp its end smooth. Trim the *triceps* tendon to make a long flap, carry it across the end of the bone, and suture it to the fascia over the anterior muscles.

ABOVE-ELBOW AMPUTATION

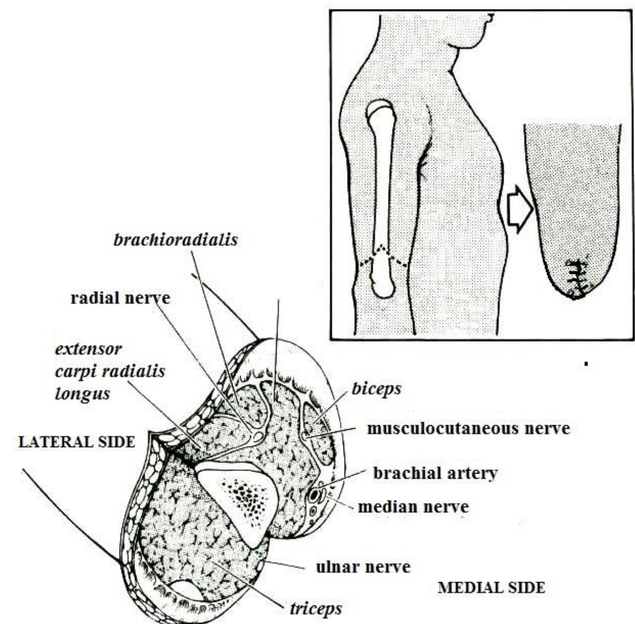

Fig. 35-11 SUPRACONDYLAR AMPUTATION.
If you leave a patient with a reasonable length of humerus, it can be used to hold things by gripping them against the chest.
After Rob and Smith with the kind permission of Graham Stack.

(c) Elbow disarticulation (GRADE 2.5)

Make equal anterior and posterior skin flaps. Start at the level of the epicondyles and curve the posterior flap 2·5cm distal to the tip of the olecranon. Bring the anterior flap just distal to the insertion of the *biceps* tendon. Reflect the flaps to the level of the epicondyles.

Start on the medial side. Find and divide the bicipital aponeurosis. Free the origin of the flexor muscles from the medial epicondyle and reflect it distally to expose the neurovascular bundle on the medial side of the *biceps* tendon. Tie and cut the brachial artery just above the joint. Gently pull the median nerve and cut it proximally. Find the ulnar nerve in its groove behind the medial epicondyle and cut it proximally in the same way. Free the *biceps* tendon from the radius, and the *brachialis* tendon from the coronoid process of the ulna.

Find the radial nerve in the groove between *brachialis* and *brachioradialis*, pull it, and cut it proximally. On the lateral side of the elbow, cut the extensor muscles 6·5cm distal to the joint, and reflect their origin proximally.

Cut the *triceps* tendon near the tip of the olecranon. Cut the capsule on the front of the joint, complete the disarticulation, and remove the forearm. Leave the articular surface of the humerus intact. Reflect the *triceps* tendon anteriorly and suture it to the tendons of the *brachialis* and *biceps*.

Make a thin flap from the extensor muscles, reflect it medially and suture it to the remains of the flexor muscles on the medial epicondyle.

MID-FOREARM AMPUTATION

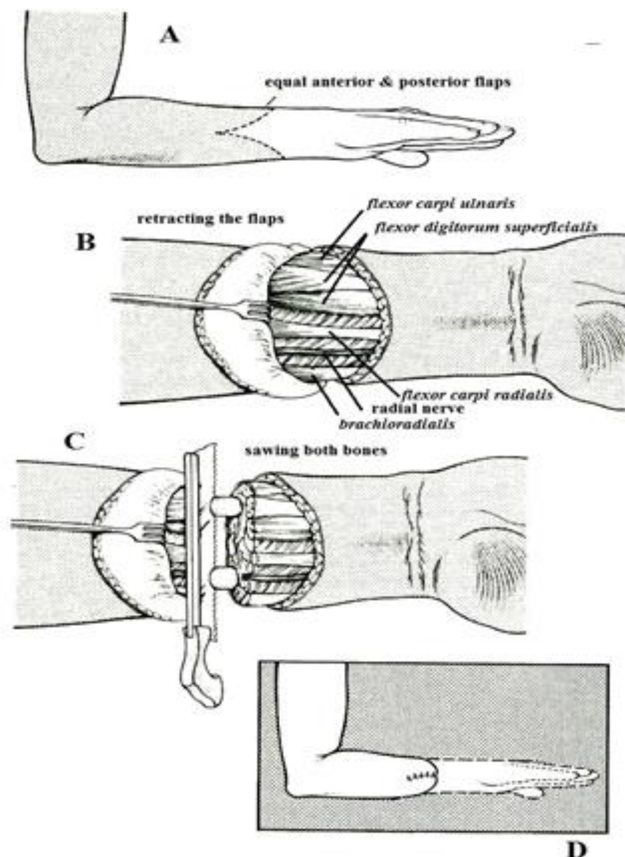

Fig. 35-12 FOREARM AMPUTATION.
Preserve as much length as you can. An elbow with even a short length of forearm is better than none. A, use equal flaps. B, reflect the flaps with the deep fascia. C, having divided the nerves and muscles, peel off the periosteum 1-2cm off the radius and ulna, and saw them cleanly through. D, final view.
After Rob C, Smith R, with the kind permission of Graham Stack.

Suture the muscle mass to cover the bony prominences and exposed tendons at the end of the humerus. Put sutures through the periosteum when necessary. Release the tourniquet, control bleeding and close the stump as in 35.3.

(d) Below-elbow and distal-forearm amputations (GRADE 2.5)

Abduct the arm on an arm-board or side-table, and place it supine. *If you cut the flaps with the arm prone, they will later be twisted.* Try to preserve as much length as possible.
If there is enough good skin, make equal anterior and posterior flaps (35-12A), as long as ½ the diameter of the forearm at the amputation site. If skin is scarce, make the best flaps you can.
Reflect the skin flaps with the deep fascia to the site of section (35-12B). Clamp, tie and cut the radial and ulnar arteries just above this site.
The radial and ulnar nerves run on the outside of their arteries, and the median nerve under *flexor digitorum profundus*; pull these nerves down gently, and cut them proximally.
Cut the muscles transversely distal to the site of section, so that they retract above it. Trim away all excess muscle. Saw the radius and ulna (35-12C) and smooth their cut edges. Suture the muscles closed over the bony stump. Release the tourniquet, control bleeding and close the stump (35.3).
If possible, amputate through the metacarpus or wrist, rather than higher up. Ischaemia is an exception. The circulation in the distal forearm is easily compromised, so if the arm is ischaemic, an amputation higher up the forearm may be better than one lower down.
If you have to amputate through the wrist, it may later be possible to make an ‘alligator mouth’ out of the 2 forearm bones (Krukenberg's operation), so that there is something to grip with.
Antero-posterior flaps are better than lateral ones, because the scar cannot retract between the bones.

(e) Wrist disarticulation (GRADE 3.1)

Make a long palmar and a short dorsal flap. Start the incision 1·5cm distal to the radial styloid, extend it distally towards the base of the first metacarpal.

Carry it across the palm, and then proximally to end 1·5cm distal to the ulnar styloid (35-13A,B). Make a short dorsal flap by joining the two ends of the palmar incision over the dorsum of the hand. Bring the dorsal flap distally level with the base of the middle metacarpal.

If skin is scarce, vary the design of the flaps. Reflect the flaps proximally with the underlying fascia to the wrist joint. Clamp, tie and cut the radial and ulnar arteries just proximal to the joint. Extend the incision proximally between *pronator teres* and *brachioradialis*, so that you can divide the median, ulnar, and radial nerves proximally. (If a neuroma forms here, it will be far from the scar.)

WRIST DISARTICULATION

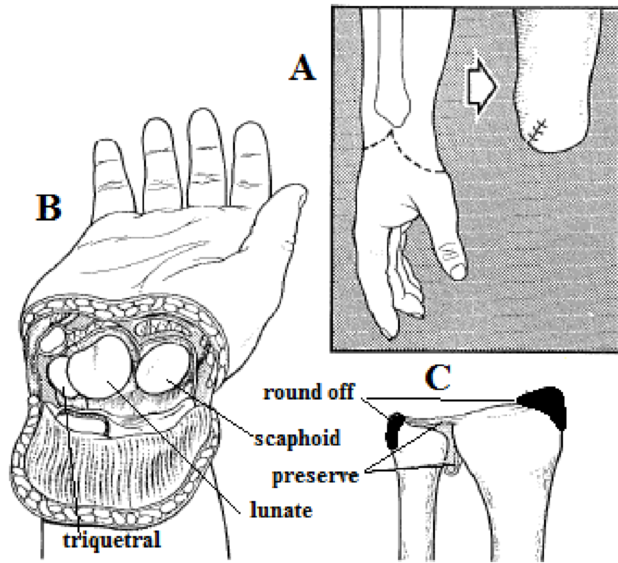

Fig. 35-13 DISARTICULATING THE WRIST.
A, make a long palmar and short dorsal flap. B, capsule of the wrist divided. C, round off the radial and distal styloids, and preserve the distal radio-ulnar joint and the triangular ligament.
After Campbell WD, Edmonson AS, Crenshaw AH (eds). Operative Orthopaedics. CV Mosby 6th ed 1980 with kind permission.

Cut all tendons just proximal to the wrist and let them retract into the forearm. Cut round the capsule of the wrist joint and remove the hand. Saw or nibble off the radial and ulnar styloids. Rasp the raw ends of the bones smooth and round. Release the tourniquet, control bleeding and close the stump (35.3).

CAUTION!
Don't injure the radio-ulnar joint or its triangular ligament. Damage to these will make rotation of the forearm difficult, and the joint will be painful.

