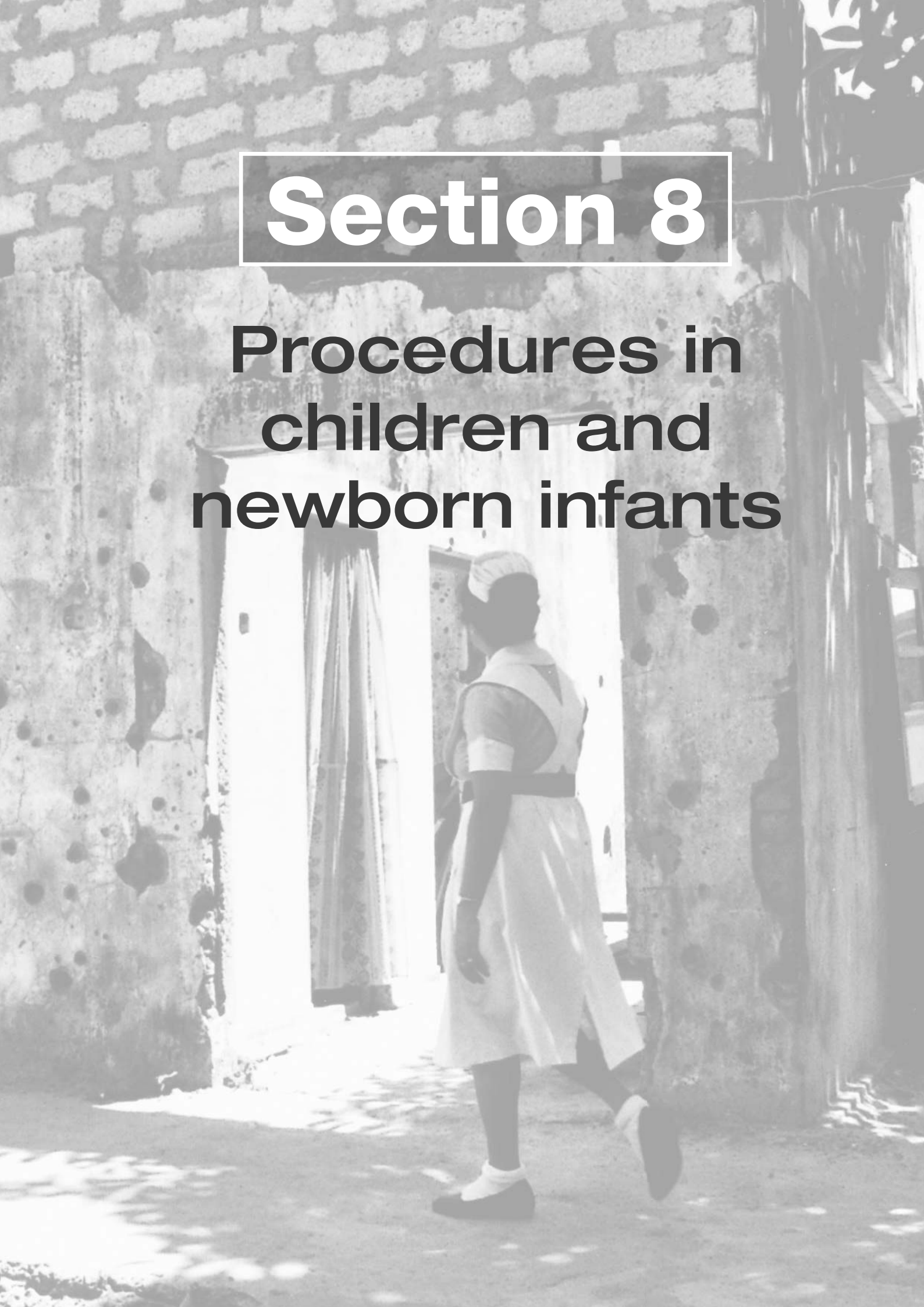


Section 8

Procedures in children and newborn infants

8.1 Preparation for procedures

Practical procedures should first be explained to the child (if they are old enough to understand this information) and the parents, any risks discussed with them and their consent obtained. Procedures on young infants should avoid hypothermia. Good light is essential. Analgesia should be given where necessary, and invasive procedures only performed when essential.

Analgesia and sedation for procedures

Some procedures have to be undertaken immediately, to save life, and many such procedures are described in this section. Clearly, there is no time to use analgesia in these circumstances, nor indeed much need to do so, as children who are in such severe collapse will have significantly depressed conscious levels. Where there is consciousness, analgesia and/or sedation is a top priority.

(For details on pain assessment and analgesia, *see* Section 1.15.)

For some procedures (e.g. chest tube insertion, dressing of burns), analgesia with a powerful drug such as ketamine should be considered, with a skilled healthcare worker (usually an anaesthetist) present and able to treat any adverse reactions immediately (*see* Section 1.24).

For planned intubation, anaesthesia is induced first (*see* Section 1.24). For some rarely used procedures such as defibrillation for cardiac arrest caused by a shockable rhythm (*see* Section 1.13), there is neither time nor need for sedation, as the patient is unconscious, whereas for defibrillation for an arrhythmia, sedation is necessary in most cases (*see* Section 5.4.C).

If ketamine is being used, give 2–4 mg/kg IM. This takes 5–10 minutes to act and the effects last for about 20 minutes. Ketamine can also be given slowly IV in this situation, 250–500 microgram/kg IV, and repeated as required to control pain. An anaesthetist or other expert in airway control must be present when ketamine is used.

When giving any analgesia, manage the child's airway, beware of respiratory depression and monitor oxygen

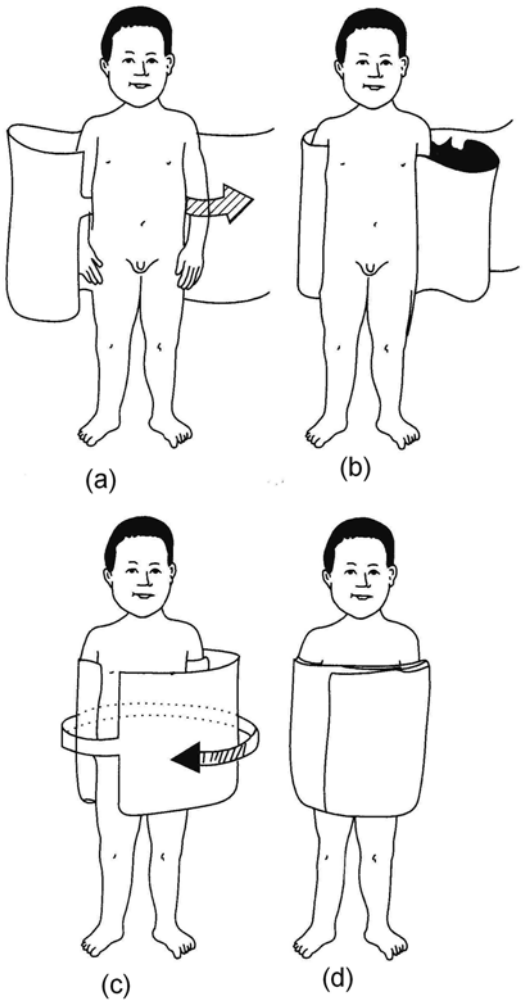


FIGURE 8.1.1 Wrapping a child so that they can be held securely for a procedure. (a) and (b). One end of a folded sheet should be pulled through under the arms on both sides. (c) and (d). The other end is then brought across the front and wrapped round the child.

FIGURE 8.1.2 Holding a child for examination of the eyes, ears and throat.

saturation with a pulse oximeter (if available). **Ensure that you have a resuscitation bag and mask available (and oxygen).**

Restraining children for procedures

Restraint is important both for the child and for the clinician who is undertaking the procedure. Clearly, the procedure will be undertaken more quickly, safely and accurately if the child is kept still. However, to prevent a child with a chronic condition who will experience many such procedures being made fearful of further attempts, sedation should be strongly considered if facilities are available for this.

If facilities do not allow or if the procedure is unlikely to require repetition, physical restraint can be used. Ideally a parent or trusted friend or relative can actually hold the child. It is also very helpful to use distraction techniques such as singing a song, telling a story or using a glove puppet. Blowing soap bubbles is a very useful distraction for children, and it costs very little to bend a piece of wire into a loop and make up some strong soap solution.

First explain to the child in an age-appropriate manner what is going to happen. **Never say 'This won't hurt' when you know it will.** Always use local analgesia if at all possible (*see* Section 1.15). Explain why they are to be wrapped up (a 'big cuddle'), what is to happen and what will happen afterwards. Give plenty of praise before, during and after the procedure.

Restraining a child for examination does not usually require wrapping, but it is wise to leave examination of the ears, nose and throat until the end of the examination.

8.2 Airway procedures

Oropharyngeal airway

For adjunct-free airway opening and airway positions, *see* Section 1.12.

The oropharyngeal or Guedel airway is used in the unconscious or obtunded patient to provide an open airway channel between the tongue and the posterior pharyngeal wall. In the conscious patient with an intact gag reflex, it may not be tolerated and may induce vomiting. It is especially useful in the convulsing and post-ictal patient.

The oropharyngeal airway is available in a variety of sizes. A correctly sized airway when placed with its flange at the centre of the incisors, and then curved around the face, will reach the angle of the mandible. Too small an airway may be ineffective, and too large an airway may cause laryngospasm. Either may cause mucosal trauma or may worsen airway obstruction. Reassessment following placement is therefore a vital part of safe insertion of an airway device.

There are two methods for inserting the oropharyngeal airway in a child, depending on whether the child is small or large. However, there is no set age for switching from one to the other, as the choice of method depends on practicality and the skills of the operator. The important thing is not to push the tongue back, as that will obstruct the airway instead of keeping it open.

The twist technique is used for the larger child and in pregnancy, and means that the convex side of the airway is used to depress the tongue as the airway is pushed into the mouth. Insert the airway upside down until the tip has passed the soft palate, and then rotate it through 180 degrees so that the natural curve of the Guedel airway follows the curve of the tongue and pharynx.

However, in the infant and small child, as the tongue is larger relative to the size of the mouth, the airway cannot be rotated in the mouth without causing trauma. Therefore

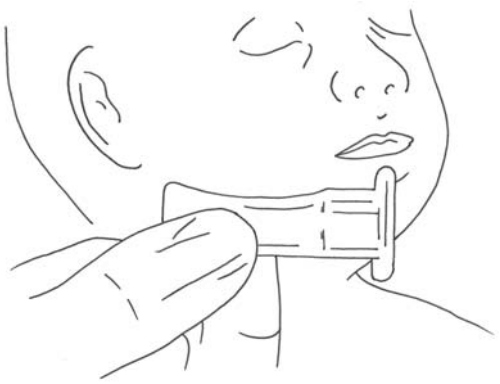


FIGURE 8.2.1 Oropharyngeal airway, showing sizing technique (correct size is illustrated).

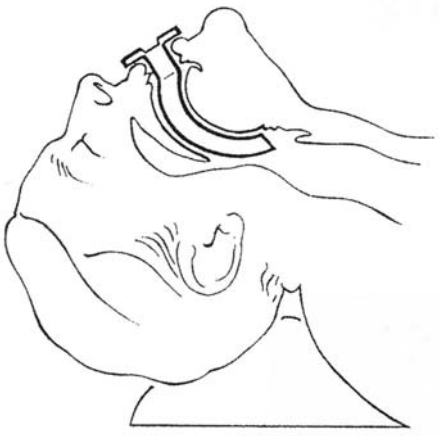


FIGURE 8.2.2 Oropharyngeal airway, showing position when inserted.

FIGURE 8.2.3 Oropharyngeal airway shown being inserted concave side up, then in place concave side down.

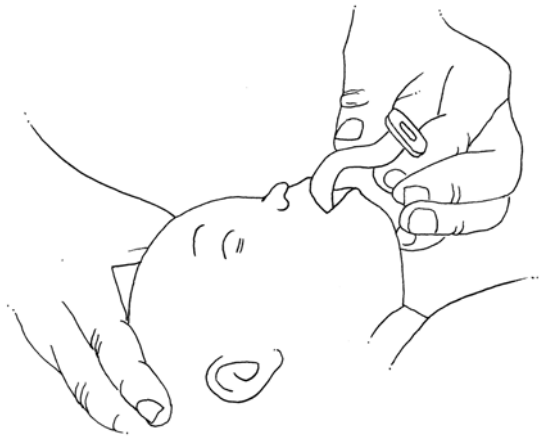


FIGURE 8.2.4 When inserting the airway without rotation, a tongue depressor can be helpful (not shown).

the tongue is depressed with a spatula and not by the reversed airway.

Ensure that insertion of one of these devices results in improvement in the patient's airway and breathing. It if does not improve the airway as shown by improved breathing, a reappraisal of the choice or size of airway is urgently required (*see also* Section 1.13).

Tracheal intubation

Aims

These are as follows:

- to secure the airway
- to protect the airway
- to facilitate prolonged and intra-operative ventilation
- for tracheo-bronchial toilet
- in the application of high airway pressures and positive end-expiratory pressure (PEEP)
- during cardiopulmonary resuscitation to improve ventilation and allow uninterrupted chest compressions.

Choice of tube

An uncuffed tube is often recommended in children who weigh less than 25 kg, as the larynx is narrowest below the glottis at the circular non-distensible cricoid ring, and inexperienced use of the cuffed tube may cause damage at that point, although the cuffed tube gives better airway protection. The choice ultimately depends on the experience of the practitioner (*see also* Section 1.13).

The correctly sized tube is one that passes easily through the glottis and subglottic area with a small air leak detectable at 20 cmH_2O (sustained gentle positive pressure).

Size of tube

The correct size of tube is:

- one that can just fit into the nostril **or**
- in preterm neonates, 2.5–3.5 mm internal diameter **or**
- in full-term neonates, 3.0–4.0 mm internal diameter **or**
- in infants after the neonatal period, 3.5–4.5 mm internal diameter **or**
- in children over 1 year:
  - the internal diameter (in mm) is age/4 + 4
  - the length of tube (in cm) is age/2 plus 12 for an oral tube, and age/2 plus 15 for a nasal tube.

Aids to intubation

- Laryngoscope: blade (straight for neonates and infants because of long, floppy epiglottis, curved for older children), bulb and handle.

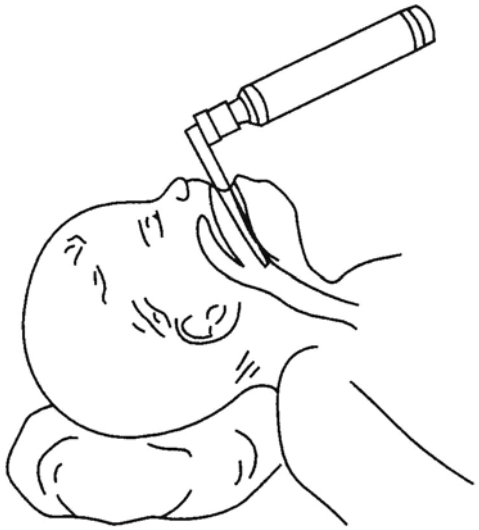


FIGURE 8.2.5 Straight-blade laryngoscope, suitable for infants.

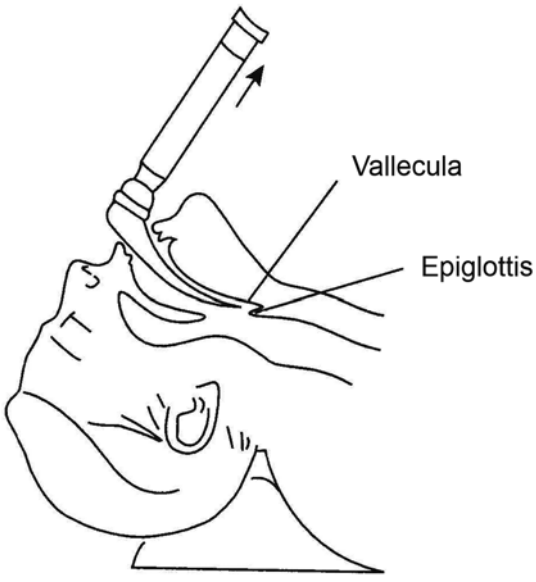


FIGURE 8.2.6 Curved-blade laryngoscope, suitable for children.

- Magill's forceps.
  - Introducer (not further than the end of the tube itself).
  - Syringe (cuffed tube).
  - Gum elastic bougie (over which the tube can pass).
  - Cricoid pressure (can aid visualisation of larynx).
  - Suction apparatus (this must be available).

Predicting difficulty

- Difficulty in opening mouth.
- Reduced neck mobility.
- Laryngeal/pharyngeal lesions.
- Congenital: Pierre-Robin syndrome, mucopolysaccharidoses.
- Acquired: burns, trauma.

If on viewing the infant's face from the side, the chin is unusually small (micrognathia), the intubation will be difficult, and **senior help is required** (but see below).

Complications

- Displacement: oesophageal, endobronchial, out of larynx!
- Obstruction: kinking, secretions.
- Trauma: lips to larynx.
- Hypertensive response.
- Spasm: laryngeal, pharyngeal.
- Aspiration: gastric contents.

Procedure

Prepare and check the equipment.

- Choose an appropriate tube size, with one size above and one size below it available.
- Get the tape ready to fix the tube.
- Suction must be available.
- Induce anaesthesia and give a muscle relaxant unless the patient is completely obtunded.
- **Do not attempt the procedure in a semi-conscious child.**

Position the child.

- Children over 3–4 years of age: the 'sniffing morning air' position (head extended on the shoulders, and flexed at the neck).
- Children under 3 years of age (especially neonates and infants): a neutral position (large occiput).
- Keep the child in a neutral position with in-line immobilisation in the case of unstable cervical spine (e.g. trauma, Down's syndrome).

Oxygenate the child using a face mask and reservoir (if patient is breathing) or bag and mask ventilation to provide high flow oxygen.

- Introduce the laryngoscope into the right side of the mouth.
- Sweep the tongue to the left.
- Advance the blade until the epiglottis is seen.
  - Curved blade: advance the blade anterior to the epiglottis. Lift the epiglottis forward by moving the blade away from your own body.
  - Straight blade: advance the blade beneath the epiglottis, into the oesophagus. Pull back, and the glottis will 'flop' into view.

Recognise the glottis.

- Insert the endotracheal tube gently through the vocal cords.
- Stop at a predetermined length.

Confirm the correct placement.

- The chest moves up and down with ventilation.
- Listen to breath sounds in the axillae and anterior chest wall.
- Confirm that there are no breath sounds in the stomach.
- Oxygen saturations do not go down.
- Carbon dioxide is measured from expired gases.

Secure the tube.

Secure with tape around the tracheal tube and on to the patient's face (see below).

Nasal intubation.

Although oral intubation is quicker and more reliable in an emergency, for prolonged ventilation nasal intubation is preferable, if a skilled operator is available, as the tracheal tube is more securely fixed. The technique is similar, but with the additional use of the Magill's forceps to grasp and guide the tracheal tube as it emerges into the posterior pharynx downward into the trachea through the vocal cords.

Intubation of the newborn infant without a laryngoscope

It is possible to intubate a newborn baby using a finger rather than a laryngoscope. This can be very helpful if you do not have a functioning laryngoscope, or if the child has facial or oral deformities that interfere with your ability to insert a laryngoscope or to see the larynx (e.g. severe micrognathia).

Procedure

- Insert the index finger of the left hand into the baby's mouth, with its palmar surface sliding along the tongue. Use the little finger if the baby is small.

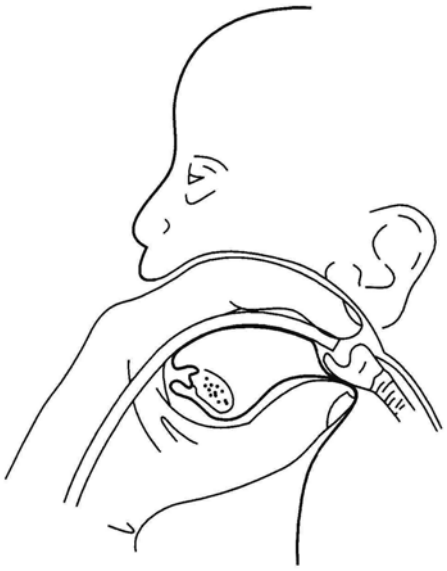


FIGURE 8.2.7 Finger intubation of the trachea in a newborn. (From Hancock PJ and Peterson G (1992) Finger intubation of the trachea in newborns. *Pediatrics*. **89**: 325–7. Reproduced with permission.)

- Slide the finger along the tongue until it meets the epiglottis. This feels like a small band running across the root of the tongue.
  - Slide the finger a little further until the tip lies behind and superior to the larynx and the nail touches the posterior pharyngeal wall.
  - Slide the tube into the mouth between the finger and the tongue until the tip lies in the midline at the root of the distal phalanx of the finger.
  - At this point place the left thumb on the baby's neck just below the cricoid cartilage in order to grasp the larynx between the thumb on the outside and the fingertip on the inside.
  - While the thumb and finger steady the larynx against side-to-side motion, the right hand advances the tube a short distance (about 1–2 cm).
  - A slight 'give' can sometimes be felt as the tube passes into the larynx, but **no force is needed for insertion**.
  - When the tube is in the trachea the laryngeal cartilages can be felt to encircle it. If it has passed into the oesophagus it can be felt between the finger and the larynx.

Fixation of endotracheal tubes

Two people should be available to do this, one of whom should hold the tube at all times.

- Cut two strips of sticky zinc oxide tape (see below); they should reach from just in front of the ear across the cheek and above the upper lip to the opposite ear.

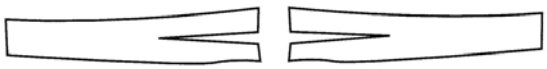


FIGURE 8.2.8 Tape for tracheal tube fixation.

