# 49 Vascular injury

## 49.1 Immediate treatment for severe external bleeding

Stopping a patient losing blood from the circulation is one of *the* most urgent of surgical tasks.
A litre or more can easily be lost internally into the peritoneal or pleural cavities, or around broken bones (44.3). External bleeding is much easier to diagnose and stop. The most useful methods are elevation, pressure (digital, bandage or by packing/balloon tamponade), suturing or tourniquet (44.2).

**(a) Elevation**:
Useful for controlling venous bleeding in a limb.

**(b) Direct pressure**
Use a digit or hand, or proper compressive bandage. *Don't do anything more until you have waited for at least 5mins by the clock*, unless a torrent of blood pours from the dressing. If bleeding stops, be thankful and *don't meddle with the dressing*.
Occasionally occluding a vessel compromises the distal circulation if there is no collateral flow. Check this if there is a delay in getting help. Releasing the pressure slightly, in this case, may get some flow distally but at the great risk of more bleeding, so remember: 'life comes before limb'

**CONTROLLING EXTERNAL BLEEDING**

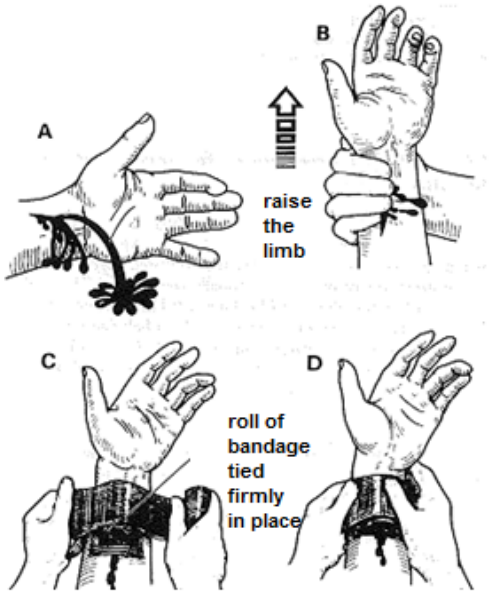



**Fig. 49-1 IMMEDIATE TREATMENT FOR A BLEEDING LIMB WOUND. A, a typical bleeding laceration. B, raise the limb and press on the wound firmly with gloved hands for 5mins. C, apply a dressing & a compressive bandage. D, *do not use a huge wodge of dressing:* this will simply soak up the blood but not produce enough pressure.** *Kindly contributed by Peter J Safár.*

SPECIFIC PRESSURE

*This is only effective if you can localize a specific bleeding vessel*. Press always on a pressure point proximal to the wound, such as (49-4) the:
(1) carotid artery against the transverse process of the 6th cervical vertebra.
(2) temporal artery against the skull just in front of the ear.
(3) subclavian artery against the 1st rib.
(4) brachial artery against the middle of the humerus.
(5) femoral artery over the mid–inguinal point.

**(c) Packing**
Use this to control deep inaccessible bleeding (55-14). Sometimes inflating a balloon (or condom) inside a wound cavity (49-2), is more effective.

**BALLOOON TAMPONADE**

**Fig. 49-2 BALLOON TAMPONADE. A simple Foley catheter inserted into a cavity and inflated can arrest exsanguinating bleeding and buy you time.** *Kindly contributed by Jan Swinnen.*

**(d) Tourniquet** (3.4, 44.2):
This is an example of proximal control; *use this in specific indications:*
(1) life-threatening or multiple bleeding wounds in a limb,
(2) the wound itself is not accessible (*e.g.* patient is trapped in a vehicle),
(3) lack of time because of other severe problems,
(4) failure of simpler measures.
Apply a pneumatic tourniquet (or the cuff normally used for taking blood pressure) at least one hand's breadth proximal to the wound, avoiding regions where nerves are at risk (e.g. directly below the knee) and joints.
A proper arterial tourniquet must have a windlass (which may be a stick) to obtain sufficiently high pressure. *Don't turn this >5 times!* (Each turn may deliver 100mm Hg pressure).

Apply the tourniquet with some padding (*e.g.* cotton) to protect the skin, but *not over clothes* which may slip. *Tighten it till the bleeding stops!*

**TOURNIQUET POSITION**

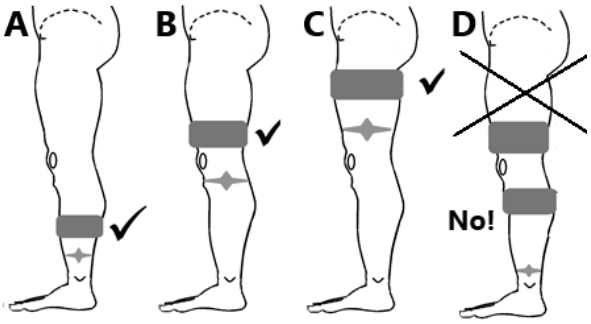



**Fig.49-3 TOURNIQUET POSITION is important. A,B.C, show correct placing of the tourniquet. D, it is too far proximal to the wound *and will cause unnecessary ischaemia. You don't need 2 tourniquets on the same leg!***

**If you have a cuff**, pump it to c. 20-40 (not >80) mm Hg than the patient's systolic blood pressure. Bleeding will stop if you have applied the tourniquet properly. *If it only impedes venous backflow (not enough pressure!) bleeding will increase*.
*Don't forget analgesics*: a correctly applied tourniquet is always painful!

**ALWAYS NOTE THE TIME WHEN YOU HAVE APPLIED THE TOURNIQUET!**

*Do not leave it >1½h on the arm & >2h on the leg; 60% less for thin adults & children.*
In the unlikely case that bleeding does not stop after you have applied the tourniquet properly, apply another tourniquet proximal to the first one.

**HAEMOSTATIC AGENTS**:
Haemostatic gauze, bone wax, hydrogen peroxide, may all help the clotting process, especially where tourniquet use is not feasible.

**HAEMOSTATS** (3-2,3-3):
**If bleeding continues in spite of applying all above mentioned measures**, a large vessel may be injured, probably an artery, more likely from a tear rather than a complete transection.

*N.B.* When an artery is completely divided, bleeding usually stops spontaneously owing to thrombus formation & muscular contraction at the injury site.

*CAUTION!*
(1) Get proximal control by pressing on a pressure point first.
(2) The vessel must be clearly visible.
(3) Secure the bleeding vessel with a haemostat (arterial clamp).
*Don't jab a haemostat blindly into a pool of blood! Be careful that you do not crush a nerve running next to an artery!*
(4) When the haemostat is in place, incorporate it in the dressings.

*N.B. Don't then remove it and try to tie the vessel until your patient is in theatre.*

**SURGICAL ANATOMY OF LIMB ARTERIES**

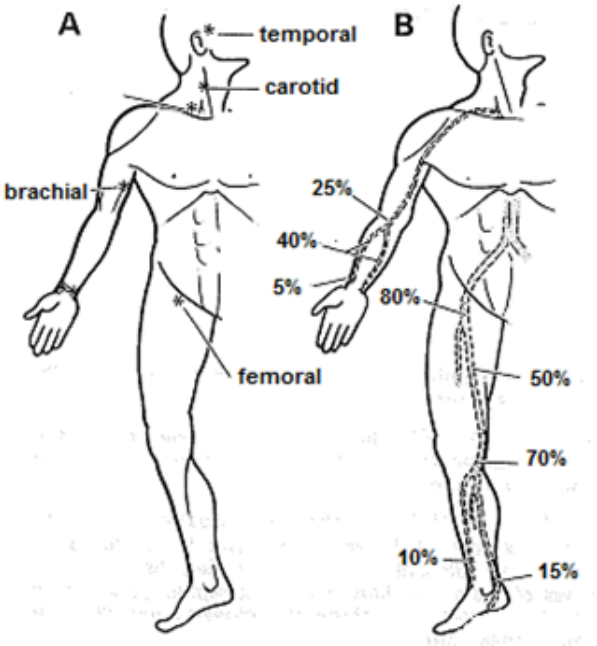



**Fig. 49-4 SURGICAL ANATOMY OF LIMB ARTERIES. A, the pressure points, where you can stop the flow in an artery with a finger or two. B, the chance of ischaemia developing if you ligate the artery.** *Modified from 'Techniques élémentaires pour médecins isolés,Institut de Médecine Tropicale Du Service de Santé des Armées le Pharo, Marseille, DGL 1981 ' with kind permission.*

**TEMPORARY SUTURES**:
In some situations, such as the scalp & face, a continuous suture is useful. You can remove this later, if necessary, to perform more aesthetic repair, especially on the face.
*Never try to use diathermy in the trauma situation.*

## 49.2 Immediate diagnosis & treatment of hidden bleeding

INTERNAL BLEEDING
A person may easily exsanguinate because of hidden bleeding into the chest or abdomen (44.3). Fractures of the pelvis or the legs may also cause profuse internal bleeding. A pelvic sling will help to decrease blood loss at the trauma site. Use tranexamic acid 1g IV slowly over 8-12mins and then 1g over 24h or 25mg/kg tds.

In any case of an injured limb, remember the possibility of vascular trauma – *especially if there is no visible bleeding*. Check if peripheral pulses are palpable with the same force in both limbs.
Use an ultrasound Doppler device (35.2), if you can. Look for the signs of ischemia (49.5).
***You must actively rule out a vascular injury!***

There are critical sites, where major arteries are at risk in trauma:
(1) distal femoral fracture (66.6),
(2) complex knee injuries (67.12-14),
(3) posterior knee dislocation (67.15),
(4) complex elbow fracture (61.1),
(5) anterior elbow dislocation (61.3),
(6) subcapital humeral fracture (60.2).
*N.B.* The most frequently involved arteries are the brachial, and popliteal including its branches.

**SYMPTOMS & SIGNS OF ARTERY INJURY:**
**Remember the 6 P's :**
(1) **p**ain,
(2) **p**araesthesia,
(3) **p**allor,
(4) **p**aralysis,
(5) **p**oikilothermia (feels cold to touch),
(6) **p**ulse missing or weak.