(f) Transcarpal amputation (GRADE 3.1)

At this level, supination and pronation of the forearm, as well as flexion and extension of the wrist, are preserved and will improve overall function. Make a long palmar flap and a dorsal flap half as long. Reflect the flaps proximally to the site of bone section, and expose the soft tissues under them. Pull the finger flexor and extensor tendons distally, cut them, and allow them to retract into the forearm. Find the 4 wrist flexors and extensors (*flexor* and *extensor carpi radialis* and *ulnaris)*, free their bony insertions and reflect them proximally to the site of bone section. Find the median and ulnar nerves and the fine filaments of the radial nerve. Pull them distally and cut them well proximal to the site of section. Clamp, tie and cut the radial and ulnar arteries proximal to the site of section. Cut the remaining soft tissues down to bone. Saw across the carpal bones, and rasp all rough edges smooth. Anchor the tendons of the wrist flexors and extensors to the remaining carpal bones in line with their normal insertions to preserve wrist function. Release the tourniquet, control bleeding and close the stump (35.3).

(g) Finger amputations in general

Don't make the mistake of not amputating early enough or often enough. A stiff, painful, useless finger is often worse than no finger. If elaborate procedures are done to save it, not only is it likely to become stiff, but the neighbouring normal fingers are likely to become stiff too. *However, leave as much length in the thumb as possible*, because length here is more important than motion.

Most patients prefer a shorter finger covered with good skin than a longer one covered with poorer skin. Therefore, ask the patient if he uses his fingers for special skills. Ask how long he would prefer you leave the stump. *It is not easy to decide on the best.* Many patients (particularly labourers and even some surgeons) hardly miss an amputated finger, for example.

A flap from the volar surface of the finger is thus usually better than a graft. But, if making a flap means sacrificing too much length, a graft may be necessary. If possible, use full-thickness skin, although a split skin graft does sometimes hypertrophy and stand up to pressure remarkably. The sides and back of a finger are less important, so that a split skin graft is good enough here.

FINGER AMPUTATIONS

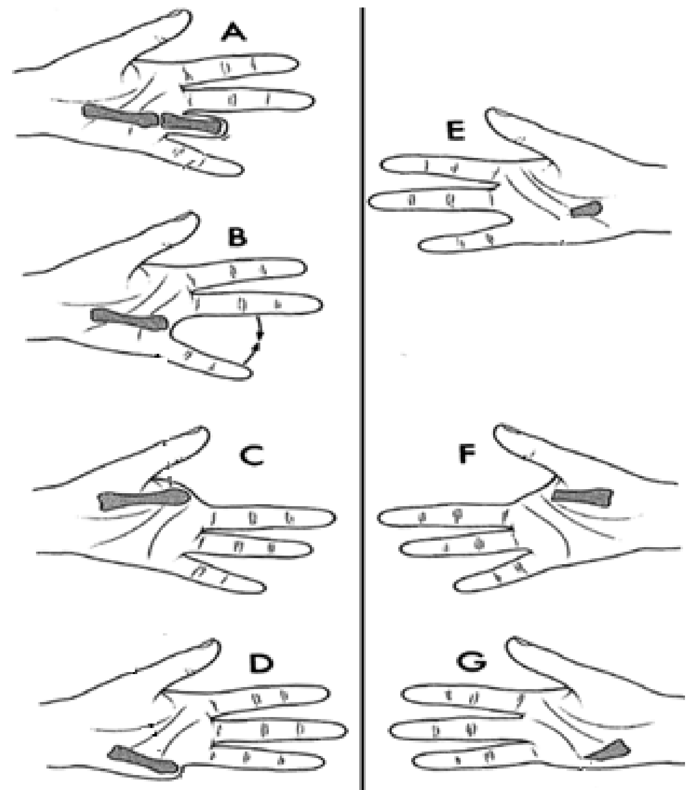

Fig. 35-14 FINGER AMPUTATIONS.
The amputations A-D are easier, uglier, and stronger than E-G. Amputating through a joint is easier than cutting through a metacarpal. A, phalangeal disarticulation, which keeps adjacent fingers apart. B,C,D, mcp disarticulations, where the mc head remains. E,F,G, mc shaft amputation removing the head.
Partly after Farquharson EL. Textbook of Operative Surgery E&S Livingstone 1969 with kind permission.

When amputating through the middle phalanx, try to retain the middle of the shaft, because the *flexor digitorum superficialis* is inserted into it. If you amputate more proximally than this, the patient will have no strength in his finger, although it will help to stop things falling out of his palm. If you are in doubt as to where to amputate, choose the more distal site. You can revise the amputation later.

An amputation through the mcp joint that does not remove the metacarpal head leaves a gap through which beans, rice or money can slip. It is usually said though that this (preferably leaving also a stump of phalanx) makes a stronger hand.

FINGER AMPUTATION INCISIONS

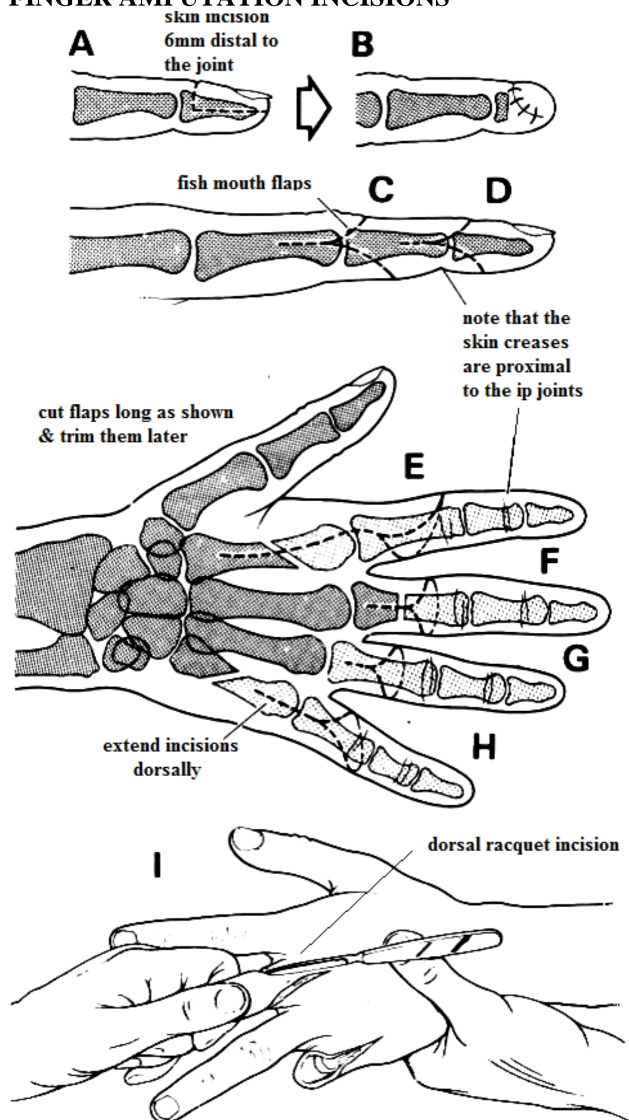

Fig. 35-15 INCISIONS FOR FINGER AMPUTATIONS.
Cut the flaps long; you can always shorten them later if necessary. A, incision preserving the base of the distal phalanx. B, final result. C,D, flaps for amputations through ip joints. E, ray metacarpal amputation of the index finger. F, proximal phalangeal amputation of the middle finger. G, mcp disartculation of the ring finger. H, ray metarcapal amputation of the little finger. I, mcp disarticulations.
Partly after Farquharson EL. Textbook of Operative Surgery E&S Livingstone 1969 with kind permission.

It is certainly an easier operation but a more elegant solution is a ray amputation through the shaft of a metacarpal below its head (35-14). This does narrow the palm, though, and reduces grip and pronation strength.

Retaining the stump of a phalanx (35-14A) further strengthens the hand by keeping the fingers apart and preventing them from deviating towards one another (35-14B). The stump will also help to stop small objects falling through the hand.

Removing an index finger causes less disability than you might expect, and even a surgeon can operate quite satisfactorily without his index finger (35-14F), provided the head of the metacarpal has been removed obliquely from the shaft. The middle finger soon learns to take over unless it is impeded by the index finger stump, which gets in the way. A finger missing from one edge of the hand (35-14F,G) is seldom a great disability, provided the head of the metacarpal is removed, so this is an elegant amputation. If great strength is not important, it is likely to be the best option.

The disadvantage of removing the metacarpal head is that it is a more difficult operation. If you are in doubt, leave the metacarpal head; you can always perform an amputation through the shaft later.

PROVIDE GOOD SKIN COVER

IF IN DOUBT, LEAVE THE METACARPAL HEAD

Use fish mouth flaps (35-15C,D). Plan them carefully in relation to the ends of the bones, and close them without tension, even if the finger has to be shorter. A shorter amputation with loose flaps is better than a longer one with tight shiny ones. Make the palmar flap a little longer than the dorsal one, because this will preserve the maximum amount of pulp tissue, which is very sensitive.

(1) PLANNED FINGER AMPUTATIONS

CAUTION! With all amputations:
(1) If in doubt, make all flaps a bit longer than you think you will need. You can always trim them later.
(2) Ask yourself if the skin of the finger you are amputating could help to close a nearby wound.
(3) *Don't suture the flexor and extensor tendons together over the bone*.
(4) Find the digital nerves and separate them from the vessels. This will be easier if you use a tourniquet. The nerves lie palmar to the vessels. Divide the nerves cleanly 1cm proximal to the volar flap. *Don't include them in the ligature of a vessel*. If possible, bury them in muscle or fat. Neuromas are sure to develop, but if you do this they will be away from the scar and the fingertip.
(5) When you amputate through a joint, trim down the condyles (where necessary), so as to avoid making a bulbous stump.

(2) INDEX FINGER MCP DISARTICULATION (GRADE 2.5)

This operation preserves the head of the metacarpal. Flex the index finger and mark out the incision on its knuckle (35-15E,16A), so that the radial flap is larger and extends nearly halfway down the shaft of the proximal phalanx. It must be long enough to meet the web of the next finger without tension.