- If available, apply some benzoin tincture to the cheeks, above the upper lip and under the chin, which will make the tape stick well.
- Make sure that the endotracheal tube is clean and that no old tape is left on it.
- Start with the broad end of the tape, and stick this on to the cheek. Then wrap one of the thinner ends carefully around the tube. It is useful if it is still possible to see the endotracheal tube marking at the lips.
- Tape the other half across the philtrum to the cheek.
- The second tape starts on the other cheek, and the thinner half is stuck across the chin, while the other half is also wrapped around the tube (see below).

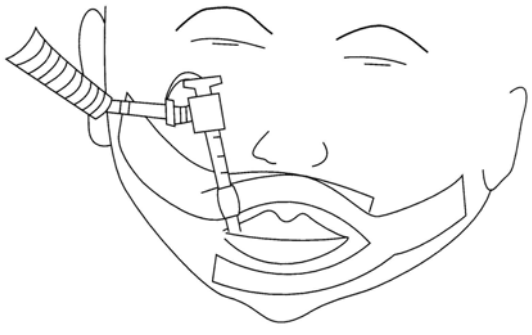


FIGURE 8.2.9 Taped tracheal tube.

Cricothyroidotomy

Cricothyroidotomy is indicated if a patent airway cannot be achieved by other means. It must be performed promptly and decisively when necessary.

Call a surgeon and an anaesthetist (if available).

In children under the age of 12 years, needle cricothyroidotomy can be performed rather than a full surgical cricothyroidotomy. In adolescents, either technique can be used, but the surgical technique allows better protection of the airway. The relevant anatomy is shown in Figure 8.2.10.

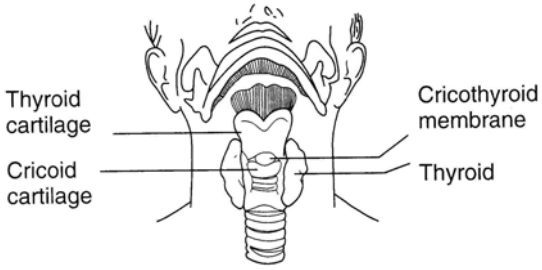


FIGURE 8.2.10 Anatomy of the larynx.

In a very small baby, or if a foreign body is below the cricoid ring, direct tracheal puncture using the same technique can be used.

Needle cricothyroidotomy

This technique is simple in concept, but far from easy in practice. In an emergency situation the child may be struggling, and attempts to breathe or swallow may result in the larynx moving up and down.

Procedure

- Attach a cricothyroidotomy cannula-over-needle (or if this is not available, an IV cannula and needle) of appropriate size to a 5-mL syringe.
- Place the patient in a supine position.
- If there is no risk of cervical spine injury, extend the neck, perhaps with a sandbag under the shoulders.
- Identify the cricothyroid membrane by palpation between the thyroid and cricoid cartilages.
  - Prepare the neck with antiseptic swabs.
  - Place your left hand on the neck to identify and stabilise the cricothyroid membrane, and to protect the lateral vascular structures from needle injury.

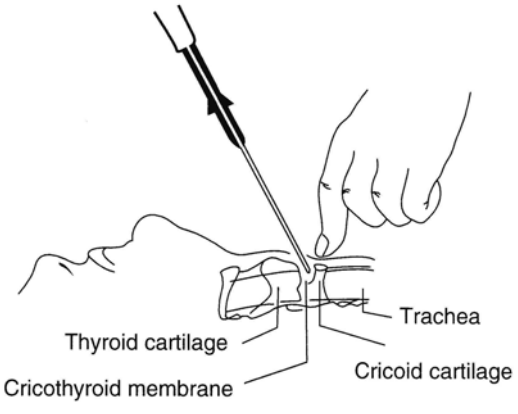


FIGURE 8.2.11 Penetrating the cricothyroid membrane.

  - Insert the needle and cannula through the cricothyroid membrane at a 45-degree angle caudally towards the feet, aspirating as the needle is advanced (*see* Figure 8.2.11).
- When air is aspirated, advance the cannula over the needle, being careful not to damage the posterior tracheal wall. Withdraw the needle.
- Re-check that air can be aspirated from the cannula.
- Attach the hub of the cannula to an oxygen flow meter via a Y-connector. Initially the oxygen flow rate (in litres) should be set at the child's age (in years).
- Ventilate by occluding the open end of the Y-connector with a thumb for 1 second, to direct gas into the lungs. If this does not cause the chest to rise, the oxygen flow rate should be increased by increments of 1 litre, and the effect of 1 second of occlusion of the Y-connector reassessed.
- Allow passive exhalation (via the upper airway) by releasing the thumb for 4 seconds.
- Observe chest movement and auscultate breath sounds to confirm that there is adequate ventilation.
- Check the neck to exclude swelling from the injection of gas into the tissues rather than the trachea.
- Secure the equipment to the patient's neck.
- Having completed emergency airway management, arrange to proceed to a more definitive airway procedure, such as tracheotomy.

Note

There are two common misconceptions about transtracheal insufflation. The first is that it is possible to ventilate a patient via a needle cricothyroidotomy using a self-inflating bag. The maximum pressure from a bag is approximately 4.41 kPa (45 cmH_2O) (the blow-off valve pressure), and this is insufficient to drive gas through a narrow cannula. In comparison, wall oxygen is provided at a pressure of 4 atmospheres (approximately 392 kPa or 4000 cmH_2O). The second misconception is that expiration can occur through the cannula, or through a separate cannula inserted through the cricothyroid membrane. This is not possible. The intratracheal pressure during expiration is usually less than 2.9 kPa (30 cmH_2O) (less than 1% of the driving pressure in inspiration). Expiration must occur via the upper airway, even in situations of partial upper airway obstruction. Should upper airway obstruction be complete, it is necessary to reduce the gas flow to 1–2 litres/minute. This provides some oxygenation but little ventilation.

Nevertheless, insufflation buys a few minutes in which to attempt a surgical airway.

Surgical cricothyroidotomy

1 Place the patient in a supine position.
2 If there is no risk of neck injury, consider extending the neck to improve access. Otherwise, maintain a neutral alignment.
3 Identify the cricothyroid membrane in the following manner. Place your finger over the most prominent part of the thyroid cartilage (the Adam's apple). Move the finger downwards (i.e. towards the chest), keeping strictly in the midline. The first dip felt is the area of cricothyroid membrane.
4 Prepare the skin and, if the patient is conscious, infiltrate with local anaesthetic.
5 Place the index and middle fingers of your left hand on each side of the midline of the neck to stabilise the cricothyroid membrane, and to protect the lateral vascular structures from injury.
6 Make a small vertical incision in the skin, and press the lateral edges of the incision outwards, to minimise bleeding.
7 Make a transverse incision through the cricothyroid membrane, being careful not to damage the cricoid cartilage.
8 Insert a tracheal spreader, or use the handle of the scalpel by inserting it through the incision and twisting it through 90 degrees to open the airway.
9 Insert an appropriately sized endotracheal or tracheostomy tube. It is advisable to use a slightly smaller size than would have been used for an oral or nasal tube (e.g. size 6.0 mm internal diameter for age 12–16 years).
10 Ventilate the patient and check that this is effective.
11 Secure the tube to prevent dislodgement.

Complications of cricothyroidotomy

These include the following:

- asphyxia
- aspiration of blood or secretions
- haemorrhage or haematoma
- creation of a false passage into the tissues
- surgical emphysema (subcutaneous or mediastinal)
- pulmonary barotrauma
- subglottic oedema or stenosis
- oesophageal perforation
- cellulitis.

8.3 Breathing procedures

Emergency needle thoracocentesis

This procedure is used for the rapidly deteriorating patient who has a life-threatening tension pneumothorax (*see* Section 7.3.A). If this technique is used in a patient who does not have a tension pneumothorax, there is a 10–20% risk of producing a pneumothorax or causing damage to the lung, or both. In such cases, immediate insertion of a chest drain is mandatory. **Patients who have undergone**

this procedure should ideally have a chest radiograph, and may require chest drainage if they subsequently need assisted ventilation.

Minimum equipment

- Swabs for disinfecting the skin.
- Large over-the-needle IV cannula (16-gauge, but 20- to 22-gauge in preterm infants).
- 20-mL syringe.

Procedure (*see* Figure 8.3.1)

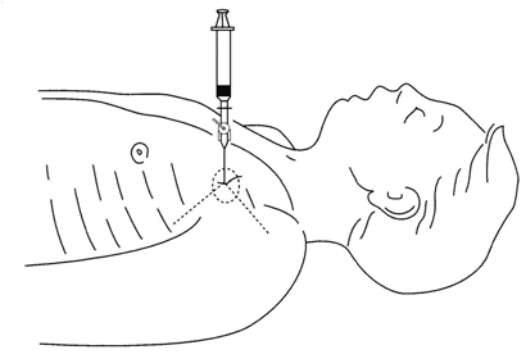


FIGURE 8.3.1 Position for inserting over-the-needle cannula for thoracocentesis.

1. Identify the second intercostal space in the mid-clavicular line on the side of the pneumothorax (the **opposite** side to the direction of tracheal deviation and the **same** side as the hyper-resonance).
2. Swab the chest wall with surgical preparation solution or an alcohol swab.
3. Attach the syringe to the over-the-needle IV cannula, ideally via a three-way tap.
4. Insert the cannula vertically into the chest wall, just above the rib below to avoid blood vessels, aspirating all the time.
5. If air is aspirated, remove the needle, leaving the plastic cannula in place.
6. Tape the cannula in place and proceed to chest drain insertion as soon as possible.

Complications

These include the following:

- local cellulitis
- local haematoma
- pleural infection
- empyema
- pneumothorax.

Insertion of a chest drainage tube

In a trauma emergency that requires a chest drainage tube, fluid resuscitation through at least one large calibre IV cannula, and monitoring of vital signs should be ongoing. Usually the patient will be receiving oxygen through a face mask with a reservoir.

Chest drain placement should be performed using the open technique described here, as this minimises lung damage. In general, the largest size of drain that will pass between the ribs should be used.

Minimum equipment

- Skin disinfectant and surgical drapes.
- Scalpel with fine straight blade.
- Blunt forceps.
- Artery forceps.
- Large clamps × 2.
- Suture.
- Local anaesthetic if the child is conscious.
- Scissors.
- Chest drain tube.
- Underwater seal or Heimlich flutter valve.

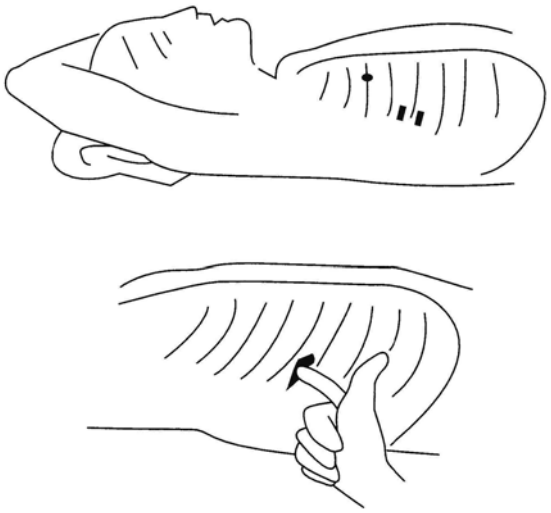


FIGURE 8.3.2 Sites for chest drain: 4th or 5th intercostal space in the anterior or mid-axillary line.

Procedure

1. Consider using analgesia or sedation in a small or apprehensive child.
2. Wash your hands and arms to the elbows, and wear a mask, surgical hat (bonnet), sterile gown and sterile surgical gloves.
3. Prepare the underwater seal with an assistant and take the sterile end of the tube, ready to connect to the chest tube once inserted. The 'seal' end should be covered by no more than 1–2 cmH_2O.
4. Decide on the insertion site (usually the fourth or fifth intercostal space in the anterior or mid-axillary line) on the side with the pneumothorax (*see* Figure 8.3.2).
5. Swab the chest wall with surgical preparation or an alcohol swab.
6. Use local anaesthetic if the child is conscious. Morphine (100 micrograms/kg IV over 10 minutes) should also be given if the child is conscious, but in the preterm infant who is not ventilated this may precipitate apnoea. Facilities to provide bag-and-mask ventilation and/or intubation should be immediately available, together with staff trained in their use.
7. Make a 2- to 3-cm skin incision along the line of the intercostal space, **immediately above the rib below to avoid damage to the neurovascular bundle which lies under the inferior edge of each rib**.
8. Using artery forceps, bluntly dissect through the subcutaneous tissues just over the top of the rib below, and puncture the parietal pleura with the tip of the forceps.

9 Put a gloved finger into the incision and clear the path into the pleura. This will not be possible in infants or small children, in which case continue to use the artery forceps.
10 Advance the chest drain tube (use the largest size that can comfortably pass between the ribs) into the pleural space without the trocar in place, but using the artery forceps to help to guide it into the pleural cavity if necessary. Pass about 3 cm and then connect to the underwater seal. Ideally advance the chest drain tube into the pleural space during expiration.
11 Ensure that the tube is in the pleural space by looking for fogging of the tube during expiration.
12 Ensure that all of the drainage holes of the chest drain tube are inside the chest.
13 Connect the chest drain tube to an underwater seal. Check that the tube is in the right place by observing intermittent bubbling of the water in the drainage bottle.
14 Secure the tube using a suture passed through the skin at the incision site (after ensuring that adequate local anaesthetic has been administered) and tied around the tube.
15 Cover the puncture site in the chest wall with a sterile dressing, and tape the chest tube to the chest wall.
16 Obtain a chest radiograph if at all possible.

If the chest drainage tube is satisfactorily positioned and working, occasional bubbles will pass through the underwater seal. The water level in the tube may also rise and fall slightly with the respiratory cycle.

Complications of chest drainage tube insertion

- Dislodgement of the chest drain tube from the chest wall or disconnection from the drainage bag.
- Drainage bag elevated above the level of the chest, and fluid flowing into the chest cavity, unless there is a one-way valve system.
- Chest drain tube kinking or blocking with blood clot.
- Damage to the intercostal nerve, artery or vein. This might convert a pneumothorax to a haemopneumothorax, or result in intercostal neuritis or neuralgia.
- Damage to the internal thoracic artery if the puncture is too medial, resulting in haemopneumothorax.
- Incorrect tube position, inside or outside the chest cavity.
- Introduction of pleural infection (e.g. thoracic empyema).
- Laceration or puncture of intrathoracic or abdominal organs. This can be prevented by using the finger technique before inserting the chest tube.
- Leaking drainage bag.
- Local cellulitis.
- Local haematoma.
- Mediastinal emphysema.
- Persistent pneumothorax from a large primary defect; a second chest tube may be required.
- Subcutaneous emphysema (usually at the tube insertion site).

Tapping the chest for diagnostic tests in pleural effusions or empyema

Diagnostic procedure

- Consider giving the child analgesia or light anaesthesia with ketamine.
- Wash your hands and put on sterile gloves.
- Lie the child on their back.
- Clean the skin over the chest with an antiseptic solution (e.g. 70% alcohol).
- Select a point in the mid-axillary line (at the side of the chest) just below the level of the nipple (fifth intercostal space; *see* Figure 8.3.2).
- Inject about 1 mL of 1% lignocaine into the skin and subcutaneous tissue at this point.
- Insert a needle or needle-over-catheter through the skin and pleura, and aspirate to confirm the presence of pleural fluid. Withdraw a sample for microscopy and other tests and place it in a container.
- If the fluid is clear (straw-coloured or brownish), pull out the needle or catheter after withdrawing enough fluid to relieve distress, and put a dressing over the puncture site. Consider a differential diagnosis of tuberculosis (*see* Section 6.1.N).
- If the fluid is thin pus or cloudy (like milk), leave the catheter in place so that you can draw out more pus several times a day. Make sure that you seal the end of the catheter so that no air can get in.
- If the fluid is thick pus which cannot pass easily through the needle or catheter, insert a chest tube as described above.

Non-invasive respiratory support (*see* Section 1.25)

Respiratory support is needed when the patient fails to sustain adequate ventilation despite treatment of the respiratory condition. Respiratory failure may result from any of the following:

- respiratory illnesses
- severe shock
- coma
- convulsions
- meningo-encephalitis
- neuromuscular disorders
- raised intracranial pressure (e.g. from trauma).

Infants and young children are more likely to progress to respiratory failure because:

- they are more susceptible to infection
- their airways are smaller
- their thoracic cage is more compliant
- their ribs are (nearer) horizontal
- their respiratory muscles are more prone to fatigue.

Women and girls who are pregnant are also more susceptible to respiratory failure. They have reduced immune function, an expanding abdominal mass which impairs lung expansion, and are more prone to gastro-oesophageal reflux and aspiration of gastric contents.

As respiratory failure progresses, it will ultimately lead to cardiorespiratory arrest and death. Thus recognition of the severity of the conditions that lead to respiratory failure, followed by appropriate treatment, will reduce morbidity and mortality.

Signs that indicate the adequacy of breathing include the following:

- intercostal, sub-costal and supra-sternal recession
- respiratory rate
- inspiratory and expiratory noises

- use of accessory muscles
- adequacy of breath sounds and chest expansion
- heart rate
- skin colour
- mental status.

To help to assess the development of respiratory failure, it is necessary to assess changes in the above clinical signs. In the following situations, however, these signs are less useful because there is absent or decreased effort of breathing:

1 with fatigue or exhaustion (e.g. after prolonged respiratory effort)
2 with loss of cerebral drive from raised intracranial pressure, poisoning or encephalopathy
3 in children with neuromuscular disease.

In these cases, pay more attention to the chest expansion, heart rate, skin colour, mental status and, if available, SaO_2 measurement.

Pulse oximetry is of additional value to measure the arterial oxygen saturation through the skin (SpO_2 or SaO_2). Values of SpO_2 of less than 92–94% in air (at sea level; *see* Section 1.13 for values at high altitude) are abnormal, and would warrant at least initial treatment with additional inspired oxygen. Values of less than 95% when the child is in oxygen are low, but even values of more than 95% in oxygen may be associated with significant hypoventilation. It is essential to remember that, in respiratory failure, normal SaO_2 while receiving additional inspired oxygen is likely to be associated with significant hypoventilation or intra-pulmonary shunting. Measurement of transcutaneous, end-expired or blood carbon dioxide levels will confirm this.

TABLE 8.3.1 Modes of respiratory support for different conditions

Mode of support	Interface with patient	Level of nursing care	Associated medical treatment	Clinical use	Examples of conditions treated
High-flow high-humidity oxygen	Nasal cannulae	Home, ward, HD	Nil	To provide a flow above the patient's needs, that helps to wash out dead space, and improves comfort and clearance of the airways. It may provide mild CPAP	Bronchiolitis, post-operative, chronic lung disease of prematurity
Continuous positive airways pressure (CPAP)	Nasal cannulae or nasopharyngeal tube	High dependency (HD)	Sedation or analgesia may be needed	To keep upper and lower airways patent and maintain adequate lung volume (oxygenation)	Neonatal respiratory distress syndrome, **bronchiolitis**
	Nasal mask or face mask	Home, ward, HD	Nil		Sleep-related upper airway obstruction
		Intensive care (IC)	Sedation or analgesia may be needed		Acute upper airway obstruction before, **instead of** or after extubation
Intermittent positive pressure ventilation (IPPV)	Nasal mask or pillows, face mask (NIPPV)	Home to IC	Nil	To treat hypoventilation (raised CO_2) when airway control and clearance are adequate	Chronic (e.g. central, neuromuscular) Acute (e.g. after surgery)
	Endotracheal tube	IC	Anaesthesia for intubation Sedation or analgesia will be needed	To treat hypoventilation when clearance and/or support of airway(s), or close control of ventilation needed	Procedures or surgery requiring anaesthesia Severe respiratory illnesses, raised intracranial pressure
	Tracheostomy	Home to IC	ENT surgical procedure	Long term ventilation where day and night support needed	Brainstem/high spinal injury or neuromuscular disease
Continuous negative extrathoracic pressure (CNEP)	Chamber or jacket	Home to IC	Nil	To keep lower airways patent and maintain adequate lung volume	Bronchiolitis and other severe lower respiratory infections, especially where the nose is blocked by secretions
Intermittent negative pressure ventilation (INEP or INPV)				To treat hypoventilation where airway control and clearance are adequate or maintained by CPAP	Central hypoventilation (e.g. apnoea of prematurity, neuromuscular disease)

Shaded areas denote those that require a lower dependency of care (e.g. that have been used in the home setting), but may be useful in acute conditions.

Bold type denotes high-risk situations in which CPAP may be ineffective and intubation may be required.

When respiratory fatigue is severe, oxygenation is poor or deteriorating, or carbon dioxide levels are raised, respiratory support should be used, if available. The various forms of respiratory support are outlined in Table 8.3.1, along with their indications.

Notes on the use of positive pressure ventilation

1 Monitoring of patient status and airway or mask pressures is necessary when undertaking any form of respiratory support (see below).
2 Positive airway pressure involves a flow of air or other gas mixture to the patient's airways. This flow may be continuous (as in CPAP) or intermittent (as in IPPV). It may vary with inspiration and expiration (as in BiPAP), or to accommodate the leaks or variable compliance of ventilator tubing, airways or lung units.
3 Mask ventilation can be well tolerated by children, but it may be more difficult for infants and young children to tolerate appliances on their face.
4 In the presence of excess airway secretions or an open mouth, nasal masks and nasal cannulae may not produce as effective airway pressures as ventilation with tracheal intubation (or relatively higher pressures may be needed for the same effect).
5 The pressures used with masks and cannulae may be higher than those used with tracheal intubation, because of the greater potential for air leaks and other volume loss in compliant upper airway structures.
6 Infants and young children will sometimes tolerate masks and cannulae only with the use of sedation, in which case close monitoring of respiratory failure must be undertaken in case full intubation and ventilation is needed.
7 Endotracheal intubation should be undertaken with rapid sequence drug or gaseous induction, and subsequent analgesia, anxiolysis and sedation should be provided.
8 Positive pressure ventilation administered through an endotracheal tube must be accompanied by adequate humidity of the inspired gases.
9 Oxygen may be administered either using a built-in mixer in the ventilator, or by entraining a supply in the ventilator tubing nearer to the patient.
10 Positive pressure ventilators should be able to provide manipulation of either the pressure or volume administered, and the time intervals for inspiration and expiration. There should be alarms for failure to cycle, and for excessive pressure and/or volume administered.

