Upper lobe
- Apical segments: sitting (1).
- Posterior segments: prone, one pillow below the affected side (2).
- Anterior segment: supine (3).

Middle lobe/lingual
- Chest tipped 15 degrees below the horizontal, lying supine, with a pillow supporting the ipsilateral hip and shoulder (4).

Lower lobe
- Apical segments: prone (5).
- Anterior basal: chest tipped 20 degrees below the horizontal, lying supine (6).
- Lateral basal: chest tipped 20 degrees below the horizontal, lying on the unaffected side (7).
- Posterior basal: chest tipped 20 degrees below the horizontal, lying on the unaffected side (8).

Note where bronchoconstriction is an issue:
1. Increase the amount of time spent doing tidal volume breathing.
2. Omit percussion.
3. Increase tidal volume breathing and omit percussion.

Consider the use of inhaled bronchodilators (e.g. salbutamol 200–500 micrograms inhaled through a spacer) (see Section 5.2.B).

Adjuncts to postural drainage
The following may be combined with postural drainage:
- chest clapping: done over the area to be cleared with a cupped hand
- chest shaking: fine manual shaking in line with rib motion during the expiratory phase of breathing
- active cycle of breathing: relaxed tidal breathing, four deep breaths to maximal inspiration with hold, and relaxed expiration. Huff – that is, forced expiration at mid to low lung volumes with the glottis open (as if misting glass), cough to clear secretions, and repeat the cycle until the chest is clear.

Relative contraindications
These include the following:
- raised intracranial pressure
- severe hypertension
- after abdominal surgery
- after major haemoptysis
- pulmonary oedema
- surgical emphysema
- after treatment of tension pneumothorax
- cardiac arrhythmias
- gastro-oesophageal reflux (only omit postures with upper body dependent).

Patient positioning
- To maximise ventilation–perfusion matching (e.g. in pneumonia, asthma, pneumothorax) in self-ventilating patients, position with the better ventilated lung uppermost.
- In severely breathless patients, use sitting with a forward lean, or the recovery position. Use pillows to raise and support the chest if the patient cannot tolerate lying flat.

8.4 Circulatory procedures
Access to and support for the circulation is vital in emergency care, to draw blood samples for diagnosis and monitoring, to infuse fluid to restore circulating volume and improve perfusion, to transfuse blood and to give treatment drugs. This section describes and illustrates many means of access to the circulation, and includes guidance on safe drug and fluid infusion.

Also included are circulatory support procedures such as defibrillation and pericardiocentesis, and techniques for other non-parenteral routes of drug administration, including intramuscular (IM), subcutaneous (SC) and intradermal (ID) injections.

8.4.A Minimising error in drug and fluid administration: giving injections

General points on safety
The information given below is adapted from the Neonatal Formulary, 11th edition (BMJ Books).
1. Drug vials once reconstituted do not contain preservatives or antiseptic. Therefore multiple sampling from them is potentially hazardous.
2 For infants, dilute drugs to ensure that volumes can be accurately measured. For example, do not use doses of less than 0.1 mL for a 1-mL syringe.

3 Serious errors can occur if the dead space in the hub of the syringe is overlooked during dilution. For example, if the active drug is drawn into a 1-mL syringe up to the 0.1-mL mark, the syringe will contain between 0.19 and 0.23 mL. If the syringe is then filled with diluent to 1 mL, the syringe will contain approximately twice as much drug as was intended. Dilution must involve first half filling the syringe with diluent and then adding active drug by using the distance between two graduations on the syringe. Mix the two by moving the plunger, and then finally add further diluent to the total planned volume of active drug and diluent. For dilutions of more than 10-fold, use a small syringe to inject the active drug, connected by a sterile three-way tap to a larger syringe. Then add diluent to the large syringe to obtain the desired volume.

4 Many drugs are equally effective whether given orally or parenterally. Oral administration is safer and less expensive. The following antibiotics are as effective given orally as given IV in a baby who is taking feeds: amoxicillin, ampicillin, chloramphenicol, ciprofloxacin, co-trimoxazole, erythromycin, fluclouxacin, fluoronazole, isoniazid, metronidazole, pyrimethamine, rifampicin, sodium fusidate, and trimethoprim.

5 If a drug is given down an orogastric or nasogastric tube, a proportion of the drug will remain in the tube unless it is flushed through.

6 Rectally administered drugs are less reliably absorbed than drugs given orally. Liquid formulations are better than suppositories in infants.

7 When giving IV drugs, do so slowly in all cases. After it has been injected into the line (ideally through a three-way tap), the normal IV infusion rate of the fluid going into the cannula can be used to drive the drug slowly into the patient.

8 Do not mix incompatible fluids IV.

9 For IV drug infusions (using a syringe/infusion pump: if available) given in addition to background IV infusions:
   - Adjust the total 24-hour IV fluid intake.
   - Never allow a surge of a vasoactive drug such as dopamine or epinephrine.
   - Never put more drug or background IV into the syringe or burette than is needed over a defined period of time.
   - Check and chart the rate of infusion, and confirm this by examining the amount left every hour.

10 Intramuscular injections need special precautions:
   - IM injections are unsafe in shock, as they will be poorly absorbed from poorly perfused muscle tissue initially, and then (especially, for example, with opiates) a high dose may be released once recovery of the circulation occurs.
   - To avoid nerve damage, only the anterior aspect of the quadriceps muscle in the thigh is safe in a small wasted infant under 1 year of age.
   - Alternate between the legs if multiple injections are required.
   - Do not give IM injections if a severe bleeding tendency is present.
   - It is essential to draw back the plunger to ensure that the needle is not in a vein before injecting potentially dangerous drugs IM (e.g. adrenaline, magnesium sulphate, lidocaine).

Care of intravascular lines

1 Placement of central venous lines: check with a lateral X-ray that the line is placed well into a major vein, and if near the heart with the catheter tip ideally in the superior vena cava at the entrance to the right atrium.

2 Placement of an umbilical arterial line should either be above the diaphragm in the thoracic aorta, or below the two renal arteries (at L4) to minimise the risk of renal or mesenteric artery thrombosis.

3 All arterial lines can result in life-threatening haemorrhage or occlusion leading to ischaemia. Procedures to ensure that these complications do not occur should be in place.