Deepen the incision dorsally until you can see the extensor tendon, then cut it and turn it distally. Separate the extensor expansion round the base of the proximal phalanx (35-16B). Cut the collateral ligaments. Cut the flexor tendons as far proximally as you can (35-16C). Cut the rest of the soft tissues, tie the vessels, shorten the digital nerves, and remove the finger. Reduce the bulk of the scar by trimming away the ligaments around the metacarpal head (35-16D), the volar plate, the collateral ligaments, and the flexor sheath.

N.B. When you cut flaps through the webs, use a complete web on one side and no web on the other side. *Don't use 2 half-webs each side.*

INDEX FINGER MCP DISARTICULATION

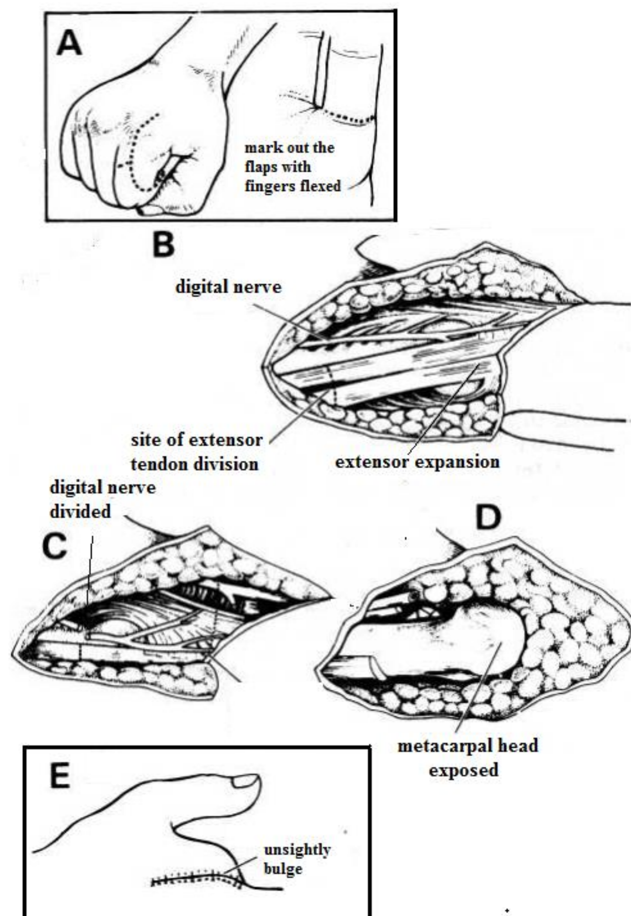

Fig. 35-16 INDEX FINGER MCP DISARTICULATION.
A, mark out the incision with the fingers flexed. B, expose the extensor expansion and split it longitudinally. C, divide the digital nerves. D, expose the metacarpal head and remove the distal part of the finger. E, final result with the metacarpal bulge.
With the kind permission of Peter London.

(3) INDEX FINGER METACARPAL RAY AMPUTATION (GRADE 3.1)

If an index finger stump will be in the way, make a dorsal racquet incision (35-17A). Keep the radial side of the flap long. You may need every millimetre. Preserve the subcutaneous tissue with the flap, and cut the extensor tendons (35-17B).

Reflect the periosteum for 1cm with an elevator, and cut the metacarpal across at the junction of its proximal and middle ⅓ (35-17C), then bevel it dorsally and radially. Separate the *interossei* and *lumbricals* from the shaft of the 2nd metacarpal. Deepen the palmar incision, and remove the flexor tendon sheath. Shorten the flexor tendons as deep in the palm as you can. Cut the vessels and nerves distal to the branches of the palmar skin. Turn the palmar flap medially, and close the skin without tension.

INDEX FINGER METACARPAL RAY AMPUTATION

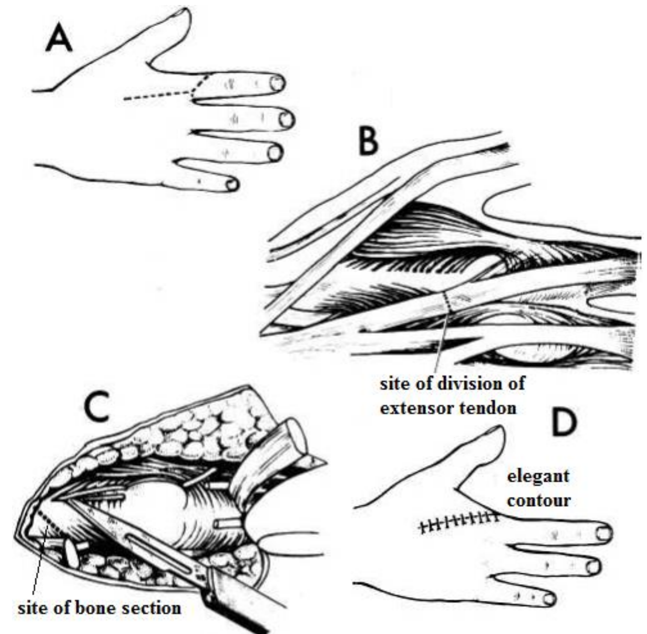

Fig. 35-17 INDEX FINGER METACARPAL RAY AMPUTATION.
A, dorsal longitudinal incision with a circular incision at mid-proximal phalanx level, leaving the skin intentionally long. B, divide the extensor tendons. C, cut through the 2nd metacarpal at an angle. D, final result with a smooth thenar bridge.
With the kind permission of Peter London.

(4) MIDDLE AND RING FINGER METACARPAL RAY AMPUTATIONS (GRADE 3.1)

Leave the base of the metacarpal, and suture the deep transverse carpal ligaments on either side of the missing metacarpal. *Failure to do this will result in a weak grip.*

CAUTION! Don't bandage the other fingers with the amputated one or they may become stiff. Encourage moving them a day or two after the amputation. Use any convenient occupational therapy, such as rolling bandages, to make sure usage of the fingers starts soon post-operatively.

DON'T SUTURE A FINGER STUMP UNDER TENSION

(5) LITTLE FINGER METACARPAL RAY AMPUTATION (GRADE 3.1)

If a little finger is stiff, and gets in the way, hindering hand function by catching on objects, make a dorsal racquet incision (35-15H); preserve the insertion of *extensor carpi ulnaris* on the base of the 5th metacarpal, and the hypothenar muscles. These provide important padding for the hand.

(6) PROXIMAL PHALANX AMPUTATION (GRADE 2.3)

Try to amputate through the neck of a proximal phalanx. *If possible, preserve even a small stump of it.* This is easier than amputating through the mcp joint. Cut appropriate flaps (35-15F).

(7) PIP FINGER DISARTICULATION (GRADE 2.3)

Do this as for a dip disarticulation below, but cut appropriate flaps (35-15C).

(8) MIDDLE PHALANX AMPUTATION (GRADE 2.3)

Proceed as for the distal phalanx below, but amputate through the mid-shaft of the middle phalanx if possible, because this retains the attachment of the *flexor digitorum superficialis* tendon to its sides, and so function at the pip joint.

(9) DIP FINGER DISARTICULATION (GRADE 2.3)

Incise the skin in the mid-lateral lines on either side of the neck of the middle phalanx. Join these 2 incisions to make a dorsal flap at the level of the joint, and a palmar flap 1cm distal to the flexor crease (35-15D). Dissect back the fibro-fatty tissue to find the digital vessels and nerves, the extensor expansion, and the flexor tendon in its sheath. If you cannot preserve tendon insertions, divide them and let them retract; *never suture the extensor to the flexor tendon over the bone stump* because of the 'quadriga effect' where the flexed amputated finger reaches the palm before the other fingers, and so weakens the grip of the hand.

Separate the nerves from the vessels, and divide the nerves proximal to the vessels. Tie the vessels without including the nerves. Complete the amputation by cutting the capsule and the collateral ligaments. Preserve the articular cartilage, which provides a 'shock pad', and close the wound.

(10) DISTAL PHALANX AMPUTATION (GRADE 2.3)

If possible, preserve the base of the distal phalanx, because of the tendons which are inserted there. Also try to preserve as much pulp as possible.

If <¼ of the nail remains, a patient will be troubled later by the irregular hooked remnant, so excise the whole nail bed.
If you have to remove some of the pulp, *don't make a flap; place a non-stick dressing and allow the wound to heal on its own.*
If you can preserve the pulp, flex the terminal joint and make a transverse incision across its dorsal surface 6mm distal to the joint (35-15A). Continue the incision as far as the sides of the phalanx, and deepen it down to the bone. Cut a long rectangular (*not pointed*) palmar flap almost to the tip of the finger. Dissect the flap off the front of the phalanx and reflect it forwards. Cut the phalanx with bone nibblers close to its base and smooth its edges. *Take care to remove bone chips and devitalized bone.*
Trim protruding condyles and the anterior part of the phalanx to make a less bulbous stump; then fold the flap and close the wound (35-15B).

35.5 Hip disarticulation

This procedure is rarely indicated. It may be necessary for advanced sepsis and malignancy; the more aggressive hindquarter amputation may be needed for malignancy.

HIP DISARTICULATION (GRADE 3.2)

Initial preparation is as for an above-knee disarticulation (35.6). Mark out a long posterior flap beforehand: make it as long as you can.

HIP DISARTICULATION

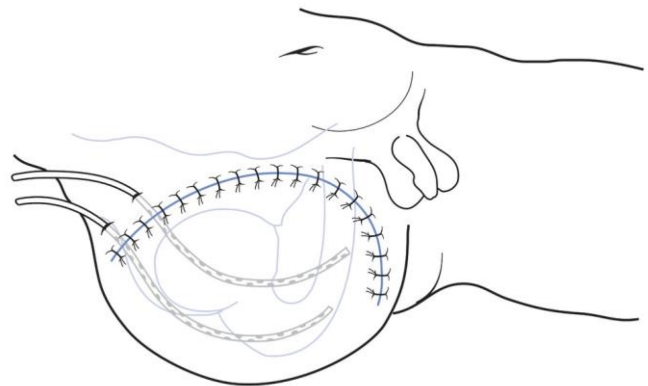

Fig. 35-18 HIP DISARTICULATION FINAL RESULT.
Create a long posterior flap. Place two suction drains. The suture should be anterior, just above the inguinal ligament.
After Greitemann B, Brückner L, Schäfer M, Baumgartner R. Amputation und Prothesenversorgung. Thieme, 4th ed. 2016.