Continuous positive airway pressure (CPAP)

CPAP has several effects on the airway and lungs of the preterm and full-term infant. These include prevention of alveolar collapse, increased functional residual capacity (FRC), and splinting of the airway. It is therefore of most value when used early in the course of respiratory disease (i.e. before too much alveolar collapse has taken place). Several units around the world use it successfully as first-line ventilatory support in even the smallest infants (< 750 grams birth weight).

Indications for CPAP

These include the following:

- signs of significant respiratory distress (tachypnoea, recession, grunting, nasal flare)
- diseases with low FRC (respiratory distress syndrome, transient tachypnoea of the newborn, pulmonary oedema)
- meconium aspiration syndrome
- apnoea and bradycardia of prematurity
- tracheomalacia.

Requirements

- Low-resistance delivery system.
- Large-bore tubing.
- Short wide connection to patient.
- Consistent and reliable pressure generation.
- Appropriate snug-fitting nasal cannulae.
- Well-positioned and secured nasal cannulae.
- Prevention of leaks, mainly via the mouth, with a chinstrap.
- Optimally maintained airway.
- Ideally warmed humidified gas.
- Prevention of neck flexion or over-extension with a neck roll.
- Regular suction to remove secretions.
- Meticulous and consistent technique.

Monitoring

- Continuous heart and respiratory rate monitoring.
- Continuous pulse oximetry, ideally pre-ductal.
- Blood gas measurements. These need not be done regularly in the stable baby with low oxygen needs unless they are required in order to assess the degree of metabolic acidosis, but in those with high oxygen requirements (FiO_2 > 40%) or in the unstable baby they should be checked regularly via an arterial line.

Complications

- **Nasal septum erosion/necrosis:** this is a result of ill-fitting nasal cannulae, and can be avoided by the fitting of snug, but not tight, cannulae (blanching of the overlying skin suggests that the cannulae are too large) which are held firmly in place to prevent rubbing as the child moves.
- **Pneumothorax:** all methods of artificial ventilation are associated with this problem. However, the more effective the CPAP is the less the work of breathing and therefore the lower the risk of pneumothoraces should be. Any pneumothorax that does occur should be drained appropriately. It is inappropriate to discontinue the CPAP.
- **Gastric distension from swallowed air:** this is important and is easily overcome by the venting of any such air via an open orogastric tube.

Insertion and securing of nasal cannulae and administration of CPAP

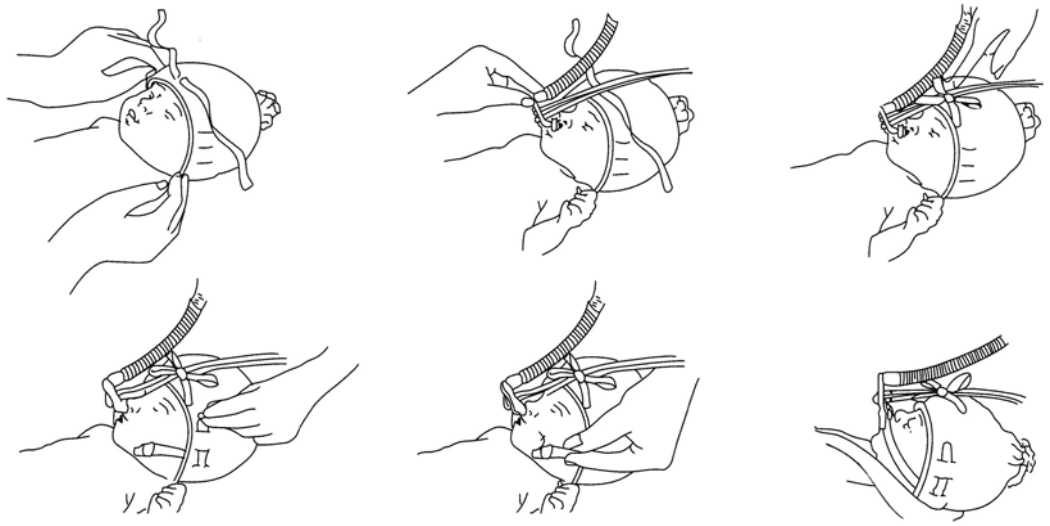


FIGURE 8.3.3 Securing nasal cannulae for giving continuous positive airway pressure (CPAP) in a baby. A special bonnet is used from which tapes hold the pipe carrying the air/oxygen mixture to the nasal cannulae to the forehead and a separate tape above the mouth to ensure the cannulae do not come out of the nasal passages..

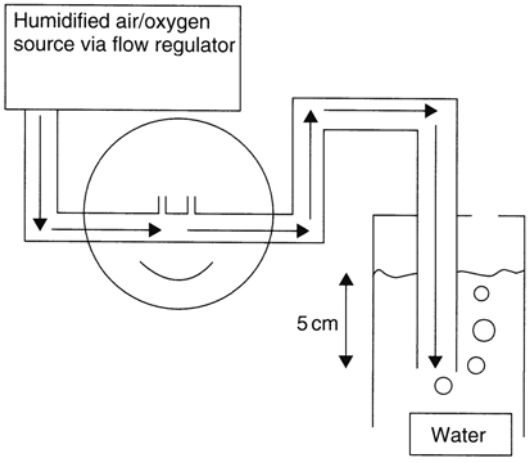


FIGURE 8.3.4 Simplified diagram of Hudson continuous positive airway pressure (CPAP). The gas flow is adjusted until a continuous trail of bubbles starts to appear in the water bottle, which is at the same height as the baby. This generates a CPAP of +5 cmH_2O.

Continuous negative extra-thoracic pressure

Continuous negative extra-thoracic pressure (CNEP) is a method by which sub-atmospheric pressure is applied to the outside of a child's chest by nursing them in a specially designed chamber. The patient's head is kept outside the chamber, thereby allowing the nose, mouth and all the airways into the lungs to remain at atmospheric pressure. As a result of this pressure difference, the chest is expanded and air is encouraged to enter the lungs. Areas of lung that were previously poorly inflated may be expanded, and this allows more chance for recovery from the lung disease.

The use of CNEP depends upon continued breathing efforts by the child to move air into and out of the lungs. When the child is inside the chamber, the breathing rate falls, the effort of breathing is reduced, and thus less energy is needed for breathing.

Indications

- Respiratory failure due to lung problems:
  - bronchiolitis
  - other causes of acute respiratory infection where the nasal airway is blocked and nasal CPAP is not possible.
- Respiratory failure due to weakness of respiratory muscles:
  - poliomyelitis.

Advantages

The absence of airway invasion:

- avoids trauma to the airways
- reduces the need for suctioning
- lowers the risk of introducing infection into the lungs
- is more comfortable for the patient, so there is less need for sedation.

Less complex equipment:

- can be managed on a general ward or at home
- is not difficult for healthcare workers and parents to learn how to use
- means that there is less utilisation of intensive care resources
- is quick to institute, not requiring medical or anaesthetic staff.

Physiological (compared with positive pressure) ventilation:

- does **not** increase pulmonary vascular resistance
- is less likely to significantly reduce cardiac output
- enhances lung perfusion, as well as ventilation.

Disadvantages

Negative pressure generated in the upper airway on

inspiration may be increased, thus exacerbating **pre-existing** upper airway obstruction.

Respiratory support may need to be interrupted for short periods.

- This means it is less suitable where the need for support to ventilation is critical and continuous
- It is also not suitable if the patient's own ventilatory efforts are inadequate to remove carbon dioxide.

Maintenance of body temperature in newborn infants may require specific attention.

Components of negative pressure system

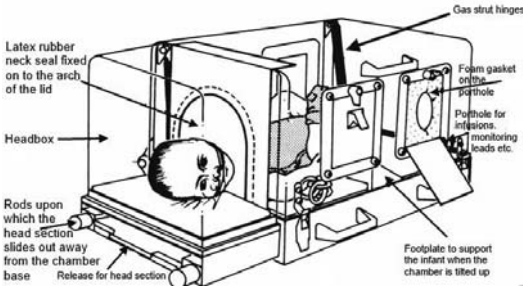


FIGURE 8.3.5 Negative pressure system.

The chamber

For low-birth-weight infants the chamber is built on to an incubator base incorporating a cabinet and heater, the latter providing servo-controlled circulation of hot air into the interior of the chamber. Particular features of the chamber shown in Figure 8.3.5 include the following:

1 release for the head section
2 rods upon which the head section slides out away from the chamber base
3 headbox
4 latex rubber neck seal fixed on to the arch of the lid
5 gas strut hinges
6 foam gasket or cuff on the porthole
7 porthole for infusions, monitoring leads, etc.
8 footplate to support the infant when the chamber is tilted up
9 compressible rubber strips below which leads, etc. can enter the chamber
10 tubing to the pressure monitor.

The neck seal

This is a piece of latex rubber with a circular hole 2–5 cm in diameter, situated near the bottom end. This is fitted around the infant's neck overlying the neck protector.

The neck protector

This is a piece of two or four thicknesses of ribbed cotton tubular stockinet. Two holes cut in the sides allow this to be fitted like a polo-necked vest over the infant.

The suction unit

This incorporates an electrical fan with a valve which provides variable levels of continuous suction. The valve is adjustable by a pressure control knob. A suction hose connects from the suction unit to the base of the chamber.

The pressure monitor

This can be a simple calibrated U-tube containing coloured alcohol or other fluid, **or** a more sophisticated pressure monitor.

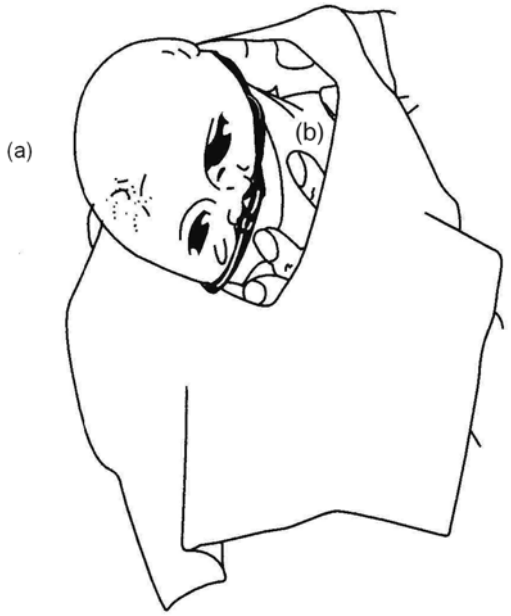


FIGURE 8.3.6 (a) Neck seal. (b) Neck protector. The neck seal is a piece of stretchy latex rubber with a circular hole 2–5 cm in diameter, which is stretched and fitted around the infant's neck, overlying the neck protector.

Safety

1 Special care must be taken not to trap the fingers or toes when closing the lid.
2 To avoid damaging the monitor leads, these must pass either (1) through the diaphragm at the base of the chamber, or (2) between a rubber strip at the foot end of the chamber and a second rubber strip on the lower edge of the lid. The monitor leads will be damaged and pressure lost if they are brought out through the sides of the chamber between the unprotected Perspex edge of the lid and the rubber seal on the base.

Care of infants who are receiving CNEP

Feeding

While receiving negative pressure, the patient would not usually be fed orally. Feeds should be given via a nasogastric tube, and this tube should be clamped off when not in use. Do not leave the tube open to air or the stomach may become distended.

If the baby develops problems with abdominal distension, the stomach should not be left on free drainage in the conventional way. Either frequent aspiration of the stomach contents should be performed, with the tube clamped off in the intervening time, or the end of the tube can be put through the neck seal (in between the silicone gel and the vest) and the tube left on free drainage inside the chamber.

If the baby's clinical condition allows this, they may be taken out of the chamber at regular intervals for breastfeeding or cup feeds.

Procedures

Most procedures, such as re-siting of an IV line, can be performed while the infant is receiving negative pressure.

When the arms are inserted through the portholes, subatmospheric pressure can be maintained by the close-fitting cuffs around the forearms.

Excessive body movement may occur during sudden loss of negative pressure when the porthole is opened or the arm removed from the cuff. This may be quite disruptive to the baby. Therefore it is preferable to minimise the number of times this occurs by taking into the chamber all the items which are needed for the procedure. When the cuffs or gaskets become soiled or torn, they must be replaced immediately.

Neck care

Pay particular attention to the patient's neck, observing it for soreness frequently, at 6- to 8-hourly intervals if possible when the patient is turned. It is important to ensure that all the layers of the neck seal are in place and that the latex does not come into contact with the baby's skin. It is not necessary to replace the neck seal components unless they are soiled or damaged. If they are in place for a prolonged period, especially in the case of a newborn preterm baby whose skin may scale and shed, it is probably better to wash and dry the neck at regular intervals when the clinical condition allows, preventing colonisation by skin commensal bacteria.

It is also important to frequently check the neck to ensure that the latex does not become too tight if the baby becomes oedematous. If this happens it is important to replace the latex with a larger size.

Controlling body temperature

The important principle to follow in the control of body temperature of babies who are receiving negative pressure is the prevention of hypothermia, rather than its treatment. Due to convective and radiant heat loss the baby is much more likely to cool rapidly and be more difficult to warm up than in the conventional incubators.

Plastic sheeting or bubble wrap may be placed over the infant's body to create a 'micro-environment'.

An overhead radiant heater may be used as an additional heat source over the headbox or chamber.

Management of problems that may arise

Inadequate pressure

- Excess leak at neck:
  - Slacken the latex into the arch in the lid.
  - Move the baby upwards.
  - Reposition the latex.
  - Double the thickness of stockinet collar under the latex.
  - Use latex with a smaller hole (if a large leak is present).
- Excess leak between chamber and base of chamber:
  - Tighten the quick-release lid and base catches.
  - Replace the rubber strip gasket around the chamber base.
- Excess leak at the portholes:
  - Renew the cuffs or foam gaskets.
  - Tighten or secure the iris diaphragm porthole.
- Inadequate suction pressure:
  - Check that the hose is plugged in at both ends.
  - Check that the access hole for suction inside the chamber is not blocked (e.g. by the sheet).
  - Check the pressure achieved by the suction unit after directly occluding the hose at the end.

Unsettled baby

- Baby breathing too hard:
  - There may be an inadequate negative pressure.
  - Check for upper airway obstruction.
  - Check for stridor, tracheal tug and carbon dioxide retention.
  - A different method of respiratory support may be needed.
- Anxiety:
  - Give reassurance and/or sedation to make the baby comfortable.
- Sore neck:
  - Check the neck and treat sore areas to relieve discomfort.

Abdominal distension

- Air swallowing:
  - Close the nasogastric tube.
  - Undertake more frequent suction or free drainage inside the chamber.

Cold baby

- Excess leak:
  - See the section on 'Inadequate pressure'.
- Cold environment:
  - Provide an overhead heater.
  - Humidify the chamber.
  - See the guidelines on temperature.

Problem: neck soreness

- Pressure or contact allergy:
  - Ensure that at the neck seal there is at least a fourfold thickness of stockinet between the latex and the skin.
  - If the latex is stretched too tightly, the baby may be suspended at the neck. Release and pleat it as described above.
  - The hole in the latex may be too small, so revise it if necessary.

Inadequate oxygen in the headbox

- Excess leak at the neck:
  - See the section on 'Inadequate pressure'.
- Inadequate oxygen:
  - Seal the top and sides of the headbox (e.g. with cling film).
  - Adjust the flow and/or concentration.
  - Two supplies of high-flow humidified 100% oxygen may be needed to provide a high concentration in the headbox.

Physiotherapy for suppurative lung diseases

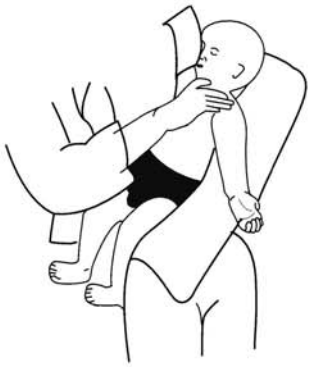
Therapy for bronchiectasis, cystic fibrosis and other conditions with excess airway secretions is described here.

Postural drainage

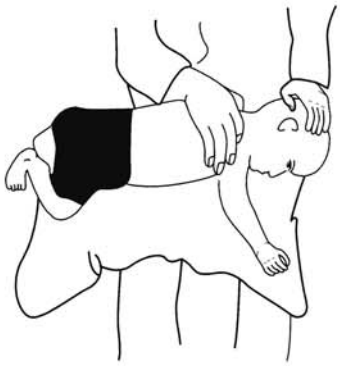
This is positioning to allow drainage by gravity from lung segments to central airways.

For infants, use a maximum of five positions in 10 minutes, progressing in older children to two to three positions in up to 30 minutes.

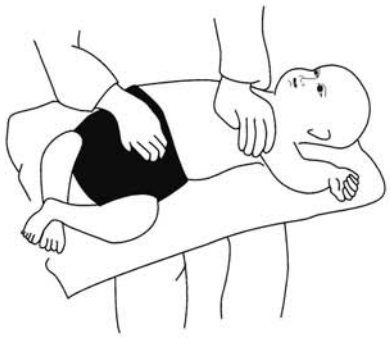
1 Apical segments upper lobes



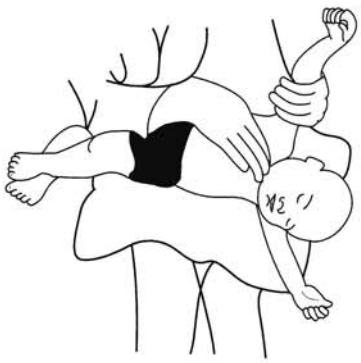
2 Posterior segment right upper lobe (reverse for left)



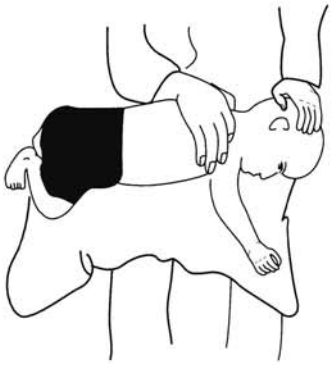
3 Anterior segments upper lobes



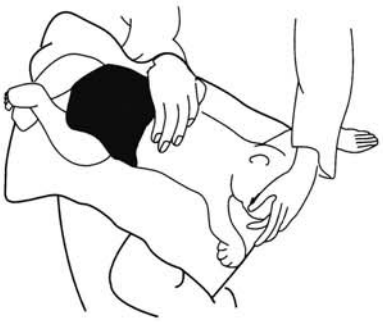
4 Right middle lobe (reverse for left)



5 Apical segments of lower lobes



6 Anterior segments of lower lobes



7 Posterior segments of lower lobes

8 Lateral segments of right lower lobes (reverse for left)

FIGURE 8.3.7 Positions for postural drainage.

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).

Figure 8.3.7 shows all of these positions in sequence.

Equipment
Carer's lap (in the case of an infant), otherwise bean bags, pillows or a tilted bed.

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.

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).

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, flucloxacillin, fluconazole, 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.
   - If there is no background infusion, give sufficient follow-up (flush) of fluid (0.9% saline, sterile water or 5% glucose) to ensure that the drug does not remain in the cannula or T-piece. Give the flush over 2 minutes to avoid a sudden surge of drug (remember the hub).
   - If the IV drug needs to be given rapidly (e.g. adenosine), do this by administering a 2-mL bolus of 0.9% saline via a second syringe, not by temporarily increasing the infusion rate (sometimes the temporary increase becomes prolonged and dangerous).
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.

- Ideally, arterial lines should be connected to a pressure transducer and alarm.

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).
   - 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.
   - For blood culture, always use a separate fresh venous 'needle stab' sample.
2 Never add anything to a line carrying total parenteral nutrition (TPN).
3 Certain infusions, such as glucose > 10%, adrenaline and dopamine, are better given through a central vein. **In an emergency, dopamine and adrenaline infusions can be given through a peripheral vein.**
4 If a continuous infusion is not required, a peripheral cannula can be stopped off with a sterile bung after flushing the drug in with 0.9% saline, sterile water or 5% glucose to clear the dead space (there is no evidence that a heparin lock is needed for a cannula in peripheral veins).
5 Central venous catheters must be firmly anchored to the skin so they do not migrate into or out of position.
   - 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).
6 Peripheral artery lines should never be used for giving drugs.
   - To maintain patency, a continuous low-rate (0.5–1.0 mL/hour) infusion of heparinised 0.9% or 0.18% saline is useful (heparin at 1 unit/mL). Clear the 1-mL dead space of the catheter before and after sampling, which must be done aseptically.
7 In neonates and infants, frequent flushing with saline 0.9% can result in sodium overload. Therefore consider using 0.18% saline or sterile water to achieve flushing.
8 Central arterial lines (usually in the aorta) can be safely used to give glucose or total parenteral nutrition if the catheter tip site is checked radiologically (not near mesenteric or renal arteries). Most drugs (except inotropes) can also be safely given by this route by slow infusion (not by boluses).
9 Do not add drugs to any line containing blood or blood products.
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).
12 When two IV drugs need to be given together and there is only one IV catheter, terminal co-infusion using a T- or Y-connector next to the catheter can be used. It is important to know whether this is safe for the drugs in question.

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 box.
  - 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** .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.

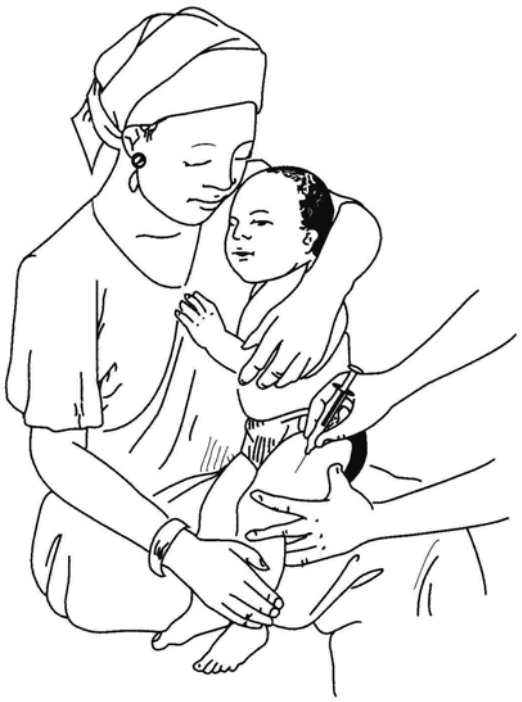


FIGURE 8.4.A.1 Holding a child for an intramuscular injection in the thigh.