4 Never give a drug into an IV cannula that has started to tissue. Some drugs (e.g. those containing calcium) can cause severe scarring. Inspect the cannula tip site before and while injecting any drug IV.

5 Local infection can become systemic, especially in neonates or in the immunosuppressed.

   - Always remove the cannula if there is erythema in tissue around it and if lymphangitis is seen. If lymphangitis is present always take a blood culture from a separate vein and start IV or IM antibiotics.
   - Always place cannulae aseptically and keep the site clean.
   - There is no evidence that frequent changes of cannula site or infusion kit are of benefit. However, it is a good idea to change the giving set after blood transfusion or if a line of blood has entered the infusion tubing from the vein and clotted there, as this can act as a site for bacterial colonisation. Otherwise change the lines every 3 or 4 days.

6 Air embolism: if air reaches the heart, unlike blood it will stay there, especially if the patient is lying flat.

   - Unless it is immediately aspirated, air in the heart can block the circulation.
   - Umbilical venous and other central venous lines are particularly dangerous. There must be a tap or syringe on the catheter at all times, especially during insertion.
   - An alternative source of air embolus is through the giving set, especially when pumps are being used.

7 Blood loss.

   - In neonates this can occur from the umbilical stump.
   - From central venous or arterial lines, it can rapidly be fatal, and therefore all connections must be Luer locked and the connections to the cannula and its entry must be observable at all times.
Use of intravenous/intra-arterial (IV/IA) access

1. When sampling from an IV/IA line, clear the dead space first (by three times its volume).
2. Blood glucose levels cannot be accurately measured from any line through which a glucose solution is infused, even if many times the dead space has been cleared.
3. For blood culture, always use a separate fresh venous ‘needle stab’ sample.
4. Never add anything to a line carrying total parenteral nutrition (TPN).
5. Certain infusions, such as glucose > 10%, adrenaline and dopamine, are better given through a peripheral vein.
6. Peripheral artery lines should never be used for giving drugs.
7. In neonates and infants, frequent flushing with saline at 1 mL of 0.9% saline or 5% glucose to clear the dead space (there is no evidence that a heparin lock is needed for a cannula in peripheral veins).
8. Central venous catheters must be firmly anchored to the skin so they do not migrate into or out of position.
9. After individual drug injections and without continuous infusion, a heparin lock is appropriate to prevent clotting of the line (10 units of heparin per 1 mL of 0.9% saline), particularly in double-, triple- or quadruple-lumen catheters (always use Luer lock connections to minimise extravasation).
10. Most IV drugs can be given into an infusion containing 0.9% saline or up to 10% glucose (the exceptions include amphotericin B, phenytoin and erythromycin).
11. If only one line is being used for an infusion and more than one drug needs to be given, try to wait 10 minutes between them. If this is not possible, separate by 1 mL of 0.18% saline/4% glucose, 0.9% saline or sterile water for injections. This is very important with an alkaline drug such as sodium bicarbonate. Always give the flush slowly over at least 2 minutes to ensure that the drug already in the line/vein does not move forward in the patient in a sudden rapid surge (especially if the catheter/vein contains an inotrope or vasoactive drug such as aminophylline, cimetidine, phenytoin or ranitidine, which can cause an arrhythmia).

Minimising IV infusion and IV drugs errors

Errors of both commission and omission occur. For example, excess IV fluids can be dangerous by causing circulatory overload, and inadequate IV fluids can be dangerous by causing hypoglycaemia (especially in the neonate, and commonly when a blood transfusion is being given and the infant is relying on IV glucose).

Extravasation can also result in the absence of a vital drug (e.g. morphine infusion for pain). Errors will always occur where human actions are involved, and it is essential to have systems in place to minimise these.

Steps to reduce errors and their impact

- Prescribe or change infusion rates as infrequently as possible, ideally once or twice daily.
- Never have more than one IV infusion line running at the same time unless this is absolutely necessary (e.g. in major trauma or shock, where two lines are needed for volume replacement and also in case one line is lost at a critical time).
- Use a burette in which no more than the prescribed volume is present (especially in infants and young children).
- Record hourly the amount given (from the burette, syringe or infusion bag) and the amount left.
- Check the infusion site hourly to ensure that extravasation has not occurred.
- Ensure that flushes are only used when essential, and are given slowly over at least 2 minutes.
- Ensure that flushes do not overload the patient with sodium.
- Be particularly careful with potassium solutions given IV (use the enteral route whenever possible).
- Check and double check the following:
  - Is it the right drug? Check the ampoule as well as the prescription chart.
  - Is it the right concentration?
  - Is the shelf life of the drug within the expiry date?
  - Has the drug been constituted and diluted correctly?
  - Is the dose right? (Two people are needed to check the prescription chart.)
  - Is it the correct syringe? (Deal with one patient at a time.)
  - Is the IV line patent?
  - Is a separate flush needed? If so, has the flush been checked?
  - Are sharps (including glass ampoules) disposed of?
  - Has it been signed off as completed (and ideally countersigned)?

Writing a prescription

- Use block capitals.
- Use approved names.
The dosage should be written in grams (g), milligrams (mg) or micrograms. Always write micrograms in full.

Volumes should be written in millilitres (mL).

Avoid using decimal places whenever possible. If this is not possible, they should be prefaced by a zero. For example, write 500 mg, not 0.5 g, and if a decimal place is used, write 0.5 mL, not 0.5 mL.

Write times using the 24-hour clock.

Routes of administration can be abbreviated as follows: IV (intravenous), IM (intramuscular), PO (orally), SC (subcutaneous), NEB (nebuliser), RECT (rectally).

‘As required’ prescriptions must be specific about how much, how often and for what purpose (indicate the maximum 24-hour dose).

Each drug should be signed for individually by a registered doctor.

Stop dates for short-course treatments should be recorded when first prescribed.

**IV drug infusions in severely ill or injured children in high-dependency care**

**Adrenaline:** in 5% dextrose or 0.9% saline. Do not mix with bicarbonate

Dose: 0.05–2 micrograms/kg/minute: this is equivalent to 0.6 mL/kg of 1 in 1000 (600 micrograms/kg) in 100 mL run at 0.5–20 mL/hour.

