3 The control of bleeding

3.1 Assisting natural mechanisms

Most surgical intervention will result in some sort of bleeding. This can also happen from an injury. The body has excellent mechanisms for controlling bleeding, so that your task is mostly supportive. The main mechanisms are the cascade of enzymatic reactions which make the blood clot, and the ability of the muscular walls of the arteries to contract.

If you fail to control bleeding adequately a patient may die, so take note of the amount of blood he loses. The loss of a given volume of blood is more serious in a child (3-1) and much more serious in a baby, than it is in a fit adult, who can usually lose 1L without the need to replace it by blood. A loss of >20% of the blood volume is critical: a child has a total of 75ml/kg of blood.

The most generally useful way of controlling bleeding is pressure, but there are also special methods for particular parts of the body, such as the scalp and the dura, the bowel (11.3) and the liver.

Most importantly, *don't panic!* Have a plan of action, starting with the simplest methods, and if these don't work, progress to more complicated techniques. Stop to reassess the situation: *don't fumble around;* you will lose valuable time and achieve nothing! *Don't try to get definitive control of bleeding from the outset:* aim for temporary control initially. This should be quick, effective and not cause more damage to the patient.

These are the methods you can use:
(a) Pressure is the simplest and most valuable way to control bleeding. When you press on tissue, the walls of its vessels come together, and where their edges are cut, thrombus will start to form. When you release the pressure you will probably find that bleeding has stopped, or that only the arteries will continue to spurt at you, and these you can tie off. Press with a gauze pack. If pressure is to succeed, you must press for long enough: this is normally at least 5mins by the clock, which is one reason why every theatre should have a clock. If the tissue behind the bleeding area is firm, as when you press a bleeding scalp against the skull, pressure is even more effective. Likewise a finger in a groin wound, pressing against the hip joint, is extremely effective. For bleeding from the finger, *don't try anything else!*

Note that putting on more and more dressings (so increasing the applied area) dissipates the pressure (which is force per unit area), so their effectiveness is reduced. If a wound dressing is soaked, remove it, and apply pressure directly to the bleeding point.

A pressure dressing is only really effective on the head, hand or foot; otherwise on a limb it acts as a venous tourniquet, which may increase bleeding! On the chest it will interfere with respiration, and it is useless on the outside of the abdomen.

Inside the abdomen, remember that pinching the base of the mesentery between the fingers of one hand will occlude its blood supply, so you can buy time if there is significant haemorrhage from the bowel or mesentery itself.

You can also control bleeding from the liver by compressing the vessels in the free edge of the lesser omentum (the Pringle manoeuvre, 15.8), or from the uterus or lower abdomen by pressing the aorta against the spine (22.11). This is most effective if you go through the avascular area of the lesser omentum after pulling the stomach downwards. Alternatively, if the bleeding is higher up, you will need to open the space between both *crura* of the diaphragm to expose the abdominal part of the thoracic aorta. Clearly, if you can get a vascular clamp onto the aorta, this is better than your fingers, *but don't give up if you don't have vascular instruments!* Just press and wait.

(b) Packing. A variation of this method is to pack a wound and to remove the pack ≤24h later, as with hepatic bleeding, bleeding from the pelvis, or after a sequestrectomy (7.5). *Note that packing does not mean stuffing gauze indiscriminately into a cavity,* but laying it carefully and methodically to obliterate a space if the packing is done inside a cavity, or laying gauze outside a solid organ on both sides like a sandwich, and wedging this firmly. If the packs become soaked at the edges, remove them gently and pack more tightly.

(c) Ligature. A haemostat (artery forceps) can be used to grasp a bleeding vessel, particularly an artery which is spurting blood at you. If the vessel is a large one which you'll need to repair, use vascular clamps or gauze-covered forceps. *Be sure you can see the vessel*. You can then tie it. Get an assistant to hold the forceps and release it when your tie is secure. If you cannot see the bleeding point, use a suture on a large needle and pass this through a good firm amount of tissue adjacent, and pull the suture towards you. This may control the bleeding, at least partially. Pass the suture in a parallel direction below the first point and so tie it as a figure-of-8 (4.8). Sometimes this does not fully control bleeding, so take 2 more bites at right angles (the 'clover' suture).

(d) Inflating a balloon in an orifice is a very useful procedure, especially in bleeding from the neck, liver or uterus. Pressure in a confined space is very effective at stopping bleeding.

(e) Repairing a bleeding vessel, either by closing a laceration in its wall or by making an end-to-end anastomosis, will be necessary to control haemorrhage in a major vessel. This may save a limb.

You may be able to control massive bleeding from a large vessel by inserting a balloon catheter into its lumen, and inflating the balloon.

Alternatively, occasionally you can put a tube shunt between the widely separated ends of a large important artery, fixing these in place with tape.

Get proximal control by formally exposing the vessel high above the bleeding point. This will only be necessary on unusual and desperate occasions. On rare occasions you may have to tie off the artery despite the consequences of distal ischaemia.