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.

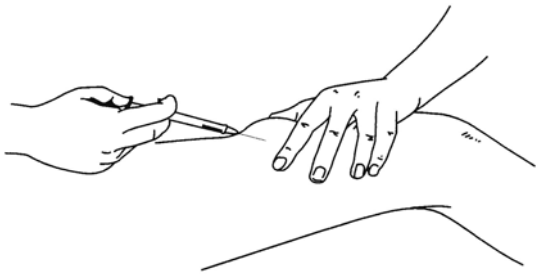


FIGURE 8.4.A.2 Giving a subcutaneous injection.

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.

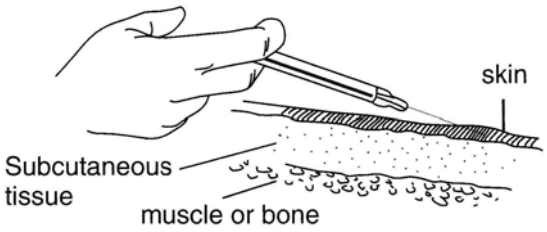


FIGURE 8.4.A.3 Giving an intradermal injection.

8.4.B Gaining circulatory access

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)
- cannula size:

neonates:	24–25G
infants:	22–24G
children:	20–22G
adolescents:	18–20G.

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.
- Clean the skin with antiseptic.
- Fix and slightly stretch the skin with your other hand.
- Pass the cannula through the skin at a slight angle (10–20 degrees). **Be decisive.**
- Stop once you are through the skin.
- Flatten the cannula to the skin and advance with the long axis of the cannula in the same direction as the vein. **Be decisive.**
- Aim to pass it into the vein at the first attempt with steady advancement.
- Always watch for blood appearing in the hub of the cannula.
- As soon as blood is seen, stop.
- Hold the needle still, and advance the cannula over the needle until the hub is at the skin.
- Hold the cannula still.
- Withdraw the needle.
- 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.

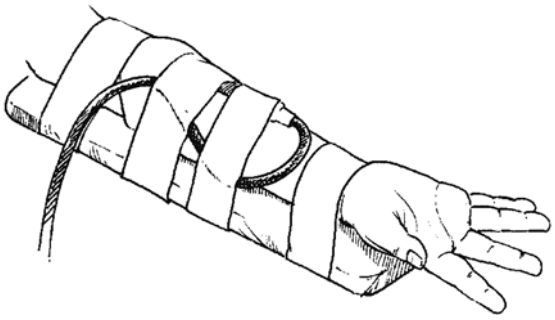


FIGURE 8.4.B.2 Arm splinted to prevent bending of the wrist.

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 septicaemia. 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 spurting of blood, withdraw the needle and apply pressure until the bleeding stops. Then look for a vein.**

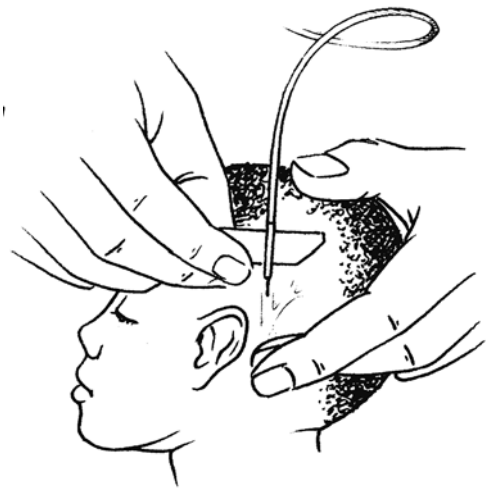


FIGURE 8.4.B.3 Inserting a scalp vein needle.

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!

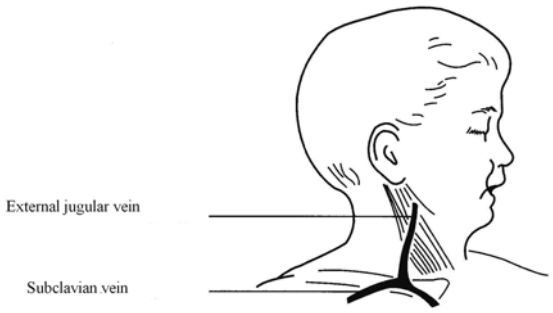


FIGURE 8.4.B.4 Position of the external jugular vein.

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).

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).

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.

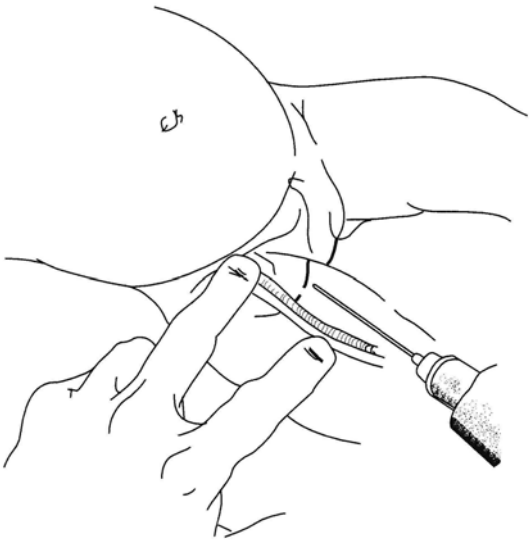


FIGURE 8.4.B.5 Femoral vein cannulation.

If you are unsure whether you are in a vein or an artery, consider transducing the pressure waveform.

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.

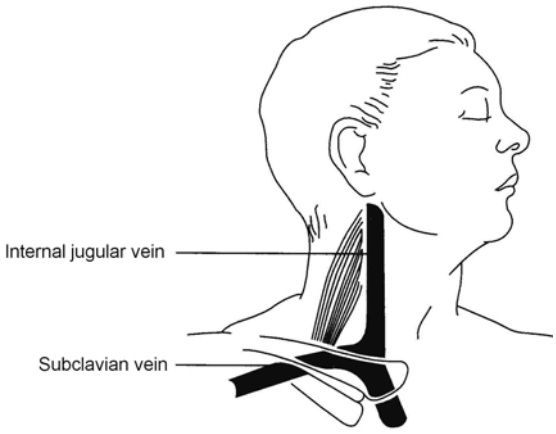


FIGURE 8.4.B.6 Position of the internal jugular and subclavian veins.

Subclavian vein

1 Place the patient in a supine position, turn the head to the contralateral side, position a roll to extend the neck a little, and identify the midpoint of the clavicle.
2 Aim for the suprasternal notch, and pass the needle just beneath the clavicle at the midpoint. The vein lies anterior to the subclavian artery and is closest at the medial end of the clavicle.
3 Subclavian artery puncture is not uncommon (it is not

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
- septicaemia 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.

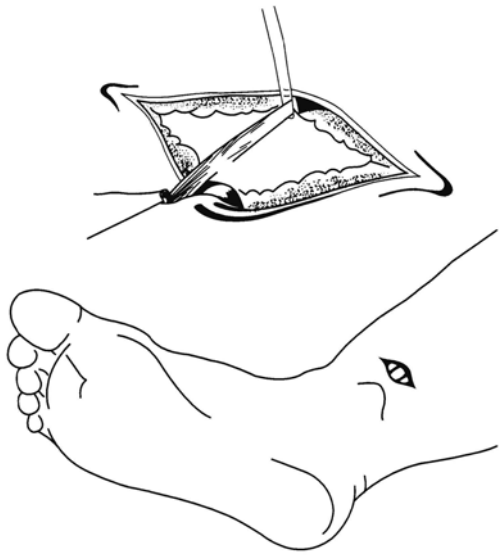


FIGURE 8.4.B.7 Cut-down incision showing vein: position of cut-down on long saphenous vein at ankle.

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.

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.

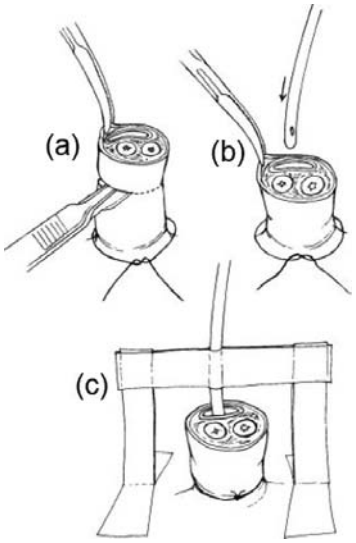


FIGURE 8.4.B.8 Insertion and securing of a catheter in the umbilical vein. (a) Preparation of the umbilical cord. (b) Inserting the catheter into the umbilical vein, which is the larger thin-walled structure towards the head. Note the two umbilical arteries, which are thick-walled and towards the legs of the baby. (c) Securing the inserted catheter to prevent kinking.

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.

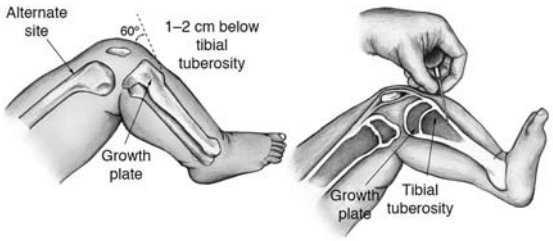


FIGURE 8.4.B.9 (a) Intra-osseous needle tibial site (X). (b) Section through bone. Image reprinted with permission from Medscape Reference (http://emedicine.medscape.com/), 2014, available at: http://emedicine.medscape.com/article/940993-overview.

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.) Clean the skin over and surrounding the site with an antiseptic solution.
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

- 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.

Unfortunately the disposable needles are extremely and prohibitively expensive for low resource settings.

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

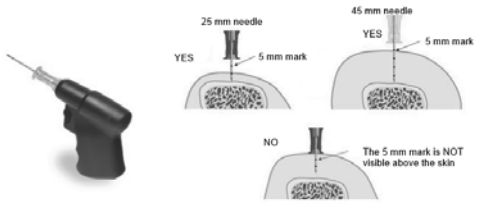


FIGURE 8.4.B.10 EZ-IO power drill and needles.

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.

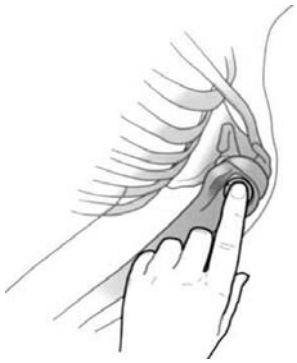


FIGURE 8.4.B.11 Site for EZ-IO needle in the proximal humerus in an adult or large child.

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 40 kg and over 40 kg.

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 5 mm 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.

   If the driver stalls and will not penetrate the bone you may be applying too much downward pressure.

   If the driver fails (this is rare) remove it, grasp the needle kit by hand and twist it into the bone marrow.
8 Remove the drill and unscrew the trochar.
9 Aspirate the bone marrow if possible directly from the needle.
10 Attach the pre-prepared connection tube containing sterile Ringer-lactate or Hartmann's solution or 0.9% saline before any infusion is given.

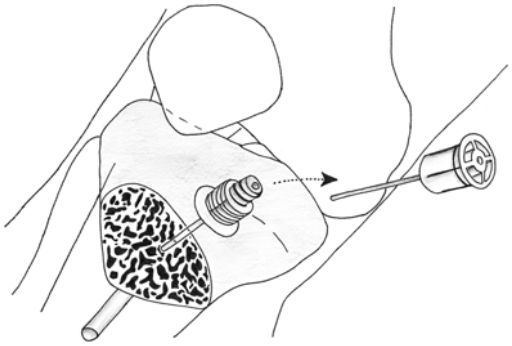


FIGURE 8.4.B.12 EZ-IO needle in place, with stylet removed.

   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 pericardiotomy. **Pericardial aspiration may not work well for viscous fluids (e.g. clotted blood) in the pericardial sac.**

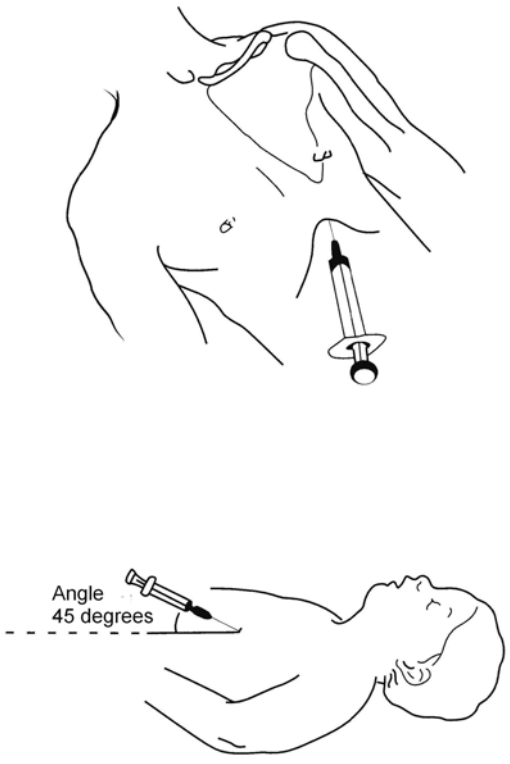


FIGURE 8.4.B.13 Position for insertion of needle in pericardiocentesis. The pericardiocentesis needle is inserted as close to the sternum as possible in order to avoid the internal mammary artery.

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 10 kg). 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

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

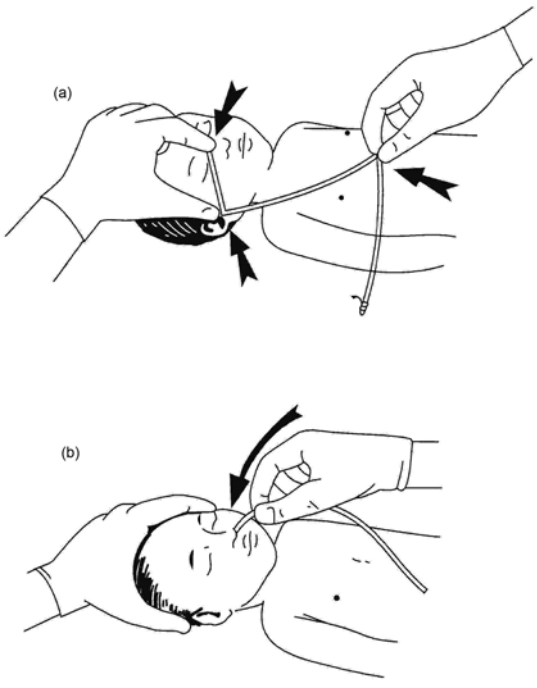


FIGURE 8.5.1 Inserting a nasogastric tube. (a) The distance from the nose to the ear and then to the epigastrium is measured. (b) The tube is then inserted to the measured distance.

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

paper (the pH should be 5.5 or less, or the litmus paper should change colour from blue to pink), or flush the tube with 2–3 mL of air (only 1 mL in the neonate) and listen over the stomach area with the stethoscope. If in doubt, X-ray the chest and/or abdomen. (Note that the acidity of the gastric fluid may be reduced in preterm infants.)

5 If there is any doubt about the location of the tube, withdraw it and start again. Withdraw immediately if the child starts coughing, as the tube may then be in the airway.
6 Secure the tube by taping it to the cheek, and record the length of tube outside the nose or mouth.
7 When the tube is in place, fix a 50-mL syringe (without the plunger) to the end of the tube, and pour food or fluid into the syringe, allowing it to flow by gravity.

The nasal route is more comfortable and secure, but if the infant has respiratory distress or is receiving CPAP, an orogastric tube is best (if passed through the nose the tube increases upper airway resistance).

Never pass a nasogastric tube in a head-injured patient. An orogastric tube is safe. If there is a base-of-skull fracture, a nasal tube could be pushed into brain tissue.

Cervical spine immobilisation

All patients with major trauma should have full spinal stabilisation if feasible from the moment of injury, and should be treated as if they have a cervical spine injury until proven otherwise. Immobilisation can be achieved:

- by holding the head still and in line (manual in-line immobilisation)
- **or** by applying a semi-rigid collar (which has been correctly fitted), sandbags on either side of the head, and tape across the forehead and the chin piece of the collar to prevent the head from being lifted upward from the bed.

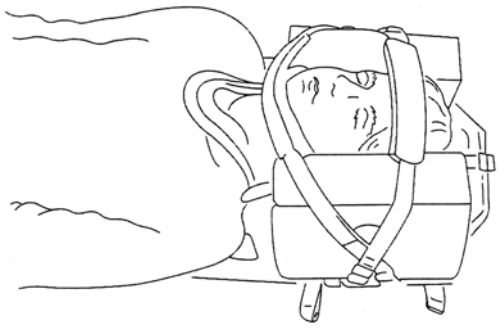


FIGURE 8.5.2 Immobilisation of the cervical spine using head blocks and straps with a cervical collar in place.

Exceptions

Two groups of patients may prove to be difficult:

- the frightened uncooperative child (most common)
- the hypoxic combative patient.

In both of these cases, over-enthusiastic efforts to immobilise the neck may increase the risk of spinal injury as the patient struggles to escape. The area of greatest mobility in the cervical spine is the C7/T1 junction, and this is at increased risk in the combative patient.

It is best to try to apply just a collar and then address the patient's other clinical needs (*see* Section 7.3).

Log roll

When examining the back of the patient with major injury, it is important to minimise the risk associated with unrecognised spinal injury. It is essential to examine the back of the patient at the end of the primary survey (or even during it if there is suspicion of serious injury to the back of the chest or abdomen).

The aim of the log roll is to maintain the orientation of the spine during turning of the patient. It requires four people for a mother or child and three for an infant. In addition, one person is required for the examination of injuries.

TABLE 8.5.1 Position of staff for log roll

	Position of staff for log roll	
Staff number	**Infant or small child**	**Larger child or mother**
1	Examination of back	Examination of back
2	Stabilisation of head and neck – in charge of the procedure	Stabilisation of head and neck – in charge of the procedure
3	Chest	Chest
4	Pelvis and legs	Pelvis
5		Legs

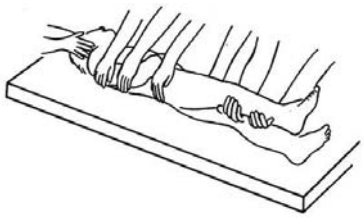


FIGURE 8.5.3 Log rolling a child.

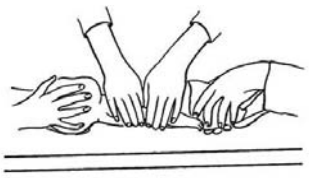


FIGURE 8.5.4 Log rolling an infant.

Incision and drainage of abscess

Indications

- The collection of localised infection.
- If there is uncertainty whether a hot red mass is an abscess, aspirate for pus before proceeding to incision and drainage.
- Multiple/recurrent abscesses may be associated with HIV, TB, malnutrition, diabetes mellitus, anaemia or foreign bodies.

Preparation of kit

The following equipment is needed:

- skin preparation materials
- scalpel
- microbiology swab
- curette
- sterile gauze.

Procedure

1 If the patient is systemically unwell, take blood cultures (before giving antibiotics).
2 Antibiotics are only indicated if the patient is systemically unwell or if spreading cellulitis is present.
3 Use general anaesthesia for certain sites (perianal, breast, cervical, etc.). Regional blocks may be used for limbs in older children. (Note that local infiltration produces poor anaesthesia in inflamed tissue.)
4 Clean the skin.
5 Incise over the most superficial tender point in the direction of skin creases. Take a sample of pus for culture and staining, including the Ziehl–Neelsen stain if indicated. **The commonest error is to make the incision too small.**
6 Insert a curette spoon or finger to break down any loculi. Send a sample of the wall of the abscess for TB if indicated.
7 Irrigate the cavity with 0.9% saline to flush out necrotic material.
8 If a large cavity exists, loosely pack it with sterile gauze. For a small cavity place a 'wick' (e.g. a piece of rolled gauze) into the wound, forming a track. Cover the wound loosely with absorbent dressing. Change the gauze packing after 24 hours, giving analgesia beforehand if needed. Remove the wick after 48 hours.
9 As the cavity discharges pus it should heal from a depth to superficially through the open skin incision.

Abdominal paracentesis

Indications

- To detect intra-abdominal injury after blunt trauma in the haemodynamically unstable child in the absence of CT or ultrasound scanning facilities. **Haemodynamic instability after penetrating trauma always requires a laparotomy.**
- To identify peritonitis.
- To identify ruptured bowel.

Preparation of kit

The following equipment is needed:

- local anaesthetic (ideally with adrenaline)
- sterile drapes
- over-needle catheter, 16- to 20-gauge
- 20-mL syringe
- warmed normal saline and infusion set
- urinary catheter and nasogastric tube
- skin prep (iodine/alcohol).

Procedure

1 The procedure must be sterile.
2 Decompress the bladder and stomach with a urinary catheter and nasogastric tube.
3 Prepare the abdomen (from the costal margin to the pubis). Drape the area with sterile towels, exposing the peri-umbilical region.
4 If the patient is conscious, infiltrate local anaesthetic in the midline (a third of the distance between the umbilicus and the pubis). If pelvic trauma is suspected, infiltrate above the umbilicus.
5 Insert the catheter over needle. Remove the needle and aspirate.
6 If more than 10 mL of fresh blood **or** turbid or bile-stained fluid **or** faeces **or** food debris are present in the aspirate, there is a serious problem, possibly indicating the need for a laparotomy.
7 If none of the above abnormalities are seen on aspiration, instil 10 mL/kg of warm sterile normal saline into the abdomen and allow 5 minutes for it to circulate. Then retrieve the fluid.