As a short-term measure, place 1 mg (1 mL of 1 in 1000 adrenaline) in 50 mL of 0.9% saline. Give 2–5 mL (40–100 micrograms) to a child (depending on size) and 1 mL (20 micrograms) to an infant under 1 year of age. Give IV slowly. Repeat as required (with ECG monitoring).

**Aminophylline:** in 5% dextrose or 0.9% saline

Loading dose (do not give aminophylline if theophylline has been received in the last 24 hours).

IV infusion over 20–30 minutes, 5 mg/kg for children under 12 years of age, and 250–500 mg total if over 12 years of age.

Then give 1 mg/kg/hour if under 12 years and 500 micrograms/kg/hour if over 12 years: this is equivalent to 50 mg/kg in 50 mL run at 1 mL/hour for those under 12 years, and 0.5 mL/hour for those over 12 years.

**Dopamine:** in 5% dextrose or 0.9% saline or undiluted (ideally via a central line). Do not mix with bicarbonate

This can be mixed with dobutamine.

Give 2–20 micrograms/kg/minute (renal = up to 5 micrograms/kg/minute); this is equivalent to 30 mg/kg in 50 mL run at 0.2–2 mL/hour.

**Ketamine:** in 5% dextrose or 0.9% saline

Give 10–45 micrograms/kg/minute: this is equivalent to 50 mg/kg in 50 mL run at 0.6–2.7 mL/hour (maximum concentration 50 mg/mL).

**Midazolam:** in 5% dextrose or 0.9% saline or undiluted

Give 1–6 micrograms/kg/minute (60–360 micrograms/kg/hour); this is equivalent to 6 mg/kg in 50 mL run at 0.5–3 mL/hour.

Or give undiluted (5 mg/mL), run at 0.012–0.072 mL/kg/hour.

**Morphine:** in 5% dextrose or 0.9% saline

Give 10–60 micrograms/kg/hour: this is equivalent to 1 mg/kg in 50 mL run at 0.5–3 mL/hour.

**Salbutamol IV:** in 5% dextrose or 0.9% saline

Give 0.6–5 micrograms/kg/minute: this is equivalent to 3 mg/kg in 50 mL run at 0.6–5 mL/hour.

**Giving injections**

First, find out whether the child has reacted adversely to drugs in the past. Wash your hands thoroughly. Use disposable needles and syringes. Clean the chosen site with an antiseptic solution. Carefully check the dose of the drug to be given and draw the correct amount into the syringe. Expel the air from the syringe before injecting. Always record the name and amount of the drug given. Discard disposable syringes in a safe container.

**Intramuscular route**

In children over 2 years of age, give the injection in the upper outer quadrant of the buttock. Choose the site carefully, well away from the sciatic nerve. In younger or severely malnourished children, use the outer side of the thigh midway between the hip and the knee, or over the deltoid muscle in the upper arm. Hold the muscle at the injection site between the thumb and first finger and push the needle (23- to 25-gauge) into the muscle at a 90-degree angle (45 degrees in the thigh). Draw back the plunger to make sure that there is no blood (if there is, withdraw slightly and try again). Give the drug by pushing the plunger slowly until the end. Remove the needle and press firmly over the injection site with a small swab or cotton wool for at least two minutes.
Subcutaneous route
Select the site as described above for intramuscular injection. Pinch up skin and subcutaneous tissue between your finger and thumb. Push the needle (23- to 25-gauge) under the skin at an angle of 30–45 degrees into the subcutaneous fatty tissue. Do not go deep to enter the underlying muscle. Draw back the plunger to make sure that there is no blood (if there is, withdraw slightly and try again). Give the drug by pushing the plunger slowly until the end. Remove the needle and press firmly over the injection site with cotton wool for at least two minutes.

Intra-dermal route
Select an area of skin which has no infection or damage for the injection (e.g. over the deltoid in the upper arm). Stretch the skin between the thumb and forefinger of one hand. With the other hand, slowly insert the needle (25-gauge), bevel upwards, for about 2 mm just under and almost parallel to the surface of the skin. Considerable resistance is felt when injecting intra-dermally. A raised blanched bleb showing the surface of the hair follicles is a sign that the injection has been given correctly.

Peripheral venous cannulation
Preparation of kit
The following equipment is needed:
- 18- to 25-gauge IV cannula or butterfly needles
- 2-mL syringe and T-piece containing Ringer-lactate or Hartmann’s solution or 0.9% saline for flushing
- tape or plaster of Paris for scalp veins
- a small splint (this can be made from a wooden spatula covered with gauze)
- alcohol swabs for skin cleaning
- local anaesthetic cream if available
- tourniquet (or assistant)

Procedure
Apply the tourniquet to distend the vein (do not forget to remove it after cannulation).

Choose a vein:
- forearm
- long saphenous vein (anterior to the medial malleolus)
- back of the hand or front of the wrist
- scalp.

Useful sites to cannulate include the dorsum of the feet and hands. The saphenous and antecubital veins are larger, but can be useful for percutaneously inserted ‘long lines’. The antecubital veins are also useful for venepuncture for laboratory studies.

If possible, place the cannula close to the bone where it is more fixed.

Decide the direction of blood flow.

Connect the connector, flush and fix. No subcutaneous swelling should be seen and there should be no resistance to injection.

If no blood is seen on advancing the cannula, but it is felt to be beyond the vein, stop.

Gently pull the cannula back in the same direction as advancement; if blood appears, stop once again. Follow the same procedure as if blood was seen on first advancement (transfixion technique).

Connect the T-piece and flush the cannula gently with Ringer-lactate or Hartmann’s solution or 0.9% saline to confirm that it is in the vein.

If the cannula is satisfactorily inserted, tape it in place by looping a thin piece of the tape under the hub and round to form a “V” shape fixing it to the skin.

When splinting, try to ‘double back’ the tape (i.e. put a short
piece and a long piece back to back, leaving just the ends of the longer piece sticky). This helps to prevent excessive amounts of tape sticking to the baby, which is particularly important in the case of more immature babies whose skin is easily damaged.

**FIGURE 8.4.B.1** Inserting an intravenous cannula into a vein on the back of the hand. The hand is flexed to obstruct venous return and thus make the veins visible.