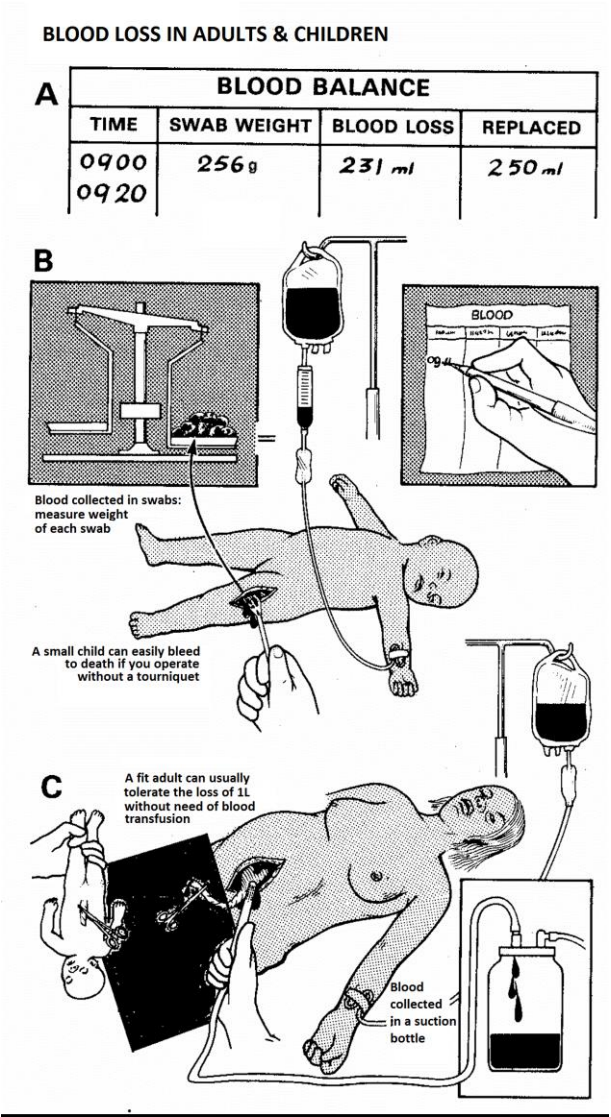

Fig. 3-1 BLOOD LOSS IN ADULTS AND CHILDREN.
A,B, when you operate on a child, make an accurate 'blood balance sheet'. In a major operation measure the blood lost by weighing the blood-soaked swabs on a balance. Replace blood lost with an equal volume of blood as soon as possible. This should be HIV-, HBV- and HCV-free. C, a fit adult, such as a mother having a Caesarean section, can tolerate a blood loss of up to 1L or even 1·5L, before you need to transfuse blood, rather than Ringer's lactate or saline. You can usually measure the blood lost in a suction bottle.

(f) Haemostatic gauze will eventually stop bleeding from the oozing cut surface of the liver, or the surface of the brain. Unlike ordinary gauze, it is slowly absorbed. It is expensive and rarely indicated. A substitute is to cut a piece of muscle, hammer it flat, and use this.

(g) Bone wax packed into the bleeding edge of the skull into the diploe, or into the marrow of a bone, will stop the bleeding if it is not too aggressive.

(h) Adrenaline, already added 1:100,000 to lidocaine solution or to saline, used to infiltrate the tissues, will minimize capillary and venous bleeding, *e.g.* during the repair of a vesico-vaginal fistula (21.18), in thyroidectomy (25.7) or cleft lip repair (31.7). You can also use a pack soaked with 1mg adrenaline in a bleeding nose (29.7), or on a bleeding tooth socket (31.3).
Never use adrenaline in the penis, or the distal parts of a limb such as a finger or toe, or in an IV forearm block, because it may constrict the vessels so much that the part becomes gangrenous.

(i) Hydrogen peroxide (6%, 20 vols) is useful not only to clean a wound infected with anaerobic organisms, but will also slow bleeding.

(j) Assisting blood clotting is important. When you have transfused >5 units of blood, the citrate in it will lower the calcium concentration in the blood and prevent it clotting. So *don't forget to add 10ml of 10% calcium gluconate IV after every 4th unit of blood*. When blood fails to clot, you can use fresh blood, but this may be impractical. You can store fibrinogen for such a purpose; fresh frozen plasma (FFP) is ideal but often pooled from several blood donors, and so its risks of HIV transmission are significantly greater than blood.

(k) Tranexamic acid (cyklokapron) 1g IV over 10mins and then 1g over 8h or as 20mg/kg tds is a useful adjunct, without these problems.

(l) Blood may fail to clot in the presence of liver disease, vitamin C deficiency, or if the patient has taken excess warfarin or its effect is potentiated by other medicines. In this case, use vitamin K 10mg IV if possible, as orally it takes 48h to be effective! Remember also that aspirin as well as garlic have an anticoagulant effect, and excessive use by patients may cause bleeding problems!

(m) Raising the bleeding part will lower the pressure in its veins, and so minimize bleeding. This is valuable if there is bleeding from a limb, or the venous sinuses of the brain (a rare and difficult emergency), when the level of the head in relation to the rest of the body is critically important. But there is a risk of air embolism if a rigid vascular channel, such as a sinus, is raised above the level of the heart.

(n) A proximal pneumatic tourniquet will control bleeding from the distal part of a limb, especially before or during an operation (3.4). For many operations this is essential, because it produces a bloodless field. Using a tourniquet in the trauma situation is useful to buy you time whilst you are organizing theatre. *Make sure you note how*

long the tourniquet is applied! A tourniquet round the cervix or uterus (22.11) can control uterine bleeding.

The common mistakes are:
(1) To panic when there is severe bleeding.
(2) Not to apply pressure when this is indicated, and not to apply it for long enough, or to apply it diffusely through more and more rolls of cotton wool and bandage.
(3) To grasp wildly with a haemostat in a pool of blood, to fail to grasp the bleeding vessel, and perhaps to injure some important structure.
(4) Not to apply the special methods for special sites.
(5) To cross-match blood too late.

A STORY ABOUT BLEEDING. A young trainee surgeon was excited to be able to assist the professor at an operation for a leaking aortic aneurysm. Predictably, there was quite a lot of bleeding seen when he released the big aortic clamps. In fact he hadn't seen so much blood in the abdomen outside of the trauma situation, where there was always frantic activity to stem the bleeding. When the professor had sutured in the graft, there was considerable oozing from the suture lines. He simply put in a big pack and asked the assistant to press gently, but firmly, till he returned, and went off to have a cup of tea! Petrified, the trainee hardly dared breathe, let alone move. When the professor came back 10mins later well refreshed, he re-scrubbed, and removed the pack; the operative field was perfectly dry.
LESSON When you control bleeding by pressure or with a pack, sufficient time (≥5mins by the clock) is all important.

