# HANDBOOK OF HOSPITAL CARE FOR NEONATES SEPTEMBER 2022


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MCAI | Maternal & Childhealth Advocacy International

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The authors welcome any suggestions for the next edition and for any corrections. These will be addressed in future printed and online versions.

**Spine**

MCAI | Maternal & Childhealth Advocacy International

# HANDBOOK OF HOSPITAL CARE FOR NEONATES JULY 2021

**Introduction**

This handbook is the second edition containing a summary of the emergency components of basic neonatal hospital care from our textbook "International Maternal & Childhealth Care. A practical manual for hospitals worldwide". The reader is referred to the new Handbooks 1 and 2 on paediatrics and Handbook 4 on obstetrics when more details on the medical problem under consideration are required. **https://www.mcai.org.uk/**

The contents of this handbook are designed to take into consideration the situation in low resource settings and to provide the best available management when drugs, supplies and equipment are limited as a result of poverty.

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We also wish to thank the editors of the neonatal section of our original textbook who contributed so much to the contents of this present handbook.: Dave Woods, June Brady, Patrick McMaster, Yawar Najam and Tsitsi Chawatama.

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Every effort has been made to ensure that the information in this book is accurate. This does not diminish the requirement to exercise clinical judgment, and neither the publisher nor the authors can accept any responsibility for its use in practice.

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## Introductory issues

The mother's needs come first if you are on your own. Most infants are quite good at looking after themselves, once they are breathing and wrapped. If possible, keep all newborn infants with their mothers. Remember that parents need to be told what is happening to their newborn child.

*When to cut and clamp the cord in an infant who needs resuscitation at birth*
There are advantages to delaying clamping of the cord for 1 to 2 minutes after birth to allow placental transfer of blood to the infant (see Section 2). However, it is important to ensure that by doing this there is no harm to the mother (for example if she needs resuscitation). Latest data suggest that if possible delayed cord clamping/cutting should also be practiced for at least 1 minute if the baby does not breathe at birth. This means that the baby should remain between the mother's legs on the birthing bed and receive bag-mask lung inflations there. The baby should be dried and covered with a clean towel as usual and will receive warmth from being close to the mother's legs. See algorithm at the end of this chapter. 'Milking' of the cord is currently not recommended by MCAI.

*Evidence suggests that air is safer for initial resuscitation than additional inspired oxygen.* However, where possible additional oxygen should be available for use in case there is not a rapid improvement in the infant's condition. Equally, hyperoxia should be avoided, especially in the preterm infant. If a pulse oximeter is available, supplementary oxygen is not needed if $SpO_2$ is >85% 5 minutes after birth. $SpO_2$ needs to be measured from the right sided wrist or hand. If oxygen is given immediately after delivery, try to keep the $SpO_2$ at this time between 88% and 98%. Later aim for keeping $SpO_2$ 94% to 98% at term or at > 32 weeks' gestation and 92% to 94% at or below 32 weeks' gestation.

***Respiratory changes at birth in the newborn infant***
The fetal lungs are fluid-filled, and the fetal circulation obtains oxygen from the placenta. At birth, the baby has to breathe air into the lungs to get oxygen into the circulation. To do this, fluid is removed from fetal lungs during labour and delivery:

Lung fluid is removed during labour and at birth by the following mechanisms:

- at the onset of labour, lung fluid production stops
- as labour progresses, re-absorption of lung fluid occurs
- fluid is removed from the lungs during vaginal delivery
- the first breaths generate relatively high pressures to inflate the lungs, which has the effect of pushing this fluid into the circulation. These first breaths establish the infant's resting lung volume, making breathing easier for the infant after these first breaths.

- Caesarean section is associated with delayed clearance of fluid from the lungs, which reduces the initial resting lung volume.

Surfactant is produced in the fetal alveoli to prevent them collapsing and decreases the work of breathing for the newborn.

Most surfactant is produced from 32 weeks to term so premature infants may need more breathing support for example CPAP (Continuous Positive Airways Pressure). Surfactant production is reduced by hypothermia, hypoxia and acidosis.

**Regarding resuscitation of the newborn Infant**
Most infants breathe well and do not need active 'resuscitation' at birth. Simply drying the infant with a warm dry sheet/towel will in most cases stimulate a cry from the infant thus expanding the lungs. Attempts to clear the airway, to stimulate breathing, or to give facial oxygen are unnecessary. Therefore, **routine airway suctioning is not needed.**

The practice of routinely performing direct oropharyngeal and tracheal suctioning of non-vigorous infants after birthIn the presence of clear amniotic fluid, routine oro-nasal pharyngeal suction (ONPS) in infants born vaginally and by Caesarean section is associated with harmful bradycardia, apnoea, and delays in achieving normal oxygen saturations, with no benefit.

Intra-partum oronasal pharyngeal suction whilst the fetal head is on the perineum and post-natal endotracheal suctioning of vigorous infants born through meconium-stained amniotic fluid (MSAF) does not prevent Meconium Aspiration Syndrome (MAS). Although depressed infants born through meconium are at risk of developing MAS, there is no evidence that endotracheal suctioning of these infants reduces MAS.

The value of suction where there is meconium-stained amniotic fluid was previously based upon poor evidence. The presence of thick, viscous meconium in a non-breathing infant where bag and mask ventilation is not inflating the lungs may be the **only** indication for **considering** visualising the oropharynx and suctioning material, which might be obstructing the airway. Tracheal intubation should never be routine in the presence of meconium and should only be performed for suspected tracheal obstruction. The emphasis is always on initiating ventilation within the first minute of life in non-breathing or ineffectively breathing infants by bag and mask ventilation and this should never be delayed.

Around 5% of infants do not breathe spontaneously after delivery. However, breathing can be started in almost all these infants by opening the airway and correctly applying bag-and-mask ventilation. With lung inflation there is an immediate and easily detectable rise in heart rate. It may be difficult to identify the infant's pulse rate by palpation at any site, so the best way to determine the heart rate is to listen over the chest with **a stethoscope**. If a stethoscope is not available try to listen with a Pinard or Ultrasonic probe or even with your own ear on the baby's chest.

Far less commonly, infants are born cyanosed, shocked, limp and hypotonic. Around 1% do not respond to bag- and-mask ventilation and need further help with advanced resuscitation.

Recent recommendations to the Neonatal Life Support Guidelines from The International Liaison Committee on Resuscitation (ILCOR) and European Resuscitation Council (ERC) relevant to resource-limited countries have been included in the algorithm at the end of this chapter.

**Additional and important issues**

The temperature of newly born infants should be maintained between 36.5ºC and 37.5ºC. Temperatures less than 36.5ºC have a strong association with increased morbidity and mortality. Even the mild hypothermia that was once felt to be inevitable and therefore clinically acceptable carries a risk. Therefore, the temperature in the delivery room should be at least 26 degrees C and immediately after birth the infant should be dried ideally in a warm towel and placed in dry towels and ideally a warm hat. However, this drying and wrapping should take less than 10 to 20 seconds, because rapid lung inflation by bag and mask ventilations are the key. As described above delayed cord clamping by keeping the baby between the mother's legs can help keep the baby warm.

In very small preterm infants the use of clear food-grade plastic wrapping (cling film) of the baby's body is recommended to maintain body temperature. A heated mattress on the resuscitation platform can be helpful.

For infants needing resuscitation, rapid/immediate intervention by airway opening and lung ventilation based resuscitation (in low resource settings usually by bag and mask) is the main priority as emphasised above.

Ventilatory resuscitation is best started with air. However, where possible, additional oxygen when available should be added to the bag and mask if there is no rapid improvement in the infant's condition.

Early application after resuscitation of nasal continuous positive pressure (CPAP) should be used to provide breathing support to all breathing infants who show signs of respiratory distress. Early use of nasal CPAP of + 5cm $H_2O$ should be specially considered to keep the small airways open and make it easier to breathe in those spontaneously breathing preterm infants who are at high risk of developing respiratory distress syndrome (RDS).

Adrenaline should be given by the IV route (usually through the umbilical vein).

**If there are no signs of life after 20 minutes of continuous and adequate resuscitation efforts, the baby's prognosis is poor, and discontinuation of resuscitation is recommended.**

**Sequence of actions during resuscitation of the newborn**
The order of actions is listed below with explanations. For a summary of newborn resuscitation see algorithm (Figure 1.8) at end of this chapter.

**1 Call for help**

**2 Start the clock or note the time**
This will help document timing of actions and duration of resuscitation.

**3 Dry the infant including the head.**
Infants are born small and wet. They get cold very easily, especially if they remain wet and in a draught. Whatever the problem, **dry the infant well, including the head.** Remove the wet towel and wrap the infant in a dry towel. It is helpful if the towels are warm. The room in which delivery takes place should be clean, warm and free of drafts. A clean, warm and well-lit area is needed for resuscitation. Initially to support delayed cord clamping for at least 1 minute, lung inflations should be given to the baby lying between the mother's legs. After cord clamping the baby can be moved to an appropriate resuscitation platform. Although a source of radiant heat is helpful in keeping the infant warm, in low resource settings the provision of heat requires significant electrical power. The neonatal platform resuscitaire shown in Figure 1.1 is inexpensive compared with those used in well-resourced settings, does not have an overhead heater but is mobile, is safe from accidental falls of the infant, has a good low battery powered LED light, a large clock-face and place for resuscitation together with places to keep the bag and masks, suction systems and towels. Because of its low cost and minimal power requirements it is suitable for all facilities in which babies are born rather than being limited to hospitals.

There is good evidence that for very preterm infants (30 weeks' gestation or earlier), immediately covering the body, apart from the face, with clean plastic wrapping, by reducing evaporative heat loss is an effective way of keeping these very small infants warm during resuscitation. A woollen cap is available can also reduce heat loss.

Drying the infant immediately after delivery will provide significant stimulation during which skin and mucous membrane colour, tone, breathing and heart rate can continue to be assessed. Observing the breathing, skin colour, heart rate and tone helps to document the infant's condition and assess their response to resuscitation.

***Figure 1.1*** *Low cost mobile resuscitation platform for neonatal resuscitation*


However, stimulation is rarely sufficient for a baby who is not breathing, and no time should be wasted: if a baby is not breathing, lung inflation assistance within 20 seconds is essential.

Remember, that as soon as the baby is breathing or crying on their own, place immediately in skin-to-skin contact with the mother (providing she is well enough). If the mother is too ill, a relative or staff member can provide temporary skin to skin care and keep the baby warm.

4. **Assess breathing effort and count the heart rate**

If poor or no breathing effort, or only gasping, the baby will need urgent lung inflations.

The heart rate should be counted over ONLY a few seconds with a stethoscope on the chest. A heart rate less than 100/min in a newborn infant is almost always due to hypoxia and effective airway opening and bag-and-mask ventilation will cause an increase in heart rate. The heart rate is used to assess effectiveness of resuscitation because chest movement in a newborn infant may be difficult to see initially.

Reassess these observations regularly (particularly the heart rate), every 30 seconds or so, throughout the resuscitation process. The first sign of any improvement in the infant with a slow heart rate will be an increase in heart rate.

A healthy infant may be born blue but will have good tone, will cry within a few seconds of delivery, will have a good heart rate (the heart rate of a healthy new-born infant is approximately 120–150 beats/minute) and will rapidly become pink during the first 90 seconds or so. An ill infant will be born pale and floppy, not breathing, and with a slow (<100) or very slow (<60) heart rate.

The heart rate of an infant is best judged by listening to the chest with a stethoscope. It can also sometimes be felt by palpating the base of the umbilical cord, but a slow rate at the cord is not always indicative of a truly slow heart rate, and, if the infant is not breathing, must not delay the immediate application of lung inflations. In addition, **if the infant is not breathing, feeling for peripheral pulses is potentially harmful as it delays the onset**

**of life-saving lung inflations**. If a stethoscope is not available, you can listen to the heart by placing your ear on the infant's chest or using a Pinard or ultrasound stethoscope.

**5. Airway: open the airway and keep it open**

Before the infant can breathe effectively the airway must be open and must be kept open. This is one of the most important skills to learn to enable the newborn to get air into the lungs when he/she takes his/her first breath.
The upper airway of any infant who is born limp and hypotonic certainly needs to be opened and maintained in just the same way as the airway of any other unconscious patient. In an unconscious patient, pharyngeal tone decreases even more than it does during sleep, causing the upper airway to narrow or close. When such a patient is laid on their back the tongue also falls back, further obstructing the airway.
There are three ways to counteract this and open the airway

a. Hold the head in the neutral position *and*
b. Support the chin *or*
c. Push the lower jaw forward.

The best way to achieve this in an infant who is not breathing well is to place the infant on their back with the head in the neutral position (i.e. with the neck neither flexed nor extended and the face parallel with the surface the baby is lying on – Figure 1.2). Most newborn infants will have a relatively prominent occiput, which will tend to flex the neck if the infant is placed on their back on a flat surface. This can be avoided by placing some support using a folded nappy or cloth under the shoulders of the infant (1 to 2 cm thick) but be careful not to overextend the neck.

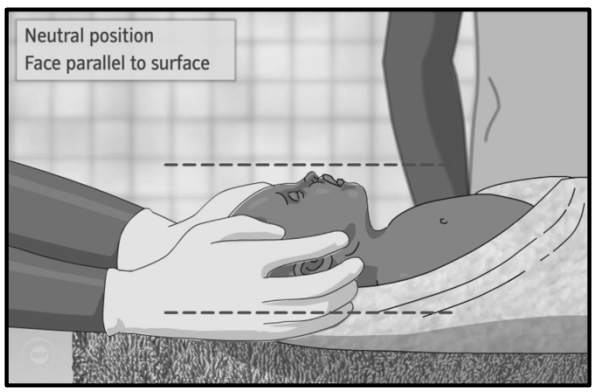


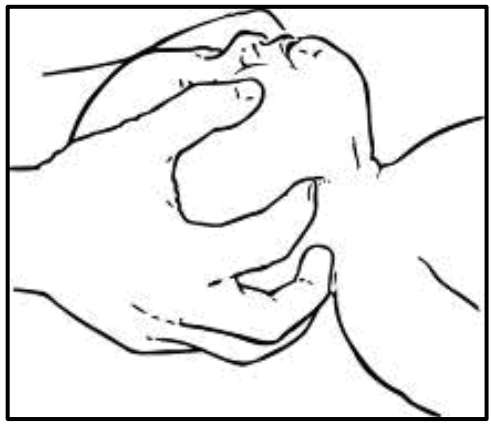

**Figure 1.2** *Neutral position of the head and neck in a new-born infant*

If the infant is floppy it may also be necessary to apply chin lift or jaw thrust (see figures 1.3 and 1.4). It is important to support the bony part of the chin or jaw. *Pressure anywhere else may merely push the base of the tongue backwards, making matters worse.*

***Figure 1.3*** *Chin lift in a new-born infant. If tone is poor it may also be necessary to support the chin.*

If tone is very poor it may be necessary to use one or two fingers under each side of the lower jaw, at its angle to push the jaw forwards and outwards ('jaw thrust') (see Figure 1.4). A second person will then usually be needed to give the inflation and ventilation breaths by squeezing the bag (for which minimal training and skill is required).

***Figure 1.4*** *Jaw thrust in a new-born infant. Note that the operator's thumbs are in a position to hold a mask in place.*



The best way to stabilise an infant's condition at birth is to ensure that the upper airway **remains** unobstructed. The infant will then have little difficulty in drawing air into the lungs when it takes its first spontaneous gasp or cry.

Unfortunately, books often talk of the need to keep the airway 'clear', giving the false impression that the infant is going to find it difficult to breathe unless all the fluid and mucus is first sucked out of the way. There is no evidence that this is ever necessary unless the infant has thick meconium within the nasal or oral airway. Moreover, it can be harmful as blind deep suction of the nose or mouth can stimulate the vagus nerve, leading to bradycardia, apnoea and laryngospasm.

Routine **intrapartum (when the fetal face is on the perineum)** oropharyngeal and nasopharyngeal suctioning for infants born with clear and/or meconium-stained amniotic fluid is **not** recommended.

*Tracheal obstruction*
Although it is rare for debris to completely block the trachea, this should be suspected if an infant tries to breathe but remains cyanosed and bradycardic, with laboured breathing and marked inter-costal and/or sternal recession. This is one of the few situations where tracheal intubation can be lifesaving.

*What to do if the trachea appears to be blocked by thick meconium*
If the infant is born through meconium and cannot be ventilated by bag and mask at birth, the oropharynx should be inspected and cleared of meconium. If intubation skills are available, the larynx and trachea should also be cleared under direct vision.

If meconium has entered the trachea, resuscitation here is only possible if the accumulated debris can be immediately removed. The easiest way to do this is to pass an endotracheal tube and then remove the debris by direct suction to the endotracheal tube. Sometimes the

meconium debris is so large that it cannot be sucked through the tube. The tube can then be removed and replaced with a clean tube to clear the remaining obstructive material. Suction may also make it easier to see the larynx during intubation.

**Breathing: Bag and mask inflation of the lungs**
Having positioned the infant's airway correctly it is usually quite easy to use a self-inflating bag and mask to provide lung inflations.

If the infant is not breathing adequately give **five inflation breaths** as soon as possible. Until now the infant's lungs will have been filled with fluid. Aeration of the lungs in these circumstances is best with slow inflations at pressures of about 30 $cmH_2O$ with the bag and mask; these are called 'inflation breaths. These initial ventilation breaths should last 2–3 seconds each. The aim is to mimic the initial breaths taken by a normal infant to open the airways, remove lung fluid and achieve its functional residual capacity. The chest may not move during the first one or two breaths as fluid is displaced.

If the baby is very preterm, such inflation breaths may injure immature lungs: give lower pressure ventilation breaths (see below) in this situation.

**After 5 inflation breaths, check the heart rate.** If the heart rate was below 100 beats/minute initially then it should rapidly increase as oxygenated blood reaches the heart. If the heart rate does increase, then you can assume that you have successfully aerated the lungs and there is adequate tissue oxygenation.

If the heart rate does not increase and/or is not greater than 100 beats per minute following 5 inflation breaths, the lungs have most likely not been aerated.
Consider adjusting the airway and /or mask

- Are the infant's head and neck in the neutral position?
- Do you need jaw thrust?
- Is the mask in the correct position on the face? that is covering the nose and mouth with no gap between the face and mask where air can escape
- Do you need a second person's help with the airway or to squeeze the bag? A relative or ward orderly can be asked to squeeze the self-inflating bag while you ensure that the mask is held firmly, in the best position on the face and with jaw thrust
- Is there an obstruction in the oropharynx (Inspect under direct vision)?

Check the airway is open and repeat 5 **inflation breaths** making sure that the chest expands with each breath.

If the heart rate increases but the infant does not start breathing, then continue to provide regular ventilation breaths at a rate of about 30–40 breaths/minute until the infant starts to breathe. Ventilation breaths resemble newborn infant's normal breathing and when undertaken through the bag and mask ensure sufficient pressures; that is just enough to see the chest move with each breath. Check every 30 to 60 seconds that the heart rate remains normal (above 100 beats/minute) and that there is no central cyanosis (best judged by looking at the colour of the tongue).

Continue ventilatory support until regular breathing is established.

Remember that the infant cannot breathe through the bag-valve-mask system, so do not leave the mask sealed to the face and expect the infant to breathe from the bag. The valve

between the bag and the mask prevents this. When the infant is breathing, remove the mask and watch closely to ensure that adequate breathing continues. If the tongue is not pink and oxygen is available, give additional inspired oxygen at 2 Litres/min.

Most infants will respond to bag-and-mask ventilation by gasping and then starting to breathe on their own without further support. If this does not happen, it is still easy to confirm that lung aeration has been achieved, because the heart rate will rise reliably and consistently above 100 beats/minute. If lung aeration has been achieved and the infant still has a slow heart rate, proceed to support the circulation (C).

If oxygen is available, applying this through the bag and mask may also help.

**Correct bag-and-mask ventilation is the single most important skill needed to provide effective resuscitation.**

There is good evidence that most infants can be resuscitated using mask resuscitation without any need for tracheal intubation. However, a small proportion of such infants require early intubation, so the equipment and the skill to intubate should ideally be available.

*Figure 1.5 Mouth-to-mouth and nose resuscitation*

Most current guidelines on neonatal care avoid discussing the role of mouth-to-mouth and nose resuscitation. The risk of HIV infection or hepatitis has further supported that reluctance. However, there is no doubt that this can be an effective way of reviving an apparently lifeless infant in the absence of equipment. Remember the following:

- Keep the upper airway open by optimising the position of the head and jaw as described above.
- Cover the infant's nose and mouth with your mouth (or cover the mouth of a big infant and just pinch the nose).
- Use the pressure you can generate with your cheeks and try to aerate the lung by slow inflations for 2–3 seconds.
- Only use as much air for each breath as you can keep in your cheeks (i.e. do not 'blow' air into the infant, but just small puffs).
- Watch for chest movement and allow time for lung recoil.
- Once the chest starts to move, sustain what has been achieved with 20–25 artificial breaths/minute.

**Checking progress with resuscitation before moving on**

- If the heart rate has not risen to over 100 beats/minute after the five initial breaths or within 30 seconds of adequate ventilation, something is wrong. The most likely problem is that you have not successfully ventilated the infant. Never move on to deal with the issues covered under letter C of the resuscitation alphabet until you are quite sure you have achieved objectives A and B. To do so is quite futile. Chest compressions will never restore the circulation until the blood being massaged from the lung to the heart contains oxygen.
- Look to see whether the chest moves each time you apply mask pressure. Movement should not be difficult to see once the first few breaths have aerated the lungs. It is usually easier to judge success with your eyes than with a stethoscope. In a newborn,

breath sounds can be heard when only the airway is being aerated, so are not a good way to judge ventilatory success.

- Check that the infant's head is well positioned. Check chin support and jaw thrust, and that the mask is correctly applied with no air leaks. Ask a second person to help you position the infant optimally and provide inflations by squeezing the bag while you hold the airway open, the mask in place and apply jaw thrust.
- Few infants need support with their breathing once their lungs have been aerated. Most will gasp, cry or breathe just as soon as an attempt is made to get air into the lungs, and then continue breathing adequately.
  - However, a few may benefit from further support if they do not start to breathe regularly, or only gasp occasionally. Some may have suffered severe hypoxia in utero, and a few may be drowsy because of drugs given to the mother during labour. Check that the heart rate remains normal (above 100 beats/minute) and that there is no central cyanosis (best judged by looking at the colour of the tongue).
  - Try to assess whether there is hypoxemia (cyanosis or $SpO_2$ less than 90% with a pulse oximeter), if the infant's breathing remains laboured and irregular or if the infant's colour remains blue. Give oxygen then if it is available, preferably with $SpO_2$ monitoring. Hyaline membrane disease, meconium aspiration syndrome, pneumonia or transient tachypnoea of the newborn are most likely.
    *Other possibilities for failed breathing include:*
    - intra-partum pneumonia (common)
    - diaphragmatic hernia
    - pneumothorax
    - pulmonary hypoplasia (possibly associated with a skeletal or renal abnormality)
    - cyanotic congenital heart disease (although this usually takes a little time to appear)
    - persistent fetal circulation.
  - If breathing requires continuous support, it is important to try and reduce mask inflation pressures to little more than half of what was needed to aerate the lung in the first place. It is easy to over-ventilate an infant with healthy lungs and to wash out so much of the carbon dioxide that normally provides the main stimulus to breathing that all such activity stops for a while. There is evidence that sustained over-ventilation can reduce cerebral blood flow.

*Endotracheal intubation*
As discussed earlier, most infants who need resuscitation can be managed with bag-valve-mask intubation. However, occasionally endotracheal intubation is required, but this must be done by someone skilled and practised in the technique. It is most likely to be required for prolonged resuscitation, in meconium aspiration, and in preterm infants with surfactant deficiency. A straight-bladed laryngoscope is preferred, and tube sizes are around 3.5 mm for a term infant and 2.5 mm for a preterm infant. Sizes larger and smaller than these should be available.

**Resuscitation of preterm infants**
Infants with surfactant deficiency may have difficulty in expanding their lungs, and in developing a normal functional residual capacity at birth.
However, the preterm lung is quite a delicate structure with relatively little elastic support, and any use of undue pressure or excessive ventilation during resuscitation can damage the lungs.

While an inspiratory pressure of 30 cm $H_2O$ may well be necessary to begin aerating the lungs at birth, the pressure should be reduced as rapidly as possible to a level that ensures that the chest is moving adequately. The key aim must be to conserve such surfactant as already exists by sustaining the lung's functional residual capacity (an objective best

achieved by providing at least 5 cm $H_2O$ of Positive End-Expiratory Pressure (PEEP). Aim to achieve this consistently throughout transfer to the neonatal unit. This can be achieved using nasal prongs (nasal CPAP), thus avoiding tracheal intubation altogether (see Handbooks 1 and 2 on paediatric illnesses).

**Orogastric aspiration of air**
If resuscitation is successful, there may be enough air inside and expanding the stomach to make it difficult for the baby to breathe due to pressure on the diaphragm. Passing an orogastric tube and aspirating air or placing it on open drainage may make it easier for the baby to breathe.

**Circulation: chest compressions**
Most infants needing help at birth will respond to successful lung inflation with an increase in heart rate followed quickly by normal breathing. Chest compressions should be started only when you are sure that the lungs are being aerated successfully.

If the heart rate remains very slow (less than 60 beats/minute) or absent following 60 seconds of ventilation with good chest movements, start chest compressions.

In infants, the most efficient method of delivering chest compressions is to grip the chest in both hands in such a way that the two thumbs can press on the lower third of the sternum, just below an imaginary line joining the nipples, with the fingers over the spine at the back. This can only be done if there is a second operator ventilating the lungs (see Figure 1.6)

If you are alone, the two-thumb method is not possible, as ventilations also need to be provided. In this situation, use the first two fingers of one hand to depress the lower sternum, while the other hand holds the mask in place (Figure 1.7). Then move the hand from the sternum to squeeze the bag or ask a relative or other member of staff to do this: it does not require training.

Compress the chest quickly and firmly, reducing the antero-posterior diameter of the chest by about one-third.

Because oxygenation is such an important part of neonatal resuscitation, the recommended ratio of compressions to inflations in newborn resuscitation is 3:1.

Chest compressions move oxygenated blood from the lungs back to the heart and out into the ascending aorta. From there the two coronary arteries will then quickly deliver oxygen to the failing heart muscle.

Chest compressions also can induce some air to enter the lungs.

It is important to allow enough time during the relaxation phase of each compression cycle for the heart to refill with blood, at the same time ensuring that the chest is inflating with each breath.

***Figure 1.6*** *Two-thumb compression of the chest, with a second operator ventilating the lungs, here using a T-piece as an alternative to bag and mask.*

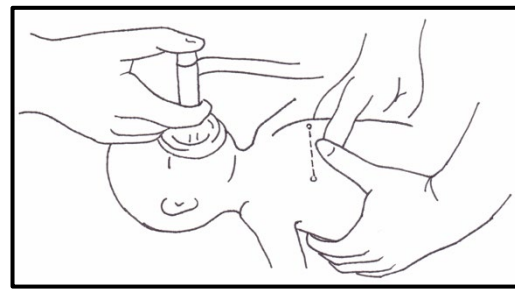
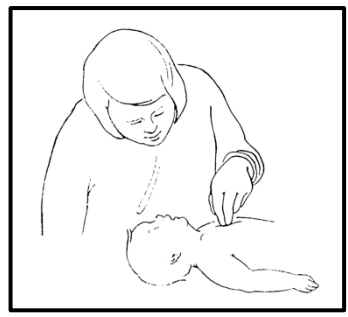


*Figure 1.7 Two-finger chest compressions. The other hand can hold the mask on the face*



The rate of chest compressions is around 120/minute. However, with pauses for ventilation, the actual total number of compressions is less than 120/minute.

Check heart rate every 30 seconds – when heart rate reaches more than 60/min stop cardiac compressions

Continue ventilation breaths until baby is breathing.

**If there no cardiac output despite effective lung ventilation and chest compressions, then the outlook for the infant is poor.**

*Drugs*
Rarely inflation of the lungs and effective chest compression will not be sufficient to produce adequate circulation and perfusion in infants. In these circumstances, drugs may be helpful. However, drugs are needed only if there is no significant cardiac output despite effective lung inflation and chest compression.

Very few drugs have proved to be of benefit. The most used drug is Adrenaline (1:10 000). This is best delivered via an umbilical venous catheter when peripheral IV access is not possible. The intra-osseous route may also be used. Each injection of a drug should be followed with a bolus of 2–3 mL of Ringer- Lactate/ Hartmann's or 0.9% saline.

Unfortunately, most of the infants in whom cardiac output only returns after drug treatment require specialist neonatal care (often with mechanical ventilation) and do not survive to discharge. Most of those who do survive later develop profound disabling spastic quadriplegia.

Where the cause of the infant's terminal apnoea is a sudden and much more abrupt hypoxic event (such as shoulder dystocia or an occasional case of late cord prolapse) these

reservations may be less valid. Here there is at least anecdotal evidence that the outlook is much less bleak if the circulation can be restarted.

Acidosis not serious enough to precipitate circulatory standstill (asystole) will nearly always correct itself spontaneously within 90 minutes once the circulation has been restored and the infant starts to breathe for him- or herself. It does not therefore call for sodium bicarbonate, the use of which is controversial. Indeed, giving bicarbonate may increase carbon dioxide levels, worsening intracellular acidosis, and increases the amount of sodium that the potentially compromised kidney will need to excrete over the next few days.

*Adrenaline*: The recommended dose of adrenaline is 10 micrograms/kg body weight (0.1 mL/kg body weight of 1:10,000 solution). If this is not effective, a dose of up to 30 micrograms/kg (0.3 mL/kg body weight of 1:10 000 solution) may be tried. Ideally, have ready-made and well-labelled 1:10 000 adrenaline solutions available on all emergency trolleys. In situations where this is not available in a ready-made state it could be prepared by adding 1 mL of 1:1000 solution to 9 mL of 0.9% saline or Ringer-Lactate/ Hartmann's solution. It is potentially dangerous to leave inadequately labeled and made up doses of adrenaline around, as giving the same volume of 1:10,000 as a 1:1000 solution could cause cardiac arrest.
**Never give any drug into the umbilical artery.**

*Naloxone (nalorphine)* can be used to reverse profound opiate-induced respiratory depression in the newborn following high doses of morphine in the mother during pregnancy or delivery. If it does prove necessary, it is best to give it intramuscularly and give a full 200-microgram 'depot' dose irrespective of body weight. If naloxone is given as a single dose IV, it will be eliminated from the body faster than the opioid drug, causing a return of the respiratory depression, and therefore the infant may stop breathing again without a naloxone infusion. Naloxone does not reverse the respiratory depressing effects of non-opiate drugs.

**Acute blood loss as a cause of circulatory arrest (circulatory volume support)**
Sudden acute blood loss is a rare, but often unrecognised, cause of acute circulatory collapse. Bleeding from an aberrant placental blood vessel (vasa praevia) or snapped umbilical cord can rapidly lead to hypovolaemic death. Other less well-recognised causes of hypovolaemic collapse include acute feto–maternal blood loss, sudden twin-to-twin transfusion, accidental incision of the placenta during Caesarean delivery and a cord ligature that has come off and not been detected.

The response to a rapid infusion of 10ml/Kg of 0.9% saline or Ringer Lactate /Hartmann's solution can be lifesaving.

Circulatory collapse probably does not occur until the infant has lost 30–40 mL/kg of blood, but 10 mL/kg of Ringer-lactate/Hartmann's solution or 0.9% saline will usually reverse the immediate critical hypovolaemia rapidly. The initial intravenous fluid bolus would ideally be 10ml/Kg of blood group O Rh-negative blood). This can be repeated once if there is no or only minimal response. A packed red cell transfusion using group-specific, or group O Rh-negative duly cross-matched blood can be given later to correct the associated anaemia.

Apart from the above specific indications, IV fluid boluses should not be used during neonatal resuscitation. There is no evidence to suggest benefit from routine use, which only compounds the problem of fluid balance that can develop over the next 2 to 3 days if severe intra-partum hypoxic ischaemic injury causes renal failure.

### Poor response to resuscitation

If the infant either fails to respond or shows a poor response to resuscitation, the most likely problem is inadequate oxygenation. The following steps should be considered:

1. Check the airway and ventilation.
2. Check for technical faults if using advanced equipment.
    a. Is the oxygen attached?
    b. Is the airway blocked?
    c. Is the endotracheal tube in the correct place?
3. Re-examine the chest to see if a pneumothorax has developed. This is not common but may cause a problem. Drain a tension pneumothorax with a small cannula over needle (21 gauge) in the second intercostal space in the mid-clavicular line. This should be followed by the insertion of a chest drain (see Section 38).
4. Consider the possibility of a congenital heart lesion (see Section 26) if the infant remains cyanosed despite breathing and having a good heart rate.
5. Consider the possibility that excessive assisted ventilatory breaths may have driven blood carbon dioxide to a low level thereby removing one of the drives by the brain to breathe spontaneously.
6. Consider the possibility of maternal opiates or sedation, such as diazepam or phenobarbitone, if the infant is pink, well perfused, but requires assisted ventilation.
7. Shock, caused by acute blood loss, should respond to a rapid bolus of 10–20 mL/kg of O-negative blood (see above).
8. Always consider the possibility of hypoglycaemia

**Stopping resuscitation**

Even with the most effective resuscitation, not all infants will survive. If the infant has been without a cardiac output after 20 minutes of resuscitation and does not respond despite effective ventilations and chest compressions, the outcome is unlikely to be altered by the use of drugs, although these should be considered. The decision to stop resuscitation should be taken by the most senior healthcare worker present, and the reason for the decision should be clearly documented. Explain sensitively to the parents that the infant has died. The infant should then be handled in accordance with cultural preference and practice.

### Apgar scores

Anaesthetist Virginia Apgar introduced these in 1953. Each factor in the Table 1.1 below is given a score between zero and two, which are then added up to give the total score. The baby's skin colour is looked at to see if their blood is circulating properly. It can be harder to detect bluish skin or a lack of colour in black and Asian babies so check the tongue and mouth.

### How does MCAI suggest you use the Apgar scores

For those babies who do not need resuscitation, the baby's wellbeing from two Apgar scores can be calculated in real time one minute after birth, and again at five minutes after birth. Each factor in Table 1.1 is given a score between zero and two, which are then added up to give the total Apgar score for each of the 2 measurements.

| Score | 0 | 1 | 2 | Acronym |
|---|---|---|---|---|
| Skin | Entire body blue or lacks colour especially mouth and tongue | Good colour but bluish hands or feet | Good colour all over | **A**ppearance |
| Heart rate | Absent | Slow <100 | Fast > 100 | **P**ulse |
| Reflex responses | No response to stimulation when drying | Grimacing facial movements when stimulated | Crying and/or coughing | **G**rimace |
| Muscle tone | Limp when drying | Some bending or stretching of limbs | Active movements | **A**ctivity |
| Breathing | Absent or gasping | Weak or irregular | Good and crying | **R**espiration |

Table 1.1

**Apgar scores when a baby needs resuscitation**

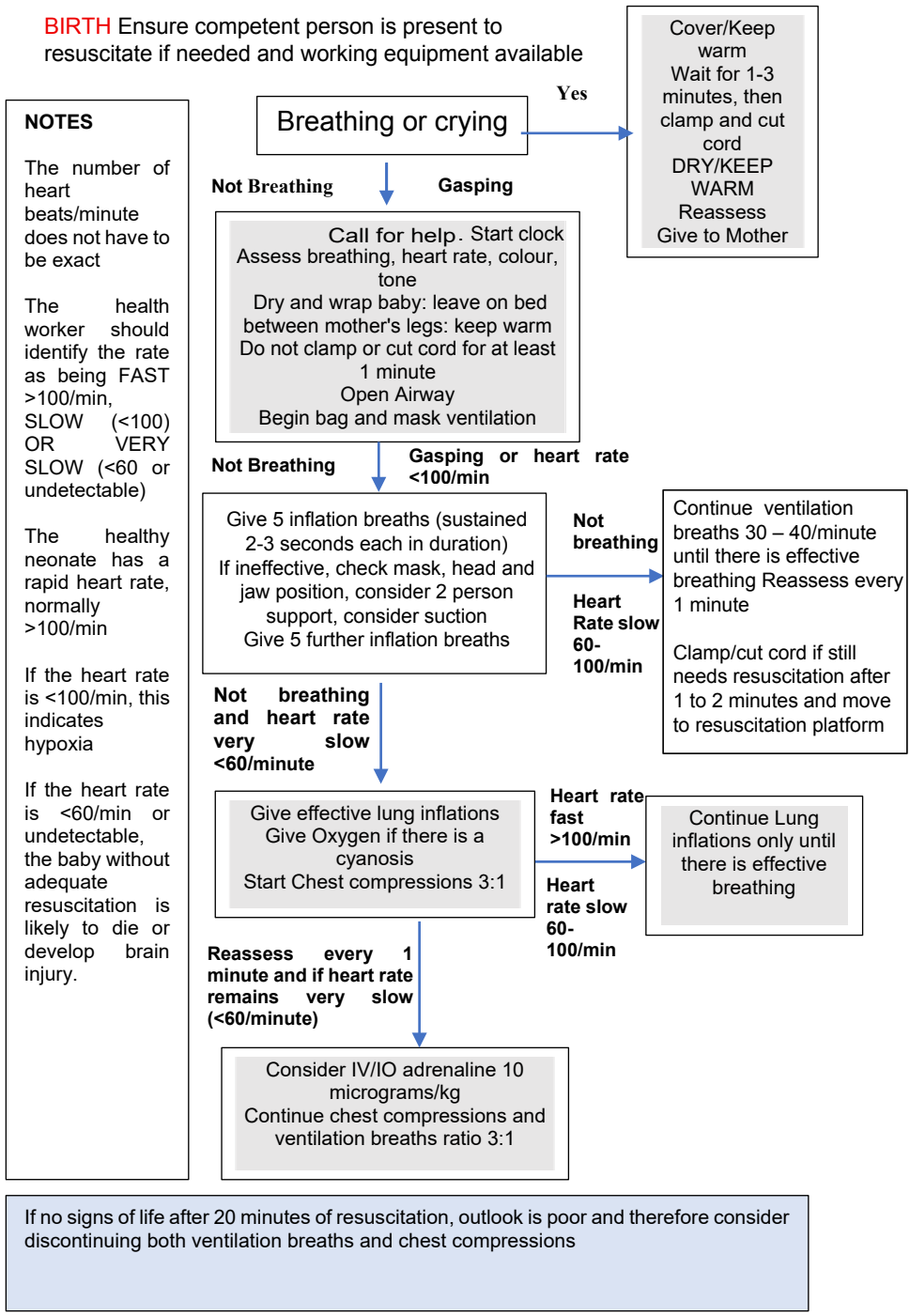
If the baby needs resuscitation, calculating the Apgar scores during resuscitation can interfere with vital aspects of treatment (ABC) and these scores can be recalled and documented when the baby no longer needs resuscitation. However, the 5 minute score is only helpful if the baby has recovered and is no longer being resuscitated. If the baby continues to need resuscitation for > 5 minutes after birth, then we suggest that the second Apgar score is undertaken only when resuscitation has ended successfully. At this time this score is documented along with the total duration of the resuscitation given in minutes (for example 9 after 12 minutes).

However, if resuscitation is discontinued and/or the baby dies, then a timed second Apgar score can be documented (for example zero at 20 minutes).

Low Apgar scores (scores < 7) after resuscitation has ended and the baby is alive means that further inpatient neonatal specialist care is required.

**The Apgar score is only one measure of newborn well-being and, especially if the second Apgar score after the end of resuscitation is < 7, or there are other concerns related to Hypoxic Ischaemic Injury such as poor feeding and seizures, there should be further checks over the coming days, weeks and months to assess the baby's development and implement measures to improve development if this is delayed.**

Resuscitation of the newborn Infant MCAI version: see UK and European Resuscitation Councils' versions, especially if preterm <32 weeks



Resuscitation Council UK

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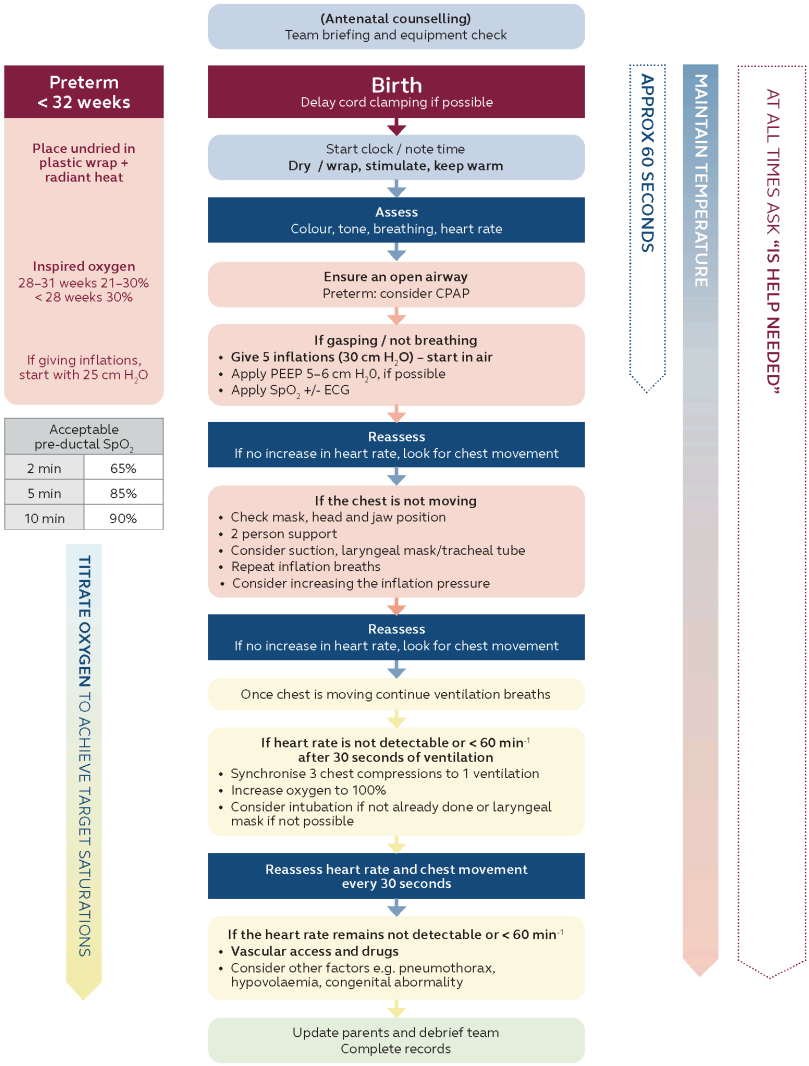
# Newborn life support



## Section 2 Immediate care of the newborn infant

**Management at delivery of a baby not needing resuscitation**

1. Deliver the baby on to the mother's abdomen or a warm surface, dry and cover.
2. Clamp cord when pulsation stopped, usually between 1 and 2 minutes after birth
3. Prevent hypothermia by nursing skin to skin.
4. Initiate early/immediate breastfeeding.
5. Minimise infection by hand washing, cord care and using clean materials.
6. Give an injection of vitamin K (see below for details)

Most babies do not need any resuscitation at birth but only require basic care to prevent infection and hypothermia. Extensive mouth suction, facemask oxygen, and vigorous stimulation in order to provoke a first gasp or cry are unnecessary rituals without clinical justification. As long as the baby becomes pink, and starts to breathe without distress, most babies should stay with their mothers and have a first feed at the breast within minutes of birth.

Colostrum, the initial milk with a clear, yellowish and thick appearance, is an extremely nutritious and concentrated feed rich in immunoglobulins (it is only present during the first 3 to 4 days). Mothers should be informed of its benefits and that it is ideal for their baby to feed on this as soon after birth as possible and as frequently as possible.

***Preventing heat loss after birth***

1. Once any necessary resuscitation process has finished and as soon as the baby becomes pink, and starts to breathe without distress, give to the mother for skin-to-skin contact and the first feed at the breast. This not only prevents hypothermia but also helps better uterine contraction following delivery.
2. The practice of using water or oil to clean the skin within a few hours of birth before the body temperature has stabilised can make the baby dangerously hypothermic. A simple drying of the skin with a warm towel or sheet is all that is required.
3. The mother's own body is the most effective source of warmth, so long as the baby is first well dried to minimise evaporative heat loss. A larger sheet or blanket can then be used to protect both mother and baby from the convective heat loss caused by draughts.
4. Babies have relatively large heads. Covering the head with a shawl, blanket or woollen cap can reduce heat loss.
5. Heat and water loss through the skin can be a particular problem in babies born before 32 weeks' gestation. This can be limited initially by wrapping all but the face in a clean plastic wrapping such as cling film or a food- grade plastic bag with a hole cut in the end of the bag for the baby's head to protrude, for a few hours after birth. **Remember that plastic over the face can cause death from suffocation.** If plastic bags or cling film are not available, the preterm baby must be wrapped well in a clean towel or blanket. However, plastic bags are very good for preventing heat loss, but only in conjunction with an overhead heat source or heated mattress.
6. If neither an overhead heater or heated mattress are available, preterm infants are best cared for by skin to skin care. If the mother is too unwell to apply continuous skin-to-skin care then a relative or even a staff member can contribute.
7. Heat supplementation can be provided by incubators, overhead heating systems, but most effectively in low resource settings by skin-to-skin (kangaroo) care.
8. The first bath must be delayed for at least 24 hours and ideally for much longer.

***Managing the placenta, cord and umbilical stump***

Babies often become relatively anaemic 4 to 6 months after birth because red cell production does not keep pace with body growth. This problem can be minimised by ensuring that blood intended for the baby is not left in the placenta at birth.

If the baby is held higher than the placenta (i.e. on the mother's abdomen) while the cord is still pulsating, blood will drain out of the baby and into the placenta, so hold the (covered) baby just below the placenta for 1-2 minutes if the cord is still pulsating. If the cord is clamped before it stops pulsating, this will also reduce the normal 'placental transfusion' at birth, especially if the uterus has not yet contracted.

Do not artificially 'milk' blood from the placenta into the baby, it is possible to leave the baby with so many red cells that the blood becomes thick and polycythaemic. Neonatal polycythaemia (see Section 17) has many complications, including putting the circulation under strain, making the capillary circulation very sluggish, and increasing the risk of jaundice.

The cord must be cut cleanly, and the cut stump secured in a manner that minimises the risk of late haemorrhage.

The umbilical stump will shrink as it dries out. Plastic clamps that shut down further as the cord starts to shrink are very effective. They are relatively inexpensive, and they do make it possible to cut the stump about 2–4 cm from the skin. An elastic band, if carefully applied, is a cheap and well-tested alternative. A stump that is left too long provides a reservoir where bacteria can breed and multiply with great speed, and therefore should not be permitted. A length of 2–4 cm is ideal.

Recent studies in resource-limited countries have shown that for home deliveries the application of 4% chlorhexidine solution immediately after birth can prevent omphalitis. Other possible antiseptics include surgical spirit or iodine.

Often the cord manifests a little 'stickiness', which may be of no concern. However, a local antiseptic should be applied if a red skin flare suggests early spreading staphylococcal cellulitis. Such babies **must also be given** an oral anti-staphylococcal antibiotic (cloxacillin or flucloxacillin). If the skin around the stump becomes oedematous with increasing redness, IV cloxacillin or oral flucloxacillin (25 mg/ kg twice daily up to 7 days age, three times daily 7-20 days) must be given. Babies who are systemically unwell always need urgent broad-spectrum antibiotic treatment, IV or IM, for septicaemia.

Ensuring that all mothers receive at least two injections of tetanus toxoid 1 month apart during pregnancy can eliminate the risk of neonatal tetanus.

*The risk of cross-infection during or after birth*
The WHO estimates that infection is responsible for one-third of all neonatal deaths (over 3000 deaths a day). Kangaroo (skin to skin) mother care has significantly reduced the number of neonatal deaths from infection by colonising babies with the mother's bacteria rather than those of the hospital.

**The baby at risk of developing problems at or soon after birth**

**1. Newborn infants who are at high risk of infection**

It is important to identify babies at risk of infection prior to delivery. If identified, the mother should be given antibiotics. Many of the babies who become infected during delivery develop respiratory signs very soon after birth, but in a few, the features are those of neonatal sepsis. In addition, there are a proportion of babies who are initially asymptomatic, and therefore prophylactic antibiotics should be commenced immediately after birth in the infant if there are risk factors for infection during pregnancy or delivery.

*When to consider antibiotics for the mother and new-born infant*

1. Symptomatic ascending infection in pregnancy or during delivery needs urgent treatment. If this is overlooked, both the mother's and the baby's life will be in danger. At birth start IV antibiotics in the newborn baby.
2. Asymptomatic infection is, however, a much commoner problem. This occasionally progresses so rapidly once labour starts that, unless treatment is started at once, the baby will die even if the most appropriate antibiotic is given immediately after birth. Because such infection by definition is silent, it is important that treatment be considered in any mother going into active spontaneous labour before 35 weeks' gestation.
3. Membrane rupture can be both a sign of and a risk factor for, ascending bacterial infection. What most people mean by premature rupture of membranes (PROM) is really preterm pre-labour rupture of membranes (PPROM), where the membranes rupture before there is any overt sign of uterine activity or any detectable uterine contractions. When this happens in the preterm baby, it is often a sign of the start of some sort of ascending infectious process. This process has already weakened the amniotic membranes and may stimulate the onset of preterm labour. Antibiotics must be given to the mother.
4. Treatment of the mother with antibiotics should also be considered **at any gestation** if the mother's membranes rupture more than 18 hours before delivery. If premature rupture of membranes occurs before the onset of premature labour contractions then infection is more likely.

Maternal fever (> or = to 37.5°C) in labour is a strong indication for initiating antibiotics for the mother. Similarly, foul-smelling or purulent liquor requires IV antibiotic treatment of the newborn from birth without waiting for any signs of infection.

In mothers with PPROM who have signs of being clinically infected always give IV antibiotics.

In Preterm Prelabour Rupture of Membranes, PPROM, where there is no evidence of infection and no evidence of labour you can delay delivery by 1 week or more (on average) by giving the mother oral amoxicillin or, better still, erythromycin.
In mothers who are in active labour 5 or more weeks before term and who give a clear history that the membranes had ruptured before they were able to detect any uterine contractions, the risk of the baby becoming infected during delivery can be reduced substantially by giving antibiotics IV (ideally probably both penicillin and gentamicin) during labour.

*Antibiotic management of perinatal infection*
Where facilities allow, a blood count, C-reactive proteins and blood cultures should be taken before starting antibiotics. However, do not wait for the results before starting if there is a risk of neonatal sepsis (see above). Because a range of bacteria can be involved, treatment of the baby needs to protect against group B streptococcal, coliform and Listeria infection, making a combination of ampicillin and gentamicin the best strategy:

Give ampicillin 30 – 60 mg/kg IV 12-hourly **plus** gentamicin 5 mg/kg every 36hrs up to 7 days age, then every 24 hours IV if more than 32 weeks' gestation, and 4 mg/kg if less than 32 weeks (Table 14.1)

WHO recommends that a neonate with risk factors for infection (i.e. membranes ruptured > 18 hours before delivery, maternal fever > 38°C before delivery (MCAI recommends >37.5°C or during labour, or foul-smelling or purulent amniotic discharge) should be treated with prophylactic antibiotics (IM or IV ampicillin and gentamicin) for at least 2 days. After this the neonate should be reassessed and treatment continued only if there are signs of sepsis (or a positive blood culture).

**2. Problems associated with preterm birth:**

1. Increased risk of infection
2. Increased risk of hypothermia
3. Nutritional difficulty. Breast milk is ideal, and everything possible should be done to help the mother sustain her lactation until the baby is ready to feed reliably from the breast. A limited ability to suck and swallow usually appears from 32 weeks' gestation, but it remains unpredictable, unreliable and uncoordinated until 36 weeks' gestation. In the event that breastfeeding cannot be initiated immediately after birth, mothers should be encouraged to start expressing breast milk, to be given by nasogastric tube or cup and spoon.

   Partial breastfeeding can also help the mother to sustain her lactation, but in any event the mother should regularly express milk. Some mothers might find expressing breast milk difficult and may require help with this.

**3. Prevention of hypothermia (see Section 5)**

Hypothermia seriously increases the risk of surfactant deficiency and hypoglycaemia and must be avoided.

**4. Vitamin K prophylaxis against haemorrhagic disease of the newborn**

Following resuscitation/stabilisation, all new-born infants should receive vitamin K 1 mg IM. Vitamin K is given to prevent Haemorrhagic Disease of the New-born (HDN), which may cause significant bleeding and even death. The IM route is preferred as it provides a depot over many weeks. Similarly, neonates requiring surgery, those with birth trauma, preterm infants and those exposed in utero to maternal medication that is known to interfere with vitamin K, are at especially high risk of bleeding and must be given vitamin K 1 mg IM. This is often forgotten in the rush to get infants who have needed resuscitation into the neonatal unit.

**5. High risk infants related to illnesses in the mother (see also Sections 8, 9, 11, 12, 13)**

**The infant of a diabetic mother**

If a diabetic mother is poorly controlled, her infant may be large for gestational age, putting him or her at risk of slow progress in labour and perhaps shoulder dystocia. At birth, the infant, although large, behaves in a similar manner to a preterm infant. There is a major risk of hypoglycaemia, caused by the intrauterine over-stimulation of the infant pancreas to produce abnormally high levels of insulin. The infant must be monitored at least hourly for hypoglycaemia in the first 6 hours and should then be monitored 4-hourly for hypoglycaemia, which should be treated as described in Section 22 with an infusion of 10% dextrose. The infant of a diabetic mother has immature lung maturation and is liable to surfactant deficiency (*see* Section 15), poor feeding and jaundice. Polycythaemia is also more likely (Section 17).

**The infant of a mother who is dependent on alcohol or drugs of addiction**

These infants have been exposed to significant levels of narcotic drugs or alcohol *in utero*, causing an increased risk of congenital abnormalities and of abnormal neurological development and behaviour during childhood. Soon after birth they may show hyper-irritability and convulsions, requiring treatment and gradually reducing sedation as they are 'weaned off' the addictive drugs to which they have been exposed (see Section 25). These infants are also at risk of having been exposed to blood-borne viruses such as HIV (Section 13) and hepatitis B and C.

## Section 3 Hospital care for all neonates, especially those born preterm and low birth weight

**Prematurity and low birth weight**
A low-birth-weight infant is one weighing less than 2.5 kg at birth. Low birth weight may be attributable to preterm delivery or intrauterine growth restriction.

A preterm infant is one born before 37 completed weeks have elapsed since the first day of the last menstrual period (259 days). Most preterm infants are born after 32 weeks' gestation.

A small-for-gestational age (SGA) infant is one whose birth weight falls below the 10th percentile on a birth weight centile chart.

Probably at least 25% of SGA infants are just constitutionally small by virtue of maternal weight, and not secondary to poor placental perfusion. The mean birth weight of infants born to mothers 4 feet 10 inches (147 cm) tall is about 500 grams less than that of infants born to mothers 6 foot 0 inches (183 cm) tall. This discrepancy increases to about 1 kg if extremes of mid-pregnancy weight are also taken into account.

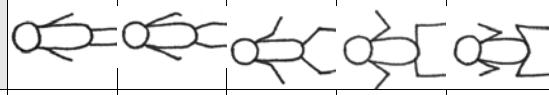
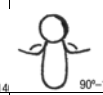
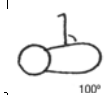
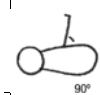
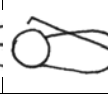
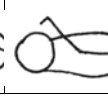
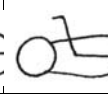
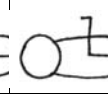
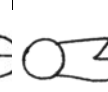
Intrauterine growth restriction (IUGR) refers to a slowing of fetal growth velocity. Most but not all IUGR infants are SGA at birth. Some IUGR infants are wasted.

A large-for-gestational age (LGA) infant is one whose birth weight is greater than the 90th percentile on a birth weight centile chart.

For most clinical purposes it is sufficient to classify infants as 'low birth weight', 'preterm' or 'small-for- gestational age'.

**Assessing gestational age**
Sometimes a mother cannot recall the date of her last menstrual period. The infant's gestational age can then be assessed to within ± 2 weeks based on a combined physical and neurological score.

**TABLE 3.1 Ballard's** physical and neurological scoring system for gestational assessment

| Sign | Neurological criteria score | | | | | | | Sign score |
|---|---|---|---|---|---|---|---|---|
| | –1 | 0 | 1 | 2 | 3 | 4 | 5 | |
| Posture | |  | | | | | | |
| Square window |  >90° |  90° |  60° |  45° |  30° |  0° | | |
| Arm recoil | |  180° |  140°–18 |  110°–14 |  90°–110 |  <90° | | |
| Popliteal angle |  180° |  160° |  140° |  120° |  100° |  90° |  <90° | |
| Scarf sign |  |  |  |  |  |  | | |
| Heel to ear |  |  |  |  |  |  | | |
| Total neuromuscular score | | | | | | | | |

**Notes on calculating the scores:**

**Posture**: With the infant supine and quiet, score as follows:

- Arms and legs extended = 0
- Slight or moderate flexion of hips and knees = 1
- Moderate to strong flexion of hips and knees = 2
- Legs flexed and abducted, arms slightly flexed = 3
- Full flexion of arms and legs = 4.

**Square window:** Flex the hand at the wrist. Exert pressure sufficient to get as much flexion as possible. The angle between the thumb and the anterior aspect of the forearm is measured and scored:

- > 90° = –1
- 90° = 0
- 60° = 1
- 45° = 2
- 30° = 3
- 0° = 4.

**Arm recoil:** With the infant supine, fully flex the forearm for 5 seconds, then fully extend by pulling the hands and release. Score the reaction:

- Remains extended 180°, or random movements = 0
- Minimal flexion, 140–180° = 1
- Small amount of flexion, 110–140° = 2
- Moderate flexion, 90–100° = 3
- Brisk return to full flexion, < 90° = 4.

**Popliteal angle**: With the infant supine and the pelvis flat on the examining surface, the leg is flexed on the thigh and the thigh is fully flexed with the use of one hand. With the other hand the leg is then extended and the angled scored:

- 180º = –1
- 160º = 0
- 140º = 1
- 120º = 2
- 100º = 3
- 90º = 4
- < 90º = 5.

**Scarf sign**: With the infant supine, take the infant's hand and draw it across the neck and as far across the opposite shoulder as possible. Assistance to the elbow is permissible by lifting it across the body. Score according to the location of the elbow:

- Elbow reaches or nears level of opposite shoulder = –1
- Elbow crosses opposite anterior axillary line = 0
- Elbow reaches opposite anterior axillary line = 1
- Elbow reaches midline = 2
- Elbow does not reach midline = 3
- Elbow does not cross proximate axillary line = 4.

**Heel to ear**: With the infant supine, hold the infant's foot with one hand and move it as near to the head as possible without forcing it. Keep the pelvis flat on the examining surface. Score as shown in Table 3.3.1 above.

After assigning the score for the physical and neurological criteria, the sum of the two scores is then used to assess the gestation based on Table 3.1.

**TABLE 3.2**
Assessment of gestation from total score. Note that wasted Small for Gestational Age infants underscore on physical criteria

| Total score | Gestational age (weeks) |
|---|---|
| –10 | 20 |
| –5 | 22 |
| 0 | 24 |
| 5 | 26 |
| 10 | 28 |
| 15 | 30 |
| 20 | 32 |
| 25 | 34 |
| 30 | 36 |
| 35 | 38 |
| 40 | 40 |
| 45 | 42 |
| 50 | 44 |

***Low birth weight and/or preterm infants***

Low birth weight is an important predictor of newborn health and survival.
WHO definitions of low birth weight are as follows:

| | |
|---|---|
| Low birth weight | < 2,500 g |
| Very low birth weight | < 1,500 g |
| Extremely low birth weight | < 1,000 g |

**Infants with birth weight in the range 2.25–2.5 kg**

These infants are normally strong enough to start feeding themselves. They need to be kept warm and closely observed for infection, but otherwise no special care is required.

**Infants with birth weight in the range 1.75–2.25 kg**
These infants sometimes need extra care but can normally stay with their mothers to receive feeding and warmth, especially if skin-to skin contact can be maintained. Close monitoring by a healthcare worker is required.

Feeds can be started within 1 hour of delivery. Many of these infants will be able to suck and can be breast- fed. Those who cannot breastfeed should be given expressed breast milk with a cup. When the infant is sucking well from the breast and gaining weight on a daily basis, they can be weaned off cup feeds.

These infants should be reviewed at least twice a day to assess their feeding ability, fluid intake and the presence of any danger signs including signs of serious bacterial infection. Such problems will necessitate close monitoring in a neonatal nursery (if available) in a similar way to the very low birth weight infant. The risk of keeping the infant in hospital (including hospital-acquired infections) should be considered.