**FIGURE 8.4.B.2** Arm splinted to prevent bending of the wrist.

Note on flushing lines
The smaller the syringe used, the greater the pressure exerted on fluid in the line. Therefore avoid using 1-mL syringes to flush a blocked line, as the line may rupture or tissue may be damaged by infiltration.

Care of the IV cannula
Secure the cannula when it has been introduced. This may require the splinting of neighbouring joints to limit the movement of the catheter. Keep the overlying skin clean and dry. Fill the cannula with Ringer-lactate or Hartmann’s solution or 0.9% saline immediately after the initial insertion and after each injection.

Blood sampling from the IV cannula
If the patient needs blood samples at the time of cannulation it is often possible to take these as the cannula is inserted. Blood can be dripped from the end of the cannula into the appropriate bottles, or a syringe can be used to gently aspirate blood from the cannula. If the cannula has been flushed prior to insertion, the first 0.5–1 mL of blood should be discarded.

Common complications
Superficial infection of the skin at the cannula site is the commonest complication. The infection may lead to thrombophlebitis, which will occlude the vein and result in fever, and may progress to septicemia. The surrounding skin is red and tender. Remove the cannula immediately to reduce the risk of further spread of the infection. Antibiotic treatment (effective against *Staphylococcus aureus*) should be given.

**IV drug administration through an indwelling cannula**
Attach the syringe containing the IV drug to the injection port of the cannula and introduce the drug. Once all of the drug has been given, inject 0.5 mL of Ringer-lactate or Hartmann’s solution or 0.9% saline into the cannula until all of the drug has entered the circulation and the catheter is filled with the infusion fluid.

**Safe IV infusions where no burettes are available**
- Mark the infusion bottle with tape for each hour to be given, and label each hour, or
- Empty until only the necessary amount to be given is left in the bottle.

**Special sites for IV cannulae**
**Scalp veins**
**Procedure**
1. Restrain the child.
2. Shave the appropriate area of the scalp with a sterile razor.
3. Clean the skin.
   - Have an assistant distend the vein by holding a taut piece of tubing or bandaging perpendicular to it, proximal to (nearest to the child’s body) the site of puncture.
4. Fill the syringe with Ringer-lactate or Hartmann’s solution or 0.9% saline and flush the butterfly set.
   - Disconnect the syringe and leave the end of the tubing open.
5. Puncture the skin and enter the vein. Blood will flow back through the tubing.
   - Infuse a small quantity of fluid to see that the cannula is properly placed and then tape it into position.
   - Care should be taken not to cannulate an artery, which is recognised by pulsation on palpation. If there is a pulsatile spurtng of blood, withdraw the needle and apply pressure until the bleeding stops. Then look for a vein.

**FIGURE 8.4.B.3** Inserting a scalp vein needle.
Scalp drips are generally more precarious than ones in the limbs, and need to be carefully observed. Infiltration into the soft tissues of the scalp can spread quickly and cause extensive necrosis if irritant. Shave the hair from an area about 2–3 cm around the site selected in order to allow for fixation by tape. Always ensure that the tip of the needle is not covered by dressings, so that infiltration is quickly seen.

**External jugular vein**

**Procedure**

1. Place child in a 15–30-degree head-down position (or with padding under the shoulders so that the head hangs lower than the shoulders). Wrapping may be necessary to restrain the child (see above).
2. Turn the head away from the site of puncture. Restrain the child as necessary in this position.
3. Clean the skin over the appropriate side of the neck.
4. Identify the external jugular vein, which can be seen passing over the sternocleidomastoid muscle at the junction of its middle and lower thirds.
5. Have an assistant place their finger at the lower end of the visible part of the vein just above the clavicle. This stabilises it and compresses it so that it remains distended.
6. Puncture the skin and enter the vein pointing in the direction of the clavicle.
7. When free flow of blood is obtained, ensure that no air bubbles are present in the tubing, and then attach a giving set.
8. Tape the cannula securely in position. One of the most important points is to ensure that the cannula is properly secured in the vein by high-quality fixation. It is easily removed by the child, so use plenty of tape!

**Preparation of kit**

The following equipment is needed:
- sterile pack
- sterile Seldinger wires
- cannula: single 16- to 22G cannula
- single, double or triple lumen if available (5 FG 5–8 cm length for neonate, 7 FG 8–15 cm length for child)
- syringe and Ringer-lactate or Hartmann’s solution or saline
- suture and tape for fixing
- local anaesthetic with fine 25G needles.

**Preparation of the child**

- Explain what is going to happen (if the child is conscious).
- Position the child.
- Sterilise the skin and maintain sterile technique.
- Apply local analgesia to the skin (if the child is conscious).

**Two insertion techniques are available**, namely:
- the same as in peripheral cannulation
- the Seldinger technique (wire)
- ideally an ultrasound probe can help identify the vein and ensure the cannula when inserted is in the correct position in the lumen of the vein.

**Seldinger method**

1. Identify the vein with cannula on syringe (same approach as for peripheral cannulation); there must be good flow.
2. Stop, and pass the cannula over the needle.
3. Disconnect the syringe.
4. Pass the wire through the cannula to three-quarters the length of wire (if there is any resistance, stop, withdraw the wire with needle, and start again).
5. Holding the wire firmly, withdraw the needle over the wire.
6. Pass the dilator over the wire (it is sometimes necessary to make a small cut at the skin) and, holding the wire firmly, withdraw the dilator.
7. Pass the cannula/catheter filled with Ringer-lactate or Hartmann’s solution or 0.9% saline over the wire (passage of the cannula should be smooth, meeting no resistance).
8. Hold the cannula, and withdraw the wire (gently if it sticks, do not force it).

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**FIGURE 8.4.B.4 Position of the external jugular vein.**

Be aware that there is a higher risk of air embolism than with peripheral venous cannulation. If infusion through a peripheral vein or scalp vein is not possible, and it is essential to give IV fluids to keep the child alive:
- set up an intra-osseous infusion
- or use a central vein
- or perform a venous cut-down.

All of these procedures are described below.

**Central venous cannulation**

This should not be used routinely. It should only be performed when IV access is urgent and, in the case of central veins, only by those who have been trained in the technique (it is best done by an anaesthetist). Remove the cannula from a central vein as soon as possible (i.e. when IV fluids or drugs are no longer essential, or when a peripheral vein can be cannulated successfully).