Interpreting the results of analysis of the retrieved fluid

Abnormal findings include the following:

- red blood cell count (unspun) > 100 000/mL: may need laparotomy if unstable
- white blood cell count (unspun) > 500/mL
- bile staining
- faeces
- Gram stain/microscopy positive.

If laparotomy is indicated, withdraw the catheter and cover the wound with a sterile dressing. Then transfer the patient to theatre.

Lumbar puncture

Preparation of kit

The following equipment is needed:

- iodine
- sterile gloves
- sterile dressings pack
- spinal needle with stylet
- collodion
- small adhesive dressing
- local anaesthetic
- sedation (in some cases).

Indications

- As part of septic screen in case meningitis is present.
- For investigating the possible cause of seizures.
- For investigating the possible cause of apnoeic episodes due to meningitis.
- As therapy in post-haemorrhagic hydrocephalus.
- For administration of drugs in leukaemia.

Contraindications

- Signs of raised intracranial pressure, such as deep coma (P or U on the AVPU scale), unequal pupils, rigid posture or paralysis in any of the limbs or the trunk, or irregular breathing.
- Skin infection in the area through which the needle will have to pass.
- Significant bleeding disorder.

If contraindications are present, the potential value of the information gained from a lumbar puncture should be carefully weighed against the risk of the procedure. If in doubt, it

might be better to start treatment for suspected meningitis, and delay performing a lumbar puncture.

Precautions

- Do not perform a lumbar puncture in the very sick patient (it may precipitate apnoea in an infant and shock in an older child).
- Excessive neck flexion when positioning can lead to hypoxaemia and acute respiratory deterioration.
- If a spinal needle is unavailable and a normal (non-stylet) needle is used, the needle bore may become blocked with skin on insertion and therefore obstruct flow. There is also the risk of tissue implantation leading to a dermoid cyst.

Procedure

There are two possible positions:

- the child lying down on the left side (particularly for young infants)
- the child in the sitting position (particularly for older children).

FIGURE 8.5.5 Holding a child lying on their left side for a lumbar puncture. Note that the spine is curved to open up the spaces between the vertebrae.

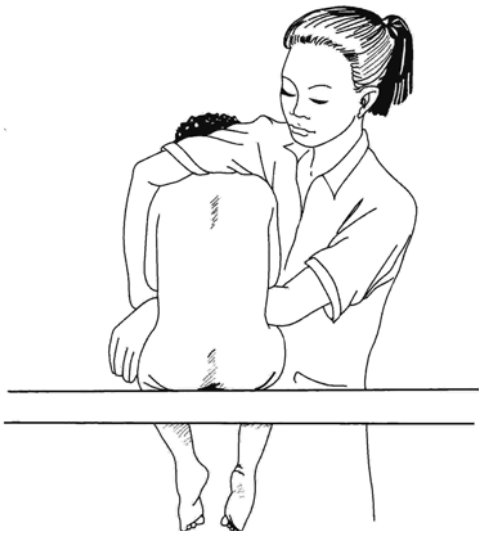


FIGURE 8.5.6 Restraining an older child in a sitting position for a lumbar puncture.

When the child is lying on their side a hard surface should be used. Place the child on their side so that the vertebral column is parallel to this surface and the transverse axis of the back is vertical (*see* Figure 8.5.5).

It is helpful to have an experienced assistant present to hold the patient. Flex the spine maximally, but avoid excessive neck flexion. Make sure that the airway is not obstructed and the child can breathe normally. Take particular care when holding young infants. The assistant should not hold a young infant by the neck or flex the neck to avoid airway obstruction.

Prepare the site

- Use aseptic technique. Scrub your hands and wear sterile gloves.
- Prepare the skin around the site with an antiseptic solution.
- Sterile towels may be used.
- In older children who are alert, give a local anaesthetic (1% lignocaine) infiltrated in the skin and subcutaneous tissue over the site.

Identify site of insertion

Locate the space between the third and fourth lumbar vertebrae or between the fourth and fifth lumbar vertebrae. (The third lumbar vertebra is at the junction of the line between the iliac crests and the vertebral column.)

Use an LP needle with a stylet (22 gauge for a young infant, and 20 gauge for an older infant and child; if these are not available, routine hypodermic needles may be used). Insert the needle into the middle of the inter-vertebral space and aim the needle towards the umbilicus.

Advance the needle slowly. The needle will pass easily until it encounters the ligament between the vertebral processes. More pressure is needed to penetrate this ligament, and less resistance is felt as the dura is penetrated. In young infants this decrease in resistance is not always felt, so advance the needle very carefully.

Stop advancing when a 'give' or puncture sensation is felt on entering the subarachnoid space (this is often not felt in neonates). Frequent stylet withdrawals during the procedure should be undertaken to see if the CSF flows, indicating that the subarachnoid space has been successfully entered. The subarachnoid space is only 0.5–0.7 cm below the skin in premature infants and 1 cm below it in term infants, so it is easy to over-penetrate by mistake. Over-penetration leads to puncturing of the anterior vertebral venous plexus and a bloody sample, so that CSF microscopy is less informative or perhaps impossible. The needle should be withdrawn and the procedure repeated in another disc space.

Withdraw the stylet. Obtain a sample of 0.5–1 mL of CSF and place it in sterile containers, allowing six drops of CSF to drip into each sample container.

Replace the stylet.

Withdraw the needle and stylet completely and apply pressure to the site for a few seconds. Put a sterile dressing over the needle puncture site, and cover the whole site with adhesive dressing.

Send samples for the following:

1 microscopy, cell type and counts, Gram and Ziehl-Neelson staining, culture and sensitivity (including for TB) and virology.
2 biochemistry (glucose, protein).

Suprapubic aspiration of urine

Indications

Usually in sick infants where urgent diagnosis is required and there is a palpable bladder that does not respond to manual expression for a clean catch.

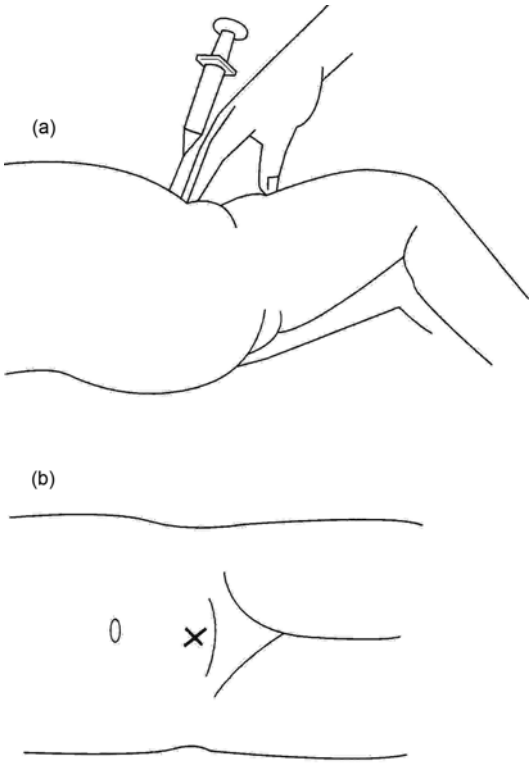


FIGURE 8.5.7 Position for carrying out suprapubic aspiration of urine in an infant. (a) Side view. (b) Abdominal view. Note the angle of insertion of the needle.

Procedure

Use a sterile technique throughout. Advance a 23- to 24-gauge needle attached to a syringe to a depth of 3 cm in the midline at the proximal transverse crease above the pubis. Withdraw the urine into a sterile syringe and transfer it to a sterile urine container,

Do this only in a child with a bladder containing sufficient urine, which can be demonstrated by percussion. Do not use urine bags to collect urine, as the specimens may become contaminated.

Have a clean urine jar ready in case the child passes urine during the procedure.

Microscopy of urine

- Urinary tract infections (UT1s) are common in children.
- Although many of these infections are not serious, some of them cause kidney damage and lead to scarring.
- Kidney scars can lead to high blood pressure, and to kidney failure later in life.
- A child with a UTI can develop kidney damage very fast, in just a few days. The only way to prevent this is to make the diagnosis and treat it at once.
- Urine microscopy is the only way to diagnose UTIs immediately and reliably.

In a patient with a UTI the urine contains:

- one species of **bacterium** at a concentration of at least 100 000/mL
- an excess of **white blood cells**.

Bacterial numbers

Most children with a UTI have in the range of 10–1000 million bacteria/mL. In fact, 100 000/mL is a very small number of bacteria. When urine is collected from children, it often becomes contaminated with a very small number of bacteria, and these are often of just one species. This means that if you rely on laboratory culture to make the diagnosis of UTI, you are likely to have many false-positives, perhaps one for every genuine case. Remember that every child diagnosed as having a UTI in this way will undergo investigations, sometimes including invasive procedures.

White blood cells

Children frequently have extra urinary white blood cells without a UTI.

- Around 10% of febrile children have hundreds of extra white blood cells.
- Girls void some urine into the vagina, so vaginal white blood cells are readily washed into the urine (as are vaginal epithelial cells, which are seen in the urine of most girls after puberty).

Children with UTIs often have no excess of white blood cells.

- White blood cells do not last long in urine, especially if it is alkaline, so it must be examined soon after collection.
- Ill infants may be unable to mount a white blood cell response.

Therefore white blood cells alone are an unreliable and potentially misleading sign.

How to count bacteria

Laboratory culture

This is the most widely used method, and the traditional approach. It remains acceptable, but if you use it you will:

- **have to accept that some positive reports will be false**
- **have to wait at least 48 hours for the result**. In real life, it is often several days or a week before a positive lab report reaches the doctor, and treatment starts. Remember that kidney damage can become permanent within 3 days
- **have to recall patients a few days later if the culture grows a mixture of bacteria**. This is usually caused by the contamination of urine as it is collected, and is common. It must be repeated in case a UTI was present as well
- **miss the occasional UTI caused by anaerobes.**

Advantages of urine microscopy

If you use this method you can:

- discard sterile urines, and reassure the child's family at once
- repeat a contaminated urine sample at once
- treat children with UTIs immediately
- diagnose anaerobic UTIs as easily as aerobic ones
- save time and money because it is quicker and cheaper than urine culture.

Choice of microscope

With an ordinary **light microscope**, bacteria are only easy to see after they have been stained.

Phase-contrast microscopes enable you to see unstained bacteria very easily, just using a drop of fresh urine on a glass slide. They look and work exactly the same as ordinary light microscopes, except that the lens (objective) and the condenser (underneath) are specially modified.

How to do urine microscopy

You can microscope fresh urine on a slide with a counting chamber. There is no need to stain or spin the urine.

The slide has two chambers, each of which has a grid etched on to the glass surface. In certain clinical situations, such as examination of peritoneal dialysis fluid for suspected peritonitis, the grid can be used to make accurate counts of the concentrations of elements present.

Usually this degree of accuracy is unnecessary. However, the grid is always useful because it confirms that the microscope is focused on the urine. If you examine a specimen with no cells or bacteria on a plain slide it is impossible to be certain otherwise.

Clean the slide and a coverslip with a tissue. Breathe over the slide to create a 'mist' on it, and quickly push the coverslip into place. This creates a chamber 0.1 mm deep with a grid etched on the bottom (*see* Figure 8.5.8).

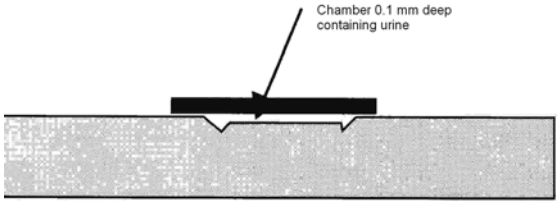


FIGURE 8.5.8 Side view of grid slide with coverslip in place.

Test the urine with a dipstick (to check for blood, protein and glucose). Then touch the tip of the dipstick on the slide so that a small amount of urine is drawn into the chamber by capillary action.

Bacteria

- Most bacteria that cause UTIs are bacilli (**rod-shaped**).
- They are easy to identify, as they look like straight lines, usually about 3 mm long.
- Mostly they remain still, or just move slightly, like a shimmer. This movement is caused by Brownian motion (which occurs when they are hit by water molecules), and is not due to them swimming.
- Rarely will you see moving bacteria.

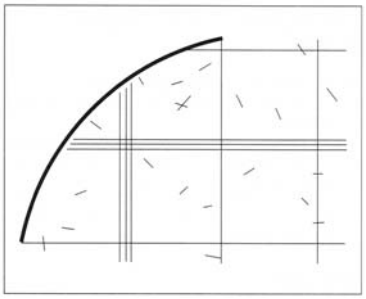


FIGURE 8.5.9 Rod-shaped bacteria.

Infections also sometimes occur with streptococci, which are bacteria that resemble strings of beads. There are always some strings that are four or more cocci long. If you think that you can see 'cocci' individually, or in clumps, these are in fact phosphate crystals. If they appear to be moving, this is just the result of Brownian motion.

White blood cells

These are round, and between 3 and 5 mm in diameter. All white blood cells have a 'granular' appearance to their cytoplasm. In the case of the larger ones you can often make out the individual granules shimmering and moving within the cell, and the nucleus (which is lobed in neutrophils).

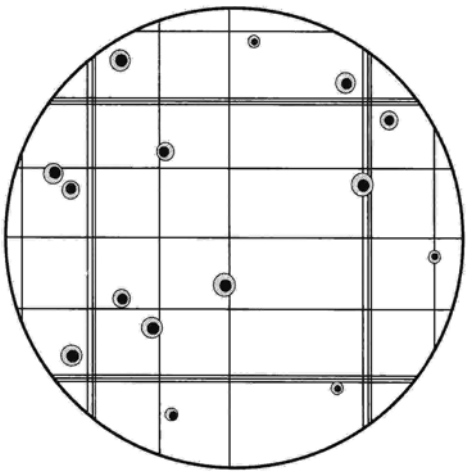


FIGURE 8.5.10 White blood cells.

Red blood cells

These are smaller than white blood cells, and do not have any content or granular appearance.

If the red cells are present because of trauma (e.g. after an injury, or post surgery) or a UTI, they will either look just like red cells in the blood (i.e. biconcave discs), or they will all appear slightly shrunken and wrinkled, or slightly swollen. The important thing is that they all look the same.

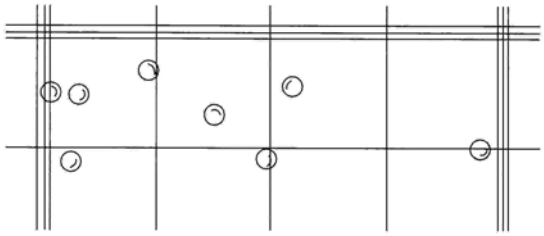


FIGURE 8.5.11 Red blood cells.

If the red blood cells are in the urine because of kidney inflammation (glomerulonephritis), they are usually smaller, but they are also all different shapes. This is probably because they get damaged as they pass down the tubules of the kidney. Sometimes the red cells are very bizarre shapes. They are referred to as 'glomerular' red cells.

Epithelial cells

These are very large flat cells with an easily visible round nucleus. They are from the vagina, and are only seen in the

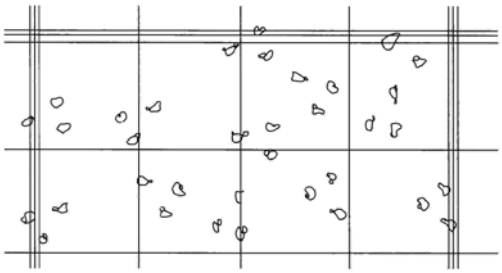


FIGURE 8.5.12 Glomerular red blood cells.

urine of older girls, in which they are common. If large numbers of epithelial cells are present this suggests particularly heavy vaginal contamination.

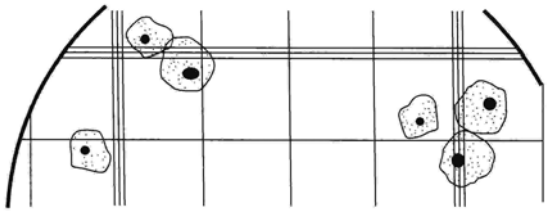


FIGURE 8.5.13 Epithelial cells.

Casts

These indicate kidney inflammation (glomerulonephritis). Casts consist of abnormal kidney tubule contents that have solidified and have retained the shape of the tubule as they passed into the urine.

Pure protein casts look glass-like, and are described as hyaline. Those consisting of debris (e.g. dead tubule cells in acute tubular necrosis) are called granular casts. Some casts are composed of red or white cells. Many casts consist of a mixture of these.

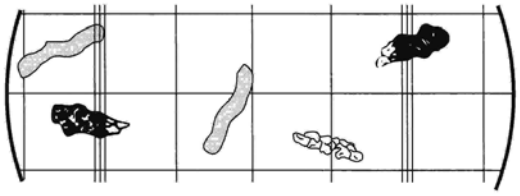


FIGURE 8.5.14 Casts.

Debris

Contaminated urine samples often contain a variety of debris. Some elements have an obvious origin, such as cotton fibres, but others cannot be identified.

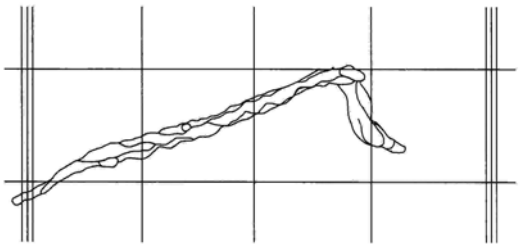


FIGURE 8.5.15 Debris.

Crystals

Urine samples often contain obvious crystals, whose shape allows their chemical origin to be identified. However, this is rarely of clinical significance.

The commonest 'crystals' in fact look more like small black dots, either singly, or in clumps (and even in casts). They move slightly (or 'shimmer') as a result of Brownian motion, and can be mistaken by the unwary for small round bacteria (cocci).

FIGURE 8.5.16 Crystals.

Diagnosing urinary tract infections (UTIs)

UTIs are primarily diagnosed by looking for bacteria.

Infected urine

About 99% of urine infections are caused by rod-shaped bacteria known as **bacilli**.

In most UTIs, every field you view will have many bacteria (in some cases thousands), and they all look the same. Therefore when you see many bacteria in fresh urine, all with the same appearance, you can be sure that the child has a UTI.

If you see at least one rod, but less than 10 rods in the centre of the grid (square 5), you have to consider the possibility of contamination, so collect another sample to see whether the finding persists (and think about vaginal lactobacilli; see below).

What to do if you find a positive microscopy

You can start treatment immediately with an appropriate antibiotic. In addition, send the urine for culture with **direct sensitivities**.

The laboratory will grow the bacteria to confirm which species they are, and to test their sensitivity to a range of different antibiotics. Without direct sensitivity testing this takes 2 days, but with it you will usually obtain the result the next day.

Sterile urine

Most urine samples will be sterile. If you see **no bacteria** or cells, check by looking at five 'size-A' squares (i.e. about five fields).

If you see nothing in that area, then you can be certain that the urine is not infected.

Even if you can see other elements, if there are no bacteria, it is not a UTI. Remember that you will see white blood cells in the urine of many children with fever (e.g. due to tonsillitis or pneumonia). Also remember that many girls have white blood cells in their urine from the vagina (and often epithelial cells, too).

Contaminated urine

If you see any of the following, **collect a repeat sample**, as the first sample is likely to have been contaminated:

- more than one shape of bacterium

- some bacteria, but also a large amount of debris (e.g. cotton fibres or many epithelial cells)
- many bacteria in a urine sample that was collected several hours ago, or from a nappy that had been on the baby for several hours.

If necessary, you need to go on collecting repeat urine samples until one is either definitely sterile or definitely infected.

Vaginal contamination

Girls void some of their urine into the vagina, so normal female urine will contain vaginal washings. In young girls this makes little difference to the microscopy findings. In older girls it is normal to see some epithelial cells (*see* Figure 8.5.13).

Also, in many older girls lactobacilli are washed into the urine. These are long rods, up to 4 mm or more. It is unusual for there to be large numbers, but they can cause confusion with a UTI. If you are uncertain, ask the lab either to Gram stain them or to culture them. Unlike the bacteria that cause UTIs, lactobacilli are Gram-positive.

They do not grow in conventional UTI culture media, so the lab will report a sterile urine. If you want to be absolutely certain, ask the lab to culture the urine anaerobically.

Recording the results

Labels can be printed to stick on the clinical notes. This is important because negative urine samples will be discarded, and this will be the only record of the test.

A typical format is as follows:

URINE PHASE CONTRAST MICROSCOPY
Name: ……. Date: ……

MICRO – Bacteria: ……..
WBC: …….. RBC: …….
Casts, etc.: …….

STICKS – Protein: …… Blood: ……
Glucose: ……
Other:……

ACTION – (tick one of the three options)
Urine not infected: sample discarded
Urine contaminated: sample repeated
UTI: urine sent for culture and direct sensitivities, and antibiotics started

SIGN and PRINT NAME:…….

Counting what you see

- For most clinical purposes it is not necessary to count the exact concentration of cells or bacteria that you see, and estimates such as 'many' or 'few' are enough.
- Sometimes it is helpful to quantify the findings more carefully (e.g. to monitor the numbers of casts in a child with glomerulonephritis).
- Occasionally it is essential to count the exact numbers (e.g. the number of white blood cells is critical for the diagnosis and treatment of peritonitis in children on peritoneal dialysis from a dialysis sample).

Calculate all the counts per microlitre (μL). Count at least 10 of each element of interest. The number and size of the squares you need to count will therefore depend on the concentration of the elements in the urine.

Figure 8.5.17 shows the etched counting grid for microscopy.

- The central square ('3') is 1 × 1 mm.
- With the cover-slip on, the chamber is 0.1 mm deep, so the central square has a volume of 0.1 μL.
- Therefore the whole grid of nine similar squares has a total volume of 0.9 μL.
- Note that 1 microlitre is one-thousandth of a mL.
- Therefore a count of 100 000 bacteria/mL is equivalent to 100/μL, so a 'significant' culture in a urinary tract infection would mean at least 100 bacteria/μL, or 10 bacteria in the central square of the grid.