Begin the incision 1-2 cm distal to the inguinal ligament. Expose the femoral vessels (49.3) and tie them. After resection of the anterior muscle group, open the joint capsule and disarticulate the hip by forced external rotation. Then create your dorsal flap as in a below-knee amputation (35.7). You can always trim the flap later if it is too long. Identify the sciatic nerve but *don't pull it*; cut it as far proximal as possible.

Beware of the accompanying artery, which may bleed profusely; if packing for 5mins does not control it, separate the artery off carefully, and tie it. Fill the acetabulum with the gluteal muscles. Leave closed drains and aim to remove these at 24-48h. Try to place the scar anteriorly, outside the weight-bearing zone, if the soft tissue envelope allows it (35-18).

35.6 Above-knee (thigh) and through-knee amputation

Whenever possible, try to save the knee joint. A knee disarticulation is better than an above-knee amputation, especially in children, where this preserves the epiphyses. However, before planning a knee disarticulation, consult if a suitable prosthesis is available.

The loss of the knee needs much more effort and energy in walking because the weight-bearing is in the groin instead of the stump. Make the femoral stump as long as possible, ≥10cm from the greater trochanter.

(a) Gottschalk procedure (GRADE 3.2)

Managing a very short femoral stump is very difficult as the femur stump retracts into abduction and flexion. To avoid this, detach the *adductor magnus* at its insertion, and wrap it round the femoral stump, and reattach it with non-absorbable suture to the lateral surface of the femur, using fine holes drilled through the bone, keeping the muscle under tension.

EFFECTS OF A SHORT FEMUR

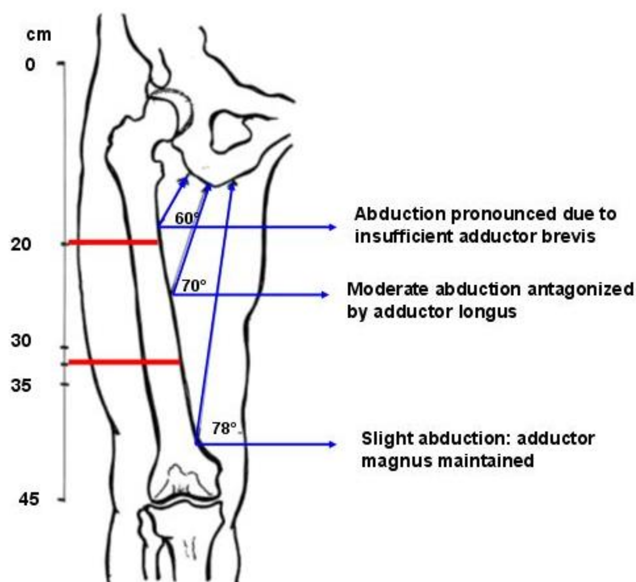

Fig. 35-19 EFFECTS OF A SHORT FEMUR.
The longer the stump, the better the result. A short stump requires much more energy to walk.
After Giannou C, Baldan M, Molde, Á. War Surgery, ICRC Geneva 2013.

Provided an above-knee amputation stump avoids the condyles of the femur, the longer it is the better, although at least 10cm length above the opposite knee is needed for fitting an artificial knee joint.

Be sure to exercise the stump immediately after the amputation, so as to strengthen:
(1) the remaining adductor muscles, and prevent the prosthesis moving outwards on walking,
(2) the extensors, because they will have to extend both the hip and the prosthesis which is to form the knee.

An amputee will also have to learn to balance with the hip instead of the foot muscles.

Study the anatomy of the leg carefully, so that you can find and tie the femoral artery under *sartorius* (35-20).

(b) Above-knee amputation (GRADE 3.1)

Administer an enema before the operation to empty the rectum. Catheterize the patient. Enclose the distal leg as far as the knee in a polythene bag, so as to isolate it from the field of operation. Preferably use spinal anaesthesia. Place a sandbag under the buttock on the side to be operated on.

Prepare the thigh with antiseptic. Raise the leg so that you can prepare the upper thigh and groin. Put a drape behind it and another one in front.

Plan to leave as much (≥25cm) of the femur from the tip of the greater trochanter (35-20B) as you can. Mark equal anterior and posterior flaps.

If there is insufficient viable skin on one side, make the contralateral flap longer rather than amputating more proximally.

Cut and reflect the flaps (35-8). Deepen the medial end of the anterior flap so as to expose the femoral artery in its canal under the *sartorius* muscle. Transfix, tie and divide the femoral artery and vein. Identify the femoral nerve, cut it clean and allow it to retract.

Begin the incision in the *quadriceps* along the line of the anterior flap, and bevel it proximally to the site of section, so as to make a muscle flap not more than 1·5cm thick.

Ask your assistant to raise the leg while you cut across and bevel the posterior muscles distal to the site of section, in the same way as the anterior ones, so they retract. Trim away any excessively bulky muscle masses. Find, clamp, and tie the profunda femoris artery on the posterior aspect of the femur. Find the sciatic nerve under the hamstring muscles, separate it from its bed without tension, cut it cleanly c.5cm proximal to the site of bone section. Tie the artery that accompanies the sciatic nerve, but *not the nerve itself* (35.5).

ABOVE-KNEE AMPUTATION

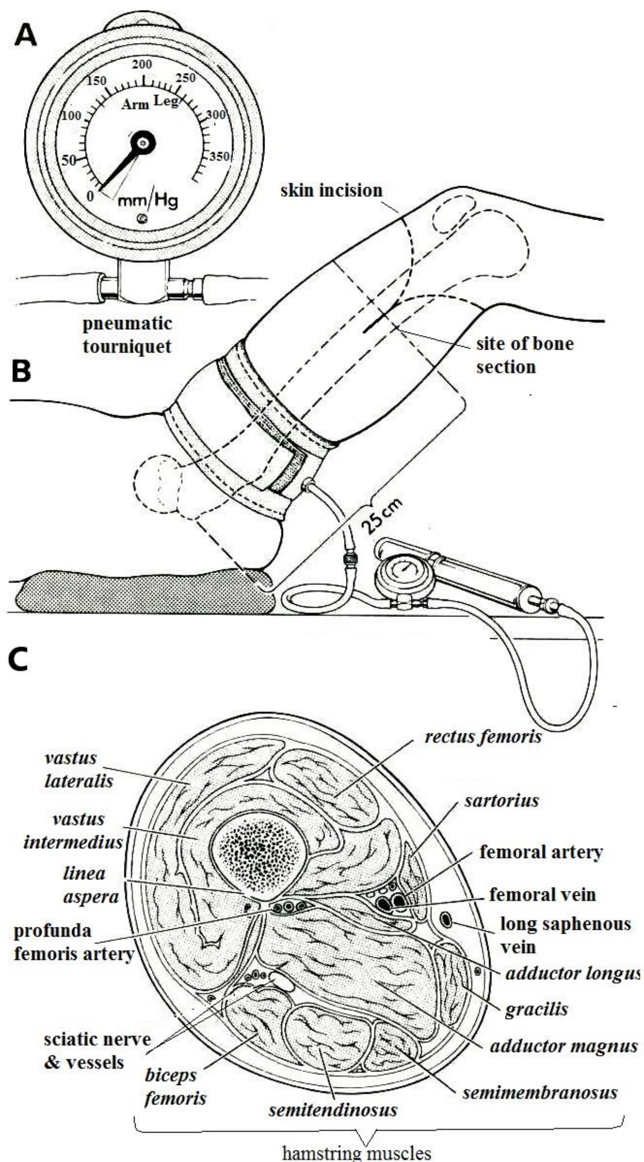

Fig. 35-20 ABOVE-KNEE AMPUTATION.
Provided the stump avoids the condyles of the femur, the longer it is the better. ***Don't use a tourniquet in the presence of ischaemia. Take care not to exceed correct inflation pressures and ischaemia time*** (3.4).

Elevate the periosteum 0.5cm only all round the femur (35-8D) and saw it across immediately distally. Remove the leg. Rasp away and make the end of the bone smooth. Control the bleeding, suture the anterior muscle flap over the end of the bone, and suture its fascia to the posterior fascia of the thigh. Trim away any excess muscle or fascia. If you insert a drain, put it deep to this flap. Close the wound (35.3). Apply plaster over the bandage.

(c) Difficulties with above-knee amputation

If a haematoma forms within the wound, open it up as much as necessary and evacuate the haematoma, otherwise it is very likely to become infected.

If the wound becomes septic, open it up and debride any dead tissue; you may need to re-fashion a stump higher up. This time, *use delayed primary closure.*

If bone protrudes through the stump, re-fashion it making sure the muscles are long enough to cover the bone end, and insist on exercises to prevent atrophy of the *quadriceps* muscle.

If the patient has to wait a long time for a prosthesis, pad the stump well, make a cast round it and fit it snugly into a sawn-off thinned-down crutch. Keep it in place with more plaster bandages. This will facilitate walking until the permanent prosthesis is ready. *If you don't do this, the quadriceps will atrophy and the patient may never walk again.*

If you have to amputate both legs above the knees, consider the possibility of getting short 'stumpy' prostheses for both legs (60-3). This may be preferable to a wheelchair, and they will be easier to balance with than prostheses of the standard length. The centre of gravity will however be closer to the ground, and two short sticks are needed. These 'stumpy' prostheses are much easier to make, because they don't have jointed knees, and need only be sockets with simple boots on. Keep them in place with cords over the shoulder.