In addition, these are sure (hard) signs:
(1) active arterial haemorrhage,
(2) a rapidly expanding (pulsatile) hematoma,
(3) absent peripheral pulse
(4) a palpable thrill or audible bruit over the wound,

These are soft (suspicious) signs:
(1) history of significant/unexplained blood loss
(2) decreased distal pulse
(3) penetrating or related bone injury,
(4) concomitant neurological deficit,
(5) ankle-brachial pressure index (ABI) <0.9 (with a difference between the affected and the unaffected limb),

**If there is a penetrating Injury,** (in other words the direction of trauma is from outside inwards), the results depend on how the artery is damaged:
(1) if only the outer layer (adventitia):
late rupture or late aneurysm,
(2) if the lumen is partly opened:
bleeding, peripheral ischaemia possible,
(3) if the vessel is completely cut:
temporary bleeding & no blood flow distally.

**If there is a blunt Injury,** in other words the direction of trauma is from inside outwards, the results depend whether the intimal or medial layer is damaged: distal blood flow may then be occluded.

If only the adventitia is undamaged, a thrombus may form blocking distal flow, or an aneurysm develops later.

**If you find signs of ischaemia in an injured limb**, you must look for an arterial injury, but remember: *life before limb*. *Don't waste time trying to tie or repair a vessel if there are life-threatening problems elsewhere!*

**If you are not sure whether there is an arterial injury or you can't find its exact location**, perform an intra-arterial angiogram (49.3). *Remember the compartment syndrome* (49.6).
*N.B. Reduce any fracture or dislocation before exploring the artery!*
*N.B. There is no need for an arteriogram if there are hard signs of injury.*

## 49.3 Principles of vascular repair

Once you have controlled bleeding as described (49.1), you need to explore the wound and tie or repair the injured vessel, depending upon its collateral circulation. You can normally safely ligate (3.2; 3-4) these arteries, *(but don't use catgut, silk or linen):*

(1) external carotid,
(2) internal & common carotid (*N.B:* though there may be 25% risk of stroke, *ligation of the internal or common carotid arteries are usually safer than repair in an emergency)*,
(3) subclavian *(N.B: this may rupture on ligation!)*,
(4) profunda femoris,
(5) radial & ulnar,
(6) posterior tibial, & anterior tibial.
*N.B. If the patient is old, or a smoker, he may rely entirely on these arteries if the natural collateral circulation is ineffective.*

These arteries almost always need repair or reconstruction:
(1) brachial,
(2) external iliac,
(3) common or superficial femoral,
(4) popliteal.

In the abdomen (55.4), you can tie:
(1) the coeliac trunk,
(2) the inferior mesenteric &
(3) internal iliac arteries,
but you need to repair:
(1) the superior mesenteric,
(2) the renal,
(3) the common iliac arteries.

You may have great difficulty finding an injured artery, because the wound may be so badly mangled. The artery may be contracted and look very thin.
To find it you may have to release the tourniquet or the proximal clamp, and look for bleeding, or feel for pulsation.

IMMEDIATE TREATMENT
Take the patient to theatre, and make sure you have good lighting available. Place a pneumatic tourniquet (if it is not already there) (3.8) loosely round the injured limb high above a leg wound so that you can inflate it in a hurry later if you need to. Disinfect the wound site and at least 20cm on either side of it. Disinfect and drape any site from where you may need to take a graft (*e.g.* the opposite leg for harvesting the greater saphenous vein). Drape the limbs in such a way that they are moveable.

**If the wound is so high up the limb that you cannot apply a tourniquet or a clamp**, be prepared to expose and temporarily clamp the subclavian (49-7) or external iliac artery (49-8).
Use a prophylactic antibiotic and infuse 5000 IU heparin before clamping any vessel.
Gently remove the dressings, and explore the wound. Ligate larger vessels with non-absorbable sutures. To be absolutely sure, especially for larger vessels, place a transfixion-suture or doubly ligate the vessel, the 2nd time 2-5mm proximally.
*N.B. Oversewing a vessel may include a nerve,* so if the patient complains afterwards of pain or has a neurological deficit, it is worthwhile re-exploring the wound when the situation is calm.

**If most bleeding has stopped**, explore the wound without further trouble.

**If the wound bleeds profusely**, inflate the tourniquet before you try to explore it. Try to find the torn artery. Expose it nicely by increasing the incision, if necessary.
Obtain proximal and distal control by placing a rubber band (best made from a sterile surgical glove) or non-crushing 'bulldog' clamp on the vessel above and below where it is torn. Once you have control, you can release the tourniquet to check if there is serious bleeding elsewhere. (You can temporarily release the clamp on the artery if you are not sure that it is on the right place, but be ready to pump up the tourniquet again immediately!)

**If you cannot find the damaged vessel** (unusual), complete the wound toilet and any other repair, then deflate the tourniquet and look again for bleeding.

**If you find massive bleeding from a major artery and you can't clamp it quickly,** insert a Fogarty catheter into the lumen of the vessel and inflate it, until the bleeding stops. In very large vessels you can use a Foley catheter for the same purpose.

**If you still cannot find the find the damaged artery** or you are unsure, try to perform an angiogram.

*Don't diagnose arterial spasm before you have opened the artery concerned* (to exclude intimal damage).

INTRA-OPERATIVE ANGIOGRAM *(check that there is no known allergy to iodine or contrast)*:
*N.B. You need an operating table with a space for an X-ray cassette, or for a limb, to have the cassette underneath it.*
Expose the required proximal artery (the external carotid for severe maxillofacial injury, the subclavian artery for an axillary injury, the external iliac or common femoral artery for a thigh injury). Use a small butterfly needle to puncture the artery. Alternatively, especially if you have ultrasound, and you have a long enough needle (38.1g, 38-4), you can cannulate the required artery without exposing it.
Just before and during hand injection of full-strength contrast, manually compress the proximal inflow.
Use boluses of 10ml half-strength contrast for each phase sequence, and try to visualize the whole extremity. Normally 2-3 boluses are enough.
*N.B. Full dose contrast may cause vasospasm* and give a false impression of arterial injury.
Afterwards, press firmly over the puncture site for 2mins (without compressing the artery completely), or oversew the puncture site with 6/0 non-absorbable suture.

LIGATION, REPAIR OR SHUNT?
Once you have controlled the bleeding and debrided wound, decide whether to tie off the injured artery, try to repair it, or put in a shunt. Check with the list above on those arteries it is safe to ligate.

*Always doubly ligate arteries!* Use an atraumatic needle if available. *Don't try to ligate where the vessel is not looking healthy!*

**If you find you can't repair the artery**, **either because of lack of time or difficulty**, restore the circulation with a shunt. You can use any sterile tubing available, such as an IV line, NG tube, suction catheter or paediatric chest drain. Make sure you have proximal & distal vascular control.

**If there is poor flow from either end**, insert a Fogarty embolectomy catheter into both proximal and distal ends of the vessel, and irrigate diluted heparin-saline (1000 IU) both distally and proximally.

Insert a clamped shunt into the distal end of the vessel and allow back bleeding into the shunt, then insert the shunt into the proximal end of the vessel and release the clamp on the shunt. Secure it in place with sutures or vessel loops (49-5). *Be careful while inserting the shunt that you make as little damage as possible to the intimal layer of the artery*. *Make sure the shunt cannot dislodge*. Close the wound loosely.

***Note the time when the shunt was inserted!***

**REMEMBER LIFE OVER LIMB!**

You can leave the shunt in place up to 24h or even longer (but maintain IV heparin), giving you time to plan what to do next. Unless you can insert a vein graft (49.3), refer the patient.

**A VASCULAR SHUNT INSERTED**

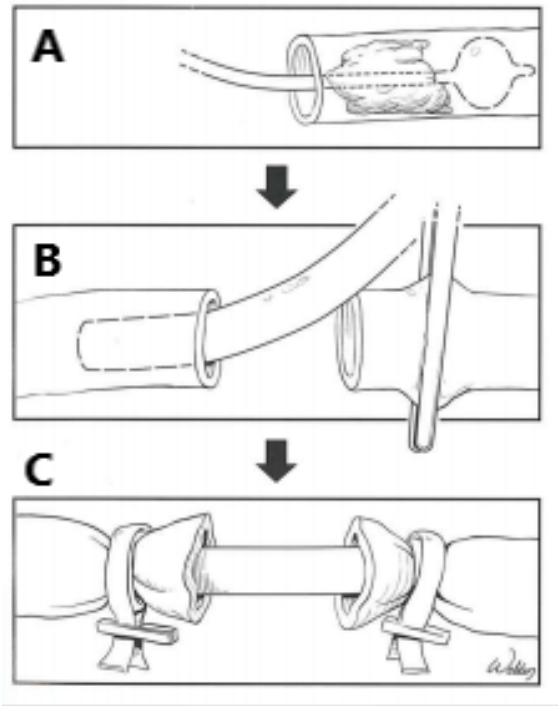



**Fig. 49-5 A VASCULAR SHUNT INSERTED. A, pass an embolectomy catheter down both ends of the vessel. B, control the distal end, release the clamp and insert the shunt. Fix this with a Rummel tourniquet (*a ligature damages the artery*). C, insert the shunt into the proximal end and fix it likewise.** *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission*

## 49.4 Exposure of arteries

EXPOSING MAJOR ARTERIES
These are the classical methods of surgery. Though you may not need this information, no surgical textbook is really complete without these, and they may be life-saving.

**(a) The external carotid artery** (GRADE 3.3)
After a severe maxillofacial injury, you may have to expose the external carotid artery. This arises from the common carotid at the upper edge of the thyroid cartilage. It runs upwards behind the neck of the mandible, and ends by dividing into the maxillary and superficial temporal arteries. It lies under the posterior belly of the *digastric* muscle, and its upper part lies deep to the parotid gland.

PROCEDURE
Tilt the table 10º head up to minimize venous bleeding; but not more, because this increases the risk of air embolism. Turn the patient's head to the opposite side, and extend it slightly.
Make an oblique incision from just below and in front of the mastoid process, almost to the thyroid cartilage. Divide the *platsyma* and deep fascia in the line of the incision, and dissect flaps upwards and downwards.