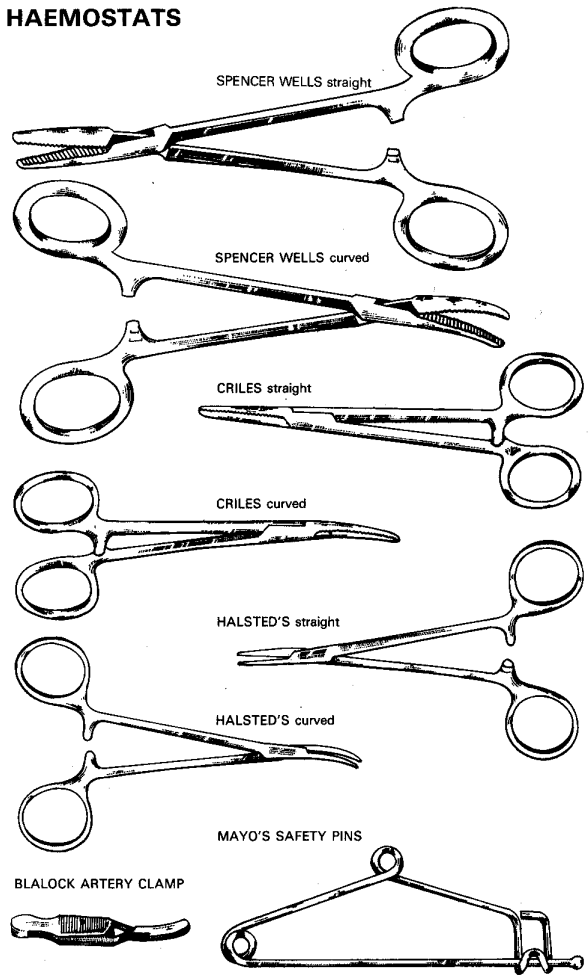

Fig. 3-2 HAEMOSTATS.
If you can see a bleeding vessel, you can usually grasp it with these locking forceps, which are one of the great inventions of surgery. *Don't use them as towel clips, because they will then no longer close finely enough for blood vessels*.

Spencer Wells are general purpose haemostats; Crile's are medium-sized and more robust than Halsted's, which are some of the finest and most delicate instruments and must be used with care. Blalock (bulldog) clamps are non-crushing clamps to stop blood spilling from a vessel whilst it is being repaired. Mayo's pins keep forceps together in bunches during sterilizing.

Spencer Wells, straight, box joint, (a) 200mm, (b) 150mm.
Spencer Wells, curved, box joint,
(a) 230mm, (b) 200mm, (c) 150mm, (d) 125mm, curved.
Crile's, straight, box joint, 140mm.
Crile's, curved, box joint, 140mm.
Halsted's, ultrafine, mosquito, haemostatic, straight, box joint, 120 mm.
Halsted's, ultrafine, mosquito, haemostatic, curved, box joint, 120mm.
Kocher's, straight, box joint, 200mm.
Kocher's, curved, box joint, 200mm.
Blalock artery clamps (various sizes).

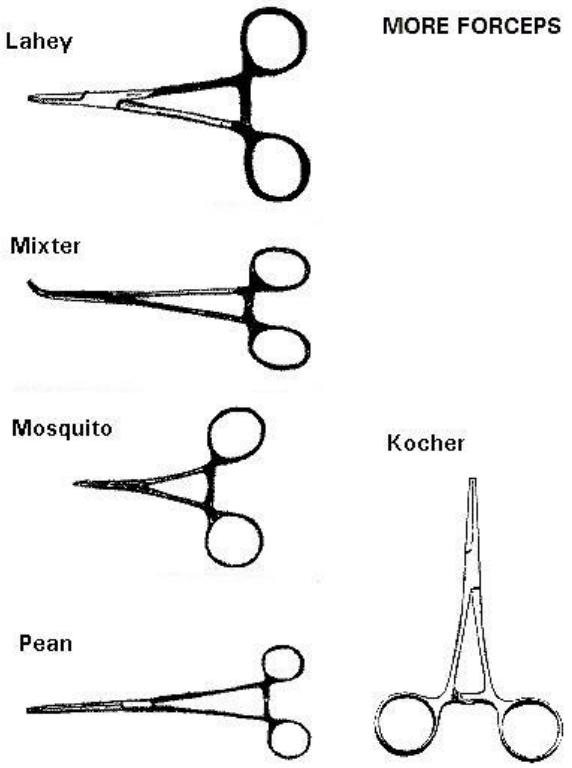

Fig. 3-3 MORE FORCEPS.
Lahey's are similar to Crile's; Mixter's have a more angled curve on their ends. The Mosquito forceps are fine and useful to hold threads. Pean's are long straight forceps. Kocher's are large haemostats with a tooth at the end of their jaws, for use on a wide vascular pedicle when an ordinary haemostat may slip.

3.2 Arterial bleeding

If you can see a bleeding vessel, you can grasp it with a haemostat (locking or artery forceps), which is one of the great inventions of surgery. Tie all larger vessels, either immediately or later. Small vessels, especially those in the skin, seldom need tying. When you remove a haemostat ≥5mins later, you will probably find that bleeding will have stopped. You can encourage it to stop by twisting the haemostat before you remove it, or if the bite of tissue is too large to twist, you can release the jaws and quickly pinch them together again a few times before you remove them.