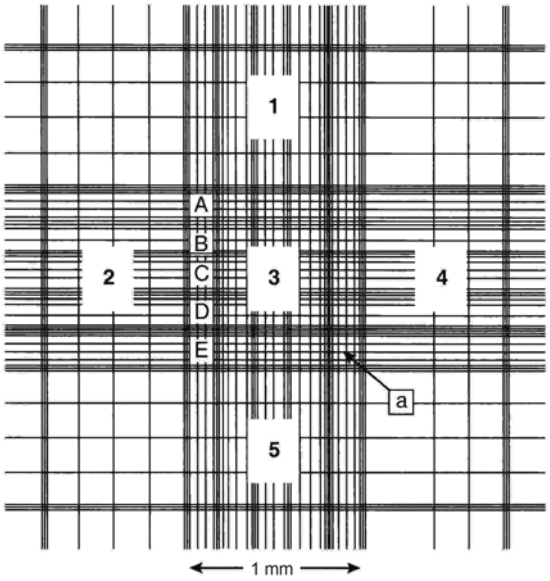


FIGURE 8.5.17 Counting grid for microscopy.

How to count

Very infrequent elements

Count all those in squares 1, 2, 3, 4 and 5, and multiply by 2.

Infrequent elements

Count all those in square 5, and multiply by 10.

Frequent elements

Count all those in five smaller squares (e.g. squares A, B, C, D and E), and multiply by 50.

Very frequent elements

Count all those in square A, and multiply by 250 (for ease of calculation, multiply by 1000 and divide by 4).

Overwhelmingly frequent elements (usually bacteria)

Count all those in one of the smallest squares and multiply by 4000.

Measuring blood glucose levels

Blood glucose levels can be measured with rapid diagnostic tests (e.g. Dextrostix, BM Stix) at the bedside, which provide an estimate of blood glucose concentration within a few minutes. There are several brands on the market, which differ slightly in how they should be used. Therefore

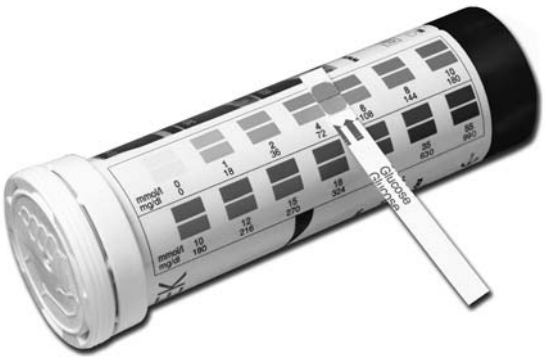


FIGURE 8.5.18 Blood glucose colour scale on side of bottle.

FIGURE 8.5.19 Electronic reading device for glucose strip. The strip is inserted into the side of the machine after the sample has been timed for the reaction to take place and the blood has been wiped off the strip.

it is important to read the instructions on the box and the package leaflet before using these tests.

Generally, a drop of blood is placed on the reagent strip and left for 30 seconds to 1 minute, depending on the brand of strip. The blood is then wiped off, and after another fixed period of time (e.g. a further 1 minute), the colour change on the reagent field of the strip is read. For this, the resulting colour is compared with a colour scale printed on the box. This allows the user to estimate the glucose level to be within a certain range (e.g. between 2 mmol/litre and 5 mmol/litre), but it does not provide exact values.

Some strips come with a battery-powered electronic reading machine. After the blood has been wiped off, the strip is inserted into the reading machine, which provides a more accurate value.

As the reagents deteriorate with exposure to ambient humidity, it is important that they are kept in a closed box, and that the box is closed immediately after a strip has been removed.

8.6 Assessing nutrition, growth and development

Measuring nutritional status

Calculating the child's weight for length

This is the most relevant measurement in nutritional assessment.

Measuring length

At ≤ 2 years

Ideally two people are needed to take this measurement, and the child should be supine on a flat surface.

The first person should:

- assist in positioning the child face up on the measuring board, supporting the head and placing it against the headboard
- position the crown of the head against the headboard, compressing the hair
- check that the child lies straight along the centre line of the board and is not slanted, and does not change position (it is usual for this person to stand or kneel behind the headboard).

The second person should:

- support the trunk as the child is positioned on the board
- lie the child flat along the board
- place one hand on the shins above the ankles or on the knees and press down firmly, and with the other hand place the foot-piece firmly against the heels
- measure the length (to the nearest 0.1 cm) and record it immediately.

The measuring board should be checked for accuracy every month.

At ≥ 3 years

- This measurement should be taken without the child wearing shoes.
- The child should stand with their heels and back in contact with an upright wall.
- The head is held to look straight forward with the lower eye sockets in line with the ears. The nose must not be tilted upward.
- A weighted block at right angles to the wall is then lowered on to the head and a scale fixed to the wall is read.
- During measurement the child should be asked to stretch their neck to be as tall as possible, but their heels must not leave the ground. The measurer should help to stretch the neck by firm pressure upward under the mastoid processes.
- Measure the height immediately to within 0.1 cm.

Measuring weight

At ≤ 2 years

- Leave a cloth in the weighing pan to prevent chilling of the child.
- Adjust the scales to zero with the cloth in the pan.
- Place the naked child gently on the cloth in the weighing pan.
- Wait for the child to settle and the weight to stabilise.
- Measure the weight (to the nearest 10 grams) and record it immediately.

Standardisation of the scales should be performed weekly or whenever the scales are moved.

At ≥ 3 years

- The child should be weighed naked or, if pants are worn, 0.1 kg should be subtracted from the weight measured.
- The bladder should be emptied before weighing.

Determining the child's percentage weight for length or SD weight for length

See Figure 8.6.1.

- Locate the row containing the child's length in the central column of the table.
- Look to the left in that row for boys, and to the right for girls.
- Note where the child's weight lies with respect to the weights recorded in this row.
- Select the weight closest to that of the child.
- Look up this column to read the weight for length of the child.

Note: Although the interpretation of a fixed percent-of-median value varies across age and height, and generally the two scales cannot be compared, the approximate percent-of-the median values for –1 SD and –2 SD are 90% and 80% of the median, respectively (*Bulletin of the World Health Organization*, 1994, **72**, 273–83).

Length is measured below 85 cm; height is measured at 85 cm or above. Recumbent length is on average 0.5 cm greater than standing height, although the difference is of no importance to the individual child. A correction may be made by deducting 0.5 cm from all lengths above 84.9 cm if the standing height cannot be measured.

Example 1. Boy of length 61 cm and weight 5.3 kg: this child is –2 SD weight for length (84% of the median: 5.3 divided by 6.3 × 100).

Example 2. Girl of length 67 cm and weight 4.3 kg; this child is less than –4 SD weight for length (less than 60% of the median: 57%).

Boys' weight (kg)					Length	Girls' weight (kg)				
-4 SD	-3 SD	-2 SD	-1 SD	Médian	(cm)	Médian	-1 SD	-2 SD	-3 SD	-4 SD
1.7	1.9	2.0	2.2	2.4	45	2.5	2.3	2.1	1.9	1.7
1.8	2.0	2.2	2.4	2.6	46	2.6	2.4	2.2	2.0	1.9
2.0	2.1	2.3	2.5	2.8	47	2.8	2.6	2.4	2.2	2.0
2.1	2.3	2.5	2.7	2.9	48	3.0	2.7	2.5	2.3	2.1
2.2	2.4	2.6	2.9	3.1	49	3.2	2.9	2.6	2.4	2.2
2.4	2.6	2.8	3.0	3.3	50	3.4	3.1	2.8	2.6	2.4
2.5	2.7	3.0	3.2	3.5	51	3.6	3.3	3.0	2.8	2.5
2.7	2.9	3.2	3.5	3.8	52	3.8	3.5	3.2	2.9	2.7
2.9	3.1	3.4	3.7	4.0	53	4.0	3.7	3.4	3.1	2.8
3.1	3.3	3.6	3.9	4.3	54	4.3	3.9	3.6	3.3	3.0
3.3	3.6	3.8	4.2	4.5	55	4.5	4.2	3.8	3.5	3.2
3.5	3.8	4.1	4.4	4.8	56	4.8	4.4	4.0	3.7	3.4
3.7	4.0	4.3	4.7	5.1	57	5.1	4.6	4.3	3.9	3.6
3.9	4.3	4.6	5.0	5.4	58	5.4	4.9	4.5	4.1	3.8
4.1	4.5	4.8	5.3	5.7	59	5.6	5.1	4.7	4.3	3.9
4.3	4.7	5.1	5.5	6.0	60	5.9	5.4	4.9	4.5	4.1
4.5	4.9	5.3	5.8	6.3	61	6.1	5.6	5.1	4.7	4.3
4.7	5.1	5.6	6.0	6.5	62	6.4	5.8	5.3	4.9	4.5
4.9	5.3	5.8	6.2	6.8	63	6.6	6.0	5.5	5.1	4.7
5.1	5.5	6.0	6.5	7.0	64	6.9	6.3	5.7	5.3	4.8
5.3	5.7	6.2	6.7	7.3	65	7.1	6.5	5.9	5.5	5.0
5.5	5.9	6.4	6.9	7.5	66	7.3	6.7	6.1	5.6	5.1
5.6	6.1	6.6	7.1	7.7	67	7.5	6.9	6.3	5.8	5.3
5.8	6.3	6.8	7.3	8.0	68	7.7	7.1	6.5	6.0	5.5
6.0	6.5	7.0	7.6	8.2	69	8.0	7.3	6.7	6.1	5.6
6.1	6.6	7.2	7.8	8.4	70	8.2	7.5	6.9	6.3	5.8
6.3	6.8	7.4	8.0	8.6	71	8.4	7.7	7.0	6.5	5.9
6.4	7.0	7.6	8.2	8.9	72	8.6	7.8	7.2	6.6	6.0
6.6	7.2	7.7	8.4	9.1	73	8.8	8.0	7.4	6.8	6.2
6.7	7.3	7.9	8.6	9.3	74	9.0	8.2	7.5	6.9	6.3
6.9	7.5	8.1	8.8	9.5	75	9.1	8.4	7.7	7.1	6.5
7.0	7.6	8.3	8.9	9.7	76	9.3	8.5	7.8	7.2	6.6
7.2	7.8	8.4	9.1	9.9	77	9.5	8.7	8.0	7.4	6.7
7.3	7.9	8.6	9.3	10.1	78	9.7	8.9	8.2	7.5	6.9
7.4	8.1	8.7	9.5	10.3	79	9.9	9.1	8.3	7.7	7.0
7.6	8.2	8.9	9.6	10.4	80	10.1	9.2	8.5	7.8	7.1
7.7	8.4	9.1	9.8	10.6	81	10.3	9.4	8.7	8.0	7.3
7.9	8.5	9.2	10.0	10.8	82	10.5	9.6	8.8	8.1	7.5
8.0	8.7	9.4	10.2	11.0	83	10.7	9.8	9.0	8.3	7.6
8.2	8.9	9.6	10.4	11.3	84	11.0	10.1	9.2	8.5	7.8
8.4	9.1	9.8	10.6	11.5	85	11.2	10.3	9.4	8.7	8.0
8.6	9.3	10.0	10.8	11.7	86	11.5	10.5	9.7	8.9	8.1

FIGURE 8.6.1 Weight-for-length reference chart (below 87 cm). SD = standard deviation score or Z-score. Based on World Health Organization data.

Monitoring weight gain

Calculating weight gain

The example below is for weight gain over 3 days, but the same procedure can be applied to any interval.

- Subtract the child's weight (in grams) that was measured 3 days earlier from their current weight.
- Divide by three to calculate the average daily weight gain (grams/day).
- Divide by the child's average weight (in kg) to calculate the daily weight gain per unit body weight (grams/kg/day).

Monitoring charts: explanation of the charts on the following pages

Figure 8.6.2 shows a weight chart which has been used to monitor the weight gain of a severely malnourished child. The horizontal 'x' axis represents the number of days after admission, while the vertical 'y' axis represents the weight of the child in kilograms (kg).

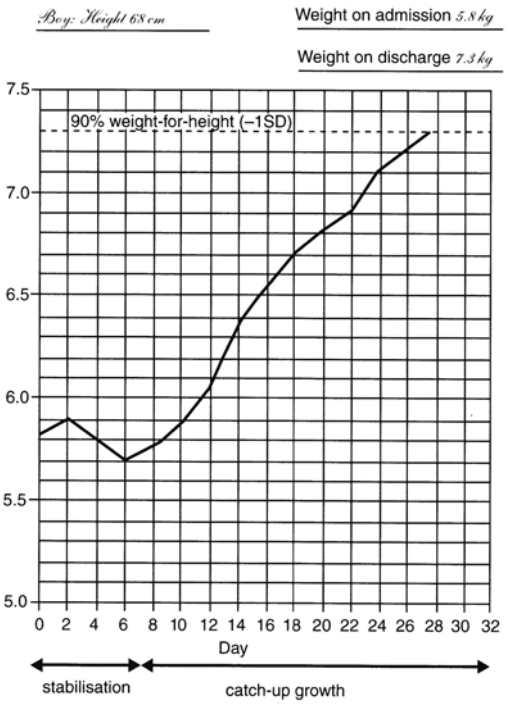


FIGURE 8.6.2 Personalised weight chart for child.

- Notice that the weight in kilograms is stepped in 0.5-kg increments. In this example, the range has been written in from 5.0 to 7.5 kg to provide a suitable range for this individual child's expected growth.
- For other children, fill in the starting weight at the appropriate level (e.g. 5 kg, 5.5 kg, 6 kg, etc., or 7 kg, 7.5 kg, 8 kg, etc.).
- Choosing an appropriate starting weight like this is preferable to using a chart with weights marked from 0, because this more flexible chart gives a larger scale and thus shows the pattern of change much more clearly.

Figure 8.6.3 shows a blank intake and output chart for recording the food given to an individual patient, the amount consumed, and any losses through vomiting or diarrhoea.

Name: Ward:

Hospital number:

Age: Weight: Date of admission:

Date ..... Feed: ..... feeds of .....mL each .....mL per day

Time	Type of feed	Volume offered (mL)	Volume left in cup (mL)	Amount taken by child (mL)	Vomit estimate (mL)	Watery diarrhoea (Yes/No)
Total:			Sub total			Total in 24 hours

FIGURE 8.6.3 Twenty-four-hour food intake chart.

Additional measurements for assessing nutritional status

Mid upper arm circumference (MUAC)

- This is measured with non-stretchable tape placed around the arm midway between the elbow and the shoulder.
- The tape should be gently tightened, but not so much that it compresses the underlying tissues.
- This measurement includes fat and muscle.

Normal values of MUAC for a child aged 1–5 years are in the range 14.0–16.5 cm.

For a child aged 1–5 years, a MUAC of < 12.5 cm indicates that the child is definitely malnourished, and a MUAC in the range 12.5–13.5 cm indicates that they are probably malnourished.

Triceps skinfold thickness

Special skinfold callipers are used to measure the double layer of skin and subcutaneous fat overlying the triceps muscle when the skinfold is lifted.

Measuring growth and development

Individual measurements of weight and height/length can be plotted sequentially on charts to identify any failure of growth. See the charts below for height and weight for boys and girls. These charts also include data for infants born prematurely, as well as head circumference measurements.

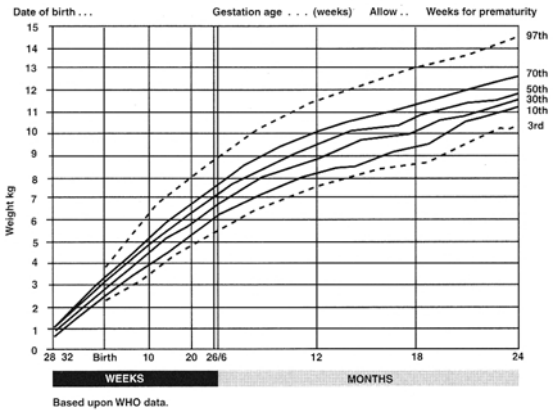


FIGURE 8.6.4 Weight chart for girls from birth to 2 years. Based on World Health Organization data.

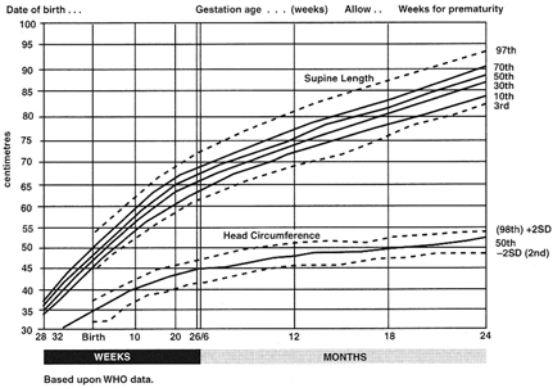


FIGURE 8.6.5 Supine length and head circumference chart for girls from birth to 2 years. Based on World Health Organization data.

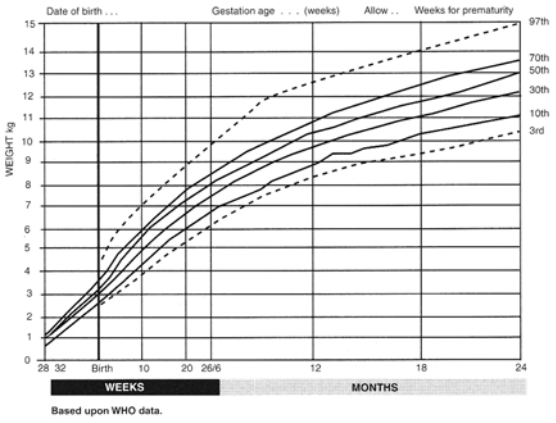


FIGURE 8.6.6 Weight chart for boys from birth to 2 years. Based on World Health Organization data.

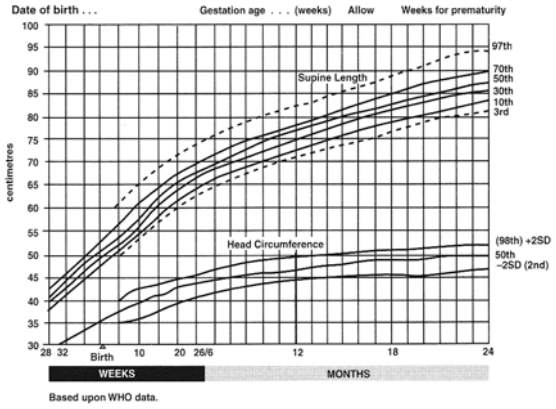


FIGURE 8.6.7 Supine length and head circumference chart for boys from birth to 2 years. Based on World Health Organization data.

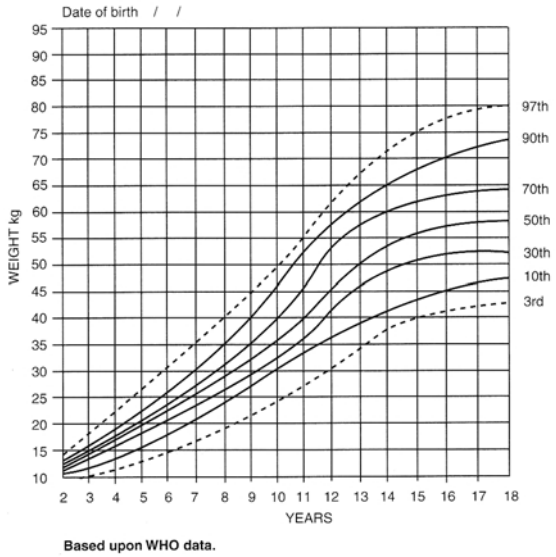


FIGURE 8.6.8 Weight chart for girls aged 2–18 years. Based on World Health Organization data.

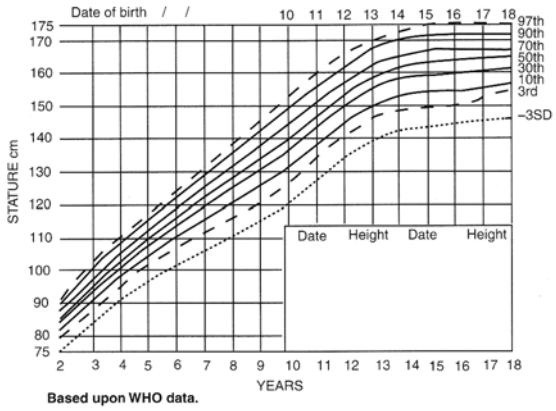


FIGURE 8.6.9 Height chart for girls aged 2–18 years. Based on World Health Organization data.

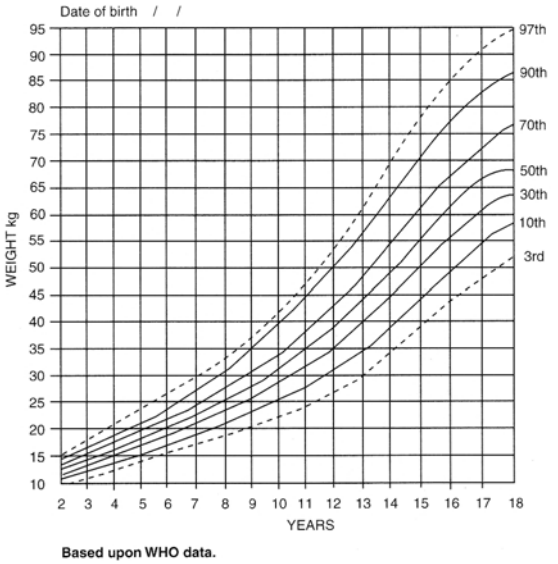


FIGURE 8.6.10 Weight chart for boys aged 2–18 years. Based on World Health Organization data.

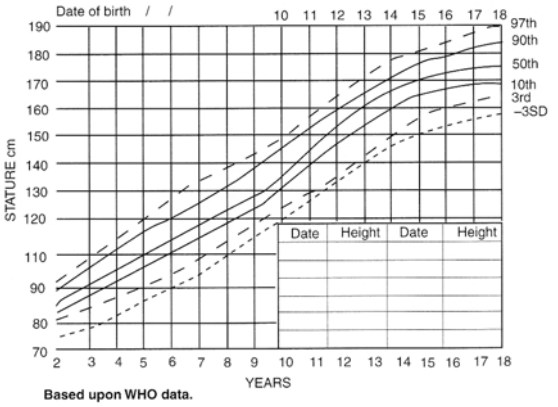


FIGURE 8.6.11 Height chart for boys aged 2–18 years. Based on World Health Organization data.