**EXPOSING THE CAROTID ARTERY**

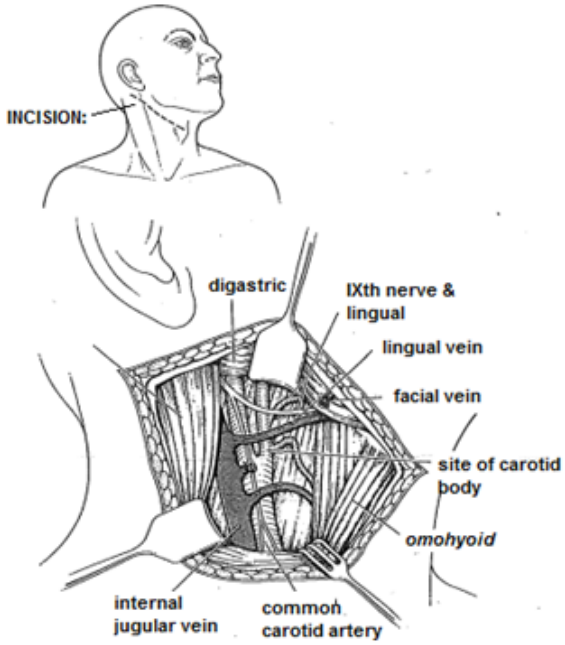



**Fig. 49-6 EXPOSING THE RIGHT EXTERNAL CAROTID ARTERY. This controls bleeding in a severe maxillofacial injury.** *Adapted from Farquharson's Textbook of Operative Surgery, Rintoul RF. Churchill Livingstone, 7th ed 1976 with kind permission.*

Free the anterior border of the *sternomastoid* and retract it posteriorly. You will then see the common facial vein. Divide this between ligatures.

Carefully retract the internal jugular vein backwards, to visualize the common carotid artery bifurcating to form the internal and external carotid arteries.

**If you have difficulty in deciding which artery is which**, find some branches of the external carotid and follow them backwards to the main stem; *the internal carotid artery has no branches in the neck*.

*CAUTION!* (1) **If you tie the external carotid**, do so just proximal to the origin of the lingual artery. (2) *Avoid the IXth nerve* which crosses the external and internal carotid vessels and then runs anteriorly to lie on the *hyoglossus* in company with the lingual vein. (3) *Avoid irritating the carotid sinus and body* in the bifurcation of the internal and external carotid vessels, as this may cause alarming fluctuations in blood pressure!

**(b) The subclavian artery** (GRADE 3.4)
When a humeral neck fracture tears the axillary artery, it may cause a huge arterial haematoma which you can only control at the site of the subclavian artery.

The subclavian artery crosses the cervical pleura in the root of the neck. It passes over the 1st rib behind *scalenus anterior* which divides it into three parts. The 1st part is medial to this muscle, the 2nd is behind it. The 3rd part, lateral to the *scalenus anterior*, is the most accessible part.

The subclavian vein lies in front of the artery and slightly inferior to it. The phrenic nerve runs down the front of *scalenus anterior*.

Very occasionally, you may have to remove the middle part of the clavicle and split the fibres of *pectoralis major*, to reach the artery in the axilla.

PROCEDURE
Tilt the table 10º head up to minimize venous bleeding. Put the patient's arm by his side, and draw it downwards to depress his shoulder. Turn the head to the opposite side.

Make an incision 2cm above the clavicle from the sternal head of the *sternomastoid* to the anterior border of the *trapezius*. Incise the superficial fascia, the *platysma*, and the deep fascia in the line of the incision. If you see the external jugular vein crossing the operative field, divide this between ligatures. Retract the *omohyoid* upwards and you will see the 3rd part of the subclavian artery, with *scalenus anterior* medially, and the trunks of the brachial plexus laterally. The subclavian vein lies in front of the artery and below it.

**EXPOSING THE SUBCLAVIAN ARTERY**

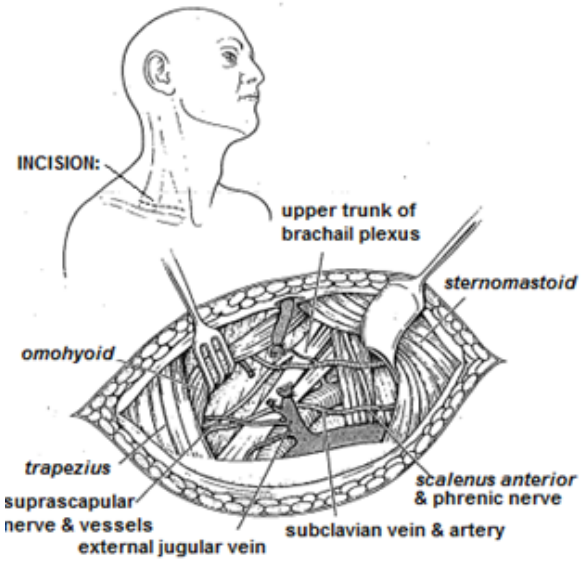



**Fig. 49-7 EXPOSING THE 3rd PART OF THE SUBCLAVIAN ARTERY. If a humeral neck fracture tears the axillary artery (rare), it may cause an arterial haematoma which you can only control at the subclavian artery.** *Adapted from Farquharson's Textbook of Operative Surgery, Rintoul RF. Churchill Livingstone 7th ed. 1976 with kind permission.*

Ligate the subclavian artery with sutures around the clavicle. *Don't try to dissect it out as it has no adventitia and will crumble to pieces!*

*N.B. Don't cut the transverse cervical artery under the omohyoid muscle, or the suprascapular artery crossing the subclavian artery*, because they help maintain the collateral circulation to the arm.

*N.B. Related damage to the brachial plexus is common.*

**(c) The axillary artery** (GRADE 3.4)

PROCEDURE

Make a lazy-S incision (49-8A) from the mid-point of the clavicle to the anterior border of the *deltoid* with the *biceps.* Retract the cephalic vein with the *deltoid* upwards, and the *pectoralis major* medially and incise the clavi-pectoral fascia (49-8B) to get proximal & distal control of the axillary artery.

You may have to divide the humeral insertion of *pectoralis major* and the insertion of *pectoralis minor* (which covers the brachial plexus branches, *i.e.* origins of the musculocutaneous, median and ulnar nerves, lying on top of the artery, 49-8C) to get adequate access. You also may need to divide branches of the thoraco-acromial vessels obscuring the axillary vein, and retract the superi-lateral branch of the brachial plexus gently upward to obtain access to the axillary artery.

## EXPOSING THE AXILLARY ARTERY

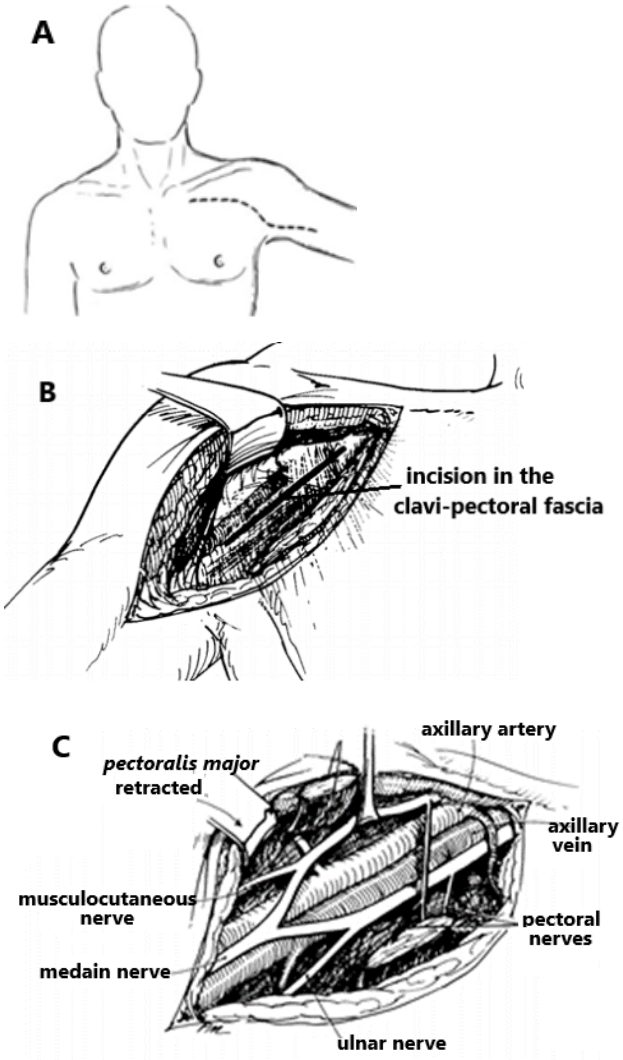
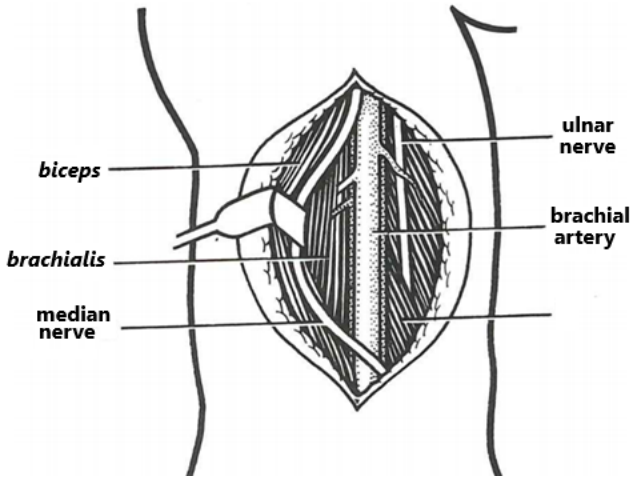



**Fig. 49-8 EXPOSING THE AXILLARY ARTERY. A, a lazy-S incision. B, incising the clavipectoral fascia. C, the axillary artery exposed.** *Adapted from Dudley H, Carter DC, Russell CG eds. Rob & Smith's Operative Surgery Butterworths 4th ed. 1989*

**(d) The brachial artery** (GRADE 3.3)
In the proximal upper arm, the brachial artery emerges behind the *teres major* tendon, and runs along the arm beneath the median border of *biceps* deep to the aponeurosis.