**Infants with birth weight below 1.75 kg**
These infants are at risk of hypothermia, apnoea, hypoxaemia, sepsis, feed intolerance and necrotising enterocolitis. The smaller the infant, the greater these risks. All infants with a birth weight below 1.75 kg should be admitted to a special care or neonatal intensive care unit (if available).

**Treatments often needed for low-birthweight and/or preterm infants**

**Oxygen**
Oxygen should be administered via nasal cannulae, nasal prongs or a head box if there are signs of respiratory distress, such as moderate to severe recession (preterm infants may show mild recession with normal breathing), and definitely in the presence of cyanosis. (See Section 33: Advanced life support)

Pulse oximetry to measure oxygen saturation is a vital part of oxygen usage in the preterm infant. Retinopathy of prematurity (ROP), previously known as retrolental fibroplasia, which leads to lifelong blindness in many cases, maybe related to high blood levels and/or fluctuating levels of oxygen saturation in the preterm infant, particularly in those below 30 weeks' gestation. However, there is no good evidence for the optimum oxygen saturation for preterm infants. On the one hand it is important to avoid hypoxaemia, which could lead to brain damage and pulmonary vasculature changes and on the other hand unrestricted oxygen may cause ROP, which could lead to blindness. The main way forward, in the view of MCAI, is to avoid $SpO_2$ levels above 98% when any neonate is receiving additional inspired oxygen.

MCAI's advice on oxygen management is that the infant at or before 32 weeks' gestation or weighing less than 1000 grams at birth should have a target oxygen saturation of 92-94%, and older than 32 weeks' gestation babies 94-98%.

**Prevention of hypothermia (see Sections 5 and 35)**
To prevent hypothermia, nurse the infant in skin-to-skin contact between the mother's breasts ('skin to skin care') or clothed in a warm room, or in an incubator. A hot water bottle wrapped in a towel can be useful for keeping the infant warm if no power for heating is available but take care not to burn the infant.

Aim for an axillary temperature of 36.5–37.5°C, with the feet warm and pink. When the mother is asleep or if she is ill, a clean incubator can be used. Incubators should be washed with disinfectant between infants and should be of a basic design that can be used appropriately by the staff available.

**Safe fluid management**

It is best to give fluids enterally rather than IV. However, if the infant is not well enough (e.g. due to severe respiratory distress), give IV fluids (see Section 15). Initially, consider giving approximately 2–4 mL of expressed breast milk every 1 to 2 hours through a nasogastric tube. This can be adjusted depending on the weight and the amount of IV fluids that the infant is receiving. With increasing age and weight gradually increase the volume and timing of each feed (the maximum time interval between feeds should not exceed 4 hours). The total fluid intake of enteral feeds plus IV fluids per 24 hours should adhere to the following fluid management guidelines:

60 mL/kg on day 1
80–90 mL/kg on day 2
100–120 mL/kg on day 3
120–150 mL/kg on day 4
150–180 mL/kg thereafter

Some infants can be fed with a cup. Use only expressed breast milk if possible. If 2–4 mL per feed is tolerated (i.e. there is no vomiting, abdominal distension, or gastric aspirates of more than half the feed) the volume can be increased by 1–2 mL per feed each day. Ideally, aim to have feeding established in the first 5 to 7 days so that the IV fluids can be tapered off. Reduce or withhold feeds if signs of poor tolerance occur. As the infant grows, recalculate the feed volume based on the higher weight. Feeds may be increased over the first 2 weeks of life to 150–180 mL/kg/day based on a 3- to 4-hourly feeding pattern.

**How to give gastric feeds (see also Section 46 on gastric tube placement)**

Place the baby's lips on the breast even though he or she is unable to suck or attach before each feed. Place expressed breast milk (EBM) in the syringe. Only use fresh milk or milk that has been stored in a refrigerator, and that has not been out of the fridge for more than 1 hour in a hot climate.

Check that the tube is in the stomach before every feed or every administration of enterally given drugs. Also check that there is not more than 10% of the previous feed in the stomach by very gentle aspiration (suction) using a 2- or 5-mL syringe. Too vigorous/strong suction can damage the lining of the stomach. Connect the syringe containing EBM and remove the plunger, giving the milk by gravity over 10–15 minutes per feed. Only if the feed does not flow in should you gently push with the plunger for a few seconds only to get it started. Never push the whole feed in. Observe the infant closely during the feed for signs of respiratory distress that might be due to lung aspiration. Replace the tube every 7 days, or sooner if it is blocked.

Give enteral feeds only if there is no abdominal distension or tenderness, bowel sounds are present, meconium has been passed, and there is no apnoea, low aspirates, no vomiting and adequate stool output.

Monitor the fluid intake by weighing the infant daily and recording the frequency of urine output. **A urine volume of 2-4ml/kg/hour suggests normal hydration.**

To weigh the baby, first place a blanket in the scales, set them to zero and then place the baby naked in the scales and cover the infant with the blanket to keep them warm.

Fluid intake may need to be adjusted frequently to maintain fluid balance. Urine output can be monitored by measuring the difference between wet nappies (diapers) and a dry one using accurate scales. Generally, expect at least eight wet nappies in a 24-hour period. Look out for signs of fluid overload (oedema) or dehydration. If possible and available, measure the plasma electrolytes, but remember that these cannot be interpreted without information on body weight and urine output.

**TABLE 3.3 Guide to volumes of each feed given every 3–4 hours at different infant weights**

| | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 | Day 8 |
|---|---|---|---|---|---|---|---|---|
| Total (mL/kg/day) | 60 | 80 | 100 | 120 | 140 | 150 | 160 | 170 |
| 1.25–1.4 kg | 10 | 15 | 18 | 20 | 22 | 24 | 25 | ≥ 26 |
| 1.5–1.9 kg | 15 | 17 | 19 | 21 | 23 | 25 | 27 | ≥ 27 |
| 2.0–2.4 kg | 20 | 22 | 25 | 27 | 30 | 32 | 35 | ≥ 35 |
| ≥ 2.5 kg | 25 | 28 | 30 | 35 | 35 | ≥ 40 | ≥ 45 | ≥ 50 |

***Enteral feeding for the newborn infant in hospital***

***Type of milk***

Breast milk will provide the nutrients required by almost all infants.

However, for preterm and low birthweight infants the following supplements are needed and recommended by WHO and below slightly differently by MCAI:

***Recommendations on vitamin and mineral supplements***

***1. WHO recommendations on Vitamin A and zinc supplements***

NOTE: WHO recommendations below do not address sick infants or infants with birth weights less than 1.0 kg (VLBW). These recommendations specifically and only address those infants with birth weights between 1.0 and 1.5 kg.

*Daily oral vitamin A supplementation* for LBW infants who are fed mother's own milk or donor human milk is not recommended at the present time, because there is not enough evidence of benefits to support such a recommendation.

*Routine zinc supplementation* for LBW infants who are fed mother's own milk or donor human milk is not recommended at the present time, because there is not enough evidence of benefits to support such a recommendation.

**2. MCAI recommendations on vitamin and mineral supplements**

**Vitamin D supplements in general**

Term breastfed infants generally do not need extra vitamin D. However, this is only true if the mother has an adequate vitamin D status. Maternal vitamin D deficiency during pregnancy and lactation is common in resource-limited countries, contributing to the low vitamin D content of breast milk. Newborn infants of mothers who have dark skin or wear concealing clothes are also at greater risk of vitamin D deficiency at birth.

Large amounts of calcium and phosphorus are transferred from the mother to the infant during the last 3 months of pregnancy, helping the infant's bones to grow. Therefore, a preterm infant may not receive sufficient amounts of calcium and phosphorus for this purpose. Vitamin D helps the

body to absorb calcium from the intestines and kidneys. Very preterm infants require adequate vitamin D supplements. Liver problems such as cholestasis and prolonged use of diuretics or steroids may also cause problems with blood calcium levels.

Therefore, without further supplementation, preterm and also some full-term breastfed infants may be at risk of vitamin D deficiency. This risk may be minimised either by supplementing the mother with large amounts of vitamin D (4000 IU/day) during pregnancy and lactation, or by supplementing the infant (400 IU/day) during the period of lactation.

VLBW infants should be given vitamin D supplements at a dose ranging from 400 IU to 1000 IU per day until 6 months of age. (IU = international unit).

**Calcium and phosphorus supplements** VLBW infants who are fed mother's own milk or donor human milk should be given daily calcium (120–140 mg/kg per day) and phosphorus (60–90 mg/kg per day) supplementation during the first months of life.

**Iron supplements** VLBW infants fed mother's own milk or donor human milk should be given 2–4 mg/kg per day iron supplementation starting at 6 weeks until 6 months of age.

**Phosphorus supplements**

These may be needed in the case of very small infants, who can become hypophosphataemic (i.e. with plasma phosphorus levels of < 1.5 mmol/litre). If untreated, this may result in metabolic bone disease. The addition of a concentrated phosphorus salt (50 mg/kg/day of phosphorus) to feeds will prevent this. Adding 0.05 mL/kg of a 4 mmol/ mL phosphorus solution to each of eight feeds per day will give 50 mg/kg/day of supplemental dietary phosphorus.

**Vitamin A supplements**

In resource-limited countries, vitamin A supplementation of the newborn infant reduces mortality. Preterm infants and VLBW or LBW infants are at high risk of vitamin A deficiency. This important subgroup of our infant population is not only born with inadequate body stores of vitamin A but is also often unable to tolerate routine oral supplementation. Vitamin A supplementation programmes significantly reduce infant mortality as well as the incidence of xerophthalmia, respiratory infection, and morbidity from gastrointestinal disease. Oral supplementation of 4000 IU/kg/day has been recommended for very-low-birth-weight (VLBW) (<1500 grams at birth) infants from establishment of full enteral feeding until discharge from the neonatal unit.

Supplementing all full-term newborn infants with oral vitamin A (100 000 IU as a single dose) within 48 hours of birth reduces infant mortality by almost 25%, with those of low birth weight deriving the greatest benefit. Alternatively, a single dose of 200,000 IU can be given to all postpartum mothers within 6 weeks of delivery, when the likelihood of pregnancy is very low, and when infants benefit most from the presence of vitamin A in breast milk.

**Vitamin K supplements**

All neonates should be given vitamin K 1 mg IM within 1 hour of birth.

Those neonates who require surgery, those with birth trauma, those who are preterm and those exposed before birth to maternal medication (that can interfere with vitamin K) are at high risk of bleeding and must be given vitamin K. If the need for surgery only becomes apparent sometime after birth, we suggest that **a repeat dose should be given before surgery.**

**Multivitamin preparations**

A multivitamin preparation (preferably containing adequate vitamins A and D) for preterm infants may be commenced from 3 weeks of age. A supply of vitamin D (400 IU/day) is particularly important for bone mineralisation.

**Iron supplements**

Iron supplements for preterm infants are usually commenced from about 6 weeks of age. Preterm infants have reduced iron stores compared with term infants, especially if the umbilical cord is clamped early. The daily dietary iron supplementation is 2–4 mg/kg of elemental iron, up to a maximum of 16 mg/day.

### *Breast milk banking*

WHO recommends that low-birth-weight babies who cannot be fed their own mother's breast milk should receive donor milk. The high maternal mortality and morbidity in low-income countries mean that there are many infants who cannot be put to the breast within a few hours of birth, and donor milk is suitable for them. In addition, there is evidence that human donor milk reduces the incidence of severe infection and Necrotising Entero-Colitis (NEC) in low-birth-weight babies, compared with formula milk.

It is possible to establish safe donor milk banks in resource-limited settings, provided that there is a microbiology laboratory able to process donor samples, and a reliable power supply to keep the banked milk frozen. A nurse or other staff member must be trained in good hand hygiene, and the importance of labelling and storage. Only simple equipment is needed.

Milk can be collected from lactating mothers who are known to have tested negative to HIV and syphilis and are non-smokers. Ideally, they should also have also been screened for hepatitis infections. Milk is collected by hand expression under supervision (as 'drip milk' is lower in calories than expressed milk). A 1-mL aliquot from each donor's sample is sent to the microbiology lab. If colony-forming organisms are grown, the whole sample is discarded. Milk can be stored in a refrigerator while awaiting the microbiology results.

Milk is pasteurised by heating for 30 minutes at 62.5°C, and then cooled and frozen. Pasteurised frozen milk can be stored for up to 6 months from the date of collection.

Supplementary formula feeding for the infants of mothers who cannot provide breast milk, or whose mothers have died, may be needed after discussion with the infant's carers.

### Electrolyte requirements when giving IV fluids

**Sodium requirements**

Infants over 48 hours of age need some sodium supplementation in a dose of 2–3 mmol/kg/day. This can most easily be given by adding 20 mL/kg of normal saline (0.9%) to the daily requirement of 10% glucose to make up the total daily fluid volume needed. This gives approximately 3 mmol of sodium per kg.

Adding sodium is open to many errors. Ready-made neonatal fluids are available in some countries and may be used to avoid this problem in some situations. The sodium requirements of very preterm infants may be much higher as urinary sodium losses may approximate 10 mmol/kg/ day in those of 29 weeks' gestation or less.

Sodium can be commenced on the third day of life (after 48 hours) in infants receiving intravenous fluids, but if there is respiratory distress it is wise to wait until the diuresis, shown by weight loss and associated with *respiratory* recovery begins (this is often delayed until the third or fourth day of life).

**Potassium requirements**

Potassium supplementation in a dose of 1–2 mmol/kg/ day will meet requirements and can be provided by adding mathematically correct and small amounts of potassium chloride to a 10% glucose fluid. **However, if IV potassium is given, the plasma potassium concentration must be monitored daily**. Potassium can be added to IV fluids but this MUST be done very carefully. Remember that too much IV potassium can be fatal. The concentration of KCl in peripheral IV solutions should never exceed 40 mmol/litre. Do not add KCl until the urine output is well established.

**Remember that it is best to give potassium and calcium supplements orally, unless very low serum values are identified.**

**Glucose requirements**

Infusing glucose at the following rates will match the normal hepatic glucose output and therefore maintain the blood glucose concentration at an acceptable level:

- term infant: 3–5 mg/kg/minute
- preterm, appropriate weight for gestation: 4–6 mg/kg/ minute
- small for gestational age: 6–8 mg/kg/minute.

A solution of 10% glucose at 60 mL/kg/day will give 4 mg (0.22 mmol) glucose/kg/minute.

These infusion rates provide minimal glucose requirements to maintain a normal blood glucose level, but higher rates will be required for growth.

Consider hyperinsulinism as a cause of the problem if an infant requires higher rates of infusion to maintain normal blood glucose levels. Always use 10% glucose/dextrose for peripheral IV infusions; an umbilical venous catheter will be needed if higher than 10% glucose requirements or limits on fluid volume necessitate a more concentrated solution (which can be damaging to thin peripheral veins).

**Composite maintenance fluid**

An alternative way to make a simple composite maintenance fluid is by adding the following to give a total volume of 100 mL:

1. 1/5 dextrose saline (0.18% normal saline with 5% dextrose) = 71 mL
2. 7.4% KCl = 2 mL
3. 10% calcium gluconate = 2 mL
4. 25% dextrose = 25 mL

**Total volume = 100 mL**

Each 100 mL of the above solution would contain dextrose 10%, potassium chloride KCl 2 mEq, Calcium gluconate 2 mEq and sodium chloride 2.5–3 mmol.

Any such mixture must be prepared under sterile conditions.

**KCl must not be added until urine output is well established.**

***Enteral and Intravenous fluid and electrolyte management for the neonate***

*Fluid requirements*

Body water content is high at birth and urine output is low for the first few days. Therefore, giving large volumes of fluid in the first few days may make an infant oedematous and worsen any respiratory disease. A simple general rule is to start an ill newborn infant who cannot take enteral fluids (breast milk) on 60 mL/kg/day IV as 10% dextrose solution, increasing in daily steps of 20–30 mL/kg/day to a maximum of 140–180 mL/kg/day. However, in a small-for-gestational-age infant it may be necessary to begin with 70–90 mL/kg/ day in order to meet the glucose requirements.

When giving fluid or blood intravenously, best practice is to use an in-line infusion chamber/burette to avoid fluid overload or a drop infusion monitor (Sino MDT Ltd. SN-1500H available from Diamedica).

***Calculating drops per minute using a paediatric burette IV giving set (drop factor 60 drops is 1ml of fluid)***

Ideally, use a 100-mL paediatric intravenous burette with a drop factor where 60 drops = 1 mL and therefore 1 drop/minute = 1 mL/hour.
So, for an infant weighing 1.8 kg on day 1: 1.8 × 60 = 108 mL per day
In each hour the fluid will be 108 divided by 24 = 4.5 mL, which with a paediatric burette giving set and drop factor of 60 drops/1 ml is 4.5 times 60 = 270 drops per hour corresponding to 4.5 drops per minute or to 9 drops every 2 minutes.

***Calculating drops per minute using a standard IV giving set burette (drop factor 20 drops is 1ml of fluid)***

Ideally use a drop infusion monitor to ensure safe fluid volumes are given.
If a standard IV giving set is used with a drop factor of 20 drops = 1 ml for the same infant weighing 1.8Kg on day 1 described above then 108 ml per day will still be required which when divided by 24 hours = 4.5ml per hour which with the standard giving set (drop factor 20 drops/ml) is 4.5 times 20 drops = 90 drops per hour or 1.5 drops per minute or 3 drops every 2 minutes.

***Fluid management of the VLBW infant***

The rate of insensible water loss (mainly through the skin) is high in some circumstances, particularly in VLBW infants and those under 29 weeks' gestation especially when an overhead heater (radiant warmer) rather than an incubator or skin-to-skin care is used. Helpful measures for reducing insensible water loss in such cases include the following:

- Place the infant from below the neck in a clean plastic bag to maintain humidity. Maintaining humidity helps to keep very premature infants warm by reducing evaporative heat loss.
- Clothe the infant or wrap the body below the head with bubble wrap or aluminium kitchen foil (with the shiny side facing inward towards the infant).
- When an overhead heater is used, the infant should not be covered, and the heater output must be adjusted in direct response to the infant's skin temperature (typically achieved by a continuous temperature probe servo system). Alternatively, a plastic bag over the infant's body from the neck down can help to preserve heat.

In the first week of life of LBW and VLBW infants, high rates of insensible water loss will be

reflected by high rates of weight loss (more than 10% of birth weight), and often, if it can be measured, an increase in the plasma sodium concentration to 150 mmol/litre or higher. If either occurs, the infant is dehydrated and fluid intake should be increased by 30 mL/kg/day. When nursing any infant under an overhead heater, it is advisable to add an extra allowance of 30 mL/kg/day right from the start (i.e. start on day 1 at 90 mL/kg/day rather than 60 mL/kg/day).

Worsening hypernatraemia can lead to dangerous convulsions (see section 21).
Note that even an additional 30 mL/kg/day might not be enough to meet the insensible losses of a very preterm infant (29 weeks or less) or VLBW infant under a radiant heater. Such infants are much better nursed in closed incubators or even with skin-to-skin care.

In VLBW infants, enteral feeds should be advanced slowly in 20–30 mL/kg/day increments. Infants who are being enterally fed but who are unable to breastfeed can be given expressed breast milk by orogastric tube or cup. A general plan for fluid enhancement is the same as in all neonates regardless of birth weight or gestation and is as earlier described and as follows:

- day 1: 60 mL/kg/day
- day 2: 85 (range 80–90) mL/kg/day
- day 3: 110 (range 100–120) mL/kg/day
- day 4: 135 (range 120–150) mL/kg/day
- day 5 and thereafter: 165 (range 150–180) mL/kg/day.

***Drug use in the newborn infant***
Relatively few drugs are needed to deal with most common neonatal emergencies.
The IV rather than the IM route should be used if the infant is already being given IV fluids, as this will reduce the amount of pain to which the infant is subjected. There are dangers associated with rapid administration or breaking into an existing IV line, leading to an increased risk of sepsis. Erecting an IV line merely to administer drugs also risks exposing the infant to dangerous fluid overload, unless a syringe pump can be used to control the rate at which fluid is infused.

***Preventing and diagnosing infection: neonatal sepsis***
Observe carefully and constantly for infection
**Table 3.4** D*anger signs for infection in all neonates*

**Danger signs associated with infection in the neonate**

**Common danger signs**

- Infant feeding less well than before.
- Infant lying quietly and making few spontaneous movements.
- Hypothermia or fever > 37.5ºC.
- Capillary refill time > 3 seconds.
- Respiratory rate ≥ 60 breaths/minute.
- In-drawing of the lower chest wall when breathing, *or* grunting.
- Cyanosis.
- History of a convulsion.

**Less common but important signs**

- Low respiratory rate (< 20 breaths/minute) or apnoea.
- Jaundice.
- Abdominal distension.

***Hypoglycaemia prevention***
Check blood glucose levels every 6 hours until enteral feeds are established, and immediately if there are any danger signs of infection.

***Apnoea/hypoxaemic episodes*** (See Section 16**)**
Monitor for apnoea, ideally with a pulse oximeter (which are now affordable and available in many resource-limited countries), supplemented by close visual monitoring of the infant by the mother or a close relative.

***Diagnosis and management of breast-feeding difficulties***
Observe closely for these and regularly check with the mother. The MCAI E-Library contains a series of videos to help manage these.

**Discharge and follow-up of low-birth-weight infants**
*Discharge when:*
1. there are no danger signs of serious infection (see Table 3.4 above)
2. the infant is gaining weight (at least 20 grams per day for 3 consecutive days) on breastfeeding alone
3. the infant is able to maintain temperature in the normal range (36–36.5°C axillary) in an open cot or with skin-to-skin care
4. the mother is confident and able to take care of the infant.

***Ensuring appropriate Immunisation***
All neonates should be given all scheduled immunisations by the time of discharge from the health facility or soon after.

***Counsel parents before discharge on:***
- the great importance of exclusive breastfeeding
- keeping the infant warm
- the danger signs that necessitate seeking care (see Table 3.5), plus advice on when to return for healthcare
- basic life-saving actions to use in the event of an emergency, particularly mouth-to-mouth and nose ventilation if prolonged apnoea occurs (especially relevant in preterm/low birth weight infants).

**A full examination should be undertaken on all newborn infants before they are discharged including a search for birth injuries (see below).**

**Birth injuries**

**Swellings around the head**
- The commonest is a caput succedaneum, which is oedematous tissue over the occiput present after a vaginal delivery. This usually resolves within a few days and is of no consequence, requiring no intervention.
- A cephalhaematoma is a lateral (sometimes bilateral) fluctuant swelling, well circumscribed by the sutures. It does not cross the midline and anatomically represents a sub-periosteal haemorrhage. There may be an associated skull fracture, but neither this nor the swelling itself usually needs treatment. The only important complication can be worsening of jaundice as the blood is degraded and reabsorbed. Never aspirate blood from a cephalhaematoma, as this can cause a serious infection.
- A subaponeurotic haemorrhage (bleeding between the skull periosteum and the scalp aponeurosis) is the least common but most dangerous scalp swelling. It represents haemorrhage beneath the aponeurosis of the scalp. Onset and

progression is often insidious, with progressive pallor due to significant haemorrhage. The boggy swelling of the head, extending from above the eyes to the occiput, may only be noticed after the infant has developed hypovolaemic shock. The infant may develop bruising behind the ears and around the eyes. This must be recognised early, as these infants often need urgent transfusion. Injection of vitamin K should be given.

**Nerve palsies**

- Facial nerve palsies are sometimes associated with forceps delivery. They usually resolve within a few days, requiring little intervention.

- Brachial plexus trauma may follow shoulder dystocia or a difficult breech delivery and reflects traction injury to the upper roots of the brachial plexus. The arm is flaccid and the wrist flexed. This can most clearly be demonstrated by eliciting an asymmetric Moro reflex. Look for signs of respiratory distress, as the phrenic nerve on the same side is sometimes affected.

X-ray should be obtained to exclude a pseudo-paresis associated with clavicular fracture or syphilitic osteitis. The humerus should also be included in the X-ray to rule out humeral fractures, which may occasionally be present. Most brachial plexus palsies resolve within 3 to 4 weeks of delivery, but rarely they can be permanent. Once fractures have been ruled out, the mother can be shown how to perform passive movements to reduce the possibility of joint contractures developing. Refer the infant for a surgical opinion if they are not better by 4 weeks.

**Fractures**

The most common types are skull and clavicular fractures. These usually require no specific treatment. However, significant skull fractures must be evaluated for intracranial bleeding. There should also be consideration of whether the injury is a birth- associated one or a subsequently inflicted injury perpetrated by a caregiver.

VLBW and LBW and/or preterm infants should be followed up at regular intervals following discharge for weighing, assessment of feeding, and assessment of general health until they have reached 2.5 kg in weight.

***TABLE 3.5*** Danger signs in discharged newborn infants for parents to be made aware of:

| **Seek advice immediately if any of the following occur** | **Seek advice very quickly if any of the following occur** |
|---|---|
| Convulsion(s), fits or seizures<br>ANY bleeding<br>Severe diarrhoea or vomiting<br>Infant appears unresponsive<br>Severe breathing problems<br>Infant feels cold | Infant refuses feeds<br>Minor diarrhoea or vomiting<br>Minor breathing problems<br>Infant is less active/interested<br>Infant feels abnormally hot<br>Jaundice |

## Section 4. Common problems requiring hospital care

Many emergencies can be prevented by attention to good feeding practices, providing adequate warmth and preventing infection. The more preterm or low birth weight the infant, the more likely it is that the following complications will occur:

- feeding difficulties
- poor temperature control, especially hypothermia
- infection – prevention and early recognition and safe management are essential
- polycythaemia
- respiratory distress and apnoea/hypoxaemic attacks
- bleeding
- jaundice and neonatal anaemia
- reduced conscious level and seizures, including hypoglycaemia
- surgical problems.

### *Feeding difficulties (please see videos on breast feeding in E-Library)*

Infants born after 34 weeks are generally mature enough to suck and swallow well but may be less demanding of feeds than term infants. Attention to the following can help all newborn infants, especially those born preterm, to establish breastfeeding:

- Encourage early and prolonged skin contact.
- Encourage small frequent feeds by waking the infant every 2 to 3 hours and putting them to the breast.
- If the infant will not latch on and suck, the mother can be encouraged to express breast milk and offer it to the infant by cup and/or spoon or if not accepted by orogastric or nasogastric tube.
- If an otherwise well infant on breast milk feeds is experiencing inadequate growth, an inadequate milk supply may be the problem. There are several possible causes for this, which can usually be identified by listening to the mother and then watching the infant feed. A relaxed mother will have a good 'let-down' reflex which gives the infant the more calorie-rich hind milk as well as the fore milk. The mother can tell when she has 'let down' by a tingling feeling in her breasts, and the infant starts to swallow rapidly. The infant must latch on properly for feeding to be successful, and this may need some assistance from the midwife. The best way to increase the milk supply for a hungry infant who is not thriving is to increase the feed frequency. Breast milk works on a demand-and-supply system, so the more the infant demands, the more the breast supplies. If the infant is not feeding vigorously enough to increase the milk supply, the mother should express milk after feeding and give it to the infant as described above.
- Avoid giving formula or breast milk by bottle. A small feeding cup (about the size of a medicine measuring cup, with a smooth rim) or a spoon can be used to feed the infant.
- Give expressed breast milk via orogastric or nasogastric tube if the infant is too unwell to suck or drink from a cup.
- As the infant becomes stronger, encourage a transition to demand breastfeeding.

#### *Specific feeding problems*

1. Ingested meconium/blood. Infants who have swallowed a lot of meconium or blood before birth may vomit and appear distressed after birth. Such problems almost always settle within a few hours without any intervention.

2. Uncoordinated feeding. Infants born before 32 weeks' gestation often have difficulty sucking and swallowing in a coordinated way. Most will initially need some tube feeds. They are not likely to start gaining weight until they are taking at least 120 mL/kg of milk

a day. Infants need to be fed regularly at least once every 4 hours, day and night. Breast milk can be supplemented with formula milk at this time if donor milk is not available. However, every effort needs to be made to sustain the mother's lactation by expression and by keeping the mother in hospital to be near her infant.

3. Regurgitation. (See also paragraph 'Aspiration pneumonia' in Respiratory section 15) Hurried frequent feeding may cause regurgitation. A poorly developed cough reflex can cause the infant to inhale milk into the lung, resulting in possible pneumonitis and even pneumonia. Newborn infants benefit from frequent small feeds every 2 to 3 hours. Feeds should be increased gradually over the first 3 to 5 days of life. Patience is required. Dehydration (and the risk of hypoglycaemia) need to be monitored for and can be prevented during this period by giving supplemental gastric or IV fluids so that total fluid intake (i.e. taking the gastric/IV and the oral intake together) does not fall below 120 mL/kg per day.

4. Feeding tubes. Tube feeding is the best option for infants who have not yet developed a coordinated suck and swallow reflex. Nasogastric tubes are easier to secure and less easily pushed out by the infant's tongue, but they can almost completely block one nostril, potentially significantly increasing the work of breathing. Therefore, orogastric tubes are preferred if respiratory distress is present. Alternatively, a fine-bore nasogastric tube can be left in place and changed as required (up to a maximum of 7 days).

***Minimal handling except by mothers.*** Small frail infants should be handled as little and as gently as possible and can lie undisturbed in their cots during a tube feed so long as the head end of the cot is elevated.

## Section 5 Temperature control and hypothermia prevention and treatment

1. Hypothermia can be due to a cold environment but remember that starvation or serious infection can also present as hypothermia. Low birthweight babies are more at risk.
2. Normal temperatures for newborn infants are 36.5 to 37.5°C (axillary) if measured over 3 minutes, and lower (around 36.0 to 37.0°C) if measured over at least 1 minute. Rectal thermometers are difficult to use and can be dangerous. If the trunk is cold, the infant is almost certainly hypothermic
3. Use a low-reading digital thermometer, not a mercury thermometer. If the axillary temperature is less than 32°C, hypothermia is severe; if it is in the range 32–35.9°C the infant has moderate hypothermia. If the infant's temperature does not register on the normal thermometer, assume that they have hypothermia.

***Hypothermia can be prevented by the following measures:***

a. Dry the infant well immediately after birth and place them in skin-to-skin contact with the mother. This is especially important for low-birth-weight infants who do not have other complications. For those with medical problems, warm the infant by skin-to-skin care. If there are adequate resources and staff, an overhead radiant heater or an air-heated incubator (set at 35–36°C) can be used.

b. Skin to skin mother-care (previously called 'Kangaroo care'') is skin-to-skin contact with the mother, where the baby is placed between her breasts and covered with a blanket. It is the most effective method for all infants, especially for those of low-birth-weight. Randomised clinical trials in both well-resourced and resource-limited countries have shown significant advantages to this technique for the infant and the mother, including an increased prevalence of breastfeeding, a reduced incidence of apneic/hypoxaemic episodes and a reduced risk of infection. Take care when examining the infant not to allow the temperature to fall (ideally room temperature in the hospital ward should be higher than 25°C).

c. A cot heated with a hot-water bottle with the top screwed in tightly and wrapped in a clean towel can be just as effective if the above are not available. Ordinary domestic radiant heaters or electrical blower type heaters can also be effective.

d. Cover the infant's head with a warm woollen hat and dress them in warm, dry clothes.

e. Keeping the nappy/diaper dry is also very helpful.

f. Avoid washing the infant before 24 hours of age, unless the mother is HIV+ve.

g. Do not leave the infant where there are any draughts.

h. The infant should sleep either with or next to the mother during the night.

4. Avoid overheating by monitoring the axillary temperature 4- to 6-hourly.

5. Feed the baby 2-to 3-hourly and continue with 4-hourly feeds during the night.

7. The development of incubators earlier in the twentieth century significantly reduced the mortality of preterm infants, but they are expensive, and require regular maintenance, thorough cleaning, and sufficient numbers of trained staff. The nursing of infants in incubators is covered by standard texts, but Table 5.1 gives the settings from which to start, adjusting the incubator temperature up or down to maintain the infant's axillary temperature at 36.0–36.5°C.

***TABLE 5.1*** Incubator temperature guidelines

| Weight of baby (grams) | Day 1 | Day 2 | Day 3 | Day 4 and subsequently |
|---|---|---|---|---|
| <1200 | 35.0°C | 34.0°C | 34.0°C | 33.5°C |
| 1200–1500 | 34.0°C | 34.0°C | 33.5°C | 33.5°C |
| 1500–2500 | 33.5°C | 33.0°C | 32.0°C | 32.0°C |
| >2500 | 33.0°C | 32.5°C | 31.0°C | 30.5°C |

8.. Do not use antipyretic drugs to control fever in a newborn infant. Instead control the environment (e.g. remove some clothes, adjust incubator temperature) and always consider the possibility of serious infection.

## Section 6. Prevention of neonatal infection

A newborn infant with risk factors for infection (membranes ruptured more than 18 hours before delivery, Preterm Pre-labour Rupture of Membranes PPROM, mother with fever 37.5°C or more before delivery or during labour, or foul- smelling/purulent amniotic fluid) should be treated with prophylactic antibiotics (ampicillin plus gentamicin IM or IV) immediately at birth and for at least 2 days. After 2 days the infant should be reassessed, and treatment continued if there are signs of sepsis (or a positive blood culture).

**Simple measures that can prevent infection in the newborn include the following:**

- Ensure a clean delivery environment for the mother and infant, including disinfectant cream for all maternal vaginal examinations (e.g. Chlorhexidine cream).
- Good cord care: the WHO recommends that the cord be kept clean and dry. It should not be covered. Local applications of creams, ointments, etc. are generally not required except in high-risk settings, where application of an antiseptic is recommended. An antiseptic solution or cream such as 4% chlorhexidine has recently been shown to reduce omphalitis and resulting neonatal mortality. It should be applied immediately after birth and for several days thereafter, if possible, preferably after every nappy change. There is also extensive successful experience with the application of surgical spirit or iodine solution to the cord.
- Exclusive breast feeding.
- Strict procedures for hand washing or the use of alcohol-based hand sprays or hand rubs for all staff and for families before and after handling infants.
- Cleaning incubators with an antiseptic before use (if skin-to-skin mother care is not possible).
- Strict sterility for all invasive procedures.
- Sterile injection practices.
- Removing intravenous cannulae when they are no longer necessary.
- Keeping invasive procedures (e.g. blood sampling, IV cannulation) to a minimum, only undertaking them when they are essential.

## Section 7. The baby with an Infection: neonatal sepsis

**Introduction**
A third of all deaths in the first month of life in most resource-limited countries are caused by infection. The most severe of these are bacterial meningitis and / or bacterial sepsis. Identification of the early signs of infection is difficult and many babies initially have subtle signs and symptoms. Infants, especially preterm infants, are very prone to infection and can become ill very rapidly once infection takes hold. Early treatment with intravenous antibiotics is vital to prevent death or severe long-term disability.

A WHO study found that more than 80% of these infants, when first seen, had one or more of the following eight danger signs:

**Table 7.1. WHO 8 danger signs in the neonate**

| | |
|---|---|
| 1. | infant feeding less than well than before |
| 2. | infant lying quiet and making few spontaneous movements |
| 3. | hypothermia or fever > 38ºC (MCAI recommends > 37.5 ºC) |
| 4. | capillary refill time > 3 seconds |
| 5. | respiratory rate > 60 breaths/minute |
| 6. | indrawing of the lower chest wall when breathing, or grunting |
| 7. | cyanosis |
| 8. | history of a convulsion |

Less common but important signs include the following:

- low respiratory rate (< 20 breaths/minute) or apnoea
- jaundice
- abdominal distension
- skin infections

***Neonatal Sepsis***

***Recognition of Sepsis***
Bacterial sepsis (septicaemia) in the newborn infant may present with any number of subtle non-specific changes in activity or physical findings. Remember the 8 WHO danger signs above. A change in feeding pattern, vomiting, irritability, pallor, diminished tone and/ or decreased skin perfusion is suggestive of neonatal infection. Other presenting physical findings may include lethargy, apnoea, tachypnoea, respiratory distress, cyanosis, petechiae or early jaundice. There may be fever, but this is not common, especially with bacterial infections occurring in the first week. However, temperature instability with hypothermia may be seen. Abnormal glucose homeostasis (hypoglycaemia or hyperglycaemia) and/or metabolic acidosis are commonly associated findings.

***Causes of Sepsis***

***Early-Onset Sepsis (first 72 hours)***
Early-onset sepsis usually occurs as a result of bacteria acquired by vertical transmission from mother to infant during late pregnancy, labour and delivery. The most frequently observed organisms vary from one part of the world to another. Gram-negative bacteria (especially Escherichia coli and Klebsiella species) predominate in many regions. Gram-positive cocci are also common, and include Group B beta-haemolytic streptococcus, other streptococcal species, Staphylococcus and Enterococcus. Less commonly, Listeria monocytogenes is isolated from newborn infants with sepsis, especially when there are foodborne epidemics.

*Maternal risk factors for early-onset sepsis*

These include the following:

1. maternal fever (37.5°C or higher) before delivery or during labour
2. prolonged rupture of membranes at any stage (18 hours or longer)
3. preterm pre-labour ruptured membranes (PPROM)
4. maternal bacteriuria during pregnancy (including E. coli and group B beta-haemolytic streptococcus)
5. prior infected infant (group B beta-haemolytic streptococcus).

Early-onset sepsis in the newborn usually results from bacteria acquired from the mother at or shortly before delivery. These infants mostly present with respiratory distress and have bacteraemia or pneumonia. However, vaginal cultures cannot be used to determine the choice of antibiotics when treating the symptomatic newborn.

***Late-onset sepsis***

Organisms causing late onset are less likely to reflect those of the maternal genital tract, although the same pathogens may be identified in infants presenting from home. The most common cause is the spread from focal infections such as conjunctivitis, omphalitis, skin infections and meningitis. A circumcision wound can also be the site of serious infection.

In the hospital setting, infection is more commonly caused by nosocomial pathogens, including coagulase-negative Staphylococci, Gram-negative enteric bacteria (e.g. Klebsiella oxytoca, Klebsiella pneumoniae, Enterobacter cloacae), Staphylococcus aureus, Pseudomonas species, Streptococcal species and Enterococcus. Fungal sepsis must also be considered.

Investigate as for early-onset sepsis, with the inclusion of a lumbar puncture and suprapubic urine for analysis and culture if indicated and treat empirically with parenteral broad-spectrum antibiotic therapy directed towards the most encountered pathogens for the particular nursery. Once cultures are positive, therapy can be directed accordingly. (For treatment of sepsis, *see* below.)

***Investigation of suspected sepsis***

In seriously ill infants with suspected sepsis, priority should be given to the structured ABC approach, while simultaneously obtaining a blood culture followed by prompt administration of antibiotics. Other tests, such as a lumbar puncture, can be performed once the infant is stable and antibiotics have been started.

In the case of an infant who is generally unwell with no clinically obvious infective focus, the following investigations should be performed if laboratory facilities are available:

- **White blood cell count** (WBC) with differential cell count may provide an indication of infection but is generally unhelpful in this setting.
- **Blood culture (about 1 mL of venous blood)**:
    - Blood culture is the gold standard for neonatal sepsis, but it is not 100% sensitive. The sensitivity may be further reduced if intrapartum antibiotics were administered to the mother antenatally.
    - Failure to sterilise the skin can render blood culture results uninterpretable. Chlorhexidine, 0.5% aqueous solution, is a very effective antiseptic. Use two different swabs, applying each for 10 seconds, and then leave the skin to dry for 30 seconds.
- **Lumbar puncture (Section 47)** if indicated: cytology, chemistry, Gram stain and culture (see meningitis section)
- **C-reactive protein (CRP)**: This is an inexpensive and useful test which may take 12 hours to become positive if an infection is present. A negative test at 48 hours in a well

infant suggests that antibiotics can be stopped.
- **Blood glucose** concentration.

Other investigations
- **Serum bilirubin** concentration if the infant appears jaundiced.
- **Chest X ray**: This may be helpful if there are any respiratory signs, but not if it means taking the infant to another department in the hospital. A portable chest X-ray is ideal (if available).
- **Surface cultures** (ear canal, umbilical stump) and gastric aspirate cultures do not correlate with either the likelihood of sepsis or the causative agent in septic infants. These cultures should not be obtained.
- **A clean catch or suprapubic aspirate of urine** for microscopy and culture:
  - This procedure is of little value in the infant suspected of having sepsis shortly after birth, but it may have a greater yield in infants with new-onset symptoms later in the first week (>3 days). A urinary tract infection should always be considered in neonates with late-onset sepsis, and the same antibiotics should be used as for other serious infections unless cultures dictate otherwise.
  - Simple microscopy on a clean catch or suprapubic urine specimen may be used to rule out a urinary tract infection. Identification of a urinary tract infection may suggest the need for ultrasound imaging of the renal tract and long-term prophylactic antibiotics.

Think also of herpes infection, congenital TORCH infection (newborn intrauterine-acquired infections, including toxoplasmosis, parvovirus B19, syphilis, HIV, varicella, coxsackie, rubella and cytomegalovirus) or neonatal malaria (rare) in a malaria-endemic region

Vaginal cultures from the mother **cannot** be used to determine the choice of antibiotics when treating the symptomatic newborn.

***Treatment of suspected bacterial septicaemia***

**Assess ABC**
- Ensure that the **airway** is open and keep it open especially if the conscious level is impaired.
- Ensure that the infant is **breathing** adequately, and if they are apnoeic, gasping or have a very low respiratory rate, consider ventilation using a bag and mask until they are breathing adequately.
- If the infant is cyanosed, give them **oxygen** until they are pink or show normal oxygen saturation in air (> 94%).

**IV Access**
- Insert an **IV cannula**, using full sterile precautions.
- Umbilical vein catheterisation may be the most effective way to gain vascular access quickly in a shocked infant less than 1 week old (see Section 44).
- Otherwise it might be necessary to site an **intra-osseous line (**Section 45**)** or cannulate a **scalp** vein (Section 42).

**Investigations**
- Take samples for full blood count, CRP, blood culture, blood glucose, lumbar puncture and other tests (urine microscopy and culture, chest X-ray, biochemical tests) if needed (and available).

**Circulation**
- If the infant is shocked, give an IV bolus of 10 to 20 mL/kg of 0.9% Saline. This can be repeated if the infant remains shocked. If more than 40 ml/Kg are clinically needed, these should be given but there is a risk of pulmonary oedema and need for respiratory support. The use of inotropes (dopamine and dobutamine), if available, can be considered in such situations, although the outlook is poor if they are needed.

**Blood Glucose**

- If possible, check blood glucose levels. If blood glucose is low (< 45 mg/dl or < 2.5 mmol/l) give 2 mL/kg of 10% glucose IV over 2–3 minutes as an initial bolus, followed by a dextrose infusion as below. If an IV line cannot be inserted and hypoglycaemia is suspected, give expressed breast milk or 10% glucose by nasogastric tube or sublingual sucrose.
- If blood glucose measurement is not available give 2 mL/kg of 10% glucose IV over 2–3 minutes as an initial bolus, followed by a dextrose infusion as below. An infant who becomes alert and active immediately following the initial bolus is suggestive of hypoglycaemia (i.e. a blood glucose concentration of < 2.5 mmol/litre, or < 45 mg/dL), and this may be part of the problem. If an IV line cannot be inserted and hypoglycaemia is suspected, give expressed breast milk or 10% glucose by nasogastric tube or sublingual sucrose. Further intermittent monitoring of the blood glucose level should be undertaken, and the infusion continued until it is clear that the infant is well enough to be fed orally.
- Start an IV infusion of 60 mL/kg/24 hours of 10% dextrose if at all possible. (see Section 22)

**Antibiotics**

- Give the first dose of antibiotics intravenously using the dose regimen outlined in the neonatal formulary. Remember to use the high dose if meningitis is suspected and continue it for the duration of therapy if meningitis is confirmed.

***Table 7.2 Antibiotics for neonatal sepsis***

| | | |
|---|---|---|
| **First Line Antibiotics** | Ampicillin (or Benzyl Penicillin) and Gentamicin | Beta-lactam antibiotics plus aminoglycosides act synergistically in treating some of the most frequently encountered neonatal pathogens.<br>Ampicillin provides better coverage than benzyl penicillin for certain Gram positive pathogens, including Listeria |
| | Third Generation Cephalosporin (Ceftriaxone, Cefotaxime, Ceftazidime) | Some Gram-positive bacteria may not be covered (e.g. Enterococcus, Listeria) if a penicillin derivative is not included.<br>Infants with suspected Gram-negative meningitis and accompanying early-onset sepsis may benefit from inclusion of a third-generation cephalosporin which offers greater penetration and killing power for enteric bacteria in the cerebrospinal fluid<br>Ceftazidime can be particularly helpful in Pseudomonas infections. |
| **Second Line Antibiotics** | e.g. ciprofloxacin, vancomycin, meropenem, piperacillin-tazobactam, linezolid | May be helpful for treating nosocomial infections and resistant organisms. However, their use should be limited to proven multi-drug-resistant organisms.<br>Inappropriate use of these expensive antibiotics may lead to even more multi-drug-resistant organisms (the so-called 'superbugs'). It is recommended that these agents should only be used in specified clinical settings where testing for antibiotic sensitivity is available or |

| | | |
|---|---|---|
| | | where an infant is not responding to standard antibiotic treatment. |
| **Specific Antibiotics** | Skin Infection: Cloxacillin (IV or oral) | Use if septic spots are present, as these are usually caused by staphylococci |

- If IV access is not immediately possible, give the initial antibiotic dose IM. Never wait for the results of cultures before starting antibiotics - any delay can reduce the infant's chances of survival as well as leading to permanent damage if meningitis is present.
- Antibiotics can be stopped after 48 hours if the blood cultures are negative and the infant is clinically well. If available, a normal CRP at 48 hours can help to exclude sepsis.
- If blood cultures are not available, and the original reason for antibiotics was **not** a severe infection, then discontinue at 48 hours if the infant is well and monitor closely for return signs of sepsis for at least a further 48 hours. If the infection was originally severe, continue the antibiotics for the full course appropriate for the site of infection.
- Therapy can be adjusted once the bacteria have been identified and antibiotic sensitivities determined.
- The duration of treatment is at least 14 days for uncomplicated Gram-positive bacteria and 21 days for Gram-negative bacteria.

**Monitoring**

- If the child has any respiratory symptoms, take a portable chest X-ray (if facilities are available). Do not move a sick infant to an X-ray department for this, as the resulting information is not worth the risks of moving them.
- Look regularly to see whether cyanosis is developing or use a pulse oximeter (if available) and give supplemental oxygen, preferably using nasal cannulae rather than a head box. Infants who become infected during delivery develop respiratory symptoms with progressive signs of septic shock within a few hours of birth.
- If an infant is breathless, especially if there is additional evidence of oxygen dependency, care must be taken with breast feeding. Cup and spoon feeding may be preferable, but some milk is very important by providing nutrition and also keeping the stomach and bowel active and in good condition. Unless the baby is unstable, some milk given in small amounts every hour (perhaps 1ml/Kg per hour) probably provides the best balance in supporting both respiration and nutrition and gastro-intestinal function.
- Watch for, prevent and correct any sign of hypothermia (skin-to-skin mother care).
- Be alert for the presence of seizures and treat them as appropriate (see Section 21) Always consider meningitis as a possible cause and increase the antibiotics to high dose if considered and if safe perform a lumbar puncture.

**Meningitis and/or septicaemia**

***Recognition of Meningitis***

Meningitis may occur at any time in the neonatal period, and is frequently fatal, with some survivors experiencing long-term sequelae. Survival and later prognosis depend on early diagnosis and rapid treatment. Confirmatory diagnosis from a lumbar puncture may take several hours, therefore it is urgent and appropriate to start antibiotic treatment empirically as soon as the diagnosis is suspected.

***Presenting features of meningitis include:***

- lethargy,
- reduced or complete lack of willingness to take feeds,
- irritability,
- a high-pitched cry,
- apneic/hypoxaemic episodes,
- lowered conscious level or even coma,
- hypotonia,
- convulsions,
- bulging or tense anterior fontanelle.

Always measure and record the head circumference.
However, once signs such as the above are present, treatment may be unsuccessful, and survivors may be handicapped. Therefore, any infant with the WHO 8 danger signs (see Table 7.1) should be started on antibiotics IV and the relevant investigations undertaken.

***Investigations for meningitis***

***General***

As with sepsis, blood investigations should include (if available):

- full blood count, blood culture, CRP, blood glucose

***Lumbar Puncture***

Lumbar puncture is potentially helpful if meningitis is suspected and should be considered in all newborn infants with neurological signs. **It is important only to attempt lumbar puncture once the infant has been stabilised**, and ideally within 2 hours of initiating antibiotic treatment. Lumbar puncture is more likely than blood culture to identify the organism responsible, and within a shorter period.

- If the infant is very unwell then this should be deferred as the baby may not be able to tolerate the lumbar puncture without becoming more unwell. Prompt treatment with antibiotics is imperative. In a baby with an infection, it is important to include / exclude the diagnosis of meningitis as this will dictate the dose and length of course antibiotics.
- A sterile technique will reduce the risk of contamination, especially when performing lumbar puncture (see Section 47) or suprapubic aspiration of urine (Section 48).
- Cerebrospinal fluid (CSF) cell counts, chemistry and Gram stain would often point towards meningitis. An elevated CSF leucocyte count ≥ 25 white blood cells/ $mm^3$) is characteristic of neonatal meningitis. The CSF protein level in meningitis may be high (> 2.0 g/litre in a term infant), and the CSF glucose level is typically low (< 30% of blood glucose value). Gram staining may reveal bacteria, but antibiotic therapy should not be directed based on this result, as rapidly growing bacilli may be mistaken for cocci, or the state of the organism may result in variable staining. Remember that a differential white blood cell count in the CSF does not help with the decision to initiate or continue antibiotic treatment.
- Sometimes the CSF picture in preterm infants who have sustained an intra-ventricular haemorrhage can show a mild increase in white blood cells in the first few weeks of life, which can be quite misleading. If there is clinical suspicion this should be treated as bacterial meningitis until cultures are known to be negative.
- If a ‘bloody tap’ is obtained it is best to treat the infant as having meningitis and repeat the lumbar puncture after 24–48 hours. The finding of many white cells or bacteria is significant even if the CSF is bloodstained.

***Treatment of meningitis***

- Assess and treat ABC as per septicaemia
- Check and treat low blood glucose
- Gain IV access and take blood samples including blood culture. Do not delay antibiotics to obtain a CSF sample and always wait until the baby is stable before performing an LP.
- Use intravenous antibiotics at the higher "meningitis" dose as per the formulary.
- First line antibiotics are as per septicaemia – either ampicillin / benzylpenicillin and gentamicin or a third-generation cephalosporin (cefotaxime or ceftriaxone).
- Monitor for and treat seizures with phenobarbitone 20 mg/ kg IM or by slow IV injection. If needed, continue with phenobarbitone at a maintenance dose of 2.5–5 once or twice daily. (see Section 21 for more details). Diazepam or midazolam can also be used to control seizures. However, always have a bag and mask available if diazepam or midazolam are given to stop fitting, as these drugs cause temporary apnoea in some patients, which can be managed with bag-and-mask ventilation until the infant is breathing adequately.

***Diarrhoea in the newborn***

***Prevention***

- Encourage frequent breastfeeding, as it helps in both preventing and treating diarrhoea in the newborn.
- Sometimes what is described as diarrhoea by the mother is in fact the normal loose breastfed stools of some infants in the first few days of life. Usually the number of stools passed per day declines quickly, and in some breastfed infants may be as infrequent as once daily.

***Treatment***

- If the infant is dehydrated, give low-osmolarity oral rehydration solution (ORS) in addition to breast milk.
- In the case of sick infants or those infants who are unable to feed orally, consider IV fluids.
- If bloody diarrhoea occurs, it is best to assume that the infant has dysentery and initiate antibiotic therapy. Avoid the use of co-trimoxazole in the light of much better and more effective antibiotics with better side-effect profiles. Ciprofloxacin is a good first- line treatment and give Ceftriaxone as second- line treatment if the infant is severely ill and local antimicrobial sensitivity is not known.
  Ciprofloxacin dose for neonates is: 15mg/kg/dose twice daily orally or 10mg/kg IV over 60mins twice daily for 5 days.
  Ceftriaxone dose in neonates up to 15days is 20-50mg/kg IV or IM once daily; and age 15-28days 50-80mg/kg IV or IM once daily, for 5 days.
- In the case of the septic and unwell infant, give IV antibiotics as outlined in Table 7.2
- WHO and UNICEF recommend zinc sulphate supplements 1mg/Kg per day dissolved in a spoon of ORS solution or sterile or boiled water for 10 to 14 days to reduce the severity of the episode and reduce recurrence during the next 2-3 months.

***Table 7.3 Antibiotic Safe Management***

| **Antibiotic Safe Management** |
|---|
| Warning: Excess and inappropriate antibiotic usage leads to multi-drug resistance, especially in a hospital setting.<br><br>The widespread use of ampicillin has caused many coliform organisms to become increasingly resistant to this antibiotic, while units that use cefotaxime extensively are |

starting to encounter serious Enterobacter and other multi-drug-resistant Gram-negative sepsis.

**Remember the following key points:**
Prevent infection (and use of antibiotics) through handwashing and infection control measures
Ensure you prescribe antibiotics appropriately only for those babies that are in need
Re-evaluate the need for antibiotics dependent on clinical picture and investigation results
Ensure you **TEST** to identify the bacteria causing the infection (if available)
Once the bacteria is identified **TARGET** the antibiotics to that bacteria
Ensure you **TREAT** for the full course of the antibiotic

## Section 8. Congenital syphilis

Syphilis is a dangerous bacterial infection caused by *Treponema pallidum* which, when it occurs in pregnancy, can cause early fetal death, stillbirth, preterm birth, neonatal death or congenital infection. Mother-to-child transmission is a major problem, especially in resource-limited countries.

Congenital syphilis may be acquired from an infected mother via trans-placental transmission of *Treponema pallidum* at any time during pregnancy. If the mother receives adequate treatment, ideally before the second trimester, the risk of adverse outcome to the fetus is minimal.

Clinical signs in infants may include any of the following:

- low birth weight with a heavy placenta
- palms and soles showing a red rash, grey patches, blisters or skin peeling
- abdominal distension due to large liver and spleen
- jaundice
- anaemia
- some low-birth-weight infants with syphilis show signs of severe sepsis, with lethargy, respiratory distress, skin petechiae or other signs of bleeding.

### Investigation

No newborn infant should be discharged from hospital without determination of the mother's serologic status for syphilis at least once during pregnancy, and also at delivery in communities and populations in which the risk of infection with congenital syphilis is high.

If you suspect syphilis, perform a venereal disease research laboratory (VDRL), rapid plasmin reagent (RPR) or rapid syphilis test on the infant's serum (not cord blood). Interpretation of the serological results in the neonate can be difficult, as maternal IgG antibodies are transferred across the placenta. A non-treponemal serological titre that is fourfold higher than the mother's titre is definitely significant, although a lower titre does not exclude congenital syphilis. As well as a careful examination of the infant, an x-ray of long bones (if available) may help with the diagnosis. Periostitis, metaphysitis and erosions of long bones are the commonest findings.
Because of the diagnostic difficulty, and the fact that infants may be asymptomatic, assessing the adequacy of maternal treatment is very important.

### Treatment

All newborn infants of mothers with syphilis should be investigated and treated.

Adequate treatment for the mother is 3 doses of benzathine penicillin, given at least 4 weeks before delivery.

Infants should be treated for congenital syphilis if they have proven or probable disease demonstrated by one or more of the following:

- physical, laboratory or X-ray evidence of active disease
- a reactive result on maternal or infant VDRL testing where the mother has had no treatment, or inadequate treatment, or has had a non-penicillin antibiotic, even if the infant is asymptomatic.

Parenteral benzyl penicillin remains the preferred drug for treatment of an infant with any signs of congenital syphilis. The dose is 100,000-150,000U/kg/day given intravenously as 50,000 U/dose (37.5 mg) 12 hourly for the first 7 days and then 8 hourly for 3 days (total 10 days).

An alternative is procaine penicillin 50 000 units/kg or 50 mg/kg as a single dose by deep IM injection daily for 10 days. Ensure that this is not injected into a vein.

Asymptomatic neonates born to VDRL-positive or RPR-positive women, who have been adequately treated, should receive 37.5 mg/kg (50 000 units/kg) of benzathine benzyl penicillin as a single IM dose into the anterolateral thigh whether or not their mothers were treated during pregnancy. Routine CSF examination is not required. Ensure that the needle is not in a vein when this drug is given, by drawing back and ensuring that no blood is in the needle, as it can cause cardiac arrest and severe CNS damage if given IV.

Early congenital syphilis generally responds well to penicillin. Recovery may be slow in seriously ill infants with extensive skin, mucous membrane, bone or visceral involvement.

If the patient is allergic to penicillin (this is unusual), give ceftriaxone IM/IV once daily for 10 days. The dose for a neonate aged up to 15 days is 50mg/kg once daily; 15-28days 75-100mg/kg once daily, or give erythromycin, 7.5–12.5 mg/kg orally, four times a day for 14 days but erythromycin is less effective.

Where congenital syphilis was treated or suspected, the baby should be followed up. Non-treponemal test titres should decline over 6 months. If titres remain high at 6-12 months, the infant should be re-evaluated. Always treat both the mother and partner for syphilis, and check for other sexually transmitted infections

## Section 9. The newborn infant of a mother with tuberculosis

Although an infant can be infected with TB in utero by trans-placental spread, or by ingesting infected amniotic fluid, this is very rare. It is more common that a mother with active TB infects her baby after delivery by droplet spread.

The signs of TB in the neonate are non-specific and may resemble sepsis, or present with poor weight gain organomegaly, respiratory symptoms and fever. The baby may not become symptomatic for 2-4 weeks. Maternal history is important.

If the mother has active lung tuberculosis and was treated for less than 2 months before birth, or was diagnosed with tuberculosis soon after birth, the infant should be evaluated for congenital tuberculosis. Congenital tuberculosis is rare but should always be considered in sick neonates or infants, especially in areas where HIV/tuberculosis co-infection is common. If possible, this should include culture of gastric washings, tracheal aspirate, urine and CSF, and chest x-ray. A tuberculin skin test should be performed, although is unlikely to be positive in the first few weeks of life.

If there is clinical or laboratory evidence of disease, the infant should receive full treatment with 4 drugs.

If there is no clinical or laboratory evidence of disease in the baby, but the woman has active disease or is still requiring treatment, the infant should be given isoniazid 10 mg/kg once daily for 6 months, and also pyridoxine 10mg daily if breast feeding.

At the age of 6 weeks, re-evaluate the infant, noting weight gain and taking an X-ray of the chest if possible. Congenital TB is most often intra-abdominal, so look for signs suggesting this. If there are any signs or findings suggestive of active disease, start full anti-tuberculosis treatment according to national guidelines.

If at the age of 6 weeks the infant is doing well and tests are negative, continue prophylactic isoniazid to complete 6 months of treatment.

*Breastfeeding:* TB is not transmitted in breast milk, and FIRST LINE maternal anti TB drugs do not produce toxicity in the newborn. Therefore, the baby should not be separated from the mother, and she should be reassured that it is safe to breastfeed.

If the mother is suspected of having multi-drug-resistant tuberculosis, an expert in tuberculosis disease treatment should be consulted, and a decision made about breastfeeding.

*BCG vaccine:* Should be given at birth, if the mother has completed anti-tuberculous therapy or has inactive disease.
If the infant is on isoniazid, BCG should be delayed until 2 weeks after treatment is completed. If BCG vaccine has already been given, repeat it 2 weeks after the end of the isoniazid treatment.

*Vitamin K:* Make sure that the baby of a mother who has been treated with Rifampicin has received Vitamin K at birth, as rifampicin can reduce vitamin K dependent clotting factors in the mother and baby.

**(see Handbooks 1 and 2 Paediatric illnesses for more details)**

## Section 10. The neonate with skin, eye and mucous membrane infections

***Mild Conjunctivitis / Blocked Tear Duct***
***Recognition***
Most conjunctivitis presents as 'sticky eyes', but this may not always be of bacterial origin, especially if it occurs in the first few days. However, a bacterial process must be considered in all cases.
Infants with a serous discharge without significant conjunctival inflammation may simply have blocked naso-lacrimal tear ducts. This usually responds to gentle pressure/massage applied in a downward motion along the nose immediately adjacent to the eyes.

***Treatment***
The discharge may be cleaned from the eye with sterile 0.9% saline drops (irrigation). Show the parent how to clean the infant's eyes with sterile normal saline or boiled and cooled clean water. The eyes should be wiped from the inside to the outside edge using a clean cotton wool swab for each eye. Hands should always be washed before and after the procedure.

If the condition worsens or if there is conjunctival inflammation or a purulent discharge, use of topical therapy should be considered. Erythromycin, tetracycline, neomycin or chloramphenicol ophthalmic ointments or drops may be considered. Apply the ointment or drops 3 to 4 times a day for 5 days after washing away any pus with sterile normal saline as described above. Treat this level of infection as an outpatient but review every 48 hours.