The aims of central venous cannulation are as follows:
- to obtain venous access when peripheral cannulation is not possible (however, in an emergency, intra-osseous cannulation is faster and easier).
- to monitor central venous pressure
- to obtain prolonged vascular access
- to obtain large-bore vascular access
- to administer certain drugs
- during resuscitation.

**Procedure**

Several routes are possible, but the most widely used are the femoral and internal jugular approaches. The femoral approach is easiest in the emergency situation. A subclavian approach may be useful in the older child.

**Preparation of kit**

The following equipment is needed:
- sterile pack
- sterile Seldinger wires
- cannula: single 16- to 22G cannula
- single, double or triple lumen if available (5 FG 5–8 cm length for neonate, 7 FG 8–15 cm length for child)
- syringe and Ringer-lactate or Hartmann’s solution or saline
- suture and tape for fixing
- local anaesthetic with fine 25G needles.

**Preparation of the child**

- Explain what is going to happen (if the child is conscious).
- Position the child.
- Sterilise the skin and maintain sterile technique.
- Apply local analgesia to the skin (if the child is conscious).
9 Confirm correct placement by aspiration of blood.
10 Suture and fix with antiseptic ointment over the entry site.
11 Confirm the position with an X-ray.

**Femoral cannulation**

This is adequate for almost all needs, is technically much easier and has lower complication rates, particularly in neonates and infants. However, if it is not a sterile procedure, there is a risk of causing septic arthritis in the hip joint.

1 Position the patient supine with the leg slightly abducted.
   Place a towel under the buttocks to raise the pelvis.
2 Clean the skin and drape with sterile towels. Locate the vein by finding the femoral arterial pulsation 2 cm below the midpoint of the inguinal ligament. The vein lies immediately medial to the artery. If the child is conscious, infiltrate the skin and subcutaneous area with 1% lignocaine.
3 With a finger on the femoral artery introduce the needle with syringe attached at an angle of 30–45 degrees to the skin along the line of the vein pointing towards the umbilicus. Advance the needle while aspirating.
4 When blood ‘flashes back’ into the syringe, stop advancing and remove the syringe from the needle. Feed the Seldinger guide wire through the needle, keeping hold of one end of the wire at all times.
5 Withdraw the needle over the wire, then feed the catheter over the wire into the vein.
6 Withdraw the wire and aspirate for blood to confirm the position. Then flush the catheter with Ringer-lactate or Hartmann’s solution or 0.9% saline.
7 Suture the catheter in place.

**Internal jugular vein**

Use a head-down position for the internal jugular and subclavian approaches, as this increases vein distension and reduces the risk of air embolism.

**Procedure**

1 Place the child in a 30-degree head-down position and turn their head to the left-hand side for the right-sided approach, which avoids the lymphatic duct. Place a towel or roll under the shoulders to extend the neck.
2 Clean the skin and drape with towels, exposing the neck to the clavicle.
3 Identify the apex of the triangle formed by the two heads of the sternocleidomastoid and clavicle, and infiltrate local anaesthetic (if the child is conscious). Alternatively, identify carotid pulsation medial to the sternomastoid at the level of the lower border of the thyroid cartilage, and the vein (usually) just lateral to this. Aim the needle at 30 degrees to the skin and towards the ipsilateral nipple (note that the neck is very short and the vein is superficial in the very young). Estimate the length of catheter from the point of skin entry to the nipple.
4 Direct the needle at 30 degrees to the skin, pointing towards the right nipple, and puncture the skin at the apex of the triangle.
5 Holding this position, advance the needle, aspirating all the time. If blood ‘flashes back’, stop advancing and remove the syringe from the needle. (If you do not cannulate the vein, withdraw the needle, but not out of the skin, and advance again slightly more laterally.)
6 Feed the Seldinger guide wire through the needle, always having control of one end of the wire.
7 Withdraw the needle over the guide wire and then feed the catheter over the wire into the superior vena cava.
8 Withdraw the wire, aspirate for blood and attach the infusion set. **Do not leave the catheter open, as this may lead to an air embolism.**
9 Suture the catheter in place and obtain a chest X-ray (if possible) to check for a pneumothorax and the position of the catheter tip, which should be in the superior vena cava (SVC), ideally at the junction of the SVC and the right atrium, but not in the right atrium.
possible to use compression to stop the bleeding, but this is rarely a problem unless coagulopathy is present).

**Complications**
These are fewer and less severe in femoral cannulation, but include the following:
- arterial puncture
- nerve damage
- pneumothorax in neck access veins
- extravasation-administered fluids/drugs
- septicemia if the procedure is not sterile or if the cannula is in place for more than 5 days.

**Cut-down venous cannulation**

**Indication**
Continuous IV access is needed where percutaneous attempts have failed. In the emergency situation, intraosseous access is faster and easier. Cut-down is less appropriate if speed is essential.

**Preparation of kit**
The following equipment is needed:
- skin prep (iodine, alcohol)
- scalpel
- suture
- IV cannula
- local anaesthetic
- curved artery forceps
- syringe and hypodermic needle
- sterile drapes.

**Procedure**
Identify landmarks. The long saphenous vein at the ankle is superior and medial to the medial malleolus of the ankle. The brachial vein at the elbow is lateral to the medial epicondyle of the humerus.

**Brachial vein:**
- Infant: one finger breadth lateral to the medial epicondyle of the humerus.
- Small child: two finger breadths lateral to the medial epicondyle of the humerus.
- Older child: three finger breadths lateral to the medial epicondyle of the humerus.

**Long saphenous vein:**
- Infant: half a finger breadth superior and anterior to the medial malleolus.
- Small child: one finger breadth superior and anterior to the medial malleolus.
- Older child: two finger breadths superior and anterior to the medial malleolus.

1. Immobilise the lower leg and clean the skin, as described above. Identify the long saphenous vein, which lies half a finger breadth (in the infant) or one finger breadth (in the small child) superior and anterior to the medial malleolus.
2. Clean the skin and drape with sterile towels.
3. Infiltrate the skin with 1% lignocaine using a fine 24- to 25G needle, and make an incision through the skin perpendicular to the long axis of the vein. Bluntly dissect the subcutaneous tissue with haemostat forceps.
4. Identify and free a 1–2 cm section of vein. Pass a proximal and distal ligature.