PROCEDURE
Put the arm at right angles on a table, with the hand supinated. Make an incision between *biceps* & *triceps*, hugging the former. Divide the deep fascia, and retract both *biceps* and median nerve, which crosses the artery superficially, laterally. The ulnar nerve lies deeper medially, and the musculocutaneous nerve is more superficial, retracted with the *biceps* (49-9).

## EXPOSING THE BRACHIAL ARTERY




**49-9 EXPOSING THE BRACHIAL ARTERY IN THE UPPER ARM. Make an incision along the medial border of *biceps,* and retract this with the musculocutaneous and median nerves laterally.** *Adapted from Dudley HAF ed. Emergency Surgery. Wright Bristol 11th ed. 1986*

**(e) The external iliac artery** (GRADE 3.3)
If a wound in the groin, or too high up in the thigh to control with a tourniquet, is bleeding, get control of the external iliac artery if you can, although this may take longer than direct control of the femoral artery. *Be careful not to injure the external iliac vein and femoral nerve* as you do so.

The external iliac artery arises at the brim of the pelvis from the common iliac artery and runs to the mid inguinal point, where it becomes the femoral artery. The external iliac vein lies medial to it, and the *psoas* muscle behind it. The femoral nerve lies about 1cm lateral to it, with the genitofemoral nerve in between. The peritoneum lies in front of the artery, until the point at which it turns upwards onto the anterior abdominal wall.

Below this point, and immediately above the inguinal ligament, the external iliac artery lies on (1) the *transversalis*, (2) *internal oblique*, & (3) *external oblique* muscles.
There are 2 branches of the external iliac artery: (1) the inferior epigastric artery, which runs upwards into the rectus sheath, (2) the deep circumflex iliac artery, which runs laterally along the back of the inguinal ligament.

PROCEDURE
Put the patient into a moderate Trendelenburg position. Make a 6cm incision 2cm above and parallel to the middle of the inguinal ligament (49-8). Incise the aponeurosis of *external* & *internal oblique* and open the transversalis fascia to expose the external iliac artery.

## EXPOSING THE EXTERNAL ILIAC ARTERY

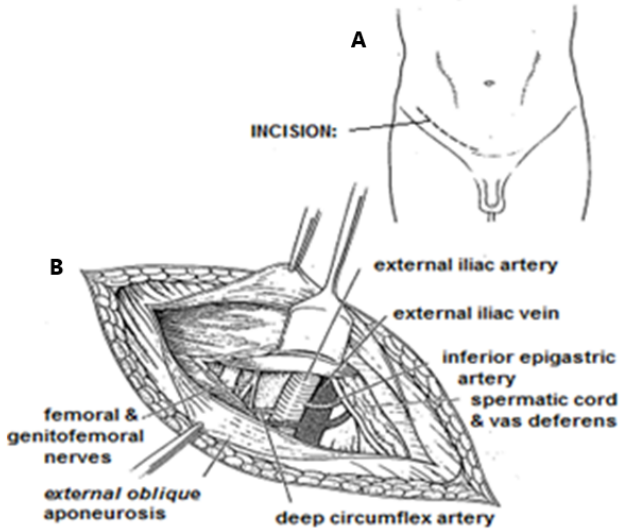



**Fig. 49-10 EXPOSING THE EXTERNAL ILIAC ARTERY. A, groin incision. B, Exposing the external iliac artery.** *Adapted from Farquharson's Textbook of Operative Surgery, Rintoul RF. Churchill Livingstone 7th ed. 1976 with kind permission.*

Incise the *transversalis* fascia, and retract the spermatic cord upwards and medially. Gently push the peritoneum cranially and you will see the external iliac artery and vein. *Be careful not to cut the inferior epigastric artery and its vein*.

Separate the external iliac artery carefully from the vein, pass an aneurysm needle round it, and control it with a rubber band sling.

**(f) The femoral artery** (GRADE 3.3)

PROCEDURE
Make a vertical incision halfway between the pubic tubercle & the anterior superior iliac spine. Cut the *fascia lata* longitudinally and enter the fatty femoral triangle. Keep the wound open with a self-retaining retractor. Identify the inguinal ligament. Palpate for the femoral artery (*it might be pulseless!);* if you find muscle, you are too lateral! Open the femoral sheath above the artery and re-position the retractor. *Don't stray medially and hit the femoral vein or stray laterally and cut the femoral nerve!*

**If there is a large groin haematoma**, and you can't get access to the femoral vessels, find the inguinal ligament (49-11) and divide it. This will lead you straight to the external iliac artery, which you can put a loop round and control as above.

## A LARGE GROIN HAEMATOMA

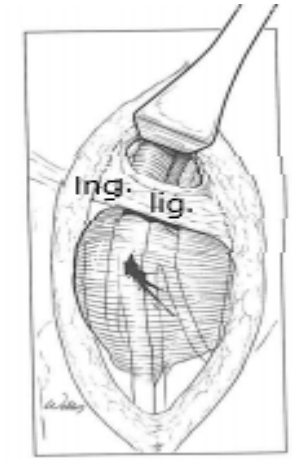



**Fig. 49-11 DEALING WITH A LARGE GROIN HAEMATOMA. Find & incise the inguinal ligament so you can get access to the proximal external iliac artery.** *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission*

***N.B. You will also need distal control!***

The femoral artery will continue to bleed from its distal end. It is control of the deep femoral *(profunda femoris)* artery that is difficult: *don't try to dissect it out!*

You will find the junction of the long saphenous and femoral veins at the mid-point of the transverse inguinal crease.

Pass a tape from the lateral side under the common femoral artery proximally and out on the medial side; pass this again under the superficial femoral distally artery after its bifurcation to the lateral side.

## ISOLATING THE DEEP FEMORAL ARTERY

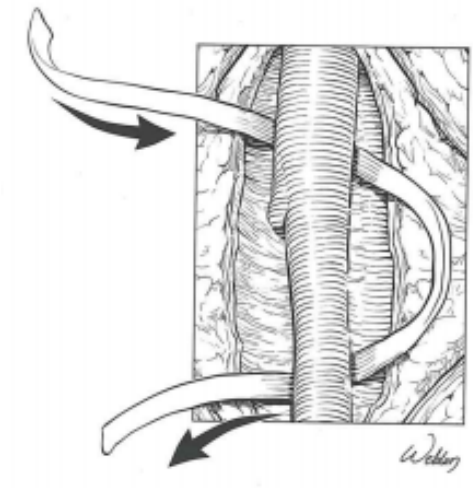


**Fig. 49-12 ISOLATING THE DEEP FEMORAL ARTERY. Pass a tape under the common & superficial femoral arteries to hook the deep femoral branch.** *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission*

Pull on this and you will hook the deep femoral branch and isolate it (49-12); if you take the tape once more round the common femoral artery, you can control both together.

**(g) The superficial femoral artery** (GRADE 3.3)
The femoral artery starts at the mid inguinal point as a continuation of the external iliac artery. It runs down the thigh obliquely, first across the femoral triangle, and then underneath the *sartorius* muscle. It ends at the junction of the middle and lower thirds of the thigh, by going through a hole in the *adductor magnus*, and becoming the popliteal artery.

As the femoral artery crosses the femoral triangle, the femoral vein lies medial to it, becoming posterior distally; the femoral nerve lies c.1cm laterally.

Further on, when the femoral artery is in the canal below *sartorius, adductor longus* & *adductor magnus* lie behind it; *vastus medialis* lies antero-laterally.
The femoral vein now lies postero-laterally, the nerve to *vastus medialis* laterally and the saphenous nerve anteromedially.

PROCEDURE
Flex the patient's thigh slightly, support it on a pillow, and rotate it externally. Draw a line from the mid-inguinal point to the adductor tubercle. The femoral artery lies under the upper ⅔ of this line. Make an adequate incision here (49-13A).
The long saphenous vein lies in the superficial fascia. *Don't divide it,* as if the femoral vein is damaged or thrombosed, it provides the main venous collateral.

Incise the deep fascia, mobilize the *sartorius* muscle, and reflect this anteriorly to expose the upper part of the femoral and profunda arteries (49-16B). Use self-retaining retractors.

Gently separate the artery from the vein and *make sure you don't damage the overlying saphenous nerve*.

To expose the lower part of the femoral artery, reflect the *sartorius* posteriorly, and divide the bridge of fibrous tissue which makes the roof of the subsartorial (Hunter's) canal.

**EXPLORING THE FEMORAL ARTERY IN THE THIGH**

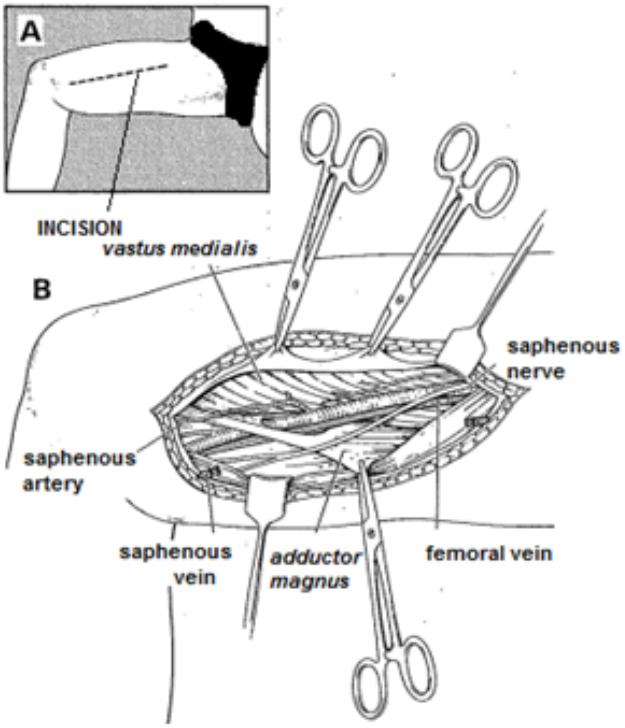



**Fig. 49-13 EXPOSING THE ROUTE OF THE FEMORAL ARTERY. A, make an incision as shown. B, divide the fascia and expose the vessels carefully.** *Adapted from Farquharson's Textbook of Operative Surgery, Rintoul RF. Churchill Livingstone 7th ed. 1976 with kind permission.*

**(h) The popliteal artery** (GRADE 3.4)
Although the popliteal fossa looks easy in diagrams, in reality all its contents are cramped together. Nerves, arteries, and veins all look much the same until you dissect them out carefully.