***Gonococcal conjunctivitis***
***Recognition***
A severe rapidly progressive purulent conjunctivitis occurring within the first few days must always be assumed to be due to Neisseria gonorrhoeae, which must be promptly identified and aggressively treated in hospital with IV antibiotics and irrigation.
***Causes***
Most strains of Neisseria Gonorrhoea are now resistant to penicillin.
***Investigations***
Swab the eye for microscopy (Gram-negative intracellular diplococci) and culture (special medium is required, such as Thayer–Martin agar).
***Treatment***
Initiate immediately before culture confirmation. Treatment with IV penicillin for 7 days has been used successfully, but because of increased worldwide resistance (penicillinase-producing gonococcus), a third-generation cephalosporin is often selected as the first-line therapy:

- ceftriaxone 125 mg IM, as a single dose
- or cefotaxime 100mg/kg IM (max 1g) IM, as a single dose
- or cefixime 20 mg/kg orally, as a single dose.

It is important to repeatedly clean the eye or irrigate with 0.9% saline until pus formation stops. It is vital to prevent corneal rupture and subsequent blindness.

In the case of a presumed or diagnosed gonococcal or chlamydial infection, the mother and partner should also be treated.

In countries with a low rate of sexually transmitted diseases, staphylococcal and Gram-negative organisms are more likely to be responsible. Staphylococcal infections can be treated with cloxacillin or flucloxacillin. The dose is: 25mg/kg orally twice daily until 7 days age; three times daily 7-20 days age; 4 times daily 21-28 days age.

***Chlamydial conjunctivitis***
***Recognition***

Chlamydia trachomatis is a common cause of infectious conjunctivitis in the newborn infant. It typically presents between 5 and 14 days. The presentation can vary from mild to moderate conjunctival erythema, and from scant mucoid discharge to copious purulent discharge. Eyelid oedema, chemosis or pseudo-membrane formation may also be present. Corneal involvement is unusual initially, although untreated chlamydia conjunctivitis can result in varying degrees of conjunctival scarring and corneal infiltrates.

***Investigations***

Chlamydia can be confirmed by culture or rapid antigen detection, but these are highly specialised procedures that may not be readily available.

***Treatment***

Without a positive laboratory diagnosis, treatment is based on clinical severity. If the condition is mild, clean the eye only. If it is moderate, use a topical antibiotic and consider giving erythromycin 12.5mg/ kg orally, 6-hourly for 14 days. This effectively treats this infection and may also eradicate upper respiratory tract colonisation.

If the condition is severe, consider gonococcal infection, irrigate and use IV or IM cefotaxime or ceftriaxone.

Ensure that the mother is appropriately referred for treatment.

***Skin pustules***

***Recognition***

Skin pustules are most commonly caused by Staphylococcus aureus. Most often these occur in small clusters in an otherwise healthy asymptomatic infant.

Sometimes staphylococcal pustules can be difficult to distinguish from erythema toxicum (a benign, non-infectious newborn rash).

***Treatment***

Topical therapy with chlorhexidine 0.5% may be all that is needed in most of these cases.

Oral therapy with a penicillinase-resistant penicillin, cloxacillin or flucloxacillin 25 mg/kg twice daily up to 7 days age; three times daily 7-20 days age; 4 times daily 21-28 days age, or first-generation cephalosporin (e.g. cephalexin 25 mg/kg 7 days, frequency as for oral flucloxacillin depending on age of neonate) may also be used if extensive pustules are found.

If septicaemia is suspected, septic investigations and IV antibiotics after admitting to hospital may be needed.

***Umbilical infection***

***Recognition***

A clinically relevant infection of the umbilical stump (**omphalitis**) presents as redness and oedema of the skin extending from the umbilicus. This should be distinguished from the ooze resulting from an umbilical granuloma, which may develop after a few weeks.

***Treatment***

Clean the area with soap and warm water and remove or drain pus and crusts. Dry and paint the area with antiseptic such as gentian violet or use a simple alcohol swab to clean the area at the time of every nappy change.

If there is only a ‘sticky cord’, manage it with local treatment only. Pus can be easily removed with a swab, whereas normal cord degeneration cannot be removed.

If there is skin redness plus oedema extending from the umbilicus treatment with anti-staphylococcal antibiotics (flucloxacillin or cloxacillin) should be immediately commenced in an oral dose of 25mg/Kg (frequency of giving dependent on age of neonate as above), for

7 days. If there is severe cellulitis extending from the umbilicus give cloxacillin or flucloxacillin IV for 7 days (see Formulary Section 14 for doses).

Omphalitis may become rapidly progressive and spread to deeper tissues.

***Cellulitis***
***Recognition***
This is most commonly caused by streptococci, but Staphylococcus aureus, Gram-negative enterococcus and anaerobes should also be considered when infection occurs at sites where there have been breaks in the skin.
***Treatment***
Treat with IV antibiotics (Cloxacillin or Flucloxacillin plus gentamicin see Formulary Section 14 below for doses) should be directed against both Gram-negative and Gram-positive bacteria.

Infection with Clostridium Tetani is common in the setting of poor maternal immunity (e.g. Malnutrition or HIV infection) or poor umbilical cord care and can cause neonatal tetanus (see Section 23 for management)

***Scalded skin syndrome***
This is a rare infection caused by toxin-producing staphylococcal organisms which leads to a toxic reaction producing the effect of both serious infection and burns.

Treat it with IV high dose cloxacillin or flucloxacillin (see Formulary below).

***Superficial candidiasis ('thrush' and 'monilial' rash)***
***Recognition***
Superficial candidiasis of the oral mucosa ('thrush') commonly manifests as white patches which are not easily scraped off the surface infected with a spatula. The nappy area may also be affected ('monilial' rash). Unlike irritant dermatitis, the erythema extends into skin folds and there may be small raised erythematous lesions.
***Causes***
Excess use of antibiotics can cause overt Candida infection (thrush)
***Treatment***
Treat with oral nystatin suspension, 1 mL after feeds (divide it between each cheek with a small syringe). Topical nystatin ointment may be used to treat the skin rash in combination with oral nystatin. Keep the nappy area dry.

Apply local treatment to the mother's nipples if they are also infected.

**Warning:** Excess and inappropriate antibiotic usage, besides being costly and generating a lot of nursing work, also leads to multi-drug resistance. Excess use can cause overt *Candida* infection (thrush) and risks the eventual emergence of multi-drug-resistant organisms, especially in a hospital setting. The wide- spread use of ampicillin has caused many coliform organisms to become increasingly resistant to this antibiotic, while units that use cefotaxime extensively are starting to encounter serious *Enterobacter* and other multi-drug-resistant Gram-negative sepsis.

## Section 11. Congenital and Neonatal malaria

**Introduction**
Malaria in the neonatal period can be congenital [transplacental or peripartum infection] or acquired after birth from the bite of an infective mosquito.

**Clinical features are indistinguishable from sepsis and all symptomatic neonates should also receive additional parenteral antibiotics.**

**Definitions**
**Congenital malaria** is defined as parasitaemia detected in the first week of life and is acquired vertically, either trans-placentally or peripartum from the mother. All types of malaria can be transmitted congenitally.

**Neonatal malaria** occurs from 8-28 days of life as a result of an infective mosquito bite.

**Clinical features**
Malaria during pregnancy has been associated with miscarriage, stillbirth, prematurity and low birth weight.

Clinical features are non-specific and similar to those seen in neonatal sepsis including fever, lethargy and poor feeding. Neurological features include irritability and seizures. There may be pallor, jaundice or hepatosplenomegaly.

**Differential Diagnosis**
The clinical features of congenital and neonatal malaria are similar to neonatal sepsis and other neonatal conditions that are relatively more common causes of illness. Congenital infections [e.g CMV, rubella, toxoplasmosis, syphilis] can also present with similar clinical signs.

**Investigations**
Systemic testing of all newborn infants in malaria endemic areas is not recommended as some clear the parasitaemia spontaneously. Investigation of malaria should be done for

- Asymptomatic newborn infants born to mothers diagnosed with malaria in the third trimester or at delivery.
- All infants < 2months of age with fever or suspected sepsis.
- Repeat testing [at 12, 24, 48 hours] where clinical suspicion remains, even if previous results was negative. Low level parasitaemia can occur in young infants.

**Blood smear** [**blood films thick and thin**] is gold standard and recommended where reliable laboratory facilities are available.

**Rapid Diagnostic Testing [RDT**]; validity of RDT in neonatal malaria is unknown. It can be used where reliable microscopy is not available.

- Check blood glucose level
- Check Hb

**Management**
All newborn infants with suspected malaria should be admitted to a neonatal unit.
Initial management includes emergency stabilisation [ABC]

**Antimalaria treatment**
Symptomatic newborn infants should be given an initial course of intravenous therapy [minimum 3 doses] due to their vulnerability and variable absorption of oral medications.

**Artesunate:** 3mg/kg slow IV or IM by 3 doses the first on admission and the second and third at 12 and 24 hours. Thereafter, give 3mg/kg once every 24 hours until baby can tolerate oral therapy [up to 7 days treatment].

In rare circumstances where intravenous dosing not available or not possible, and there are no signs of shock, give Artemeter IM 1.6mg/Kg on admission, at 12 and then at 24 hours. By this time IV Artesunate should be available and should be substituted for Artemeter.

Artemesinin–combination therapy [ACT] is used in asymptomatic babies with a positive malaria screen and symptomatic babies who have received 3 doses of IV or IM Artesunate and are clinically improving.

- Artesunate –Amodiaquine [AS-AQ] 5mg/kg AS and 10mg/kg AQ, oral, once daily for 3 days. Dilute 1 co-formulated tablet of AS-AQ [ 25/67.5mg] into 2ml of 0.9% saline.
  **OR**
- Artemether-Lumefantrine [AL]1.7mg/kg Artemeter, 12mg/kg lumefantrine, oral twice daily for 3 days. Dilute one co—formulated tablet of AL [20/120mg] in 10ml of 0.9% saline.
- Note: ACT preparations are unstable and require immediate administration once prepared.
- **The combination of Artesunate-Sulfadoxine/Pyrimethamine should not be used in the first week of life.**

Antibiotic therapy for neonatal sepsis should be commenced in all symptomatic babies due to the difficulty in differentiating the two diagnoses and the relatively higher frequency of neonatal sepsis.

**Prevention**
Preventative measures include;

- Adequate screening and treatment of malaria during pregnancy.
- Use of insecticide treated bed nets.

## Section 12. Varicella zoster (chickenpox) in pregnancy and the neonate

### Introduction

Pregnant women and newborn infants are at risk of severe disease from varicella, involving serious effects on organs such as the lungs.

Varicella is transmitted from respiratory aerosols and skin lesions in chickenpox itself, and from the skin lesions but not aerosols in shingles (which is not infectious until the skin lesions appear).
In chickenpox, patients are infectious for 48 hours prior to emergence of the rash and until all of the skin lesions are crusted over.

The incubation period is 10–21 days.

Non-immune patients are those without a history of chickenpox or shingles or a completed vaccination profile. Immune status can be checked with blood varicella IgG measurement (if available).

***Clinical features in pregnancy***

***Congenital varicella syndrome (CVS)***

In the first or early second trimester infection may result in stillbirth, or the neonate may be born with a group of physical abnormalities known as congenital varicella syndrome (CVS). This is rare, occurring in 1–3% of women infected with chickenpox in the first 20 weeks of gestation (the period of maximum risk is between 12- and 20-weeks' gestation). There may be dermatomal scarring, limb hypoplasia, ocular abnormalities, low birth weight and early death. Survivors may have long-term developmental problems. An infant with CVS has a 30% risk of mortality in the first few months of life, and a 15% risk of developing herpes zoster between 2 months and 3 years of life.

***Varicella pneumonia***

Pregnant women with chickenpox may be more likely than non-pregnant women to develop severe pneumonitis. The risk is greatest in the third trimester, especially if lung disease is already present, or if the patient is a smoker or is immunocompromised (e.g. due to HIV infection).

Symptoms start as a non-productive cough, which can rapidly progress to respiratory failure within 36–48 hours. The cough becomes increasingly productive, with tachypnoea, dyspnoea, cyanosis and chest pain.

***Perinatal infection***

If a neonate is exposed (mother has a rash) around the time of birth (from 5 days before to 2 days after delivery), there is a 17–30% risk of dangerous perinatal infection. This is characterised by skin lesions, disseminated intravascular coagulation, pneumonitis and hepatitis, and it has a mortality of up to 30%.

***Management***

***Maternal contact with varicella during pregnancy***

If the patient is immune (see above for definition), no treatment or isolation is required.
If she is non-immune and an IgG test is not available and affordable, and if she has had a significant contact with chicken pox or shingles, then give varicella zoster immunoglobulin (VZIG) (see below for details) within 4 days of contact if possible (maximum of 10 days after

contact). Avoid contact with other pregnant women. The patient should be counselled regarding the signs of infection so that she can be treated early if it occurs.

Significant exposure to chicken pox occurs after very limited contact with an infected person (any face-to-face contact and as little as 15 minutes in the same room as an infectious patient). The risk of contracting chicken pox from exposure to shingles is very low if the infection is not in an exposed area.

**Chickenpox during pregnancy**
If this is mild, give oral aciclovir (see below for dose regimen) for 7 days, starting within 24 hours of the appearance of vesicles, and avoid contact with other pregnant women. In mild cases, Aciclovir leads to little improvement. It is most important in women at risk of severe disease (immuno- compromised, HIV infected, history of respiratory disease or smoking).
If it is severe, give IV aciclovir for 7 days. High- dependency care should be provided if available, as appropriate.

**Prevention of neonatal chickenpox if the mother is infected from 7 days before to 7 days after birth**
Give VZIG to the neonate as soon as possible after delivery. Isolate the mother and infant. This is crucial as chicken pox is very contagious (see above).
In addition, give IV aciclovir to the neonate if the onset of maternal symptoms was between 5 days before, and 2 days after the birth, as this is the period of highest risk of severe neonatal disease.

**Infant in contact with chickenpox other than from mother, or from mother who develops chickenpox more than 7 days after the birth**
If the mother is immune and the infant is full term at birth, no prophylaxis is needed. Mild illness may occur.

If the mother is not immune and the infant is less than 4 weeks of age, and full term at birth, give varicella zoster immunoglobulin (VZIG) (if available).

If the infant is preterm, and regardless of maternal immunity, give VZIG.

If VZIG is not available, IV aciclovir should be given to other infants exposed in hospital, as prophylactic use has been reported to reduce disease severity.

Regardless of whether VZIG is given, monitor the baby for signs of infection to enable early treatment should infection occur. VZIG may extend the incubation period to 28 days.

Shingles is very rare in infants and, if present, suspect HIV infection.

***Doses of VZIG and aciclovir***
***In pregnancy***
*Aciclovir* is of no benefit if commenced more than 24 hours after the appearance of chickenpox vesicles.

- Oral route: 800 mg five times daily for 7 days (mildly ill cases only).
- IV route: 10 mg/kg/dose every 8 hours for 7 days.

Side effects include nausea, vomiting, diarrhoea, headache and nephrotoxicity. Reduce the dose or dosage interval in patients with impaired renal function.

## Section 12. Varicella zoster (chickenpox) in pregnancy and the neonate

*Varicella zoster immunoglobulin (VZIG):* 1gram IM. Anaphylaxis is rare but ensure that adrenaline is available.

***In the neonate***

*Aciclovir* 10–20 mg/kg IV every 8 hours for at least 7 days. Side effects are as described above.

*Varicella zoster immunoglobulin (VZIG*): 250 mg by deep IM injection.

## Section 13. Prevention of mother-to-child transmission (PMTCT) of HIV infection and Anti-Retroviral Treatment (ART) in pregnancy

Consolidated ART guidelines published by the WHO in 2016 recommend that all pregnant and breastfeeding women infected with HIV should be commenced on ART (one simplified triple regimen), as lifelong treatment. This means that ART should be present throughout the duration of MTCT risk (i.e. throughout breastfeeding).

As most women should continue ART following delivery, an effective link with HIV treatment programmes is essential.

Prophylactic treatment for the baby depends on risk factors for transmission. See table 13.1, and risk factors below.

***TABLE 13.1*** *WHO guidelines for ART in pregnancy for HIV infected women, and infant prophylaxis.*

| **For pregnant women being given lifelong ART** | **For infants of mothers at high risk of acquiring HIV **** | **Breastfed infants of mothers with HIV, at high risk of acquiring HIV **** | **Infants of mothers who are on ART and not high risk,** |
|---|---|---|---|
| Preferred regimens:<br>TDF/3TC /DTG*<br>TDF + 3TC + EFV (as fixed-dose combination)<br>Alternative regimens:<br>AZT + 3TC + EFV<br>or AZT + 3TC + NVP | Daily nevirapine (NVP) for 6 weeks PLUS zidovudine (AZT) twice daily for 6 weeks. | Daily nevirapine (NVP) for minimum 12 weeks PLUS zidovudine (AZT) twice daily for 6 weeks. | Daily nevirapine (NVP) for 6 weeks. |

*This is the preferred regime where Dolutegravir (DTG) is available. Women who are not taking folate fortified foods, or who want to become pregnant, should be counselled on risks. www.who.int/hiv/pub/arv/arv-update-2019-policy/en

** High- risk infants are defined as those:

1. born to women with established HIV infection who have received less than 4 weeks of ART at the time of delivery; OR
2. born to women with established HIV infection with a viral load >1000 copies/ml in the four weeks before delivery, if viral load measurement is available; OR
3. born to women with incident HIV infection during pregnancy or breastfeeding; OR
4. identified for the first time during the postpartum period, with or without a negative HIV test prenatally

***Women first diagnosed with HIV during labour or immediately postpartum:***
The infants of these women are at high-risk, see table 13.1.

***Co -trimoxazole prophylaxis to prevent Pneumocystis Jiroveci (formerly Carinii) pneumonia. (PCP)***
HIV-exposed infants (children born to women with HIV) should be given co-trimoxazole prophylaxis from 4–6 weeks of age, and this should be continued until HIV infection has been excluded and the infant is no longer at risk of acquiring HIV through breastfeeding.

(*WHO 2016 Consolidated guidelines on the use of antiretroviral drugs for treating and preventing HIV infection).*
Co-trimoxazole prophylaxis has been shown to be very effective in HIV infected infants and children, in reducing mortality, and the likelihood of PCP as a cause of severe pneumonia. PCP is now unusual in countries where prophylaxis is routine. Co-trimoxazole also protects against common bacterial infections, toxoplasmosis and malaria.

*When Co-trimoxazole should be discontinued:*
If severe cutaneous reactions, such as Stevens-Johnson syndrome occur, or if there is renal and/or hepatic insufficiency, or severe haematological toxicity (severe anaemia or pancytopaenia). It is contraindicated in infants with glucose-6- phosphate dehydrogenase (G6PD) deficiency.

In an HIV exposed infant, only after HIV infection has confidently been excluded:
- For a non-breastfeeding child under the age of 18 months, this is by negative DNA or RNA virological HIV testing.
- For a breastfed HIV exposed child under the age of 18 months, negative virological testing is only reliable if performed 6 weeks after cessation of breastfeeding.
- For a breastfed HIV exposed child over 18months of age, negative HIV antibody testing 6 weeks after stopping breastfeeding.

Cotrimoxazole is a combination of trimethoprim/sulfamethoxazole (TMP/SMX) Recommended doses of 6-8mg/kg of TMP once daily should be used.

For infants under 5 Kg, give 2.5ml of suspension (40mg TMP/200mg SMX in 5 ml), or 1 paediatric tablet, or ¼ adult tablet (contains 20mg TMP/100mg SMX). Tablets can be crushed.

***Table 13.2.*** *Simplified dosing for neonates for Zidovudine and Nevirapine*

| **Drug** | **Strength of tablet or oral liquid (mg or mg/5ml)** | **Birth to 6 weeks *2,000 to 2,500g** | **Birth to 6 weeks > 2,500 g** | **>6 weeks Any weight** |
|---|---|---|---|---|
| Zidovudine Up to 6 weeks of age | 10mg/ml | 1ml twice/day | 1.5 ml twice daily | Not needed |
| Nevirapine Up to and after 6 weeks of age | 10mg/ml | 1ml once /day | 1.5 ml once daily | 2ml once daily |

* Infants weighing <2000 g should receive mg/kg dosing; the suggested starting dose is 2 mg/kg once daily for Nevirapine AND 2mg/kg twice daily for Zidovudine

***HIV-2 infection***
HIV-2 is much less transmissible than HIV-1 (the MTCT risk is 0−4%).
Non-nucleoside reverse transcriptase inhibitors (NNRTIs) such as NVP and EFV are not effective against HIV-2, and a triple nucleoside reverse transcriptase inhibitor (NRTI) combination is recommended.

***Table 13.3*** *Treatment of HIV-2 infection*

| |
|---|
| Mother requires treatment with AZT + abacavir (ABC) + 3TC<br><br>Infant of mother with HIV-2 requires treatment with AZT twice a day until 4–6 weeks |

***Management of the delivery:***
Labour can be a worrying time for the HIV-positive woman, particularly because of possible underlying fears about her own HIV infection and the risk of infecting her baby. She will need reassurance and support, and it is important to ensure she knows that with all of the interventions that are given, her baby is more likely to be HIV-negative than infected.

Get close to the mother, greet her and be seen to shake hands with her, to help to reduce the stigma around touching those infected with HIV. Support her relatives and encourage her to tell her partner so that he can be tested for HIV. Promote safer sex and advise her to use condoms to prevent transmission of HIV.
Standard precautions should be used when caring for women in labour, whether or not they have HIV infection. Always wear gloves when touching body fluids and dispose of single-use syringes and needles safely.

***During delivery, to reduce MTCT:***
- avoid artificial rupture of membranes
- avoid prolonged rupture of membranes
- avoid unnecessary episiotomy, but also avoid a tear.

Both blood and placenta will contain HIV, so wear gloves, an apron and eye protection. Avoid direct contact of blood on your skin. Blood on intact skin should be washed off immediately. HIV-positive blood on an open wound or splashed into the eye can transmit HIV and should be washed immediately (use soap and water for a wound, and water for an eye) and managed in the same way as a needlestick injury (with post-exposure prophylaxis with ART).

***Essential postnatal care for HIV-exposed infants***
1. Completion of ART prophylaxis regimen.
2. Routine newborn and infant care, including routine immunisation and growth monitoring.
3. Co-trimoxazole prophylaxis.
4. Early HIV diagnostic testing and diagnosis of HIV-related conditions.
5. Continued infant feeding counselling and support, especially after early HIV testing.
6. Nutritional support throughout the first year of life, including support for optimal infant feeding practices, and provision of nutritional supplements and replacement foods if indicated.
7. ART for HIV-infected children when indicated.
8. Treatment monitoring for all children receiving ART.
9. INH prophylaxis when indicated.
10. Adherence support counselling for caregivers.
11. Malaria prevention and treatment where indicated.
12. Diagnosis and management of common childhood infections and conditions, and integrated management of childhood illness (IMCI).
13. Diagnosis and management of TB and other opportunistic infections.

***Abbreviations:***

| | | |
|---|---|---|
| 3TC – Lamivudine | AZT – Zidovudine | DTG – Dolutegravir |
| EFV – Efavirens | NVP – Nevirapine | TDF – Tenofovir |

## Section 14. Drugs used to treat severe infections in the neonate

***Ampicillin (or amoxicillin)***

Give 100 mg/kg per dose IM or IV where meningitis or Group B streptococcus is likely, and 60 mg/kg per dose in other situations. Give one dose every 12 hours in the first week of life, every 8 hours in an infant aged 1–3 weeks, and every 6 hours in an infant older than this. Oral dosing can sometimes be used to complete a course of treatment.

***Benzyl penicillin***

Give 50mg/kg every 12 hrs up to 7 days age, every 8hrs 7-28 days IV if meningitis or tetanus is a possibility. Give 25 mg/kg (50000 units/kg) per dose in all other situations, including syphilis. Time the interval between each dose as for ampicillin. 25mg/kg 12 hourly up to 7 days age, increasing to 8hrly if necessary; 8hrly if 7-28days age. . Increase up to 50mg/kg 8hrly in severe infection. Oral dosing (with phenoxymethylpenicillin) can sometimes be used to complete a course of treatment.

***Cefotaxime***

Give 50 mg/kg per dose IV or IM. Time the interval between each dose as for ampicillin.

*Ceftriaxone by IV infusion*

Neonate up to 15 days give 20-50mg/Kg once daily with doses at the higher end of the recommended range used in severe cases.

Neonate 15 days to 28 days give 50-80mg/Kg once daily with doses at the higher end of the recommended range used in severe cases.

***Chloramphenicol***

This remains a useful antibiotic, although there is a serious risk of death from liver failure if the dose suggested here is exceeded. **Warning: The problem is not the dose but incorrect mixing, as the bottle contains 1000 mg, so it is easy to overdose.** Give 12.5 mg/kg once every 12 hours to infants less than 14 days old. Give this dose every 8 hours to infants aged 14 – 28 days, unless there is evidence of liver damage or renal failure. Infants older than this can be given 12.5 mg/ kg once every 6 hours from the outset. Oral dosing can be used to complete any course of treatment. (The dose can be doubled in those over 1 month of age with severe infection.) Be very careful if the IV dose has to be diluted to obtain the correct dosage.

***Cloxacillin (or flucloxacillin) by slow IV injection***

Neonate up to 7 days give 25mg/kg 12 hourly.

Neonate 7 days to 20 days give 25mg/kg 8 hourly.

Neonate 21days to 28 days give 25mg/kg 6 hourly.

In serious infections give 100 mg/kg per dose IM or IV. Oral treatment can often be given to complete a course of treatment (25 mg/kg standard, 50 mg/kg severe, 100 mg/kg in infections such as osteomyelitis).

***Erythromycin***

Give 12.5 mg/kg per dose orally once every 6 hours. There is no satisfactory IM preparation.

***Eye drops (and ointments)***

Prophylactic chloramphenicol 0.5% eye drops, or 1% eye ointment can be used to minimise the risk of gonococcal infection (IM/IV ceftriaxone is being used for overt infection). Tetracycline ointment 1% should be used (with oral erythromycin) to treat chlamydia

conjunctivitis (this condition is not prevented by silver nitrate use). *Pseudomonas* infection requires treatment with systemic antibiotics and topical gentamicin 0.3% eye drops.

***Gentamicin***

1. Give 5 mg/kg IM or IV once every 36 hours up to 7 days of age, and every 24 hours from 7 – 28 days.
2. If the infant weighs less than 2 kg, give 4 mg/kg per dose.
3. Leave 36–48 hours between each dose if there is renal failure.
4. If the infant is less than 32 weeks' gestation, give 4–5 mg/kg 36-hourly.
5. If the infant is more than 32 weeks' gestation, give 4–5 mg/kg 36 hourly up to 7 days of age, then 24 hourly.

***Hepatitis B vaccine***

Give 0.5 mL IM into the thigh as soon as possible after or within 12 hours of birth. Remind the mother that the infant will require booster injections at 6 weeks and 14 weeks after birth. Infants born to mothers infected during pregnancy or who are known high-risk carriers with a positive hepatitis B e-antigen should also be given 200 units of hepatitis B immunoglobulin (HBIG) IM into the other thigh within 24 hours of birth. Breastfeeding can safely continue.

***Metronidazole***

Give a 15 mg/kg loading dose and 7.5 mg/kg per dose once every 12 hours in infants less than 34 weeks gestational age, and every 8 hours in infants more than 34 weeks gestational age. Treatment can be given IV or orally, but solubility makes IM use unsatisfactory. If the IV route is used, start the maintenance dose 12 hours after loading if <34 weeks, and 8 hours after loading if >34 weeks. If the oral route is used, give the first dose 12 hours after loading.

**Miconazole**

This controls infection with candida ('thrush') more effectively than topical nystatin. Use the oral gel at least four times a day and the skin cream twice a day for at least 7 days. Topical treatment with 0.5% aqueous gentian violet for not more than 4 days may be equally effective. Oral nystatin drops (1 mL four times a day) can be used to reduce heavy intestinal tract carriage.

**TABLE 14.1 Antibiotics for use in the neonatal period**

| Drug | Route | Single Dose | Frequency | Postnatal age | Gestation |
|---|---|---|---|---|---|
| **Ampicillin** | IV, IM | 30-60mg/kg | 12 hourly | < 7 days | Any |
| | | 30-60 mg/kg | 8 hourly | 7–21 days | Any |
| | | 30-60mg/kg | 6 hourly | > 21 days | Any |
| | *Reduce dose frequency in severe renal impairment and birth asphyxia*<br>*Use higher doses of 100mg/kg in case of suspected Group B strep infection or meningitis* | | | | |
| **Benzyl Penicillin** | IV, IM | 25–50 mg/kg | 12 hourly | < 7 days | Any |
| | | 25–50 mg/kg | 8 hourly | 7–28 days | Any |
| | | 25–50 mg/kg | 6 hourly | > 28 days | Any |
| | *Reduce dose frequency in severe renal impairment and birth asphyxia* | | | | |
| | IV, IM | 50 mg/kg | 12 hourly | < 7 days | Any |
| | | 50 mg/kg | 8 hourly<br>6 hourly | 7- 21 days<br>>21 days | Any |

## Section 14. Drugs used to treat severe infections in the neonate

| Drug | Route | Single Dose | Frequency | Postnatal age | Gestation |
|---|---|---|---|---|---|
| **Cefotaxime** | | | | | |
| | *Reduce dose by 50% in severe renal impairment* | | | | |
| **Ceftazidime** | IV, IM | 50mg/kg | 24 hourly | < 7 days | Any |
| | | 50mg/kg | 12 hourly<br>8 hourly | 7 –21 days<br>> 21 days | Any |
| | *Reduce dose interval to 24 hours in severe renal impairment* | | | | |
| **Ceftriaxone** | IV, IM | 50mg/kg<br><br>50 – 100mg/kg depending on diagnosis | 24 hourly | Up to 15 days<br><br>15 – 21 days | Any |
| | Avoid in infants < 36 weeks' gestation or if jaundiced. Follow special IM preparation instructions | | | | |
| **Chloramphenicol** | IV, IM | 12.5mg/kg | 12 hourly | < 14 days | |
| | | 12.5mg/kg | 8 hourly | >14-28 days | |
| | *There is a serious risk of death from liver failure if the dose suggested is exceeded Oral dosing can be used to complete any course of treatment* | | | | |
| **Cloxacillin** | IV, IM | 25 mg/kg mg/kg | 12 hourly | < 7 days | Any |
| | | 25mg/kg | 8 hourly | > 7 -20 days | Any |
| | *Double the dose in severe infection and if CNS is involved Increase dose interval to 24 hours in severe renal impairment* | | | | |
| **Erythromycin** | PO | 12.5mg/kg | 6 hourly | | |
| | *There is no satisfactory IM preparation* | | | | |
| **Gentamicin** | IV | 5mg/kg | 36 hourly | < 7 days | >32 weeks > 2Kg |
| | | 5mg/kg | 24 hourly | 7-28 days | >32 weeks > 2Kg |
| | | 4mg/kg | 36 hourly | < 7 days | <32weeks <2Kg |
| | | 4mg/kg | 24 hourly | > 7 days | >32 weeks < 2Kg |
| | *If renal failure, leave 36 to 48 hrs between doses* | | | | |
| **Metronidazole** | IV, PO | 15mg/kg | (***loading) dose***) | Start 12 hrs after | IV, PO |

**Section 14. Drugs used to treat severe infections in the neonate**

| Drug | Route | Single Dose | Frequency | Postnatal age | Gestation |
|---|---|---|---|---|---|
| | | | | loading if <34 wks and after 8 hrs after loading if > 34 wks | |
| | | 7.5mg/kg | 12 hourly | | |
| | | 7.5mg/kg | 8 hourly | | |
| | *Infuse over 30 minutes*<br>*Injection solutions can be given rectally* | | | | |
| **Miconazole** | Oral gel | | 6 hourly | | |
| | Skin ointment | | 6 hourly | | |
| | *This controls infection with* Candida *('thrush') better than topical nystatin*<br>*Use for at least 7–10 days* | | | | |
| **0.5% Aqueous Gentian violet** | Apply | | Once daily for 4 days | | |
| **Oral nystatin drops** | PO | 1mL | 6 hourly | | |
| | *Can be used to reduce heavy intestinal tract carriage* | | | | |

## SECTION 15. Neonatal Respiratory disorders

***Table 15.1 Clinical features of respiratory distress in the newborn***

| | |
|---|---|
| **Tachypnoea** | Typically, respiratory rate 60 breaths/minute or higher (try and measure over at least 1 minute as infant's rate maybe irregular) |
| **Recession** | Of the chest wall and sternum - tugging of the soft tissues between the ribs or at the edges of the rib cage as a result of increased inspiratory effort. |
| **Expiratory grunting** | A prolonged expiratory effort, usually with an audible noise in an attempt to generate PEEP through a partially closed glottis |
| **Nasal flaring** | An attempt to increase to size of the airway and reduce resistance |
| **Apnoea** | **Either respiratory pauses lasting for more than 20 seconds or intermittent shorter apnoea with cyanosis or severe falls in oxygen concentration (< 92%)** |
| **Gasping** | Indicative of altered respiratory drive usually due to hypoxia: will lead very shortly to death if not treated |
| **Tachycardia** | Indicative of systemic hypoxic stress |
| **Pallor** | Reactive vasoconstriction to redistribute blood supply to essential organs |
| **Oxygen desaturation** - | $SaO_2$ < 94% in air, often less than 92% in more severe cases |
| **Altered consciousness** | If severe hypoxia reduces brain function |
| **Central Cyanosis** | Observed blueness of the mucous membranes indicative of poor oxygenation: a late change indicating severe respiratory distress or cardiac problem |

Many signs are relatively non-specific and may reflect not just conditions that affect the respiratory system, but also cardiac, neurological, and metabolic problems.

Not all these signs may be present depending on severity. Some signs such as desaturation & cyanosis may be masked if oxygen is being given.

Changes in clinical signs over time are important and may give a clue to a developing problem.

***Table 15.2 Causes of early respiratory distress (in first 12 to 24 hours of birth)***

| **Common** | |
|---|---|
| **Transient Tachypnoea of the newborn (TTN)** | 'Wet lung' caused by a delay in clearing lung fluid after birth |
| **Respiratory Distress Syndrome (RDS)** | Surfactant deficiency causing stiff lungs and inflammation usually in the immature lungs of the preterm infant |

| | |
|---|---|
| **Common** | |
| **Pneumonia** | Lung infections – often GBS or enterococcus – acquired before or during delivery |
| **Less Common** | |
| **Pneumothorax** | Air leak around one of the lungs |
| **Aspiration** | Of meconium or other particulate matter – blood, mucus, vernix often associated with hypoxic stress and gasping in the more mature baby. |
| **Rare** | |
| **Pulmonary Hypoplasia** | Underdeveloped lungs – may be associated with prolonged oligohydramnios or conditions restricting thoracic movement whilst in the uterus |
| **Pulmonary Haemorrhage** | Bleeding into the lungs, may occur with coagulation abnormalities. |
| **Congenital Abnormality** | Of lung or upper airway – e.g. diaphragmatic hernia, oesophageal atresia +/- tracheal fistula, Pierre Robin Sequence, choanal atresia. |
| **Non-Respiratory Causes** | |
| **Metabolic abnormalities** | May present with acidosis and increased respiratory effort from attempts to compensate through $CO_2$ clearance. |
| **Congenital heart disease** | Usually presents later, with cyanosis or failure as the ductus arteriosus closes and lung vascular resistance falls (section 26). Respiratory failure is seen after the first week in association with tachycardia, pallor, sweating, hepatomegaly and excessive weight gain |
| **Persistent Pulmonary Hypertension of the Newborn PPHN** | lung pressures fail to fall after birth, reverse shunting of deoxygenated blood may complicate other respiratory conditions after birth and make hypoxia and acidosis worse |
| **Severe Anaemia** | Decreased oxygen transport systems leading to increased effort in order to achieve adequate oxygen levels. |
| **Hypothermia** | |

Respiratory disorders typically present in the first few hours after birth. Symptoms may be non-specific and the clue to the cause may lie in a good history and examination. The differential diagnoses include many non-respiratory causes which need to be excluded. Sometimes it is not possible to be clear on the cause immediately, and treatment has to be pragmatic and reflect the uncertainty.

Maternal fever during labour and prolonged rupture of the membranes (more than 18 hours) particularly point to pneumonia or sepsis. Pneumonia may also be due to

congenital syphilis. Pneumothorax should be considered if the infant has been resuscitated using positive-pressure ventilation (although it has also been described as occurring spontaneously in about 1% of normal term infants). Transient tachypnoea is more common among infants delivered by elective Caesarean section (in the absence of spontaneous labour). Surfactant deficiency and infection are the most likely causes in preterm infants.

***General principles of treatment of respiratory diseases of the newborn***

*1. Resuscitation vs Stabilisation:* Are there life-threatening features? - Is resuscitation required? – If so then refer to 'resuscitation of the newborn infant: section 1. Otherwise, stabilisation is the objective.

*2. Thermal Care* – General principles apply – ensure babies are kept in an appropriate environment to maintain normal temperatures.

*3. Minimal Handing* – Try to allow babies to rest, the stress of frequent handling can be exhausting. Prone positioning can reduce the work of breathing. Undertake Skin to Skin care providing this does not compromise airway and breathing, and the baby can be suitably monitored.

*4. Airway* – Ensure the airway is open – exhausted babies may require support to keep the airway open. Support the head in the neutral position and, if necessary, provide jaw support. If there are thick secretions, then these may need clearing using a wide bore suction catheter under direct vision. Use the catheter gently. Try not to provoke a gag reflex in the conscious baby as this may result in apnoea, vomiting and further compromise.

*5. Breathing* – Ensure the infant is breathing. If the infant is apnoeic, gasping or has a very slow respiratory rate, then resuscitation is required - it may be necessary to support breathing. In the first instance use an appropriately sized mask with a positive pressure device such as a self-inflating bag with or without oxygen to re-establish effective respiration whilst determining the next steps.

6. Essential to neonatal intensive care is an *oxygen saturation monitor*. Pulse oximetry should be employed to assess initial disease severity, to monitor subsequent progress, and to ensure that such supplies of oxygen as are available are optimally used. It is possible to keep a baby clothed and warm while monitoring saturations. The ZUG pulse oximeter (https://www.zugmed.com) has proven reliable in Liberia and, unlike others advocated for low resource settings, has not shown any problems related to the fluctuating power supplies experienced in the country.

Aim to keep the oxygen saturations in the normal range (preterm babies below 32 weeks 92 to 94%, babies at or above 32 weeks' gestation and at term 94% - 98%). If required, titrate supplemental oxygen against other vital signs. When providing additional inspired oxygen, you **must** avoid hyperoxia ($SpO_2$ >98%) especially in the preterm infant.

7. Oxygen should be given either with an oxygen concentrator or from cylinders. An oxygen supply must be always available in areas where newborn infants are treated. The amount delivered must be closely monitored. An increase in the amount over time may be the only sign of deterioration.

Giving oxygen into a clear plastic hood placed over the head (head box) stops the oxygen supply from dropping - unlike tents or the incubator where the concentration falls every time the tent is lifted, or incubator door opened. Oxygen is an expensive resource and must not

be wasted in this manner. If a headbox is used, a battery-operated oxygen analyser can measure the exact concentration of oxygen being inhaled by the baby.
Nasal cannulae optimise the efficient use of the available oxygen supply. They prevent wasting of oxygen and make it very much easier to move and handle the infant without disrupting the supply. Although they make it more difficult to quantify how much oxygen is needed to address hypoxia as the measurement is only the flow delivered through the nasal cannulae, not the concentration delivered, practically this is an important measurement to document as a vital sign when treating respiratory failure.

Infants with respiratory distress should have their actual oxygen needs monitored and adjusted at regular intervals. Measuring the inspired oxygen concentration needed is one way of assessing the infant's changing condition. This can be done using a combination of a pulse oximeter with an inspired oxygen monitor placed in a head box next to the infant's face. A simpler alternative for achieving this objective involves titrating the oxygen flow to maintain saturation on the pulse oximeter in the range 94–98% for term infants and those at > 32 weeks' gestation and lower, at 92 to 94%, for preterm infants at 32 weeks' gestation or less, as described earlier.

Keeping the infant fully clothed with a pulse oximeter attached makes it possible to reduce the need for other monitoring of pulse and respiration, thus keeping the infant warm with minimal handling.

***Nasal CPAP (see below for details)***
In severe cases of respiratory failure, if available, nasal continuous positive airway pressure (n CPAP) represents a most appropriate respiratory support in low resource settings.

***Heated, humidified high-flow nasal cannula (HHHFNC) oxygen therapy***
This is a powerful and effective form of non-invasive ventilation suitable for neonates and is also described in detail below.

***Invasive ventilation***
Intubation and ventilation may be rarely needed in some infants with severe respiratory failure but requires highly complicated and expensive equipment and specially trained staff which are not usually available in low resource settings. Again, in the latter situation, arterial or capillary blood gas measurement can be helpful for determining the need and monitoring the requirements for this high level of respiratory support but requires sophisticated and expensive equipment.

***Circulation*** – Circulatory problems are not often the primary consideration. If hypoxic and stressed, then a tachycardia might be expected. Make an assessment of circulatory sufficiency, if evidence of compromise – cool peripheries, poor capillary return, then this will need addressing and one of the most likely causes will be neonatal sepsis (see Section 7)

It is important to watch trends in heart rate, respiratory rate and effort. Increases in any of these may be a marker of deterioration. When supplemental oxygen is given it can mask the worsening of hypoxaemia, so watch for an increase in the inspired oxygen needed to maintain saturations as well as falling saturations.
Feeds & fluids - Infants with serious respiratory distress may not cope with the extra demand of normal breast feeding. An orogastric tube may be required to ensure adequate intake, (nasogastric tubes can be more stable, but can block the nostril which in the obligate nasal breather may compromise the airway). Breast milk or 10% glucose may be given in limited quantities (up to 60 ml/kg/day). It may be necessary to reduce the volume of feed or adjust the feed volume &/or frequency if feeds are having a detrimental effect on respiratory stability. Encourage expression of milk by the mother. This is vital to preserve the breast

milk supply for when her infant has recovered even if not used. If facilities exist, milk can be stored for later use.

If significantly compromised such that gastric distension compromises breathing, and enteral feeds are felt undesirable, then an intravenous infusion of 10% glucose (60 mL/kg/day) may be a better option. Infants less than 2 days old should be started on an IV infusion of 10% dextrose at 60–90 ml/kg/24 hours. For infants more than 3 days old sodium chloride should be added to 10% dextrose to provide 2–3 mmol/kg/day of sodium chloride and used at the age-appropriate giving rates (see fluid management Section 3 and 4).

If a syringe driver or volumetric pump is not available then, because of the low volumes being infused, in neonates it is advised to use a paediatric burette (chamber) where 1 mL = 60 micro-drops (1 drop/minute = 1 mL/hour). Caution: A standard infusion set gives 20 drops/mL and can lead to dangerous fluid over- load if it is not carefully controlled.

An infusion monitor (for example: Sino MDT Ltd SN-1500H) which counts the drops given by a standard IV fluid giving set can be particularly helpful in helping to achieve accurate intravenous fluid volumes (see Section 32).

*Infection* – In many cases of respiratory compromise bacterial infection is a contributing factor. It can be difficult to exclude, especially in low resource settings. Give antibiotics IV or IM (the IV route is preferable) at least for the first 48 hours in all infants with respiratory distress. Take blood for culture first wherever possible. Antibiotics can be stopped if the blood culture results are negative and/or the infant is well after 72 hours.

*Infection control* - Take strong steps to prevent nosocomial (healthcare associated) cross- infection within the unit (from patient to patient, staff to patient or relative to patient). This can be a particular problem not only with some bacterial infections (e.g. E. coli, Klebsiella), but also with some dangerous viral infections (e.g. respiratory syncytial virus, RSV) that are more commonly seen later in the first month of life.

*Other investigations* - To gain further insight into the possible cause of the problem, a portable chest X-ray (if available: extremely unlikely in low resource settings) can be useful. Moving a baby to a fixed X-Ray machine may be risky and should only be undertaken if the baby is safe to move and information from the X-Ray considered vital.

A blood count and electrolytes (if available) may be important in helping manage severely ill babies, especially those on IV fluids.

***Management issues in specific respiratory conditions***

**Primary surfactant deficiency (respiratory distress syndrome (RDS), or hyaline membrane disease)**

Surfactant deficiency is by far the commonest cause of respiratory distress in a preterm infant in the first 3 days of life. It is a self-limiting condition because birth triggers a gradual increase in surfactant production. The challenge is to support the infant for the first 2–3 days (72 hours) of life without doing further damage to the lung, until such time as the surfactant deficiency resolves itself.

The role regarding the use of antenatal steroids in mothers in low resource settings with preterm labour is currently under review by WHO and is not being currently advised.

The key features of RDS (cyanosis, an expiratory 'grunt', tachypnoea, and intercostal and/or subcostal recession) characteristically become evident within 4 hours of birth.

Therapy follows basic principles above - namely:

1. Good thermal care (avoidance of hypothermia) & minimal handling of the infant.
2. Respiratory support with supplementary oxygen especially early nasal CPAP
3. Careful management of fluids – may need to stop feeds and give IV replacement. Keeping the infant 'nil by mouth', has been one of the standard ingredients of care for those with surfactant deficiency for more than 50 years.
4. Treating for possible additional lung infection in all cases. Give antibiotics IV or IM (the IV route is preferable) at least for the first 48 hours in all infants with respiratory distress, as bacterial infection may be contributing to the surfactant deficiency and therefore the infant's respiratory problems. Take blood for culture first wherever possible. Antibiotics can be stopped if the blood culture results are negative, and the infant is well after 72 hours.

Elective surfactant administration in well-resourced settings has changed the profile of the condition, reducing the time spent on respiratory support, but is expensive and requires appropriate cool storage facilities.

**Early** non-invasive respiratory support has become recognized as an effective way of supporting babies with RDS and is preferred as it avoids the complexity and potential complications of intubation and invasive ventilation. The application of nasal CPAP (or high flow) is now a standard approach. Making the infant breathe against a constant positive airway pressure generates PEEP and splints the lungs, holding the alveoli open. This reduces the work of breathing, stimulates the production of surfactant, and by preventing collapse, lessens the mechanical effects which damage the alveolar epithelium. The expiratory grunt that is a characteristic feature of this condition is the infant's own method of sustaining positive end-expiratory pressure (PEEP) and holding the alveoli open. Making the infant breathe against a constant positive airway pressure gradient achieves the same result. By applying this pressure at the nose (nasal CPAP), the complications associated with tracheal intubation can often be avoided. It can sometimes, however, lead to an increase in $CO_2$ if there is rebreathing of gas which should be avoided.

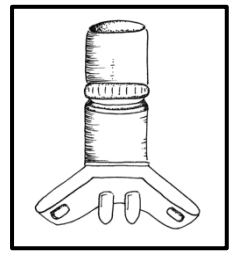
Invasive ventilation may still be necessary in more severe cases – where surfactant might be considered. However, intubation and mechanical ventilation whilst necessary, require more intensive monitoring and the therapy itself can cause problems through bypassing muco-ciliary protection against infection. The effect of the ventilation on fragile lungs may increase the likelihood of chronic lung disease.

To be maximally effective, we now know that CPAP should be applied as soon as there is **any** evidence of respiratory distress in a preterm infant and also in term infants with other causes of respiratory failure such as pneumonia or Transient Tachypnoea in the Newborn TTN (see below). CPAP given via paired short cannulae or a specially made nasal mask is probably best, as it minimises airway resistance.

A simple 'bubble flow' CPAP circuit can be constructed using a set of nasal prongs, tubing and a water reservoir (see reference below). Alternatively purpose-built CPAP systems with special nasal cannulae which are better able to provide pressures of 5–8 $cmH_2O$ can be acquired (a system specially designed for resource-limited settings based on an oxygen concentrator is available: www.diamedica.co.uk).

The 3-mm nasal cannulae that are normally used to provide supplemental oxygen may provide a degree of CPAP, especially when higher flow rates are applied (6–8 litres/minute), but there is a need for an air–oxygen blender to ensure that excessive and harmfully high concentrations of oxygen are not given and **humidification** of the air–oxygen mixture is also required as otherwise the dry gas will cause epithelial damage - so their use alone is not really a satisfactory solution.

***Figure 15.1***–Nasal continuous positive airway pressure (CPAP) applied via 'Argyll' nasal prongs. Can be connected to any positive pressure system. The prongs come in different sizes.



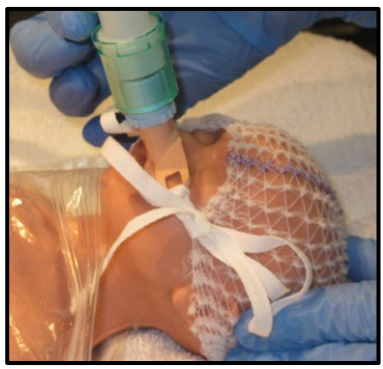
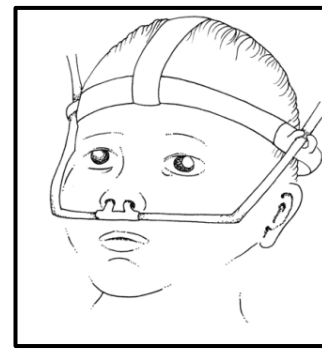


***Figure 15.2*** *Nasal continuous positive airway pressure (CPAP) equipment*



Regular nursing attention is necessary to make sure that the nasal cannulae remain correctly positioned and do not cause necrotic pressure damage to the nose.

*Reference: Falk M, Donaldsson S, Drevhammar T (2018) Infant CPAP for low-income countries: An experimental comparison of standard bubble CPAP and the Pumani system. PLoS ONE 13(5): e0196683 10.1371/journal.pone.0196683 [PMC free article] [PubMed] [CrossRef] [Google Scholar] + correction PLoS One. 2018; 13(7): e0201083.*

***HHHFNC***

Heated, humidified high-flow nasal cannula (HHHFNC) oxygen therapy provides warmed, humidified oxygen at flow rates that exceed minute volume requirements. HHHFNC therapy is increasingly used in preterm infants.

Flow rates of 1 L/kg/min to 2 L/kg/min can deliver high oxygen concentrations and some degree of positive intrathoracic airway pressure. HHHFNC has been used increasingly for support of neonates with severe respiratory distress.

HHHFNC oxygen therapy minimizes the inspiration of room air (and the subsequent dilution of supplemental high fraction of inspired oxygen [FiO2] gas) that occurs during low-flow oxygen therapy, by using supplemental gas flow rates that 'wash out' anatomic dead space. Efficient humidification and heating by commercial high-flow devices allows gas to flow at rates that would not be well tolerated or comfortable for patients, were they delivered by other means.

Compared with nasal CPAP which delivers gas flow at changing rates to maintain constant and positive intrathoracic pressure during inspiration and expiration, HHHFNC provides a constant, steady flow of gas. Airway pressures vary with inspiration and exhalation because the delivered gas flow is unchanging. HHHFNC oxygen therapy provides some degree of positive nasopharyngeal and intrathoracic pressure during exhalation, and usually only

when higher gas flows (approximately 2 L/kg/min) are administered. Both upper and lower airway resistance are reduced. Washout of anatomic dead space in the upper and intrathoracic airways reduces work of breathing.

Neonatal studies have shown that respiratory rates and work of breathing are reduced. Extensive neonatal literature exists to support the role of this therapy in reducing need for invasive ventilation.

For HHHFNC therapy to be effective and safe, medical gases must be adequately heated and humidified. A high-flow delivery of dry gas can irritate airways, activate bronchospasm and thicken or dry out respiratory and nasopharyngeal secretions. Circuit-size must be large enough to minimize resistance to gas flow, and nasal cannulae must be small enough to fit but not obstruct the patient's nostrils. Cannulae that are too big or excessive nasal secretions can lead to increased intrathoracic pressure in patients who cannot open their mouths to relieve pressure at higher gas flows. Commercial devices for neonates either have a pressure relief valve built into the circuit or are designed to sense excessive circuit pressure and reduce gas flow accordingly.

When initiating HHHFNC therapy, the starting flow rate is set at 1 L/kg/min to 2 L/kg/min and increased as needed to minimize clinical signs concerning the work of breathing (e.g., retractions, tachypnoea, grunting, nasal flaring). The maximum flow rate should be 2 L/kg/min. Commonly, oxygen concentration is started at an FiO2 of 50% and titrated up (or down) as needed to achieve a target oxygen saturation of 94% to 98%. As work of breathing improves, flow rate can then be slowly titrated down. The FiO2 for delivered gas should be reduced based on oxygen saturation and determined independently of the titrated flow rate. When patients can tolerate a lower gas flow rate and FiO2, they can be switched to low-flow O2 respiratory support.

In some neonates initiating HHHFNC therapy worsens respiratory distress, due to breath-stacking or auto-PEEP. In such cases, work of breathing may improve with a reduction in flow rate.

HFNC has similar rates of efficacy to other forms of non-invasive respiratory support in preterm infants for preventing treatment failure, death, and chronic lung disease.

Thanks to the Canadian Paediatric Society for this review:
https://www.cps.ca/en/documents/position/nasal-cannula

**Transient tachypnoea of the newborn (TTN)**

Most of these infants are born at or near term and there is an association with delivery by Caesarean section which has not been preceded by labour. The condition relates to a delay in clearing lung fluid after birth. The presenting symptoms are indistinguishable from RDS. However, unlike RDS, the signs tend not to progress with time in the hours after birth. These infants will recover on their own with appropriate care based on the principles above. Few need additional inspired oxygen or other support for more than 72 hours.

As it is not possible to definitely diagnose TTN, give antibiotics IV or IM (the IV route is preferable) at least for the first 48 hours in all infants with respiratory distress, as bacterial infection maybe a contributory cause of the infant's respiratory problems. Take blood for culture first wherever possible. Antibiotics can be stopped if the blood culture results are negative, and the infant is well after 72 hours.

**Bacterial pneumonia**

Basic principles of respiratory support apply. Pneumonia, once diagnosed, should be managed as outlined in Section 7 on suspected neonatal sepsis, remembering that there may be systemic infection (septicaemia) as well as pneumonia.

**Aspiration pneumonia**

Aspiration of particulate matter can occasionally obstruct the trachea. It can also cause a chemical pneumonitis. Aspiration requires gasping and in a situation of hypoxic stress can occur in utero. Blood, mucus, and vernix may also cause problems at birth, and after birth, gastroesophageal reflux of stomach contents (acid or milk). Meconium and gastric acid are irritant, and if aspirated into the lung, provoke an inflammatory reaction which may exacerbate matters and prolong respiratory problems.

The published evidence does not support routine suctioning on the perineum at birth in situations where meconium is present. Nor does it support routine intubation and suctioning of the trachea after birth – which in the conscious infant can provoke reflex apnoea and bradycardia. If, however, in the non-breathing infant initial attempts at lung inflation are not successful, then it is important to consider inspection under direct vision and if there is then visible evidence of meconium or other particulate matter in the airway, suctioning with a large bore catheter.

Basic principles of care apply (as above). If there has been aspiration then the lungs may be stiffer, and a greater degree of effort may be required by the infant, or support such as nasal CPAP provided to help breathing. The patchy nature of the problems caused by aspiration can lead to other difficulties such as intrapulmonary shunting and persistent pulmonary hypertension (see below). It can also lead to air trapping and increased risk of pneumothorax (see below).

There is an increased risk of infection with aspirated matter, so IV antibiotics are indicated until treated, or excluded.

With minimal handling, IV fluid and supplemental oxygen, most of these infants can be expected to make a complete recovery if there has been no associated hypoxic cerebral damage.

After birth, recurrent minor unrecognised reflux of gastric contents including acid and aspiration is probably more common than a single massive episode of aspiration. Over time this may render an infant more oxygen dependent. Infants who are hypotonic and have a poor cough reflex are at greater risk. Reflux, regurgitation, and aspiration may precipitate or apnoeic/hypoxaemic episodes.

Prolonged positive pressure respiratory support may increase gastric distention and the likelihood of vomiting and subsequent aspiration. Passage of a gastric tube and decompression of the stomach can reduce this tendency.

**Pneumothorax**

This is present more frequently than expected and may occur spontaneously in up to 1–2% of infants. It is often asymptomatic, and may be associated with meconium aspiration, high inflation pressures used during mechanical ventilation or resuscitation, and respiratory distress syndrome. It does not automatically need to be treated unless there is progressive respiratory distress. Confirmation by chest X-ray (if available) may incur delay in treatment, especially in the case of a rapidly developing tension pneumothorax.

It is possible to diagnose a clinically significant pneumothorax by simple observations. The abdomen may be distended by downward displacement of the liver and spleen. The breath sounds may be reduced on the affected side. A hyper-resonant chest with mediastinal shift (trachea +/- cardiac apex deviated away from the side of the suspected pneumothorax) and rapidly deteriorating clinical condition with severe hypoxaemia and/or cardiovascular compromise (bradycardia, hypotension) strongly suggests a tension pneumothorax. This requires an immediate needle thoracocentesis (see Section 38) usually followed (if this results in an immediate improvement in respiratory and cardiovascular function) by the insertion of a chest drain into the fourth or fifth intercostal space in the mid to anterior axillary line (see Section 38).

In an emergency with a rapidly deteriorating cardiac and respiratory function, this **must be done without prior X-ray confirmation**. Transillumination can be useful if a 'cold light' (fibre-optic light source) is available (the affected side may glow brightly).

A pneumothorax that does not result in severe respiratory distress, and is not under tension, may spontaneously resolve without mechanical removal of the pleural air, but oxygen and careful monitoring are required.

### Persistent fetal circulation

This is a potentially life-threatening condition leading to poor lung perfusion after birth. It may complicate fetal hypoxia, meconium aspiration, early bacterial pneumonia, diaphragmatic hernia, respiratory distress syndrome or (very occasionally) be a primary disorder.

With airway hypoxia, the pulmonary vasculature fails to relax. As a result of this, pressures in the right ventricle remain high and there is persistence of the 'fetal circulation' with reverse shunting of deoxygenated blood from the right side of the heart across the atrial septum (via the Patent Foramen Ovale -PFO), and from the pulmonary artery into the aorta (via the duct). The systemic arterial supply is then deoxygenated and the reduction in oxygenation of the blood returning to the lungs perpetuates the situation with increasing hypoxia and acidosis. The condition can be difficult to differentiate from some congenital cardiac conditions where there is right-left shunting.

In its primary form (that is without associated other lung pathology) the lungs appear clear with a lack of vascular shadowing on chest X-Ray as the arteries are in spasm. Oxygenation is the problem; carbon dioxide clearance may be adequate.

Basic principles of respiratory care apply. It is important to ensure good airway oxygenation (achieving the levels of $SpO_2$ described earlier) as this helps the lung vasculature to relax and can prevent the condition either developing or deteriorating. Delivery of higher concentrations of oxygen may be necessary. Hypercarbia and acidosis are triggers. Optimise ventilation and, if measurements are available, aiming for a low normal $CO_2$ and correct metabolic acidosis (some advocate slight alkalinisation pH 7.45).

Since the effect of pulmonary hypertension is reverse shunting because of raised pulmonary artery pressures, it is vital to optimise the systemic circulation and maintain a good systemic blood pressure to try and reverse any shunting tendency.

Fluids and/or inotropes/pressors may be required. (see Section 28, circulation). Pulmonary vasodilators, such as inhaled nitric oxide, sildenafil, or magnesium sulphate, have all been used to good effect. However, nitric oxide is expensive and requires special delivery systems and systemic drugs can lead to significant systemic hypotension and make matters worse. They should be used very selectively in a controlled environment in specialised centres. Survival is more likely in a unit that can provide sustained respiratory support, and early transfer should be considered when possible.

As it is not possible to make a definite diagnosis of Persistent Fetal Circulation in low resource settings, give antibiotics IV at least for the first 48 hours in all infants with respiratory distress, as bacterial infection maybe a contributory cause of the infant's respiratory problems. Take blood for culture first wherever possible. Antibiotics can be stopped if the blood culture results are negative, and the infant is well after 72 hours.

**Pulmonary Haemorrhage**

This may occur in preterm infants with other lung conditions and with coagulation disorders. There is an association with persistent duct because of the increased blood flow through the lungs. It is characterised by relatively sudden onset of desaturation, respiratory distress, increased work of breathing, and visible blood in the airway, or frothy blood-stained secretions up an endotracheal tube if intubated.

It can be a difficult condition to treat. Increased levels of oxygen and respiratory support are required. High levels of PEEP may reduce the tendency for further bleeding. Circulatory support with fluids and a fresh blood transfusion may be required if significant volumes are lost. Any clotting dysfunction may also need to be dealt with by a fresh blood transfusion from a live donor. An extra dose of vitamin K may be helpful and should be given.