Measurement of head circumference

- Use a non-stretchable tape.
- Measure around the forehead above the eyebrows to the maximum occipital point.
- Measure twice for accuracy.

Assessment of pubertal state

Girls

The following should be recorded.

Breast development

- **Stage 1.** Pre-adolescent: elevation of papilla only.
- **Stage 2.** Breast bud stage: elevation of breast and papilla as a small mound, and enlargement of areola diameter.
- **Stage 3.** Further enlargement and elevation of breast and areola, with no separation of their contours.
- **Stage 4.** Projection of areola and papilla to form a secondary mound above the level of the breast.

- **Stage 5.** Mature stage: projection of papilla only, due to recession of the areola to the general contour of the breast.

Pubic hair

- **Stage 1.** Pre-adolescent: the vellus over the pubes is not further developed than that over the abdominal wall (i.e. there is no pubic hair).
- **Stage 2.** Sparse growth of long, slightly pigmented downy hair, straight or slightly curled, chiefly along the labia.
- **Stage 3.** Hair is considerably darker, coarser and more curled, and spreads sparsely over the junction of the pubes.
- **Stage 4.** Hair is now adult in type, but the area covered is still considerably smaller than in the adult; there is no spread to the medial surface of the thighs.
- **Stage 5.** Hair is adult in quantity and type, with distribution of the horizontal (or classically 'feminine') pattern; there is spread to the medial surface of the thighs but not up the linea alba or elsewhere above the base of the inverse triangle (spread up the linea alba occurs late, and is rated as Stage 6).

Document whether axillary hair is present.
Document age at menarche.

Boys

The following should be recorded.

Genital (penis) development

- **Stage 1.** Pre-adolescent: the testes, scrotum and penis are of about the same size and proportion as in early childhood.
- **Stage 2.** Enlargement of the scrotum and testes. The skin of the scrotum reddens and changes in texture. There is little or no enlargement of the penis at this stage.
- **Stage 3.** Enlargement of the penis, which initially is mainly an increase in length. Further growth of the testes and scrotum.
- **Stage 4.** Further enlargement of the penis, with an increase in breadth and development of the glans. The testes and scrotum are larger, and the scrotal skin is darkened.
- **Stage 5.** Genitals are adult in size and shape.

Pubic hair

- **Stage 1.** Pre-adolescent: the vellus over the pubes is not further developed than that over the abdominal wall (i.e. there is no pubic hair).
- **Stage 2.** Sparse growth of long slightly pigmented downy hair, straight or slightly curled, chiefly at the base of the penis.
- **Stage 3.** Hair is considerably darker, coarser and more curled, and spreads sparsely over the junction of the pubes.
- **Stage 4.** Hair is now adult in type, but the area covered is still considerably smaller than in the adult; there is no spread to the medial surface of the thighs.
- **Stage 5.** Hair is adult in quantity and type, with spread to the medial surface of the thighs but not up the linea alba or elsewhere above the base of the inverse triangle (spread up the linea alba occurs late, and is rated as Stage 6).

Document whether axillary hair is present.

Testicular volume

The approximate volume at each genital stage is shown.

- **Stage 1:** 1.5–3 mL.
- **Stage 2:** 4–6 mL.
- **Stage 3:** 6–10 mL.
- **Stage 4:** 10–12 mL.
- **Stage 5:** 15–20 mL.

Source: The standard illustrations in Tanner JM (1962) *Growth at Adolescence*, 2nd edn. Oxford: Blackwell Scientific Publications.

Section 9

Appendix

Normal values for vital clinical signs

Estimating the weight of a child in an emergency

For an infant (defined as up to 12 months old), the birth weight:

- doubles by 5 months
- triples by 1 year
- quadruples by 2 years.

After 12 months, the following formula can be applied, but it may need to be modified according to whether the child is small or large compared with the average:

Weight (kg) = 2 (age in years + 4).

Normal vital signs

TABLE 9.1 Normal vital signs by age in children and in pregnant women and girls

Age (years)	Heart rate (beats/minute)	Systolic blood pressure (mmHg)	Respiratory rate (breaths/minute)
< 1	110–160	70–90 (> 60)	30–40
1–2	100–150	80–95 (> 70)	25–35
2–5	95–145	80–100 (> 75)	25–30
5–12	80–120	90–110 (> 75)	20–25
> 12	60–100	100–120	15–20
Pregnant women and girls	70–110*	95–135	15–20

*Heart rate in pregnancy increases by 10–15 bpm.

WHO defines tachycardia as > 160 bpm if < 1 year; > 120 bpm if 1–5 years and if > 110 bpm in pregnancy consider shock may be developing or present.

WHO considers fast breathing is present if < 2 months respiratory rate ≥ 60 bpm; for children aged 2 months to 12 months if respiratory rate is ≥50 bpm and for children 1–5 years if respiratory rate is ≥ 40 bpm.

TABLE 9.2 Normal heart rates when awake and asleep

Age group	Heart rate when awake (beats/minute)	Heart rate when asleep (beats/minute)
Newborn to 3 months	90–190	90–160
3 months to 2 years	80–150	80–120
2–10 years	70–120	70–90
10 years to adulthood	55–90	50–90

TABLE 9.3 Normal systolic and diastolic blood pressure

Age group	Systolic blood pressure (mmHg)	Diastolic blood pressure (mmHg)
Birth (12 hours, 3 kg)	50–70	25–45
Neonate (96 hours)	60–80	20–60
Infant	80–90	53–66
2–4 years	95–105	53–66
7 years	97–112	57–71
15 years	112–128	66–80
In pregnancy	95–135*	60–85

*In pregnancy if systolic BP is < 90 mmHg consider shock may be present and if < 95 mmHg investigate for possible indicators of developing shock.

Blood pressure is difficult to measure and interpret in infants and children under 5 years of age. Do not base decisions to treat hypertension on the results of electronic sphygmomanometers, as they can be inaccurate. Always check with a hand-pumped machine.

The following quick formula can be used to calculate normal systolic pressure in children:

Median (50th centile) systolic blood pressure in children = 85 + (2 × age in years).

Capillary refill time

The normal capillary refill time (CRT) is up to 3 seconds. It is important to be aware that in colder environments peripheral CRT is not a reliable test of perfusion.

Urine output

WHO recommendations are as follows:

- Infants: 2 mL/kg/hour
- Children: 1 mL/kg/hour
- Pregnant adults: > 30 mL/hour or > 100 mL every 4 hours.

Normal core body temperatures

- Infants: 36.5–37.5°C (97.7–99.5°F)
- Children: 36.0–37.2°C (96.8 – 98.6°F).

If an infant or child has a temperature of 37.5°C or more, a fever is present.

To convert °C to °F multiply by 9, then divide by 5 then add 32.

To convert °F to °C deduct 32, then multiply by 5, then divide by 9.

Circulating blood volume

- At birth: 100 mL/kg
- At 1 year of age: 80 mL/kg
- At 12 years of age: 70 mL/kg
- In pregnancy: 100 mL/kg.

Normal values for laboratory measurements

Haematology

TABLE 9.4 Normal laboratory values for haemoglobin concentration

Age	Haemoglobin concentration (grams/dL)
1–3 days	14.5–22.5
2 weeks	14.5–18.0
6 months	10.0–12.5
1–5 years	10.5–13.0
6–12 years	11.5–15.0
12–18 years:	
Male	13.0–16.0
Female	12.0–16.0

TABLE 9.5 Normal laboratory values for platelet count

Age group	Platelet count ($\times 10^9$/litre)
Newborn	84–478
Child	150–400

TABLE 9.6 Normal laboratory values for erythrocyte sedimentation rate (ESR), white blood cell count (WBC) and lymphocyte count

Age group	*ESR (mm/hour)*
All ages	0–10
Age group	*WBC ($\times 10^9$/litre)*
1–2 days	9.0– 34.0
Neonate	6.0–19.5
1–3 years	6.0–17.5
4–7 years	5.5–15.5
8–13 years	4.5–13.5
≥ 13 years	4.5–11.0
Age group	*Median lymphocyte count ($\times 10^9$/litre)*
> 1 year	4.1–6.0

Chemistry

TABLE 9.7 Chemistry: normal laboratory values

Substance	Age	Normal range	
Albumin (grams/litre)	Preterm	18–30	
	Full term to 7 days	25–34	
	< 5 years	39–50	
	5–19 years	40–53	
Amylase (units/litre)	All ages	30–100	
ASO titre (Todd units)	2–5 years	120–160	
	6–9 years	240	
	10–12 years	320	
Bicarbonate (mmol/litre)	All ages:		
	Arterial	21–28	
	Venous	22–29	
Bilirubin (conjugated) (µmol/litre)	> 1 year	0–3.4	
Calcium (mmol/litre)	0–24 hours	2.3–2.65	(1.07–1.27 ionised)
	24 hours to 4 days	1.75–3.00	(1.00–1.17 ionised)
	4–7 days	2.25–2.73	(1.12–1.23 ionised)
	Child	2.15–2.70	(1.12–1.23 ionised)
Chloride (mmol/litre)	Neonate	97–110	
	Child	98–106	
Creatinine (µmol/litre)	Neonate	27–88	
	Infant	18–35	
	Child	27–62	
Glucose (mmol/litre)	Preterm neonate	1.4–3.3	
	0–24 hours	2.2–3.3	
	Infant	2.8–5.0	
	Child	3.3–5.5	
Magnesium (mmol/litre)	0–7 days	0.48–1.05	
	7 days to 2 years	0.65–1.05	
	2–14 years	0.60–0.95	
Osmolarity (mosmol/litre)	Child	276–295 (serum)	
Potassium (mmol/litre)	< 2 months	3.0–7.0	
	2–12 months	3.6–6.0	
	Child	3.5–5.5	
Sodium (mmol/litre)	Neonate	136–146	
	Infant	139–146	
	Child	135–145	
Urea (mmol/litre)	Neonate	1.0–5.0	
	Infant	2.5–8.0	
	Child	2.5–6.6	

Oxygen saturation (SpO_2)

The normal range is 95–100%, although oxygen saturation depends on altitude, and corrections will be needed for those living more than 1000 metres above sea level.

Table 9.8 lists the oxygen saturation levels measured in studies conducted at a range of different geographical locations above sea level.

TABLE 9.8 SpO_2 levels measured at a range of different altitudes

Altitude	Location	n	Age group	SpO_2 (%)	Author(s)	Year of study
Sea level	UK	70	2–16 years Mean 8 years	Range: 95.8–100 Median: 99.5	Poets *et al.*	1993
Sea level	Peru	189	2 months to 5 years	Range: 96–100 Mean: 98.7	Reuland *et al.*	1991
1610 m	Colorado	150	< 48 hours 3 months	95% CI: 88–97 Mean: 93 95% CI: 86–97 Mean: 92.2	Thilo *et al.*	1991
1670 m	Nairobi	87	7 days to 3 years	Range: 89.3–99.3 Mean: 95.7	Onyango *et al.*	1993
2640 m	Bogota	189	5 days to 2 years	Range: 84–100 Mean: 93.3	Lozano *et al.*	1992
2800 m	Colorado	72	3–670 days	Range: 88–97 Mean: 91.7	Nicholas *et al.*	1993
3100 m	Colorado	14	6 hours to 4 months 1 week 4 months	Range: 81–91 Mean: 80.6±5.3 Mean: 86.1±4.6	Niemeyer *et al.*	1993
3658 m	Tibet*	15	6 hours to 4 months	Immigrant: 76–90 Indigenous: 86–94	Niemeyer *et al.*	1995
3750 m	Peru	153	2–60 months	Range: 81–97 Mean: 88.9	Reuland *et al.*	1991

Values shown are those in quiet sleep.

*Ranges are values for those born to immigrant Chinese mothers and for those indigenous babies whose families have lived at that altitude for innumerable generations.

Blood gases (normal arterial range)

- pH: 7.35–7.45.
- pCO_2: 4.5–6.0 kPa (35–45 mmHg).
- pO_2: 10–13 kPa (75–98 mmHg).
- Standard bicarbonate: 21–27 mmol/L

In pregnancy:

- pH: 7.40–7.46
- pCO_2: 3.7–4.2 kPa (28–32 mmHg)
- Standard bicarbonate: 18–21 mmol/L

Circulating blood volume

- At birth: 100 mL/kg.
- At 1 year: 80 mL/kg.
- At 12 years: 70 mL/kg.
- In pregnant women and adolescent girls: 100 mL/kg.

Equivalent values for certain drugs used in an emergency

1 mg of prednisone or prednisolone is equivalent to 4 mg of hydrocortisone and 150 micrograms of dexamethasone or betamethasone.

Adrenaline (epinephrine) 1 in 1000 contains 1000 micrograms in 1 mL.

Adrenaline (epinephrine) 1 in 10 000 contains 100 micrograms in 1 mL.

Measurements of medical supplies

Uncuffed tubes in children under 25 kg in weight (aged 6–7 years)

Internal diameter of endotracheal tube:

- Full-term baby: 3.0–3.5 mm.
- Age < 1year: 4.0–4.5 mm.
- Age > 1 year: size of tube = age/4 + 4 mm.

Length of endotracheal tube:

$$\frac{\text{Age in years}}{2} + 12 \text{ in cm (oral tube).}$$

$$\frac{\text{Age in years}}{2} + 14 \text{ in cm (nasal tube).}$$

French gauge Fr = circumference of tube in mm.

Urinary catheters: for neonate to 1 year of age* 5–6 Fr; from 2 to 8 years 6–8 Fr; from 8 to12 years 10–2 Fr; from 13 to 18 years 12–16 Fr and in pregnancy from 14–16 Fr.

*Feeding tubes may be used but are not ideal

Nasogastric tubes: birth to 5 months size 8 Fr; 6 to 12 months size 10 Fr; 1 to 3 years 10–12 Fr; 4 to 7 years 12 Fr; 8 to 12 years 12–14 Fr; 12 to 18 years 14–18 Fr; in pregnancy 16–20 Fr.

Fluid and electrolyte management

Normal requirements for fluid

The blood volume is about 100 mL/kg at birth, falling to about 80 mL/kg at 1 year of age. The total body water content ranges from 800 mL/kg in the neonate to 600 mL/kg at 1 year of age and thereafter. Of this, about two-thirds (400 mL/kg) is intracellular fluid, the rest being extracellular fluid. Thus initial expansion of vascular volume in a state of shock can be achieved with relatively small volumes of fluid: 20 mL/kg (a quarter of the blood volume) will usually suffice. However, this volume is only a fraction of that required to correct dehydration, as the fluid has been lost from all body compartments in this condition. Clinically, dehydration is not detectable until more than 3–5% (30–50 mL/kg) of the body fluid has been lost.

It is important to remember that although fluid must be given quickly to correct loss of circulating fluid from the blood compartment (i.e. in shock, except in malnutrition; *see* Section 5.10.B), it must be given carefully in dehydration (*see* Section 5.5.B).

Fluids in neonates after the first 3 days of life are often prescribed on the basis of 150 mL/kg/day. However, this is not related to fluid needs, but is merely the volume of standard formula milk required to give an adequate protein and calorie intake.

Fluid requirement can be divided into four types:

1 for replacement of **insensible losses** (through sweating, respiration, gastrointestinal loss, etc.)
2 for replacement of **essential urine output** (the minimal urine output to allow excretion of the products of metabolism, etc.)
3 extra fluid to maintain a **modest state of diuresis**
4 fluid to replace **abnormal losses** (e.g. blood loss, severe diarrhoea, diabetic polyuria losses, etc.).

A useful formula for calculating normal fluid requirement is provided in Table 9.9. It is simple, can be applied to all age ranges and is easily subdivided. The formula gives total fluid requirements – that is, types (1), (2) and (3) listed above.

TABLE 9.9 Normal fluid requirements

Body weight	Volume of fluid (mL/24 hours)	Volume of fluid (mL/hour)	Na^+ (mmol/ 24 hours/kg)	K^+ (mmol/ 24 hours/kg)	Energy (kcal/ 24 hours)	Protein (grams/ 24 hours)
First 10 kg	100	4	2.0–4.0	1.5–2.5	110	3
Second 10 kg	50	2	1.0–2.0	0.5–1.5	75	1
Subsequent kg	20	1	0.5–1.0	0.2–0.7	30	0.75

For example:

- an infant weighing 6 kg would require 600 mL per day
- a child weighing 14 kg would require 1000 + 200 = 1200 mL per day
- a child weighing 25 kg would require 1000 + 500 + 100 = 1600 mL per day.

In practice, the healthy child only drinks when they are thirsty, but it is useful to have an idea of how much fluid a child should be expected to need. Of course, if there are excess losses, as in diarrhoea or fever, or if the ambient temperature is especially high, leading to high insensible losses, more fluid is required. Except in cardiac or renal disease, a good way to check whether a child is taking in enough fluid is to see whether they have a satisfactory urine output of at least 2 mL/kg/hour.

Average fluid requirements in pregnancy are 1500–2500 mL/day. This depends on levels of activity, ambient temperature and whether or not the mother has a fever.

Rehydration

Fluid deficit + normal fluid requirements + ongoing losses (sweat, diarrhoea, vomit, etc.).

Fluid deficit (mL) = percentage dehydration × weight (kg) × 10.

Ongoing losses:

- After each loose stool:
  - age < 2 years: 50–100 mL
  - age ≥ 2 years: 100–200 mL
- After each vomit: 2 mL/kg body weight.

Some useful information about biochemical measurements

- 1 ounce = 28 mL
- Percentage solution = number of grams in 100 mL (e.g. 10% dextrose = 10 grams in 100 mL).
- One millimole = molecular weight in milligrams.
- Some useful atomic weights:

hydrogen	1.0
carbon	12.0
nitrogen	14.0
oxygen	16.0
sodium	23.0
phosphorus	31.0
chlorine	35.5
potassium	39.1
calcium	40.1

  Therefore, for example:
  1 mmol NaCl = 58.5 mg
  1 mmol $NaHCO_3$ = 84 mg
  1 mmol KCl = 74.6 mg.
- The equivalent weight of an electrolyte = molecular weight/valency (e.g. Ca = 40/2).
- Useful figures to know:
  - 30% NaCl = 5 mmol/mL each of Na^+ and Cl^-
  - 0.9% NaCl = 0.154 mmol/mL each of Na^+ and Cl^-
  - 15% KCl (15 grams/100 mL) = 2 mmol/mL each of K^+ and Cl^- (also called concentrated or strong KCl)
  - 10% calcium gluconate (10 grams/100 mL) = 0.225 mmol/mL (note that 1 mL of calcium chloride 10% is equivalent to 3 mL of calcium gluconate 10%)
  - 8.4% $NaHCO_3$ = 1 mmol Na^+ and 1 mmol HCO_3^-/mL

  - 1 mL/hour of normal saline = 3.7 mmol Na^+ in 24 hours.
- Serum osmolarity = 2(Na^+ + K^+) + glucose + urea (normally 285–295 mosmol/litre).

Normal requirements for electrolytes (unless there are excessive losses)

There are obligatory losses of electrolytes in stools, urine and sweat, and these require replacement. Any excess is simply excreted in the urine.

TABLE 9.10 Electrolyte content of body fluids

Fluid	Na^+ (mmol/litre)	K^+ (mmol/litre)	Cl^- (mmol/litre)	HCO_3^- (mmol/litre)
Plasma	135–145	3.5–5.5	98–108	20–28
Gastric fluid	20–80	5–20	100–150	0
Intestinal fluid	100–140	5–15	90–130	13–65
Diarrhoea	7–96	34–150	17–164	0–75
Sweat	< 40	6–15	< 40	0–10

TABLE 9.11 Normal water and electrolyte requirements in pregnancy

Maintenance requirements/24 hours	Volume of fluid (mL/day)	Sodium requirement (mmol/day)	Potassium requirement (mmol/day)
	1500–2500	150	100

Commonly available crystalloid and colloid fluids

TABLE 9.12 Commonly available crystalloid fluids

Fluid	Na^+ (mmol/litre)	K^+ (mmol/litre)	Cl^- (mmol/litre)	Energy (kcal/litre)
Isotonic crystalloid fluids				
Saline 0.9% (normal)	150	0	150	0
Glucose 5% (50 mg/mL)	0	0	0	200
Hartmann's solution or Ringer-lactate solution*	131	5	111	0
Hypertonic crystalloid fluids				
Saline 0.45%, glucose 5%	75	0	75	200
Glucose 10% (100 mg/mL)	0	0	0	400
Glucose 50%	0	0	0	2000

*Hartmann's or Ringer-lactate solution also contains HCO_3^- as lactate 29 mmol/litre and calcium 2 mmol/litre.

To make 10% glucose/dextrose solution in Ringer-lactate/Hartmann's or 0.9% saline, remove 100 mL from a 500 mL bag and inject into it in a sterile manner 100 mL of 50% dextrose/glucose.

To make 5% glucose/dextrose solution in Ringer-lactate/Hartmann's or 0.9% saline, remove 50 mL from a 500 mL bag and inject into it in a sterile manner 50 mL of 50% dextrose/glucose.

To make a 10% solution of glucose for injection in treating hypoglycaemia and if there is only 50% dextrose/glucose solution available:

- either dilute 10 mL of the 50% solution in 40 mL of sterile water
- OR add 10 mL of 50% dextrose to 90 mL of 5% glucose which will give an approximate 10% glucose solution.