(d) Knee disarticulation (GRADE 2.5)

Knee disarticulation is one of the easier amputations. It preserves the distal femoral epiphysis in a child, and so allows the stump to grow. It cuts little muscle and no bone, so is quick with little bleeding, and infection is unlikely. If performed with lateral flaps, it is a good amputation for ischaemia.

Furthermore, it allows the normal weight-bearing end of the bone to carry the weight of the prosthesis. It is preferable to amputating at thigh level. Prostheses are easier to use than for above-knee amputations.

(e) Through-knee amputation (GRADE 3.1)

Consider a through-knee amputation in any frail and elderly patient unsuitable for a below-knee amputation.

Cut a long, broad anterior flap, and a shorter posterior flap (35-21A). Mark these out with the knee flexed. Start the anterior flap on the medial side 1cm proximal to the knee joint line. Extend it 10cm below this, crossing the leg c.5cm below the tibial tuberosity, and then curve it proximally to end at a point on the lateral side of the knee opposite to where you started. Start the posterior flap at this point, and extend it so it crosses the back of the leg 5cm below the popliteal flexor crease. Then curve it proximally on the medial side to meet the starting point of the anterior flap.

CAUTION! Don't fashion an anterior flap if it might have an inadequate blood supply. If so, cut lateral and medial flaps, the latter 2cm longer than the former, beginning just above the tibial tuberosity.

Get your assistant to hold the knee half-flexed. Make the anterior incision down to bone, and the posterior to deep fascia. Lift the edge of the posterior flap and

divide the medial hamstrings from the tibial tuberosity. This exposes the main trunk of the popliteal artery: doubly ligate this and divide it. Tie off the popliteal vein. Behind the artery, find the tibial nerve, draw it gently into the wound, and cut it clean (35-21D).

N.B. Divide the popliteal artery below its superior genicular branches which supply the soft tissues of the knee. These arise high in the popliteal fossa.

Reflect the anterior flap upwards with its underlying fascia to reveal the patellar tendon. Cut this at its insertion onto the tibial tuberosity. You can then lift up skin, fascia, patellar tendon, lower part of the capsule and the synovial membrane of the knee as a single flap proximally as far as the joint line.

KNEE DISARTICULATION

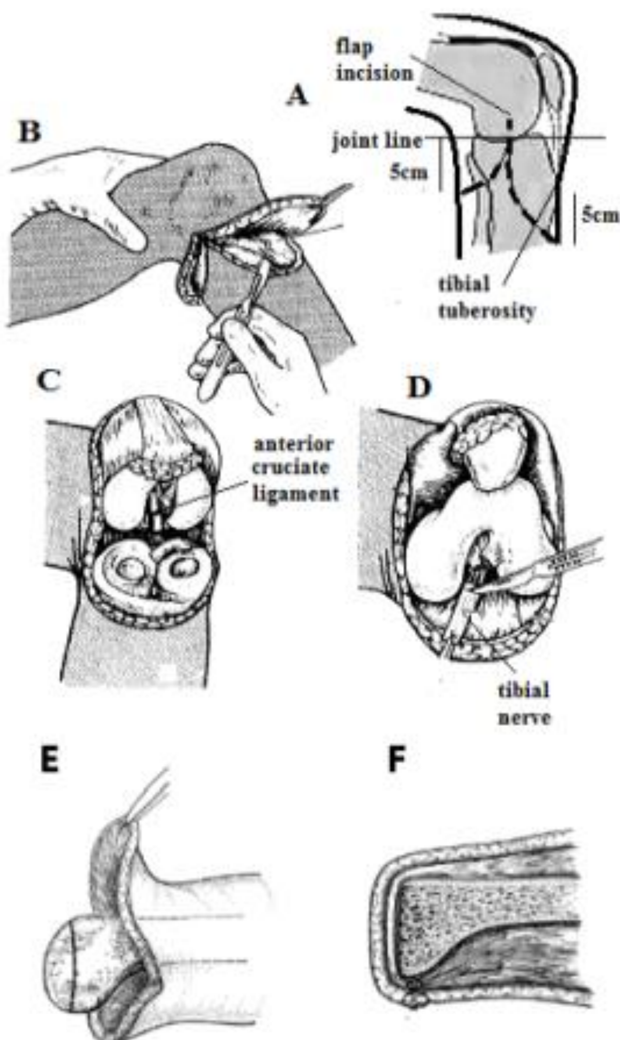

Fig. 35-21 KNEE DISARTICULATION.
A, mark out the flaps, with the knee flexed, starting 1cm above the joint line. ***If the blood supply for a long anterior flap is bad*****, make medial and lateral flaps. B, raise the flaps. C, cut the cruciate ligaments and the posterior joint capsule and leave the patella tendon anteriorly between the retinaculum. D, cut the tibial nerve. E, cut off the condyles. F, close the stump with the scar posteriorly.**
After Campbell WD, Edmonson AS, Crenshaw AH (eds). Operative Orthopaedics. CV Mosby 6th ed 1980 with kind permission.

Now expose and divide the *biceps femoris* tendon and the iliotibial tract on the lateral aspect of the knee. Find the common peroneal nerve deep to the *biceps femoris* tendon, cut it clean proximally so it retracts above the level of the amputation. Then reflect the short posterior flap and complete division of the capsule and ligaments of the knee round the whole circumference of the joint below the menisci. Detach the heads of *gastrocnemius* from the femoral condyles, and remove the lower leg.

CAUTION!
(1) The popliteal vessels lie very close to the posterior surface of the knee joint. If you have already tied them high up, they should not be in danger.
(2) *There is no need to disturb the articular cartilage of the femur, or to remove the patella*.

Leave the patella anteriorly between the reticnaculum, where it is perfectly stabilized. (*Don't remove it.*) It improves the rotational stability of the stump for fitting a prosthesis (35-21E). Nibble or saw off the medial and lateral sides of the condyles. Remove the tourniquet (if present), control bleeding, drain and close the stump with the suture line lying posteriorly (35-21F).

(f) Gritti-Stokes amputation (GRADE 3.1)

A useful variation which creates a bony weight-bearing surface, allowing the patient to crawl, is the Gritti-Stokes amputation. Saw off the end of the femur *above* the condyles at 30°, and saw the posterior surface of the patella off flat, sloping upwards and backwards (*without detaching it from its tendon*). Then bring the patellar tendon round and fix the undersurface of the patella to the joint capsule and bony stump of the femur. *You don't need wires to do this.*

GRITTI-STOKES AMPUTATION

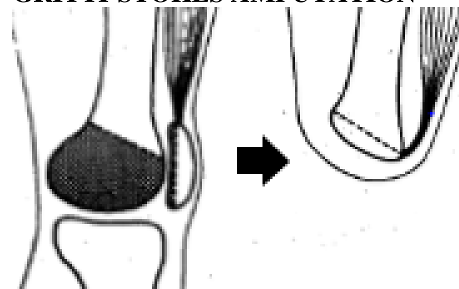

Fig.35-22 MODIFIED GRITTI-STOKES AMPUTATION.
Secure union of the patella to the femoral stump by a slanted bone cut.

35.7 Below-knee (lower leg) amputation

With a good prosthesis, an amputee can walk, run and climb almost normally, even if he is a bilateral amputee. The best length of stump for a prosthesis is 12-18cm below the tibial tuberosity.

TYPES OF PROSTHESES

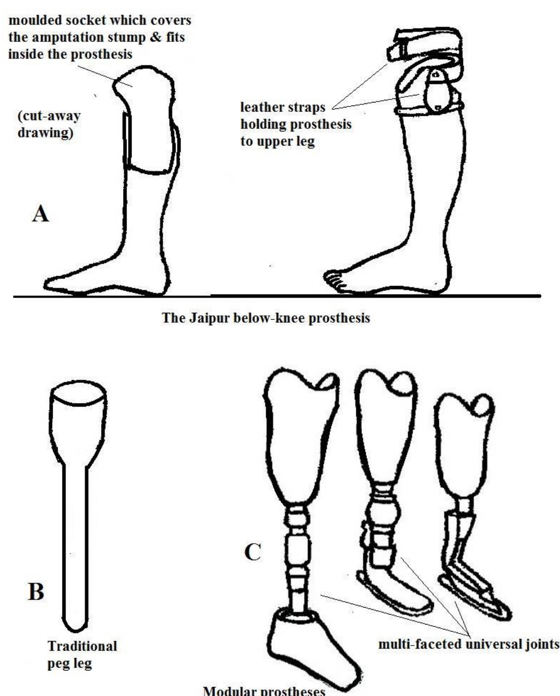

Fig. 35-23 TYPES OF PROSTHESES.
A, the Jaipur foot. B, the peg leg. C, the modular jointed prosthesis.
Kindly contributed by George Poulton.

The Jaipur type of prosthesis (35-23A) is cheap, versatile and readily available. For the traditional type of peg leg (35-23B), a shorter 10cm stump is needed. An ultra-short lower leg stump is better than no functional knee joint. The shortest possible stump must end just below the tibial tuberosity, where the patellar tendon inserts.

CAUTION! Don't amputate below the muscle area of the calf, because the tissue here has a poor blood supply.

CAUTION! Don't amputate below the knee if there is a fixed flexion deformity of the knee >30º from full extension or *if the popliteal pulse is not palpable* as the flap will depend on the *profunda femoris* artery.

(a) Below-knee amputation (GRADE 3.2)

Initial preparation is as for an above-knee amputation (35.6). Suspend the knee over a screen bar attached to the operating table for ready access; if you cannot do this, place an inverted bowl under the lower leg. Prepare the skin right up to the groin, in case you need to convert to a through- or above-knee amputation (35.6). Make sure you have consent for this.

Mark the skin, ensuring a long posterior flap (35-24A). If you are not certain of the geometry of the flaps, cut them too long rather than too short. Measure the circumference of the leg usually 10-12cm (≥5cm) below the tibial tuberosity, and divide this length into thirds. Start the skin incision anteriorly at this point and continue transversely round each side of the tibia ⅓ of the way round; then continue down the leg the same length (usually 4cm below the anterior incision), and finally join both incisions posteriorly.