The popliteal artery begins as the continuation of the femoral artery, at the opening in *adductor magnus*. It then runs downwards in the popliteal fossa until it reaches the lower border of the *popliteus*, where it divides to form the anterior and posterior tibial arteries, and the peroneal artery.

The popliteal vein lies medial to the lower end of the artery and crosses it posteriorly to lie posterolateral to its upper part.

The medial popliteal nerve crosses the popliteal artery and vein posteriorly from the lateral side above, to the medial side below. The lateral popliteal nerve lies more superficially in the lateral part of the fossa.

**EXPOSING THE POLITEAL ARTERY**

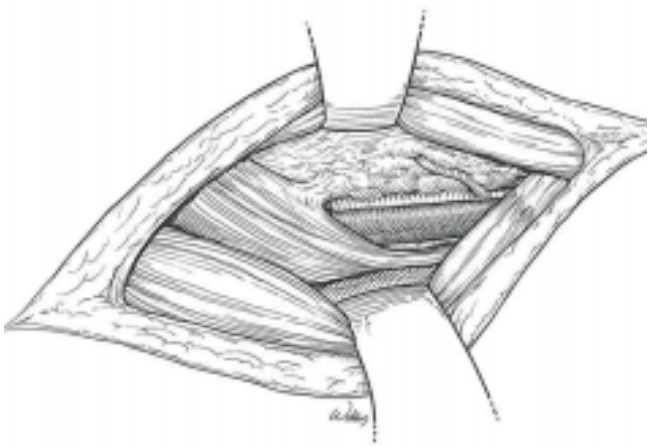


**Fig. 49-14 EXPOSING THE PROXIMAL POPLITEAL ARTERY. Always begin with a lower leg fasciotomy.** *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

PROCEDURE
Begin with a lower leg fasciotomy, because you will need one later. Make a 10cm incision in the groove between *vastus medialis* & *sartorius,* somewhat distal to the distal femoral incision (49-14). Palpate the lower border of the femur. Incise the fascia behind it and try to feel for the popliteal artery. *Beware: the popliteal vein lies just next to it as well as the saphenous nerve!* Put a sling round the proximal popliteal artery.

Since exposure of the popliteal region is complex, it is better to create a tunnel between the femoral condyles with a finger big enough to enable you to pass a reversed saphenous vein graft through it later. Expose the distal popliteal artery through a separate incision 1cm behind the tibial border. *Make sure you don't damage the saphenous vein just posterior to your incision!* Divide the deep fascia behind the tibia, and carefully dissect the popliteal vein adjacent to the artery.

## 49.5 Vessel repair

OPTIONS FOR ARTERIAL REPAIR
Your choice in arterial injury is:
(1) Direct repair, if the defect is <25% of the circumference,
(2) Using a patch, if the defect is <50% of the circumference,
(3) Primary end to end anastomosis, if the defect is <2cm long,
(4) Inserting a graft, if the defect is >2cm long.
(5) Inserting a shunt, especially if there is an open fracture associated.
These last 2 may be quite long, *e.g.* in the adductor canal of the thigh, or in the popliteal fossa.

EQUIPMENT YOU NEED:
(1) Non-crushing arterial clamps.
(2) A very fine needle holder.
(3) Fine dissecting forceps (*e.g.* Adson's or ophthalmic forceps.
(4) Vessel loops made from strips 5mm wide, 10cm long cut from sterile surgical gloves.
(5) Half circle round–bodied atraumatic (or better, micropoint) needles on 6/0 mono-filament sutures. (Double-ended sutures are ideal.)
(6) Magnifying spectacles (*e.g.* Bishop Harman loupe): *very* useful.
(7) Heparin (or citrate solution from a blood transfusion bottle or bag).
(8) A fine blunt-ended hollow probe (for flushing).
(9) A good suction device.
(10) *Cross-matched blood!*
(11) Good lighting.
(12) Bipolar cautery (if possible)

Vascular surgery is normally considered to be strictly the work of a specialist. But the patient must reach such expertise within 4h of the injury; if this is impossible, you will have to do as best as you can yourself, *e.g.* by using a shunt. If you operate carefully, and handle the injured artery gently, you may succeed in repairing it, or at least ligating it. In so doing, you may save a patient's life, even if you cannot save the limb. *Don't try heroics which take hours of fine surgical craftsmanship*, if circumstances are against you. *The penalty for failure may be worse than accepting limb loss.*

***A VASCULAR REPAIR MUST NEVER BE UNDER TENSION!***

Other than the tools described, you do not need any special equipment, but this sort of surgery will take you a rather long time. Use the finest instruments you have; eye instruments are suitable if you treat them carefully, and so are eye sutures. But successful repairs have been done with coarser ones. You will need good aseptic technique, a strong light, adequate anesthesia, good eyesight, or magnifying spectacles, and maybe a blood transfusion.

*You must perform wound toilet carefully*, removing all dead or non-viable tissue. *Make sure adjacent bone fractures are well-aligned and fixed beforehand. Do not hesitate to enlarge the wound to improve visibility. If orthopaedic repair will take long, insert a temporary shunt.*

You have to stop the proximal flow in arteries before you can repair them; for this you can use tape, a rubber band or a non-crushing arterial clamp.

***NEVER PUT A CRUSHING CLAMP ON AN ARTERY YOU WISH TO REPAIR!***

Even rubber protection over the jaws of a haemostat will not prevent arterial injury. Instead

use special arterial 'bulldog' clamps, or the Rummel vascular tourniquet (49-17A).
This is simply a length of stout linen, cotton tape, or vessel loop passed round the artery and then threaded through a rubber or plastic tube.
By pulling the tape and pushing the tube down onto the artery you will occlude it. In order to stop blood clotting in an occluded artery, inject diluted heparin into both proximal and distal ends.

TORN ARTERIES
Arteries are elastic, so mobilize enough of the artery above and below the wound to let you work on it. However, if they go into spasm & retract, then you may have to search for their ends. Occlude the flow above and below the arterial injury. In an emergency, ask your assistant to hold the artery between first finger and thumb. Irrigate heparin-saline into the vessel on each side of the injury. Try to preserve any reasonably sized branches, because these will help to maintain the collateral circulation if the repair fails.

**If the artery is only partly divided or cut longitudinally**, you may be able to close it primarily – the injury must not involve >25% of its circumference: *you must not narrow the lumen* and produce a stenosis – better in this case to use a patch.

**If the artery has been nearly cut across**, re-unite its cut ends.
**If a length of the artery is bruised or torn**, **or its cut ends are ragged**, trim the damaged piece (49-16A,C) and bring clean ends together for anastomosis (49-16D,E).
You may be able to excise ≤2cm and still bring the ends together after mobilizing the artery properly. *Make sure that there is no tension* on the anastomosis!
**If the ends of the injured artery will not come together easily**, insert a reversed saphenous vein graft.

PRIMARY ARTERIAL SUTURE (GRADE 3.2)
This is usually only feasible for knife injuries.
For successful results, remember:
(1) primary suture may create a stenosis,
(2) use 5/0 or 6/0 sutures, or 4/0 for larger vessel,
(3) always make an everting suture (from inside outwards, from proximal to distal) on the arterial wall,
(4) keep 1mm distance between sutures,
(5) keep the knots on the outside of the artery.
Before completing the closure, flush and rinse both arms of the reconstructed vessel with heparin-saline, inspect the lumen, and restore the blood flow. Only then finish applying & tying your suture.

***DON'T TRY PRIMARY ARTERIAL REPAIR IF THERE IS CONTAMINATION OR CONTUSION OF THE VESSEL WALL.***

PATCH ANGIOPLASTY (GRADE 3.3)
Harvest a piece of saphenous vein (35.8), open it out, make sure the *intima* faces inwards, and discard any segment with a valve in place.
Trim a template of glove material to size to match the arterial defect you wish to close, and use this to cut out the vein patch carefully.

Start at the distal end of the patch, or at the end which is more difficult to reach. Place a continuous everting suture (49-13B), sewing the patch onto the defect. Continue till you reach the middle of the circumference of the patch, taking care to place the points of the suture slightly further apart on the vessel than on the patch. Then start again where you began and go round the other way on the patch to reach where you had stopped before. Before completing the suture, release the clamps to flush the distal and proximal ends and rinse both with heparin-saline in both directions, as with the primary repair.

ARTERIAL END-TO-END ANASTOMOSIS (GRADE 3.3)
*There should never be any tension on the anastomosis!* If the ends of the injured artery do not come together easily, insert a vein graft!

It is best to make oblique cuts across an artery (49-16E), rather than perpendicular cuts. Place a cut piece of glove behind the artery to make it easier to see where to put your sutures. Before you start the anastomosis, allow the artery to bleed from both ends to flush out any thrombus that may have formed within its lumen. Squeeze any more thrombus out of the cut ends of the artery and irrigate heparin-saline into both ends of the artery.

**THROMBECTOMY**

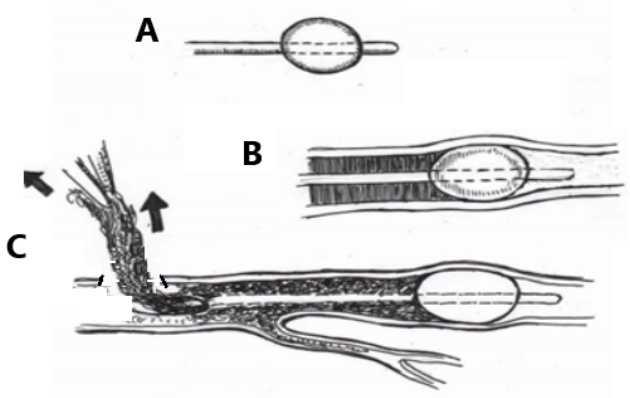



**Fig. 49-15 EXTRACTING A THROMBUS. A, The balloon of the Fogarty catheter passed beyond the thrombus (or embolus) & inflated. B, Extracting the thrombus from an artery, through the arteriotomy.** *After Fogarty TJ, Krause RJ,*

*Hafner CD, A method of extraction of arterial emboli and thrombi. Surg Gyn Obs 1963; 116:241-4.*

ARTERIAL THROMBECTOMY (GRADE 3.2)
If there is no backflow or no inflow perform a Fogarty manoeuvre if possible. Introduce the catheter gently into the blocked lumen of the artery for 10cm or so, and then inflate the balloon; pull the catheter gently back (49-14). You may have to repeat this till you get a good flow.