Either of these methods will encourage the blood in the vessel to clot and will minimize bleeding, so that fewer vessels need tying.
Haemostats can be large or small, straight or curved, so that they rest over the edge of the wound. Haemostats do have some disadvantages. Each time you tie off a bleeding vessel you leave some crushed tissue and some suture material in the wound. If this is excessive, it can encourage delayed healing or infection later.
The tips of haemostats, especially small ones, must meet accurately, so good-quality instruments are important. *Never misuse haemostats as towel clips!* Box joints are worth the extra expense. Order them in sets of 6 (you can hardly have too many) because they will enable you to make up several sets (4.12).
It is best to cut skin boldly, which produces less bleeding, than tentatively and timidly, which produces a sawing type of action on the vessels.

(a) To tie an artery, use the following materials in this order of preference: long-acting absorbable, linen thread, cotton thread, or silk. *Don't use catgut for larger and more important vessels*: it slips off too easily and may be reabsorbed too quickly.
Grasp the bleeding artery with a haemostat. Either:
(1) Tie it with one firm reef knot.
(2) Tie it with a surgeon's knot (4.8) followed by 2 to 3 more throws.
(3) Transfix it, tie it with a reef knot, then pass one ligature through it with a needle, and tie it with another reef knot. This is the method for critically important vessels, such as those of the renal pedicle. For even more security, tie it proximal to a branch, and then cut it distal to this.

If it is a critically important vessel, ask yourself if what you've done is enough. If not, do it again: put a 2nd tie in a separate groove.

If there is a long length of vessel distal to your tie, shorten it, so as not to leave too much dead tissue in the wound, but *don't shorten it too much!*

If other methods of controlling severe arterial bleeding have failed, you may, very occasionally, have to expose and tie a major vessel, such as the external carotid or the subclavian artery. Use linen, cotton thread, or silk; *don't divide the vessel after you have tied it*, as it may recannulate.

(b) To control bleeding from a large pedicle, such as that of the spleen or uterus, *don't try to use a single ligature*. Control of the vessels will be safer if you take one or more bites of the pedicle and tie them separately.

(c) To control a difficult bleeding artery, try to get into the correct tissue plane. First find the artery by feeling for pulsation. Push the points of a fine haemostat into the connective tissue around it and separate them to open up a plane (3-4B). Gradually develop this plane until you can see the artery you are looking for. In this way you will avoid tying some important nerve in the ligature.

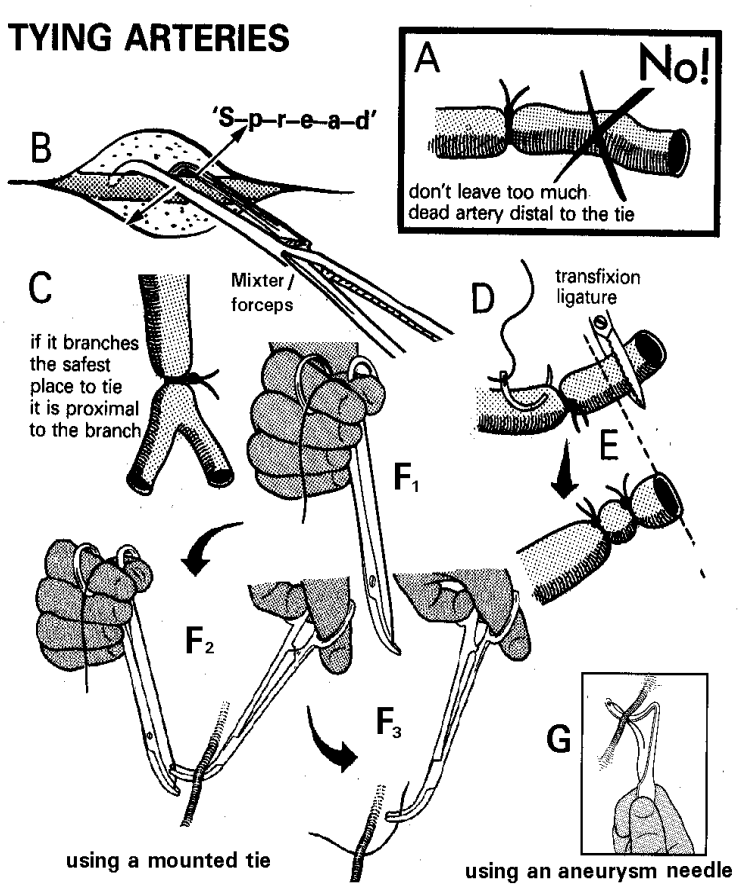

Fig. 3-4 TYING ARTERIES.
A, *don't leave too long an end*; this will leave unnecessary dead tissue in the wound. B, to free a vessel buried in tissue, insert Mixter forceps and spread the tissues. C, if possible, put the ligature proximal to a branch. D, tie the artery and insert a transfixion ligature; the needle is going through the vessel and its distal end is about to be cut off. E, completed ligature. F1, hold a length of suture material in a curved haemostat. F2, pass another curved haemostat under the vessel to grasp the suture material. F3, pull the suture material under the vessel. G, using an aneurysm needle.

TO GET A LIGATURE ROUND AN ARTERY, either use an aneurysm needle, or pass a curved haemostat under it, and ask your assistant to pass into your other hand a curved haemostat with a ligature 'bowstrung' across it (3-4F). This is useful in 'deep' surgery. You may be able to use ligaclips (4.10).

3.3 Diathermy

Heat causes coagulation of blood in vessels; this has been known for centuries. In order for an electric current to provide sufficient heat on a small area but without causing muscle spasm and cardiac dysrhythmia, diathermy uses radiofrequency currents of 0·5-1·5MHz.

(a) In monopolar diathermy, there is a high current density ensured at the point of contact with the active electrode at the diathermy probe tip but the current is then dissipated in a large volume of tissue through a large surface area 'indifferent' electrode, usually a plate placed under the buttock (3-5A). You must make sure this contact is good and uniform, otherwise a burn may result.