**Lung hypoplasia**

Chronic loss of liquor for many days before birth can impede lung growth enough to threaten survival, but what looks like a serious problem at delivery can occasionally resolve quite rapidly after 1–2 days. However, where the oligohydramnios is due to bilateral renal agenesis or dysplasia, the prognosis for survival is very poor. The stiffness of the small malformed lungs in these cases causes marked intercostal and subcostal recession with un-relievable cyanosis. Chest X-ray will often reveal an untreatable pre-terminal pneumothorax. The infant's face may appear flattened and there may be limited extension of the elbows and knees due to oligohydramnios.

Several rare generalized skeletal abnormalities that affect rib growth can also cause severe untreatable lung hypoplasia

**Congenital malformations**

***Congenital Diaphragmatic Hernia (CDH):***

The most common congenital defect causing respiratory distress soon after birth is diaphragmatic hernia. This occurs in 1 in 4000 births, and more commonly affects the left side.

Clinical examination reveals respiratory distress, and reduced air entry on the affected side with a displaced cardiac apex beat and scaphoid (indrawn) abdomen. A chest X-ray if possible is diagnostic – demonstrating visible loops of bowel in the thorax. The immediate priorities are stabilization rather than immediate transfer.

Basic principles of respiratory care apply (see above). Whilst increased ambient oxygen may be required, non-invasive positive pressure support may cause a problem as it increases gut distension and potential respiratory embarrassment. If increased support is required, intubation if available, may be preferred for this reason. Reduce any tendency for the gut to dilate by decompression with a gastric tube on open drainage, withhold feeds and provide intravenous fluids. Pulmonary hypertension often complicates matters so higher concentrations of oxygen may be required.

Stabilisation of respiration with mechanical ventilation following intubation or continuous negative extra-thoracic pressure (CNEP) can be helpful if available

Engage with surgical services early. Once stable, transfer will be required. This can be challenging. Restricted lung growth means that only about 50% of these infants have any chance of survival. CDH may be associated with other congenital abnormalities and syndromes.

**Tracheo-oesophageal abnormalities**

**Tracheo-oesphageal fistula** This may present with respiratory difficulties. If there is also oesophageal atresia then the infant cannot swallow secretions. Drooling, poor feeding and respiratory difficulty are typical symptoms. Passage of an orogastric or nasogastric tube is not possible. X-ray is diagnostic. Continuous drainage of the oesophageal pouch is required, intravenous fluids and transfer to a surgical centre is necessary (if available).

**Upper airway and tracheal abnormalities**
Congenital abnormalities of the trachea or upper airway can cause problems. Cleft palate can present with feeding difficulties, but also aspiration. Floppy larynx and tracheal abnormalities present with stridor or apnoea. The same applies for external compression of the trachea by masses or abnormal vasculature.

Careful clinical examination may provide a clue to the cause. Positive pressure support and sometimes intubation are required to stabilize the situation. Surgery may be required in some cases (if available).

**Pierre Robin Syndrome** is a condition in which an infant has a smaller than normal lower jaw (mandible) so that especially during sleep the tongue extends backwards into the throat, and causes difficulty breathing (snoring and stridor with falls in $SpO_2$ especially when supine and asleep)). There is also often a cleft palate. The goals of treatment focus upon breathing and feeding and optimizing growth and nutrition despite the breathing difficulties. If there is evidence of airway obstruction then the infant should be placed in the prone position during sleep, which helps bring the tongue base forwards away from the back of the throat.
If airway obstruction is severe, placement of a nasopharyngeal airway inserted into the nose and down the pharynx, ending just above the vocal cords can be helpful. This airway acts as a "splint" which maintains opening of the airway by keeping the tongue from falling back on the posterior pharyngeal wall and occluding the airway, therefore preventing airway obstruction, hypoxia, and asphyxia.

Frequent small feeds, possibly initially (with expressed breast milk) through an orogastric tube if breast feeding is difficult, may be needed to maintain nutrition. This is very important as growth of the baby enlarges the airway and makes airway obstruction less of a problem.

**Congenital heart disorders**
Some of these disorders can occasionally cause overt cyanosis from birth, but there are not usually any associated signs of respiratory distress (*see* Section 26).

## Section 16. Apnoea/hypoxaemic episodes

Episodes of apnoea and hypoxaemia, usually occurring together, are common in ill full-term or preterm newborn infants.

These episodes can be defined as a cessation of respiration or a hypoxaemic event associated with signs of cardiorespiratory decompensation (bradycardia, cyanosis with falls in oxygen saturation, and pallor). Such episodes are particularly common in preterm infants under 32 weeks' gestation where they are sometimes referred to as 'apnoea of prematurity'. In term infants, apnoeic/hypoxaemic episodes are usually associated with an underlying pathological condition where there is airway hypoxia (such as pneumonia or airway obstruction). Sometimes they are associated with severe anaemia.

***Causes of episodes of apnoea/hypoxaemic episodes that can occur in both preterm and full-term infants***

*Pulmonary parenchymal disease*
Any condition that causes airway hypoxia or decreased lung compliance can contribute to hypoxaemic/apnoeic episodes. Appropriate pulmonary support including adequate airway oxygenation should be provided and the underlying pulmonary condition should be treated.

*Airway obstruction*
This may result from simple mal positioning of the head (e.g. hyper-flexion or hyper-extension of the neck), especially in preterm infants. Congenital airway anomalies such as tracheo-oesophageal fistula or an aberrant thoracic blood vessel compressing the trachea (vascular sling) may also present with hypoxaemic/apnoeic episodes. Maintaining proper head positioning or surgical correction of the underlying anomaly (if available) should be provided.

*Infection*
Infection must always be suspected, and IV antibiotics administered until infection has been ruled out by subsequent clinical outcome and laboratory results.

*Convulsions (see Section 21)*
Convulsions may present primarily as episodes of hypoxaemia or apnoea. This possibility should be considered especially in term or near-term infants with no other identifiable cause of apnoea. In such cases there may be a poor response to positive pressure ventilation. Convulsions in the first 1 to 3 postnatal days are usually due to intra-partum hypoxia (birth asphyxia).

If there is a history of an operative vaginal delivery (e.g., forceps) or other birth trauma, this may indicate the possibility of an intracranial haemorrhage.

*Gastro-oesophageal reflux*
Sometimes recurrent apnoeic/hypoxaemia is associated with gastro-oesophageal reflux, particularly in neurologically compromised infants with poor airway-protective reflexes. Note that Caffeine may make reflux worse through its effect on the gastro-oesophageal sphincter tone.

*Maternal medication:*
If mother has received opiates for control of pain during labour within a few hours of delivery, then this can have a depressant effect on the baby's breathing. Usually this is not a major issue, and support of respiration allows time for the medication to clear. If necessary, but rarely required, Naloxone hydrochloride 200mg as single IM dose, or alternatively a single

dose of 60mg/kg, can be used to reverse these effects. Intramuscular administration provides a 'depot' effect with sustained release and a longer time of action. The risk of intravenous administration of naloxone is that it wears off before the opiate has cleared from the system. There is a theoretical risk of convulsion should naloxone be given to a baby where the mother has had long term opiates (for analgesia, or substance abuse). It is rare for opiates to cause a problem in these cases because of chronic fetal exposure.

Magnesium Sulphate if given in high doses to the mother for severe pre-eclampsia or eclampsia may also produce temporary apnoeic episodes in the neonate.

***Treatment of apnoea/hypoxaemic episodes***

1. Gentle stimulation may be all that is required immediately to start the infant breathing again.
2. Bag-and-mask resuscitation may occasionally be called for, and there should always be this equipment immediately available and ready to use (not locked away in a cupboard) should this be necessary.
3. If available, oral caffeine may reduce the number of episodes in a preterm infant. Caffeine seldom causes the tachycardia and other side effects associated with theophylline. It is advisable to continue caffeine for 4–5 days after cessation of apnoea/hypoxaemic episodes. Recurrent episodes that do not respond to caffeine occasionally require a period of nasal CPAP or mechanical ventilation.
4. A pulse oximeter with the alarm turned on for hypoxaemia is the best way of detecting absent ventilation as this can occur despite continued breathing movements. This will also identify any baseline low oxygen saturation due to airway hypoxia which, when treated, may help to prevent apnoea/hypoxaemic episodes.

***Specific management issues in treating episodes of apnoea/hypoxaemia in the preterm***

Here, apnoea/hypoxaemic episodes vary significantly in duration and severity and are especially severe in very-low-birth-weight infants. Sometimes, isolated bradycardia with oxygen desaturation events is identified without clinically apparent apnoea. The exact mechanisms responsible are not fully understood but include a mixture of impaired central nervous system respiratory control ('central apnoea'), intrapulmonary shunting from airway hypoxia and upper airway obstruction.

Treatment of the underlying cause, if one can be identified, is important. Gentle stimulation may be all that is required immediately to start the infant breathing again.

Caffeine (see Table 16.1), by its effect on the respiratory centre, may reduce or even eliminate the severity and frequency of apnoeic/hypoxaemic events. Caffeine is the preferred therapy because it has a long half-life (allowing once daily dosing), fewer side effects and serum levels do not have to be monitored. Continuous positive airway pressure (CPAP) or rarely mechanical ventilation may become necessary if apnoea is persistent and severe.

***TABLE 16.1*** Caffeine doses for apnoea/hypoxaemic episodes in premature infants given intravenously or orally

| Preparations | Each dose | Dose frequency | Notes on administration |
|---|---|---|---|
| Caffeine citrate | 20 mg/kg | Loading dose given slowly if IV over 30-60 minutes | If oral dose is too large, divide into two and give 1 hour apart. Start maintenance 24 hours after loading dose. |
| | 5 mg/kg | Standard Dose - once daily | |

| Preparations | Each dose | Dose frequency | Notes on administration |
|---|---|---|---|
| | 10 mg/kg | High dose – once daily | |
| | | | |
| Caffeine base | 10 mg/kg | Loading dose given slowly if IV over 30-60 minutes | |
| | 2.5 mg/kg | Standard Dose - once daily | |
| | 5 mg/kg | High dose – once daily | |

*Note: Caffeine citrate 10mg = Caffeine base 5mg*

## Section 17. Polycythaemia in the neonate

### Introduction

Polycythaemia is defined as a venous haematocrit > 65% or Hb > 22 g/dL. A haematocrit (also called packed cell volume (PCV)) above 65%, means that the blood becomes more viscous (thick) which can produce dangerously reduced capillary perfusion in many organs. There is a risk is of cerebral, renal or mesenteric vein thrombosis, leading to problems affecting the brain, kidneys and gut.

### Clinical presentation

The baby can be hypotonic, drowsy, have poor sucking, be irritable, jittery and, when severe, have convulsions. These are important danger signs.

### Causes

This potentially harmful condition occurs in up to 4% of births and risk factors include:

- being either small or large for gestational age
- intrauterine growth retardation
- being an infant of a diabetic mother
- being one of twins with a shared placenta

“Milking” of the umbilical cord at birth increases the amount of blood transferred into the baby which can also produce this condition.

### Investigation

Capillary samples can have a higher haematocrit and if > 65% should be confirmed by a venous sample. Screen high risk babies at 2, 12 and 24 hours by capillary blood measurement of PCV and then if > 65% confirm with a venous sample.

Check blood sugar and serum bilirubin and calcium if possible. Hypoglycaemia, jaundice and hypocalcaemia are associated features of polycythaemia.

### Treatment

1) Exclude dehydration: weigh the baby and compare current weight with birth weight. Normally babies lose 5–7% of their body weight in the first 3–4 days and regain their birth weight level by 10–14 days. If the baby’s weight at 24 hours has dropped by 5% or more (or at 3 days of age has dropped by 10% or more) from the birth weight, then dehydration is present.
2) Supervise feeding and, if necessary, increase enteral feeds or give IV fluids.
3) Check blood glucose and bilirubin levels and treat appropriately (see below).
4) *If venous PCV is 65–70%* and no danger signs, bilirubin is below phototherapy levels and no hypoglycaemia is present, treat conservatively. Ensure adequate fluid intake by direct observation of feeding and daily weights.
5) *If venous PCV is 70–75%* and there are no danger signs, treat polycythaemia by giving additional fluid of 20 mL/kg per day enterally or IV. Also treat jaundice with phototherapy and hypoglycaemia with glucose, if necessary IV.
6) *If PCV is > 75% or there are any danger signs,* then partial exchange transfusion (PET) should be undertaken urgently. PET involves the exchange of 20 mL/kg by repeatedly taking off aliquots of blood of up to 5 mL at a time and replacing IV with equal volumes of Ringer-Lactate or 0.9% saline. Ideally blood will be taken from a peripheral vein but, if this is not possible, use an umbilical venous catheter placed aseptically. At the end of the procedure, re-check the PCV, Hb, bilirubin and blood glucose levels. Continue to monitor the clinical state of the baby and the PCV until it is shown to fall below 60%. Re-check blood glucose and bilirubin levels as appropriate.

## Section 18 Haemorrhage in the neonate

### *Causes of haemorrhage*

An infant's blood volume approximates to 80 mL/kg of body weight. Peripartum haemorrhage of relatively small amounts of blood can therefore result in hypovolaemic shock in the newborn. Common causes may include a slipped ligature on the umbilical cord, intrauterine feto–maternal haemorrhage (diagnosed by the Kleihauer–Betke test), or sub-galeal haemorrhage. Vasa praevia or an accidental incision of the placenta during Caesarean section are other causes. Bleeding in the first week of life is uncommon but may signify haemorrhagic disease of the newborn or clotting factor deficiency.

The Kleihauer–Betke test is a blood test used to measure the amount of fetal haemoglobin transferred from the fetus to the mother's bloodstream. It is usually performed on Rhesus-negative mothers to determine the dose of Rho(D) immune globulin needed to inhibit the formation of Rh antibodies in the mother and prevent Rh disease in future Rh-positive children. It is also the standard method of quantitating feto–maternal haemorrhage. The test exploits the differential resistance of fetal haemoglobin to acid. A standard blood smear prepared from the mother's blood is exposed to an acid bath. This removes adult haemoglobin, but not fetal haemoglobin, from the red blood cells. Subsequent staining makes fetal cells (containing fetal haemoglobin) appear rose-pink in colour, whereas adult red blood cells are only seen as 'ghosts'. The percentage of fetal to maternal cells is calculated under a microscope.

### *Presenting features*

The infant will appear pale with weak peripheral pulses, tachypnoea and a tachycardia that may exceed 200 beats/ minute. Blood pressure may be low or undetectable even in a term infant but is very difficult to measure in neonates. The haematocrit and haemoglobin concentration may be normal in an infant with acute hypovolaemic shock and are an unreliable early indicator of the amount of blood lost in the first few hours after the bleed.

Common sites of blood loss include the umbilical stump and the gastrointestinal tract. In the latter case, there may be doubt as to whether blood is of maternal origin (blood swallowed at delivery or from a bleeding nipple) or infant origin. In some cases, this can be resolved by the Apt test.

*Apt test*

Mix 1 part of the blood-containing fluid (vomitus, gastric aspirate or liquid stool) with 5 parts of distilled water. Centrifuge it, and then mix 1 mL of the supernatant with 1.25 mL of 0.25% sodium hydroxide (NaOH). A yellow- brown colour signifies maternal blood, whereas fetal haemoglobin remains pink. The solution must be pink to start with.

### *Treatment when shock is present*

In an emergency where the infant is shocked, take a blood sample from the baby for blood grouping and cross-matching then take a blood sample of 30ml directly from the mother's vein and infuse 10mL/Kg IV into the baby over 5 minutes.

Alternatively, if available, give 10ml/Kg of virus screened O Rh-negative blood.

Fresh maternal blood is best because it is warm and contains clotting factors and does not require testing for viruses.

Always give 1 mg of vitamin K (Phytomenadione) IV.

If maternal blood, or O-negative or cross-matched blood is not available, use 10–20 mL/kg of 4.5% albumin or Ringer-lactate/Hartmann's solution or 0.9% saline.

***Treatment when bleeding is present, but shock is not yet present***

If shock is not present but bleeding is continuing and the baby is exhibiting severe anaemia but is not yet shocked, take a blood sample from the baby for blood grouping and cross-matching, haemoglobin, platelet count (if possible), film and whole blood clotting time studies and give virus tested cross-matched blood (10 to 20 mL/kg) at a rate depending on the degree of bleeding (usually the first 10 mL/kg can be safely given over 5 minutes), monitoring the response and reducing the rate of infusion as improvement occurs. Sometimes a further 10–20 mL/kg of cross-matched blood may be necessary, preferably given at a rate of not more than 5mls/kg/hr.

If cross matched blood is not available within a safe time give maternal blood as described in shock above.

Always also give 1 mg of vitamin K (Phytomenadione) IV. Bleeding due to haemorrhagic disease of the newborn usually stops within 30 minutes of vitamin K administration.

If bleeding continues after Vitamin K and high-level blood transfusion services are available, give 20 mL/kg of fresh-frozen plasma (if available) and administer platelets (again if available and measurable) if the count is < 60 000/ $mm^3$. Fresh live donor blood may also help to stop the bleeding.

## Section 19 The neonate with jaundice

**Introduction**
Up to 80% of normal term infants become jaundiced a few days after birth and for most it is a benign process for which no treatment is necessary. Nearly all preterm babies have visible jaundice from day 3 for a few days. This is because bilirubin is released from the breakdown of red blood cells and the neonatal liver takes time to develop its ability to turn it into a soluble form and effectively excrete it. The serum bilirubin level usually rises after the first 24 hours of life and peaks at 100–300 µmol/litre (6-18mg/dL) by 3 to 5 days after birth.

In a minority of cases, serum bilirubin can rise to very high levels (over 425 µmol/litre (25mg/dL) and cause brain damage, deafness, convulsions, and death. Careful monitoring of babies with jaundice, consideration of the possible causes of more severe jaundice and prompt treatment, if necessary, can protect the babies at risk of severe hyperbilirubinaemia from these devastating side effects.

***Causes of early neonatal jaundice (up to 10 days of age)***
*Physiological jaundice* is common, affecting up to 80% of normal term infants. Jaundice can be considered physiological and not requiring treatment if the following criteria are met:

- Jaundice is not present in the first 24 hours of life.
- The infant is well, and free from signs of infection, without enlargement of the liver or spleen.
- The bilirubin concentration does not exceed 300 µmol/ litre (approximately 18 mg/dL) at any stage (term infants only). The safe limit for preterm infants is probably nearer 250 µmol/ litre (15mg/dL).
- The bilirubin concentration reaches a peak on the fourth or fifth day of life.
- The jaundice is no longer visible by the end of the second week of life in term infants or by the end of the third week of life in preterm infants.

**Serious causes of jaundice in the first 10 days of life:**

| Underlying cause | Clues and questions to ask | Management |
|---|---|---|
| Exaggerated physiological jaundice | Is the baby dehydrated? Is there polycythaemia? Is there excessive bruising? | Encourage early unrestricted breast feeding. If the haematocrit (PCV) is >65% treat according to polycythaemia section 17 above. **Do not feed with water.** |
| Infection | Was the liquor foul smelling? Did the membranes rupture more than 18 hour prior to delivery? Was the mother unwell during labour? Is the baby lethargic? Does the baby have a fever? Is there an associated rash, low platelets or hepatosplenomegaly? | Treat the baby with antibiotics, keep skin to skin and encourage early unrestricted breast feeding or feed with a nasogastric tube if necessary. Consider malaria or intrauterine infections such as syphilis, CMV, toxoplasmosis, rubella, hepatitis. |
| Haemolysis | Was the jaundice visible in the first 24 hours of life? Is mother blood group O with a baby with blood group A or B or AB? Is mother rhesus negative with a rhesus positive baby? Was the | Encourage early unrestricted breastfeeding. Start phototherapy if jaundice has appeared in the first 24 hours of life or refer promptly to a centre which has phototherapy. Check |

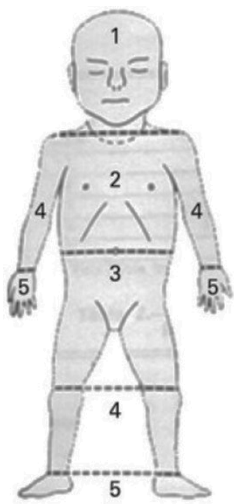
| Underlying cause | Clues and questions to ask | Management |
|---|---|---|
| | baby anaemic at birth? Is there a family history of jaundice: in particular G6PD or congenital spherocytosis? Is the baby a boy and at greater risk therefore of G6PD deficiency? | haemoglobin as baby might need treatment for anaemia. |
| Prematurity | Is the baby less than 37 weeks' gestation? Is the birthweight less than 2.5kg? | Encourage early unrestricted breastfeeding, feed with a nasogastric tube if necessary. Start phototherapy at lower levels than for term babies (see WHO advice below) |
| Rare metabolic causes: for example, Galactosaemia | Is the baby very unwell with low blood glucose, lethargy, hepatosplenomegaly and clotting problems? Did feeding make the situation worse? | IV fluids (10% glucose-D10) and refer to specialist centre (if available) |

***Investigations***

***Establishing the severity of jaundice***

Estimating the degree of jaundice visually is not accurate but may be the only means available to healthcare professionals in some parts of the world. The face becomes yellow first, jaundice is visible on the trunk at higher bilirubin levels and finally, the palms of the hands and soles of the feet become jaundiced.

Kramer's index appears below. Look at the naked baby in natural light. Eyes, gums and blanched skin are useful places to look for jaundice across all skin tones. These observations are only estimates and should be confirmed by formal testing if possible.




| Grade | Extent of Jaundice | Levels of bilirubin |
|---|---|---|
| 0 | None | |
| 1 | Face and neck only | 5mg/dL or 86µmol/L |
| 2 | Chest and Back | 6-8mg/dL or 103-137µmol/L |
| 3 | Abdomen below umbilicus to knees | 9-12mg/dL or 154 -205µmol/L |
| 4 | Arms and legs below knees | 13-15mg/dL or 222-257µmol/L |
| 5 | Hands and feet | >15mg/dL or >257µmol/L |

*Note:* *µmol/litre divided by 17.1 = mg/dL*
*mg/dL multiplied by 17.1 = µmol/litre.*

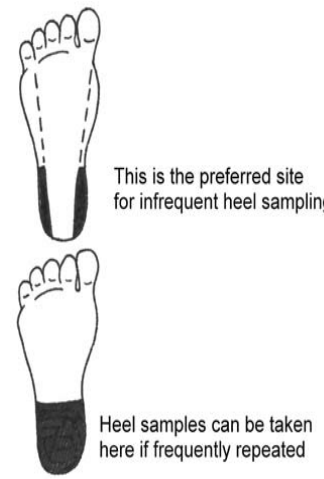
The bilirubin concentration can be most simply and accurately measured by simple spectrophotometry of serum obtained by centrifuging blood in a capillary tube. Several easily operated machines are available. Ward based devices for assessing the bilirubin content of a spun micro-haematocrit tube optically are accurate until the level exceeds 350 µmol/litre and are adequate for most clinical purposes. If these devices are used, staff should be trained in this technique, and the machine should be calibrated daily and checked with control specimens of known bilirubin content. Using dirty tubes (or cuvettes), haemolysed or lipaemic (containing obvious fat on examining tube) samples can produce significant errors. Use plastic tubes, not glass ones, to keep staff safe from blood borne viruses if a tube should break.

The accurate measurement of values in excess of 350 µmol/litre is only possible in a biochemistry laboratory.

Direct or conjugated bilirubin presents no threat to the brain. It only accounts for a small fraction of the total serum bilirubin level in the first week of life. Decisions about treatment should therefore be based on the total serum bilirubin level, remembering that even laboratory estimates have limited precision.

***Collecting blood***

- wrap the baby and allow him/her to breastfeed to reduce the pain felt
- clean the overlying skin
- grip the foot firmly enough to make it go red but not white. Stab the back third of the foot just once and then squeeze gently and intermittently to stimulate blood flow.
- use a new disposable 2.4-mm blood lance each time you sample. Using a needle can cause osteomyelitis if the bone is touched. Never penetrate more than 2mm if only a needle is available.
- slight finger pressure exerted through a cotton ball on the site for about a minute is usually enough to stop any further bleeding after the procedure is over.
- the healthcare worker should be careful not to prick their own finger. Gloves should be worn.




***Investigations for early onset jaundice***

A good principle to remember is to measure bilirubin levels and investigate if:

- jaundice appears on day 1 in any infant
- jaundice appears on day 2 in any preterm infant
- the palms of the hands or soles of the feet are yellow in any sick neonate or in any infant of any age.

1. The mother's and infant's ABO and Rhesus blood groups. Save serum to crossmatch if exchange transfusion is needed
2. Direct Coombs test (if positive this indicates an isoimmune haemolytic anaemia)
3. Complete blood count and reticulocyte count (anaemia and reticulocytosis indicate haemolysis, high PCV suggests polycythaemia and/or abnormal white blood cells indicate possible infection)
4. Peripheral blood smear (abnormal red cell morphology and/or fragmented red cell forms suggest a specific red cell disorder and/or haemolysis)
5. G6PD screen (if possible)
6. Syphilis serology

7. Thyroid function tests ($T_4$, TSH) (if possible).
8. Urine test for non-glucose-reducing substance (for possible galactosaemia) (if possible).

***Treatment***
Most jaundiced babies do not need treatment. Ensure good hydration with frequent breastfeeds. Supplementary water is unnecessary and harmful because it reduces breastfeeding.

If it is not possible to measure bilirubin levels in your facility, phototherapy should be started in the following babies:
- All babies with jaundice appearing less than 24 hours of age
- All babies less than 37 weeks' gestation with jaundice appearing less than 48 hours of age
- All babies with yellow palms and soles
- All sick babies with visible jaundice

If serum bilirubin measurements are available, treat jaundiced babies as per the Table 19.1 below:

***TABLE 19.1*** *WHO recommendations (2012) for phototherapy and exchange transfusion levels of unconjugated bilirubin*

| | **Phototherapy** | | **Exchange transfusion** | |
|---|---|---|---|---|
| Age | Healthy newborn >35 weeks' gestation | Newborn <35 weeks gestation or ill term babies with risk factors | Healthy newborn >35 weeks' gestation | Newborn <35 weeks' gestation or ill term babies with risk factors |
| Day 1 | Any visible jaundice | | 260 mmol/litre (15 mg/dL) | 220 mmol/litre (10 mg/dL) |
| Day 2 | 260 mmol/litre (15 mg/dL) | 170 mmol/litre (10 mg/dL) | 425 mmol/litre (25 mg/dL) | 260 mmol/litre (15 mg/dL) |
| Day 3+ | 310 mmol/litre (18 mg/dL) | 250 mmol/litre (15 mgd/L) | 425 mmol/litre (25 mg/dL) | 340 mmol/litre (20 mg/dL) |

In general, the smaller the infant and the sicker the infant, the more urgent the need to intervene. Bilirubin in plasma is normally bound to albumin, but in a sick acidotic infant less binding occurs, and more 'free' bilirubin will be available to enter the central nervous system. Therefore, consider intervening about 40 µmol/litre below the indicated level in such circumstances.

The specific bilirubin levels for which phototherapy and exchange transfusions need to be considered in infants born before 31 weeks' gestation are less certain. A frequently used guideline is to initiate phototherapy when the bilirubin level approaches 85 µmol/litre/kg birth weight (which equals approximately 5 mg/dL/kg birth weight), and to consider an exchange transfusion for levels above 170 µmol/litre/kg birth weight (which equals approximately 10 mg/dL/kg birth weight).

Ill infants with continuing jaundice should be given a prophylactic 1 mg IM injection of vitamin K if it is not clear that they received such an injection at birth, to minimise the risk of potentially fatal late vitamin K deficiency bleeding.

***Notes on Phototherapy***
Light in the blue-green region of the spectrum (not ultraviolet) converts bilirubin to its water-soluble isomer lumirubin, which can be excreted in urine and stools.

In infants who are very yellow, it is best to use light from a bank of at least six 60-cm 20-watt fluorescent strip lights suspended not more than 30 cm above the unclothed infant (lights placed 60 cm from the infant are only about half as effective). Placing a white sheet under and round the infant seems to increase the effectiveness of any treatment. While under phototherapy, it is important to monitor body temperature and to protect the infant from draughts. The baby's eyes should be masked to protect them from the bright light.

The infant should be nursed naked in an incubator, under a radiant heater or in a cot, allowing maximum skin exposure. Feeding, especially breastfeeding, should continue, as more frequent breastfeeding is helpful not only in eliminating meconium from the bowel but also in enhancing bilirubin clearance via the stools and urine. The infant can be removed from under the lights for breastfeeds as necessary (intermittent treatment has been shown to be as effective as continuous treatment). Fluid other than breast milk (e.g. breast milk substitute, water, sugar water) should not be given. However, the total daily fluid intake may need to be increased by about 10%, especially in preterm infants, in order to minimise additional water losses from evaporation and convection.

Troublesome side effects of phototherapy include rashes and profuse watery stools, but these are rare and do not require treatment. The trend in bilirubin level should be checked twice a day. Phototherapy can be stopped when the serum bilirubin level is 50 µmol/litre (3 mg/dL) below the phototherapy threshold. This will usually be after 24 hours continuous phototherapy or longer if treatment is intermittent or the cause of the jaundice is haemolysis as the process of excessive red blood cell breakdown is on-going.

***Notes on Exchange transfusions***
This entails a volume of the infant's blood equal to the body weight in kg × 2 × 80 mL being exchanged in small aliquots (samples) with O Rhesus-negative blood, or blood cross-matched against maternal antibodies. It takes at least 2 hours to do and is a very risky procedure which should only be undertaken in a neonatal unit where the staff are experienced in the use of this procedure. Even in experienced hands, 1% of infants may suffer a sudden cardiac arrest during or shortly after the procedure.

Exchange transfusion is used when bilirubin levels rise above the threshold values in Table 19.1 putting the infant at risk of developing bilirubin-induced neurological dysfunction (BIND) or a more severe form of bilirubin encephalopathy, often termed kernicterus. In such cases, the bilirubin level needs to be immediately lowered with a double-volume exchange transfusion. Refer babies who are jaundiced on day 1 of life and at risk of haemolysis to a specialist centre (if available) urgently.

The functions of exchange transfusion include the following:

- removal of maternal antibodies
- removal of antibody-coated red blood cells before they haemolyse
- correction of the associated anaemia
- lowering of total bilirubin levels, if there is sufficient time for equilibration between intravascular and extravascular levels.

Exchange transfusion is generally only undertaken if the rate of red blood cell breakdown is likely to exceed the ability of phototherapy to control bilirubin levels. This is very likely to occur in infants with a positive Coombs' test who are already anaemic (because of fetal haemolysis) at birth. A cord blood haemoglobin level of less than 140 grams/litre serves to identify most of these infants.

If available, human immunoglobulin 500 mg/kg, given as an IV infusion over 2 hours, reduces the number of infants who require an exchange (especially if due to Coombs' positive Rhesus or ABO incompatibility). It also decreases the number who require a 'top-up' transfusion for late neonatal anaemia.

***Exchange transfusion method***

1. Calculate the infant's circulating volume (= 80 mL/kg). Twice this amount of blood will be required. Do not exceed this (usually 1 bag of whole blood = 450 mL). Do not use blood that is more than 4 days old.
2. Check that the blood has either the same ABO group as the infant or is blood group O Rhesus-negative and in addition is compatible with the mother's serum.
3. Ensure that the infant is closely monitored throughout the procedure.
4. This is a sterile procedure, so gloves and gowns must be worn and universal precautions applied.
5. Secure umbilical vein access. Pass the umbilical venous catheter (UVC) as described in Section 44 and check its position with an X-ray (if available). Ideally it should be positioned in the vena cava just outside the right atrium, but a position below the liver is also acceptable if the line will sample and flush easily. A line positioned in the liver should not be used.
6. Ideally, use a blood warmer if available (especially for low-birthweight infants). Otherwise warm the blood bag by placing it under the mother's or health worker's clothing next to the skin.
7. Set up a closed circuit with either a four-way tap, or two three-way taps. The four links are:
    a. the infant
    b. the syringe for removing and replacing blood
    c. the blood to be transfused
    d. the route for discarding the infant's blood.
8. Make sure that the total blood in and out is recorded by an observer. Both of you should plan to spend at least 2 hours on the procedure.
9. Decide on the size of aliquot (sample) you will be exchanging with each draw and infusion. This is roughly as follows:
    a. baby weighing < 1500 grams: 5 mL
    b. baby weighing 1500–2500 grams: 5–10 mL
    c. baby weighing 2500 grams: 10–15 mL
10. If you use small aliquots, remember to add an allowance for the 'dead space' in the tubing between the syringe and the baby.
11. You should draw out each aliquot over 2–3 minutes to avoid abrupt changes in blood pressure and replace over 3–4 minutes with the observer keeping a running total.
12. Send the first aliquot for measurement of bilirubin, electrolyte and calcium concentrations.
13. Halfway through the procedure check the blood glucose (always), calcium and potassium concentrations (if available).
14. Measure them again, together with the bilirubin concentration, at the end of the procedure.
15. Rarely, it may be necessary to exchange more than once in quick succession.

Symptomatic hypocalcaemia may occur as the citrate in donor blood binds calcium. This responds best to halting the procedure for 15 minutes. Giving calcium gluconate is of little benefit and may be hazardous, so is best avoided.

Although the potassium concentration of the blood is often 8–10 mmol/litre, this does not usually cause significant hyperkalaemia.

| **RISKS OF EXCHANGE TRANSFUSION** |
|---|
| Cardiac arrest in 1% |
| Fatal air embolism |
| Hypo- or hyper-volaemia leading to poor gut and renal perfusion |
| Swings in blood pressure leading to intracranial bleeds and necrotizing enterocolitis |
| Donor blood > 5 days old causes hyperkalaemia and arrhythmias |
| Cold blood causes major cold stress |
| CMV, HIV, Hepatitis C or B infection |
| Clotting problems |
| Hypocalcaemia with convulsions |

Because of all of these risks, if at all possible, exchange transfusion should be undertaken in a neonatal unit where the staff are experienced in this procedure.

**Prolonged jaundice**

Most babies clear their jaundice by the 3rd week of life. P*rolonged jaundice* means jaundice persisting beyond 14 days in term babies and beyond 21 days in preterm infants. 3% of breastfed infants are still slightly jaundiced up to 12 weeks after birth, usually due to the breastmilk itself preventing certain proteins in the infant's liver from breaking down bilirubin into a soluble form that can be excreted. Rarer but more serious causes of prolonged jaundice need to be considered and excluded.

***Serious causes of prolonged jaundice:***

| **Underlying cause** | **Clues and questions to ask** | **Management** |
|---|---|---|
| Any of the causes listed for early onset jaundice | As above in the early onset jaundice table. Is the baby thriving? | Depends on cause |
| Biliary atresia | Are the baby's stools pale? Is the urine dark? Is the liver palpable? Is there poor weight gain? Is there diarrhoea? | Measure direct bilirubin as well as total bilirubin if possible. Treatment is surgical and should be done before the age of 6 weeks so transfer the baby to a specialist centre. |
| Thyroid dysfunction | Is the baby lethargic? Is there poor feeding? | Investigate and treat with thyroxine if TSH high |
| Neonatal hepatitis | Is the baby unwell? | Supportive care. Vitamin K if unwell. |
| Congenital infections | See other sections of this book for clinical signs | Treat where possible syphilis, malaria, CMV, Toxoplasmosis, HIV, Rubella |
| Severe malnutrition | | See chapter in Paediatric Handbook 1 |

In prolonged jaundice, it is important to determine not only the total bilirubin concentration but also *the amount and proportion of conjugated bilirubin*. Conjugated (direct) bilirubin is not neurotoxic, but its presence signifies the presence of biliary obstruction attributable to potentially serious conditions such as neonatal hepatitis or biliary atresia.

The history can be informative if laboratory investigations are not available. The presence of pale unpigmented stools or dark urine would be suggestive of biliary obstruction. Urine can also be tested with a reagent strip for bilirubin (if positive for bilirubin, the diagnosis of biliary obstruction is supported, provided that the infant is not receiving phototherapy when unconjugated bilirubin appears in the urine). It is important to identify biliary atresia promptly, as operative intervention (if available) is more likely to be successful if undertaken within 8 weeks of birth. Even mild jaundice merits review if the stool becomes grey or putty coloured rather than yellow or green.

It is important that congenital hypothyroidism and glucose-6-phosphate dehydrogenase (G6PD) deficiency are identified.

Tests in prolonged jaundice should include the following:

- liver function tests including total and direct (conjugated) bilirubin
- the mother's and infant's blood groups
- direct Coomb's test (if positive this indicates an isoimmune haemolytic anaemia)
- complete blood count and reticulocyte count (anaemia and reticulocytosis indicate haemolysis, high PCV suggests polycythaemia and/or abnormal white blood cells indicate possible infection)
- peripheral blood smear (abnormal red cell morphology and/or fragmented red cell forms suggest a specific red cell disorder and/or haemolysis eg. Hereditary spherocytosis)
- G6PD screen
- syphilis serology
- malaria screen
- HIV screen
- thyroid function tests (T4, TSH)
- urine test for non-glucose-reducing substance (for possible galactosaemia)
- urine for microscopy (occasionally urinary tract infections can cause prolonged jaundice)
- ultrasound scan of liver (if skilled interpretation is available)

If the direct proportion is more than 20% or the total direct bilirubin more than 25 µmol/litre, this signifies cholestatic/obstructive jaundice, and a coagulation profile should also be requested. Treat the baby with 1mg vitamin K if clotting is abnormal and transfer to a specialist centre (if available).

## Section 20 The neonate with severe anaemia

**Introduction**
Anaemia is defined as haemoglobin or haematocrit more than 2 standard deviations below the mean for age. The American Academy of Pediatrics states that, at birth, the normal haemoglobin concentration for a term newborn is 19.3±2.2 g/dL (193±220 g/L), with a haematocrit of 61%±7.4% (0.61±0.074). The peak is at 2 hours after birth and then these levels start to drop. The increased oxygenation in the baby after birth negatively feedbacks on erythropoiesis, fetal red blood cells have a short life span and so the haemoglobin concentration will fall over the first couple of months of life to reach a typical physiological lowest value of 90 to 110g/L in a 2- to 5-month-old baby. This process is more pronounced in preterm infants and nearly all babies born before 28 weeks of gestation will need a transfusion during their stay on the neonatal unit. See below for suggested transfusion thresholds at various postnatal ages.

**Causes**
The most common cause of mild anaemia in the neonatal period is the physiological process of the breakdown of red blood cells after birth and the delay in making new ones.
Pathological more severe anaemia can occur when red blood cells are broken down too rapidly, too much blood is lost, or the bone marrow does not produce enough new red blood cells. Causes include:

1. haemorrhage
    a. haemorrhagic disease of the newborn
    b. bleeding from umbilical cord especially with a precipitous delivery
    c. sub-galeal bleeding into the scalp after traumatic instrumental delivery
    d. slipped ligature on the umbilical cord
    e. vasa praevia or an accidental incision of the placenta during Caesarean section
    f. disseminated intravascular haemorrhage (DIC) associated with severe sepsis
2. twin-to-twin transfusion
3. feto–maternal haemorrhage
4. placental abruption
5. haemolysis due to
    a. Rhesus incompatibility
    b. ABO incompatibility
    c. Red blood cell enzyme defects eg. G6PD deficiency
    d. Red blood cell membrane defects eg. spherocytosis
    e. Intrauterine infections including malaria
6. exaggerated physiological process in preterm infants

**Presentation**
Neonates with anaemia are generally pale and or jaundiced. If anaemia is severe the baby will have tachypnoea, tachycardia, and sometimes a flow murmur when you listen to the heart. They may lack the energy to feed effectively and seem lethargic.

Hepatosplenomegaly may be seen in haemolysis and / or congenital infection.

Bleeding in the first week of life is uncommon but may signify classic **haemorrhagic disease of the newborn**. Common sites of blood loss include the umbilical stump and the gastrointestinal tract. This can be prevented by administration of 1mg vitamin K to every newborn at birth. Babies who did not receive vitamin K at birth and are exclusively breastfed are at risk of late haemorrhagic disease of the newborn as well at 2 – 12 weeks of age.

An infant's blood volume approximates 80 mL/kg of body weight. Peripartum haemorrhage of relatively small amounts of blood can therefore result in hypovolaemic shock in the

newborn. The haematocrit and haemoglobin concentration may be normal in an infant with acute hypovolaemic shock and are an unreliable early indicator of the amount of blood lost in the first few hours after a bleed.

Newborn babies with a haemolytic cause for their anaemia are at risk of rapidly becoming worse due to dissociative shock (insufficient haemoglobin to effectively carry oxygen to the tissues). Early exchange or top-up transfusions can save their lives.

**Investigations**

| TEST | WHAT DOES THE RESULT MEAN? |
|---|---|
| Reticulocyte count | Increased in haemolysis. A low reticulocyte count suggests congenital bone marrow failure e.g. Congenital infections such as parvovirus, HIV, syphilis, rubella, CMV |
| Direct antiglobulin test (DAT) or indirect antiglobulin (Coombs) test | DAT always positive in Rh incompatibility, usually positive in ABO incompatibility. Coombs likely to be positive in ABO incompatibility even if DAT negative. |
| Blood film/smear | Often normal in G6PD deficiency but there may be bite and blister cells, large number of spherocytes in spherocytosis, a few spherocytes in ABO incompatibility, schistocytes (fragments of RBCs) in DIC secondary to sepsis or birth asphyxia. |
| Clotting studies | Prothrombin time (PT), thrombin time (TT) and activated partial thromboplastin time (APTT) are slightly longer in newborn but function might be normal. Whole blood clotting time is the best measurement for low resource settings (see below) |
| Group and Cross match | Baby and mother should be tested. Blood for transfusion should be ABO compatible with both and RhD compatible with the baby. If in doubt, use O- blood |
| Kleihauer test on maternal blood | If fetal red blood cells are seen in mother's blood, there has been a fetus to maternal haemorrhage. |
| Apt test | If the pink supernatant turns yellow brown, the blood from the infant's GI tract is maternal (see method below) |

***Whole blood clotting test (WBCT)***

1. If laboratory clotting tests are not available, transfer 2 mL of venous blood into a small dry clean plain glass test tube (approximately 10 mm x 75 mm).
2. Hold the tube in your closed fist to keep it warm (+ 37°C).
3. After 4 minutes, tip the tube slowly to see if a clot is forming. Then tip it again every minute until the blood clots and the tube can be turned upside down.
4. Failure of a clot to form after 7 minutes, or formation of a soft clot that breaks down indicates a blood clotting disorder (coagulopathy)

***Kleihauer–Betke test***: a blood test used to measure the amount of fetal haemoglobin transferred from the fetus to the mother's bloodstream. (Section 18)

***Apt test:*** a test used in neonatal gastrointestinal bleeding to determine whether the blood is from the mother (during birth for example or from breastfeeding from cracked nipples) or from the baby (which may signify haemorrhagic disease of the newborn). (Section 18)

***Treatment of anaemia***

Haemolysis may continue for several weeks after birth even if it is not severe enough to require intervention in the first week of life. An attempt should therefore be made to check all infants with a positive Coombs' test for late anaemia when they are about 6 weeks old. Infants with a capillary haemoglobin level of less than 80 grams/litre or a haematocrit (PCV) of less than 25% should then receive a 'top-up' transfusion of 20 mL/kg of cross-matched or group O Rhesus-negative blood given over 2 hours. Red cell concentrate or packed cells are preferable. Daily folic acid (1 mg/day) for at least 1 week can help to reduce anaemia.

***Blood transfusion***

The British Committee for Standards in Haematology suggest the following transfusion thresholds:

| POSTNATAL AGE | Transfuse if on O2 or CPAP | Transfuse if not in O2 |
|---|---|---|
| First 24 hours | Hb less than 120g/L | Hb less than 100g/L |
| Days 1-7 | Hb less than 100g/L | Hb less than 100g/L |
| Days 8-14 | Hb less than 95g/L | Hb less than 75-85g/L |
| Over 14 days | Hb less than 85g/L | |

https://www.transfusionguidelines.org/transfusion-handbook/10-effective-transfusion-in-paediatric-practice/10-2-neonatal-transfusion

https://www.msdmanuals.com/professional/pediatrics/perinatal-hematologic-disorders/perinatal-anemia#v1087357

https://www.karger.com/Article/Fulltext/357378

## Section 21 The neonate with seizures, fits or spasms

Seizures (also called fits or convulsions) have been reported to affect about 0.1% of term infants and 10% of those weighing less than 1500 grams at birth. Uncontrolled seizures can cause damage to the infant brain and therefore it is vitally important to treat seizures early to prevent further brain injury

***Presenting features***
It is very important to differentiate true seizures (due to uncontrolled electrical activity of the brain) from other involuntary movements (e.g. extreme jitteriness or benign myoclonic jerks). This can be very difficult.

Seizures may be difficult to recognise (apnoea, staring, lip smacking / grimacing, deviation of the eyes, cycling movements of the limbs) or more obvious (tonic extensor posturing or clonic movements). Involvement of a limb or one side of the body does not necessarily imply a focal cause in the neonate.

The presence of associated autonomic instability and / or lateral eye deviations may signal seizure activity. The absence of these findings or elimination of the movements when the limbs are restrained indicate a non-seizure event.

A bulging anterior fontanelle may suggest infection or large intracranial haemorrhage with raised intracranial pressure which both predispose to seizures. It is important to always measure and record the head circumference on presentation.

***TABLE 21.1*** *Differentiating between seizures and jitteriness*

| Well but jittery baby | Infant with clonic seizures |
|---|---|
| No abnormal eye movements | Abnormal eye movements |
| No apnoea | Apnoea |
| No colour changes | Pallor or cyanosis |
| No heart rate changes | Tachycardia |
| Easily triggered by handling and stopped by gentle passive flexion of the affected limb | Independent of handling |
| Rhythmical movement | Jerky with fast and slow components that are not equal |

***Causes of seizures***
The commonest causes of seizures are:

- Hypoxic Ischaemic Encephalopathy / Birth Asphyxia
- Hypoglycaemia
- CNS Infection
- Hypocalcaemia

All causes include the following:

1. *Neurological Causes*

- **Hypoxic Ischaemic Encephalopathy**: this is the most common cause of seizures in a term infant. Onset is usually within the first 24 hours, and it almost never starts after the third day
- **Intracranial Haemorrhage, Subarachnoid Haemorrhage or Cerebral infarctions**: these are also common causes of neonatal seizures. With subarachnoid haemorrhage, seizures may or may not be focal. However, unilateral tonic–clonic seizures are often observed with cerebral infarction. Although intraventricular haemorrhage occurs most

frequently in low-birth-weight infants or at gestational ages under 32 weeks, very rarely it may manifest in term or near-term infants with neonatal seizures. Always give 1 mg IV vitamin K

*2. Infective Causes*

- **Meningitis** – although meningitis is not the commonest cause of neonatal convulsion, it must always be excluded by lumbar puncture and antibiotics commenced urgently pending the results of culture
- **Sepsis** – as a consequence of severe illness
- **Tetanus** - remains a problem in many low-resource countries

*3. Metabolic Causes*

- **Hypoxaemia:** ensure the baby is not hypoxaemic ($SpO_2$ < 94% at term or at > 32 weeks' gestation and not < 92% at or below 32 weeks' gestation)
- **Hypoglycaemia** (<2.5 mmol/l or 45 mg/dl): always check blood glucose levels
- **Hypocalcaemia** (<1.75 mmol/l) or **Hypomagnesaemia** (<0.6 mmol/l)**:** check plasma calcium and magnesium levels
- **Hyponatraemia and Hypernatraemia**: seizures are uncommon unless the plasma sodium level is < 120 mmol/l or > 160 mmol/l. Seizures in infants with hypernatraemia may result from associated cavernous sinus thrombosis. A rapid fall or rise in serum sodium level, as may occur with too rapid therapeutic correction, may be more injurious than the absolute value of serum sodium level. A slow correction is desirable in such situations
- **Bilirubin Encephalopathy** (see above Section 19 on jaundice)
- **Rare inborn errors of metabolism** (e.g. urea cycle defects, non-ketotic hyperglycinaemia) require measurement of serum amino acids, urine fatty acids, serum lactate, serum pyruvate and blood ammonia levels (unfortunately often not available). Measuring the anion gap can also be quite helpful. A high value may be suggestive of an inborn error of metabolism

*4. Other Causes*

- Maternal substance abuse, particularly opiate withdrawal

***Investigations***

These should include the following:

- Lumbar puncture and blood culture
- Full blood count, PCV, CRP
- Blood glucose, calcium, urea and electrolytes, and blood ammonia (if available)
- Blood gas analysis to help further assess acid– base status
- Cranial ultrasound (if available)
- Intracranial imaging (CT or MRI if available)
- Baseline and follow-up electroencephalograms (if available) may aid diagnosis and treatment
- Save urine, plasma, and CSF for metabolic studies (if available) if seizures are protracted.

***Treatment*** *See Figure 21.1*

Management of a neonate with seizures is as follows:

- Airway
- Breathing - Treat low $SpO_2$ or cyanosis with oxygen. Fits that interfere with respiration need to be treated and may require respiratory support.
- Circulatory access – intravenous or intraosseous
- Measure blood glucose. If less than 2.5mmol/l or 45 mg/dl or if blood glucose measurement not available - give Glucose, IV, IO, orally or NG (2 mL/kg of 10%

glucose)
- Hypocalcaemia – give Calcium Gluconate 10% 2ml/kg over 5-10 min with ECG monitoring
- Hypomagnesaemia – Magnesium sulphate 50% 0.2 ml/kg by deep IM injection or Magnesium Sulphate 10% 1ml/kg by IV infusion over 10 min.
- Give high dose antibiotics, IV or IM, as there is a strong possibility of meningitis or sepsis
- Stop the seizure with an anticonvulsant:
    - phenobarbital, 20 mg/kg over 15 minutes IV or IM
    - further phenobarbital 10mg/kg over 15 mins IV up to total 40mg/kg
    - paraldehyde 0.4ml/kg rectally
    - phenytoin 20mg/kg over 20 mins
    - diazepam 300 microgram/Kg IV slowly or 500 microgram/Kg rectally
- Monitor the heart rate and respiratory rate, and oxygenation (ideally with pulse oximetry) – anticonvulsants may affect breathing so close monitoring and treatment is needed. Treat low $SpO_2$ or cyanosis with oxygen.
- Consider long term anticonvulsant therapy: the earlier the fits appear, the more frequent they are (more than two or three per hour) and the longer they last (more than 3 minutes), the more likely it is that long term anticonvulsants will be needed.

When managing neonatal seizures, it is best to focus on the limited number of conditions where immediate treatment can have a major impact on long-term outcome. It is essential to consider the three main treatable causes of fitting, namely hypoglycaemia, hypocalcaemia, and meningitis as any delay in these diagnoses could have serious consequences.

There are many situations where seizures are simply the outward sign of damage that cannot be reversed, even though it may be possible to stop continuing seizure activity from making matters worse.

Focal seizures can sometimes be the sign of what was otherwise a silent haemorrhagic infarction of part of the brain. While investigation would explain what was going on, it would not alter management.

***Anticonvulsant treatment***
Anticonvulsants may precipitate a need for respiratory support. Therefore, always have a bag-valve-mask available. There is little evidence for one anticonvulsant over another in neonatal care.

**Phenobarbital**
This is the first-line IV drug for neonatal seizures.

Give a 20 mg/kg IV loading dose slowly over at least 5 minutes, to minimise the risk of shock, hypotension or laryngospasm. Additional 10 mg/kg may be required if seizures persist or recur (70% response rate) up to a total of 40mg/kg.

This can then be followed by maintenance dose of 2.5 to 5 mg/Kg once or twice daily.

Always have a bag-valve-mask available to support ventilation.

With hypoxic encephalopathy usually only a loading dose is needed. Seizures have been reported to respond to this dose 40% of the time. An additional 10 mg/kg may be required if seizures persist or recur (70% response rate).

**Phenytoin**

This is the second-line drug for neonatal seizures.
Give an 18mg/kg loading dose (diluted in 10–15 mL of normal/0.9% saline) IV slowly over 10–20 minutes (monitor for hypotension and cardiac arrhythmia, making sure that the drug does not leak into the tissues), and then 2.5-5.0 mg/kg IV 12 hourly. Orally from 1month age Initially 1.5-2.5mg/kg twice daily, then adjusted according to response to 2.5-5mg twice daily.

This drug requires the presence of a 0.9% saline filled IV line (because the drug crystalizes out in dextrose solutions). The same problem also renders the IM route unavailable. Flush the line before and after infusion with 0.9% saline

Infants more than 2 to 3 weeks old may need a considerably larger maintenance dose. Oral absorption of phenytoin may be quite unpredictable, so this would need to be monitored. Phenytoin is dangerous in infants with hypoxic ischaemic encephalopathy who may also have hypoxic ischaemic heart injury.

**Diazepam**
This is an alternative to Midazolam (if Midazolam is available) and if no IV access but has more respiratory depression side effects. Dose of 1.25 to 2.5mg can be given rectally and can be repeated after 10 minutes

Diazepam can be given IV at a dose of 300 microgram/kg over 5 minutes or rectally in a dose of 1.25-2.5mg. The rectal dose can be repeated **once only** after 10 minutes if the infant is still fitting.

However, it is vital that hypoglycaemia has been excluded and treated before giving this drug.

A working bag-valve-mask of suitable size must be ready next to the infant before this drug is given.

**Midazolam (if available)**

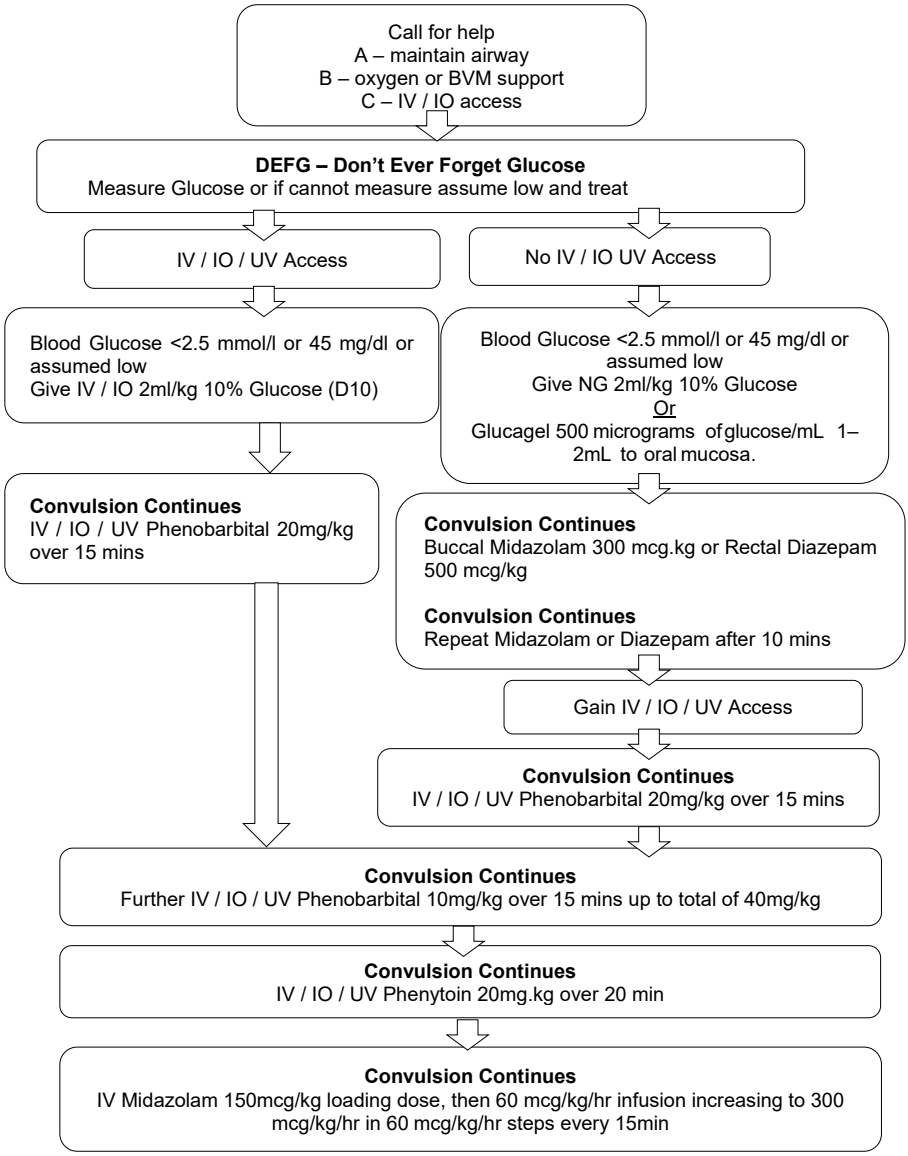
Can work in children where phenobarbital has been unsuccessful. Can be given IV (150 micrograms/kg loading dose then 60 micrograms/kg/hour infusion increasing by 60 micrograms/kg/hour every 15 min to max 300 micrograms/kg/hour).

If no IV access, midazolam can be given by buccal route (300 micrograms/kg). This can be repeated after 10 minutes if seizure not ceased

It can cause respiratory depression, so a bag and mask must be available when it is used, and the infant must be monitored closely.

**Maintenance Therapy**
Once seizures are controlled, maintenance therapy (which is rarely needed) with a single agent (usually phenobarbital) is often possible. Discontinuation of treatment depends on the underlying cause of the seizures but aim to withdraw anticonvulsants as soon as possible.

***Figure 21.1*** *Pathway of care for the neonate who is fitting*



## Section 22 Hypoglycaemia (glucose < 2.5 mmol/litre or < 45 mg/dL)

Hypoglycaemia is a common problem in the nursery; it can occur in infants who appear well, as well as in those who are sick. It is important to identify any infant at risk and implement preventative and curative measures as early as possible. Untreated symptomatic hypoglycaemia can result in brain damage.

Infants at risk of developing hypoglycaemia include the following:

1. infant of diabetic mother
2. preterm infant
3. small-for-gestational-age or wasted infant
4. large-for-gestational-age infant
5. post-term infant
6. sick infant with infections and respiratory failure
7. infant who is not receiving adequate breast milk.

The definition of hypoglycaemia is controversial, and no studies have determined an absolute value at which organ dysfunction will occur. However, it is known that a prolonged low level of symptomatic hypoglycaemia is associated with brain injury. At the time of writing, most neonatologists prefer to maintain blood glucose levels above 2.5 mmol/ litre (45 mg/dL).

### *Causes of neonatal hypoglycaemia*

#### *Increased utilisation of glucose (hyperinsulinism)*

- Infants of diabetic mothers.
- Respiratory distress.
- Abrupt interruption of high glucose infusion.
- Polycythaemia.
- Hypothermia.

*Rare causes of hyperinsulinism include:*

- erythroblastosis fetalis
- islet-cell hyperplasia
- Beckwith–Wiedemann syndrome
- insulin-producing tumours
- maternal beta-agonist tocolytic therapy
- rarely mal-positioned umbilical arterial catheter infusing a high concentration of glucose into coeliac and mesenteric arteries (T11–T12), stimulating insulin release.

#### *Decreased production/stores of carbohydrate*

- Prematurity.
- Small-for-gestational-age or wasted infant.
- Inadequate caloric intake.

#### *Mixed increased utilisation and/or decreased production from other causes*

- Perinatal stress (e.g. due to hypoxia, sepsis, shock, hypothermia).

*Rare causes*

- Defects in carbohydrate metabolism (galactosaemia, fructose intolerance, glycogen

storage disease).
- Endocrine deficiency (adrenal insufficiency, hypothalamic insufficiency, glucagon deficiency).
- Defects in amino acid metabolism (maple syrup urine disease, propionic acidaemia, methylmalonic acidaemia, tyrosinaemia).

**Diagnosis of hypoglycaemia**

There are few data on normal blood glucose levels in the first week of life, particularly for healthy breastfed term infants. Moreover, there is little evidence that a transient low blood glucose concentration in term infants who show no physical signs is harmful. However, asymptomatic hypoglycaemia may rapidly progress to symptomatic hypoglycaemia. Fits due to hypoglycaemia typically start in a previously well infant on or after the second day of life.

Indications for measuring the blood glucose concentration of a term infant include lethargy, poor feeding, temperature instability, respiratory distress, new onset apnoea/hypoxaemia, jitteriness, pronounced hypotonia, diminished consciousness and seizures. The association between such signs and low blood glucose levels is described as 'symptomatic hypoglycaemia'.

Beware of blaming 'hypoglycaemia' alone for these signs. Remember that an infant who seems drowsy may be infected, and low blood glucose concentration may merely be an associated finding. It is important to try to establish the underlying cause of the problem.

– Although laboratory estimates of blood glucose concentration are ideal for diagnosing and managing this condition, reagent strips can be helpful.