Bring the cut ends of the artery together with two stay sutures at opposite sides. Two more intervening stays may help steady the artery and rotate it, where necessary. *Make your sutures from proximal to distal, tacking the distal intima down to prevent it lifting like a valve.*

**If the artery is >5mm in diameter**, starting at the back of the artery, place a continuous everting suture with points 1mm apart (49-17B).

**If the artery is <5mm in diameter**, use an interrupted suture. When the suture is nearly complete, release the clamps first, flush and rinse the artery in both directions with heparin-saline, as before. Then complete the suture and release the distal clamp first. This low pressure retrograde flow will show up any leaks. If there is a significant leak, close it with 1 or 2 sutures.

**REPAIRING INJURED ARTERIES**

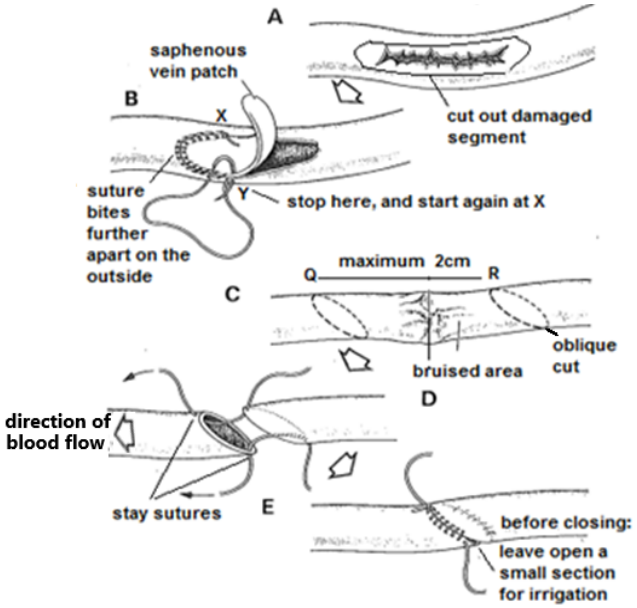



**Fig. 49-16 REPAIR OF INJURED ARTERIES. A, a ragged laceration needing part of the wall excised. B, suturing on a patch: start at X, with suture bites further apart on the outside than on the inside of the curve. C, a bruised section of artery needing total excision; cut the artery *obliquely*. D, as long as the excised portion (QR) is <2cm long, start the anastomosis with stay sutures opposite each other, suturing from proximal to distal. E, before completing the anastomosis, flush the vessel with heparin-saline.** *After Blackburn G, Field Surgery Pocket Book, Min Defence, HM Stationery Office, London. with kind permission.*

Then press lightly on the anastomosis with gauze and gradually release the proximal clamp. The repair will bleed, but this will usually stop spontaneously in 5mins. If it does not, and there is an obvious leaking site, put in more sutures. *Be patient: do not put in more and more sutures in panic!*

Finally, remove the piece of glove you put behind the anastomosed artery.

**END-TO-END ARTERIAL ANASTOMOSIS**

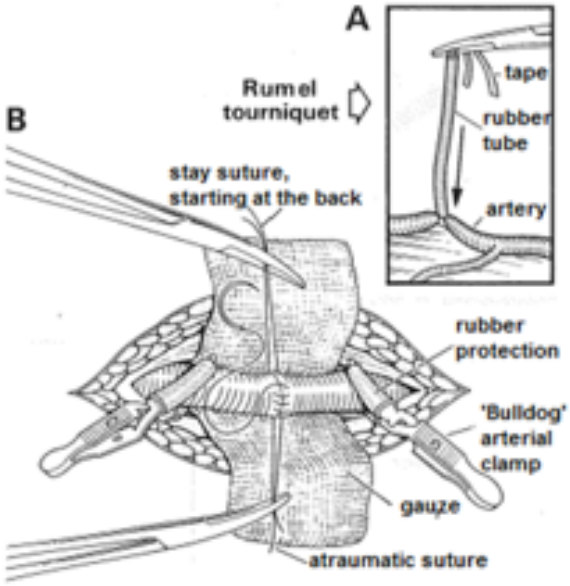



**Fig. 49-17 END-TO-END ARTERIAL ANASTOMOSIS. A, insert a tape into a tube, and sling it round the artery to obstruct it, and hold it with a clamp. B, use protected arterial clamps. Start the anastomosis at the back.** *Adapted from Dudley H, Hamilton Bailey's Emergency Surgery, Butterworth 9th ed. 1976 with kind permission.*

REVERSED SAPHENOUS VEIN GRAFT (GRADE 3.4)
**If a large section of an artery is injured** so that you cannot bring its ends together, use a piece of saphenous vein to bridge the gap. Although you are only using a vein, it will withstand arterial blood pressure adequately, and will resist infection better than an artificial graft. This is a procedure for the careful operator where referral is not an option (35.8).

Expose the saphenous vein (*don't take it from the injured leg, unless you have to*) through an adequate incision along its length, starting at the groin. Remove a suitable length of vein, and doubly ligate with 4/0 monofilament all its side branches and cut them off.

*N.B.* The cephalic vein in the arm is another choice.

Proximally (for larger branches) it is better to transfix them. Remove the isolated segment of vein, turn it round so that the foot end becomes the proximal end.

Clamp the distal end with a haemostat, and irrigate the vein with heparin-saline under mild pressure. This will show up leaks from any ligated side branches (35-25) you may have missed. It will also distend the vein most usefully, but *take care not to distend it too much*. Leave it distended with heparin-saline and lying in some heparin-saline or blood while you prepare the artery to receive it.
Trim both ends of the vein obliquely to the correct length and anastomose the ends to the artery, as above.
*Make sure you have reversed the vein and any valves do not block the blood flow.*

Remove the distal arterial clamp just before the last sutures, as before, so that any air caught inside the vein can escape through the remaining gap between your last sutures. Rinse proximal and distal arms as before with heparin-saline.

Leave the repair under a warm saline pack while you wait 10mins. Then inspect it, and if it is pulsating, cover it with adjacent tissue and close the wound. *Make sure near-by fractures are well aligned before you attempt any vascular repair!*

ARTERIAL BYPASS (GRADE 3.4)
Where greater arterial damage exists, or you have had to tie off one of the critical arteries listed earlier, you can insert a bypass using a long segment of reversed saphenous vein.

Harvest the saphenous vein as before, but *make sure you have enough length.* Start with the distal anastomosis; remember to turn the vein round so the valves do not block the blood flow.
Make a longitudinal arteriotomy of at least 15mm (or at least 3 times the diameter of the artery) at a suitable site where the artery is undamaged. Start at the heel of the graft and suture as for a patch graft. The flatter the angle, the better the haemodynamics of the subsequent blood flow.

**If you are performing an above-knee bypass,** place the vein underneath *sartorius*, along the adductor canal.

**If you are performing a below-knee bypass**, place the vein through the popliteal region in between the femoral condyles (where the popliteal artery normally lies).

**Once you have exposed the artery, controlled haemorrhage, and excised the damaged segment,** you are ready to start. Fill the graft with heparin-saline before pulling it through its preformed channel: in that way, it is less likely to twist.
Use a long straight artery clamp to pull the bypass vein graft along the channel you have made.
Finally perform the proximal end-to-side anastomosis in the same way. Similarly, before completing the sutures, flush and rinse as before; then release the distal clamp. *Make sure there is adequate backflow.* Then release the proximal clamp. There should now be a good pulse visible or palpable on the graft.
*Make sure you can also feel the pulse on the distal artery.* The peripheral part of the limb should now warm up: check the peripheral pulses!

WOUND TOILET
Do this carefully. Remove all dead or non-viable tissue from the wound (46.2). If there is a fracture combined with the arterial injury*,* first realign the bone before inserting a shunt. If you don't do this, you will not be able to judge the length of the graft needed.

Cover the arterial repair with living muscle or subcutaneous tissue. *Don't leave it exposed while waiting for delayed primary closure*. You can rotate a tissue flap over it, or partially close the wound. If the wound was a very contaminated, use a vacuum dressing, *but never put the sponge directly on the vessel*! Some healthy tissue should always cover your reconstruction.

TORN VEINS
You can safely tie most lacerated veins without causing any disability, but those bigger than the common femoral vein you should repair, if possible.
Repairing a large vein is usually more difficult than suturing an artery, because blood wells up into the wound, instead of spurting out, and obscures the view. However, a simple continuous suture usually suffices.

Veins you should repair are the:
(1) internal jugular vein,
(2) external iliac vein,
(3) common femoral vein.
*Try always to repair combined arteriovenous injuries: deal with the vein first, before repairing the artery. Always harvest the saphenous vein from the uninjured leg,* if possible.

Sponge holding forceps are useful in pressing onto a torn vein because they flatten it. If possible, use lateral occluding clamps which will let you see the edges of the tear and insert a layer of fine continuous sutures.

**If bleeding continues**, press firmly on the vein above and below the tear. This will empty it and show you its hole outlined against the posterior wall.

Venous walls are very delicate and easily torn: use only 6/0 sutures and only attempt to repair big veins. Sutures readily tear a small vein wall and enlarge a hole in it.

**If all else fails**, occlude the vein above and below the tear, and ligate it. Fortunately, you can tie nearly all veins in case of emergency.

POSTOPERATIVE CARE
After a vascular repair, monitor the patient carefully, looking for signs of haemorrhage, distal ischaemia infection or compartment syndrome.

Elevate a limb slightly and begin isometric muscle exercises on the 1st day postop. (Bed rest may still be necessary for wounds.)