5. Tie off* the distal end of the vein, keeping the ties as long as possible for traction.
6. Make a small hole in the upper part of the exposed vein, gently dilate the opening with the tip of a closed haemostat, and insert the cannula (without the needle/trocar in it) into this, while holding the distal tie to stabilise the position of the vein.
7. Secure the cannula in place with the upper ligature.
8. Attach a syringe filled with Ringer-lactate or Hartmann’s solution or saline and ensure that the fluid flows freely up the vein. If it does not, check that the cannula is in the vein or try withdrawing it slightly to improve the flow.
9. Tie the distal ligature* around the catheter, and then close the skin incision with interrupted sutures.
10. Place antiseptic ointment (e.g. iodine) over the wound, and suture or tape the catheter to the skin (ensure that local anaesthetic is used at the suture site if the child is conscious). Cover with sterile dressing.

* It is also possible to dispense with the proximal and distal ligatures and simply penetrate the vein directly with a plastic over-the-needle cannula as you would if penetrating the skin externally. Once in the vein, remove the inner needle and secure in position.

**Complications**
These include the following:
- haemorrhage or haematoma
- perforation of the posterior wall of the vein
- nerve transection
- phlebitis
- venous thrombosis.

**Umbilical vein catheterisation**

**Indications**
- Where there is urgency during resuscitation of the newborn to give IV fluids and drugs.
- Temporarily for exchange transfusion. The catheter should not be left in position between exchanges.
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Time of insertion
Catheterisation is usually easy in the first 4 days of life, and possible from 5 to 7 days.

Passing an umbilical vein catheter is the quickest and easiest way to access the circulation in the newborn.

Preparation of kit
The following equipment is needed:
- gown and gloves
- sterile instruments including:
  - fine scissors
  - forceps
  - scalpel
- silk suture for retaining
- 5 French gauge umbilical catheter
  - a sterile feeding tube may be satisfactory if an umbilical catheter is not available, but measure the length first so that you will know how much you have passed by measuring the length from the hub to the umbilical insertion. Cannulae designed for use as umbilical vein cannulae are usually marked in 5-cm increments
- a three-way tap
- 0.5% chlorhexidine or 10% povidone-iodine for cleaning the skin
- sterile cotton wool balls
- sterile towels or drapes to cover the baby’s abdomen
- sterile 2-mL syringe and connector filled with Ringer lactate or Hartmann’s solution or 0.9% saline.

Procedure
1 Assemble the syringe, three-way tap and catheter. Flush and fill the catheter with sterile 0.9% saline. Then close the tap to prevent air entry (which may cause air embolus).
2 Clean the umbilical cord and surrounding skin with 0.5% chlorhexidine or 10% povidone-iodine, and then loosely tie a suture around the base of the cord.
3 Cut back the cord to about 2 cm from the base.
4 Cover the skin with towels to form a sterile working surface.
5 Hold the cord at an edge with forceps.
6 Identify the vein. It is usually gaping, larger, and well separated from the two small thicker-walled arteries.
7 Hold the catheter approximately 2 cm from the end with non-toothed forceps, and insert the tip into the vein. Gently advance the catheter, which should pass easily.
8 Insert the catheter for a distance of 4–6 cm.
9 Check that the catheter is not kinked and that blood draws back easily. If there is a block, pull gently on the cord, pull back the catheter partly and reinsert.
10 The catheter can be secured by winding a suture round it several times and then passing a stitch through the cord base. An additional safeguard is to form two wings of tape which can then be taped to the abdominal wall, always remembering that it is preferable to use as little tape as possible in smaller babies. However, it is essential that the catheter does not fall out.

Occasionally the umbilical vein is kinked and advance of the catheter is blocked at 1–2 cm beyond the abdominal wall. Gentle traction on the cord usually relieves this.

If obstruction occurs at more than 2 cm, and only partly gives way with pressure, the catheter is probably either wedged in the portal system or coiled up in the portal sinus. It is advisable to withdraw the catheter part way and reinsert it.

Care of indwelling catheters
Leave the cord exposed to air. Remove blocked catheters.

Removal of the catheter
1 Use sterile technique.
2 Remove a specimen of blood for culture.
3 If possible, place a purse-string suture around the vessel at the base of the umbilicus and withdraw the catheter slowly.
4 Tighten the purse-string suture.
5 Apply pressure to the umbilical stump for 5–10 minutes.

Time of removal of catheter
Remove the catheter as soon as possible as dictated by the clinical state of the baby. The infection rate rises after 24 hours. Complications are more common with venous catheters than with arterial ones, so venous catheters should rarely be left in.

Complications
These include the following:
- thrombosis survivors may develop portal vein thrombosis
- embolism from clots in the catheter, or from injected air
- vascular perforation
- vascular damage from hypertonic solutions (more common when the tip is in the portal system)
- haemorrhage from a disconnected catheter
- necrotising enterocolitis or bowel perforation may occur as a complication of exchange transfusion
- infection
- there is no evidence that prophylactic antibiotics are of any value.
Intra-osseous needle insertion

Intra-osseous infusion is a safe, simple and reliable method of giving fluid and drugs in an emergency when venous access is not possible (e.g. in shock).

Site for needle

The first choice for the puncture is the proximal tibia. The site for needle insertion is in the middle of the antero-medial surface of the tibia, at the junction of the upper and middle third, to avoid damaging the epiphyseal plate (which is higher in the tibia), 2–3 cm below the tibial tuberosity. An alternative site for needle insertion is the distal femur, 2 cm above the lateral condyle.

Intra-osseous needles (15- to 18-gauge)

If a purpose-made intra-osseous needle is not available, a number of alternatives can be used, including bone-marrow needles, short lumbar puncture needles or a large-calibre venepuncture needle. For example, a green needle can be used in a neonate. The disadvantage of venepuncture needles is that they may carry a fragment of bone into the marrow. This is not dangerous, but it may block the needle. Also the bevel of these needles is long, and extravasation of fluid is more likely than with a purpose-made intra-osseous needle.