TABLE 9.13 Commonly available colloid fluids

Colloid	Na^+ (mmol/litre)	K^+ (mmol/litre)	Ca^{2+} (mmol/litre)	Duration of action (hours)	Comments
Albumin 4.5%	150	1	0	6	Protein buffers
Gelofusine	154	< 1	< 1	3	Gelatine
Haemaccel	145	5	12.5	3	Gelatine
Pentastarch	154	0	0	7	Hydroxyethyl starch

Drop factor for IV infusions

Fluids can be calculated in drops/minute as follows. First identify from the IV giving set what the 'drop factor' is (for standard giving sets this may be 10, 15 or 20 drops = 1 mL). For micro-drop systems, which often accompany giving sets with burettes, 1 mL = 60 drops. When setting the infusion rate with the flow controller on the giving set below the chamber where the drops occur, always set and count the rate over a full minute.

Calculating drip rates for a standard giving set with a drop factor of 20 drops/mL

- One mL = 20 drops in standard giving set.
- Number of drops/minute = mL/hour with a standard giving set divided by 3.

With a micro-dropper infusion giving set with a drop factor of 60 drops/mL, 1 mL = 60 micro-drops.

Measuring neurological state

A = ALERT
V = responds to **VOICE**
P = responds to **PAIN =** Glasgow Coma Scale score of ≤ 8.
U = UNRESPONSIVE

Hypoglycaemia: definition and blood glucose conversion

Hypoglycaemia is defined as a blood glucose concentration of < 2.5 mmol/litre or < 45 mg/dL.

1 mmol/litre = 19 mg/dL of glucose.

Examples of charts that can be used to monitor patients in hospital

NAME		WEIGHT		AGE				
DATE	TREATMENT	DOSE	REGIMEN	SIGN	NURSES: TIME GIVEN 1.	2.	3.	4.

FIGURE 9.1 Example of a prescription chart.

Ward : _____

Name : _____ **Hospital number :** _____

Age : _____ **Weight :** _____ **Date of admission :** _____

Date……..…..Feed……..……feeds of……mL each= ……..……mL per day

Time	Type of feed	Volume offered (mL)	Volume left in cup (mL)	Amount taken by child (mL)	Vomit estimate (mL)	Watery diarrhoea (Yes/No)
Total:				**Subtotal**		**Total taken in 24 hours**

FIGURE 9.2 Twenty-four-hour food intake chart.

PAEDIATRIC DEPARTMENT: MULAGO HOSPITAL
TREATMENT CHART

NAME :……………………………………………………………….DATE OF BIRTH :……………………………..UNIT NO :

DATE PRESCRIBED	DRUG	DOSE	ROUTE	REGIMEN	DATE						
				06							
				12							
				14							
				18							
				22							
				24							
				06							
				12							
				14							
				18							
				22							
				24							
				06							
				12							
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				18							
				22							
				24							
				06							
				12							
				14							
				18							
				22							
				24							
	PARACETAMOL		Oral/NG	06							
				12							
				14							
				18							
				22							
				24							

STAT DOSES OF DRUGS OR FLUID				DATE	TIME	GIVEN

INTRAVENOUS FLUID											
BLOOD PRODUCTS											

FIGURE 9.3 Drug and intravenous fluid chart. NG, nasogastric.

PAEDIATRIC DEPARTMENT: MULAGO HOSPITAL
CARE CHART

NAME: ……..AGE: ……DATE OF ADMISSION: …..……HOSPITAL NO: ……...

DATE							
TIME							
TEMPERATURE							
PULSE							
RESPIRATORY RATE							
BLOOD PRESSURE							
0_2 SA%							
AVPU							
WEIGHT							
OXYGEN THERAPY							
CONVULSIONS							
FLUIDS: RECORD AMOUNT AND TYPE							
INTRAVENOUS	**1**						
	2						
NASOGASTRIC	**1**						
	2						
ORAL	**1**						
	2						
24-HOUR TOTAL INPUT							
OUTPUT: URINE							
OUTPUT: STOOL							
OUTPUT: VOMIT							
BLOOD PRODUCTS							
POSITION CHANGE							
SKIN CARE							
EYE CARE							
MOUTH CARE							
PAIN RELIEF							
GENERAL ASSESSMENT							
HEALTH EDUCATION							

OUTCOME:
……
……

FIGURE 9.4 Chart for clinical observations with fluid input and output. AVPU scale: A = alert, V = responds to verbal stimulus, P = responds to pain, U = unresponsive.

Date: _____ Hospital record number: _____

1 Child's name:		**Mother's name:**			
Age:		Weight on admission:			
2 Diagnoses / main problems:					
1					
2					
3					
4					
3 Vital signs		Day 1	Day 2	Day 3	Day 4
• Conscious level (AVPU)					
• Temperature					
• Respiratory rate					
• Pulse rate					
4 Fluid balance (record volumes and times)					
IV					
By nasogastric tube					
Oral					
Fluid output					
5 Treatments given (sign on chart when given)					
Name of treatment:	Dose:				
1					
2					
3					
4					
6 Feeding / nutrition					
Child breastfed					
Drink taken					
Food taken					
Feeding problems (give details)					
Weight					
7 Outcome (circle one of the following): Discharged well / Absconded / Transferred / Died					

FIGURE 9.5 Chart for monitoring vital signs, fluid balance, treatments given and feeding/nutrition. AVPU scale: A = alert, V = responds to verbal stimulus, P = responds to pain, U = unresponsive.

NEONATAL SPECIAL CARE BABY UNIT: MULAGO HOSPITAL
CARE CHART

NAME: ……DATE OF BIRTH: ……UNIT NO: ……

DATE														
	AM	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**	**AM**	**PM**
TEMPERATURE														
PULSE RATE														
RESPIRATORY RATE														
CONVULSIONS														
WEIGHT														
MILK FEEDS NG / ORAL **1**														
2														
INDICATE **3**														
IF **4**														
OTHER **5**														
THAN **6**														
MILK **7**														
8														
IV FLUIDS														
BLOOD PRODUCTS														
24-HOUR INPUT TOTAL														
OXYGEN THERAPY														
PHOTOTHERAPY														
OUTPUT: URINE														
OUTPUT: STOOL														

FIGURE 9.6 Neonatal care chart. NG, nasogastric.

NEONATAL SPECIAL CARE BABY UNIT: MULAGO HOSPITAL
TREATMENT CHART

NAME: ……………… ……………………………………………….DATE OF BIRTH : …………………………………….UNIT NO : ………………

DATE PRESCRIBED	DRUG	DOSE	ROUTE	REGIMEN	DATE						
				06							
				12							
				14							
				18							
				22							
				24							
				06							
				12							
				14							
				18							
				22							
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				14							
				18							
				22							
				24							
				06							
				12							
				14							
				18							
				22							
				24							
STAT DOSES OF DRUGS OR FLUID				DATE		TIME		GIVEN			
	VITAMIN K		IV / IM								
INTRAVENOUS FLUID											
BLOOD PRODUCTS											

FIGURE 9.7 Neonatal treatment chart.

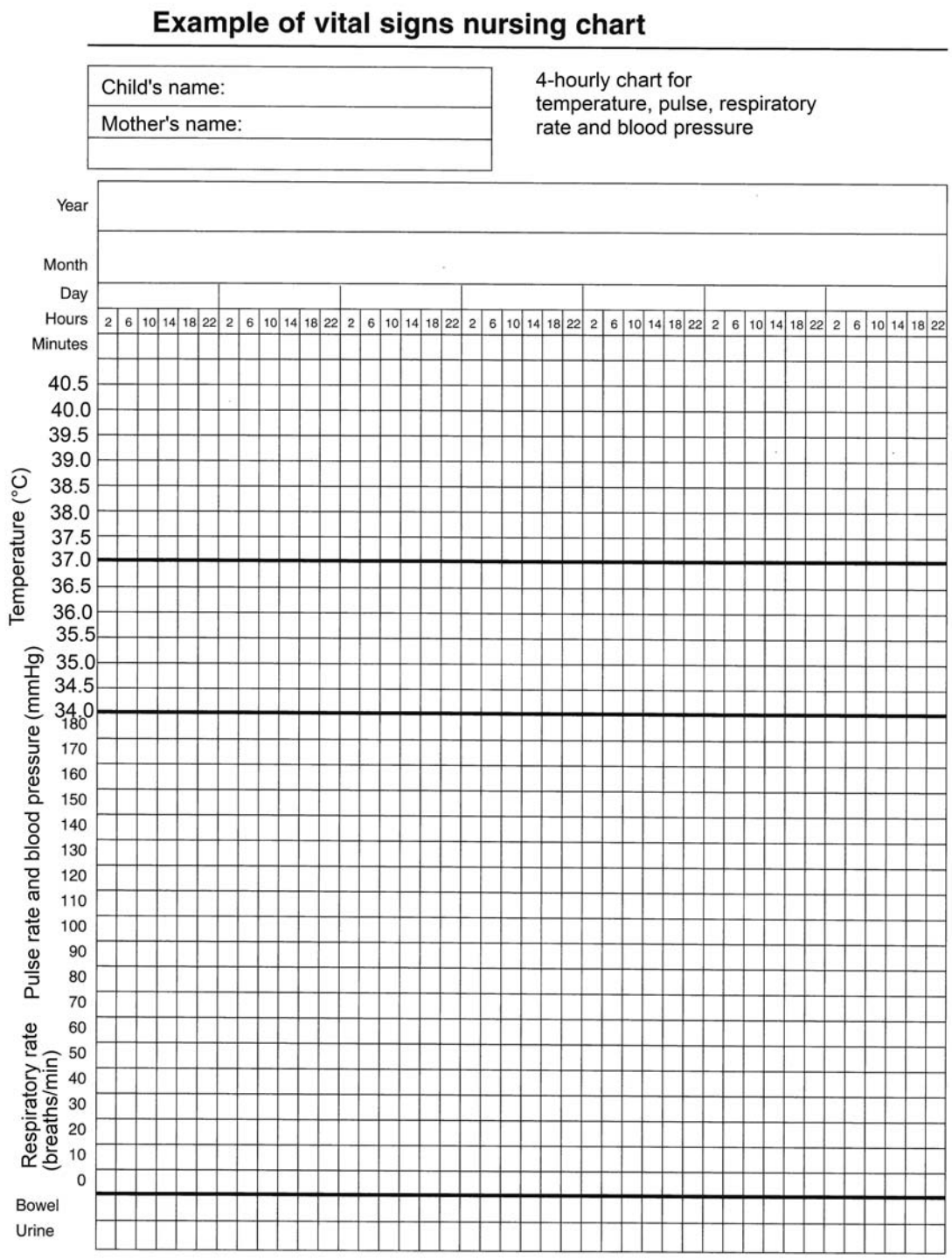

FIGURE 9.8 Chart for vital signs in children.

FIGURE 9.9 Advice card for mothers.

WHEN TO TAKE YOUR BABY BACK TO THE HOSPITAL OR CLINIC

If your baby is not feeding as well as he/she has been
If your baby is lying quietly for longer than normal
If your baby is floppy
If your baby has a fever (feels hot or is sweating)
Is breathing faster than normal
Has sucking in of the ribs when breathing or any difficulty breathing
Is pale or has a blue tongue
Has a fit (starts shaking and loses consciousness)
Cannot be woken from sleep
Has yellow hands or feet
Has any skin infection
Has an enlarged tummy
Has stopped breathing suddenly
Has diarrhoea
Has vomited more than once or the vomit is green

NAME: ..... **.M OR F Date of birth** .....

ADDRESS:.....

AGE	VACCINE
Birth	BCG against TB and Oral polio No:0
6 weeks	DTP No:1, HiB No: 1, Oral polio No: 1, HBV No: 1
10 weeks	DTP No:2, HiB No: 2, Oral polio No: 2, HBV No: 2
14 weeks	DTP No:3, HiB No: 3, Oral polio No: 3, HBV No: 3
9 months	Measles No: 1 and Yellow fever if at risk
12-15 months	Measles No: 2

Estimating body surface area

In paediatrics, body surface area is commonly used to calculate some drug dosages. This is because in children beyond the neonatal period, metabolic rate, renal clearance and some other bodily functions vary more closely with surface area than they do with weight.

In practice, using surface area as the basis for prescribing means that smaller children receive relatively more drug than they would if weight was being used.

For many drugs, the therapeutic margin is wide enough for it not to matter which method of dosage calculation is used, but for some it makes a significant difference, and avoids ineffective under-prescribing in smaller children. Examples of drugs for which it should be used are most cancer chemotherapy agents, and corticosteroids.

Although there are several widely used formulae and nomograms that relate surface area to body weight and height, Boyd's self-adjusting power equation that relates it to body weight alone has been shown to be the most reliable method of estimation. A major advantage is that for any particular weight, it is merely necessary to read the surface area from a table (*see* Table 9.14). This is not only quicker, but it also reduces the risk of making an error almost to zero.

TABLE 9.14 Surface area and weight

Weight (kg)	Surface area (m^2)	Weight (kg)	Surface area (m^2)	Weight (kg)	Surface area (m^2)
0.7	0.07	12	0.56	38	1.23
1.0.0	0.10	13	0.59	40	1.27
1.6	0.14	14	0.62	42	1.32
2.0.0	0.16	15	0.65	44	1.36
2.6	0.19	16	0.68	46	1.40
3.0.0	0.21	17	0.71	48	1.44
3.6	0.24	18	0.74	50	1.48
4.0.0	0.26	19	0.77	52	1.52
4.5	0.28	20	0.79	54	1.56
5.0.0	0.30	22	0.85	56	1.60
5.5	0.33	24	0.90	58	1.63
6.0.0	0.35	26	0.95	60	1.67
7.0.0	0.38	28	1.00	65	1.76
8.0.0	0.42	30	1.05	70	1.85
9.0.0	0.46	32	1.09	75	1.94
10.	0.49	34	1.14	80	2.03
11.	0.53	36	1.19	90	2.19

WHO/UNICEF child growth standards (2009) and the identification of severe acute malnutrition in infants and children under 5 years of age

(*See* Figure 9.10 and Figure 9.11)

Boys' weight (kg)					Length	Girls' weight (kg)				
-4 SD	-3 SD	-2 SD	-1 SD	Médian	(cm)	Médian	-1 SD	-2 SD	-3 SD	-4 SD
1.7	1.9	2.0	2.2	2.4	45	2.5	2.3	2.1	1.9	1.7
1.8	2.0	2.2	2.4	2.6	46	2.6	2.4	2.2	2.0	1.9
2.0	2.1	2.3	2.5	2.8	47	2.8	2.6	2.4	2.2	2.0
2.1	2.3	2.5	2.7	2.9	48	3.0	2.7	2.5	2.3	2.1
2.2	2.4	2.6	2.9	3.1	49	3.2	2.9	2.6	2.4	2.2
2.4	2.6	2.8	3.0	3.3	50	3.4	3.1	2.8	2.6	2.4
2.5	2.7	3.0	3.2	3.5	51	3.6	3.3	3.0	2.8	2.5
2.7	2.9	3.2	3.5	3.8	52	3.8	3.5	3.2	2.9	2.7
2.9	3.1	3.4	3.7	4.0	53	4.0	3.7	3.4	3.1	2.8
3.1	3.3	3.6	3.9	4.3	54	4.3	3.9	3.6	3.3	3.0
3.3	3.6	3.8	4.2	4.5	55	4.5	4.2	3.8	3.5	3.2
3.5	3.8	4.1	4.4	4.8	56	4.8	4.4	4.0	3.7	3.4
3.7	4.0	4.3	4.7	5.1	57	5.1	4.6	4.3	3.9	3.6
3.9	4.3	4.6	5.0	5.4	58	5.4	4.9	4.5	4.1	3.8
4.1	4.5	4.8	5.3	5.7	59	5.6	5.1	4.7	4.3	3.9
4.3	4.7	5.1	5.5	6.0	60	5.9	5.4	4.9	4.5	4.1
4.5	4.9	5.3	5.8	6.3	61	6.1	5.6	5.1	4.7	4.3
4.7	5.1	5.6	6.0	6.5	62	6.4	5.8	5.3	4.9	4.5
4.9	5.3	5.8	6.2	6.8	63	6.6	6.0	5.5	5.1	4.7
5.1	5.5	6.0	6.5	7.0	64	6.9	6.3	5.7	5.3	4.8
5.3	5.7	6.2	6.7	7.3	65	7.1	6.5	5.9	5.5	5.0
5.5	5.9	6.4	6.9	7.5	66	7.3	6.7	6.1	5.6	5.1
5.6	6.1	6.6	7.1	7.7	67	7.5	6.9	6.3	5.8	5.3
5.8	6.3	6.8	7.3	8.0	68	7.7	7.1	6.5	6.0	5.5
6.0	6.5	7.0	7.6	8.2	69	8.0	7.3	6.7	6.1	5.6
6.1	6.6	7.2	7.8	8.4	70	8.2	7.5	6.9	6.3	5.8
6.3	6.8	7.4	8.0	8.6	71	8.4	7.7	7.0	6.5	5.9
6.4	7.0	7.6	8.2	8.9	72	8.6	7.8	7.2	6.6	6.0
6.6	7.2	7.7	8.4	9.1	73	8.8	8.0	7.4	6.8	6.2
6.7	7.3	7.9	8.6	9.3	74	9.0	8.2	7.5	6.9	6.3
6.9	7.5	8.1	8.8	9.5	75	9.1	8.4	7.7	7.1	6.5
7.0	7.6	8.3	8.9	9.7	76	9.3	8.5	7.8	7.2	6.6
7.2	7.8	8.4	9.1	9.9	77	9.5	8.7	8.0	7.4	6.7
7.3	7.9	8.6	9.3	10.1	78	9.7	8.9	8.2	7.5	6.9
7.4	8.1	8.7	9.5	10.3	79	9.9	9.1	8.3	7.7	7.0
7.6	8.2	8.9	9.6	10.4	80	10.1	9.2	8.5	7.8	7.1
7.7	8.4	9.1	9.8	10.6	81	10.3	9.4	8.7	8.0	7.3
7.9	8.5	9.2	10.0	10.8	82	10.5	9.6	8.8	8.1	7.5
8.0	8.7	9.4	10.2	11.0	83	10.7	9.8	9.0	8.3	7.6
8.2	8.9	9.6	10.4	11.3	84	11.0	10.1	9.2	8.5	7.8
8.4	9.1	9.8	10.6	11.5	85	11.2	10.3	9.4	8.7	8.0
8.6	9.3	10.0	10.8	11.7	86	11.5	10.5	9.7	8.9	8.1

FIGURE 9.10 Weight-for-length reference chart (below 87 cm). Based on World Health Organization data.

Boys' weight (kg)					Height	Girls' weight (kg)				
-4 SD	-3 SD	-2 SD	-1 SD	Médian	(cm)	Médian	-1 SD	-2 SD	-3 SD	-4 SD
8.9	9.6	10.4	11.2	12.2	87	11.9	10.9	10.0	9.2	8.4
9.1	9.8	10.6	11.5	12.4	88	12.1	11.1	10.2	9.4	8.6
9.3	10.0	10.8	11.7	12.6	89	12.4	11.4	10.4	9.6	8.8
9.4	10.2	11.0	11.9	12.9	90	12.6	11.6	10.6	9.8	9.0
9.6	10.4	11.2	12.1	13.1	91	12.9	11.8	10.9	10.0	9.1
9.8	10.6	11.4	12.3	13.4	92	13.1	12.0	11.1	10.2	9.3
9.9	10.8	11.6	12.6	13.6	93	13.4	12.3	11.3	10.4	9.5
10.1	11.0	11.8	12.8	13.8	94	13.6	12.5	11.5	10.6	9.7
10.3	11.1	12.0	13.0	14.1	95	13.9	12.7	11.7	10.8	9.8
10.4	11.3	12.2	13.2	14.3	96	14.1	12.9	11.9	10.9	10.0
10.6	11.5	12.4	13.4	14.6	97	14.4	13.2	12.1	11.1	10.2
10.8	11.7	12.6	13.7	14.8	98	14.7	13.4	12.3	11.3	10.4
11.0	11.9	12.9	13.9	15.1	99	14.9	13.7	12.5	11.5	10.5
11.2	12.1	13.1	14.2	15.4	100	15.2	13.9	12.8	11.7	10.7
11.3	12.3	13.3	14.4	15.6	101	15.5	14.2	13.0	12.0	10.9
11.5	12.5	13.6	14.7	15.9	102	15.8	14.5	13.3	12.2	11.1
11.7	12.8	13.8	14.9	16.2	103	16.1	14.7	13.5	12.4	11.3
11.9	13.0	14.0	15.2	16.5	104	16.4	15.0	13.8	12.6	11.5
12.1	13.2	14.3	15.5	16.8	105	16.8	15.3	14.0	12.9	11.8
12.3	13.4	14.5	15.8	17.2	106	17.1	15.6	14.3	13.1	12.0
12.5	13.7	14.8	16.1	17.5	107	17.5	15.9	14.6	13.4	12.2
12.7	13.9	15.1	16.4	17.8	108	17.8	16.3	14.9	13.7	12.4
12.9	14.1	15.3	16.7	18.2	109	18.2	16.6	15.2	13.9	12.7
13.2	14.4	15.6	17.0	18.5	110	18.6	17.0	15.5	14.2	12.9
13.4	14.6	15.9	17.3	18.9	111	19.0	17.3	15.8	14.5	13.2
13.6	14.9	16.2	17.6	19.2	112	19.4	17.7	16.2	14.8	13.5
13.8	15.2	16.5	18.0	19.6	113	19.8	18.0	16.5	15.1	13.7
14.1	15.4	16.8	18.3	20.0	114	20.2	18.4	16.8	15.4	14.0
14.3	15.7	17.1	18.6	20.4	115	20.7	18.8	17.2	15.7	14.3
14.6	16.0	17.4	19.0	20.8	116	21.1	19.2	17.5	16.0	14.5
14.8	16.2	17.7	19.3	21.2	117	21.5	19.6	17.8	16.3	14.8
15.0	16.5	18.0	19.7	21.6	118	22.0	19.9	18.2	16.6	15.1
15.3	16.8	18.3	20.0	22.0	119	22.4	20.3	18.5	16.9	15.4
15.5	17.1	18.6	20.4	22.4	120	22.8	20.7	18.9	17.3	15.6

FIGURE 9.11 Weight-for-length reference chart (87 cm or above). Based on World Health Organization data.