Make sure the wire connections in the instrument are sound, because poor contacts will increase the heat and so cause burns. Usually you will pick up a blood vessel with dissecting forceps, and touch the forceps with the diathermy tip. As metal is a good conductor of current, little heat is generated in its passage through the forceps.
Make sure though that your gloves have no holes, otherwise you may experience an electric shock and burn when the metal forceps come in contact with your own skin!

(b) In bipolar diathermy, the current passes between two point electrodes placed across the vessel to be coagulated. In this way a very high current density, and so much heat, is produced over a very small volume of tissue, with virtually no heat generated elsewhere (3-5B). Bipolar diathermy only works with low currents, and is therefore most suitable for small blood vessels, and fine surgical procedures.

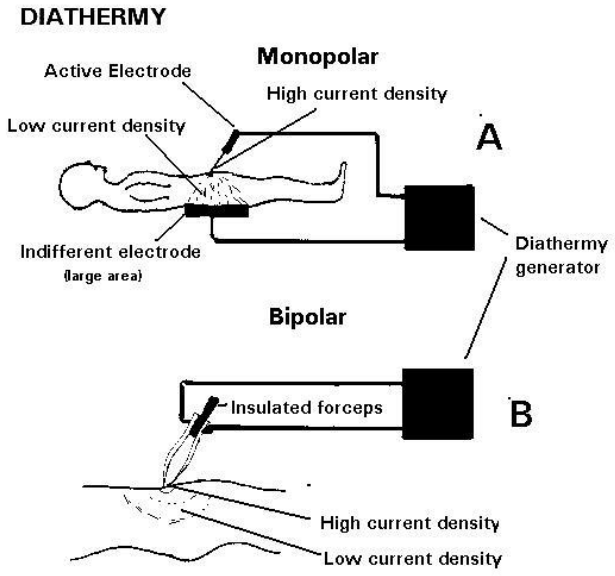

Fig. 3-5 DIATHERMY.
A, monopolar diathermy produces high current density at the active electrode dissipated through the body tissues through the 'indifferent' electrode with resulting low current density. B, bipolar diathermy produces high current density across insulated diathermy forceps tips.
After Sear JW, Rosewarne F. Anaesthesia for Surgeons, Oxford Textbook of Surgery, OUP 1994 p.83 Fig.2,3.

Radiofrequency generators produce different waveforms to give a coagulating (repetitive bursts of current cycles) or a cutting (continuous current) pattern; these are blended together for endoscopic resection (*e.g.* in prostatectomy).

DANGERS OF DIATHERMY
If you touch the skin or vessels very close to the skin edge with the diathermy electrode, you will produce a skin burn. If small, it is best to excise this, especially if it is on the edge of a wound. Otherwise, treat it like any other skin burn wound.

Don't use diathermy on the penis: you may cause thrombosis in the *corpora* unless you use bipolar diathermy.

Don't use diathermy on the groin if the scrotum is not in contact with the rest of the body: you might cause coagulation in the testicular vessels, especially if you lift the scrotum up in your hand.

Don't use diathermy in an amputation for an ischaemic leg (35.3): you will increase tissue necrosis.

Don't use diathermy on large blood vessels: tie them instead.

If the patient has a cardiac pacemaker, the diathermy current may affect this; so place the indifferent electrode far away, or use bipolar diathermy.

Don't use diathermy in the presence of inflammable anaesthetic agents, *e.g.* ether, and take care, if you use spirit-based skin cleansing preparations, that the fluid does not pool: serious burns may result.

Don't use diathermy on an obstructed bowel: it may detonate if methane gas has accumulated inside!

Reduce the current of the diathermy inside the mouth in operations under GA, because nitrous oxide as well as oxygen supports combustion, and its concentration is always higher there than elsewhere.

3.4 Bloodless limb operations

One of the great advantages of operating on a limb is that you can use a tourniquet to prevent bleeding. This will save blood and enable you to see the tissues more clearly. You can use any of these:

(a) A special pneumatic tourniquet which resembles the cuff of a sphygmomanometer. The pressure at which a tourniquet is applied is important; this is more easily controlled pneumatically, so a pneumatic tourniquet is much the best. Also you can, if necessary, let it down rapidly during an operation to perfuse the tissues, or to find arteries that need tying. The Conn improved pneumatic tourniquet with dial, complete in a case, in adult and child sizes is one of the most useful surgical appliances, and is almost essential; *alas, few hospitals have them*.

(b) An Esmarch bandage is a strip of red rubber. It is satisfactory, provided:
(1) You spread it out carefully over an encircling cotton wool pad.
(2) You don't put it on too tight, especially on a thin limb. (You can make one from an inner tube of a motorcycle tyre (3-6): the tube from an ordinary car tyre is too thick.)

(c) A reliable sphygmomanometer. You may not have a special pneumatic tourniquet, so this is probably what you will have to use.

A tourniquet will prevent blood entering a limb, but it will not remove blood which was already there when you applied it. Remove this blood in 2 ways:
(1) Raise the limb for ≥1min to help the blood to drain before applying the tourniquet. This is the only safe thing to do if there is sepsis. It will leave a little blood in the vessels, which can be an advantage, because you can more easily see where they are.
(2) Wind an Esmarch bandage round the limb from its distal to its proximal end to squeeze out the blood. Then apply a pneumatic tourniquet (or a sphygmomanometer) round the base of the limb to stop blood entering it. Finally, remove the Esmarch bandage. This will provide an almost totally bloodless field, *but is only safe if there is no sepsis*, which would then be spread proximally.

N.B. A tourniquet has disadvantages:
(1) **If you apply too much pressure for too long over too narrow an area**, you may injure the nerves to the limb, and cause a paresis; this is usually only temporary, but it may be permanent. A transient radial nerve palsy is common, even if you apply a tourniquet correctly.
(2) **If you forget to take a tourniquet off, so that it is left on for ≥6h**, Volkmann's ischaemic contracture, myoglobinaemia, or gangrene may follow. This happens more easily if there is arterial disease.
(3) **If a tourniquet is too loose**, it may obstruct only the veins, and increase bleeding.
So apply a tourniquet carefully; record the time when you applied it, and *don't leave it on too long*.