Other equipment needed

This includes the following:
1. a sterile 2-mL syringe containing 1–2% lignocaine to be used whenever the patient is conscious (otherwise the procedure will be very painful)
2. two sterile 5-mL syringes
3. sterile 20- or 50-mL syringes and ideally a three-way tap.

Procedure

1. Place padding under the child’s knee so that it is bent at 30 degrees from the straight (180-degree) position, with the heel resting on the table.
2. Locate the correct position (described above and shown in Figure 8.4.B.9).
3. Wash your hands and put on sterile gloves. (To avoid osteomyelitis, the procedure must involve strict asepsis using an antiseptic solution and sterile gauze to clean the site, with the operator wearing sterile gloves.)
4. Infiltrate with lidocaine down to the periosteum if the child is conscious.
5. Ask an assistant to stabilise the proximal tibia by grasping the thigh and knee above and lateral to the cannulation site, with the fingers and thumb wrapped around the knee but not directly behind the insertion site.
6. Insert the needle at a 90-degree angle with the bevel pointing towards the foot. Advance the needle slowly using a gentle but firm twisting or drilling motion.
7. Stop advancing the needle when you feel a sudden decrease in resistance or when you can aspirate blood. The needle should now be fixed in the bone and stand up by itself.
8. Remove the stylet.
9. Aspirate the marrow contents (which look like blood), using the 5-mL syringe, to confirm that the needle is in the marrow cavity and to provide bone marrow/blood for the following tests when appropriate: blood glucose, haemoglobin, group and cross-matching, blood culture and urea and electrolytes. Hb, glucose and electrolyte measurements may not be accurate after infusions have been previously given. Note that failure to aspirate bone-marrow contents does not mean that the needle is not correctly placed.
10. Attach the second 5-mL syringe filled with Ringer-lactate or Hartmann’s solution or 0.9% saline. Stabilise the needle and slowly inject 3 mL while palpating the area for any leakage under the skin. If no infiltration is seen, start the infusion.
11. Attach the 50-mL syringe, usually containing Ringer-lactate or Hartmann’s solution or saline, but compatible blood or 10% glucose can be used if hypoglycaemia is suspected, and push in the infusion fluid in boluses. It is not possible to infuse fluid through the intra-osseous needle using a standard IV giving set. The fluid has to be pushed in under light pressure, and if large volumes are needed (e.g. when giving boluses of fluid to treat shock) then 20-mL or 50-mL syringes should be used.
12. Check that the calf does not swell during the injections of fluid.
13. Secure IV access as soon as possible.
14. When the needle has been removed, cover with a sterile dressing.

Do not place distal to a major fracture or where there is infection.

Give prophylactic antibiotics after the immediate emergency has been managed.

All drugs and fluids that are given IV (including 10% glucose) can be given into the bone marrow, and they will reach the heart and general circulation as fast as if they had been given through a central vein.

Remove the intra-osseous needle as soon as venous access is available. In any case, it should not be in place for more than 8 hours.

Complications

These include the following:

- dislodgement
- misplacement (penetration through posterior cortex, failure to penetrate cortex), resulting in:
  - haematoma
  - tissue necrosis
  - compartment syndrome
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- skin infection
- osteomyelitis
- tibial fracture in babies.

**The scalp vein needle as an intra-osseous device**

In infants, a green “butterfly” (scalp vein) needle can be used as an intra-osseous needle with the same precautions as above.

**Battery-powered intra-osseous device**

The EZ-IO drill is a powered device that enables rapid insertion of an intra-osseous needle.

Various sizes of needle are available (see Figures 8.4.B.10 and 8.4.B.11) for different-sized patients.

**FIGURE 8.4.B.10** EZ-IO power drill and needles.

The landmarks are as before, using the upper end of the tibia. In adults in particular, the upper outer aspect of the humerus can also be used.

**FIGURE 8.4.B.11** Site for EZ-IO needle in the proximal humerus in an adult or large child.

The procedure is less painful for the conscious patient due to its rapidity, the drilling effect and the sharpness of the needles. The EZ-IO needles are available in two sizes, for patients under 40kg and over 40kg.

The procedure for insertion is as follows:

1. Take universal precautions for sterile procedure.
2. Clean the site.
3. Choose an appropriate size of needle and attach it to the drill. It will fix magnetically.
4. Remove the safety cap from the needle.
5. If the patient is conscious, control their movement during insertion.
6. Hold the drill and needle at 90 degrees to the skin surface and push through the skin without drilling, until bone is felt. Ensure that at least 5mm of the needle is visible at this point.
7. Squeeze the drill button and drill continuously, applying gentle steady downward pressure until there is sudden loss of resistance – there is a palpable “give” as the needle breaches the cortex. Release the trigger and stop insertion at this point.
8. If the driver stalls and will not penetrate the bone you may be applying too much downward pressure.
9. If the driver fails (this is rare) remove it, grasp the needle kit by hand and twist it into the bone marrow.
10. Remove the drill and unscrew the trochar.
11. Aspirate the bone marrow if possible directly from the needle.
12. Attach the pre-prepared connection tube containing sterile Ringer-lactate or Hartmann’s solution or 0.9% saline before any infusion is given.

**FIGURE 8.4.B.12** EZ-IO needle in place, with stylet removed.

Do not attach a syringe directly to the EZ-IO catheter hub except when drawing blood with the needle set stabilised by hand (sterile).

11. There is an optional device for securing the needle, but this is not essential.
12. Proceed with the required therapy. It should be noted that rapid infusion of fluid may be painful for the conscious patient.
13. Apply a sterile dressing.
14. When removing the catheter, attach a Luer lock syringe, and continuously rotate it clockwise while slowly and gently applying traction to the catheter. Do not rock or bend the catheter during removal.
15. Do not leave the catheter in place for more than 24 hours.

**Needle pericardiocentesis**

Needle pericardiocentesis is a rarely used skill but can be life-saving when indicated.

**Indications**

This procedure is used:

- to reduce a pericardial effusion that is causing haemodynamic compromise
- to diagnose pericarditis.

In the trauma situation this procedure is performed when cardiac tamponade is suspected. This is usually, but not always, caused by a penetrating injury between the nipple line and the shoulder blades. The clinical findings are shock, muffled heart sounds (although this is a difficult sign to elicit with confidence) and distended neck veins. It is important...
to differentiate between this and tension pneumothorax, in which the trachea is deviated and air entry reduced on the affected side. Ideally this procedure should be carried out under ECG control, but if that is not available, extra care must be taken.