– The blood glucose concentration in the first 6 hours of life is very often low (1.5–2.0 mmol/litre). There is no evidence that this is harmful for otherwise healthy term infants, who adapt by mobilising other fuels. Consequently, early testing (under 6 hours of age) is pointless, unless neurological signs are pre- sent or there are other conditions that necessitate testing.

– In newborn infants the serum glucose concentration is about 0.5 mmol/litre lower than that of whole blood.

*When to test*

- Symptomatic infants (lethargy, poor feeding, temperature instability, respiratory distress, new onset apnoea/hypoxaemic episodes, jitteriness, and seizures) should be tested immediately.
- Infants at risk should be tested within 1 hour after birth (as such infants rapidly become hypoglycaemic after delivery) and then 3-hourly until blood glucose levels are stable at 2.5 mmol/litre (45 mg/dL) or higher. Continue to monitor until feeds are well established.
- In infants with hypoglycaemia, check the blood glucose concentration every 20–30 minutes from the beginning of treatment, then hourly until it is stable at 2.5 mmol/ litre (45 mg/dL) or higher. Continue to monitor frequently (every 4–8 hours) during treatment, and while decreasing supplemental IV glucose infusions.

*Laboratory diagnosis*

- Reagent strips are useful and rapid, but in general are less reliable than laboratory plasma glucose measurements. Reagent strips may show a glucose level as much as 15% lower than plasma glucose levels. Whenever possible, it is preferable to use a calibrated glucometer.
- Laboratory plasma glucose determinations (if available) are useful for confirming hypoglycaemia detected by reagent strips, but blood samples must be processed promptly for accurate values, as glycolysis occurs in standing whole blood samples. Do not wait for laboratory confirmation before initiating therapy.

***Management of hypoglycaemia***

*Infants at risk of hypoglycaemia but appearing to be well*

1. Initiate early feeding within 1 hour after birth with breast milk (or formula BUT only if breast milk is not available) and repeat every 2–3 hours.
2. Feeding with 5% glucose is not recommended in infants, because milk provides more energy.
3. Infants of diabetic mothers are unlikely to develop hypoglycaemia on the second day of life if tests in the first 24 hours are satisfactory.

*Infants with symptomatic hypoglycaemia who are unable to feed or who fail correction of glucose levels with enteral feeding*

1. Establish an IV line and take a sample for blood culture and other biochemical tests (if available).
2. Give an IV glucose bolus 200 mg/kg over 5 minutes (2 mL/kg of 10% glucose in water). If the infant almost immediately becomes more alert and active *'on the end of your needle'* you have made the diagnosis, even before the laboratory report comes back.
3. In such situations it is then important to keep the blood glucose level stable by starting a sustained infusion of 10% dextrose at 5 mL/kg/hour (or 5–8 mg/kg/minute) for the next 2 to 4 days while gradually reducing IV and building up oral feeds.
4. If further episodes of symptomatic hypoglycaemia occur, the bolus should be repeated, and the infusion rate increased by 10–15%.
5. An infant who seems drowsy may be infected, and a low blood glucose concentration may be an associated finding rather than the main cause of the problem. It is important to exclude infection and initiate antibiotics if indicated.
6. When administering I V boluses, never use higher concentrations of glucose (> 10%) because of the risk of intra-ventricular haemorrhage and/or cerebral oedema.
7. The concentration of glucose in the maintenance fluids can be adjusted in accordance with the total daily fluid requirements.
8. If using IV infusion concentrations higher than 12.5%, an umbilical venous catheter needs to be inserted because of the risk of tissue damage in the event of fluid extravasation.
9. Most infants will correct hypoglycaemia with infusion of 5–8 mg/kg/minute; not infrequently, however, infants with severe intrauterine growth restriction or wasting and those with hyperinsulinism may require infusion rates of up to 12–15 mg/kg/minute.
10. When normal blood glucose levels have been stable for 12–24 hours and the infant is tolerating enteral feeding, decrease the IV glucose infusion by 10–20% each time levels are higher than 2.5 mmol/litre (45 mg/dL).
11. Always decrease the IV infusion gradually because of the risk of precipitating hypoglycaemia.
12. If you are unable to gain IV access, a feed of breast milk should be started if the infant is conscious. Hypostop Gel, an oral glucose mixture containing 500 micrograms of glucose/mL, can be helpful (if available). Apply 1–2 mL to the oral mucosa. Sub-lingual sugar can also be highly effective in this situation (0.2g/Kg) and repeated as necessary.
13. If hypoglycaemia persists beyond the first 48 hours of life and requires large infusions of glucose (greater than 8 mg/kg/minute), evaluation for endocrine or metabolic disorders (if available) should be considered.

## Section 23 Neonatal tetanus

Do not forget tetanus. Neonatal tetanus has to be considered if a previously well and still conscious infant starts to develop increasingly frequent muscle spasms 3–14 days after birth. This becomes more relevant if there is any doubt about the way the umbilical cord was managed at birth, or if there is no proof that the mother was ever immunised with tetanus toxoid vaccine. Involuntary muscle contractions are typically triggered by quite light touch or sound, and the hands and jaw are often held firmly clenched.

***Treatment of tetanus***

1. Airway and breathing are frequently compromised. Secure and maintain the airway and ensure adequacy of ventilation. Oxygen will help if the spasms are causing hypoxaemia. Monitor with a pulse oximeter.
2. Insert an IV line for drug and antibiotic administration.
3. Give high-dose benzyl penicillin 60 mg/kg IV one dose every 12 hours in the first week of life, every 8 hours in an infant aged 1–3 weeks, and every 6 hours in an infant over 3 weeks of age. Oral dosing (with phenoxymethylpenicillin) can sometimes be used to complete a course of treatment.
4. Metronidazole may also be used. Neonatal dose as page 81. Give for 7 days.
5. Give a 150 unit/kg dose of IM human tetanus immunoglobulin. Other IM injections must be avoided, as they will provoke spasms.
6. If the infant is in acute prolonged spasm, this should be terminated by giving diazepam by bolus IV infusion over 15 minutes (dose 200 micrograms/kg) or rectally (400 micrograms/kg). Ensure that for IV infusion, diazepam is diluted to 100 micrograms/mL, and that extravasation (very irritant) does not occur. Slow and incomplete absorption means that IM diazepam is not effective. Always ensure that a bag and mask are immediately available when giving diazepam, in case apnoea occurs.
7. To prevent further spasms, give an IV loading dose of 25–40 mg/kg of magnesium sulphate over 20–30 minutes.
8. Subsequently give 10–20 mg/kg of magnesium sulphate IV 4-hourly to control spasms. If this is not available or does not control spasms, give IV diazepam 200 micrograms/kg every 4–6 hours.
9. Stop diazepam if magnesium sulphate alone controls the spasms.
10. Reduce the dose of diazepam if apnoeic episodes occur.
11. Always have a bag and mask available in case the patient stops breathing as a result of the diazepam plus magnesium.
12. When stable, a nasogastric tube, ideally passed by an anaesthetist, will allow fluids, food and drugs to be given with minimal disturbance. Feeds need to be given frequently (ideally hourly) and in small amounts due to reduced gut motility. Regular breast milk feeds via a nasogastric tube are essential.
13. Excision of the umbilical stump is not indicated.
14. The disease itself does not induce immunity, so after recovery tetanus vaccine must be given for future prevention.
15. Treat any obvious umbilical infection with an additional broad-spectrum antibiotic.
16. Minimise handling, provide care in a quiet dark room and give frequent small tube feeds of breast milk.
17. Immunising the mother (give two 0.5-mL doses 1 month apart) will prevent a similar tragedy in any future pregnancy.

## Section 24 Hypoxic-ischaemic encephalopathy in the neonate

This is an abnormal neurological state of infants who have suffered significant lack of oxygen and/or circulation to vital organs before, during or immediately after birth. It is sometimes referred to as birth asphyxia. It is characterised by the following:

- signs of fetal distress in labour and low Apgar scores (6 or less at 5 minutes) despite appropriate resuscitation measures
- neonatal neurological abnormalities soon after delivery
- evidence of multi-organ dysfunction such as oliguria (signifying acute tubular necrosis of the kidneys), increased transaminase levels (hepatic necrosis), necrotising enterocolitis or myocardial dysfunction.

*Hypoxic-ischaemic encephalopathy-related problems in the days after birth*

- Reduced consciousness and/or convulsions: treat with phenobarbital and check glucose levels to rule out hypoglycaemia.
- Phenobarbital is given IV initially 20mg/Kg by slow IV injection then orally or IV at 2.5 to 5 mg/Kg once daily adjusted according to response.
- Apnoea/hypoxaemic episodes: these are common after severe perinatal asphyxia and is sometimes associated with convulsions. Manage with oxygen administered by nasal cannulae and resuscitation with bag and mask.
- Inability to suck: feed with expressed breast milk via a nasogastric tube. Beware of delayed emptying of the stomach, which may lead to regurgitation of feeds.
- Poor motor tone: the infant may be floppy or have limb stiffening (spasticity).

Sarnat's clinical grading system (*see* Table 24.1) may be used to help to guide treatment and give some indication of the prognosis.

### Additional treatment of hypoxic ischaemic encephalopathy

1. Treatment is generally supportive, with close attention to monitoring of good respiratory function, glucose levels and fluid balance.
2. Avoid hyponatraemia, which may result from inappropriate antidiuretic hormone secretion and excessive IV hypotonic solutions.
3. Acute renal failure is often present; if so, restrict fluids to measured urine output and gut losses plus 15 mL/kg/24 hours for full term and 24 mL/kg/24 hours for preterm infants (to reflect insensible losses), and avoid giving potassium supplements.
4. Keep the axillary temperature at 35.5–36.0°C. Avoid overheating.
5. Cooling infants for 72 hours under carefully controlled conditions has shown improved neurological outcomes. This should only be undertaken by experienced teams.

### *Prognosis*

The prognosis is good in Sarnat's stage 1, guarded in stage 2 and very poor in stage 3. About 50% of stage 2 infants will recover without sequelae. Infants in stage 3 will either die or be left severely disabled. A decision must therefore be made with the family about the implementation or continuation of intensive care in such cases.

**TABLE 24.1** Sarnat's grading of hypoxemic-ischaemic encephalopathy

| | Mild (stage 1) | Moderate (stage 2) | Severe (stage 3) |
|---|---|---|---|
| Conscious level | Hyper-alert | Lethargic | Unconscious |
| Muscle tone | Normal | Hypotonic | Flaccid |
| Seizures | Rare | Common | Severe |
| Feeding | Sucks weakly | Needs tube feeds | Needs tube feeds or IV fluids |
| Respiration | Spontaneous | Spontaneous | Absent |

### Management

Once bacterial meningitis has been excluded, intrapartum hypoxia or birth trauma will turn out to be the underlying problem in most infants presenting with fits in the first 2 to 3 days of life. Most of these infants already look stressed and unwell within a few hours of birth. The onset may be a little more sudden and abrupt in the preterm infant who suffers a sudden intraventricular haemorrhage. These infants usually become progressively more unconscious and unresponsive over time, and there is relatively little that can be done to improve the long-term outlook. An attempt should be made to minimise hypoxia, and anticonvulsant treatment is sometimes initiated in the hope that it will reduce the number of apnoea/hypoxaemic episodes. Many of these infants are too ill to accept even tube feeds, and, where this is the case, it may be appropriate to minimise the risk of hypoglycaemia by giving IV glucose.

Unfortunately, an infusion of more than 3 mL/kg of 10% dextrose per hour may result in water retention if there is accompanying renal failure. The outlook is poor for infants who have not recovered and started to feed normally within 1 week of birth.

## Section 25 Other causes of fits in the newborn

Rule out any other cause, including biochemical causes other than hypoglycaemia.

Remember that biochemical disturbance may not be the main underlying problem. In many infants, the evidence of hypoglycaemia or any other biochemical disturbance is only a sign of another more serious underlying illness. Of these, by far the most important treatable condition is meningitis. Unless the infant is otherwise entirely well it is important not to miss this possibility.

Other important diagnostic possibilities include hypocalcaemia, hyponatraemia and hypernatraemia. Often a history and clinical features will aid the recognition of these biochemical abnormalities, and a serum level will confirm the diagnosis. Any existing problem will be made worse if hypernatraemia is corrected too rapidly.

***Fits due to hypocalcaemia*** (a serum total calcium level of < 1.7 mmol/litre), with or without hypomagnesaemia, are generally benign and occur unexpectedly in an otherwise well but hyper-reflexic infant more than 2 to 3 days old. As with hypoglycaemia, signs may settle 'on the end of the needle' if the infant is given 1–2 mL/kg of 10% calcium gluconate in equal dilution as a slow IV infusion. Such seizures usually respond extremely well to oral supple- mentation. It is appropriate to investigate the mother for an unrecognised endocrine abnormality (if facilities allow this). Do not allow IV calcium to go outside the vein as it will cause severe tissue damage.

***Toxic substances provided by a traditional healer*** are important causes of seizures and reduced conscious level in neonates in some countries.

### *Bilirubin encephalopathy*

Infants with brain damage due to jaundice are stiff and semi-conscious, but seldom have fits. Signs usually appear quite abruptly 3 to 6 days after birth, but by the time they appear it is too late to initiate treatment.

### *Inborn errors of metabolism*

Other more complex biochemical disturbances are usually associated with metabolic acidosis and progressively deepening coma in an infant who was initially well for 1 to 2 days after birth. They are generally too complex to treat without substantial biochemical support, but it may be appropriate to take specimens for later diagnostic evaluation, because many of these conditions are familial and genetically determined. Pyridoxine deficiency is one of the few rare treatable conditions.

### *Meningitis*

*See* Section 7.

### *Other less common causes of neonatal seizures/fits*

**Drug-related seizures:**

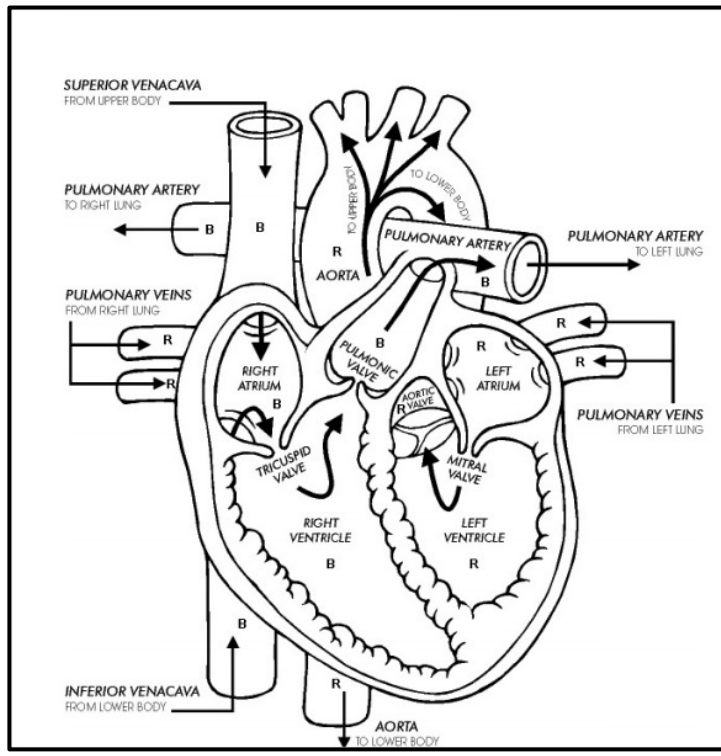
Accidental infiltration of the fetal scalp during the injection of lidocaine into the maternal perineum prior to episiotomy can cause fits simulating intrapartum hypoxia. With supportive treatment there is every prospect of complete recovery.

Some infants born to drug-dependent mothers show signs of drug withdrawal, starting 1 to 2 days after delivery. A small minority may have seizures. Minimal handling in a quiet dark room with small frequent feeds and a more gradual withdrawal from the drug to which they have been exposed is the only treatment usually necessary.

**Congenital brain abnormalities:** It is said that up to 10% of otherwise unexplained neonatal seizures are associated with the existence of some underlying cerebral problem (often cortical dysgenesis). Some of these infants will benefit from continuing anticonvulsant treatment (phenobarbital). see Section 21.

## Section 26 Congenital heart disorders and heart failure

*Diagram of the normal human heart:* ***Figure 26.1***




Congenital heart disease (CHD) occurs in 6-13 per 1000 live births. Most of these are mild forms but 15% are potentially life-threatening and a third of these are cyanotic (the baby cannot adequately oxygenate and appears blue).

Cardiac defects may present as any of the following:

1. cyanosis in the newborn period
2. cyanosis in the older infant
3. cardiovascular collapse in the newborn period
4. an heart murmur without symptoms
5. signs of cardiac failure in infancy (poor feeding, poor weight gain, breathlessness)

This section explains how to recognise the presence of congenital heart disease in each of these clinical scenarios and provides enough information to make a working diagnosis. Management decisions can then be made when modern imaging techniques are not immediately available.

### The cyanotic newborn infant

*Is there a cardiac problem?*

When an infant is referred as a 'blue baby', first check to see whether there is genuine central cyanosis. Examine the lips and tongue for blue discoloration and confirm the clinical

impression by measuring the oxygen saturation. Less than 94% is abnormal. If there is central cyanosis, you need to distinguish whether this is due to a **cardiac** or **respiratory** problem as the management of each is different.

***TABLE 26.1*** *Features that distinguish cardiac from respiratory cyanosis in the neonate*

| Cardiac cyanosis | Respiratory cyanosis* |
|---|---|
| Mild tachypnoea but no respiratory distress<br>May have cardiac signs on examination<br>Arterial blood gas: $PaO_2$ decreased, $PaCO_2$ decreased or normal (if available)<br>Fails hyperoxia test | Respiratory distress<br>Chest X-ray: abnormal lung fields<br>Arterial blood gas: $PaO_2$ decreased, $PaCO_2$ increased or normal (if available)<br>Passes hyperoxia test |

*A respiratory cause for cyanosis is more likely in infants born preterm.

The **hyperoxia test** is performed as follows:

- Ensure that there is good IV access.
- Monitor oxygen saturations continuously.
- Give 100% oxygen for 10 minutes.
- Ideally, take an arterial blood gas sample in the right arm (preductal). If not available, measure $O_2$ saturations with a pulse oximeter sited on the right arm.

If $PaO_2$ is lower than 20 kPa (150 mmHg), a cardiac cause of cyanosis is likely (the test has 'failed').
If $PaO_2$ is higher than 20 kPa, a respiratory cause of cyanosis is likely (the test has 'passed').

Where it is not possible to measure arterial blood gases, oxygen saturations may be used as a guide instead. A neonate with oxygen saturation less than 85% ($PaO_2$ less than 50 mmHg) in both room air and 100% oxygen is very likely to have a cyanotic CHD and will need early intervention for this.

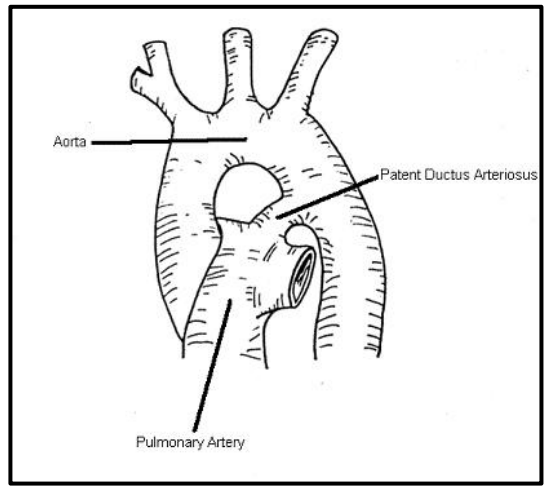
*In parts of the world where echocardiography is easily available, the hyperoxia test is discouraged because oxygen administration could cause closure of the arterial duct, precipitating profound hypoxaemia in some types of cyanotic congenital heart disease.*

For this reason, where an echocardiogram is not possible to diagnose cyanotic heart disease, prostaglandin E (which opens the duct), if available at the time of the test, should be given if oxygenation deteriorates.

Measuring pre- and post-ductal oxygen saturations using pulse oximetry can help distinguish between cardiac and respiratory causes of low oxygen saturations.

Arterial blood supply to the right arm comes off the aorta before the ductus arteriosus and is therefore termed "pre-ductal". The blood supply to the legs is "post-ductal". Blood supply to the left arm can be either pre- or post-ductal so the left hand should not be used to measure oxygen saturations in a newborn baby.

*Figure: 26.2 Patent ductus arteriosus*




***How to measure pre- and post-ductal oxygen saturations:***

The saturation probe is applied to the baby's right hand (provides a pre-ductal reading) and either foot (provides a post-ductal reading). For best readings tape must be applied to the right hand & either foot to hold the probe in place. It is necessary to wait until a stable good quality waveform is seen. A sustained, good signal with both readings of ≥ 94% and the difference between the readings less than or equal to 3% is accepted as normal. Babies with more than 3% difference in their pre- and post-ductal saturations (for example. pre-ductal 94%, post ductal 89%) may have a duct dependent cardiac lesion. There is no reason for such a differentiation in respiratory disease.

Persistent pulmonary hypertension of the newborn (PPHN) may mimic cyanotic heart disease using these clinical criteria; saturations in the right arm may be significantly higher than those in the feet, suggesting right-to-left shunting across the arterial duct.
However, PPHN is usually distinguished by a history of fetal distress and resuscitation needed at birth, and there may be neurological signs associated with a prolonged labour and/or clinical suspicion or laboratory confirmation of sepsis or pneumonia.

***What type of cardiac defect is present?***
Cyanotic cardiac defects can be divided into three broad categories, as described below.
Once cyanotic congenital heart disease is suspected, attempt to place the defect in one of the three categories. This may be done using Table 26.2, which describes the typical findings in each physiological category. These guidelines assist the clinician but are not infallible, and the nature of the defect is sometimes only clear after echocardiography.

***TABLE 26.2*** *Features that help to distinguish the three types of cyanotic congenital heart defect*

| Investigations | 1) Low pulmonary blood flow | 2) Complete TGA | 3) Common mixing lesions |
|---|---|---|---|
| $PaO_2$ at rest | Often ≤ 35 mmHg | Often ≤ 35 mmHg | Often ≥45 mmHg |
| $SpO_2$ at rest | < 80% | < 80% | 80–90% |

| Investigations | 1) Low pulmonary blood flow | 2) Complete TGA | 3) Common mixing lesions |
|---|---|---|---|
| $PaO_2$ hyperoxia test<br><br>$SpO_2$ hyperoxia | Often ≤ 50 mmHg<br><br>< 90% | Often ≤ 50 mmHg<br><br>< 90% | 75–200 mmHg<br><br>90–100% |
| Chest X-ray | Reduced pulmonary vascular markings | Normal or increased pulmonary vascular markings with or without narrow mediastinum | Normal or increased pulmonary vascular markings |
| Pre- and post-ductal saturations | Pre-ductal O2 saturations higher | Post-ductal O2 saturations often higher | Both pre- and post-ductal $O_2$ saturations may be < 94% |

## Cyanotic congenital heart diseases with a low pulmonary blood flow

***TABLE 26.3*** Conditions with a low pulmonary blood flow

| | |
|---|---|
| 1a | Critical pulmonary stenosis |
| 1b | Pulmonary atresia with intact ventricular septum |
| 1c | Tetralogy of Fallot (with severe right ventricular outflow tract obstruction) |
| 1d | Pulmonary atresia with ventricular septal defect |
| 1e | Absent right atrioventricular connection (tricuspid atresia) |

*1a) Critical pulmonary stenosis and 1b) Pulmonary atresia with intact ventricular septum*
These two conditions are similar pathologies with either complete or almost complete closure of the pulmonary valve. Both are often associated with hypoplasia of the right ventricle. There is either no murmur or a soft murmur at the lower left sternal border (tricuspid regurgitation). The chest X-ray usually shows a normal heart size. The precordial leads on the ECG usually show decreased right ventricular voltages (small R waves in leads V1 and V2) and dominant left ventricular voltages (prominent S waves in leads V1 and V2 and prominent R waves in leads V5 and V6).

*1c) Tetralogy of Fallot and 1d) pulmonary atresia with ventricular septal defect*
These two pathologies are also similar, but in Fallot's tetralogy the right ventricular outflow tract is open, albeit narrow, generating a high-pitched ejection systolic murmur at the upper left sternal border. In both defects, the cardiac silhouette on the chest X-ray has a concavity on the left heart border where there is usually a convexity produced by the right ventricular outflow tract and pulmonary artery. The ECG shows dominant right ventricular voltages (normal neonatal RS progression).

*Clinical findings in tetralogy of Fallot*
- May present with increasing cyanosis.
- May present with an ejection systolic murmur at the upper left sternal border.

- Reduced pulmonary vascular markings on chest X-ray, and concavity on the left heart border where there is usually a convexity produced by the right ventricular outflow tract and pulmonary artery.
- Children are often asymptomatic, but there may be sudden periods of increased cyanosis known as hyper-cyanotic spells.

*Characteristics of hyper-cyanotic spells in tetralogy of Fallot*

- Spells often occur on waking from sleep or after feeding.
- The infant becomes restless and agitated.
- There is increased cyanosis and pallor.
- Respiration is often rapid and shallow.
- In severe spells, crying is followed by limpness or loss of consciousness.
- Spells usually last 1–5 minutes but may last longer when severe.
- The ejection systolic murmur shortens or becomes inaudible.

*1e) Absent right atrioventricular connection (also known as tricuspid atresia)*
There is often a long harsh systolic murmur (this may arise from a restrictive ventricular septal defect or pulmonary stenosis). The precordial leads on the ECG show decreased right ventricular voltages and dominant left ventricular voltages. The QRS axis is characteristically directed to the left and superiorly between 0 and -90 degrees.

In defects where there is low pulmonary blood flow the physiology is the same regardless of the precise anatomy of the defect. Deoxygenated blood returning from the systemic veins cannot flow through the right side of the heart to the lungs. The pulmonary blood supply is therefore via the arterial duct. The deoxygenated blood from the right side of the heart shunts to the left side of the heart (via either an atrial or a ventricular septal defect), and the left ventricle receives both deoxygenated blood from the right heart and oxygenated blood from the pulmonary venous return. Blood entering the aorta is therefore not fully oxygenated, and the infant appears cyanosed. If the duct closes, the infant becomes profoundly cyanosed and is unlikely to survive unless pulmonary blood flow is rapidly restored. This is duct-dependent pulmonary circulation, an example of which is shown in Figure 26.3.

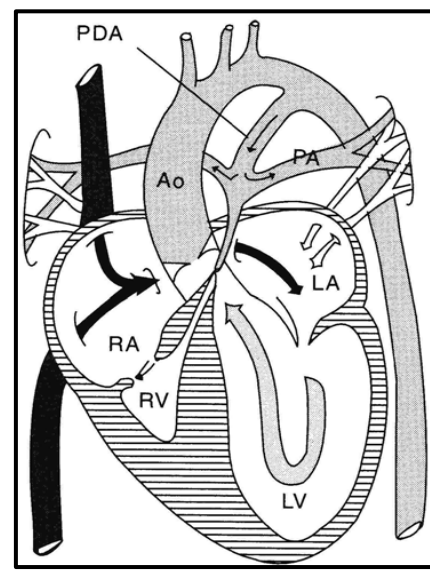



***Figure 26.3*** *The circulation in pulmonary atresia* with intact *ventricular septum. PDA, patent ductus arteriosus; Ao, aorta; PA, pulmonary artery; LA, left atrium; LV, left ventricle; RV, right ventricle; RA, right atrium.*

**2.Complete transposition of the great arteries (TGA)**
Here the aorta arises from the right ventricle and the pulmonary artery arises from the left ventricle (see Figure 26.4). Systemic venous return enters the right side of the heart and is recirculated to the systemic arteries. Pulmonary venous return enters the left side of the heart and is recirculated to the lungs. Oxygenated blood and deoxygenated blood are therefore separated in two parallel circuits. Oxygenated blood enters the systemic circulation only when

there is mixing between the two circuits. Mixing occurs at atrial level (across the foramen ovale) and at ductal level (while the duct remains open). Systemic oxygen saturation reflects the amount of mixing (which in turn depends on the size of these communications). If the atrial communication is small, oxygenation may therefore be duct dependent.

There is usually no murmur. The ECG shows dominant right ventricular voltages (normal neonatal RS progression). Therefore, if a newborn is severely cyanosed and otherwise appears clinically normal, actively look for a narrow mediastinum on the chest X-ray to help to make the diagnosis.

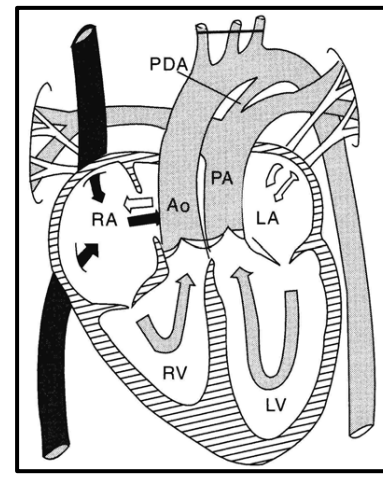
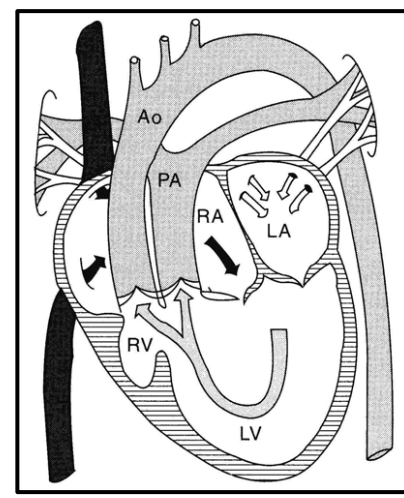



***FIGURE 26 4****. Transposition of the great arteries (TGA). For explanation of abbreviations, see legend to Figure 26.3.*

**3.Common mixing lesions**

In common mixing lesions, oxygenated pulmonary venous blood and deoxygenated systemic venous blood mix in one of the cardiac chambers. An example (double outlet left ventricle) is shown in Figure 26.5 The systemic output is therefore only partly oxygenated. The relative amounts of pulmonary and systemic blood in the mixture determine the oxygen saturation and the mode of presentation. If pulmonary blood flow is high, cyanosis is minimal, and the infant usually presents at about 2 months of age in heart failure. If pulmonary blood flow is low (the complex lesion may coexist with pulmonary stenosis), cyanosis is severe and is often detected early.

***FIGURE 26.5*** *The circulation in double-outlet left ventricle. For explanation of abbreviations, see legend to Figure 26.3.*



Once the defect has been placed in one of these above 3 categories, immediate management decisions can be made. Although it is not imperative to reach a more specific diagnosis, an anatomical diagnosis can sometimes be made using clinical information and simple investigations.

***Management of defects with low pulmonary blood flow or complete TGA***

If there is a possibility of transferring the baby to a facility with specialist cardiology care, the baby needs the arterial duct to be kept open while you arrange transfer.

- Do not give oxygen after the hyperoxia test, as it may precipitate ductal closure.
- Start IV prostaglandin E (PGE) (if available) to maintain ductal patency. Commence either prostaglandin E1 (PGE1) or prostaglandin E2 (PGE2) at 5 nanograms/kg/minute and increase in steps of 5 nanograms/kg/minute to a maintenance dose of 10 or 20 nanograms/kg/minute. Higher doses than this have been used but cause apnoea.
- PGE2 can be given orally as a maintenance dose of 40-50 micrograms per kg every 2 hours.

*Dose of PGE:* Dilute 150 micrograms/kg body weight to a final volume of 50 mL with Glucose 5% or Sodium Chloride 0.9%; an intravenous infusion rate of 0.1 mL/hour provides a dose of 5 nanograms/kg/minute.

*Expected action of PGE*: oxygen saturations should improve up to that expected with a mixing lesion (about 85%).

*Side effects of PGE*: apnoea, low blood sugar, vasodilation and hypotension

If there is no possibility of transfer to a cardiologist, the baby should receive palliative care.

**Management of tetralogy of Fallot**

The anatomy should be confirmed by echocardiography, preferably within a few weeks of presentation, and surgical correction should be carried out between 6 and 12 months of age (although it can be carried out later).

Hyper-cyanotic spells may be life- threatening. If a child starts to have such spells, discuss this with a paediatric cardiologist immediately, as it is an indication for urgent surgery.

If **hyper-cyanotic spells** are more than a few minutes induration, treat them urgently as follows:

1. Knee–chest position.
2. Give oxygen by face mask.
3. Give an IV bolus of Ringer-lactate or Hartmann's solution 10–20 mL/kg, as during spells children are often relatively hypovolaemic.
4. Give IV or IM morphine, 100 microgram/kg (or IV ketamine 1 mg/kg).
5. Give IV propranolol at an initial dose of 20 micrograms/kg with a maximum of 100 micrograms/kg (have isoprenaline ready in case of excessive beta–blockade).
6. Adrenaline may make spells worse.
7. General anaesthesia and artificial ventilation are needed in intractable cases.
8. If cyanosis persists, consider an emergency aortopulmonary shunt.

***Management of common mixing lesions***

- If possible, monitor the infant on the neonatal unit and arrange for an echocardiogram as soon as possible to define the anatomy.
- If oxygen saturations fall progressively to less than 70%, commence PGE and arrange for an urgent paediatric cardiology review.

- Once paediatric cardiology advice has been obtained and the anatomy is defined it may be possible to discharge the baby without further treatment.

## Cyanotic defects with high pulmonary blood flow

In cyanotic defects with high pulmonary blood flow (mostly common mixing defects), pulmonary flow increases as pulmonary vascular resistance decreases over the first few weeks of life, resulting in progressively worsening cardiac failure.

***TABLE 26.4*** *Cyanotic defects with high pulmonary blood flow*

| |
|---|
| Truncus arteriosus |
| Total anomalous pulmonary venous connection |
| Double outlet left ventricle |
| Absent right atrioventricular connection with large ventricular septal defect (tricu atresia) |
| Pulmonary atresia with large or multiple aorto-pulmonary collateral arteries |
| TGA with large ventricular septal defect |

### *Findings in defects with high pulmonary blood flow*

May present with cardiac failure at 2–6 weeks of age.
Active precordium.
Murmur usually present (may be systolic, diastolic or continuous).
Increased pulmonary vascular markings on chest X-r ay.

### *Management of cyanotic defects with high pulmonary blood flow*

Define the anatomy by echocardiography. Manage cardiac failure medically (see later in this section). Surgical correction or pulmonary artery banding will be necessary in most cases.

## The older infant with cyanosis

*Is there a cardiac problem?*

When an older infant presents with cyanosis, cardiac pathology is likely if:

- Respiratory distress is not severe.
- There is no carbon dioxide retention.
- Respiratory pathology is not evident on the chest X-r ay.
- The cardiovascular examination is abnormal (see below).

*What type of cardiac defect is present?*

The cyanotic defects that commonly present after the neonatal period are **tetralogy of Fallot and cyanotic defects with high pulmonary blood flow**. They may escape detection at birth because cyanosis is initially only mild. In tetralogy of Fallot, (see earlier in this section) there is right ventricular outflow tract obstruction and a large ventricular septal defect (VSD) (right ventricular hypertrophy and aortic override are the other components of the tetralogy). The right ventricular outflow tract obstruction limits blood flow to the pulmonary arteries, causing deoxygenated blood to shunt right to left across the VSD, resulting in cyanosis. With time, the right ventricular outflow tract obstruction usually becomes more severe, causing further reductions in pulmonary blood flow, more right to left shunting, and increasing cyanosis.

## Neonatal cardiovascular collapse

***Is there a cardiac problem?***

When an infant presents in shock in the first month of life, the working diagnosis is often dehydration or sepsis. The following features help to distinguish cardiac causes of poor systemic output from non-cardiac causes:

- collapse in the first 2 weeks of life
- poor feeding, lethargy and tachypnoea prior to collapse
- hepatomegaly
- pulmonary oedema and cardiomegaly on chest X-ray
- lack of response to intravascular volume expansion
- cardiac murmur (not always present)

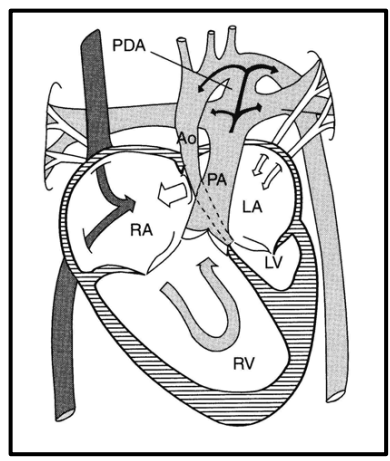
***What type of cardiac defect is present?***

Left heart obstruction is the most likely cardiac cause of cardiovascular collapse with low systemic output in the first 2 weeks of life:

***TABLE 26.***5 Causes of left heart obstruction

| |
|---|
| Critical aortic stenosis |
| Hypoplastic left heart syndrome (HLHS) |
| Coarctation of the aorta |
| Interrupted aortic arch |

***FIGURE 26.6*** *Hypoplastic left heart. For explanation of abbreviations, see legend to Figure 26.3.*




***Hypoplastic left heart syndrome (HLHS)***

In hypoplastic left heart syndrome all the left heart structures are small (see Figure 26.6). There is insufficient forward flow through the left ventricle and the aortic valve to support the systemic circulation. Pulmonary venous return cannot pass through the left heart, so it crosses the atrial septum and enters the right atrium, mixing with systemic venous return. Mixed pulmonary and systemic venous blood enters the right ventricle and is pumped to the pulmonary arteries and also across the arterial duct to supply the systemic circulation. Ductal flow passes to the descending aorta and retrogradely around the aortic arch to supply the

head and neck vessels and the coronary arteries. Ductal flow is not fully oxygenated, so there is a degree of central cyanosis. When the duct closes, the cardiac output falls precipitously, the infant becomes shocked, and cardiac failure develops. This is duct-dependent systemic circulation. The haemodynamics are the same in critical aortic stenosis.

*Coarctation of the aorta*

Coarctation of the aorta consists (see Figure 26.7) of a narrowing in the descending aorta close to the aortic end of the arterial duct. Contractile tissue may extend from the duct into the aorta so that when the duct closes it draws in the adjacent section of aorta, causing obstruction. Flow to the head and neck vessels is maintained, but flow to the lower body distal to the coarctation site is dramatically reduced. The infant becomes shocked and acidotic. Cardiac failure develops secondary to high systemic afterload. This is also an example of the systemic circulation depending on ductal patency (although systemic blood flow may not directly depend on a right-to-left shunt through the duct).

In interrupted aortic arch, perfusion to the lower part of the body depends on right-to-left ductal flow and presentation is similar to that of coarctation.

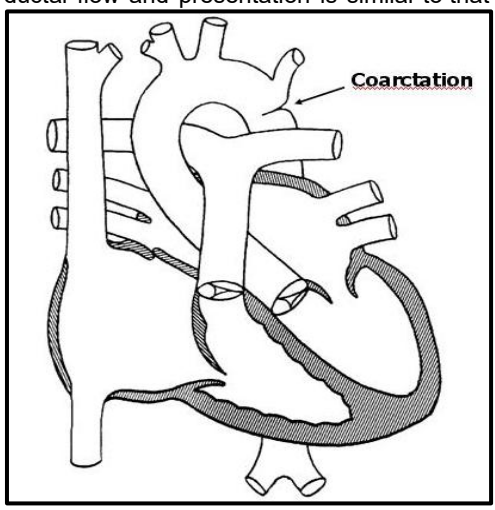



*Figure 26.7 Coarctation of the aorta*

The following features help to distinguish between the lesions causing left heart obstruction:

- If all of the pulses are weak or absent, consider HLHS or critical aortic stenosis.
- If the right arm pulses are palpable and the femoral pulses are weak or absent, consider coarctation or interrupted aortic arch (note, however, that all pulses may initially be impalpable if the cardiac output is poor).
- If four limb blood pressures demonstrate significantly lower blood pressures in the legs than in the right arm (a gradient of more than 20 mmHg), consider coarctation or interrupted aortic arch.
- Coarctation often presents towards the beginning of the second week of life.
- HLHS often presents in the first 2 days of life.
- In HLHS, the ECG shows reduced left ventricular voltages (small R waves in leads V5 and V6).

Other cardiac causes of cardiovascular collapse in the first few weeks of life are supraventricular tachycardia (SVT) and cyanotic congenital heart disease with duct-

dependent pulmonary blood flow (when the duct closes, the ensuing profound hypoxaemia causes acidosis and cardiovascular collapse). SVT should be evident on the ECG and cyanotic heart disease should be suspected when the oxygen saturation remains low after instituting the management described below for left heart obstruction.

## Emergency management of low systemic output secondary to left heart obstruction

- Check the ECG (to exclude SVT as a cause of collapse)
- Obtain peripheral IV access if not already established (if IV access is difficult, intra-osseous access should be obtained)
- Give a fluid bolus of 10 mL/kg Ringer-lactate or Hartmann's solution if not already given
- Commence intravenous prostaglandin $E_1$ (Alprostadil) or $E_2$ (dinoprostone) (if available, see earlier Management of defects with low pulmonary blood flow or complete TGA)
- Check blood sugar levels, full blood count, urea and electrolytes, coagulation, calcium levels and magnesium levels, and correct abnormalities.
- Take blood cultures and treat with IV antibiotics, as sepsis cannot be excluded.
- Measure pre- and post-ductal oxygen saturations and check arterial blood gas (using the right arm) if possible.
- Give IV furosemide 1 mg/kg if the chest X-ray shows pulmonary oedema.
- Reassess whether further intravascular volume is needed
- Ask for an urgent paediatric cardiology advice. If advice and transfer not available, counsel parents and give palliative care.

## Heart murmurs without symptoms

When a newborn infant presents with a heart murmur but without symptoms, first examine them for cyanosis and measure the pre- and post-ductal oxygen saturation. If there is desaturation, refer the infant for an echocardiogram, as cyanotic congenital heart disease requires a detailed anatomical assessment. Tetralogy of Fallot is the most likely diagnosis. If cyanosis is excluded, the infant may have an innocent cardiac murmur or one of the following defects.

### Innocent murmurs without a cardiac disorder

Innocent murmurs throughout childhood are common. They tend to be **s**oft, **s**hort, **s**ystolic, **s**ymptomless and they **s**hift with position. The baby or child looks well, heart sounds themselves are normal and femoral pulses palpable.

The *Still's murmur* is a vibratory short systolic murmur heard at the lower left sternal border or apex.
The *venous hum* is a soft continuous murmur heard best below the clavicles and is abolished by pressure over the jugular vein or lying down with the neck flexed.
The *pulmonary flow murmur* is a soft ejection systolic murmur at the upper left sternal border and may be confused with an ASD or mild pulmonary stenosis.
The *neck bruit* is an ejection systolic murmur that is maximal above the clavicle and may be confused with aortic stenosis.

**Initially asymptomatic heart lesions**

Table 26.6

| Left-to-right shunts | Left or right heart obstruction |
|---|---|
| Small to moderate-sized VSD<br>Small to moderate-sized PDA<br>Atrial septal defect (ASD)<br>Partial AVSD | Pulmonary stenosis<br>Aortic stenosis<br>Coarctation of the aorta |

- In **coarctation**, the right arm blood pressure is often elevated, the femoral pulses are weak or impalpable, and there is brachial-femoral delay. The murmur radiates to the back.
- The **patent ductus arteriosus** (PDA) has a continuous murmur that is loudest in the left infraclavicular region.
- The **ventricular septal defect** (VSD) has a harsh pansystolic murmur that is loudest at the lower left sternal border radiating to the lower right sternal border.
- **Aortic stenosis**, **pulmonary stenosis**, **atrial septal defect** (ASD) and partial **atrioventricular septal defect** (AVSD) all have an ejection systolic murmur at the upper left sternal border.
- In **aortic stenosis** the ejection systolic murmur is harsh and may be heard at the upper right and left sternal border. The murmur radiates to the carotid arteries and there is often a carotid thrill. There may be an ejection click at the apex if the stenosis is at valvar level.
- In **pulmonary stenosis**, the ejection systolic murmur is harsh and radiates to the back. There may be an ejection click along the left sternal border if the stenosis is at valvar level.
- In an **atrial septal defect** (ASD) there is a soft ejection systolic murmur at the upper left sternal border from increased flow across the pulmonary valve. There is sometimes a fixed widely split-second heart sound, and there may be a mid-diastolic murmur at the lower left sternal border (from increased flow across the tricuspid valve) when the left-to-right shunt is large.
- In **partial atrioventricular septal defect** (AVSD) there is an abnormal atrioventricular valve and a defect in the atrial septum. There may be a blowing pansystolic murmur at the lower left sternal border or apex from atrioventricular valve regurgitation. The ejection systolic murmur may mimic an ASD, but the defect is distinguished by a superior QRS axis on the ECG.

Unless the murmur is clearly innocent, perform an echocardiogram. Where this is not available, do an ECG and chest X-ray.

***ECG findings***

*Right Ventricular Hypertrophy* RVH may indicate significant right heart obstruction or high pulmonary artery pressure (secondary to a large left-to-right shunt or pulmonary vascular disease). Right ventricular hypertrophy (RVH) criteria on ECG:

- R wave in lead V1 > 98th centile for age (see table below)
- neonatal RS progression beyond the neonatal period (dominant R waves in lead V1 and dominant S waves in lead V6) or
- an upright T wave in lead V1 before the teenage years

*Left Ventricular Hypertrophy* LVH may indicate significant left heart obstruction. Left ventricular hypertrophy (LVH) criteria on ECG:

- T inversion in leads V5 and V6
- loss of the Q wave in lead V6 or
- the amplitude of the R wave in lead V6 plus S wave in lead V1 > 98th centile for age (see table below).

The website, https://litfl.com/paediatric-ecg-interpretation-ecg-library/, is a useful resource for those wishing to learn more about both adult and paediatric ECGs.

Cardiomegaly and increased pulmonary vascular markings on the chest X-ray may indicate a large left-to-right shunt.

Any infant who is thought to have an anatomical defect based on the clinical examination, or any infant with an abnormal ECG or chest X-ray, should be referred to a paediatric cardiologist for an echocardiogram and opinion if possible. If there is evidence of a significant left-to-right shunt in a VSD or PDA, the referral should be as soon as possible, as there is still a risk of pulmonary vascular disease even when the infant does not present in heart failure.

## Heart failure in infancy

Heart failure occurs when the heart is unable to pump enough blood to meet the metabolic needs of the body. The term is often used to indicate the clinical changes that occur when the cardiac pump cannot meet the workload it is presented with. This may occur either because the pump is weak (due to a primary abnormality of the cardiac muscle) or because the workload imposed on the heart is higher than normal. The latter is the case in congenital heart disease, where heart failure occurs because the heart is pumping against a high resistance (in the case of obstructive lesions) or because it is volume loaded (commonly in left-to-right shunting cardiac lesions).

*The physiology of left-to-right shunts*
A large defect between the ventricles or great arteries allows free communication between the left and right sides of the heart. Left and right heart pressures therefore equalise, and pulmonary artery pressure is maintained at systemic level. The pulmonary vascular resistance then determines the pulmonary blood flow. In the newborn period the pulmonary vascular resistance is high, which limits the pulmonary blood flow and therefore the left-to-right shunt across the defect. Over the first 6 weeks of life, the pulmonary vascular resistance gradually falls, allowing pulmonary blood flow and the left-to-right shunt to increase. This gives rise to heart failure, which usually appears after 4 weeks of age. If the pulmonary arteries are exposed to high pressure and flow for a prolonged period, pulmonary vascular disease develops. This normally becomes significant between 12 and 18 months of age. High pulmonary vascular resistance secondary to pulmonary vascular disease reduces the left-to-right shunt, and symptoms of heart failure gradually resolve. Eventually, pulmonary resistance becomes so high that flow across the defect becomes right to left, and cyanosis develops (Eisenmenger's syndrome). The pulmonary artery pressure remains high throughout, and it is only the amount of flow through the lungs that changes.

### *Heart failure in the neonate*

**TABLE 26.7** *Diagnosis of heart failure secondary to congenital heart disease in infancy*

| Symptoms | Signs |
|---|---|
| Easily tired Poor feeding<br>Breathlessness (particularly during feeds)<br>Sweaty (particularly during feeds) | Failure to thrive Tachypnoea<br>Increased respiratory effort<br>Tachycardia > 160 bpm<br>Sweating<br>Pallor<br>Hepatomegaly<br>Gallop rhythm |

*What type of cardiac defect is present?*
Heart failure **in the first few weeks of** life is a medical emergency. The following causes should be considered:

- supraventricular tachycardia (SVT)
- complete atrioventricular heart-block
- high-output cardiac failure
- left heart obstruction

Perform an ECG to detect supraventricular tachycardia and heart block. Check the haemoglobin level, as severe anaemia may cause high-output cardiac failure. Also examine the baby for cranial and hepatic bruits, as cranial and hepatic arteriovenous malformations are a potential (although very rare) cause of high-output cardiac failure.

If these tests are negative, refer the infant to a paediatric cardiologist (if available), as a left heart obstructive lesion is likely and there may be duct-dependent systemic circulation. Consider the use of prostaglandin to keep the ductus arteriosus open until the referral can be achieved (if that is possible).

Heart failure in infancy presenting **after the first few weeks** of life may be caused by any of the following:

- the left-to-right shunting lesions listed in Table 26.8
- cyanotic congenital heart defects with high pulmonary blood flow
- the same causes that present in the first few weeks of life
- myocarditis or cardiomyopathy

***TABLE 26.8*** *Common left-to-right shunting lesions that cause heart failure*

| |
|---|
| Large ventricular septal defect (VSD)<br>Atrioventricular septal defect with large ventricular component (AVSD)<br>Large persistent ductus arteriosus (PDA) |

Examine the child for cyanosis and measure the oxygen saturation. It should be possible to detect those children with cyanotic defects immediately (note, however, that children with AVSD are sometimes only mildly desaturated).

Next, attempt to detect the children with left-to-right shunts, looking for the following features which are present in significant shunts:

- hyperdynamic precordial impulse

- apical impulse displaced laterally and inferiorly
- apical mid-diastolic murmur (from increased flow across the mitral valve)
- loud second heart sound (from increased pulmonary artery diastolic pressure)
- cardiomegaly and increased pulmonary vascular markings on the chest X-ray
- signs of heart failure and pulmonary oedema on the chest X-ray in severe cases

If these examination findings are not present and there is no evidence of SVT on ECG, a left heart obstructive lesion should be considered. Some of these can be surgically treated and if they are suspected the infant should be referred for paediatric cardiology review without delay if this is available in the country.

**If there is evidence of a large left-to-right shunt, refer the infant to a paediatric cardiologist within a few weeks (again if available in the country). These signs must not be missed, as a remediable cardiac defect is rendered inoperable by delay.**

Although it is not imperative to make a more specific diagnosis, the following clinical features discriminate between the three most common left-to-right shunts:

- The persistent arterial duct has a continuous murmur that is maximal in the left infra-clavicular area.
- A large ventricular septal defect has a quiet pansystolic murmur that is maximal at the lower left sternal border radiating to the lower right sternal border. There may also be a soft ejection systolic murmur at the upper left sternal border from increased flow across the pulmonary valve.
- An atrioventricular septal defect with a large ventricular component may have a blowing pansystolic murmur at the lower left sternal border or apex from atrioventricular valve regurgitation. The ECG shows a characteristic superior QRS axis (between -30 and -180 degrees).

**Non-cardiac causes of heart failure**

In addition to these congenital heart defects, the following causes of heart failure should be considered in the neonate:

- Severe anaemia
- Severe malnutrition
- Excessive intravenous fluids
- Myocarditis
- Cardiomyopathy

Anaemia is a common and often severe problem in poorly resourced settings. When the haemoglobin falls below 70 g/l cardiac output must increase to maintain oxygen delivery and heart failure frequently develops with a haemoglobin < 50 g/l). The treatment is careful blood transfusion, but the increase in intravascular volume may precipitate worsening heart failure. Blood must therefore be infused slowly in small boluses and an exchange transfusion may be needed if there is clinical deterioration. Furosemide 1 mg/kg IV may be given during transfusion.

Protein-calorie malnutrition is also an important cause of cardiac failure in disadvantaged countries (see Handbook 1) with specific contributions from certain vitamin deficiencies (see Handbook 1). Although cardiac failure is unusual at presentation, it may occur after several days of re-feeding. Rapid re-feeding can cause a hyper- metabolic state, demanding an increase in cardiac output which cannot be met by the malnourished heart which has a decreased cardiac reserve. The problem is exacerbated by coexisting anaemia, blood transfusion, inappropriate intravenous fluid administration and high sodium diets.

***Management of heart failure (see also page 151 for resuscitation)***

Monitor heart and respiratory rates, respiratory distress, and oxygenation regularly during treatment of acute heart failure. It is necessary to both control the symptoms of failure and to determine and treat the underlying cause.

- Treat severe anaemia if present, be careful with IV fluids and ensure adequate nutrition
- Nasogastric feeding if there is inadequate oral intake
- Skin to skin care with the legs hanging down can help
- Treat hypoxaemia with oxygen to keep $SpO_2$ > 94%
- In an emergency where there is pulmonary oedema, give furosemide 1 mg/kg IV which should produce a diuresis within 2 hours. If the initial dose is ineffective, give 2 mg/kg IV and repeat after 12 hours if necessary
- For chronic heart failure seek advice from a paediatric cardiologist and give oral furosemide 1 mg/kg once a day, twice a day or three times a day
- Spironolactone 1 mg/kg once a day or twice a day in combination with furosemide, matching the dose frequency, to enhance diuresis and prevent furosemide-related hypokalaemia
- If furosemide is used without spironolactone, oral potassium 3–5 mmol/kg/day, should be given (supplemental potassium is not required if furosemide is given for less than 4 days).

## Section 27 Gastro-intestinal problems in the neonate

*Recognition of gastrointestinal problems*

| SYMPTOM | POSSIBLE DIAGNOSES | MANAGEMENT (IF AVAILABLE) |
|---|---|---|
| Bile-stained vomiting with abdominal distension | Bowel obstruction<br>Hirschsprung's disease<br>Necrotising enterocolitis | Antibiotics, abdominal x-ray, IV D10%, nasogastric or orogastric tube, keep nil by mouth, skin-to-skin and refer to surgical centre (if available) |
| Bilious vomiting without distension | Malrotation, duodenal atresia, sepsis | Antibiotics, abdominal x-ray, IV D10%, nasogastric tube, keep nil by mouth, skin-to-skin and refer to surgical centre |
| Excessive frothy salivation following delivery (especially if history of polyhydramnios) | Oesophageal atresia | Antibiotics, chest and abdominal x-ray, IV D10%, large bore nasogastric tube and aspirate frequently, keep nil by mouth, skin-to-skin and refer to surgical centre |
| Excessive vomiting without bile at a few weeks of age | Urinary tract infection<br>Pyloric stenosis<br>Volvulus<br>Intussusception | If the baby is alert, dehydrated and hungry as soon as he/she vomits and the vomiting is projectile straight after a feed, insert an IV line, start D10%, insert a nasogastric tube and keep nil by mouth. Put the baby skin-to-skin for transfer to a specialist centre for an operation to relieve the blockage. |

**Bowel obstruction** presents with severe vomiting, often associated with abdominal distension, in the first few days of life and requires referral for surgical review (if available). This is particularly true if the vomit is green (bile stained), as this is suggestive of duodenal atresia or bowel obstruction requiring urgent surgical intervention. If severe vomiting develops in an infant who has passed changing stool, the diagnosis of volvulus, pyloric stenosis or intussusception must be considered. Duodenal atresia is more common in infants with Down's syndrome. A paediatric surgical opinion should be sought if available.

**Oesophageal atresia** should always be considered in the infant with a history of polyhydramnios or excessive frothy salivation following delivery. Surgery is much more likely to be successful if it can be performed before aspiration pneumonia develops. Pass a large-bore catheter as far down the oesophagus as possible and aspirate frequently. If an X-ray shows that the tube has stopped at the level of the heart and has not entered the stomach, the diagnosis is made. Such an infant needs urgent referral for surgery, with steps taken to suck the blind upper oesophageal pouch clear of all accumulating secretions at least every 15 minutes before and during transfer. Site an IV line and ensure that the infant does not become hypoglycaemic.

***Necrotising enterocolitis (NEC)***

Although it can occasionally be seen in term babies, NEC is primarily a disease process of the gastrointestinal (GI) tract of premature neonates that results in inflammation and bacterial invasion of the bowel wall. It occurs in 5-10% of babies less than 1500g at birth and remains one of the leading causes of morbidity and mortality in this population with a mortality of approximately 20–40%. Although it is more common in infants who have received feeds, about 15–20% of affected infants may never have been fed. It is much less common in infants fed exclusively on human milk. The precise cause of NEC is unknown.

*Presenting features*
NEC should be suspected in an infant who had started to accept oral feeds and then develops an ileus or becomes lethargic and starts passing a bloody stool. The problem is caused by the sudden focal invasion of bacteria into an area of ischaemic gut, and an abdominal X-ray will often show gas accumulating within the gut wall. Common signs of NEC include the following:

- abdominal distension or tenderness
- intolerance of feeding
- bile-stained vomit or bile-stained fluid up the nasogastric tube
- blood in the stools.

Features of multisystem failure, such as coagulopathy, petechial haemorrhage, oliguria and haematuria, may be associated with NEC.

*Investigations*
A plain abdominal X-ray (if available) may show an abnormal gas pattern in the form of:
free intra-peritoneal air, best seen with a left side down (lateral decubitus) X-ray, where free air may be easily seen overlying the dense hepatic tissue, intramural gas (pneumatosis intestinalis) or gas in the portal tracts of the liver.

A complete blood count with differential cell count, blood culture and serum electrolytes should be obtained when available. Regular weighing, frequent blood pressure measurements, and continuous heart and respiratory rate monitoring are required.

*Treatment*
Stop all enteral feeds for at least 5 days and provide IV fluids, typically 120 mL/kg/day of 10% glucose with added electrolytes. Adjust fluids as indicated based on weight change, urine output and serum electrolyte values. Place an orogastric tube on low-pressure continuous suction or leave the tube open with intermittent very gentle gastric aspiration (every 4 hours). The goal here is to keep the intestines decompressed. The volume of gastric fluid aspirated is usually relatively small, so additional fluid in addition to basic replacement fluid is seldom required.
Start parenteral broad-spectrum antibiotics (usually ampicillin and gentamicin). Because of the probable association of Gram-negative anaerobes, also give metronidazole, especially if there is pneumatosis, perforation or evidence of peritonitis. Broader-spectrum antibiotics may be considered in the presence of extensive disease, poor response or based on culture results.

Treat any accompanying shock with Ringer-lactate or Hartmann’s solution or colloid, such as 4.5% albumin, 10 mL/kg over 15 minutes. Repeat if necessary.

Measure the haemoglobin concentration daily and transfuse if it falls below 10 g/dL.

If the infant is bleeding, give 1 mg vitamin K IV and fresh blood transfusion to replace clotting factors and platelets.

Give iv pain relief if available.

The principal goal of therapy is to rest the bowel and treat any contributing or evolving bacterial infection with antibiotics. The duration of this therapy is usually 10–21 days, depending on the severity of the process. Serial abdominal X-ray studies (if available) are indicated early in this disease to monitor for pneumatosis intestinalis or perforation. Ideally, parenteral nutrition should be given at this time in place of simple 10% glucose and electrolytes but is rarely available in low resource settings. An infant who is sucking and showing interest in feeding is usually ready for enteral feeding and enteral feeds (breast milk) are reintroduced slowly at the end of antibiotic therapy (initially 20–30 mL/ kg/day), with careful monitoring for abdominal distension or other signs of obstruction.

In seriously ill infants or infants who do not improve after 48 hours a surgical opinion should be sought.

Even in hospitals with good surgical support, perforation of the bowel is not necessarily an indication for a laparotomy. The conventional surgical approach has been laparotomy with resection of the perforated and adjacent necrotic bowel. A stoma and mucus fistula may be created with later anastomosis. An alternative surgical approach is to place a peritoneal drain, with laparotomy reserved for later complications, if they develop (e.g. bowel obstruction from adhesions or bowel wall strictures). Although there is some controversy about which approach is best, studies suggest that the overall mortality may be similar with either approach.

Although immediate mortality is quite high, many cases resolve without surgical intervention. Occasionally a stricture may develop about a month later in the affected area of gut.

***The infant with severe dehydration***

*Severe dehydration is rare during the first 4 weeks of life (please refer to Handbook 1 for information on management).*

***Pyloric stenosis***

This is a classical cause of gastric outlet obstruction in infants. It has a prevalence rate of about 1.5 to 4 in 1000 live births among white populations but is less common in Africans and Asians. It is more common in males than in females, with a ratio of between 2:1 and 5:1. There appears to be an increased risk to firstborn infants with a positive family history.