N.B. Never use a Samway's tourniquet. (This is a rubber tube with a hook at one end: it too easily injures the tissues beneath it.)

IF YOU APPLIED A TOURNIQUET, IT IS YOUR RESPONSIBILITY TO REMOVE IT

TOURNIQUETS
INDICATIONS
(1) Wound toilet in an injured limb, particularly if this has to be followed by repair of the vessels, nerves, and tendons.
(2) Any hand operation, other than a very small one. Hand injuries, and hand sepsis.
(3) The exploration and drainage of bones and joints, when this is anatomically possible, as in the lower humerus, the elbow and parts distal, or the lower femur, the knee, and parts distal.

CONTRAINDICATIONS
(1) The SS and CS varieties of sickle cell disease, *but not AS heterozygotes*.
(2) Ischaemia due to arterial disease.

ANAESTHESIA. A tourniquet is painful and a conscious patient will not usually tolerate one for >5mins. You will therefore need either GA or regional anaesthesia in most cases.

HANK (42yrs) was to have a bunion removed. The junior resident was asked to apply an Esmarch tourniquet. He had never applied one before, so he just wound the whole bandage round the patient's unpadded leg. 10 days later at the follow-up clinic the patient had a numb foot.
LESSON Learn how to apply a tourniquet before you apply one.

SITES FOR APPLYING A TOURNIQUET
There are only 4 of these:
(1) The middle of the upper arm (3-6D).
(2) The finger (3-6F). Use part of a rubber glove. This is only safe for a short procedure, such as draining a pulp infection.
(3) The upper thigh, a hand's breadth below the groin in an adult (3-6E). At this point the femoral artery lies close to the femur and is easily compressed.
(4) The cervix (23.7).

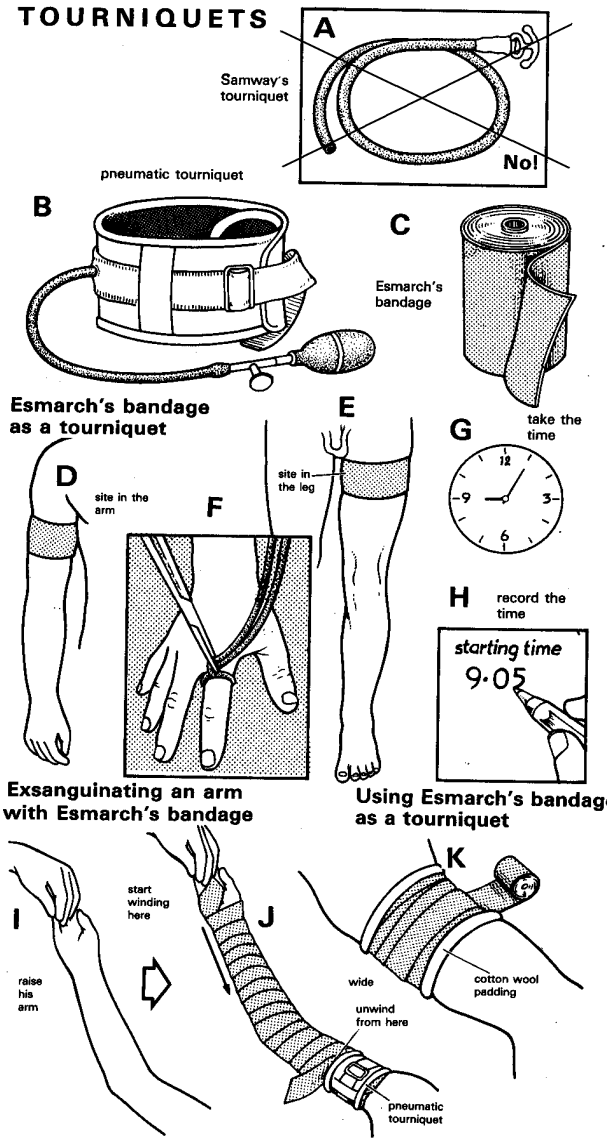

Fig. 3-6 TOURNIQUETS.
A, *don't use Samway's tourniquet,* as you may damage the tissues. B, a pneumatic tourniquet is much the best. C, the Esmarch bandage is a roll of red rubber. D, site to apply it in the arm. E, site in the leg. F, use a rubber catheter as a finger tourniquet. G & H, when you apply a tourniquet, take the time and record it. I, if you want to exsanguinate the arm, raise it and then apply Esmarch bandage, starting at the hand. J, inflate the pneumatic tourniquet, then unwind the bandage, starting proximally in the limb. K, you can use an Esmarch bandage as a tourniquet.

N.B. Don't exsanguinate a septic limb or where there is malignancy distally with an Esmarch bandage; you can use a simple tourniquet, though.

CAUTION!
(1) *A tourniquet on the forearm or on the lower leg is dangerous*, because you may damage the radial nerve at the ulna, or the common peroneal nerve at the neck of the fibula.
(2) Tie a tourniquet to the operating table, to prevent anyone forgetting it, because the patient cannot later be lifted off the table without removing it. *A tourniquet hidden under drapes can easily be forgotten.*

THE SAFE TIMES for an adult of average build are: the arm 1½h, the leg 2h. Shorten these times by 60% in a thin adult or in a child <8yrs. Apply a tourniquet to a finger for a few minutes only. The responsibility for keeping within these times lies with the anaesthetist, who should remind the surgeon every 15mins how long a tourniquet has been applied, and write on a board in the theatre when it was applied.

ELEVATE THE LIMB for a few minutes before you apply any kind of tourniquet. If you are going to apply an Esmarch bandage, now is the time to apply it.