If a long posterior flap is not possible because of dubious skin vascularity, the skew flap is an alternative. It also moves the resultant scar away from the anterior crest of the tibia, on which a prosthesis socket rubs, and produces a more cylindrical stump, easier for fitting a prosthesis. In fact, the skew flap is actually a short posterolateral and a longer anteromedial flap based on a longitudinal leg axis tilted 15º laterally. Mark a fish-mouth incision 2cm lateral to the subcutaneous crest of the tibia (35-24C), with the length of the flap ¼ the circumference of the leg.

If you have to make a very short stump in the upper tibia, remove the fibula completely to avoid a tibiofibular disassociation.

BELOW-KNEE AMPUTATION

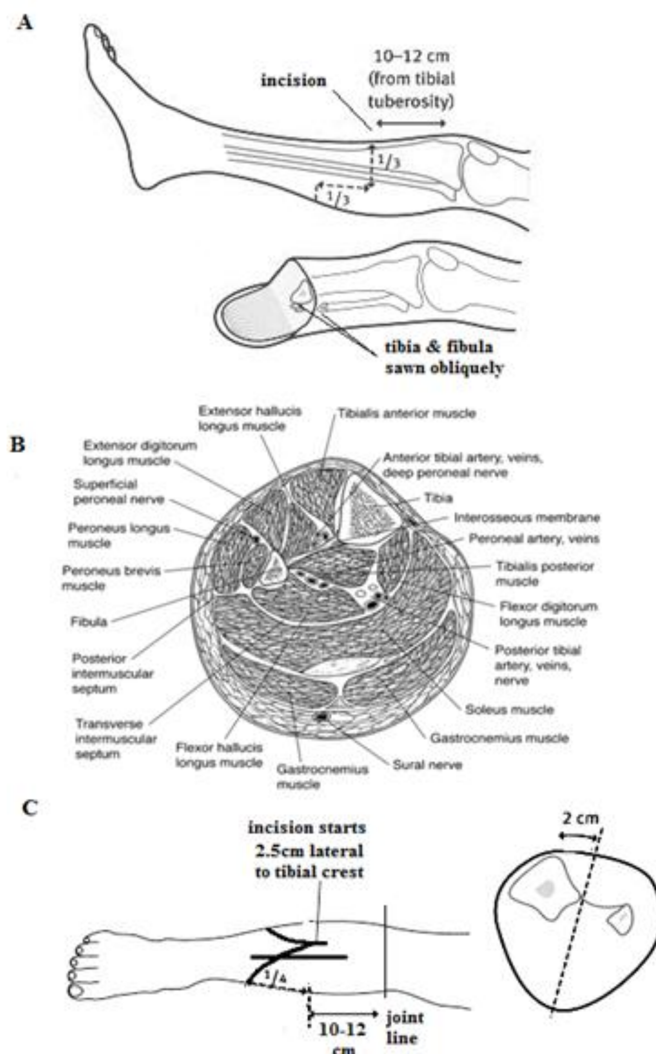

Fig. 35-24 BELOW-KNEE AMPUTATION.
A, incision using a long posterior flap. Mark the skin on either side of the tibia ⅓ of the total circumference at a point 10-12cm below the tibial tuberosity, and then mark down along the leg the same length. B, cross-section through the lower leg. C, skew flap showing apex of unequal fish-mouth incision placed 2cm lateral to the tibial crest 10-12cm below the joint line, with a flap length ¼ the circumference of the leg. The result is a suture line at 15º tilt to the leg axis.
A,C, After Marshall C, Stansby G. Amputation and rehabilitation. Surgery 2010;28(6):284-7. B, After Fraipont MJ, Adamson GJ. Chronic exertional compartment syndrome. J Am Acad Orthop Surg 2003; 11(4):268-76.

Hold the distal tibia forwards with a strong hook inside its medullary canal, and expose the posterior tibial and peroneal vessels lying under *tibialis posterior*; ligate and divide these and cut the posterior tibial nerve clean, allowing it to retract.

Then slice obliquely through the calf muscles to reach the posterior skin incision; a large sharp amputation knife is best for this, giving a clean cut. Remove most of the *soleus* muscle as it plays no part in the vascularity of the myoplastic flap. Bevel the anterior corner of the tibia at 45º and smooth the edges with a rasp.

Then turn the flap anteriorly and suture it over the tibial stump. Secure haemostasis and suture the deep fascia of the posterior flap to the tibial periosteum. It is important that there is absolutely *no tension* in this suture.

Close the stump *again without tension*. *Don't cut off 'dog ears'.*

If there would be tension at this point, divide the tibia and fibula more proximally; you may find you have to divide the vessels and nerves again proximally also.

Avoid a knee flexion contracture at all costs! The normal tendency is to flex the knee, but you must keep it extended and elevated on a pillow or Braun-Böhler frame to decrease oedema.

If you have no frame, apply a plaster back-slab in the immediate post-operative period, and later only at night. Instruct the patient to keep the knee in extension on a pillow, to lie prone in bed as often as possible, and to avoid hanging the leg over the side of the bed or over the hand-piece of the crutches.

(b) Difficulties with a below-knee amputation

If a haematoma forms within the wound, open it up as much as necessary and evacuate the haematoma, otherwise it is very likely to become infected.

If the wound becomes septic, open it up and debride any dead tissue; you may need to re-fashion the stump if there is enough length. However, it usually means making a through- or above-knee amputation. This time, *use delayed primary closure.*

If the wound is repeatedly septic, and you have excluded diabetes, HIV, and removed any foreign bodies, think of TB. *Send samples NOT in formalin.*

If bone protrudes through the stump, re-fashion it making sure the tibia is bevelled and the myoplastic flap is long enough to cover the bone end, and insist on exercises to prevent atrophy of the muscles.

If a fixed knee flexion contracture develops, make a through-knee amputation, or cut the stump even shorter and then fit a peg leg.

35.8 Ankle and foot amputation

Always try to save as much length of the leg as you can. *Don't perform an amputation in the distal ⅓ of the tibia*, as you won´t get a proper stump. If you cannot save the heel, perform a below-knee amputation. However, if you can save the heel, your patient will be able to walk short distances (*e.g.* to the toilet at night) without a prosthesis. In communities where people walk barefoot or farmers work in muddy fields and rice paddies, a heel-preserving amputation, which is an end-bearing stump, is often preferable. Amputation at a higher level will definitely involve the use of special footwear, crutches or a prosthesis.

However, the important elements are preservation of the heel and its special weight-bearing skin. So make sure the plantar flap reaches the anterior incision snugly; it should not be under tension, but also not too loose or the heel will capsize off the end of the leg stump.

TYPES OF HINDFOOT AMPUTATIONS

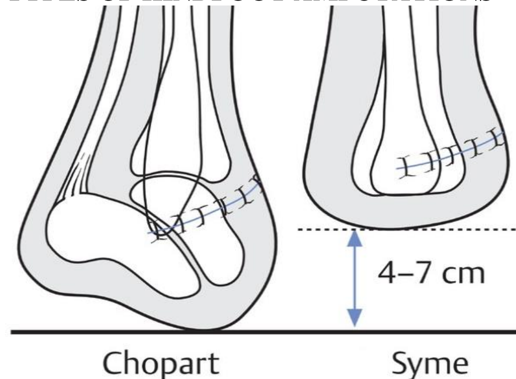

Fig. 35-25 TYPES OF HINDFOOT AMPUTATIONS.
Syme´s amputation is the most technically demanding. Chopart amputation requires close follow-up.
After Greitemann B, Brückner L, Schäfer M, Baumgartner R. Amputation und Prothesenversorgung. Thieme, 4th ed. 2016.

(a) Chopart amputation

In the Chopart amputation, you disarticulate the foot between the hindfoot (talus and calcaneus) and the midfoot (midtarsal disarticulation). You lose less length than in the Syme's operation (35-25). But *beware of developing an equinus deformity* because of the isolated pull of the Achilles tendon. Avoid this by fixing the *tibialis anterior* to the talus and the *peroneus longus* to the calcaneum. So dissect these tendons out carefully. Then put the stump in a cast for 6wks with dorsiflexion.

METHOD
Apply a tourniquet to the thigh (3.4), support the calf with a towel, and let the ankle protrude over the end of the table. Stand beyond the end of the table facing the foot. Mark out the flaps with a permanent marker. Hold the ankle at 90°.

Start the incision 2cm below the distal tip of the lateral malleolus. Bring it over the front of the ankle, level with the distal end of the tibia, to a point opposite to where you started, 2cm inferior to the tip of the medial malleolus in a curved moon shape. Then, complete the incision under the sole of the foot, well anterior to the heel pad.

Carefully dissect out the *tibialis anterior* and *peroneus longus* tendons, divide them as far distally as possible, and hold each out of the way with a stay suture.

Plantarflex the foot and disarticulate between the hindfoot bones (talus and calcaneum) and the midfoot bones (navicular and cuboid). Take care not to damage the plantar flap by retracting this out of the way.

Tie and cut the posterior tibial artery and vein just proximal to the cut distal edge of the heel flap. Divide the posterior tibial nerve adjacent to the artery. Tie the anterior tibial artery in the anterior flap similarly. Then remove the foot.

Drill holes anteriorly into the talus and calcaneum and fix the 2 tendons in place with a screw. Try to get the balance right. You may need to lengthen the Achilles tendon (32.9). Then release the tourniquet, control bleeding, close the wound and put in POP in dorsiflexion for 6wks.