*Presentation*

Pyloric stenosis typically presents at 2–8 weeks of age, with a peak occurrence at 3–5 weeks. The vomiting is projectile and non-bilious. Occasionally there is coffee-ground vomiting due to gastritis or oesophagitis. The infant remains hungry after vomiting and is otherwise not ill looking or febrile. Around 2–5% of infants have jaundice associated with indirect hyperbilirubinaemia. Non-bilious projectile vomiting, visible gastric peristalsis in the left upper abdomen, and in those presenting late a hypochloraemic hypokalaemic metabolic alkalosis are the cardinal features of pyloric stenosis.

*Diagnosis*

A definite diagnosis can be made in 75% of infants with pyloric stenosis by careful physical examination of the upper abdomen. **An absolute prerequisite for this is a calm and cooperative infant, a warm environment, good light and patience.** With the patient in the supine position, in the mother's left arm and sucking on the left breast, and the

surgeon sitting on the left side of the patient, the left hand is used to feel the classically described 'olive' to the right of the rectus muscle, often palpated against the spinal column. Visible gastric peristalsis is often noticed.

*Investigations*

- Ultrasonography is the most used imaging technique for diagnosis. A positive finding is a pyloric canal length of 16 mm or more and a pyloric muscle thickness of 4 mm or more. A diameter of more than 14 mm is also considered abnormal.
- Blood investigations in an advanced situation may show the typical hypochloraemic hypokalaemic metabolic alkalosis.

*Management*

1. It is most important to prepare the patient appropriately and adequately for anaesthesia and surgery.
2. Intravenous fluid resuscitation with 5% glucose in 0.9% saline with 20–40 mEq/litre of potassium chloride is the optimal fluid.
3. Urine output and serum electrolytes should be monitored.
4. The stomach should be aspirated before the operation.
5. Ramstedt's pyloromyotomy performed through a right upper quadrant or supraumbilical incision is curative and is associated with a low morbidity.
6. Most of these patients can be started on feeds about 6 hours after surgery.
7. Those who present with haematemesis from gastritis may benefit from delay of feeding for an additional 6–12 hours after surgery.
8. Vomiting in the early post-operative period is thought to be secondary to discordant gastric peristalsis or atony.

***Intestinal obstruction***

This is the most common condition requiring emergency surgery in infants. Most causes result from complications of congenital anomalies or from inflammatory conditions that affect the bowel.

*Causes*

- Extrinsic causes: incarcerated hernia and vascular bands, intussusception, anomalies of rotation (volvulus and Ladd's bands, para-duodenal and para-caecal hernias), post-operative adhesions.
- Intrinsic causes: inspissation of bowel contents (meconium ileus, distal intestinal obstruction syndrome in patients with cystic fibrosis), roundworm obstruction.
- Peristaltic dysfunction: Hirschsprung's disease.
- Inflammatory lesions: tuberculosis, Crohn's disease.

*Symptoms and signs*

Patients present with cramping abdominal pain with anorexia, nausea and vomiting, which progresses to become bilestained. Abdominal distension occurs, with the degree being directly related to the site of obstruction in the gastrointestinal tract, such that the distension is greater the more distal the obstruction.

On examination, the patient may have tachycardia and signs of dehydration. Tenderness and hyperactive bowel sounds are present on abdominal examination.

Chest and abdominal films are taken to confirm the diagnosis of obstruction and rule out the presence of free air.

*Treatment*

The goal of treatment is to relieve obstruction before ischaemic bowel injury occurs.

Intravenous access is established, and blood collected for baseline investigations, including a full blood count, urea, creatinine and electrolytes, and cross-matching.

Intravenous fluids (Ringer-lactate or Hartmann's solution with 10% glucose) are started according to the guidelines of 4 mL/kg/hour.

Some patients may need one or more IV boluses (10– 20 mL/kg) with Ringer-lactate or Hartmann's solution or albumin at the start of resuscitation.

A nasogastric tube is passed for decompression.
Give broad-spectrum IV antibiotics such as:

Cefuroxime 50 mg/kg 8-hourly or 12-hourly in the neonate < 7 days of age PLUS

Metronidazole 7.5 mg/kg 8-hourly IV. Neonate < 34weeks corrected GA loading dose 15mg/kg followed by 7.5mg/kg after 12hrs, then 7.5mg/kg 12hrly. Neonate >34 weeks corrected GA, loading dose 15mg/kg, followed by 7.5mg/kg after 8 hrs, then 7.5mg/kg 8hourly

**OR**

Benzylpenicillin 50 mg/kg 12hrly up to 7days age, 8hrly 7-28days, 4-6hrly thereafter (max per dose 2.4g every 4hrs)
PLUS Gentamicin see Section 14
PLUS Metronidazole 7.5 mg/kg 8-hourly IV. Neonate < 34weeks corrected GA loading dose 15mg/kg, followed by 7.5mg/kg after 12hrs, then 7.5mg/kg 12hrly. Neonate >34 weeks corrected GA, loading dose 15mg/kg, followed by 7.5mg/kg after 8 hrs, then 7.5mg/kg 8hourly

Once the patient is adequately resuscitated and fluid and electrolyte imbalances have been corrected, laparotomy is performed, and the cause treated. Transfer to a facility where paediatric surgical and anaesthetic skills are available should be undertaken if the patient's condition will tolerate this. Otherwise, or in the absence of such a facility in the country, surgery should be performed.

At all times adequate analgesia should be given (*see* Section 34).

***Hirschsprung's disease***

This is characterised by an absence of ganglion cells in the affected intestine. The incidence is about 1 in 4400–7000 live births; the male: female ratio is about 4:1, and in long segment disease it approaches 1:1. The longer the segment of without ganglia (aganglionosis), the higher is the familial incidence.

*Associated conditions*

These include Down's syndrome (4–16%), Waardenburg syndrome, multiple endocrine neoplasia 2A and Von Recklinghausen's disease. A higher incidence of enterocolitis has been noted in patients with Hirschsprung's disease and Down's syndrome.

*Presentation*

The usual presentation is with delay of passage of meconium beyond 48 hours after birth. (Around 95% of full-term infants pass meconium within 24 hours after birth, and the remainder pass it within 48 hours.) The infant then has episodes of constipation, abdominal distension, vomiting and poor feeding, and fails to thrive. They may also present with a history of constipation with explosive diarrhoea, the latter indicating the development of enterocolitis.

*Differential diagnosis*

Hirschsprung's disease should be considered in the differential diagnosis of any infant who has constipation dating back to the newborn period. However, constipation related to dietary and habitual problems needs to be carefully ruled out in order to avoid unnecessary X-rays and biopsies.

*Examination*

On examination the infant has a distended abdomen, and after a rectal examination there is often explosive passage of flatus and faeces.

A plain X-ray of the abdomen may show dilated bowel loops with paucity of air in the location of the rectum. Barium enema may show the characteristic coning, although a simple colonic dilatation can occur in any chronic constipation.

Rectal biopsy remains the gold standard for diagnosis. It should be performed at least 2 cm above the anal valves, as the normal anus has a paucity or absence of ganglion cells at the level of the internal sphincter. Although suction rectal biopsy with acetylcholinesterase staining has become the accepted standard for diagnosis in most centres, a full-thickness rectal biopsy under general anaesthesia is equally useful if such facilities are not available.

*Treatment*

Enterocolitis remains the major cause of morbidity and has a mortality rate of around 6–30%. It manifests clinically as explosive diarrhoea, abdominal distension and fever. The pathophysiology is not fully understood. The diagnosis is made on clinical grounds, and treatment is conservative, consisting of IV fluids and rectal washouts to decompress the colon.

Surgery

The surgical treatment of Hirschsprung's disease has evolved from a three-stage procedure (initial colostomy with multiple sero-muscular biopsies, pull-through of the ganglionic colon as the second stage, and closure of colostomy as the third stage) through a two-stage procedure (colostomy at the transition zone initially, and pull-through as a second stage) to a one-stage procedure without a colostomy. The essential prerequisite for a primary pull- through is adequate preparation with colonic washouts.

**Peritonitis due to bowel perforation**

The most frequent causes of bowel perforation in the neonate are NEC and Hirschsprung's disease.

Management starts with an adequate history and clinical examination, followed by chest and abdominal X-rays (if available). Adequate resuscitation should be carried out as outlined in the section on intestinal obstruction. After this a laparotomy is performed and the cause treated. Treatment includes fluid resuscitation if necessary, and antibiotics (either a third-generation cephalosporin or gentamicin plus metronidazole with doses as for intestinal obstruction earlier in this section).

## Section 28 Shock in the neonate

In the early stages of shock, the body has mechanisms to try to combat this process. The sympathetic nervous system attempts to protect the vital organs by diverting blood away from muscle, skin and the digestive system and directing it to the heart, brain and kidneys. This gives rise to some of the earlier signs of shock, such as cold peripheries, increased capillary refill time, cerebral anxiety or agitation, tachycardia to increase cardiac output, and reduced urine output as the kidneys conserve fluid.

Later signs such as depressed consciousness, weak pulses, falling blood pressure and acidotic breathing (shallow and rapid) show that the body's compensation mechanisms are failing. It can be seen that it is vital to recognise and treat shock in the patient as soon as possible, as this will give the best chance of patient recovery.

### Clinical diagnosis of shock in the neonate

The signs of shock are listed below, although not all of them are present in all types of shock.

- **Tachycardia** (best measured with a stethoscope).
- **Weak pulse** (ideally central – brachial, femoral or carotid, but difficult to feel in the neonate).
- **Low blood pressure** (this is a late sign and very difficult to measure in neonates).
  - Extreme central pallor (severe anaemia).
  - Raised respiratory rate (due to acidosis).
- **Cold skin with poor circulation**.
- **Prolonged capillary refill time (CRT) > 3 seconds.**
- Increased skin sweating in some cases.
- Agitation and anxiety (this is an early sign).
- **Reduced conscious level.**
- Reduced urine output (this is an early sign).

The WHO diagnosis of shock includes all of the above signs that are highlighted in bold type.

The problem is that shock is quite difficult to diagnose in the early stages, as some signs also occur because of medical causes other than shock. The diagnosis in the early stages depends on the following:

- tachycardia, which is a very useful sign of shock, but also occurs with fever and with anxiety or fear
- anxiety and/or agitation and persistent crying
- prolonged capillary refill time, which also occurs in dehydration and is influenced by environmental temperatures and by how hard the nail bed or sternum is pressed
- cold skin, which is also dependent on environmental temperature
- reduced urine output, which is also dependent on fluid intake.

It is vital that if any of these early signs are noted in a patient that they are not dismissed as some unrelated cause but are seriously considered as likely to be indicating the development of shock.

This is why it is so useful to have regular vital signs (pulse, respiration, conscious level, temperature and blood pressure) observations on patients, so that abnormal trends can be detected early.

It is also important to note that shock is not diagnosed because of one physical sign alone but based on several signs occurring together. For example, a tachycardia alone does not

diagnose shock, but if you note a tachycardia, you should look for cold limbs, prolonged capillary refill time, or a history suggestive of a cause of shock, such as a fever, severe diarrhoea or bleeding.

**P*athological mechanisms that can cause shock***

The main mechanisms of shock in the neonate:

- loss of fluid or blood: hypovolaemic shock (e.g. diarrhoea, blood loss)
- failure of the heart pump: cardiogenic shock (e.g. cardiac arrhythmias, cardiomyopathy, myocarditis, malnutrition)
- abnormal function of vessels supplying nutrients and oxygen to tissues: distributive shock (e.g. sepsis, anaphylaxis)
- inadequate capacity of the blood to release oxygen that is dissociative shock (e.g. severe anaemia, carbon monoxide poisoning)
- restriction of circulation to the tissues: obstructive shock (e.g. some congenital heart diseases, tension pneumothorax).

In an individual with shock, often several of these mechanisms may coexist. Therefore, the clinician must consider which emergency treatments will be effective and which will be harmful for any patient. One of the most difficult situations is in the anaemic malnourished infant with sepsis, where fluid is required to expand the circulating volume, but the heart is already failing and may not be able to cope with a rapid fluid infusion.

**Basic management of shock**

Shock is managed according to the following principles:

- High concentrations of oxygen are safe and must be given regardless of the cause of shock.
- Airway and breathing stability or support must be established promptly first (the only exception is to stop exsanguinating external bleeding).
- Frequent reassessment, at least after every therapeutic manoeuvre, is vital to avoid both under-infusing and over-infusing fluids.
- The underlying pathology must be treated to arrest the pathological process.

The clinical diagnosis of the cause of shock is not easy or definitive. Shock is a spectrum of conditions and mechanisms, and it is a clinical challenge.

Immediate resuscitation is needed to maintain oxygenation and perfusion of vital organs. Once this is under way, the cause of shock needs to be found and treated. Diagnosis depends on history, clinical examination, and response to treatment given. It is often possible to identify the cause of shock with a good history and a careful examination.

*Investigations*

- Haemoglobin measurement is essential.
- Blood glucose measurement is essential, as some signs of shock are the same as signs of hypoglycaemia.
- Plasma electrolyte measurements are helpful, especially sodium, potassium, and bicarbonate (if available).
- Blood Lactate measurement is helpful (if available).

*Choice of intravenous fluid*

Fluid infused into the circulation should approximate to plasma in its electrolyte content, osmolality and pH.

*Dextrose-only fluids*

Although glucose/dextrose is necessary to prevent or manage hypoglycaemia, fluids containing only dextrose should never be used for the emergency management of shock. The reason for this is that the dextrose is rapidly metabolised, so the effect of a dextrose-only IV fluid on the child's body is as if pure water had been given. The outcome of this treatment would be severe hyponatraemia, which could quickly lead to convulsions, brain damage or death. In addition, this pure water is rapidly moved out of the circulation and into the cells, and the state of shock is then no better than before the infusion.

***TABLE 28.1*** *Diagnostic pointers to the clinical causes of shock in infancy*

| | |
|---|---|
| Diarrhoea and/or vomiting with signs of severe dehydration | Gastroenteritis (see Section 27 and volvulus, intussusception (see Section 27) |
| Fever, non-blanching (purpuric) rash | Meningococcal septicaemia |
| Urticaria, wheeze, oedema, exposure to allergen | Anaphylaxis |
| Trauma | Blood loss, tension pneumothorax, internal bleeding, spinal cord transection |
| Burns | Fluid loss from burns |
| Pallor, tachycardia, severe malaria, severe acute malnutrition | Severe anaemia, often with malnutrition and malaria |
| Fever, signs of shock and a very sick child | Septicaemia and malaria |
| Baby < 4 weeks old: cyanosis, with no response to oxygen, very weak pulses | Congenital heart disease |
| Very fast pulse, heart failure | Cardiac arrhythmia and cardiomyopathy (see Handbook 1) |

*Sodium-containing fluids*

The fluid traditionally infused into the circulation for the management of shock has been 'normal saline' (0.9% sodium chloride, NaCl). This fluid has increasingly been shown to be potentially dangerous, especially in the sick patient. An infusion of normal saline can cause a hyperchloraemic acidosis (a high chloride concentration leading to an acidosis), which in the shocked patient, who is already acidotic, can cause a deterioration in the health of cells in vital organs, even though perfusion of the cells has been improved by the increased circulating volume.

There are sodium-containing alternatives to normal saline which are safer as they approximate more closely to human serum in content (*see* Table 28.2), although they are a little more expensive. We recommend the use of either Ringer-lactate or Hartmann's solution for all fluid replacement in shock. Recognising that not all hospitals will have access to these solutions immediately, there may sometimes be no alternative but to start fluid replacement with normal saline. However, if more than 20 mL/kg needs to be given, one of the safer alternatives should be used in these very sick infants if at all possible.

**TABLE 28.2** Comparison of electrolytes, osmolality and pH levels in IV fluids with those in human serum

| Fluid | $Na^+$ (mmol/litre) | $K^+$ (mmol/litre) | $Cl^-$ (mmol/litre) | $Ca^{2+}$ (mmol/litre) | Lactate or bicarbonate (mmol/litre) | Osmolarity (mOsm/litre) | pH |
|---|---|---|---|---|---|---|---|
| Human serum/plasma | 135–145 | 3.5–5.5 | 98–108 | 2.2–2.6 | 22–30 | 276 to 295 | 7.35–7.45 |
| Ringer-lactate or Hartmann's solution | 131 | 5.0 | 111 | 2.0 | 29 | 279 | 6.0 |
| 0.9% 'normal' saline | 154 | 0 | 154 | 0 | 0 | 310 | 5.4 |

***Initial management of shock***

Even though it may be clear on initial inspection that the infant is in shock, the priority must still be to call for help, manage the airway, manage breathing and then manage the circulation.

*Call for help*. Include an anaesthetist.

*Manage the airway*

**At this stage also stop any obvious exsanguinating bleeding.**

Assess the airway by the simple technique of gently shaking the baby and looking for a response. Any vocalisation such as a reply or crying indicates an open airway and some ventilation. In the absence of a response, formally open the airway with a head tilt/chin lift or a jaw thrust manoeuvre to the neutral position (*see* Section 32), and assess breathing by looking, listening, and feeling for its presence.

Stop any obvious exsanguinating bleeding by applying external pressure.

*Breathing*

**All infants with suspected shock must receive high-flow oxygen.**
In the absence of spontaneous breathing, give assisted ventilation with a bag-mask.

*Circulation*

Intravenous access with a short wide-bore venous cannula, or placement of an intra-osseous line (see Section 45) is vital. More than one line is preferable, as rapid fluid resuscitation may be needed, although always start treatment as soon as the first access has been achieved and insert the second IV line when possible later. Take blood samples for the following investigations: full blood count, glucose levels, electrolytes, blood culture (and, if relevant, cross-matching)

*Nutritional status*

While starting to give fluid, assess the infant's nutritional status. Look for visible severe wasting or marasmus. The WHO recommended criteria are as follows: *'Look at the arms, legs and chest. The marasmic child does not look just thin but appears to be all skin and bone. The skin looks too large for the body, there is no fat on the child and you will see the outlines*

*of the ribs. There is also severe muscle wasting of the arms, legs and buttocks. The head may appear relatively large because of wasting of the body.'* Use the mid upper arm circumference (MUAC) to assess marasmus, as the urgency of the child's need for treatment precludes a weight and height measurement.

Look also for Kwashiorkor. Check for oedema of both feet. Look at the bare feet. Press the top of the foot gently with your thumb for a few seconds. Oedema is present if a definite dent is left in the tissues. Look and feel to determine whether the infant has oedema of both feet.

*Some assessment of weight will be necessary to calculate the amounts of fluid and antibiotics to be given.*

*Severe anaemia*

In very anaemic infants (with either obviously pale palms or haemoglobin levels less than 3–4 grams/dL), crystalloid alone may worsen oxygen delivery to the tissues. These infants need blood transfusion, either packed cells or a partial exchange transfusion, in addition to initial slow fluid resuscitation.

An infant with a haemoglobin level of less than 5 grams/dL will also need a transfusion of 10 mL/kg of packed cells over 4 hours, watching continuously for evidence of pulmonary oedema. If pulmonary oedema develops, Furosemide 1 mg/kg IV may be required, but if possible pulmonary oedema of severity requiring diuretics should be avoided by a slow and vigilant approach to therapy in these very sick infants.

*Hypothermia*

Keep the patient warm, but do not overheat them, as this will cause peripheral vasodilatation and reduce the blood supply to vital centres. Hypothermia will exacerbate poor peripheral perfusion, acidosis, and coagulation abnormalities.

Elevate the patient's legs (raise the foot of the cot).

*Importance of hypoglycaemia in shock*

If the infant has a reduced level of consciousness or has a convulsion, hypoglycaemia may be present. Always measure the blood glucose concentration in this situation. However, if blood glucose measurement is not possible, always treat as for presumed hypoglycaemia and, in addition to the IV fluids given above, give 2 mL/ kg of 10% glucose IV or, if there is no IV access, by intra-osseous needle.

*Intravenous crystalloid fluids in shock*

The next step is to give fluid intravenously. In most cases this should be a crystalloid such as Hartmann's or Ringer-Lactate (R/L) solution; but give normal saline (0.9%) if this is all that is available. In infants, the initial volume of fluid to be given is usually 10 mL/kg, especially in severe anaemia or malnutrition. 10ml/Kg represents 12.5% of the circulating volume. Shock is not usually clinically evident until 25% of the circulation has been lost, so any infant with signs of shock must have lost at least this amount of fluid from the circulation.

In infants with shock start with IV boluses of 10 mL/kg of crystalloid, or ideally blood if the cause of shock is haemorrhage or severe anaemia and reassess after each bolus.

The next important step is to reassess the patient's vital signs to see whether the fluid has helped, and to ensure that circulatory overload has not given rise to a situation where more IV fluids may produce very dangerous heart failure (see Section 26 for clinical signs of this).

During this reassessment, give IV antibiotics, as shock without obvious fluid loss, is probably sepsis.

At this point, some infants will need more crystalloid fluid, while others will not, or they will need other fluids (e.g., blood). Many will need additional treatments.

*The importance of reassessments*
While treating shock, reassess the infant, ideally continuously, until signs of shock have resolved.

***When signs of shock have resolved***

When shock has resolved and the patient's level of consciousness has returned to normal, the remaining estimated fluid deficit MUST be taken by mouth or by gastric tube, especially if there is malnutrition and/or anaemia (due to the danger of a large IV fluid volume).

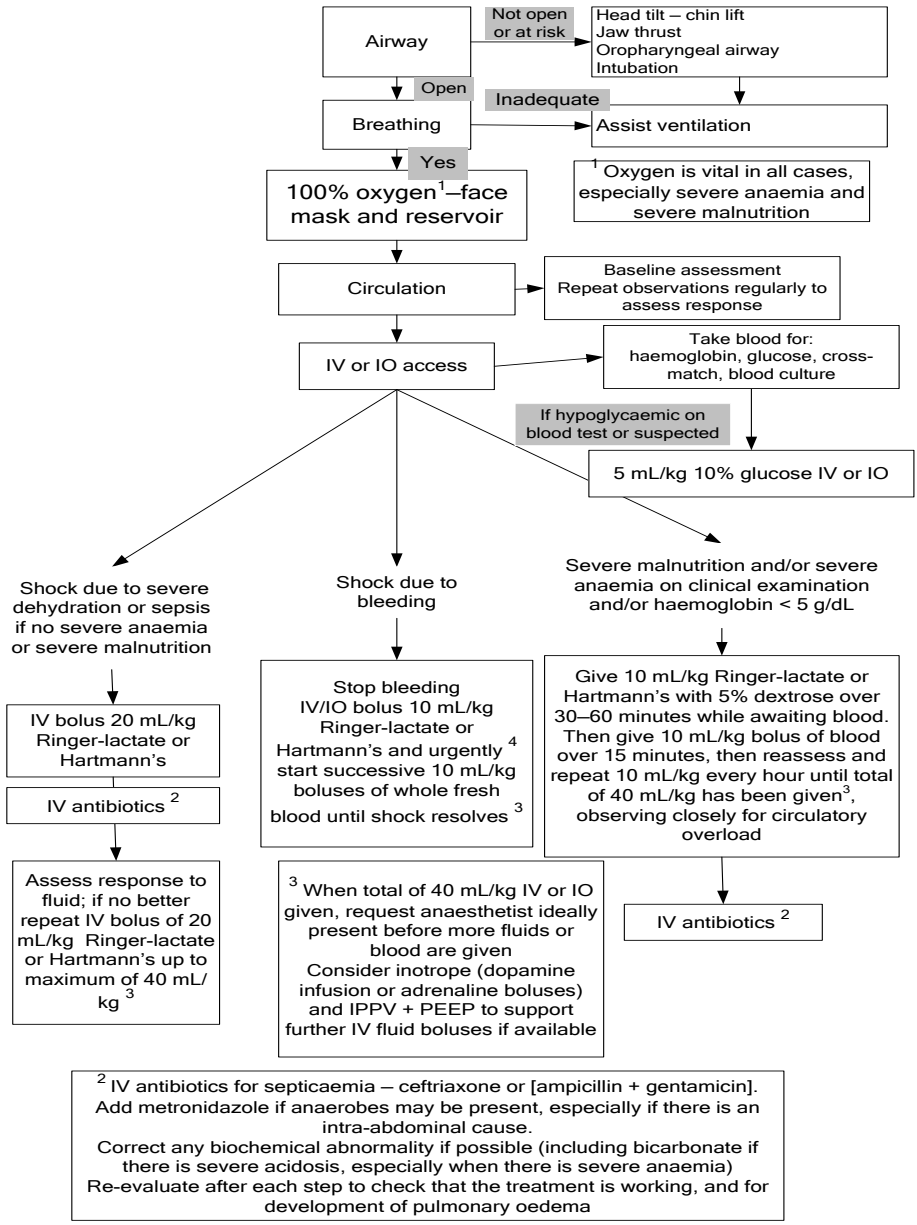



***Figure 28.1*** *Pathway of care for the infant with shock that is not cardiac in origin*

## Section 29 Pneumonia in the neonate and infant

Pneumonia is responsible for around two million deaths annually in children under 5 years of age. In resource-limited countries, most of these infections are bacterial, and the most common causative bacteria are *Streptococcus pneumoniae* and *Haemophilus influenzae*. In severely malnourished children, *Klebsiella pneumoniae* and *Staphylococcus aureus* are common causative organisms.

*Immunisation*

Pneumococcal conjugate vaccine has been introduced to the primary immunisation schedule in many well-resourced countries and reduces the incidence of X-ray-proven pneumonia in infants by around one-third. The HiB vaccine (against encapsulated *Haemophilus influenzae* type B) will not protect against unencapsulated *H. influenzae*, which causes some cases of pneumonia in resource-limited countries. Nevertheless, the HIb vaccine is very effective against other very serious infections caused by *H. influenzae* (e.g. meningitis, epiglottitis), and should be given to all infants in every country.

### *Management of the infant with acute lower respiratory infection (ALRI)*

Children at greatest risk of dying from an ALRI have the following risk factors:

- age under 1 year
- malnutrition
- pneumonia as a complication of infection with measles, pertussis, malaria or HIV.

### *Diagnosis of ALRI*

In many hospitals in resource-limited countries, special tests (e.g. blood culture, microbiology of respiratory secretions, X-rays) may be limited or unavailable. However, because the prevalence of bacterial pneumonia is high, the diagnosis must usually be made clinically. This will not be 100% accurate, so a few children may receive antibiotics unnecessarily (i.e. clinical diagnosis has less than 100% specificity). However, it is more important not to miss children who do need antibiotics (i.e. clinical diagnosis should have a good sensitivity). Clinical diagnosis may be as accurate as an X-ray and more helpful in deciding whether treatments such as oxygen are indicated. The clinical features will also help to decide how severe the infant's infection is and what treatment is appropriate.

The following clinical features should be recorded:

- The presence of cyanosis, which is best seen in the lips or tongue. It may be missed if the lighting is poor or if the infant is anaemic (e.g. due to co-infection with malaria), and it can be difficult to detect in infants with black skin. Cyanosis is a late sign of respiratory problems, and, if possible, oxygenation should be assessed with a pulse oximeter. Normal saturation at sea level ($SpO_2$) is greater than 94%.
- Inability of the infant to breast feed.
- The presence of chest wall in-drawing (an inward motion of the lower chest wall when the infant breathes in).
- The presence of grunting (expiratory braking).
- Elevated respiratory rate. Respiratory rate is measured over 1 minute, using a suitable timing device. The respiratory rate varies with age. Table 29.1 lists the abnormal values for respiratory rate for the neonate.

**TABLE 29.1** WHO definition of abnormally fast breathing

| Age | Abnormally fast breathing |
|---|---|
| < 2 months | ≥ 60 breaths/minute |

Remember that conditions such as severe anaemia, dehydration and high fever are themselves accompanied by a raised respiratory rate.

A high fever in an infant with breathing difficulties may be due to pneumonia, bacterial tracheitis or even epiglottitis. If the airway is clear, the most likely diagnosis is pneumonia. Although high fever and respiratory signs are the usual way for pneumonia to present, pneumonia should always be considered as a major cause of neonatal sepsis.

Clinical examination (or chest X-ray) cannot reliably differentiate between a viral pneumonia and a bacterial one, so all cases must be treated with antibiotics.
*Features of pneumonia in the neonate include*:

- fever, cough, breathlessness, lethargy and poor feeding
- signs of consolidation:
  - dull percussion
  - reduced breath sounds
  - bronchial breathing may be absent in an infant
- chest X-ray may show pleural effusion or empyema as well as consolidation.

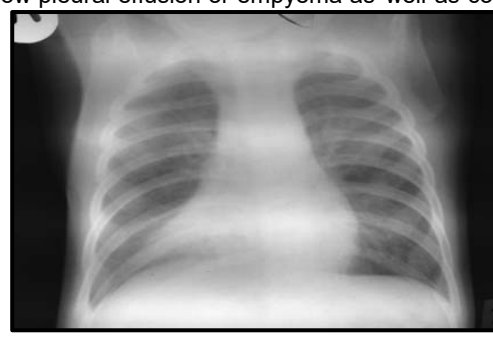


***FIGURE 29.1*** *Right middle lobe pneumonia. Note the loss of the right heart border.*

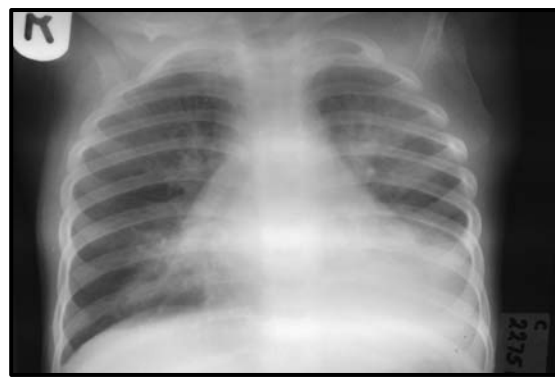



***FIGURE 29.2*** *Left lower lobe pneumonia. Note that the silhouette of the diaphragm cannot be seen on the left. The right middle lobe is also affected.*

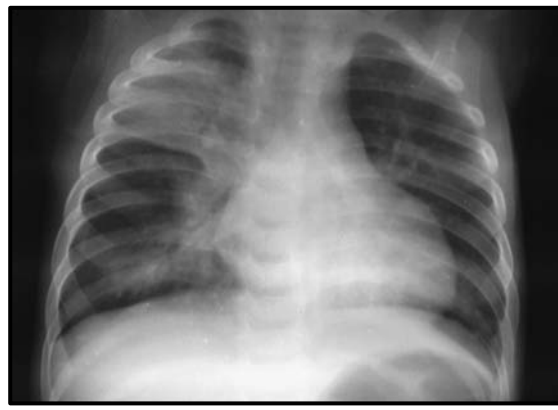


**FIGURE 29.3** Right upper lobe pneumonia. Note that the horizontal fissure is pulled up.

Auscultation should always be undertaken, but only after first checking for cyanosis, observing the breathing pattern and the other signs as described above. Important clinical signs include evidence of the following:

- consolidation or effusion/empyema
- wheeze
- bronchiolitis (hyperinflation with crackles at the lung bases)
- alveolitis (e.g. in HIV-induced Pneumocystis pneumonia) with end-inspiratory crackles.
- pericardial involvement (rare)
- pneumothorax (rare).

A chest X-ray may be helpful if there is any doubt about the diagnosis or if the infant is seriously ill. *Figures 29.1 to 29.3* show the appearance of lobar pneumonia affecting different lobes.

Additional features of pneumonia usually include a fever and a cough.

Table 29.2 gives guidelines for the assessment and treatment of acute respiratory infection.

*Diagnosis of severe pneumonia*

This is diagnosed by the presence of cough or difficult breathing plus at least one of the following:

- central cyanosis
- inability to breastfeed or drink, or vomiting after every drink
- convulsions, lethargy, or unconsciousness
- severe respiratory distress.

In addition, some or all of the other signs of pneumonia may be present, such as the following:

- fast breathing: ≥ 60 breaths/minute
- nasal flaring
- grunting (in young infants)
- lower chest wall in-drawing
- chest auscultation signs of pneumonia:
- decreased breath sounds
- bronchial breath sounds

- crackles
- abnormal vocal resonance (decreased over a pleural effusion, and increased over lobar consolidation)
- pleural rub.

Obtain a chest X-ray (if available) and measure $SaO_2$. For infants with no evidence of pneumonia but with signs suggesting a chest infection, look for ear and throat infections or infections in another system and treat accordingly.

***TABLE 29.2*** *The management of neonates with different severities of Acute Lower Respiratory tract Infection (ALRI) (modified from the WHO Pocket Book of Hospital Care for Children, second edition 2014)*

| Sign or symptom | Classification | Treatment |
|---|---|---|
| Central cyanosis and/or SpO2 < 90%<br>Severe respiratory distress (e.g. head nodding, gasping, chest wall indrawing, grunting)<br>Fast breathing ≥60 breaths/minute<br>Decreased breath sounds and/or bronchial breathing<br>Crackles in the lung fields<br>Vocal resonance and percussion suggesting consolidation and/or effusion<br>Pleural rub<br>Inability to drink, vomiting, reduced consciousness<br>Plus signs of pneumonia in the row below | Severe pneumonia | Admit to hospital<br>Give IV/IM appropriate antibiotics*<br>Give oxygen<br>Manage the airway<br>Treat high fever if present<br>If the neonate has possible HIV infection, refer to specific guidelines (Paediatric Handbook 2 and see Section 13) |
| Fast breathing but no chest wall in-drawing: ≥60 breaths/minute in a child aged < 2 months<br>Definite crackles on auscultation | Pneumonia that is not severe | Admit to hospital if not already there |
| No signs of pneumonia or severe pneumonia | No pneumonia Cough or coryza | Home care<br>Advise the mother to return for follow-up in 5 days if not improving<br>If coughing for more than 14 days, consider investigations for TB, asthma, inhaled foreign body, pertussis, HIV, bronchiectasis and lung abscess (see Paediatric Handbook 2 for details). |

See details of antibiotics, routes of administration and durations for different categories of pneumonia in section 'Antibiotics' below

***Oxygen***

Neonates with severe or very severe pneumonia are likely to be hypoxaemic. However, cyanosis is a late sign of hypoxaemia.

**Oxygen must always be available in sufficient quantity to provide 24-hour treatment without depending on the availability of a reliable electricity supply.**

Give oxygen if the baby shows any of the following:

- if a pulse oximeter is available, $SpO_2$ of less than 94% (at sea level; lower values will be normal at high altitude, and normal values of SpO2 should be known for healthy local babies in your area if it is at high altitude). Aim to maintain $SpO_2$ in the range 94–98%.
- restlessness (if oxygen makes the infant more comfortable)
- severe chest wall in-drawing
- a breathing rate of 60 breaths/minute or more
- grunting
- gasping **urgently needed and may also need assisted ventilation.**

Give oxygen until the signs of hypoxia (e.g., severe lower chest wall in-drawing, high breathing rates and/or $SpO_2$ < 94% in air) are no longer present.

*Oxygen delivery*

A good source of oxygen is an oxygen concentrator. This is a durable piece of equipment, but it requires a continuous supply of mains electricity to provide oxygen. It works on the 'molecular-sieve' principle, removing nitrogen from room air.

The alternative is cylinder oxygen, but cylinders must be replenished regularly and need to be always available, which is expensive and may give rise to transport difficulties. A combination of the two supplies of oxygen is essential.

An oxygen generator which can provide oxygen and fill cylinders when the electrical power is available (e.g. Diamedica). The concentrator or cylinder should be connected to a low-flow meter.

The use of a flow splitter will allow up to four babies to receive oxygen from one source. The oxygen should be delivered to the baby using nasal cannulae. These should be only 2–3 mm long, to avoid nasal irritation.

**A mask and reservoir should be used to give high-flow oxygen during resuscitation.**

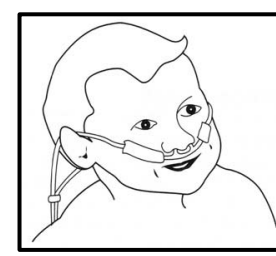


***FIGURE 29.4 Nasal*** *cannulae for delivering oxygen. The cannula has been taped to the infant's cheeks, close to the nostrils. The tubing is run under the infant's shirt to stop them pulling it and leads to the low-flow meter and oxygen concentrator or cylinder. A flow splitter may be used.*

Nurses should check frequently that the nasal cannulae are not blocked with mucus and are in the correct position, and that all connections are secure.

***Antibiotics***

Infants who are vomiting or who require IV fluids should have their antibiotics given for the first 48 hours intravenously (preferably), or intramuscularly if vascular access is difficult to achieve or maintain. Some antibiotics, such as gentamicin, are always given IV or IM. Certain antibiotics are reserved for specific circumstances, such as high-dose co-trimoxazole for suspected *Pneumocystis jirovecii* pneumonia, and flucloxacillin or cloxacillin for pulmonary abscess or bacterial tracheitis where *Staphylococcus aureus* is likely to be responsible. These are described at the end of this section on antibiotics.

***Treatment for severe pneumonia (doses for infants)*:**

Give ampicillin 50 mg/kg IM/IV or benzyl penicillin 50 000 units/kg that is 30 mg/kg IM or IV 4-6 hourly, (max 2.4gm every 4 hours) plus gentamicin 7.0 mg/kg IM or IV once a day for 5 days. Then, if the infant responds well, complete treatment with oral amoxicillin (30 mg/kg three times a day, maximum 500 mg, or 1 gram in severe cases) plus IM or IV gentamicin 7 mg/kg once daily for a further 5 days.

- Alternatively, if the above are not available, give chloramphenicol (25 mg/kg IM or IV every 8 hours) until the infant has improved. Then continue orally four times a day for a total course of 10 days.
- Or use ceftriaxone (80 mg/kg IM or IV once daily) or cefotaxime (50 mg/kg IV 6-hourly) for 10 days.
- If the infant does not improve within 48 hours, switch to gentamicin (7mg/kg IM or IV once a day) and cloxacillin (50 mg/kg IM or IV every 6 hours), as described below for possible staphylococcal pneumonia.

*For pneumonia that is not severe:*

- Give amoxicillin 30mg/kg three times daily for 5 days.
- Unusually in neonates who have some of the signs suggestive of non-severe pneumonia without a high fever but with wheeze, the most likely diagnosis is bronchiolitis (see Section 30). This is caused by a virus, and in the absence of signs suggesting the development of secondary bacterial infection (severe pneumonia), antibiotics are not necessary. WHO recently published the following conclusion: Antibiotics are not routinely recommended for children aged 2 months to 5 years with non-severe pneumonia (that is, fast breathing with no chest indrawing or danger signs) with a wheeze but no fever (temperature below 37.5°C), as the cause is most likely to be viral. **In neonates, antibiotics should always be given under these circumstances.**

***Treatment for neonate with any degree of pneumonia***

1. Nurse in a thermo-neutral environment (lightly clothed in a warm room at around 25°C).
2. *Fever*: Remember that fever may not be simply due to the pneumonia. Consider other diagnoses, such as malaria. If the infant has fever (≥ 39°C or ≥ 102.2°F) that appears to be causing distress, give paracetamol orally or rectally, 10–15 mg/kg 4-6-hourly. **DO NOT give *NSAIDs.***
3. Remove by gentle suction under direct observation any thick secretions in the throat which the infant cannot clear.
4. Ensure daily maintenance fluids appropriate for the infant's age but avoid over-hydration.

Encourage breastfeeding and oral fluid intake.

5. If the infant cannot drink, insert a nasogastric tube and give maintenance fluids in frequent small amounts. If the infant is taking fluids (ideally breast milk) adequately by mouth or cup, do not use a nasogastric tube, as it increases the risk of aspiration pneumonia.

*Failure to improve* If the infant has not improved after 2 days, or if their condition has worsened, re-examine them thoroughly, looking for signs of pleural effusion/empyema

and other causes of fever. If possible, obtain a chest X-ray. This may show a pleural effusion or empyema (see Handbook 1 for details of management) into which antibiotics cannot penetrate, or it may show the characteristic pneumatocoeles (lung abscesses) of staphylococcal pneumonia.

Also consider *Mycoplasma pneumoniae* or *Bordetella pertussis* infections. Pertussis should be recognisable because of the characteristic cough with vomiting and the whoop. Infants with Pertussis can present with apnoeic/hypoxaemic episodes and need oxygen treatment. Prescribe erythromycin if either of these infections is suspected. It should be given orally as follows; 125 mg 6-hourly (infants)

*Pneumonia that does not respond to standard antibiotics within 2 weeks*

*Tuberculosis*
An infant with persistent fever for more than 2 weeks and signs of pneumonia should be evaluated for tuberculosis. If another cause of the fever cannot be found, tuberculosis should be considered and treatment for tuberculosis, following national guidelines, may be initiated and response to anti-tuberculous treatment evaluated.

*Infants who are HIV-positive or in whom HIV is suspected*
Some aspects of antibiotic treatment are different in infants who are HIV-positive or in whom HIV is suspected. Although the pneumonia in many of these children has the same causes as in children without HIV, pneumocystis pneumonia (PCP), often at the age of 4–6 months, is an important additional cause which must be treated when present (*see* Handbook 2). While confirming the diagnosis, give ampicillin plus gentamicin as described above for severe pneumonia.

*Staphylococcal pneumonia*
Staphylococcal pneumonia is suspected if there is rapid clinical deterioration despite treatment, a pneumatocoele or necrotising pneumonia with effusion on chest X-ray, numerous Gram-positive cocci in a smear of sputum, or heavy growth of *Staphylococcus aureus* in cultured sputum or empyema fluid.

- Treat with flu/cloxacillin (50 mg/kg IM or IV every 6 hours, max per dose 2g every 6 hours and gentamicin (7 mg/kg IM or IV once a day) for at least 7 days.

When the infant improves, continue cloxacillin/flucloxacillin orally four times a day for a total course of 3 weeks. Note that cloxacillin can be substituted by another anti- staphylococcal antibiotic, such as oxacillin, flucloxacillin or dicloxacillin.

*Shock (see Section 28)*
This may be a problem in pneumonia, arising from high fever and poor fluid intake and from septicaemia.
Look for signs of shock (tachycardia, weak pulse, poor peripheral circulation, and capillary refill time prolonged by more than 3 seconds).

- If the neonate is shocked: site an intravenous line and give a bolus of crystalloid Hartmann's solution/Ringer-lactate 0.9% saline or colloid 10mL/kg then reassess and repeat a further 10mL/Kg bolus if needed
- If the infant is not shocked but is clinically dehydrated (see Paediatric Handbook 1): Give oral rehydration solution (ORS10 mL/kg/hour for 2 to 4 hours orally or via nasogastric tube. Encourage breastfeeding.

*Special issues regarding ALRI in the neonate*
Young infants with severe ALRI/pneumonia may not cough, but rather they may present with apnoeic/hypoxaemic episodes, poor feeding, or hypothermia. Remember that in neonates the abnormal respiratory rate cut-off is higher (≥ 60 breaths/minute).

Note that some chest wall in-drawing is normal during REM (dream) sleep in all infants.

All neonates with ALRI/pneumonia should be admitted to hospital for treatment.

Bronchiolitis is a frequent diagnosis (see Section 30), and usually involves hypoxaemia due to ventilation to perfusion mismatch. Oxygen is usually required. Additional respiratory support in the form of nasal CPAP (see Section 39) may also be necessary if available, especially if there is apnoeic/hypoxaemic episodes or severe respiratory distress leading to exhaustion.

Grunting (a short expiratory noise at the start of expiration) is common and usually an indication for oxygen.

Avoid using chloramphenicol in infants under 2 months of age (there is a risk of development of 'grey baby syndrome'). Use benzylpenicillin or ampicillin plus gentamicin instead.

Respiratory infection in neonates may rapidly develop into septicaemia, shock and death, so it is essential to act quickly.

## Section 30 The neonate with bronchiolitis

This is a lower respiratory viral infection, typically most severe in young infants, occurs in annual epidemics, and is characterised by airways obstruction and wheezing. Respiratory syncytial virus is the most important cause. It is much more serious in preterm infants and in those with congenital heart disease. Secondary bacterial infection may occur and is common in some settings. Episodes of wheeze may occur for months after an attack of bronchiolitis.

***Clinical features of bronchiolitis***

- Infants are coryzal, have a cough and may feed poorly or even be unable to suck and feed. There may be vomiting.
- The nose is often obstructed by secretions.
- On examining the chest, there may be hyperinflation, chest wall in-drawing, nasal flaring, grunting, wheeze, and fine crackles at the lung bases.
- Young infants may present with apnoeic/hypoxaemic episodes which may be recurrent and life-threatening.
- There may be hypoxaemia, with $SaO_2$ less than 94%, with or without cyanosis.
- Some infants will have such severe respiratory distress that there is gasping; this is pre-terminal.

*Treatment*

1. Only supportive treatment (e.g., oxygen, gentle suction of the nose, nasal CPAP and fluids) is of benefit. Antibiotics and bronchodilators have no role. However, in the most severe cases and unless you are certain that pneumonia is not present, it is safer to give antibiotics.
2. Non-invasive respiratory support to help to overcome small airway obstruction (nasal CPAP and continuous negative extra-thoracic pressure (CNEP) may be valuable (see Handbook 1). CNEP may be more effective because of the nasal blockage that accompanies bronchiolitis.
3. Give oxygen by nasal cannulae to keep $SaO_2$ in the range 94–98% for term infants and those 32 weeks' gestation or more and lower, at 92 to 94%, for preterm infants less than 32 weeks' gestation. Check that the nasal cannulae are in the correct place and check frequently that they are not blocked by secretions.
4. Nasal clearance. Gentle nasal suction should be used to clear secretions in patients in whom nasal blockage is thought to be adding to respiratory distress. This may be aided by saline nasal drops or spray.
5. Ensure that daily maintenance fluids are achieved. If this is not possible by mouth, use gastric feeding (ideally by orogastric rather than nasogastric tube as the latter can compromise the airway). This should be considered in any patient who is unable to maintain oral intake or hydration (use the mother's expressed breast milk if possible and if tolerated).
6. If the patient is vomiting despite nasogastric feeding, or severe respiratory distress is present, give fluids IV (see Section 15)
7. If there are signs of pneumonia, give antibiotics (see Section 29).
8. If fever ( ≥ 39°C or ≥ 102.2°F) is causing distress, give paracetamol. High fever is rare in bronchiolitis and should make you suspect bacterial infection.

*Failure to improve*

If the condition worsens suddenly, consider pneumothorax, although this is uncommon. Tension pneumothorax associated with major respiratory distress and shift of the heart requires immediate relief by needle thoracocentesis (i.e., placing a needle to allow the air that is under pressure to escape) (*see* Section 38). If needle thoracocentesis is helpful, insert a chest tube with an underwater seal until the air leak closes spontaneously and the lung expands (*see* Section 38). The signs of pneumothorax in severe bronchiolitis may be difficult

to detect clinically. However, needle thoracocentesis in the absence of a pneumothorax may cause one, so if you are unsure, take a chest X-ray. Even on a chest X-ray, the diagnosis may be very difficult due to the areas of hyperlucency in bronchiolitis caused by air trapping.

If respiratory failure develops, nasal continuous positive airways pressure (CPAP) (see Section 39) or continuous negative extra-thoracic pressure (CNEP) may be of benefit (see Paediatric Handbook 1 for details).

If apnoea/hypoxaemic episodes develop (this is most likely in premature infants), give bag-valve-mask resuscitation, then nasal CPAP or CNEP. Sometimes intubation and ventilation may be needed in a high-dependency ward (if available); if so, contact an anaesthetist urgently.

*Infection control*

Bronchiolitis is infectious and easily transmitted to other infants in hospital. Babies in the neonatal unit are particularly at risk. The following strategies may reduce the risk of cross-infection (*see* Handbook 2):

- hand washing between patients
- the wearing of gloves and aprons
- ideally isolate the affected patient, but close observations are needed
- restrict visiting by anyone with symptoms of upper respiratory tract infection.

# SECTION 31 Structured approach to emergencies in the neonate or infant

**Introduction to the Structured Approach**
Both within the hospital setting and in the emergency room and even in the home setting, patients of all ages including neonates and infants may present as an emergency. We will not know what is wrong with them (the diagnosis) but in waiting to find that out by tests, a seriously ill patient may die in the meantime.

The structured approach to emergencies is aimed at supporting critical body functions until a clear diagnosis and treatment plan can be achieved. This section describes the structured approach to assessment and the simple early interventions that can stop the infant becoming more ill. The section does include some mention of the interventions used after assessment to stabilise the infant, but these are expanded more fully in the relevant chapters.

Infants and children more commonly become seriously ill with respiratory or circulatory problems mainly caused by infections. In contrast, adults suffer more frequently from heart diseases which, while benefitting from a structured approach, has a different emphasis.

***Primary assessment and resuscitation***

The initial actions are:

- Assessment and Management of the Airway
- Assessment and Management of Breathing
- Assessment and Management of the Circulation

This is conveniently remembered as an “ABC approach” and is all about maintaining an oxygenated blood supply to vital organs including the heart itself, the brain, kidneys etc.

The order of intervention is Airway first, then Breathing, then Circulation. The reason for this order is because oxygen cannot be carried around in the blood to the vital organs if the blood is not oxygenated first, and the lungs cannot oxygenate the blood if there is no airway to allow air containing oxygen to enter the lungs.

If you are alone with the patient, you must start with Airway, then move to Breathing and then to Circulation. If there is a team available, ABC can be assessed and managed together but importantly, there should be a team leader in that event to avoid confusion.

Following cardiac arrest, outcome is poor especially in babies and children. Early recognition and management of potential respiratory, circulatory, or central neurological failure which may progress rapidly to cardiac and/or respiratory arrest will reduce mortality and secondary morbidity. The following section outlines the physical signs that should be used for the rapid primary assessment and emergency treatment of neonates.

Central neurological failure (D for disability) is the fourth stage of the primary assessment and relates to pathologies that have caused the patient to lose consciousness resulting in significant effects on vital organs. (More detail later in this section)

During resuscitation, interventions that are either lifesaving or designed to prevent the patient reaching a near-death situation are performed. These include such procedures as basic airway opening procedures, suction, oropharyngeal airway insertion, intubation, assisted ventilation, venous cannulation, and fluid resuscitation (when safe and appropriate). At the same time, oxygen is provided to all patients with life-threatening Airway, Breathing or Circulatory problems. Vital signs are recorded, and

essential monitoring is established. However, additional inspired oxygen is not needed during the immediate assisted ventilation which is part of neonatal resuscitation at birth as high levels of oxygen can be harmful to prematurely born neonates.

***Secondary assessment and emergency treatment***

The structured approach outlined in this section allows the health worker to focus on the appropriate level of diagnosis and treatment during the first hours of care. *Primary assessment and resuscitation* are concerned with the maintenance of vital functions and the administration of life-saving treatments, whereas *secondary assessment and emergency treatment* follow, allowing more specific yet still urgent therapies to be started. Secondary assessment and emergency care require a system-by-system approach to minimise the risk of significant conditions being missed.

This sequential primary assessment and any necessary resuscitation occur before any illness-specific diagnostic assessment or treatment takes place. Once the patient's vital functions are working safely, *secondary assessment and emergency treatment* can begin.

After each intervention, its effects should be tested by reassessment. Regular reassessments are a key component of the structured approach.

**Structured approach to any infant presenting as an emergency**

***Training***

Members of the clinical team must know their roles. They will ideally have trained together in:

- clinical situations and their diagnoses and treatments
- drugs and their use, administration, and side effects
- emergency equipment and how it functions.

The ability of a facility to deal with emergencies should be assessed and reinforced by the frequent practice of emergency drills involving the structured approach.

***Initial management***

1. Stay calm.
2. Do not leave the neonate unattended.
3. Have a team leader in charge to avoid confusion.
4. Shout for help. Ask one person to go for help and another to get emergency equipment and supplies (e.g. oxygen and emergency kit). Ideally resuscitation equipment and drugs should be available on one dedicated trolley.
5. Assess and resuscitate in sequence using the structured approach – Airway, Breathing, Circulation, Disability (Neurological Status) (see below).
6. Constantly reassess the patient, particularly after any intervention.

**Primary assessment and resuscitation**

**Assessment and resuscitation occur at the same time.**

The order of assessment and resuscitation enables identification of immediately life-threatening problems, which are treated as they are found. A rapid examination of vital ABC functions is required.

***Primary assessment and resuscitation of the Airway***

The priority is establishment or maintenance of airway opening. If there is a need for resuscitation in a patient who is bleeding (e.g., in cases of trauma or blood clotting disorders), try to stop this at the same time as you are opening the airway.

In assessing the airway, we are, in fact assessing both the airway and the breathing. The way that we can tell if an airway is open is to see the patient breathing. If the patient is breathing, the airway must be open, although it may not be properly open and so we will always put the airway for which we have concerns into the optimum position for the patient's age (see below for correct position for the airway in a neonate/infant).

PRIMARY ASSESSMENT
LOOK – for chest or abdominal movement.
LISTEN – for breath sounds.
FEEL – for breath.
An Infant who is able to cry has a clear airway.

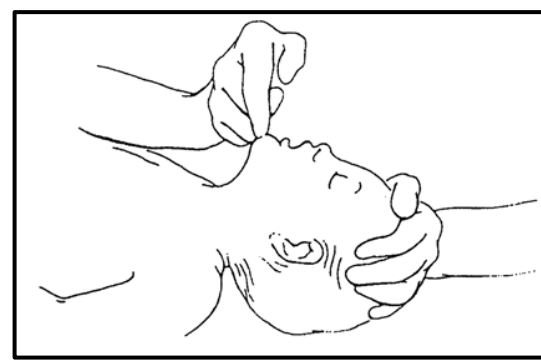
*Looking* for breathing involves watching the chest and the abdomen to see if either or both are moving. The chest moves outward when breathing in. The abdomen often moves inward when the baby breathes in.
*Listening* for breathing involves auscultating with a stethoscope or just listening with your ear near the infant's mouth/nose
*Feeling* for expired air at the mouth or nose

Sometimes the infant may be breathing but making noises as they do so. This usually means that the airway, while open, is not fully open or it is partially obstructed,

Signs associated with airway obstruction may include any of the following:
- an absence of breathing
- stridor, snoring, or gurgling in the throat
- cyanosis
- chest wall recession
- reduced consciousness, or coma.

**Resuscitation of the Airway**
If there is no chest movement or there is some chest movement but with breathing marked by difficulty, open the airway by putting the head and neck into the neutral position as shown in the figure below.

***Figure 31.1.*** *There is more detail on this manoeuvre in section 32 on Basic Life Support*



- This is a head tilt and chin lift manoeuvre, (the alternative jaw thrust manoeuvre is shown in Section 32 on basic life support). If the manoeuvre opens the airway and breathing starts, keep the airway open manually until it can be secured or the infant recovers.

- Sometimes (although rarely), there may be blood, vomit, meconium or a foreign body contributing to the obstruction, Remove any liquid with gentle suction under clear vision and a foreign body by direct vision also

Give oxygen to all patients (apart from when resuscitation at birth is required- see Section 1)

If there is no improvement after adjusting the airway manually and trying different techniques, place an oropharyngeal airway, which may be helpful if the patient is unconscious and has no gag reflex. (See Section 33)

If the airway is still obstructed, a definitive airway by intubation or surgical airway may be needed. Call urgently for a nurse anaesthetist.

Reassess the airway after any airway-opening manoeuvres. If there continues to be no evidence of air movement, then airway opening can be assessed by performing an airway-opening manoeuvre while giving rescue breaths.

**Primary assessment and resuscitation of Breathing**

An open airway does not guarantee adequate ventilation. The latter requires an intact respiratory centre and adequate pulmonary function augmented by coordinated movement of the diaphragm and chest wall.

*Primary assessment*

Assess whether breathing is adequate by:

*assessing effort*:

- recession
- rate
- added noises
- accessory muscles
- nasal alar flaring

*assessing efficacy:*

- listening for reduced or absent breath sounds, or any wheezing, with a stethoscope or ear on chest wall
- chest and/or abdominal expansion (symmetrical or asymmetrical)
- abdominal excursion

*assessing effects*

- oxygen saturation ($SpO_2$) if available
- heart rate rising
- skin or mucous membrane colour becoming pinker
- consciousness improving

*Evidence of life-threatening respiratory difficulty Includes the following:*

- absence of breathing (apnoea)
- very high or very low respiratory rates, Normal rates in a neonate are between 30-60 breaths per minute at rest.
- gasping, which is a sign of severe hypoxaemia, and may indicate impending respiratory arrest and death
- severe chest wall recession, usually with increased respiratory rate, but pre-terminally (just before death) with a fall in respiratory rate
- severe hypoxaemia (cyanosis or oxygen saturation below 94%)
- signs of tension pneumothorax (respiratory distress with hyper-resonant percussion)

- major trauma to the chest (e.g. tension pneumothorax, haemothorax, flail chest) (see Paediatric Handbook 1)

*Evidence of respiratory difficulty which can worsen if not treated*

This includes the following:

- increased respiratory rate >60 breaths per minute
- inspiratory stridor a harsh noise on breathing in
- reduced or absent breath sounds on auscultation
- expiratory wheezing a high-pitched noise on breathing out
- chest expansion (most important), and reduced abdominal excursion
- pulse oximetry showing oxygen saturation ($SpO_2$) of less than 94% (normal SpO2 in a neonate at sea level is 94–100% in air). Aim to keep the oxygen saturations in the normal range (preterm babies at or below 32 weeks' gestation 92 to 94%. Babies at above 32 weeks' gestation and at term keep at 94% - 98%). If required, titrate supplemental oxygen against other vital signs. When providing additional inspired oxygen, you must avoid hyperoxia ($SpO_2$ >98%) in the preterm infant.

Note: Fast breathing can be caused by either an airway problem, lung disease or metabolic acidosis.

Care should be taken when interpreting single measurements. Infants can show rates of between 30 and 90 breaths/minute depending on their state of activity. It is more useful to use trends in measurements as an indicator of improvement or deterioration.

***Other signs of breathing difficulty***

*Chest wall recession*

- Intercostal, subcostal or sternal recession reflects increased effort of breathing, which is seen inparticular in infants, who have more compliant (floppy) chest walls.
- The degree of recession indicates the severity of respiratory difficulty.
- In the patient with exhaustion, chest movement and recession will decrease. This is a sign of imminent collapse.

*Inspiratory or expiratory noises*

- Stridor, usually inspiratory, indicates laryngeal or tracheal obstruction.
- Wheeze, predominantly expiratory, indicates lower airway obstruction.
- Volume of noise is not an indicator of severity.

*Grunting*

- This is observed in infants with stiff lungs to prevent airway collapse (it is the noise made by closure of the larynx during expiration).
- It is a sign of severe respiratory distress.

*Accessory muscle use*

- In infants, the use of the sternocleidomastoid muscle creates 'head bobbing' and does not help ventilation.
- Flaring of the alae nasi is also seen in infants with respiratory distress.

*Exceptions*

**Increased effort of breathing does not occur in 3 circumstances:**

1. exhaustion
2. central respiratory depression (e.g., from raised intracranial pressure, poisoning or encephalopathy)
3. neuromuscular disease.

***Effects of breathing failure on other physiology***

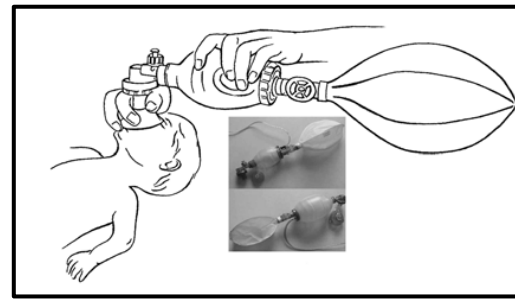
**Heart rate** is increased with hypoxia, but decreases when hypoxia is severe, when bradycardia is a sign of the that cardiorespiratory arrest is about to occur.

**Skin and/or mucous membrane colour:** hypoxia first causes vasoconstriction and pallor. Cyanosis is a late sign and may indicate impending cardiorespiratory arrest. In an anaemic patient it may never be seen, however hypoxic the patient is.

**Mental status:** hypoxia causes drowsiness followed by loss of consciousness.

***Resuscitation of breathing***

In the patient with absent or inadequate breathing, it is essential to breathe for the patient using:



Bag-valve-mask ventilation: if using oxygen, add a reservoir to increase the oxygen concentration.

Intubation (if skilled professionals are available) and provide assisted ventilation through the tube if long-term ventilation is needed or bag–mask ventilation is ineffective.

Give high-flow oxygen to all patients with respiratory difficulty but avoid hyperoxaemia ($SpO_2$ > 98%) in preterm neonates.

Give as much oxygen as possible through a mask with a reservoir bag to any patient who is breathing but has respiratory difficulty or the other signs of hypoxia (e.g. cyanosis).

**Situations in which additional emergency breathing treatment is given**

1 Perform needle thoracentesis if the diagnosis is tension pneumothorax (see Section 38). This should be followed by a chest drain.
2 Give immediate nasal continuous positive airway pressure (CPAP) if a neonate has severe respiratory distress (see Section 39).