*N.B.* Treating a patient with 7500 IU heparin IV continuously over 24h, or otherwise 2500 IU tid, needs very careful monitoring for haemorrhage, and *may not be wise in your situation.*

DIFFICULTIES WITH ARTERIAL REPAIR

**If the wound becomes infected,** the arterial repair may break down & bleed, or thrombose. *Don't try to make another repair until all the infection has settled.* You will have to remove the infected arterial segment, and put in a shunt or resort to a distal amputation.

**If the arterial repair thromboses,** this is due to inadequate debridement, residual distal thrombus, severe anastomotic stenosis, or flow interruption of a vein graft from kinking, twisting, external compression or failure to reverse its flow orientation. Unfortunately, you will have to repeat the operation.

Other dreaded complications are compartment syndrome (49.8), false aneurysm or arteriovenous fistula (49.9).

## 49.6 Stab wound close to a major artery

The common danger site for this emergency is the groin. Open and explore the wound early, so as to examine the artery and repair it if necessary. This will be easier than trying to deal with the arterial hematoma or false aneurysm that may result from leaving it.
Explore the wound under GA (ketamine is usually ideal). Try to get proximal control of the vessel (if necessary expose a proximal artery, through a separate incision, 49.3). Repair the damage by direct suture, patch or graft, as needed (49.3)

**If the artery and vein are both injured**, use suction to find out where to press to gain control. Separate the two vessels to prevent an arterio-venous fistula.

***ALWAYS EXPLORE STAB WOUNDS CLOSE TO ARTERIES!***

## 49.7 Pulsating arterial haematoma

Several things may occur if bleeding from an injured artery cannot escape to the surface:
(1) Blood may track widely in the tissues.
(2) A tense arterial haematoma may form locally, which may press on the collateral vessels and obstruct them.
(3) The outer layers of the haematoma may become organized and form a traumatic (false) arterial aneurysm (35.8).
(4) A false aneurysm may rupture into a vein, forming an arteriovenous fistula.

Initially, an arterial haematoma may be difficult to diagnose. Suspect that this is likely whenever an artery is injured by a penetrating wound (especially in the groin), a fracture or even needle puncture.

**If it is rapidly expanding**, explore it before it becomes an aneurysm or an arteriovenous fistula, both of which are even more difficult to treat.

**If there are no signs of distal ischaemia,** apply a bandage and wait for the fistula to 'mature'.

EXPLORING A PULSATING HEMATOMA (GRADE 3.2):
Apply a tourniquet proximally to control bleeding. If this is not possible, control the external iliac artery (49.3).

Make an adequate incision to explore the wound. Expose the artery first proximal to the injury, and control its flow with an arterial clamp, or tape. Try to get distal control in the same way.
Remove the clots. Use suction to define the anatomy carefully; you may find you have to improve proximal control. When there is no more bleeding, repair the injured artery (49.3) and ligate injured veins. Finally, release the clamp or tourniquet cautiously to see if your repair leaks. If so, press on it for 5mins and look again.

**If the haematoma is below the elbow or knee**, you may tie the injured artery.

**If the haematoma is above the elbow or knee**, try to repair the injured artery. If you feel you cannot do this, or you don't have the necessary equipment, insert a shunt (49-5).

## 49.8 Limb compartment syndrome

The circulation in a limb is probably impaired and there is danger of ischaemic damage (Volkmann's ischemic contracture (44.8) or even gangrene) if a patient with a limb injury:
(1) has severe pain (*always believe him!)*,
(2) has loss of sensation in the fingers or toes,
(3) has peripheral pallor or cyanosis,
(4) has cold fingers or toes,
(5) cannot move the fingers or toes,
(6) has absent distal pulses,
- the 6 P's (49.1) – even if the pulse is still palpable, and capillary return is still normal, suspect the compartment syndrome.

*Pain is often out of proportion to the visible signs.*

***Don't rely entirely on the figures, though!***
The commonest causes of these disasters are:

(1) An unsplit cast on a forearm or lower leg fracture (58.2).
(2) A child's supracondylar humeral or forearm fracture (72.6,7) .
(3) A fractured tibia (68.2).
(4) Any complicated fracture or crush injury, especially if delayed >4h.
(5) An elbow (61.3) or knee dislocation (67.15).
(6) Gallows or extension traction for a femoral fracture (72.4).
(7) A bullet wound & combined arterio-venous injury.
(8) Re-perfusion injury after arterial ligation or repair, *especially the popliteal.*
(9) Burn contracture (34.2).
(10) Tourniquets left *in situ* too long.
(11) Snake bites (46.11).
(12) Acute venous thrombosis.
(13) Chronic muscle exertion.
You may be better off performing a fasciotomy pre-emptively, especially in a popliteal artery repair.

ASLAM (43) struck his forearm while water-skiing but did not fracture it. Eight hours later it became acutely painful and he could not extend his wrist or fingers. He consulted his neighbour, an orthopaedic surgeon, who decompressed his forearm within the hour, from wrist to elbow, leaving his skin and fascia open. Dark swollen muscle bulged out of the wound. He was discharged the following morning, and his incision was closed 5 days later. He recovered completely.
LESSONS (1) Remember the compartment syndrome. A happy outcome followed what might have been a major tragedy after a minor injury. (2) *Don't delay!* Immediate decompression is imperative.

When a patient's fracture is reduced the pain should lessen. *Severe postoperative pain is thus a critical early sign.*

After a fracture, or even after bruising of the lower leg, blood and oedema fluid may collect in all, or any, of these compartments. As the volume of fluid increases, the intra-compartmental pressure rises so that the circulation to the foot is obstructed.

The cure is simple: FASCIOTOMY!

**MEASURING TISSUE COMPARTMENT PRESSURE**

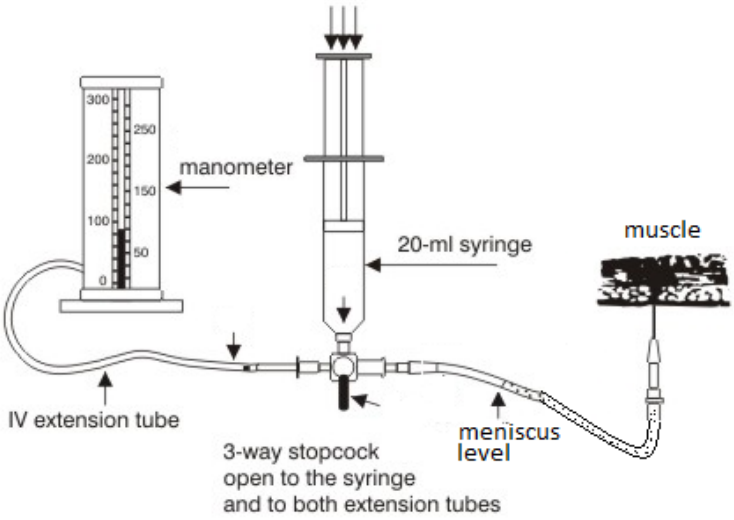



**Fig. 49-18 TISSUE COMPARTMENT MEASUREMENT. *Do this only in dubious cases!* A, connect a syringe with the plunger at the 15ml mark to IV tube connected to an 18G needle and another IV tube to a manometer via a 3-way stopcock. B, aspirate saline into the tubes and syringe so that a meniscus rests c. ¾ the length of the injection tube. C, close the stopcock, and insert the needle into the muscle compartment without spilling fluid. D, now open the 3-way stopcock so that the syringe is open to both manometer & muscle compartment. E, depress the plunger of the syringe gently and watch the meniscus. Measure the manometric pressure just when the fluid level begins to move.** *After Whitesides TE Jr, Haney TC, Morimoto K, Harada H. Tissue pressure measurements as a determinant for the need of fasciotomy. Clin Orthop Relat Res. 1975; 113:43-51*

You can measure the tissue pressure in the compartment easily (49-18). *Make sure the manometer and the limb are at the same level*. If the pressure is >30mm Hg, or the difference between diastolic BP and tissue pressure is <30mm Hg, the limb is in danger.
*N.B. 30mm Hg = 40cm $H_2O$.*

You must diagnose the compartment syndrome in time. Unless you perform a fasciotomy within 4h of symptoms starting & open up each compartment in turn through a generous longitudinal incision, the soft tissues will die. So **if you cannot perform the**

**measurements** (49-18) in time, go straight ahead with fasciotomy!

**If the muscles feel tense, swollen, and almost woody hard**, decompression is urgent. However operation is still worthwhile even if a patient presents late. Perform a fasciotomy liberally or even prophylactically in patients with arterial injuries or the suspicion of ischaemia. Open up all the muscle compartments using long scissors, *not a knife*. *N.B. Beware rhabdomyolysis* (49.9) !

***THE AFTER-EFFECTS OF A FASCIOTOMY ARE MINIMAL, BUT ISCHAEMIC MUSCLE NEVER RECOVERS.***

*Arterial spasm from local blunt injury may produce the same effects, and also needs rapid treatment.*

There are 2 compartments in the forearm, where muscles are enclosed and separated from each other by strong fascia:
(1) The anterior compartment with the flexors.
(2) The posterior compartment containing the extensors.

There are 4 compartments in the lower leg,
(1) The lateral compartment with the *peroneal* muscles.
(2) The anterior compartment with the *extensor* muscles of the ankle and toes.
(3) The superficial posterior compartment with the *gastrocnemius* and *soleus* muscles.
(4) The deep posterior compartment with the deep *flexors*.

TREATMENT

**If the symptoms persist**, proceed urgently with fasciotomy.

**If the limb is in a cast**, split, open, and elevate it.

**If this does not rapidly relieve the symptoms**, remove the cast entirely.
Unfortunately, in removing the cast you will lose immobilization of a fracture. So, as soon as the circulation returns, apply skeletal traction. Later, reposition the fracture if necessary, and reapply the cast.

WHICH COMPARTMENT?
Function relates to the compartment affected, but stretching an ischaemic muscle causes pain, so:

**If extending the fingers is weak,** the anterior compartment is ischaemic.
**If flexing the fingers is weak** (rare)**,** the posterior compartment is ischaemic.

**If flexing the foot and toes causes pain,** the anterior compartment is ischaemic.
**If extending the foot and toes causes pain,** the anterior compartment is ischaemic.