FIXATION OF TENDONS IN THE CHOPART AMPUTATION

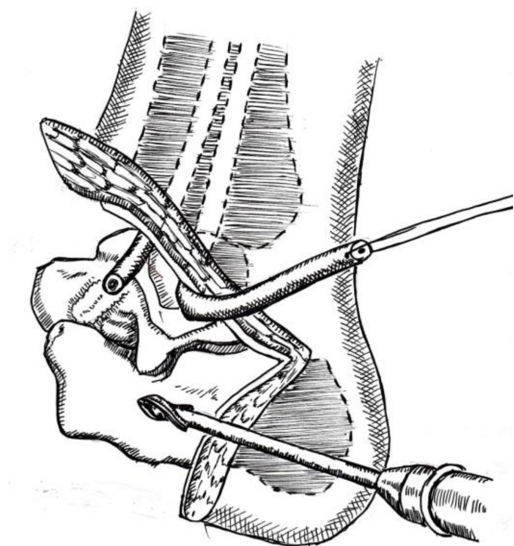

Fig. 35-26 FIXING THE TENDONS IN CHOPART'S AMPUTATION.
With the *tibialis anterior* tendon already fixed in the talus with a screw, drill a hole in the calcaneum to fix the *peroneus longus* tendon.

(b) Syme's ankle disarticulation (GRADE 3.4)

It is possible to disarticulate the ankle and adapt the stump so that it can be weight-bearing (the Syme's amputation). You need to remove all the bones of the foot and saw off the malleoli, so that the end of the tibia is flat. And you have to dissect the full-thickness heel pad very carefully subperiosteally from the calcaneum.

The patient will be able to walk about his house on it, without a prosthesis or crutches. For longer distances he can wear a simple and durable 'elephant boot'.

SYME'S FOREFOOT AMPUTATION

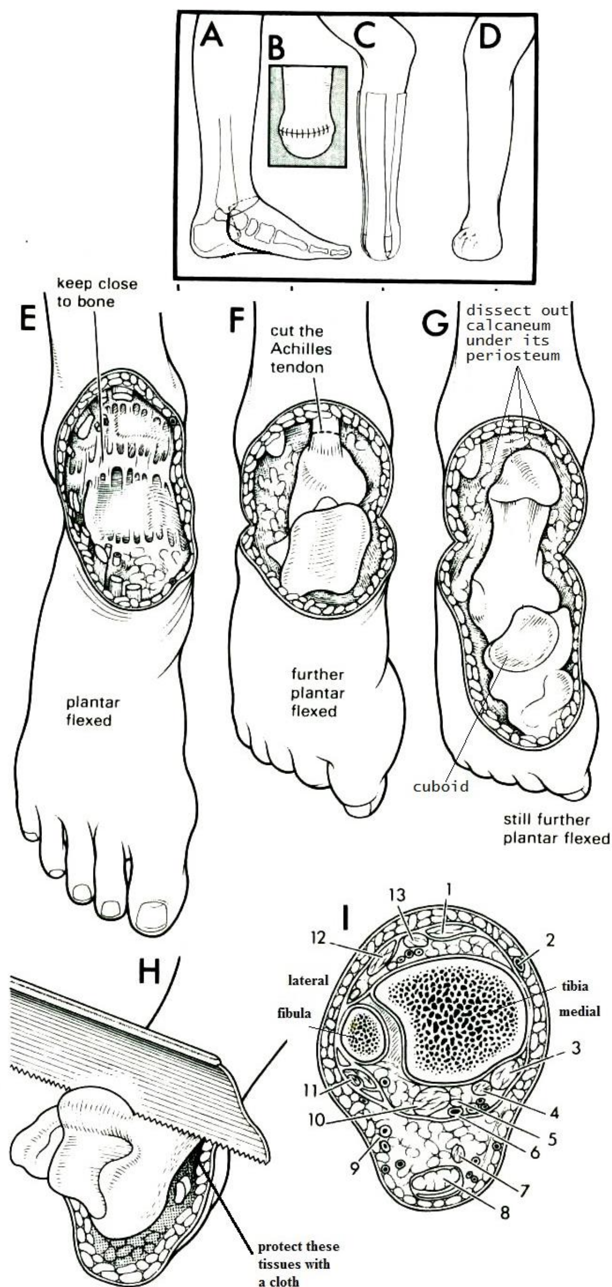

Fig. 35-27 SYME'S AMPUTATION.
A, keep the flap as long as you can (you can always reduce it later). B, completed stump immediately after suture. C, stump held in place with strapping post-operatively. D, ultimate appearance of the stump. E, expose the ankle joint and cut its ligaments. F, further plantar flex the foot and cut its Achilles tendon. G, extreme flexion allows the calcaneum to be dissected out of its surrounding tissues subperiosteally. H, saw through the lower end of the tibia, protecting the soft tissues.
I, cross-section of the ankle joint with (1) *tibialis anterior* tendon, (2) great saphenous vein, (3) *tibialis posterior* tendon, (4) *flexor digitorum longus* tendon, (5) tibial nerve, (6) posterior tibial artery and vein, (7) *plantaris* tendon, (8) Achilles tendon and its overlying bursa, (9) small saphenous vein, (10) *flexor hallucis longus* tendon, (11) *peroneus longus* and *brevis* tendons, (12) *extensor digitorum* tendon, and (13) *extensor hallucis longus* tendon.
After Campbell WD, Edmonson AS, Crenshaw AH (eds). Operative Orthopaedics. CV Mosby 6th ed 1980 with kind permission.

The distal tibial epiphysis is preserved, so it is also a good amputation for a child. It is an excellent amputation if well done, but it is also the most difficult of the amputations we describe. Nonetheless, if a Syme's amputation fails, a below-knee amputation is still possible.

CONTRAINDICATIONS
(1) Arterial disease, unless this is strictly confined to the distal part of the foot. At least one of the posterior tibial or dorsalis pedis pulses should be palpable.
(2) Infection (Syme's amputation has a special posterior flap and is not suitable for delayed primary closure).
(3) If the skin over the Achilles tendon is too thin.

METHOD
Begin as for the Chopart amputation above. Cut all structures down to the bone. Forcibly plantarflex the foot and cut all anterior structures down to the bone.

Put a knife into the ankle joint between the medial malleolus and the talus and cut the deltoid ligament. Do the same on the lateral side and cut the calcaneo-fibular ligaments.

Put a bone hook posteriorly in the talus to plantarflex the foot even more. Using a new, sharp scalpel blade, dissect the tissues away from the medial and lateral sides of the talus and calcaneum, *keeping as close to the bone as you can* (35-27E).

Then cut the calcaneum out of the heel, leaving behind the periosteum and specialized fibrofatty tissue which is essential for weight-bearing. Work at it from all sides keeping very close to bone. *This is the most difficult and the most critical part of the operation. Avoid buttonholing the skin.*

Pull the talus and calcaneum forward with a bone hook. Dissect posteriorly, and cut the posterior capsule of the ankle and the Achilles tendon (35-27F). Using a step incision, cut the Achilles tendon about 10cm proximal to the heel flap. This will prevent the heel stump displacing. *If you don't do this, the Achilles tendon tends to pull up the back of the stump*. Cut it high up, *or else you may injure the posterior tibial vessels*.

Then dissect subperiosteally round the ball of the heel, so as to free the calcaneum and reach the first incision on the sole (35-27G). As you do so, steadily dislocate the foot downwards more and more, until you reach the distal end of the plantar skin flap and finally free it from the ankle.

CAUTION!
(1) *Keep within the periosteum very close to the bone* as you dissect the calcaneum out of the heel flap, or you will cut the posterior tibial and peroneal arteries which are very close to the back of the joint capsule. If necessary, remove the calcaneum piece by piece.
(2) *Don't trim away any muscle or fat in the heel pad*, because it is needed for walking.
(3) Keep close to the bone, and *don't buttonhole the heel flap*.

Divide the vessels and nerves as above. Remove the whole foot except for the heel flap. Dissect the heel flap from the malleoli, and reflect it posteriorly. Saw off the malleoli and the articular cartilage of the tibia in a single cut (35-27H).

Make sure that the ends of the tibia and fibula are accurately horizontal, so weight-bearing is put squarely on the stump.

CAUTION! The cut surfaces of the bones must be parallel to the ground on standing.

Find the nerves and cut them well proximally. Pull the plantarflexor tendons and cut them so that they retract into the stump of the foot. Round off and smooth all the sharp corners of the tibia and fibula. Release the tourniquet, control bleeding, and close the stump. If you are amputating a child's ankle, *don't destroy the distal tibial epiphysis*. Bring the heel flap forward to cover the ends of the bones.

CAUTION!
(1) *Don't remove the dog ears, however big:* they carry an important share of the blood supply of the flap and will disappear later.
(2) Prevent the heel pad from tilting out of alignment with the tibia; *this is a real disaster!*

Apply two long U-shaped strips of strapping (35-27C). Put the 1st piece on starting below the knee posteriorly, bring it round the flap, and then anteriorly, so as to flex the flap over the stump. Apply the 2nd strip from one side to the other. Keep these strips in place for at least 3wks, and replace them as necessary. Check the strapping daily, to make sure that the heel pad is centred over the tibia. Adjust it if necessary. At 2wks, put on a well-moulded cast right round the stump. Avoid weight-bearing. At 6wks, take the mould for the prosthesis, and apply a weight-bearing cast. At 12wks get ready the definitive prosthesis or elephant boot.

(c) Lisfranc amputation (GRADE 2.4)

CONTRAINDICATIONS
Gangrene, particularly in a diabetic. Absent foot pulses.

METHOD
Make a long plantar and a short dorsal flap (35-28). This will bring the suture line dorsally. Start the dorsal incision at the site of bone section on the anteromedial aspect of the foot. Curve it distally a little to reach the midpoint of the lateral side.

Take the plantar incision distally beyond the metatarsal heads 1cm proximal to the crease of the toes. The foot is thicker medially, so make the flap slightly longer on the medial than on the lateral side.

Cut the plantar flap to include the subcutaneous fat and a thin bevelled layer of the plantar muscles. Reflect the plantar flap proximally to the site of bone section and then disarticulate the metatarsals from the midfoot bones (cuneiforms and cuboid).