***Primary assessment and resuscitation of the Circulation***

***Primary assessment***

The circulatory system is more difficult to assess than airway and breathing in the neonate, and individual measurements must not be over-interpreted.

If there is no palpable pulse, a very slow heart rate < 60 beats/minute in a neonate or no 'signs of life' (e.g., movements, coughing, normal breathing), cardiac arrest or near-cardiac arrest is likely, and basic life support must be started (see Section 32).

Agonal gasps (irregular, infrequent breaths) do not provide adequate oxygenation and are not for these purposes a 'sign of life'.

In addition to cardiac arrest or near-arrest, shock and heart failure are additional life-threatening issues that it is important to identify.

**Shock**

The following clinical signs can help to identify shock (inadequate circulation) (see Section 28).

*Heart rate*

The normal heart rate in babies in the first month of life is between 120 and 160 beats per minute It is easier to count with a stethoscope than by palpation

- Heart rate increases in shock and heart failure.

Bradycardia (less than 100 beats/minute) due to hypoxaemia may be a sign of near cardiorespiratory arrest in the neonate.
The WHO definition of tachycardia in infants is a heart rate of > 160 beats/min

*Pulse volume*

Absent peripheral pulses or reduced strength of central pulses can signify shock.

*Capillary refill time (CRT)*

- Pressure on the centre of the sternum or on the fingernail for 5 seconds should be followed by return of the circulation to the skin within 3 seconds or less. CRT may be prolonged by shock, cold environment, or the vasoconstriction that occurs as a fever develops.
- Prolonged CRT is not a specific or sensitive sign of shock and should not be used alone as a guide to the need for or the response to treatment.

*Blood pressure*

- Measuring blood pressure in the neonate is very difficult and in an emergency is rarely helpful. If measured only the systolic pressure is useful.
- The cuff should cover at least 80% of the length of the upper arm, and the bladder should be more than two- thirds of the arm's circumference.

Systolic blood pressure in infancy

| Age (years) | Systolic blood pressure (mmHg) 50th centile |
|---|---|
| < 1 | 80–90 |

*Effects of circulatory failure on other organs*

*Respiratory system*: tachypnoea and hyperventilation occur as a result of the acidosis caused by poor tissue perfusion.

*Skin*: pale or mottled skin indicates poor perfusion.

*Mental status*: circulatory failure causes initial agitation, then drowsiness, followed by unconsciousness.

*Urine output*: a reduction in urine output to < 2 mL/kg/ hour in infants indicates inadequate kidney function.

*WHO definition of shock is cold hands, plus CRT of > 3 seconds, plus a weak and rapid pulse.*

Life-threatening shock is usually associated with:

- severe tachycardia
- a weak-volume pulse (ideally assess centrally: brachial, femoral or carotid arteries)
- low blood pressure (this is a late sign, and difficult to measure in infants)
- extreme central pallor (if due to severe anaemia)
- raised respiratory rate (due to acidosis)
- poor skin circulation, with a CRT of > 3 seconds
- reduced conscious level.

Always give high flow oxygen.

In most cases of shock, if visually obvious bleeding is the cause, then the priority must be to stop this.

If the loss of fluid causing shock is due to severe gastroenteritis (unusual in the

neonate), there will usually be evidence of severe dehydration and a history of profound or long-standing diarrhoea. Give 10 mL/kg of Ringer-Lactate/Hartmanns or 0.9% saline as an initial IV or IO bolus as rapidly as possible, reassess, and then repeat if necessary. Additional potassium may be required if this is safe to administer (see Section 3). Usually it may be safer to give potassium as part of NG or oral ORS.

- Adequate perfusion of vital organs in neonates may best be indicated by a decrease in tachycardia and improved level of consciousness.
- If shock is due to septicaemia with purpura (meningococcus infection), give IV or IO boluses of Ringer-lactate/ Hartmann's or 0.9% saline as fast as possible, 10-20 mL/ kg in the infant, and then reassess. Also give antibiotics IV. Usually at least 40 mL/kg in infants will be required to overcome shock (see Section 28). In this situation, inotropes may be valuable if they are available and safe to use (see Section 28).
- If shock is due to anaphylaxis, give adrenaline, 10 micrograms/kg (0.1 mL/kg of 1 in 10 000) IM in addition to IV or IO fluid. Anaphylaxis is rare in infants

***Heart failure***

This life-threatening situation can be seen in severe anaemia, after fluid overload and in the presence of structural heart disease. It is important to distinguish heart failure from shock, as the resuscitation required is different. Some of the following signs will be present in infants with heart failure:

- tachycardia out of proportion to respiratory difficulty
- severe palmar/mucous membrane pallor (if anaemia is the cause)
- some heart murmurs (if structural heart defect is responsible)
- an enlarged, sometimes tender, liver
- crepitations on listening to the lung bases
- cyanosis that does not respond to oxygen in the case of infants with cyanotic congenital heart disease.

**Resuscitation of infants with heart failure**

1. Tilt the patient head-up.
2. Give oxygen.
3. Give furosemide 1–2 mg/kg by IV/IO injection.

If the patient has severe anaemia, give careful blood transfusion or preferably partial exchange transfusion. Successively remove 10-mL aliquots of the patient's blood and replace each 10 mL with 20 mL of packed donor red blood cells until shock has resolved.

*Other situations in the neonate where emergency treatment is given for heart failure with shock.*

1. Supraventricular tachycardia can cause both shock and heart failure. The heart rate in infants with this problem can reach > 220 beats/ minute. If available, ECG will confirm cardiac arrhythmia. Treat by vagal manoeuvres or adenosine if rapid IV access is available (see Handbook 1). If this fails, attempt defibrillation if the correct sized equipment is available
2. In ventricular tachycardia, defibrillation is needed if shock is present (see Handbooks 1and 2).
3. If congenital or rheumatic heart disease or cardiomyopathy is the cause of heart failure, inotropes may be appropriate, but specialist advice will be needed.
4. If cyanotic congenital heart disease in the newborn is the cause of shock, specialist paediatric cardiology advice will be necessary (see Section 26).

***Primary assessment and resuscitation of neurological failure (disability)***

Always assess and treat Airway, Breathing and Circulation problems before undertaking neurological assessment.

***Primary assessment***

***Conscious level: AVPU***

Alert is the normal state for an awake infant. If the infant does not respond to gentle shaking to wake them up, it is important that assessment of the response to Pain is undertaken next. A painful central stimulus can be delivered by supra-orbital ridge pressure or by gently pulling frontal hair. An infant who is Unresponsive or who only responds to pain has a significant degree of coma which can seriously interfere with vital Airway and Breathing functions.

***Seizures/fits/convulsion (see Section 21)***

Generalised convulsions, also known as 'fits' or 'seizures', can seriously interfere with vital Airway and Breathing functions, both during the fit itself and immediately afterwards, when lowered levels of consciousness may be present.

***Posture***

Many infants who have a serious illness in any system are hypotonic. Stiff posturing, such as that shown by decorticate (flexed arms, extended legs) or decerebrate (extended arms, extended legs) posturing, is a sign of serious brain dysfunction. These postures can be mistaken for the tonic phase of a convulsion. Alternatively, a painful stimulus may be necessary to elicit these postures.

Severe extension of the neck due to upper airway obstruction can mimic the opisthotonos that occurs with meningeal irritation. In infants, a stiff neck and full fontanel are signs that suggest meningitis but are not always present.

Neonatal tetanus (see section 23) produces a characteristic increase in muscle tone with spasms when stimulated.

***Pupils***

Many drugs and cerebral lesions have effects on pupil size and reactions. However, the most important pupillary signs to seek are dilatation, lack of reactivity to light and inequality, which suggest possible serious brain disorders.

Hypoglycaemia

Infants are prone to hypoglycaemia for various reasons in the immediate days after birth. Always check blood glucose levels or suspect hypoglycaemia in any unwell infant, especially if they have impaired consciousness. Hypoglycaemia with a blood glucose level of less than 2.5 mmol/L (45 mg/dL) can cause impaired consciousness, coma or fits.

***Respiratory effects of central neurological failure***

The presence of any abnormal respiratory pattern in a patient with coma suggests mid- or hindbrain dysfunction.

***Circulatory effects of central neurological failure***

Systemic hypertension with sinus bradycardia (Cushing's response) indicates compression of the medulla oblongata caused by herniation of the cerebellar tonsils through the foramen magnum. This is a late and pre-terminal sign.

*Raised intracranial pressure (ICP)* may cause:

- hyperventilation
- slow sighing respirations
- apnoea
- hypertension
- bradycardia.

***Resuscitation for neurological problems***

1. If the patient is unconscious (P or U on the AVPU scale) but their airway and breathing are adequate, place them in the recovery position, so that if they vomit there is less likelihood of aspiration because, when unconscious, the gag reflex may not be operative.
2. If the patient is unconscious or fitting, always give oxygen.
3. If hypoglycaemia is a cause of reduced consciousness (or a suspected cause, but immediate blood glucose measurements are not possible), treatment with glucose is urgently required. Give 2.5 mL/kg of 10% glucose IV or IO in the infant and repeat if required. Recheck the blood glucose level after 20 minutes, and if the level is low (< 2.5 mmol/litre or < 45 mg/ dL), repeat the IV/IO glucose (2.5 mL/kg).
4. If convulsions occur in an infant and continue in your presence for more than 5 minutes and there is no hypoglycaemia, give IV or rectal anticonvulsants.

   **Always make sure that a bag and mask are available** in case the patient stops breathing, which is possible and a frequent complication. The safest anticonvulsant in the neonate with this problem is IV phenobarbital. Loading dose 20mg/kg slowly IV, then 2.5-5mg/kg 1-2 times daily.

   Commonly used other anticonvulsants in this situation are diazepam or, if there is no IV access, rectal diazepam, rectal paraldehyde, or buccal midazolam (see Section 21).

   a. IV or IO diazepam: 300-400 micrograms/kg IV over 5 minutes and repeat after 10mins if required
   b. rectal diazepam: 1.25-2.5mg
   c. rectal paraldehyde: 0.4 mL/kg
   d. buccal midazolam: 300 micrograms/kg.
5. If seizures are due to neonatal tetanus, magnesium sulphate is much safer and more effective than phenobarbital or a benzodiazepine (see Section 23).
6. In any case where meningitis or encephalitis is suspected, it is vital that suitable antibiotics and/or antiviral drugs are started IV or IO as soon as the condition is suspected. Antibiotic choices might include Ceftriaxone, Benzyl Penicillin, Amoxicillin and Gentamicin in the newborn. Consider adjunctive treatment with dexamethasone 150 micrograms/kg every 6 hours for 4 days

***Secondary assessment and emergency treatments***

The secondary assessment takes place once vital functions have been assessed and the initial resuscitation of those vital functions has been started.

Secondary assessment includes a focused medical history, a focused clinical examination, and specific investigations. It differs from a standard medical history and examination in that it is designed to establish which emergency treatments might benefit the patient.

At the end of secondary assessment, the practitioner should have a better understanding of the illness or injury likely to be affecting the patient and may have formulated a differential diagnosis. Emergency treatments will be appropriate at this stage – to treat either specific disorders e.g., meningitis or conditions (e.g., respiratory failure). Emergency treatments will be undertaken at this stage in addition to those given as part of resuscitation/life-saving treatments, to manage specific components of serious illnesses or injuries (e.g., IV antibiotics for neonatal sepsis). The establishment of a definite diagnosis is part of definitive care and usually requires various investigations.

The history often provides the vital clues. In the case of infants, the history is often obtained from an accompanying parent. Do not forget to ask any health worker who has already seen the patient about the initial condition and about treatments and the response to treatments that have already been given.

Some patients will present with an acute exacerbation/complication of a known condition, such as epilepsy. Such information is helpful in focusing attention on the appropriate system, but the practitioner should be wary of dismissing new pathologies in such patients. The structured approach avoids this problem. Unlike trauma, illness affects systems rather than anatomical areas. The secondary assessment must reflect this, and the history of the complaint should be sought with special attention to the presenting system or systems involved. After the presenting system has been dealt with, all of the other systems should be assessed, and any additional emergency treatments commenced as appropriate.

The secondary assessment is not intended to complete the diagnostic process, but rather it aims to identify any problems that require emergency treatment.

The symptoms, signs, and treatments relevant to each emergency condition in the neonate are elaborated further in the relevant sections of this handbook.

## Section 32 Basic Life Support for the newborn infant

### Introduction

Basic life support (BLS) is a technique that can be employed by one or more rescuers to support the respiratory and circulatory functions of a collapsed patient using no or minimum equipment.

Basic Life Support for the neonate is somewhat different from Resuscitation at Birth (see section 1). Basic Life Support is to be used when a baby who has been breathing has a cardiorespiratory arrest.

The international guidelines for resuscitation from cardiac arrest (European Resuscitation Council, 2010) detail two approaches to basic life support. The two approaches are “adult “and “child”. The difference arises from the fact that most sudden cardiac arrests in adults are primarily cardiac in nature with respiration having carried on at least to a degree before the heart stops.

In children (including babies) on the other hand, cardiac arrest is more often the result of a primary respiratory or circulatory pathology with the cessation of cardiac activity occurring subsequent to respiratory or circulatory arrest.

The sequence of actions in the ‘child’ programme is predicated on a hypoxic event (including any respiratory failure or obstruction, or hypoxia at a cellular level as seen in shock). In this type, re-establishing oxygenation is of prime importance, and moving the oxygenated blood to the coronary and cerebral arteries is the second step. Therefore, the rescuer’s sequence of actions after assessment starts with rescue breaths and then moves on to chest compressions. The ‘child’-type cardiac arrest is seen in almost all infants (excluding those rare arrhythmic events in infants with congenital or acquired heart disease and those in whom sudden, unexpected collapse is preceded by apparent normal respiratory and circulatory function). This includes patients who have had convulsions, trauma (including drowning), poisoning, bleeding, sepsis, etc.

NOTE:
The International Resuscitation Guidelines recommend the same ratio of compressions to breaths during CPR for all children regardless of size (except for Resuscitation at Birth, section 1, which is 3 compressions to one breath).
The reason for this is that the generally available BLS guidelines are to some extent mainly designed to be taught to the lay public (although professional clinicians use them too) and are made simple and easy to remember for the following purpose.
Many sudden and unexpected deaths in adults (the most likely group to die) occur outside any hospital. Well performed BLS applied very quickly in the moments after collapse has a better chance of helping the patient to survive than a complex series of different types of resuscitation methodologies which would cause confusion and thus poor competence in the inexperienced provider.
The adult ratio of compressions to ventilations is 30 to 2 and the child ratio is 15 to 2 in the International Guidelines.
The problem is that in the age group called “child” there is a very large range of physical size from the premature newborn to a well grown 17-year-old. Despite this range, all children are more likely than adults to have causes of unexpected collapse related more closely to primary respiratory or circulatory pathologies than to cardiac ones as children do not suffer from coronary arterial disease.
This means that the emphasis in “child” resuscitation (and, indeed, young adult resuscitation) should be on respiratory support with a higher number of ventilatory interventions.

**Definitions**
A newborn is a child just after birth
A neonate is a child in the first 28 days of life
An infant is a child under one year old
A child is from one year old to puberty or 16 years

All "child" resuscitations start with 5 Rescue Breaths to reflect the importance of breathing in resuscitating children. The subsequent sequences of compression to ventilations ratios can therefore be related to the child's size and the clinical setting.

*For example:*
The sequence taught in the neonate therefore includes five preliminary rescue breaths and the subsequent ratio of compressions to ventilations is 3:1.
In the infant up to one year, after the five rescue breaths the ratio of compressions to breaths of 5:1 was used widely for many years and seems a good compromise between the generalized guidelines for all ages and the response of a trained health worker to the need of an individual patient.
Over the age of one year, the 15:2 ratio is more appropriate.
As this handbook gives guidance on the care of the newborn, the neonate and the small infant, only the 3;1 and the 5:1 ratios are likely to be needed.
It is important to point out that the majority of good evidence from research as to the efficacy of the various recommendations for resuscitation has been done only on adults. The guidance for children has largely been based on animal experiments and on a desire to simplify the whole body of guidance as described above to facilitate urgency of response.

## The Guidelines for Basic Life Support

### *'Are you all right?'*
An initial simple assessment of responsiveness consists of gently shaking the neonate by the shoulder resulting in some vocalisation or opening their eyes.

### *Airway-opening actions*

An obstructed airway may be the primary problem, and correction of the obstruction can result in recovery without the need for further intervention. If the patient is unconscious but breathing, the recovery position should be used.

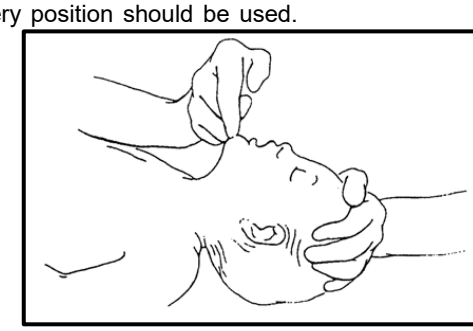


***FIGURE** 32.1 Head tilt with chin lift in neutral position for the neonate and older infant.*

If the patient is not breathing, this may be because the airway is blocked by the tongue falling back and obstructing the pharynx. Attempt to open the airway using the head tilt/chin lift manoeuvre. The rescuer places their nearest hand on the patient's forehead and applies pressure to tilt the head back gently. The correct position is 'neutral' in the infant (0–1 year of age) (see Figure 32.1).

The fingers of the other hand should then be placed under the chin, and the chin of the supine patient should be lifted upwards. As this action may close the patient's mouth, it may be necessary to use the thumb of the same hand to part the lips slightly.

As an alternative to the head tilt/chin lift, the jaw thrust manoeuvre can be very effective, but requires more training and experience.

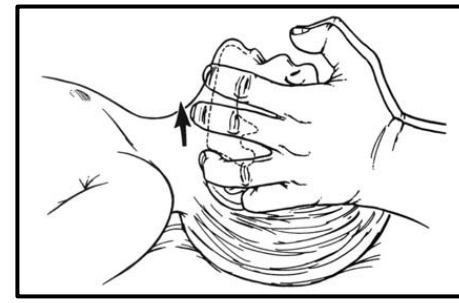


***FIGURE 32.2*** *Jaw thrust to open airway.*

Jaw thrust is achieved by placing two or three fingers under the angle of the mandible bilaterally and lifting the jaw upward (see Figure 32.2).

The openness of the airway should then be assessed by:

- looking for adequate chest movements
- listening for breath sounds
- feeling for breaths.

This is best achieved by the rescuer placing their face above that of the patient, with the ear over the nose, the cheek over the mouth, and the eyes looking along the line of the chest. They should take no longer than 10 seconds to assess breathing.

If there is any object obvious in the mouth and it is easy to reach, remove it.
Do not perform a blind finger sweep in the mouth. A blind finger sweep can damage the soft palate, and foreign bodies may be forced further down the airway and become lodged below the vocal cords.

*Figure 32.3 Mouth to mouth and nose breathing support*

***Breathing actions***

If airway-opening techniques do not result in the resumption of adequate breathing within 10 seconds, and a self-inflating bag–mask system is not available, then the rescuer should commence mouth-to-mouth-and-nose exhaled air resuscitation.

*Definition of adequate breathing*

A patient may have very slow or shallow breathing, or take infrequent, noisy, agonal gasps. Do not confuse this with normal breathing.

*Rescue breaths*

If in doubt about the adequacy of breathing, five initial rescue breaths should be given. While the airway is held open, the rescuer uses a bag and mask of appropriate size for the neonate. The rescuer must ensure that the mask creates a leak proof seal on the baby's face.

In the absence of a bag and mask, the rescuer should undertake mouth to mouth and nose ventilations (Figure 32.3). While the airway is kept open the rescuer takes a breath and seals his mouth around the patient's mouth and nose or mouth only. Slow and gentle exhalation by the rescuer should make the patient's chest rise just visibly. Too vigorous a breath will cause gastric distension and may cause stomach contents to rise and block the airway. The

rescuer should take a breath himself between rescue breaths to maximise oxygenation of the patient.

**Change to a bag and mask as soon as one is available**

If the chest does not rise with each breath given, the airway is not clear. The usual cause is failure to correctly apply the airway-opening techniques discussed earlier. The first step is to readjust the head tilt/chin lift position and try again. If this is not successful, jaw thrust should be tried. If two rescuers are present, one should maintain the airway while the other compresses the bag and breathes for the patient. Correct placement of the mask and procedures such as jaw thrust require training, but compression of the bag can usually be undertaken by an untrained person such as a relative, porter or volunteer.

Failure of both head tilt/chin lift and jaw thrust should lead to suspicion that a foreign body is causing the obstruction (see below).

While performing rescue breaths, the presence of a gag reflex or coughing is a positive sign of life (see below).

### *Circulation actions*

Once the initial five breaths have been given successfully, circulation should be assessed and managed.

Check signs of life and/or pulse (take no more than 10 seconds).

Even experienced health professionals can find it difficult to be certain that the pulse is absent within 10 seconds, so the absence of 'signs of life' is the best indication for starting chest compressions, especially in an infant. 'Signs of life' include movement, coughing, gagging or normal breathing (but not agonal gasps, which are irregular, infrequent breaths). Thus, the absence of evidence of normal breathing, coughing or gagging (which may be noticed during rescue breaths) or absence of any spontaneous movement is an indication for chest compressions.

Inadequacy of circulation is also indicated by the absence of a central pulse for up to 10 seconds, but it can be difficult and therefore time wasting to be certain about this – hence the current emphasis on assessing the presence of 'signs of life'.

In infants, if a slow pulse (less than 60 beats/minute) is felt or better heard by stethoscope, this is also an indication for chest compressions. Infants have a short fat neck, so the carotid pulse may be difficult to identify. The brachial artery in the medial aspect of the ante-cubital fossa or the femoral artery in the groin can more easily be felt in infants but always the best and most reliable sign of need for chest compressions in the neonate is listening to the heart beat using a stethoscope and noting whether the heart rate is above or below 60 beats/minute. If there is a bradycardia below 60/minute accompanied by signs of poor perfusion, which include pallor, lack of responsiveness and poor muscle tone, and/or there are no signs of life, start chest compressions.

Start chest compressions if:

- there are no signs of life ***or***
- there is no pulse ***or***
- there is a slow pulse or heart rate (less than 60 beats/minute in an unconscious infant with poor perfusion).

"Unnecessary" chest compressions are almost never damaging. It is important not to waste vital seconds before starting chest compressions after oxygenating the patient with the rescue breaths. If there are signs of life and the pulse is present (and has an adequate

rate, with good perfusion), but apnoea persists, ventilation breaths must be continued until spontaneous breathing resumes.
Please note that too rapid ventilation breaths may, by removing too much carbon dioxide, inhibit respiratory drive.

### *Chest compressions*

For the best output, the neonate must be placed on his/her back, on a hard surface. The chest should be compressed by a third of its depth.

*Position for chest compressions*

Chest compressions should compress the lower half of the sternum.

In neonates, chest compressions can be most effectively achieved using the hand-encircling technique: the neonate is held with both the rescuer's hands encircling or partially encircling the chest. The thumbs are placed over the lower half of the sternum and compression is carried out as shown in Figure 32.4.

This method is only possible when there are two rescuers, as the time needed to reposition the airway precludes the use of the technique by a single rescuer if the recommended rates of compression and ventilation are to be achieved.

The single rescuer should use the two-finger method as shown in Figure 32.5, employing the other hand to maintain the airway position.

Once the correct technique has been chosen and the area for compression identified, three compressions should be given to each ventilation breath.

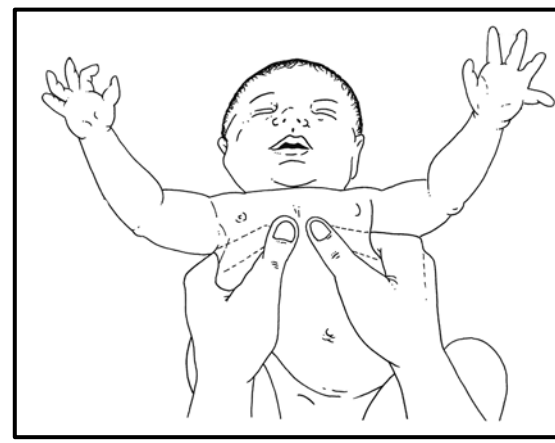


**FIGURE 32.4** Two-thumb method for chest compressions in an infant (two rescuers).

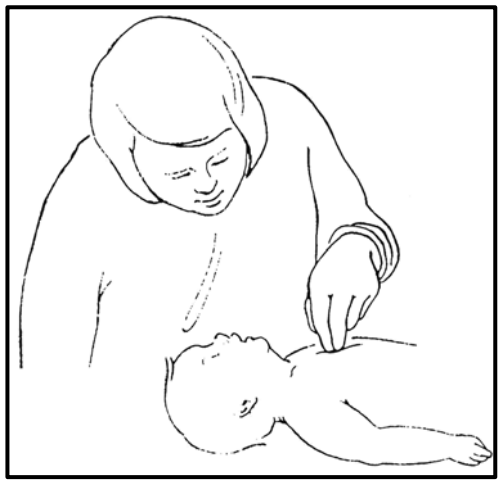


**FIGURE 32.5** *Two-finger method for chest compressions in an infant (one rescuer).*

***Continuing cardiopulmonary resuscitation***

The compression rate is 100–120 compressions per minute. A ratio of 3 compressions to 1 ventilation breath is maintained irrespective of the number of rescuers. With pauses for ventilation there will be less than 100–120 compressions per minute, although the rate is 100–120 per minute. Compressions can be recommenced at the end of inspiration and may augment exhalation.

In the case of an infant over 28 days, a ratio of 5:1 compressions to ventilations is used

Basic life support must not be interrupted unless the patient moves or takes a breath.

Continually check that the compressions and ventilations are satisfactory and, if possible, alternate the rescuers involved in this task. Any time spent readjusting the airway or re-establishing the correct position for compressions will seriously decrease the number of cycles given per minute. This can be a real problem for the solo rescuer, and there is no easy solution. In neonates the free hand can maintain the head in the neutral position. The correct position for compressions does not need to be measured after each set of ventilations.

**TABLE 32.1** Summary of basic life support techniques in neonates and infants

| | Newborn Infants |
|---|---|
| **Airway** | |
| Head-tilt position | Neutral |
| **Breathing** | |
| Initial slow inflation breaths | Five |
| **Circulation** | |
| Heart rate check with stethoscope | Is it above or below 60/minute |
| Pulse check | Brachial or femoral or 'signs of life' |
| Landmark for compressions | Lower half of sternum |
| Technique | Two fingers or two thumbs |
| CPR ratio | 3:1 or 5:1 |

If recovery occurs and signs of life return, place the patient in the recovery position and continue to reassess them and ensure that specialist help arrives.

Chest-compression-only CPR.
If a bag and mask is not available, and you are either unable or unwilling to give rescue breaths, give chest compressions only. This is particularly relevant in countries where there is a high prevalence of HIV, hepatitis or TB (see below).

If chest compressions only are given, these should be continuous at a rate of 100 compressions per minute.

Stop to recheck the patient only if they start to breathe normally; otherwise, do not interrupt resuscitation.

***Continue resuscitation until:***

- qualified help arrives and takes over or
- the patient starts breathing normally or
- you become exhausted.

***Basic life support using mouth to mouth and nose ventilations and infection risk***

Only a small number of cases have been reported. The most serious concerns are meningococcus and TB. In the case of meningococcus, rescuers involved in the resuscitation of the airway in such patients should take standard prophylactic antibiotics.

There have been no reported cases of transmission of either Hepatitis B or HIV infection through mouth-to-mouth ventilation. Blood-to-blood contact is the single most important route of transmission of these viruses, and in non-trauma resuscitation the risks are negligible. Sputum, saliva, sweat, tears, urine and vomit are low-risk fluids.

Precautions should be taken, if possible, in cases where there might be contact with blood or amniotic fluid. Devices that prevent direct contact between the rescuer and the patient (such as resuscitation masks) can be used to lower the risk. Gauze swabs or any other porous material placed over the patient's mouth is of no benefit in this regard.
Infection rates vary from country to country, and rescuers must be aware of the local risk. In countries where HIV/ AIDS is more prevalent, the risk to the rescuer will be greater.

**Bag-valve-mask ventilation is always preferable to mouth-to-mouth ventilation and it is vital that in all areas where neonates are cared for working bag and mask systems are always available.**

**The recovery position**

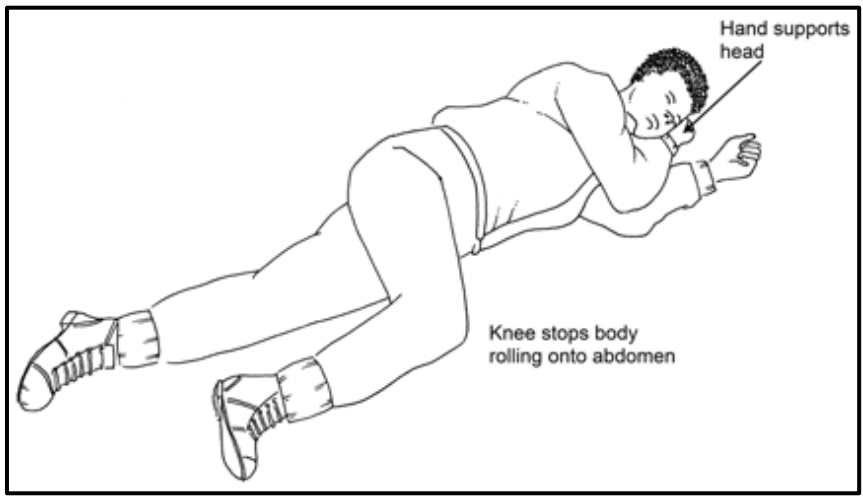
The patient should be placed in a stable, lateral position that ensures maintenance of an open airway with free drainage of fluid from the mouth, ability to monitor and gain access to the patient (see Figure 32.6). The Resuscitation Council (UK) recommends the following sequence of actions when placing a patient in the recovery position:

- Kneel beside the patient and make sure that both of their legs are straight.
- Place the arm nearest to you out at right angles to their body, elbow bent with the hand palm uppermost.
- Bring the far arm across the chest and hold the back of the hand against the patient's cheek nearest to you.
- With your other hand, grasp the far leg just above the knee and pull it up, keeping the foot on the ground.
- Keeping their hand pressed against their cheek, pull on the far leg to roll the patient towards you on to their side.

- Adjust the upper leg so that both the hip and knee are bent at right angles.
- Tilt the head back to make sure the airway remains open.
- Adjust the hand under the cheek, if necessary, to keep the head tilted.
- Check the patient's breathing regularly.

If the patient has to be kept in the recovery position for more than 30 minutes, turn them to the opposite side in order to relieve the pressure on the lower arm.

***Figure 32.6*** *The recovery position.*



## Section 33 Advanced Life Support for the neonate

In low resource settings, much of the equipment and treatments described here will be unavailable but it is useful for the neonatal student to understand the equipment and treatments for advanced life support. It is important to understand, however, that although more equipment and drugs look advanced, it is the Basic Life Support, quickly and effectively applied that saves lives and is continued throughout Advanced Life Support.

Much of the equipment described here is in use by health workers who are trained in anaesthetics. On occasions, an anaesthetist may be called to assist with a seriously ill patient and a familiarity with this equipment and its use is helpful for the neonatal clinician.

### *Airway and breathing*

Management of the airway (A) and breathing (B) components of the ABC must take priority in all situations. Resuscitation will fail if effective ventilation does not occur.

Before effective resuscitation techniques can be applied, it is essential that the operator is able to:

1 understand the airway equipment available and how to use it
2 recognise respiratory failure and when it may occur
3 perform a systematic and prioritised approach (the structured ABC approach) to the management of the infant who has a problem of the airway or breathing (see Section 31).

### *Airway: equipment and skills for opening and maintaining the airway*

Essential airway and breathing equipment include the following:

- face masks (ideally with reservoirs)
- airways
- self-inflating bag-valve-mask devices
- tracheal tubes, introducers and connectors
- laryngoscopes
- Magill's forceps
- suction devices

This equipment should be available in all resuscitation areas, ideally on a resuscitation trolley. It is crucial to gain familiarity with it before an emergency situation occurs.

*Pharyngeal airways*

Oro pharyngeal airway is the main device used in the neonate (see Figures 33.1 and 33.2)

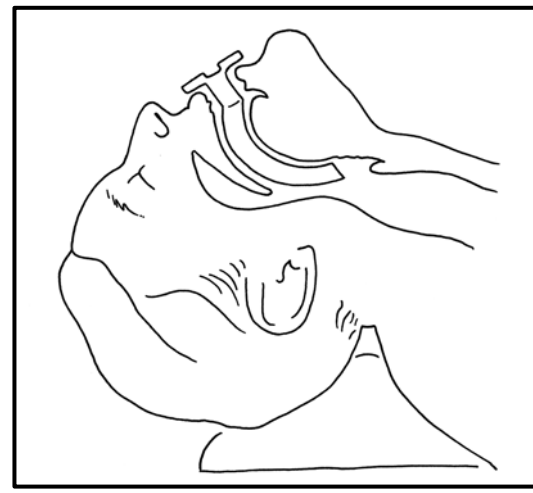


***FIGURE 33.1*** *Oropharyngeal airway, showing position when inserted.*

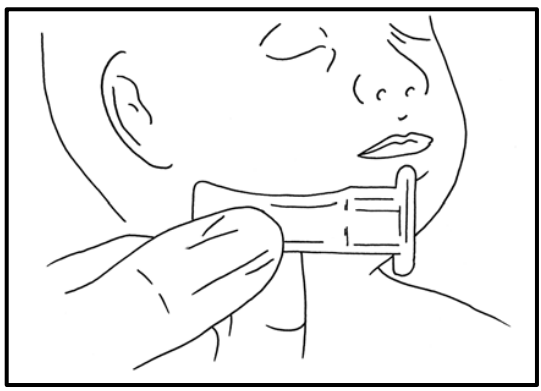


***FIGURE 33.2*** *Oropharyngeal airway, showing sizing technique.*

*Oropharyngeal airways*

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 patient with an intact gag reflex, it may not be tolerated and may induce vomiting.

The oropharyngeal airway is available in a variety of sizes. A correctly sized airway when placed with its flange at the centre of the incisor teeth, 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.

The important point is not to push the tongue back by inserting the airway carelessly.

In infants as the tongue is larger relative to the size of the mouth, the airway cannot be rotated in the mouth without causing trauma. Therefore, the tongue is depressed with the airway or a spatula and not by the convex side of the airway (see Figure 33.3).

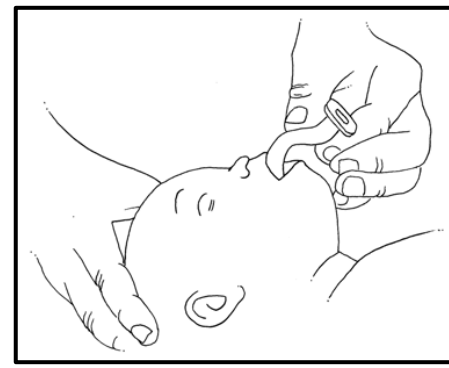


***FIGURE 33.3*** *When inserting the airway without rotation, a tongue depressor can be helpful (not shown).*

*Nasopharyngeal airways*

For long-term use, the nasopharyngeal airway is often better tolerated than the Guedel airway. It is contraindicated in fractures of the base of the skull. It may also cause significant haemorrhage from the vascular nasal mucosa if it is not inserted with care, preferably with lubrication (KY jelly for example). A suitable length can be estimated by measuring from the lateral edge of the nostril to the tragus of the ear. An appropriate diameter is one that just fits into the nostril without causing sustained blanching of the alae nasi. If small-sized nasopharyngeal airways are not available, shortened endotracheal tubes may be used.

Ensure that insertion of one or other of these devices results in an improvement in the patient's airway and breathing. It if does not improve the airway as shown by improved breathing, then a reappraisal of the choice or size of airway is urgently required.

*Laryngoscopes*

There are two principal designs of laryngoscope, namely straight bladed and curved bladed.

The straight-bladed laryngoscope is usually employed to directly lift the epiglottis, thereby uncovering the vocal folds. The advantage of this approach is that the epiglottis is moved sufficiently so that it does not obscure the cords. The potential disadvantage is that vagal stimulation may cause laryngospasm or bradycardia.

The curved-bladed laryngoscope is designed to move the epiglottis forward by lifting it from in front. The tip of the blade is inserted into the mucosal pocket, known as the vallecula, anterior to the epiglottis, and the epiglottis is then moved forward by pressure in the vallecula. This may be equally effective for obtaining a view of the cords, and it has the advantage that less vagal stimulation ensues, as the mucosa of the vallecula is innervated by the glossopharyngeal nerve instead.

A laryngoscope blade appropriate for the age of the patient should be chosen; **in infants a straight blade is usually used**. It is possible to intubate with a blade that is too long, but not with one that is too short.

Laryngoscopes are notoriously unreliable pieces of equipment which may develop flat batteries and unserviceable bulbs very quickly between uses. Therefore, it is vital that a spare is available at all times, and equipment must be regularly checked to ensure that it is in good working order.

**It is essential to work with nurse anaesthetists to ensure advanced respiratory equipment is always working and available.**

*Tracheal tubes*

Un-cuffed tubes should be used during resuscitation, by operators who do not have paediatric anaesthetic experience. If the operator is familiar with cuffed tube placement, both cuffed and uncuffed tubes are acceptable for infants but the youngest infants will usually need an uncuffed tube.

In infants the larynx is circular in cross section and the narrowest part of it is at the cricoid ring, rather than the vocal cords. An appropriately sized tube should give a relatively gas-tight fit in the larynx, but the fit should not be so tight that no leak is audible when the bag is compressed. Failure to observe this condition may lead to damage to the mucosa at the level of the cricoid ring, and to subsequent oedema following extubation.

Neonates usually require a tube of internal diameter 3–3.5 mm, although preterm infants may need one of diameter 2.5 mm.

For infants of weight over 3 kg and up to 1 year in age a size 3 cuffed tube maybe acceptable.

The size of tracheal tubes is measured in terms of their internal diameter in millimetres. They are available in whole-and half-millimetre sizes. The clinician should select a tube of appropriate size, but also have ready one a size smaller and one a size larger.

In the case of resuscitation in a neonate where the lungs are very 'stiff' (e.g. in a cardiac arrest from severe bronchiolitis), a cuffed tube rather than an uncuffed tube may be used by a non-expert, but the risk of airway damage from the cuff must be balanced against the risk of failure to inflate the lungs.

*Tracheal tube introducers*

Intubation can be facilitated by the use of a stylet or introducer, which is placed through the lumen of the tracheal tube. There are two types – either soft and flexible or firm and malleable.

The soft and flexible type can be allowed to project beyond the tip of the tube, so long as it is handled very gently. **The firm type is used to alter the shape of the tube, but can easily damage the tissues if allowed to protrude from the end of the tracheal tube.** Tracheal tube introducers should not be used to force a tracheal tube into position.

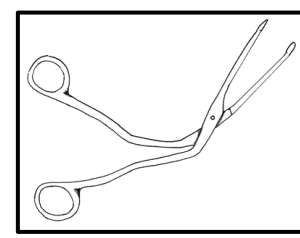
Bougies, which are flexible, deformable, blunt-ended gum elastic rods of different sizes, can be used to help to introduce a tracheal tube when access is difficult. A Seldinger technique is used. The bougie is introduced into the trachea using the laryngoscope, the endotracheal tube is then passed over it into the trachea, and finally the bougie is removed.

*Tracheal tube connectors*

The proximal end of the tube connectors is of standard size, based on the 15-mm/22-mm system, which means that they can be connected to a standard self-inflating bag.

*Magill's forceps*

Magill's forceps (see Figure 33.4) are angled to allow a view around the forceps when they are in the mouth. They may be useful to help to position a tube through the cords by lifting it anteriorly, or to remove pharyngeal or supra-glottic foreign bodies.



*Suction devices*

These are used to remove blood, vomit and secretions from the mouth and throat, usually with a rigid suction tube (Yankauer suction tube; see below). In resuscitation areas, ideally

the suction device should be connected to a central vacuum unit. This consists of a suction hose inserted into a wall terminal outlet, a controller (to adjust the vacuum pressure), a reservoir jar, suction tubing and a suitable sucker nozzle or catheter. In order to aspirate vomit effectively, it should be capable of producing a high negative pressure and a high flow rate, although these pressures and flow rates can be reduced in non-urgent situations, so as not to cause mucosal injury.

Portable suction devices are required for resuscitation when central suction is not available (as is the case in most resource-limited hospitals), and for transport to and from the resuscitation room. These are either manual, mains electrical or battery powered. A manual or battery-operated suction system must be available at all sites where resuscitation may be needed.

To clear the oropharynx of debris (e.g. vomit or solid meconium), a rigid sucker (e.g. Yankauer sucker) should be used with care not to damage delicate tissue or induce vomiting. The Yankauer sucker is available in sizes suitable for the neonate French Gauge 6). It may have a side hole, which can be occluded by a finger, allowing greater control over vacuum pressure.

Tracheal suction catheters (see Figure 33.5) These may be required after intubation to remove bronchial secretions or aspirated fluids. In general, the appropriate size in French gauge is numerically twice the internal diameter in millimetres (e.g. for a 3-mm tube the correct suction catheter is a French gauge 6).

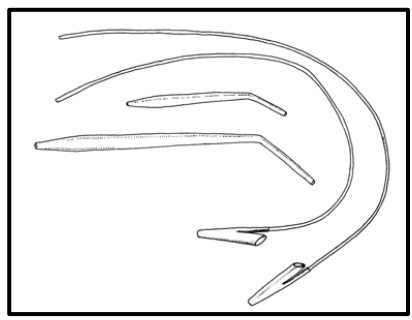


***FIGURE 33.5*** *Tracheal and oral or nasal suction catheters.*

*Advanced airway techniques*

Advanced airway techniques are used when the above techniques fail to maintain and protect an airway over the longer term, particularly if there is potential for it to become obstructed and thus prevent accurate control of oxygenation and ventilation. Advanced airway techniques (tracheal intubation, and surgical cricothyroidotomy) are described in Paediatric Handbook 1.

**Breathing: equipment and skills for helping the neonate to breathe**

The following equipment for oxygenation and ventilation should be readily available:

- an oxygen source
- masks for those who are spontaneously breathing
- close-fitting face masks (for artificial ventilation)
- self-inflating bag-valve systems to be used with close-fitting face masks
- T-piece and open-ended bag systems (only to be used by those with anaesthetic skills)
- mechanical ventilators
- chest tubes
- gastric tubes.

*Oxygen treatment* Indications

Give oxygen to neonates:

- with respiratory distress (severe in-drawing of the lower chest wall, also known as recessions, raised respiratory rate, gasping, grunting with each breath, nasal flaring, head bobbing, etc.)
- with cyanosis (blueness) that is central (around the lips and tongue, or inside the mouth in babies with dark skin)
- who are shocked
- who are fitting
- who are unconscious, with abnormal reduced oxygen saturation ($SpO_2$) on a pulse oximeter.

Ideally, where the resources for this are available, oxygen therapy should be guided by pulse oximetry. Give oxygen to full term infants with a $SpO_2$ of < 94% and aim to keep $SpO_2$ at 94–98% (except at high altitude, where normal oxygen saturation levels are lower). For $SpO_2$ levels needed in preterm infants see Section 15)

**Using a pulse oximeter**

1. Switch on and make sure any mains supply is also switched on (this will charge the internal battery, if this exists) - the sensor should light up.
2. Apply the sensor to a finger or toe or ear in pregnancy.
3. Fix the sensor in position:
   - flexible sensors should be secured with either their own sticky tape, or additional sticky tape that stretches, so arterial pulsations are not impaired
   - rigid sensors, or 'crocodile clips,' usually attach on a finger and do not need further fixation
   - It is important that ambient light does not pass between the emitting and receiving light sensors: all the emitted light must go through the tissue.
4. In situations of bright light, or poor skin perfusion, consider covering the sensor using, for example, a dark coloured glove, mitten, or sock.
5. Wait for a short period of time, usually 30 seconds, before reading the measurement of $SpO_2$ and heart rate from the oximeter, but **only when an adequate arterial plethysmograph pulsation is found.** Most oximeters will have either a bouncing bar display or arterial pulse waveform that is in time with the patients pulse or heart rate.
6. Set the low and high alarm limits for the oxygen saturation (eg 91% and 99%) and pulse rate.
7. Take readings of $SpO_2$ and pulse rate when a good pulsation is present, and the values are stable.
8. May not get accurate reading if patient shivering, moving, if cold hands or feet, wearing nail varnish or if there is carbon monoxide poisoning, as with for example burns.
9. *Note*: skin colour, sickle cell disease and other haemoglobin disorders do not significantly affect the measurement of $SaO_2$.

If pulse oximeters are not available, the need for oxygen therapy has to be guided by clinical signs, which are less reliable.

**Provision of oxygen**

Oxygen must be always available. The two main sources of oxygen are cylinders and oxygen concentrators.

***Oxygen cylinders*** contain compressed gas. A flowmeter needs to be fitted to regulate flow. A hissing noise can be heard if gas is being delivered. Flow meters are used to ascertain how much oxygen is being delivered. Take the reading of flow rate from the middle of the ball. Always switch off the flow when the source is not in use (ensure that the indicator ball is at the bottom of the flow meter and not moving).

**Do not leave anything inflammable near to the oxygen supply. Do not allow smoking near to the oxygen supply.**

At least once a day, check that an adequate oxygen supply is available (ideally use a signed logbook). If a gauge indicating the amount left in the cylinder is not available, switch on the flow and listen for a hissing noise. Replace empty cylinders promptly. Ensure that cylinders are stored and secured in an upright position in suitable containers so that they cannot fall over and cause injury. Cylinder keys to permit changes of regulator should be tied to each cylinder.

***Oxygen concentrators*** produce more than 95% oxygen with a flow of 1–8 litres/minute but, unlike cylinders, they require a continuous electricity supply. For this reason, all areas where patients might need oxygen must have both cylinders and concentrators.

It is also advisable to use an oxygen sensor to regularly check the concentration of oxygen being produced by each concentrator.

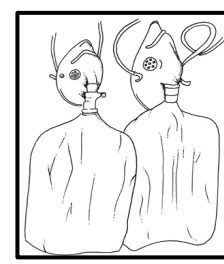
There are now small oxygen plants available that can provide oxygen for a defined area or even for the whole of a hospital or health facility. Some of them can be used to fill oxygen cylinders as well, thus providing a constant back-up (see Paediatric Handbooks).

*Oxygen delivery*

A mask with a reservoir bag (see Figure 33.6) allows up to 100% oxygen to be delivered. Without a reservoir, it is only possible to deliver around 40% oxygen. If only low flow rates of oxygen are available, do not use a reservoir bag. Because oxygen is a dry gas, humidity, if available, can be valuable in patients with respiratory failure.

If an oxygen mask is being used, ensure that the mask is large enough to cover the mouth and nose. Both low- and high-flow oxygen can be given. Hold the mask in place using the elastic strap around the back of the head and/or ask the mother to hold it as close as possible to the infant's face.

***FIGURE 33.6*** *oxygen mask with reservoir bags*



Nasal cannulae (also known as nasal prongs) (see Figure 33.7) are the preferred method of oxygen delivery in most circumstances in the neonate, as they are safe, non-invasive, reliable and do not obstruct the nasal airway. Also, they support humidification by the nasal mucosa before oxygen reaches the lungs which is very important.

Head boxes are **not** recommended in low resource settings, as they use up too much oxygen and deliver a low concentration.

Face masks can be used for resuscitation purposes, ideally with a reservoir attached to deliver 100% oxygen.

*Monitoring of oxygenation*

Nursing staff must know how to place and secure the nasal cannulae correctly. Check regularly that the equipment is working properly and remove and clean the cannulae at least twice a day.

Monitor the patient at least every 3 hours to identify and correct any problems, including:

- $SpO_2$ values measured by pulse oximeter
- nasal cannulae out of position
- leaks in the oxygen delivery system
- incorrect oxygen flow rate
- airway obstructed by mucus (clear the nose with a moist wick or by gentle suction).

*Pulse oximetry*

Normal oxygen saturation at sea level in a full term born infant is 95–100%. Oxygen is ideally given to maintain oxygen saturation at 94–98%. Different cut-off values might be used at high altitude or if oxygen is scarce. Aim for values of 92–94% in preterm infants < 32 weeks' gestation and do not allow values to exceed 98%. The response to oxygen therapy in lung disease can be measured with the pulse oximeter, as the patient's $SpO_2$ should increase (in patients with cyanotic heart disease, $SpO_2$ may not increase significantly when oxygen is given). The oxygen flow can be titrated using the pulse oximeter as a monitor to obtain a stable $SpO_2$ without giving too much oxygen (not above 98%). This is especially important in pre-term babies with respiratory disease (see Section 15).

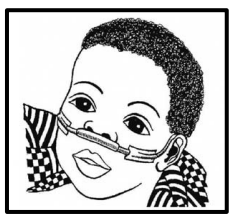


***FIGURE 33.7*** *Nasal cannulae delivering oxygen and taped in place.*

*Assessment of oxygenation at and above sea level*

A systematic review in 2009 found an $SpO_2$ of 90% is the 2.5th centile for a population of healthy children living at an altitude of approximately 2500 m above sea level. This decreases to 85% at an altitude of approximately 3200 m.

*Duration of oxygen therapy*

Give oxygen continuously until the full-term infant is able to maintain an $SpO_2$ of 94% or higher in room air. When the patient is stable and improving, take them off oxygen for a few minutes. If the $SpO_2$ remains in the range 94–98%, discontinue oxygen, but check again 30 minutes later, and 3-hourly thereafter on the first day off oxygen to ensure that the patient is stable. Where pulse oximetry is not available, the duration of oxygen therapy has to be guided by clinical signs, which are less sensitive.

*Breathing for the patient*

Face masks with seal over nose and mouth for positive pressure ventilation (see Figure 33.8)

These face masks are used for bag–mask ventilation. Masks are available in various sizes, and the appropriate size to cover the mouth and nose should be chosen.

Face masks for mouth-to-mouth or bag-valve-mask ventilation in infants are of two main designs. Some masks conform to the anatomy of the patient's face and have a low dead

space. Circular soft plastic masks give an excellent seal and are often preferred. Masks should ideally be clear so that the infant's colour or the presence of vomit can be seen.

***FIGURE 33.8*** *Face masks with cushioned rim for a leak-proof fit, and round shape for infants.*

***Self-inflating bags (see Figure 33.9)***

This is one of the most important pieces of equipment, allowing hand ventilation by face mask without a supply of gas. The 500 mL bags are appropriate for term neonates. There are also 250-mL to 300 mL version for small premature babies. These bags have pressure-limiting valves that operate at 30–45 cm $H_2O$. Test the valve by placing the mask on a surface and pressing the bag and ensuring that the valve opens. It can be over-ridden, if necessary, for stiff, poorly compliant lungs.

The bag connects to the patient through a one-way valve to direct exhaled air to the atmosphere. The other end connects to the oxygen supply and can attach to a reservoir bag which allows high concentrations (up to near 100%) of oxygen to be delivered. Without the reservoir bag, only concentrations of up to 40% can be delivered.

The bag itself is easily dismantled and reassembled. It is important to realise that this system will operate without an attached oxygen supply, allowing resuscitation to be initiated before oxygen is available. However, if resuscitation is failing, check that oxygen is being delivered into the bag and to the patient and that the oxygen supply has not been disconnected.

Always use high-flow oxygen (if available) and a reservoir bag during resuscitation apart from at birth where room air is satisfactory for almost all babies (see Section 1).

It is important to clean the system after each patient.

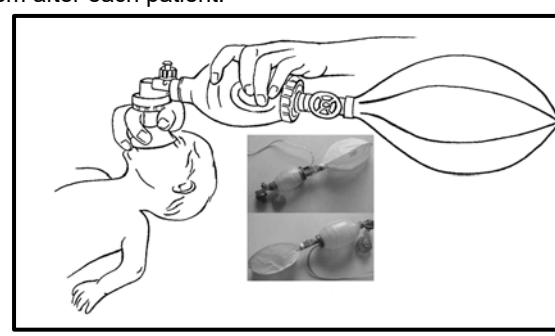


***FIGURE 33.9*** *Two sizes of self-inflating bags and masks.*

It is essential that the mask is properly sized and correctly placed over the mouth and nose of the infant (see Figures 33.10 and 33.11).

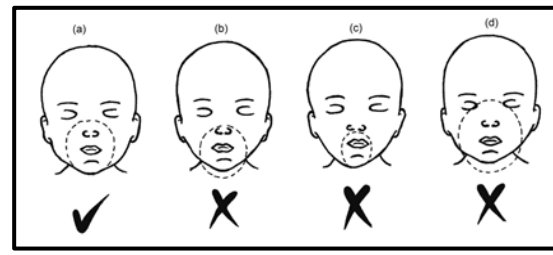



***FIGURE 33.10*** *(a) Correct placement of infant mask. (b), (c) and (d) Incorrect placement of infant mask.*

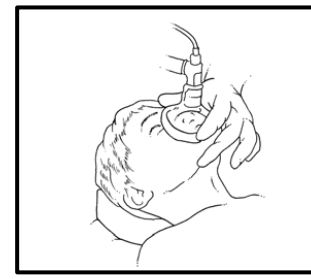


***FIGURE 33.11*** *A single-handed grip on mask.*

***FIGURE 32.12*** *Two-handed grip on mask incorporating jaw thrust.*

If the chest does not rise, the airway is not clear. The usual cause is failure to correctly apply the airway-opening techniques discussed previously. The first step in the neonate is to try is to readjust the head-tilt/chin-lift to the neutral position and try again. If this is not successful, the jaw-thrust manoeuvre should be tried (see Section 32 Figure 32.2). Failure of both the head-tilt/chin-lift and jaw-thrust manoeuvres should lead to suspicion that rarely a foreign body is causing the obstruction.

Once breathing has restarted, replace the bag-valve-mask system with a simple face mask and reservoir. **Because of the internal valves it is not possible to spontaneously breathe through the bag-valve-mask system.**

*Chest tubes*

In neonatal cases with a significant pneumothorax (particularly tension pneumothorax), ventilation may be compromised, and insertion of a chest drain is mandatory (see Section 38).

*Gastric tubes (see Section 46)*

Insertion of a gastric tube is essential for feeding neonates with respiratory failure. It is essential after intubation and may also relieve respiratory distress in spontaneously breathing patients including those with abdominal emergencies or gastric stasis. It allows decompression of a stomach full of air from both bag and mask ventilation as well as air swallowed by a distressed patient. Without a gastric tube, the patient may vomit or there may be aspiration of stomach contents. In addition, venting of stomach gas will avoid diaphragmatic splinting.

A nasogastric tube will increase airway resistance through the nose, which in a spontaneously breathing infant with respiratory failure can be significant. An orogastric tube has less effect on ventilation but is less readily tolerated and less easily fixed in position.

*Further information*

Additional breathing procedures are described in Sections 31 to 32.

**Circulation: equipment and skills for maintaining the circulation**

Details of how to undertake the following procedures in the neonate are covered in Sections 42-45:

- peripheral venous cannulation
- blood sampling from an IV cannula
- umbilical venous catherisation
- intraosseous cannulation and infusion
- cut-down long saphenous venous cannulation

*Management of cardiac arrest*

Cardiac arrest occurs when there is no effective cardiac output. Before any specific therapy is started, effective basic life support must be established.

*Four cardiac arrest rhythms can occur:*

asystole
pulseless electrical activity (including electromechanical dissociation)
ventricular fibrillation
pulseless ventricular tachycardia.

These are divided into two groups.

1. Asystole and pulseless electrical activity, which do not require defibrillation and are called 'non-shockable' rhythms.

2. Ventricular fibrillation and pulseless ventricular tachycardia, which do require defibrillation, are called 'shockable' rhythms. For details of managing these forms of cardiac arrest in the neonate please see the Paediatric Handbook 2.

*Reversible causes of cardiac arrest*

The causes of cardiac arrest in infancy are multifactorial, but the two commonest final pathways are through hypoxia and hypovolaemia. All reversible factors are conveniently remembered as the 4Hs and 4Ts (see below). Sometimes cardiac arrest is due to an identifiable and reversible cause, such as shock due to massive haemorrhage, septicaemia or severe diarrhoea. In the trauma setting, cardiac arrest may be caused by severe hypovolaemia or tension pneumothorax or pericardial tamponade (see Paediatric Handbook 2).

It is often appropriate to give an early IV bolus of Ringer-lactate/Hartmann's solution or 0.9% saline (10 mL/kg in an infant), as this will be supportive in cases related to severe hypovolaemia.

In addition, however, a tension pneumothorax requires definitive treatment. Continuing blood replacement and the prevention of haemorrhage may also be required.

Rapid identification and treatment of reversible causes such as hypovolaemic shock, hypothermia, electrolyte and acid–base disturbance (if measurements are available), and tension pneumothorax are vital.

During CPR it is important to continually consider and correct reversible causes of the cardiac arrest based on the history of the event and any clues that are found during resuscitation.

*The 4Hs and 4Ts*

1 Hypoxaemia is a prime cause of cardiac arrest in the neonate, and its reversal is key to successful resuscitation.
2 Hypovolaemia may be significant in arrests associated with neonatal sepsis, neonatal malaria and gastroenteritis. It requires infusion of crystalloid, and in the case of haemorrhage, blood should be given.
3 Hyperkalaemia, hypokalaemia, hypocalcaemia, acidaemia and other metabolic abnormalities may be suggested by the patient's underlying condition (e.g. renal failure), tests taken during the resuscitation or clues from the ECG. Intravenous of 10% calcium gluconate is indicated in infants with hyperkalaemia and hypocalcaemia. 1ml/kg 10% calcium gluconate can be given over 5-10mins and repeated once. Unfortunately, in low resource settings there is limited if any ability to diagnose or manage these conditions, and it can be dangerous to give IV calcium without the ability to measure electrolytes.
4 Hypothermia requires particular care. A low-reading thermometer must be used to detect it.
5 Tension pneumothorax ~~is~~ especially associated with Pulseless Electrical Activity (PEA) and may occur as a rare complication of neonatal resuscitation.
6 Toxic substances, resulting either from accidental or deliberate overdose or from an iatrogenic mistake, may require specific antidotes.

### *Non-shockable cardiac arrest*

#### Asystole

This is the most common cardiac arrest rhythm in infants. The response of the heart to prolonged severe hypoxia and shock (which are the usual pathologies in these groups) is progressive bradycardia leading to asystole.

The ECG (if available: rare in low resource settings) will distinguish asystole from ventricular fibrillation, ventricular tachycardia and pulseless electrical activity. The ECG appearance of ventricular asystole is an almost straight line; occasionally P-waves are seen (see Figure 33.13). Check that the appearance is not caused by an artefact (e.g., a loose wire or disconnected electrode). Turn up the gain on the ECG monitor.

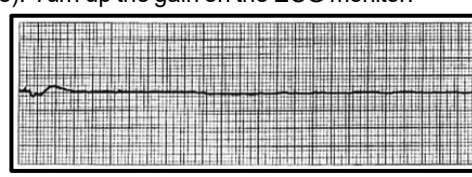


**FIGURE 33.13** ECG appearance of asystole.

#### Pulseless electrical activity (PEA)

This is the absence of a palpable pulse or other signs of life despite the presence on the ECG monitor of recognisable ECG complexes that normally produce a pulse (see Figure 33.14). PEA is treated in the same way as asystole and often rapidly leads onto asystole.

PEA can occur with identifiable and reversible causes such as severe sepsis, hypovolaemia and tension pneumothorax. PEA is also seen in hypothermic patients and in those with electrolyte abnormalities.

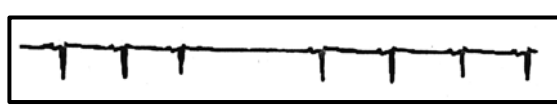


**FIGURE 33.14** Pulseless electrical activity (PEA) in an infant with no pulse or signs of life.

*Management of asystole/PEA in neonates*

The first essential step is to establish ventilations and chest compressions effectively. Ensure an open airway, initially using an airway manoeuvre to open the airway and if necessary, stabilising it with an airway adjunct.

Ventilations are provided initially by bag and mask with high-concentration oxygen.

Provide effective chest compressions at a rate of 100–120 per minute with a compression to ventilation ratio of 3:1. The depth of compression should be at least one-third of the antero-posterior diameter of the chest, and compressions should be given in the lower half of the sternum. Ideally a cardiac monitor is attached. Properly performed basic life support is key to any chance of successful resuscitation from cardiac arrest. Ensure that the person performing chest compressions is keeping the correct rate and depth of compression, and if possible, change operator every 2 to 3 minutes, to avoid fatigue causing poor performance.