**ANTERIOR FOREARM FASCIOTOMY**

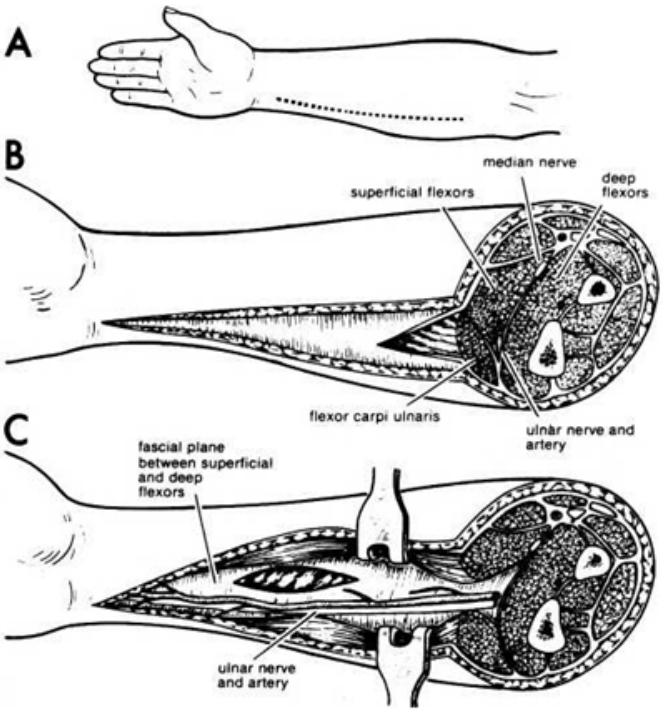



**Fig. 49-19 ANTERIOR FASCIOTOMY IN THE FOREARM A, the incision. B, cutting the fascia over *flexor carpi ulnaris.* C, cross-section showing the positions of the ulnar nerve and artery.** *After Sheridan GW, Matsen 3rd FA, Fasciotomy in the treatment of the acute compartment syndrome J Bone Joint Surg Am 1976;58(1):112-5 with kind permission*

ANTERIOR FOREARM FASCIOTOMY
(GRADE 1.4)

Make an incision from the medial epicondyle to the ulnar end of the flexor crease on the wrist (49-19A). Incise the fascia over the *flexor carpi ulnaris* (49-19B), and retract this muscle medially. mRetract the *superficial flexor* muscles laterally, and incise the fascia over the *deep flexors*.

Decompress each muscle by making a longitudinal incision through its sheath, carefully avoiding its nerve. The pale compressed muscle tissue will bulge up gratefully, as you release the pressure in its sheath. If you have acted in time, a conspicuous hyperaemia will follow. If you are too late, the deep flexor muscles will be mauve, yellow or necrotic.

The nerve lies close to the artery under the *flexor carpi ulnaris*, and between it and the *deep flexors* (49-19C).

*CAUTION! Don't cut the ulnar nerve or ulnar artery*. Put K-wires through the 2nd, 3rd, & 4th metacarpals (64.29), suspend the arm vertically,

and leave the wound open, unsutured, under a gauze or hypochlorite dressing. Continue to apply traction. This usually reduces the fracture.

*CAUTION!*
*Don't re-apply a cast till the swelling has subsided. Don't close the compartments!*

Leave the wound wide open, covered with gauze, and a suction dressing if possible. The gap will usually close as the swelling subsides. If necessary, close the wound with a skin graft, or delayed primary suture.

**DECOMPRESSING THE FOREARM IS AN ACUTE EMERGENCY**

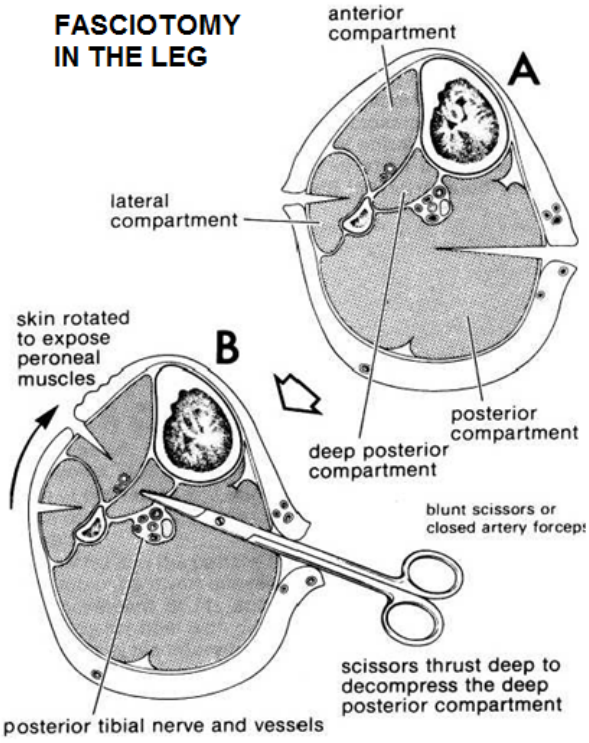



**Fig. 49-20 FASCIOTOMY IN THE LEG. A, incisions for the lateral and posterior compartments. B, opening up the deep posterior compartment, showing how you can slide the skin incision you have used to open the lateral compartment forwards, so that you can also open the anterior compartment through it.** *Kindly contributed by Peter Bewes.*

LEG FASCIOTOMY (GRADE 1.4)
*Make at least 2 incisions in opposite compartments* because you may otherwise miss dangerous muscle necrosis in an unopened compartment.
*Make sure you always open both compartments in the forearm and all 4 in the lower leg.*

DIFFICULTIES WITH COMPARTMENT SYNDROME

**If you have no K-wire,** decompress the forearm, splint it with a plaster backslab, and refer the patient as soon as you can.

**If the ischaemia is advanced when you decompress the forearm,** maintain a high alkaline urine output, to assist the excretion of the myoglobin released from the necrotic muscle, and watch for renal failure (44.10).

**If a contracture develops,** apply splints to minimize the deformity as much as possible.

**(a) Medial incision:** make a 15cm longitudinal incision on the medial side of the leg. Cut through deep fascia from the knee to the ankle. Incise the turgid, dark, reddish blue, ischaemic muscle of the posterior compartment.
Slide the skin incision anteriorly over the subcutaneous tissue (49-20), and incise the muscle under it so as to decompress the anterior tibial compartment. This will enable you to decompress both compartments through the same incision.

*Don't miss out cutting the retinaculum* which keeps the tendons of the anterior muscles in place at the ankle).

DIFFICULTIES WITH FASCIOTOMY
**If the circulation returns to the foot**, no further incisions are necessary.

**(b) Lateral incision:** make a similar 15cm longitudinal incision on the lateral side of the leg. Incise the fascia and the muscle directly underneath it, and decompress the peroneal compartment
.
**If the circulation does not return to the foot in a few minutes**, deepen the medial incision to open up the deep posterior compartment. Push scissors deeply into it and open the blades, as if you were exploring an abscess by Hilton's method (6-3).
*Don't use a knife in the depths*, or you may cut the posterior tibial artery, or tibial nerve.

**If circulation still does not return,** expose the artery: a tightly contracted artery may look like a piece of solid cord. The distal part of the brachial artery, the femoral, the popliteal, and the tibial arteries can all contract like this.
Expose the injured vessel through an adequate incision. This alone may be enough to make it start pulsating again.

**If the artery does not start pulsating** after exposing it and part of it looks like a piece of whipcord, expose the healthy artery above and

below the cord-like section. Expose it on all sides, so that there is no tissue surrounding it.

**If the artery fails to dilate**, open an ampoule of 2% papaverine, or less satisfactorily, pethidine, or 2% lidocaine (without adrenaline), and spray this onto the contracted segment.
Then lay a warm moist pack on it, and wait 10mins, after which the artery will usually have increased in size and will have started to pulsate.

**If the artery is still not pulsating**, apply an arterial clamp above the constriction, and inject 2ml 2% lidocaine with a little heparin, between the clamp and the constriction. This may distend it enough to make it start pulsating. Wait another 10mins while the heparin acts.
Then release the clamp. **If the artery is torn or the spasm does not recover**, repair or graft it (49.3).

**If there is a fracture,** apply calcaneal traction until definitive treatment is possible later.

**If the muscle does not recover rapidly**, contractures are likely. Splint the extremity in the position of function.

**If the patient presents >6h***, it is still worthwhile performing a delayed decompression,* because any improvement will result in some functional gain and gangrene is much less likely.

**If the compartment syndrome is several days old***, don't perform a fasciotomy.* Splint the limb in the position of function (neutral and slightly everted). If it survives, it will still be useful for some activities. *Fasciotomy at this late stage will not help* and may lead to infection and an otherwise unnecessary amputation.

## 49.9 Rhabdomyolysis

Decompression of a compartment may result in rhabdomyolysis (the re-perfusion injury). The urine becomes dark or 'bloody' looking; the dipstick is positive but there are no red cells on microscopic examination. Look for myoglobin in the urine, if you can.

Rhabdomyolysis occurs when muscles remain immobile, during seizures, in long-standing splinting, in patients collapsed for longer periods on the ground, in crush injury (58.16), excessive exercise and being suspended in torture (47.1).

This is more likely to occur in sickle cell disease, in drowning (43.7), hypothermia (45.2), hyperthermia (45.3), and drug & alcohol abuse, even without compartment syndrome, as well as in certain snake bites (46.11).

Maintain a high urine output to excrete the myoglobin (which blocks the kidneys). Aim for a urine output of 2–3ml/kg/h). You may need to infuse 6l/day; (children may require 2-3x maintenance dose). Try to monitor the CVP if possible.

For moderate and severe rhabdomyolysis and in patients with acidosis, dehydration, or underlying renal disease, add 44mEq of sodium bicarbonate to 1L 0.9% saline, and infuse this at 100 mL/h as part of the total IV fluid administered.
Try to adjust the IV bicarbonate concentration or rate to achieve a urine dipstick pH>6.5-7.0.

*CAUTION! Don't alkalinize the urine in children*. *Using sodium bicarbonate* may potentiate hypocalcaemia.

To increase urine output if it is inadequate, use mannitol (in adults) and furosemide. You will need to be aggressive with IV fluid input to be sure of a good urine output until all the myoglobin is excreted.