LISFRANC AMPUTATION

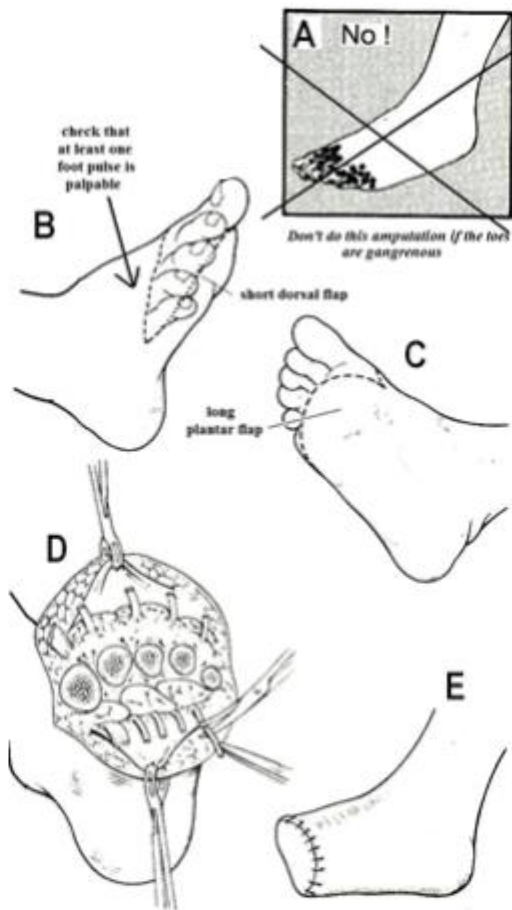

Fig. 35-28 LISFRANC (TARSO-METATARSAL) DISARTICULATION.
A, this is *not for gangrene!* B, make a short dorsal flap. C, long plantar flap. D, expose the metatarsals after division of flexor tendons. E, adapt the length of the posterior flap to give a nice completed stump.
Adapted from Rob & Smith with kind permission.

Find the nerves and cut them well proximally. Pull the plantarflexor tendons and cut them so that they retract into the stump of the foot. Release the tourniquet, control bleeding, and close the stump.

(d) Toe amputations (GRADE 2.2)

N.B. Try to preserve the hallux which gives 'lift-off' when walking.

CONTRAINDICATIONS
Absent foot pulses.

METHOD
Make a V-incision over the mtp joints on the dorsum, and an inverse V across the proximal phalanges on the plantar surface (so the scar finishes up dorsally, 35-29C).

For the hallux, use a modified racquet incision, with the 'handle' over the distal 2cm of the 1st metatarsal, lateral to the extensor tendon, in order to preserve a skin flap long enough to cover the metatarsal head (35-29A).

TOE AMPUTATIONS

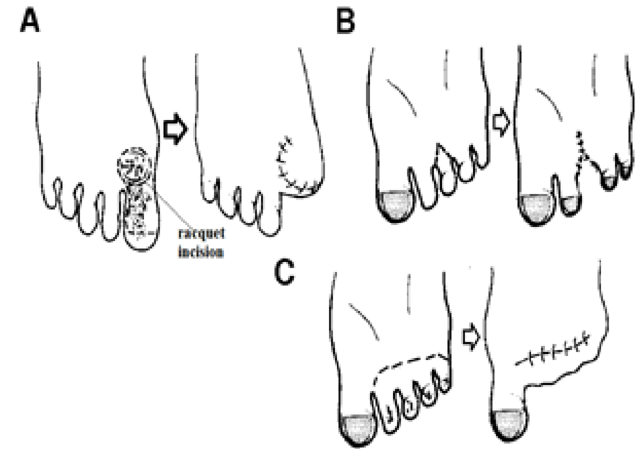

Fig. 35-29 TOE AMPUTATIONS.
A, hallux: make a special curved racquet incision for the hallux. B, 3rd toe: make a V incision proximally on the dorsum, and an inverted V distally on the plantar surface for another toe. C, lateral toes: make a flap to close the wound on the dorsal surface if you are amputating all lateral 4 toes.

Divide both flexor and extensor tendons, and suture them together around the 1st metatarsal head to secure the sesamoid bones. Carefully disarticulate the mtp joint. Release the tourniquet, control bleeding and close the stump.

35.9 Aneurysms

An aneurysm is a dilation of an artery; it can occur anywhere. The 'false' aneurysm of traumatic origin occurs when there is a laceration of the artery and blood leaks out into a confined space, clots and forms a false capsule. 'True' aneurysms can occur in large vessels (aorta or iliacs) but then require advanced vascular surgery; in smaller vessels, their treatment is not so complicated. The blood in an aneurysm does not flow smoothly, and so may clot; pieces of thrombus may detach and be carried further downstream as emboli.

Occasionally the aneurysmal sac may become infected secondarily, or it may originate from a septic embolus (the so-called 'mycotic' aneurysm). Its main danger is increase in size and rupture.

An aortic aneurysm >7cm diameter has a 20% risk of rupture within 1yr. This occasionally occurs into a vein, resulting in an arterio-venous fistula, or stomach or bowel, resulting in initially obscure, intermittent, usually minor rectal bleeding, and then later a sudden massive gastrointestinal haemorrhage.

Remember: *aneurysms pulsate!* So, if you find a swelling which pulsates, *don't incise it thinking it is an abscess!* Check, if you can, by performing an ultrasound of the swelling (38.2e).

Weakening of the arterial wall also occurs with HIV disease, sickle cell disease, syphilis, salmonellosis and *staphylococci*.

There are also rare fungal causes, and elastic tissue disorders such as Ehlers-Danlos and Marfan syndromes.

Aneurysms of the aorta or iliacs require advanced surgery, so refer the patient if possible. For smaller vessels, there are the following options:

In a limb, if the aneurysm is chronic, the collateral circulation will be adequate. Perform a Hunterian ligation: check that pulsation and flow distal to the aneurysm is present (preferably by ultrasound); then expose the artery feeding the aneurysm above and below it, and ligate it doubly on both sides. If the aneurysm sac is large or infected, it is best to open it and remove the contents.

If the aneurysm is acute, the collateral circulation will be inadequate. Excision with vein grafting is necessary. This is not as difficult as it may appear; if you are able to perform bowel anastomoses, you should be able to manage a vascular anastomosis with a fine non-absorbable running suture, with small spaces between bites.

N.B. Don't use haemostats to clamp vessels you wish to suture late: they will be irreparably damaged!

Remember:
(1) use fine instruments (even eye equipment),
(2) use rubber or cotton tape to isolate, retract or interrupt the flow in vessels,
(3) use heparin to prevent blood which is not flowing from clotting: *use a maximum of 3,000 units into the vessel in an adult*.

SAPHENOUS VEIN GRAFT (GRADE 3.3)

Make a 10cm longitudinal groin incision, and carefully dissect out an adequate length of long saphenous vein. Tie its tributaries. Ligate above and below the site you wish to divide the vein. Remove a segment of vein and reverse its direction (because of its valves); then hold its ends with bulldog clamps and fill it with heparinized saline. This will distend the vein to the correct size, and show up leaks from tributaries you have not ligated; put ties round these.

Trim the ends of the vein, and leave it clamped with heparinized saline inside till you are ready to use it, under a warm pack.

Put a gauze or rubber drain behind the artery you wish to repair. Release the clamp on the artery to flush out any clots, and reclamp it. Place the vein graft (*with the valves reversed,* and the proximal clamp removed) adjacent to the proximal arterial segment. Put in two stay sutures bringing together the corners of both artery and vein. With one of these threads, make a continuous suture of the back layer till you reach the other stay suture; knot these together on the outside of the vessel.

SAPHENOUS VEIN GRAFT

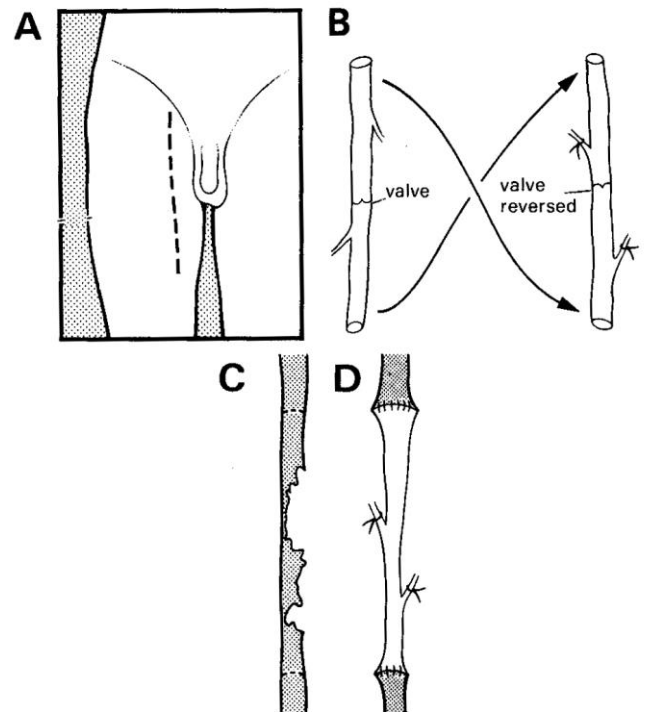

Fig. 35-23 SAPHENOUS VEIN GRAFT.
A, groin incision. B, reverse the orientation of the excised segment of vein. C, damaged arterial segement to be excised. D, vein graft sewn in place.
Kindly contributed by Peter Bewes.

Then continue on the front layer. Now put two more stay sutures bringing together the corners of the vein graft and the distal arterial segment. Complete the anastomosis as before, making sure your knots are outside the vessel. Release the clamp to let the graft fill with blood before finally closing the last suture. Introduce some heparin into the distal arterial segment and then release the distal arterial clamp. Check for leaks; apply pressure and check again. *Don't be too hasty to insert another suture as this may cause a further leak!*

Check if you can palpate a distal pulse; if so, all is well. If not, check that the proximal pulse is palpable; if it is not, release the lower anastomosis slightly with a fine artery forceps to let out clot, and introduce some heparin. Otherwise instil heparin proximally.