If available, ultrasound is the easiest/safest way of making a diagnosis of cardiac tamponade.

**Preparation of kit**
The following equipment is needed:
- ECG monitor
- syringe
- skin prep
- local anaesthetic
- over-needle cannula (16- to 18-gauge)
- sterile drapes.

**Technique**
1. Position the patient supine and attach the ECG. Stand on the patient’s right with the ECG monitor at the patient’s head so that you can see it easily.
2. Clean the skin from nipples to umbilicus and drape with sterile towels to expose the peri-xiphoid region. This must be a sterile procedure. Infiltrate local anaesthetic at the costal margin just below the xiphoid process.
3. Attach the cannula to the syringe. Insert the cannula just below and to the left of the xiphoid process. Angle the needle at 45 degrees to the skin and pointing towards the tip of the left scapula.
4. Advance the needle, holding this position, aspirating all the time and watching the cardiac monitor. As you enter the distended pericardial sac, fluid will flow back into the syringe. If the myocardium is touched, the ECG pattern will change (arrhythmia, ectopics, ‘injury’ pattern). If you can aspirate large amounts of bright red blood you have entered the ventricle, in which case you should withdraw slightly.
5. If successful, cardiac function should improve immediately. Withdraw the needle, attach a three-way tap, and secure the cannula for further aspirations.
6. This is a temporary procedure, and some patients will require a formal pericardiectomy. **Pericardial aspiration may not work well for viscous fluids (e.g. clotted blood) in the pericardial sac.**

**Defibrillation**
There are two indications for this procedure:
1. In cardiac arrest when the rhythm is ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT) (see Section 1.13). The dose is 4 joules/kg in children.
2. In supraventricular tachycardia (SVT) or ventricular tachycardia without shock (see Section 5.4.C). The dose is 0.5 joules/kg, rising to 1 joule/kg then 2 joules/kg if the first shocks were unsuccessful.

In any patient who is not *in extremis*, anaesthesia/sedation must be given before the DC shock is administered.

**Safety**
A defibrillator delivers enough current to cause cardiac arrest. The user must ensure that other rescuers are not in physical contact with the patient (or the trolley) at the moment when the shock is delivered. The defibrillator should only be charged when the paddles are either in contact with the child or replaced properly in their storage positions. **Oxygen must be discontinued and be moved right away from the patient.**

**Procedure**
Basic life support should be interrupted for the shortest possible time (see steps 5 to 9 below).
1. Apply gel pads or electrode gel.
2. Select the correct paddles (paediatric paddles for patients weighing less than 10kg). If only adult paddles are available for a small child, put one on the front of the child’s chest and one on the back.
3. Select the energy required.
4. Place the electrodes on the pads of gel, and apply firm pressure.
5. Press the charge button.
6. Wait until the defibrillator is charged.
7. Shout ‘Stand back!’
8. Check that all of the other rescuers are standing clear.
9. Deliver the shock.

**Correct paddle placement**
The usual placement is antero-lateral. One paddle is put over the cardiac apex in the mid-axillary line, and the other is placed just to the right of the sternum, immediately below the clavicle.

**Good paddle contact**
Gel pads or electrode gel should always be used (if the latter is used, care should be taken not to join the two pads together).
areas of application). Firm pressure should be applied to the paddles.

**Correct energy selection**
The recommended level in VF or pulseless VT cardiac arrest is 4 joules/kg (with no patient sedation).

In arrhythmias with a pulse, the dose is 0.5 joules/kg, then 1 joule/kg, then 2 joules/kg if the previous doses were unsuccessful (always with sedation).

**Automatic external defibrillators (AEDs)**
Automatic external defibrillators (AEDs) are used in adults both to assess cardiac rhythm and to deliver defibrillation (see Section 1.13 for details). In children, AEDs can accurately detect ventricular fibrillation at all ages, but there is concern about their ability to identify tachycardic rhythms in infants correctly. At present, therefore, AEDs can be used to identify rhythms in children but not in infants.

Many AEDs now have paediatric attenuation pads which decrease the energy to a level more appropriate for the child (aged 1–8 years), or leads that reduce the total energy to 50–80 joules. This means that AEDs can be used for all children over the age of 1 year. Institutions that treat infants who might need defibrillation must provide manual defibrillators.

**Guidance**
- With a manual defibrillator use 4 joules/kg to defibrillate patients of all ages.
- With an unattenuated AED (see above), children over 8 years of age can be defibrillated.
- With an AED with paediatric pads or paddles, children aged 1–8 years can be defibrillated.

### 8.5 Other procedures

#### Insertion of an orogastric or nasogastric tube

**FIGURE 8.5.1** Inserting a nasogastric tube. (a) The distance from the nose to the ear and then to the epigastrium is measured. (b) The tube is then inserted to the measured distance.

The nasogastric tube is used to feed any child who is unable to take food by mouth.

#### Preparation of kit
The following equipment is needed:
- nasogastric tube
- lubricant
- pH indicator paper or litmus paper
- syringe
- stethoscope
- adhesive tape.

In preterm infants:
- 4 French gauge tube is used for infants who weigh ≤ 1000 grams
- 6 French gauge tube is used for infants who weigh > 1000 grams (and most neonates)
- 8 to 10 French gauge tube is used for abdominal decompression (e.g., in infants with ileus or who are receiving continuous positive airway pressure).

#### Procedure
1. Place the child supine with their head in the “sniffing” position.
2. Measure the length of the tube from the nose via the earlobe to the midpoint between the xiphoid and the umbilicus. Mark the tube at this point with indelible pen.
3. Feed the tube lubricated with KY Jelly or saline through either the nose or the mouth directly backwards. (The neonate is a nose breather, and therefore if there is respiratory distress the oral route may be preferred.) Try to advance the tube as the child swallows. If a baby has respiratory distress, a gastric tube is best passed through the mouth.
4. Check the position of the tube by very gently aspirating 0.2–0.5 mL of stomach contents using a small (2- or 5-mL) syringe (larger ones can damage the gastric mucosa) and checking the change in the pH indicator.