REMEMBER TO USE ANALGESICS if you keep a tourniquet on for more than 30mins: it is painful!

PNEUMATIC TOURNIQUET. Place a folded towel, or a thin layer of cotton wool, around the limb at the site where the tourniquet is to be applied. Wrap this snugly round the limb: *it must not be loose*. Pump it up to the appropriate reading for 'arm', or 'leg', on the scale. For a child, use a lower pressure as indicated on the scale. Drape it out of the way of the operation, but keep the dial where you can read it. If the bag becomes contaminated, autoclave it (2.4).

USING A SPHYGMOMANOMETER AS A TOURNIQUET
On the leg apply the cuff over the femoral artery. On the arm apply it as if you were taking the blood pressure (BP), or if necessary higher up the arm. Bandage it in place with a firm unyielding bandage, and fix this with adhesive strapping. Inflate the cuff until the distal pulses just disappear. Remember the pressure, and let the cuff down again. When you want to use the cuff, blow it up to 80-100mm Hg above the pressure which just stops the pulses. This is about 200mm for the arm in an adult and 180mm in a child. For an adult leg blow it up to 250mm. Ask an assistant to keep the cuff at this pressure, and to inflate it as necessary if the pressure drops.
CAUTION! Don't inflate any cuff to >80-100mm above the pressure that will just obliterate the pulse.

USING AN ESMARCH BANDAGE
Raise the limb and squeeze blood out of it. Tape a folded towel or a thin layer of cotton wool in position over the limb. Apply the Esmarch bandage over c.12cm. Put on the first 2 layers of the bandage without pulling.
Next, do a trial run to find how many turns are necessary to obliterate the pulse. Pull out the bandage to about ¾ of its potential expansion length with each wind. Count how many winds you need to obliterate the pulse.
When you do apply it, apply 2 more winds than are necessary to obliterate the pulse. When you have finished, it should feel moderately firm, but *not rock-hard*.
CAUTION!
(1) *Don't apply a tourniquet over too narrow a band of muscles.*
(2) *Don't ever wind on more than five turns after you have obliterated the pulse*.
N.B. Every turn may add 100mm Hg more pressure.

TOURNIQUET TIME:
1½h IN THE ARM and 2h IN THE LEG;
60% LESS FOR THIN ADULTS AND CHILDREN

EXSANGUINATING A LIMB
INDICATIONS
Any operation in which you want a completely bloodless field, particularly orthopaedic.

CONTRAINDICATIONS
(1) Sepsis.
(2) Amputations for malignancy. It may spread both of these.

AT THE END OF THE OPERATION
There are 2 ways of controlling bleeding after you have applied a tourniquet:
(1) Release it just before you close the wound. Use this method when you do a fine operation on the hand, for example. It will reduce the blood clot in the tissues, and the stiffness and fibrosis that this might cause. Release the tourniquet, raise the limb, apply large swabs to the wound, and press on them firmly for 5 mins. Normally, bleeding will stop, though you should expect a measure of post-operative bleeding.
(2) Release it at the end of the operation after you have closed the wound. Use this method after operations in which clot in the tissues will be less important, as when you do a sequestrectomy (7.5). Tie any major vessels when you meet them during an operation. When the operation is complete, suture the wound, apply a dressing, and let down the tourniquet. Remove the pressure dressing 48h later. Usually, this is all that is necessary.
Observe the circulation in the limb at least hourly; the capillary reflex is important, so pinch the nail beds. Always check that a tourniquet is removed post-operatively: this must be part of the time-out procedure (1.8).

3.5 Post-operative bleeding

After you have closed an operative wound, it may start bleeding:
(1) During the first 48h (reactionary haemorrhage) because a clot in a vessel has been displaced, or a ligature has slipped.
(2) 8-14 days later (secondary haemorrhage) when the wound has become infected and eroded a vessel, usually quite a small one, sometimes a larger one.

One of the purposes of monitoring a patient immediately after an operation is to watch for reactionary haemorrhage, so make sure your staff observe carefully for early signs of blood loss, and understand what to do.

If a wound bleeds, try firm local pressure and packing. If it bleeds briskly, you may have injured an artery, such as the inferior epigastric. Minor bleeding is probably coming from the subcutaneous tissues, and is unlikely to be serious.

If local pressure fails to control bleeding, *don't apply more and more dressings;* take the patient back to theatre, open and, if necessary, enlarge the wound.
Irrigate it thoroughly with warm water. You can usually do this under LA. Remove the sutures and tie (3.2) or coagulate any bleeding vessels that you can see: you may need to put a running suture to control such bleeding. Liga clips may be useful (4.10).
If necessary, remove a pressure bandage or split a cast lengthways and open it at least 2cm. If you need to immobilize an open fracture, loosely apply a well-padded cast. You may need to re-apply the tourniquet, *but don't forget to remove it!*

If you have had to re-open a haematoma, add a single dose of prophylactic antibiotic (2.9).

N.B. Particular operations, *viz.* draining a peritonsillar abscess (6.12), removing a sequestrum (7.5), any laparotomy (11.2,10), draining an empyema of the gallbladder (15.4), cholecystectomy (15.8), liver biopsy (15.11), laparotomy for pancreatic abscess (15.15), splenectomy (15.17), block dissection of the groin (17.8), laparotomy for ectopic gestation (20.6), Caesarean section (21.10), D&C (23.4), myomectomy (23.7), hysterectomy (23.15), mastectomy (24.5), thyroidectomy (25.7), prostatectomy (27.20), eversion of hydrocoele (27.24), tonsillectomy (29.12), dental extraction (31.3) or varicose vein ablation (35.1), all have their own specific hazards.

If there are signs of circulatory failure post-operatively, with a fast pulse, pallor, perhaps with abdominal distension, confusion or even coma, this may be the result of:
(1) Blood lost at the operation not being replaced, especially if there was hypovolaemia before bleeding began.
(2) Fluid lost into the sequestrated bowel not being replaced.
(3) Anaesthesia too deep and depressed respiration, leading to hypoxaemia and hypotension.
(4) Overdosage of opioids, such as morphine or pethidine.
(5) Use of a high subarachnoid (spinal) anaesthetic.
(6) Septicaemia.

If bright red blood comes from a drain or incision, there is profuse arterial bleeding. Restore the circulating volume with 2L Ringer's lactate fast. Transfuse blood if the systolic blood pressure remains <90mm Hg. *Don't wait till the blood pressure is normal! Stop the haemorrhage!*

If you aspirate large quantities of fresh blood from a nasogastric tube after upper gastro-intestinal surgery, there is probably bleeding from a suture line. This is unlikely to stop spontaneously. You will probably need to re-open the abdomen to deal with the problem.

If there is bleeding some days after a laparotomy, the blood may be coming from a stress ulcer, or from a pre-existing duodenal ulcer unrelated to the previous pathology. This may threaten life. Treat this as described (13.4).

If blood is not clotting properly, check the clotting time. Take 5ml into a dry glass tube; invert it every 30 seconds, keeping it at body temperature, and time when it clots. If this takes >8mins, there is a clotting defect. Administer 10mg vitamin K IV. Use whole blood or packed cells and FFP to replace the blood loss, to try to replace the clotting factors.

Disseminated Intravascular Coagulation (DIC) may develop, especially with retained products of conception. If blood clots in ≤2·5min, it is hypercoagulable: thereafter if the clot lyses in 30mins, fibrin degradation has occurred. Use whole blood, FFP and fibrinogen 4-8g if available, to correct the clotting disorder.

3.6 Complications of blood transfusion

Blood is a dangerous substance and transfusion can cause severe, lasting problems, even death. Your laboratory ought to be able to cross-match any blood you transfuse; in a dire emergency, it is best to use the same group as the patient, then A(Rhesus)+ if the patient is A-ve or vice versa. But otherwise you should use O-ve blood, but you can probably get away with O+ve, except in women of child-bearing age. Even then there may be significant incompatibility problems.

The most important of the complications is transmission of hepatitis and HIV disease, and therefore your laboratory must be able to check for these also. There remains the danger of the 'window' period for HIV and so you should always think about auto-transfusion, even in the presence of mild sepsis (5.3).

These are the commoner infections that can be transmitted by blood transfusion:
1. Hepatitis A, B, C, D.
2. HIV disease.
3. Malaria.
4. Staphylococcal (or other bacterial skin) sepsis.
5. Atypical mononucleosis (glandular fever).
6. Brucellosis.
7. Cytomegalovirus.
8. Syphilis.
9. Yersinia.
10. Trypanosomiasis.

Apart from these, there may be ABO or Rhesus (Rh) incompatibility as well as 26 other types of cross-reactions, as well as plasma reactions and problems related to the blood being still frozen or overheated.

A graft-versus-host disease can rarely occur, producing an ARDS-type lung injury.

Stored blood may have [K^+] of 40-70mM, so multiple transfusion may produce a dangerous hyperkalaemia, and the citrate used to preserve its liquidity may produce a worsening acidosis. However, often more importantly, as stored blood loses its clotting factors after 24h, coagulation becomes disrupted. Further, the citrate soaks up calcium, and this further aggravates bleeding. Haemorrhage may even be exacerbated by a consumptive coagulopathy producing DIC.

If your laboratory produces packed red cells (because other blood products are filtered off), there are no platelets in the blood. Using whole blood avoids this problem and holds the clotting factors necessary for haemostasis. Stored blood is just not as good!

However, there may be a greater risk of multiple pulmonary emboli (the acute respiratory distress syndrome), and an antigenic response producing release of vasoactive substances and complement as well as depressing the reticulo-endothelial system. Blood transfusion definitely decreases immunity, and the risks of recurrence after cancer surgery may increase by c. 10%.

Finally, if you transfuse an anaemic patient, especially if his anaemia is chronic and compensated, you can so increase the blood volume that you tip him into acute heart failure. This is particularly important in children.

(a) Protocol

Check the blood units individually for compatibility (name, hospital and batch numbers, group) and expiry date. Make sure an IV line is patent and flushed with saline. Warm the blood (*don't heat it up!*). Check the blood unit to be used again, and make sure it is signed for. Attach the blood unit to a blood-giving IV infusion set (with a filter). Observe the patient ½hrly for pyrexial or other reactions, and chart infusion volumes.

N.B. Don't stop a transfusion because of a minor pyrexia especially if the patient is septic anyway.

Administer 10ml (2.2mmol) 10% calcium gluconate IV with every 4th unit of blood transfused.

N.B. 10ml of 10% calcium chloride IV provides 6.8mmol.

Administer 20mg furosemide IV with each unit of blood if cardiac failure is feared.

Stop the transfusion if there is a serious reaction; administer 100mg hydrocortisone IV, and preserve the blood unit for laboratory analysis later.

(b) Life-threatening emergencies

Severe haemorrhage often occurs in unforeseen circumstances. It is best to be prepared rather than sorry after the event. Try to keep at least 2 units of O-ve blood continuously available in your hospital, because there will be no problem transfusing this in 95% of your patients.

If you cannot get O-ve, O+ve will be satisfactory for 85-95% of cases, so if a patient is *in extremis, don't fear the risk of 5-15%!*

Fresh blood is often better than stored blood; try to have reliable persons (tested regularly HIV-ve) in your community available to assist in an emergency with blood transfusion. Remember to try to correct clotting disorders, if present.

N.B. Fresh frozen plasma can be stored for a long time as opposed to blood and should therefore be available via the national/regional blood bank. However, as one unit is collected from more than one donor, the risk of HIV, hepatitis transmission etc. is that much greater.