If asystole or PEA is identified, consider giving Adrenaline 10 micrograms/kilogram (0.1 mL of 1:10 000 solution per kg) intravenously or intraosseously (IO). Adrenaline increases coronary artery perfusion, enhances the contractile state of the heart and stimulates spontaneous contractions. The drug is best given through either umbilical vein catheter, but if one is not in place, it may be given through a peripheral line. Where there is no existing IV access, the IO route is recommended as the route of choice, as it is rapid and effective. In each case, the adrenaline is followed by a normal crystalloid flush (2 mL of Ringer Lactate/Hartmanns or 0.9% saline).

If available, and as soon as is feasible, a skilled and experienced operator (usually an anaesthetist) may intubate the infant's airway. This will both control and protect the airway and enable chest compressions to be given continuously, thus improving coronary perfusion. Once the patient has been intubated and compressions are uninterrupted, the ventilation rate should be around 20-30 breaths per minute. It is important for the team leader to check that the ventilations remain adequate when chest compressions are continuous. An algorithm for non-shockable rhythms is shown in Figure 33.15.

During and following adrenaline treatment, chest compressions and ventilation should continue. It is vital that chest compressions and ventilations continue uninterrupted during advanced life support, as they form the basis of the resuscitative effort. The only reason for interrupting compressions and ventilation is to shock the patient if necessary (see Handbook 1 and 2), and to check the rhythm. A brief interruption may be necessary during difficult intubation. Giving chest compressions is tiring for the operator, so if enough personnel are available, change the operator frequently and ensure that they are achieving the recommended rate of 100–120 compressions per minute together with a depression of the chest wall by at least one-third of the antero-posterior diameter of the chest.

At intervals of about 2 minutes during the delivery of chest compressions, pause briefly to assess the rhythm on the ECG monitor (if available). If asystole persists, continue CPR while again checking the electrode position and contact.

- If there is an organised rhythm, check for a pulse and signs of life.
- If there is a return of spontaneous circulation (ROSC), continue post-resuscitation care, increasing the ventilation rate to 20 -30 breaths per minute.
- If there is no pulse and no signs of life, continue the protocol.
- Give adrenaline about every 4 minutes at a dose of 10 micrograms/kg IV/IO in infants.

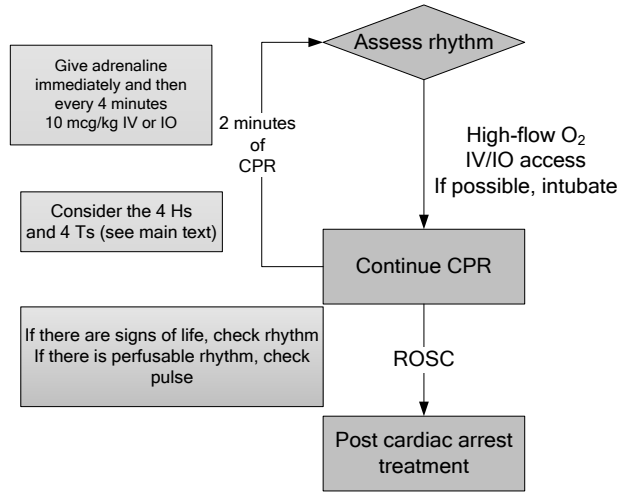



***FIGURE 33.15*** *Algorithm for the treatment of non-shockable (asystole and PEA) rhythms in infants. CPR, cardiopulmonary resuscitation; IV, intravenous; IO, intra-osseous; ROSC, return of spontaneous circulation*

### *Shockable cardiac arrest*

These arrhythmias are rare in neonates but either of them may occur in patients with sudden collapse, hypothermia, poisoning by tricyclic antidepressants, or cardiac disease. Further details of managing shockable cardiac arrests are in the Textbook.

### *Drugs used in non-shockable cardiac arrest*

#### *Oxygen*

Although 100% oxygen must be used during the resuscitation process, once there is return of spontaneous circulation (ROSC) this can be detrimental to tissues that are recovering. Pulse oximetry should be used to monitor and adjust for oxygen requirement after a successful resuscitation. $SpO_2$ should be maintained in the range 94%–98%.

#### *Adrenaline*

Adrenaline is the first-line drug for treatment of cardiac arrest. Its effect is to increase blood flow to the brain and myocardium by constricting alternative arterioles.

The initial IV or IO dose is 10 micrograms/kg (0.1 mL/ kg of 1 in 10 000 solution) in infants. In infants with no existing IV access, the intra-osseous route is recommended as the route of choice, as it is rapid and effective. In each case, adrenaline is followed by a 0.9% saline flush (2mL).

#### *Glucose*

Hypoglycaemia is defined as a glucose concentration of less than 2.5 mmol/litre (45 mg/dL) (see Section 22)

All infants can become hypoglycaemic when seriously ill. Blood glucose levels should therefore be checked frequently, and hypoglycaemia must be corrected. If it is suspected and blood glucose levels cannot be measured, always give 2.5 mL/kg of 10% glucose preferably IV or Intra-Osseously (IO) or alternatively enterally (via a gastric tube).

## Section 34 Pain control in the newborn infant

### Special issues with regard to pain in the newborn infant

- Most studies (some of them controlled) have shown that neonates (both premature and full term) react to pain.
- Infants can easily be forced to put up with suffering.
- Small doses should be measured and given by mouth with an oral syringe.
- Adequate general anaesthesia, using morphine when needed, should be given for all surgical procedures on neonates.
- Local anaesthetics must be used when they would be used in an older child undergoing the same procedure

***How can pain in the neonate be recognised?***

- Cry
- Agitation
- Facial expression
- Rise in heart rate and respiratory rate
- Hypoxaemia, fall in oxygen saturation

### Pain control during procedures in neonates

- Breastfeeding during procedures may be helpful.
- In all cases, comfort and containment (swaddling) should be provided by a parent or nurse.

### Local anaesthetic drugs

***Infiltration (the most widely used method)***

*Lidocaine 0.5–1%*

- Used for rapid and intense sensory nerve block.
- Onset of action is within 2 minutes; the procedure must not be started until an anaesthetic effect is evident.
- Effective for up to 2 hours.

*Doses:*

infants maximum dose given locally 3 mg/kg – 0.3 mL/kg of 1% solution or 0.6 mL/kg of 0.5% solution

Lidocaine/adrenaline combinations are not recommended for neonates.

***Complications of local anaesthesia***

*Prevention of complications*

- Use the lowest effective dose.
- Inject slowly.
- Avoid accidental injection into a vessel. There are three ways of doing this:

1. the moving needle technique (preferred for tissue infiltration): the needle is constantly in motion while injecting, which makes it impossible for a substantial amount of solution to enter a vessel
2. the plunger withdrawal technique (preferred when considerable amounts are injected into one site): the syringe plunger is withdrawn before injecting, and if blood appears the needle is re-positioned, and another attempt is made
3. the syringe withdrawal technique: the needle is inserted, and the anaesthetic is injected as the syringe is being withdrawn.

### Symptoms and signs of lidocaine allergy and toxicity

Lidocaine can be absorbed through mucous membranes in a large enough dose to be toxic. Symptoms of allergy: shock, redness of skin, skin rash/hives, bronchospasm, vomiting.

*Table 34.1 Lidocaine toxicity*

| ***Severe toxicity*** | ***Life-threatening toxicity (very rare)*** |
|---|---|
| Sleepiness<br>Disorientation<br>Muscle twitching and shivering | Tonic–clonic convulsions<br>Respiratory depression or arrest<br>Cardiac depression or arrest |

- Direct IV injection of even a small amount may result in cardiac arrhythmias and convulsions (see above).
- Resuscitative facilities and healthcare professionals with resuscitative skills should be present.

**Systemic drug treatment for pain in the neonate**

STEP 1: Paracetamol
STEP 2: Morphine for moderate to severe pain **in addition to paracetamol**
Plus, an adjuvant* if appropriate
*An adjuvant is another drug (e.g. steroid or anxiolytic) or type of treatment that can prevent and relieve pain.

**Non-opiate analgesics**
**Paracetamol**
1. This is the most widely used analgesic and anti-pyretic.
2. It does not cause respiratory depression.
3. It is dangerous in overdose but a very safe and effective drug if used in recommended doses.
4. It is given by mouth, rectally or intravenously.
5. The maximum daily dose should not be given for more than 3 days.
6. Caution is needed in patients with liver impairment.
7. There are no anti-inflammatory effects.
8. Paracetamol can have a morphine-sparing effect, lowering the dose, and therefore severity of side effects of morphine.

**Non-steroidal anti-inflammatory drugs (NSAIDs) (e.g. ibuprofen, diclofenac) are not recommended in neonates**

**Opiate analgesics**
**Morphine**
Morphine is the most important drug in the world for pain control, and the WHO recommends that it should be universally available.

In resource-limited countries it is mostly administered orally, which is useful for chronic or anticipated pain, but less effective for acute pain. The latter requires IV administration of morphine.

**In the neonate, we recommend paracetamol for most painful conditions but if oral morphine is given, monitor closely for apnoeic/hypoxaemic conditions.**

At an appropriate oral dose of morphine, analgesia occurs without impaired consciousness. Nausea and vomiting are rare with oral treatment, but when morphine is given intravenously for the first time it may produce this side effect.

***Intravenous use of morphine***

1. In single doses it has minimal harmful haemodynamic effects in a supine patient with normal circulating blood volume. However, in hypovolaemic patients it can contribute to hypotension. Therefore: monitor the patient's cardiovascular status and have an IV fluid bolus of Ringer-lactate/Hartmann's solution ready (10 mL/kg for a neonate).
2. In excessive dosage it can produce a dose-dependent depression of ventilation and decreased respiratory rate, leading to apnoea.
3. IV morphine can cause vomiting
4. Patients who are receiving morphine in hospital (where it is often intravenously administered) need observation and/or monitoring of respiratory rate and sedation.
5. Morphine is better controlled by the IV than the IM route. If using the IV route, give a small dose initially and repeat every 3–5 minutes until the patient is comfortable. Individuals vary widely with regard to the dose needed to provide pain relief.
6. It is rarely appropriate to give morphine intramuscularly, and **for patients who are in shock, giving morphine IM is dangerous, as it can be initially poorly absorbed, and then quickly absorbed when perfusion improves, potentially leading to a high blood level of the drug.**

*Naloxone*

Naloxone is an opiate antagonist that reverses the sedative, respiratory-depressive and analgesic effects of morphine, and so should be given to treat morphine overdose.

*Table 34.2 Orally administered drugs for mild or moderate pain*

| ***Medicine*** | ***Neonate 0–29 days*** |
|---|---|
| Paracetamol | 10mg/kg every 6–8 hours.<br>Maximum 4 doses in 24 hours<br><br>Maximum dose of 5mg/kg if jaundiced |
| Ibuprofen | ***Not recommended*** |
| Diclofenac | ***Not recommended*** |

*Preparations of analgesic drugs for use in the neonate:*

Paracetamol: oral suspension, 120 mg/5 mL,

*Table 34.3 Intravenous paracetamol for mild or moderate pain*

| *Age/weight* | *Dose* | *Maximum dose in 24 hours* |
|---|---|---|
| Preterm over 32 weeks | 7.5 mg/kg every 8 hours | 25 mg/kg |
| Term neonate | 10 mg/kg every 4–6 hours | 30 mg/kg |

**Intravenous paracetamol**

1. Paracetamol IV is formulated as a 10 mg/mL aqueous solution (in ready-to-use 50-mL and 100-mL vials for infusion over 15 minutes).
2. It is useful, effective and safe.
3. The peak analgesic effect of IV paracetamol occurs within 1 hour, with a duration of approximately 4–6 hours.
4. **Ensure that the correct dose is given, as serious liver toxicity can occur in overdose.**
5. Side effects are rare. They include rashes, blood disorders and hypotension on infusion.
6. Caution is needed in patients with severe renal impairment, severe malnutrition (and thus low reserves of hepatic glutathione) or dehydration.
7. Paracetamol helps to reduce the dose of morphine required and is very effective when used in combination with morphine.

**Oral and rectal morphine (see Table 34.4)**

Table 34.4 recommended doses for oral and rectal morphine in the neonate

| *Initial dose (adjust according to response)* | *Interval* |
|---|---|
| 50–100 micrograms/kg | Every 4 hours |

**Intravenous IV morphine**

**Intravenous** morphine is only needed if oral preparations are not going to be absorbed (e.g. in shock) or where rapid emergency onset is needed. IV morphine is potentially less safe, especially if staff shortages mean that the correctly calculated dose is not given.
We suggest that the total dose recommended is drawn up in 10mls 0.9% saline and that 2ml boluses of this solution are given every 3--5 minutes until the patient is comfortable.

| *Age* | *Dose* | *Interval* |
|---|---|---|
| Neonate | 25–100 micrograms/kg<br>Usual start dose 50microgram/kg | Every 6 hours |

The dose should be adjusted according to response, and each dose be administered over at least 5mins.

***Monitoring during morphine administration:***

Side effects occur only in overdose and should not be seen at the doses stated here. *They include the following:*

1. Respiratory depression. If the respiratory rate is: < 20 breaths/minute
Alert medical staff and ensure that bag/valve/mask and naloxone are available.
Monitor $SaO_2$ as appropriate (it should be higher than 94% in air).
2. Constipation. Use prophylactic laxatives.
3. Monitor for urinary retention.
4. Patients with liver and renal impairment may need lower doses and longer time interval between doses
5. Caution in patients with head injuries

***Naloxone doses to reverse opioid induced respiratory depression***

**Always ventilate with bag/valve/mask first if the patient is unresponsive before giving naloxone**. This is because arrhythmias and pulmonary oedema can be caused if naloxone is given to a patient with high blood carbon dioxide concentrations.

*Dose*: Neonate to 1 month of age: 100 microgram/kg repeated every 2--3 minutes until adequate response (maximum 2mg)
*Preparations:* Ampoule 400 microgram/mL

For the newborn, to treat respiratory depression due to maternal opioid administration during labour or delivery, 60 microgram/kg, alternatively 200 micrograms as a single IM dose is recommended.

## Section 35 Practical procedures in the infant

Practical procedures should first be explained to the parents, any risks discussed with them and their consent obtained. Procedures on infants should avoid hypothermia. Good light is essential. Analgesia should be given where necessary, and invasive procedures only performed when essential.

**Preventing hypothermia in infants especially the newborn and especially small and preterm infants**

**Skin to Skin Mother Care (KMC)**
This technique has been shown to be the most effective way of achieving the following in poorly resourced environments

- Preventing hypothermia
- Promoting breast feeding and growth
- Reducing infection risk
- Monitoring and reducing apnoea and stress in the baby
- Empowering the mother

*Hypothermia: what is a normal body temperature for a baby?*
Axillary temperature measured for 3 minutes = 36.5-37.4$^{o}$C
Axillary temperature measured for 1 minute = 36.0-37.0$^{o}$C

**Hypothermia**
Mild = 36-36.4$^{o}$C
Moderate = 32.0 -35.9$^{o}$C
Severe = below 32.0$^{o}$C

*What harm does hypothermia cause?*

- Reduces the amount of oxygen available to the baby's tissues
- Causes tissue acidosis
- Stops the baby's lungs producing surfactant to help breathing
- Increases the likelihood of severe infection
- Slows weight gain

All these problems are worse in the pre-term and Small for Gestational Age SGA baby

*Why is the newborn baby so prone to hypothermia?*

- High surface area to weight
- Absence of subcutaneous fat causes skin to lose heat easily
- Not very active
- Cannot shiver
- Have limited special brown fat

All these problems are worse in the pre-term and Small for Gestational Age SGA baby

*What can we do to prevent hypothermia?*

- Keep the delivery room and postnatal ward warm (over 25$^{o}$C) and draft free

At birth

- Dry the baby well and wrap in a dry cloth
- Place baby skin to skin on mother's breasts, cover them both
- Place hat on baby
- Do not bathe for at least 24 hours
- Keep baby in skin-to-skin care for as long as practicable

Keeping the baby in skin-to-skin contact with the mother prevents hypothermia
If the baby is too warm, the breasts cool the baby down

If the baby is too cold, the breasts warm the baby up
Preventing hypothermia improves growth, reduces infection risk and promotes lung maturation

*Early, demand-led breast feeding*
KMC encourages early breast feeding (best within an hour of birth)
KMC facilitates successful and prolonged breast feeding
Therefore, growth is optimized.

*Reducing infection in the small baby*
Being in skin-to skin contact with the mother as long as possible means that the baby can be colonised by the mother's bacteria (to which the baby has placentally transferred antibodies) instead of dangerous hospital bacteria.

*Apnoea/hypoxaemia and stress in small babies*
Low birth weight/preterm babies are prone to apnoea/hypoxaemic episodes. Skin to skin care can help identify these. The mother's breathing and heartbeat may help by providing gentle stimulation.
Mother can be taught to recognise apnoea and other abnormal breathing, stimulate the baby and call for help if needed
Studies show that babies in skin-to-skin care are less stressed than babies in cots and incubators

*Skin to skin care and its benefits for mothers*
Mothers report feeling empowered, more confident with their baby and more fulfilled.
Fathers performing skin to skin care felt more confident and content too!

**It is important to note that skin to skin care is beneficial to all babies, especially preterm and low birth weight infants but also including full term healthy babies,**

*What is needed for skin-to-skin care?*
- Mother who understands importance and is willing to learn
- Staff with skills and knowledge
- Supportive environment in hospital and at home

*Mothers' needs*
- Chair where mother can sit comfortably
- Beds arranged so mother is propped up when sleeping (chest 15 degrees up)
- Personal and clothes washing facilities
- Meal facilities
- Education on care of baby
- Recreational/income generating activities

*Care of baby*
- Position so that airway is open
- Show mother how to monitor breathing
- Show mother how to stimulate if apneic
- Monitor temperature: if low/high, consider infection

Teach mother about danger signs

*What happens if the baby needs treatments?*
- Naso or orogastric tube feeds
- Intravenous antibiotics
- Oxygen by nasal prongs

- Nasal CPAP

*Can all be given during skin-to-skin care?*
Only phototherapy needs baby's skin exposed

*When mother needs a rest, or she is ill*
- Clothe the baby and put in a warmed cot with blankets
- Better still, other family members can do skin to skin care too

*Skin to skin care at home*
Vital to continue skin to skin care after discharge at home for several months to:
- Prevent hypothermia
- Improve weight gain
- Reduce infections

All family members can help, including older children

**Technique of skin-to-skin care**

*i) Moby wrap*
*ii) Plain cotton binders*
*iii) Kalafong wrap (The Thari) (see Figure 35.1 for how to do this)*

a. This is a one-piece wrap, 3 metres long, with a central panel and 4 long straps
b. With the lower edge of the central panel in the middle of the mother's lower chest, wrap the bottom straps around the back.
c. Cross the bottom straps at the back and bring the straps to the front just below the breasts.
d. Tie a square knot in front, being sure that the knot is on top of the center-piece of fabric, which will provide a secure basis for the infant's legs and bottom. Make sure that the straps are tied just below the breasts and not around the waist because the waist level may position a small infant too low on the mother's chest, which may compromise the infant's airway.
e. Wrap the top straps around the mother's back
f. Cross the top straps at the back and bring them over the shoulders toward the front. Let the top straps dangle in front, leaving the centre-piece top edge loose so that it creates a pouch for the infant.
g. Position the infant prone inside the pouch created by the center-piece. The infant's legs and arms should be flexed with the hands beside the infant's head.
h. Gently turn the infant's head to the side if necessary. Be sure that the top edge of the center-piece is at the midline level of the infant's ear.
i. Pull the dangling top straps further forward. This action tightens the centre piece around the infant, securing the infant up against the chest. Tie the top straps to the bottom straps. Each strap is attached to the bottom strap with its own square knot.
j. The wrap should be tied firmly and securely to enable the mother to release her hold on the infant so that her arms are free while the infant remains safely contained.
k. It is important that the upper edge of the centre piece pouch secures the infant's head at the level of the infant's ear, ensuring that a safe airway is maintained.
l. The lower edge of the centre-piece can now be tucked into a skirt and blouses and jackets are easily worn over the wrap.

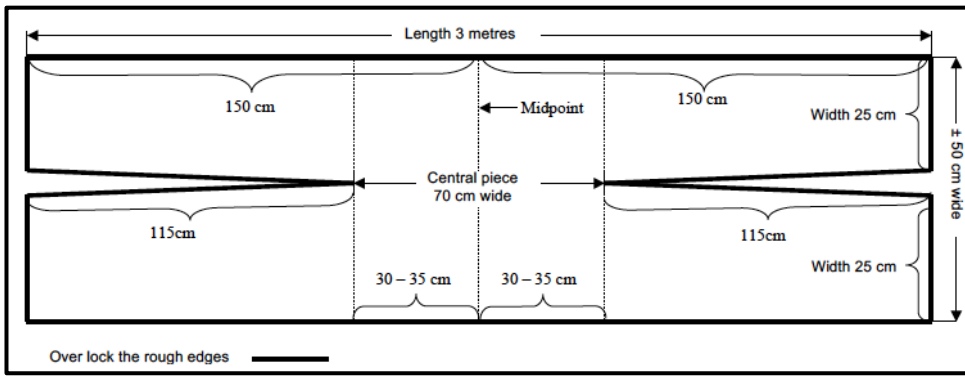
*Choices of material from which to make the Thari*

*Polyester Cotton*: It works well and is inexpensive. The material tears easily and it is not necessary to cut the material with a pair of scissors. Unfortunately, poly cottons are usually 110 cm wide and only 2 wraps can be made from 3 metres of material. If one can get cheap cotton material that is 150 cm wide, one is able to get 3 wraps from 3 metres of material.

*Cotton knit (t-shirt material):* T-shirt material stretches a lot. It would be better to use a material that contains Lycra, but Lycra is expensive.

*A thin Denim material* also works well, it lasts very long especially if you use it over and over in the ward, but unfortunately denim is quite expensive.

Wraps can be made from old sheets, if funds are not available to buy new material.




*Teaching the mother how to assess the baby's breathing*

i. The mother should be constantly aware of the baby's breathing by *looking* at the baby for respiratory or nasal movement, *listening* for breath sounds and *feeling* for exhaled air. The mother should be helped to recognise rapid breathing and chest wall recession indicating increased breathing efforts.

ii. If she cannot detect breathing or is not sure, she should call for help (either from a nurse or from another mother or relative to get a nurse) and stimulate the baby usually by gently pinching the ear.

*Helping the mother to breast feed the infant while still in the wrap*

Small infants should have a combination of demand feeding and scheduled feeding. While demand feeding is preferable, as it is infant led, some infants may be too drowsy to demand and will therefore take insufficient milk for growth. If a baby is feeding less often than 2 hourly, he/she should be woken for a feed. There will be further discussion on this topic in the nutrition and growth and breast-feeding tutorials.

The advantage of the baby remaining in the wrap while breast feeding is that he/she is still close to mother with all the sensory input to keep him/her calm and to encourage breast feeding. Also, there is no period of exposure risking hypothermia.

i. The wrap must be loosened, and the baby's position moved so that he is able to comfortably access the breast in the usual nursing position.

ii. An additional blanket may be needed if there are any exposed parts of the naked baby or the mother needs privacy.

iii. Both breasts may be used, or if the baby is feeding frequently then only one breast per feed may be used.

iv. Once the baby has finished feeding, he should be replaced in the upright open airway position and firmly secured again.

*Enabling skin to skin care to continue when mother is asleep*

It is relatively easy to continue skin to skin care when the mother is ambulant, seated or lying down but awake. She may be concerned about continuing while asleep. The position for sleeping skin to skin care is with the mother's upper body elevated at up to $30^0$ to the horizontal by means of pillows.

*Figure 35.1 Applying the Kelafong skin to skin wrap*

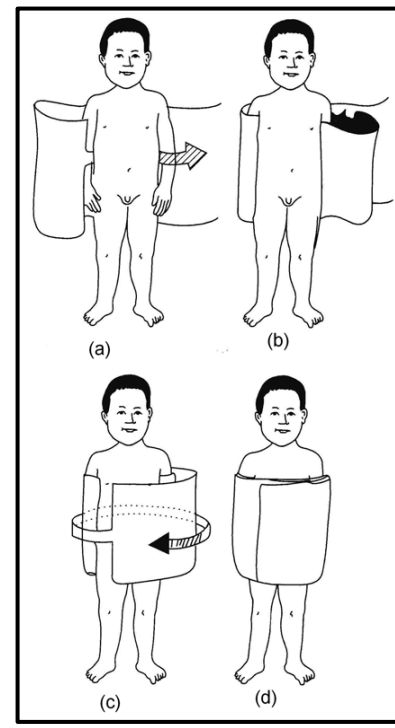
## Section 36 Restraining infants for giving analgesia and doing procedures

Restraint is important both for the infant and for the clinician who is undertaking the procedure. Clearly, the procedure will be undertaken more quickly, safely and accurately if the infant is kept still. If facilities do not allow, or if the procedure is unlikely to require repetition, physical restraint can be used. Ideally a parent or relative can actually hold the infant.

**Analgesia and sedation for procedures**

Some procedures have to be undertaken immediately, to save life. Clearly, there is no time to use analgesia in these circumstances, nor indeed much need to do so, as infants 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 34)

***FIGURE 36.1*** *Wrapping an infant 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 infant.*




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.

If ketamine is being used, give 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, 1mg/kg/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 infant's airway, beware of respiratory depression and monitor oxygen saturation with a pulse oximeter (if available). Ensure that you have a resuscitation bag and mask available (and oxygen).

Always use local analgesia if appropriate (see Section 34).

## Section 37 Tracheal intubation

**This is a procedure that must only be undertaken by a highly trained health worker, usually a nurse anaesthetist or doctor.**

*Aims*

These are as follows:

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

The correctly sized tube is one that passes easily through the glottis and subglottic area with a small air leak detectable at 20 cm$H_2O$ (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

*Aids to intubation*

1. Laryngoscope: blade (straight for neonates and infants because of long, floppy epiglottis).

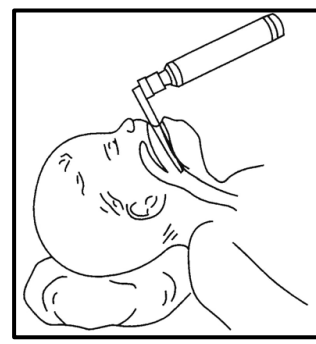


*Figure 37.1 Straight-blade laryngoscope, suitable for infants.*

2. Magill's forceps.
3. Introducer (not further than the end of the tube itself).
4. Gum elastic bougie (over which the tube can pass).
5. Cricoid pressure (can aid visualisation of larynx).
6. 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, endo-bronchial, outside of the larynx: usually then in the oesophagus
- Obstruction: kinking, secretions.
- Trauma: lips to larynx.
- Hypertensive response.
- Spasm: laryngeal, pharyngeal.
- Aspiration: gastric contents.

*Procedure*
1. Prepare and check the equipment.
2. Choose an appropriate tube size, with one size above and one size below it available.
3. Get the tape ready to fix the tube.
4. Suction must be available.
5. Induce anaesthesia and give a muscle relaxant unless the patient is completely obtunded. Do not attempt the procedure in a semi-conscious infant.
6. Position the infant. Neonates and infants: a neutral position (large occiput).
7. Oxygenate using a face mask and reservoir (if patient is breathing) or bag and mask ventilation to provide high flow oxygen.
8. Introduce the laryngoscope into the right side of the mouth.
9. Sweep the tongue to the left.
10. Advance the blade until the epiglottis is seen.
11. Straight blade: advance the blade beneath the epiglottis, into the oesophagus. Pull back, and the glottis will 'flop' into view.
12. Recognise the glottis.
13. Insert the endotracheal tube gently through the vocal cords. Must see tube pass through the vocal cords.
14. Stop at a predetermined length.
15. Confirm the correct placement.
16. The chest moves up and down with ventilation.
17. Listen to breath sounds in the axillae and anterior chest wall.
18. Confirm that there are no breath sounds in the stomach.
19. Oxygen saturation does not go down.
20. Carbon dioxide is measured from expired gases (ideal if available).

*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 and through the vocal cords.

*Fixation of endotracheal tubes*
1. Two people should be available to do this, one of whom should hold the tube at all times.
2. 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.

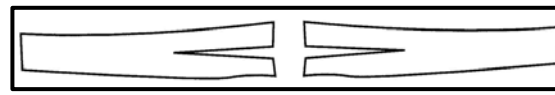
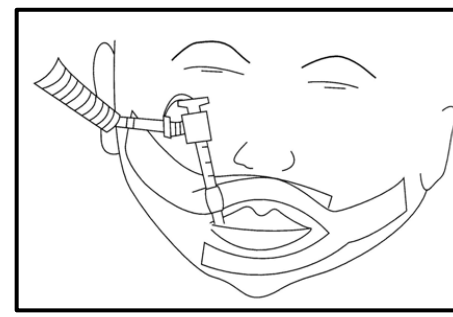


*Figure 37.2 Tape for tracheal tube fixation.*

3. If available, apply some benzoin tincture to the cheeks, above the upper lip and under the chin, which will make the tape stick well.
4. Make sure that the endotracheal tube is clean and that no old tape is left on it.
5. 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.
6. Tape the other half across the philtrum to the cheek.
7. 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 37.3 Taped tracheal tube*



## Section 38. Emergency needle thoracocentesis and chest drain

This procedure is used for the rapidly deteriorating patient who has a life-threatening tension pneumothorax. A chest X-Ray is **not** needed before this is performed as the diagnosis is made on clinical findings and X-ray leads to life threatening delay. 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 X-ray (if available) AFTER the procedure 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 38.1)

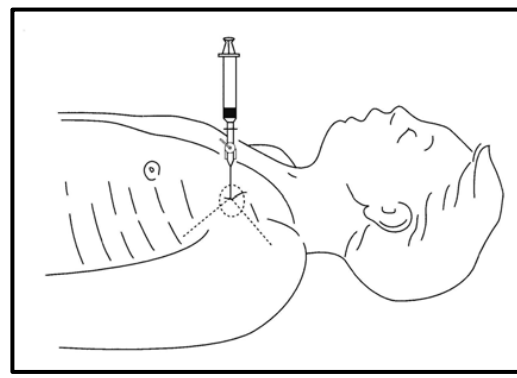


*Figure 38.1* Position for inserting over-the-needle cannula for thoracocentesis.

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
- 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 infant is conscious.
- Scissors.
- Chest drain tube.
- Underwater seal or Heimlich flutter valve.

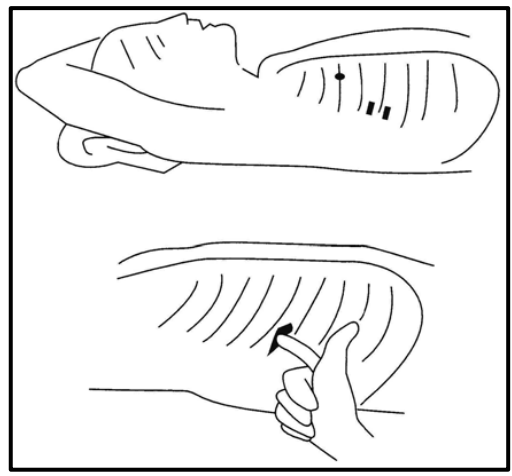


*Figure 38.2 Sites for chest drain: 4th or 5th intercostal space in the anterior or mid-axillary line.*

*Procedure*

1. Use analgesia as appropriate.
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 cm$H_2O$.
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 38.2).
5. Swab the chest wall with surgical preparation or an alcohol swab.
6. Use local anaesthetic if the infant is conscious. Morphine (50 micrograms/kg IV over 10 minutes) should be given if the infant 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 1- to 2-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. Clear the path into the pleura with 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 2-3 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 X-ray if 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 system.
- Drainage system wrongly 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 haemo-pneumothorax or result in intercostal nerve damage.
- Damage to the internal thoracic artery if the puncture is too medial, resulting in haemo-pneumothorax.
- Incorrect tube position, inside or outside the chest cavity.
- Introduction of pleural infection (e.g. thoracic empyema).
- Laceration or puncture of intra-thoracic or abdominal organs. This can be prevented by using the finger technique before inserting the chest tube.
- Leaking drainage system.
- 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).

## Section 39 Nasal Continuous positive airway pressure (nCPAP)

Nasal CPAP has a number of beneficial 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 respiratory distress (tachypnoea, recession, grunting, nasal flare)
- diseases with low FRC (respiratory distress syndrome, pneumonia, transient tachypnoea of the newborn, pulmonary oedema)
- meconium aspiration syndrome
- apnoeic/hypoxaemic episodes
- tracheomalacia.

*Requirements*
- Low-resistance delivery system.
- Large-bore tubing.
- Short and wide connection to patient.
- Consistent and reliable pressure generation.
- Appropriate snug-fitting nasal cannulae.
- Well-positioned and secured nasal cannulae.
- Optimally maintained airway.
- Warmed humidified gas.
- Prevention of neck flexion or over-extension.
- 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 are only available in a well-resourced setting. 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.

*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 infant 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 nCPAP.
- Gastric distension from swallowed air: this is important and is easily overcome by the venting of any such air via an open drainage orogastric tube.

*Insertion and securing of nasal cannulae and administration of nCPAP*

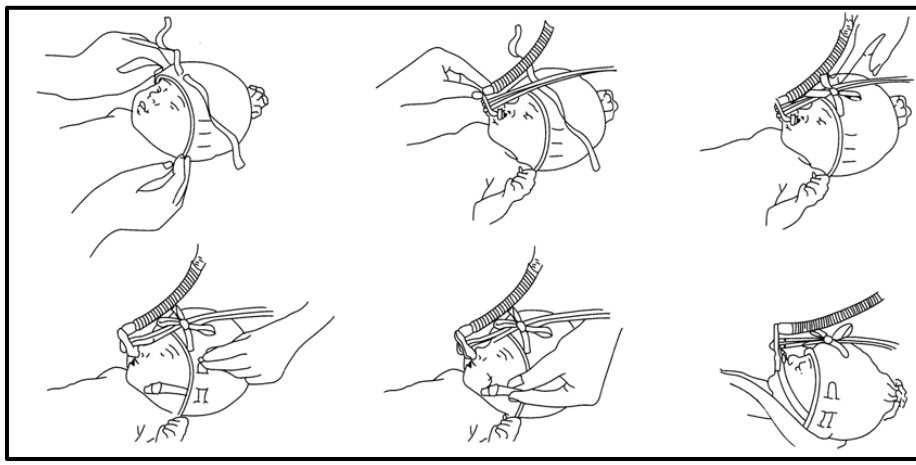


*Figure 39.1 Securing nasal cannulae for giving nCPAP in a baby. A special bonnet is used from which tapes hold the pipe carrying the air/oxygen mixture to the nasal cannulae to the forehead and a separate tape above the mouth to ensure the cannulae do not come out of the nasal passages.*

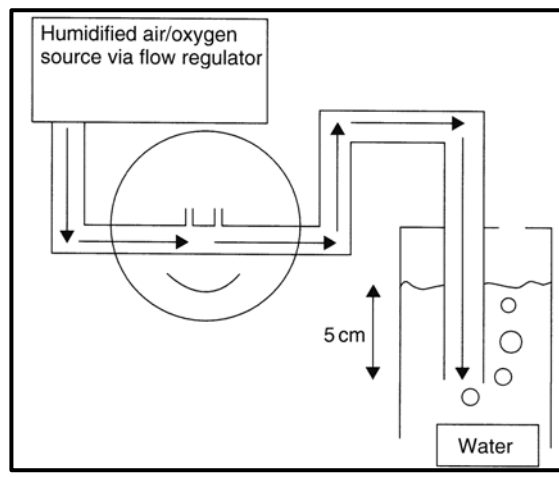



*Figure 39.2 Simplified diagram of Hudson continuous positive airway pressure (CPAP). The gas flow is adjusted until a continuous trail of bubbles starts to appear in the water bottle, which is at the same height as the baby. This generates a CPAP of +5 cmH2O.*

## Section 40 Safety when giving drugs orally, intramuscularly, and intravenously

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.

### Minimising errors in drug and fluid administration

*General points on safety*

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.
8. 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).
9. If the IV drug needs to be given rapidly 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).
10. Do not mix incompatible fluids IV.
11. For IV drug infusions (using a syringe/infusion drip monitor SN-1500 H from Sino MDT Ltd: if available) given in addition to background IV infusions:
12. Adjust the total 24-hour IV fluid intake.
13. Never allow a surge of a vasoactive drug such as dopamine or epinephrine.
14. Never put more drug or background IV into the syringe or burette than is needed over a defined period.
15. Check and chart the rate of infusion and confirm this by examining the amount left every hour.
16. 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 and 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 or lidocaine).

*Care of intravenous cannulae*

- 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.
- 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.
- *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 lines are particularly dangerous. There must be always a tap or syringe on the catheter, especially during insertion.
  An alternative source of air embolus is through the giving set, especially when pumps are being used.
- *Blood loss.*
  In neonates this can occur from the umbilical stump.
  From umbilical 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 always observable.
  Arterial lines must only be in place if there are sufficient trained staff available and should be connected to a pressure transducer and alarm.

*Use of intravenous IV access*

- When sampling from an IV 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.
- Certain infusions, such as glucose > 10%, adrenaline and dopamine, are better given through an umbilical vein. In an emergency, dopamine and adrenaline infusions can be given through a peripheral vein.
- 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).
- 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), (always use Luer lock connections to minimise extravasation).

- To maintain patency, a continuous low-rate (0.5–1.0 mL/hour) infusion of 0.9% saline is useful. Clear the 1-mL dead space of the catheter before and after sampling, which must be done aseptically.
- In neonates, frequent flushing with saline 0.9% can result in sodium overload. Therefore, consider using 0.18% saline to achieve flushing.
- Do not add drugs to any line containing blood or blood products.
- 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).
- 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 0.9% saline. 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 a cardiac arrhythmia).
- 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 combination of drugs in question.

*Minimising IV infusion and IV drug 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*
1. Prescribe or change infusion rates as infrequently as possible, ideally no more than once or twice daily.
2. 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).
3. Use a burette in which no more than the prescribed volume is present (especially in infants).
4. Record hourly the amount given (from the burette, syringe or infusion bag) and the amount left.
5. Check the infusion site hourly to ensure that extravasation has not occurred.
6. Ensure that flushes are only used when essential and are given slowly over at least 2 minutes.
7. Ensure that flushes do not overload the patient with sodium.
8. Be particularly careful with potassium solutions given IV (use the enteral route whenever possible).
9. 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 can check the prescription chart.)
- Is it the correct syringe? (Deal with one patient at a time.)
- Is the IV line open?
- Is a separate flush needed? If so, has the flush been checked?

- Are sharps (including glass ampoules) safely disposed of?
- Has it been signed off as completed (and ideally counter-signed)?

*Writing a prescription*

1. Use block capitals.
2. Use approved names.
3. The dosage should be written in grams (g), milligrams (mg) or micrograms. Always write micrograms in full.
4. Volumes should be written in millilitres (mL).
5. 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.
6. Write times using the 24-hour clock.
7. Routes of administration can be abbreviated as follows: IV (intravenous), IM (intramuscular), PO (orally), SC (sub- cutaneous), NEB (nebuliser), RECT (rectally).
8. 'As required' prescriptions must be specific about how much, how often and for what purpose (indicate the maximum 24-hour dose).
9. Each drug should be signed for individually by a registered/licensed doctor or other qualified professional.
10. Stop-dates for short-course treatments should be recorded when first prescribed.

## Section 41 Giving injections to the neonate

Wash your hands thoroughly. **MUST 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 infants, 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 41.1 Holding a child for an intramuscular injection in the thigh.*

*Subcutaneous route (Figure 41.2)*
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.

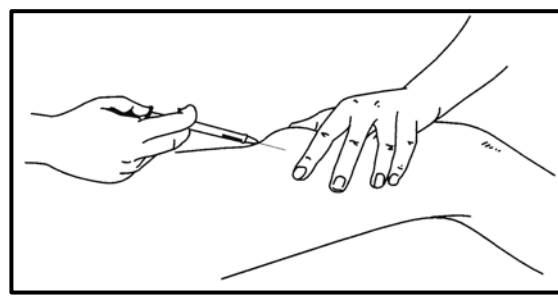


*Figure 41.2 Giving a subcutaneous injection.*

*Intra-dermal route (Figure 41.3)*
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.

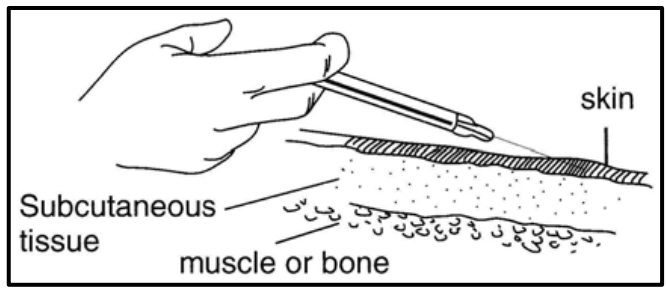



*Figure 41.3 Giving an intradermal injection*

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## Section 42 Gaining circulatory access by peripheral venous cannulation

*Preparation of kit*

The following equipment is needed:

- 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

*Procedure*

1. Apply the tourniquet to distend the vein (do not forget to remove it after cannulation).
2. Choose a vein:
   - forearm
   - long saphenous vein (anterior to the medial malleolus)
   - back of the hand or front of the wrist
   - scalp.
3. 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.
4. If possible, place the cannula close to the bone where it is more fixed.
5. Decide the direction of blood flow.
6. Clean the skin with antiseptic.
7. Fix and slightly stretch the skin with your other hand.
8. Pass the cannula through the skin at a slight angle (10–20 degrees). Be decisive.
9. Stop once you are through the skin.
10. Flatten the cannula to the skin and advance with the long axis of the cannula in the same direction as the vein. Be decisive.
11. Aim to pass it into the vein at the first attempt with steady advancement.
12. Always watch for blood appearing in the hub of the cannula.
13. As soon as blood is seen, stop.
14. Hold the needle still and advance the cannula over the needle until the hub is at the skin.
15. Hold the cannula still.
16. Withdraw the needle.
17. Connect the connector, flush and fix. No subcutaneous swelling should be seen and there should be no resistance to injection.
18. If no blood is seen on advancing the cannula, but it is felt to be beyond the vein, stop.
19. 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).
20. 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.
21. 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.
22. When splinting, try to 'double back' the tape (that is 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.

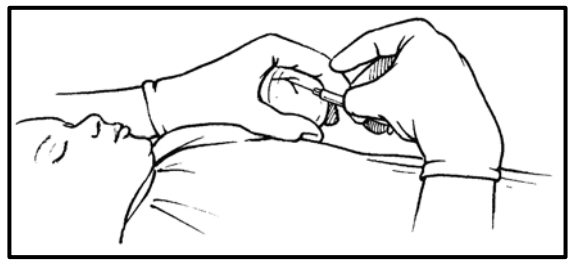


*Figure 42.1 Inserting an intravenous cannula into a vein on the back of the hand. The hand is flexed to obstruct venous return and thus make the veins visible.*

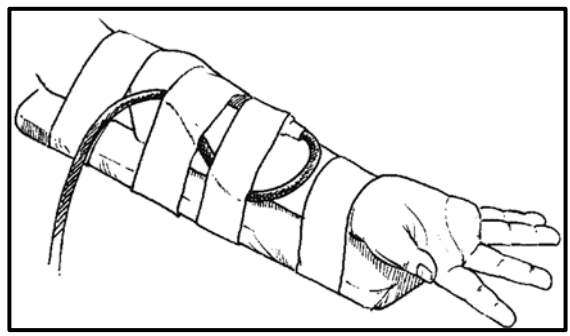


*Figure 42.2 Arm splinted to prevent bending of the wrist.*

*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 near-by 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.

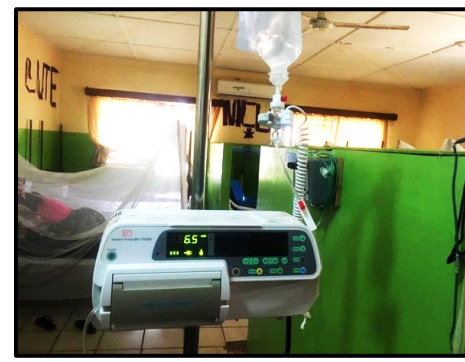
*Common complications*
Superficial infection of the skin at the cannula site is the commonest complication. The infection may lead to thrombophlebitis, which will occlude the vein and result in fever, and may progress to septicaemia. The surrounding skin is red and tender. Remove the cannula immediately 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.
A useful device to reliably count the drops of IV fluid administered from a standard giving set is valuable in neonatal intensive care (for example device SN-1500H from Sino MDT Ltd. supplied by Diamedica) see Figure 42.3.

Figure 42.3 Drip rate infusion monitor



***Special sites for IV cannulae***

**Scalp veins**
*Procedure*
1. Restrain the infant.
2. Shave the appropriate area of the scalp with a sterile razor.
3. Clean the skin.
4. Have an assistant distend the vein by holding a taut piece of tubing or bandaging perpendicular to it, proximal to (nearest to the infant's body) the site of puncture.
5. Fill the syringe with Ringer-lactate or Hartmann's solution or 0.9% saline and flush the butterfly set.
6. Disconnect the syringe and leave the end of the tubing open.
7. Puncture the skin and enter the vein. Blood will flow back through the tubing.
8. Infuse a small quantity of fluid to see that the cannula is properly placed and then tape it into position.
9. 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.

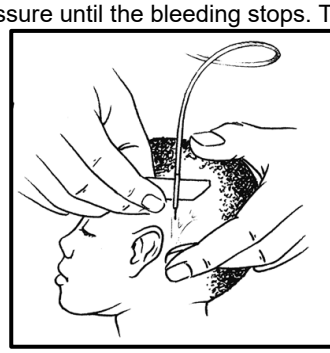


*Figure 42.4 Inserting a scalp vein needle.*

Scalp vein cannulae are generally more vulnerable 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 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 cannulation**

*Procedure*

1. Place infant 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 infant (see above).
2. Turn the head away from the site of puncture. Restrain the infant 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 infant, so use plenty of tape!

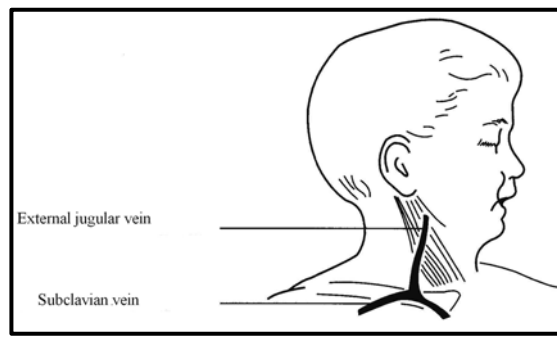



Figure 42.4 Position of the external jugular vein.

Be aware that there is a higher risk of air embolism through an external jugular vein 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 infant alive:

- set up an intra-osseous infusion
- use the umbilical vein if less than 7 days old
- or use a central vein (**but only if you are skilled as access can be dangerous)**
- or perform a venous cut-down.

All of these procedures are described in Sections 43, 44 and 45 below.

## Section 43 Long saphenous vein cut-down cannulation

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

*Preparation of kit*
The following equipment is needed:

- skin preparation (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.

**Long saphenous vein:**

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) 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 (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 infant is conscious). Cover with sterile dressing.

* It is also possible not to use 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.

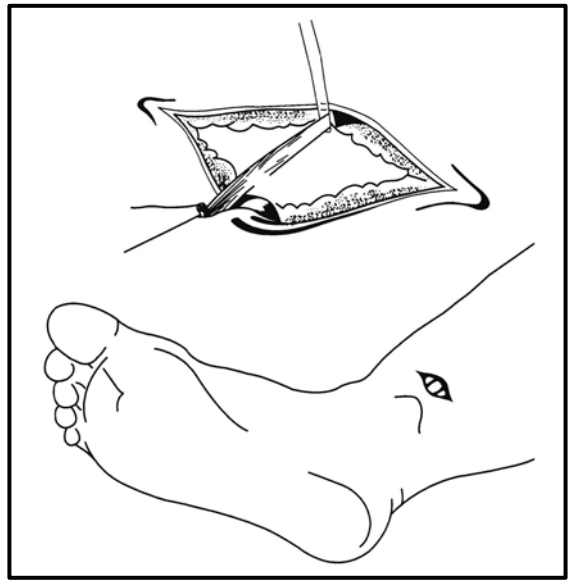


*Figure 43.1 Cut-down incision showing vein: position of cut- down on long saphenous vein at ankle.*

*Complications*
These include the following:

- haemorrhage or haematoma
- perforation of the posterior wall of the vein
- nerve transection
- phlebitis
- venous thrombosis

## Section 44 Umbilical vein cannulation

*Indications*
Where there is urgency during resuscitation of the newborn to give IV fluids and drugs. Temporarily in the neonate 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
- 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.

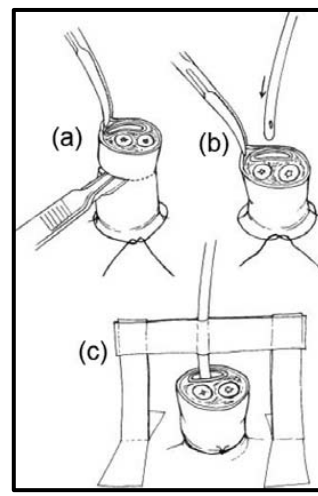



*Figure 44.1 Insertion and securing of a catheter in the umbilical vein. (a) Preparation of the umbilical cord. (b) Inserting the catheter into the umbilical vein, which is the larger thin-walled structure towards the head. Note the two umbilical arteries, which are thick-walled and towards the legs 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 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.
11 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.
12 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 umbilical vein 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*

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.

## Section 45 Intra-osseous needle insertion

Intra-osseous infusion is a safe, simple and reliable method of giving fluid and drugs in an emergency in the neonate 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.

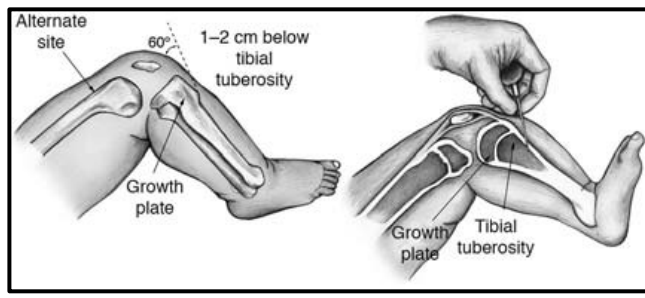



*Figure 45.1 (a) Intra-osseous needle tibial site (X). (b) Section through bone.*

*Other equipment needed*
This includes the following:

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

*Procedure*

1 Place padding under the infant'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 45.1).
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 infant 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 2-5-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.
15 Do not place distal to a major fracture or where there is infection.
16 Give prophylactic antibiotics after the immediate emergency has been managed.
17 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.
18 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.

*Battery-powered intra-osseous device*
The EZ-IO drill is a battery powered device that enables rapid insertion of an intra-osseous needle.
Unfortunately, the disposable needles are extremely expensive for low resource settings.
Various sizes of needle are available (see Handbook 1) for different-sized patients.

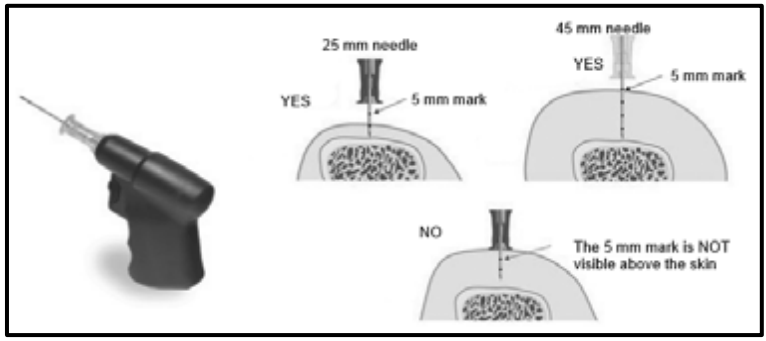



*Figure 45.2 EZ-IO power drill and needles.*

The landmarks are as before, using the upper end of the tibia.

The procedure is less painful for the conscious patient due to its rapidity, the drilling effect and the sharpness of the needles.

*The procedure for insertion is as follows:*
Take universal precautions for sterile procedure.

1 Clean the site.
2 Choose an appropriate size of needle and attach it to the drill. It will fix magnetically.
3 Remove the safety cap from the needle.
4 If the patient is conscious, control their movement during insertion.
5 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.
6 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.
7 If the driver stalls and will not penetrate the bone you may be applying too much downward pressure.
8 If the driver fails (this is rare) remove it, grasp the needle kit by hand and twist it into the bone marrow.
9 Remove the drill and unscrew the stylet.
10 Aspirate the bone marrow, if possible, directly from the needle.
11 Attach the pre-prepared connection tube containing sterile Ringer-lactate or Hartmann's solution or 0.9% saline before any infusion is given.

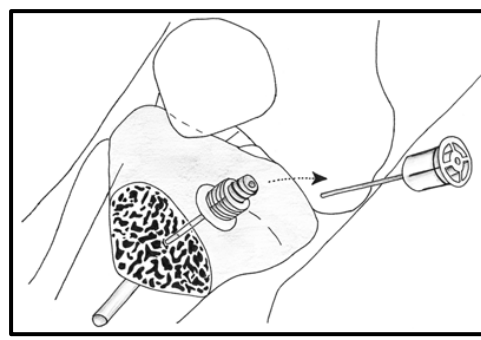


*Figure 45.3 EZ-IO needle in place, with stylet removed.*

12 Do not attach a syringe directly to the EZ-IO catheter hub except when drawing blood with the needle set stabilised by hand (sterile).
13 There is an optional device for securing the needle, but this is not essential.
14 Proceed with the required therapy. It should be noted that rapid infusion of fluid may be painful for the conscious patient.
15 Apply a sterile dressing.
16 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.
17 Do not leave the catheter in place for more than 24 hours.

## Section 46 Insertion of an orogastric or nasogastric tube

A nasogastric tube is used to feed any infant 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.

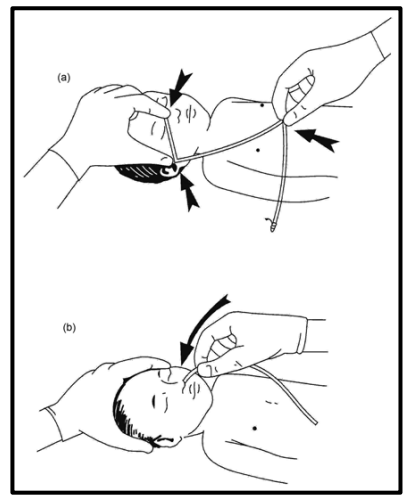



*Figure 46.1 Inserting a nasogastric tube. (a) The distance from the nose to the ear and then to the epigastrium is measured. (b) The tube is then inserted to the measured distance.*

*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 infant 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 infant 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 infant 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.

8 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).

9 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.

10 Never use high pressure suction to remove fluid from the stomach. This can damage the inside wall of the stomach and lead to bleeding or ulceration.

## Section 47 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

*Indications*

- As part of septic screen in case meningitis is present.
- For investigating the possible cause of seizures.
- For investigating the possible cause of apnoea/hypoxaemic episodes due to meningitis.

*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 antibiotic 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)
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*
The infant lying down on the left side

*Figure 47.1 Holding an infant lying on their left side for a lumbar puncture. Note that the spine is curved to open the spaces between the vertebrae.*

1 When the infant is lying on their side a hard surface should be used.
2 Place the infant on their side so that the vertebral column is parallel to this surface and the transverse axis of the back is vertical (see Figure 47.1).
3 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 infant 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.
4 *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 should be used.

5 *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.)
6 Use an LP needle with a stylet (22 gauge for a young infant, and 20 gauge for an older infant; 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.
7 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.
8 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 success- fully 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.
9 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.
10 Replace the stylet.

11 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.
12 Send samples for the following: microscopy, cell type and counts, Gram and Ziehl-Neelson staining, culture, and sensitivity (including for TB) and virology: biochemistry (glucose, protein levels).

## Section 48 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.

*Procedure*
1 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,
2 Do this only in an infant 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.
3 Have a clean urine jar ready in case the infant passes urine during the procedure.

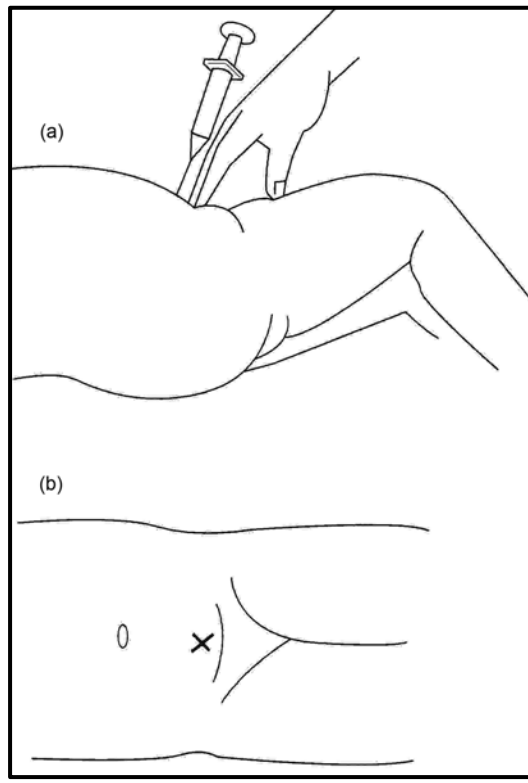



Figure 48.1 Position for carrying out suprapubic aspiration of urine in an infant. (a) Side view. (b) Abdominal view. Note the angle of insertion of the needle.

## Section 49 Helping families when a baby dies before or after birth

*Introduction*
Often it is felt that a little amount of life equates with a little amount of loss, but nothing could be further from the truth. When a baby is stillborn, dies during labour or soon after the time of birth, the impact on the parents is huge. They grieve for a whole future that will never be fulfilled.

Hospital staff may think it is best to say nothing or as little as possible to a mother when a baby has died. This is partly so as not to intrude, and partly as a protection against the painful feelings that other people's distress always arouses in us. Relatives and friends may believe that they are protecting a mother by hiding feelings and not talking about the loss.
However, we know that acknowledging the baby's life and death, and helping the parents to accept the reality, also helps them to accept their painful feelings and grieve for the baby. Talking to parents about their baby, even if he or she was stillborn or had a very short life, gives recognition to their role as mother and father, and acknowledges the baby's place in the family.

*What is mourning?*
This has been defined as the emotional process that occurs after a loss. William J Worden is a psychologist, who has studied bereavement and grief. He believes that mourning is an essential, although painful, healing process, which can be achieved through a series of tasks.

1. Facing Reality
2. Experiencing the pain of grief, as well as sadness, this may include feelings of anger and guilt.
3. Adjusting to the new reality
4. Re-investing in the future and moving on with life. This doesn't mean forgetting the baby who has died but it means putting sadness aside and looking to the future.

It is important and helpful in the long term that the bereaved person gradually accepts the reality of the death, to allow them to begin the task of adjustment. Being able to see their dead baby, being involved in preparations for the funeral, and observing rituals and traditions, all help people to face the reality of what has happened.

*How do parents react to the news that their baby has died?*
People react in different ways when told the news that their baby has died. Some may react strongly, crying or shouting or even collapsing. Others may react in the opposite way, appearing controlled or detached. Sometimes parents deny, or refuse to talk about, what has happened.

*How can nurses and doctors help?*
Nothing we can do can make everything better or take away the bereaved parents' pain. Our role is to help them through the tasks of grieving. To do this we need to allow them to express their feelings of sadness.
It does not help to put off mentioning the baby's death, or to avoid talking about what has happened. Instead, we should try to listen in a supportive and caring way.

*How can we become good listeners?*
We need to make time for listening, not hurrying away or implying that we are busy.
We need to listen with our ears, listening to the words, the tone of voice and the feelings being conveyed by the bereaved person.
We need to listen with our eyes, looking at the person, and letting them know that we are concentrating on what they are saying.

We need to listen with our heart, communicating our interest by our own voice and body language.

Everyone is different. Nurses and doctors need to give the bereaved person 'permission' (? the opportunity) to express their feelings in their own way. We must be patient, as stress can make it hard to take in bad news, and it may be necessary to repeat what you have said more than once. It can be useful to ask the parent to tell you what they have understood from you. This way you can be sure that what they heard and understood was correct.

*Helpful Memories.*
When a baby is stillborn or dies after only a very short life, it can be particularly difficult for parents to have good memories to hold onto as they struggle to adjust to what has happened.
Mothers often remember vividly every detail of the labour the birth and afterwards. Parents have said how much it meant to them when nurses and doctors were kind and gentle with them and told them all they could about what had happened to their baby. In contrast, if staff were harsh, hurried or not willing to listen to them and answer their questions, their pain was made worse.
Parents should be given time and privacy to be with their baby even after death. The baby's body after death should be handled with as much care and respect as before death. If they want to, parents should be helped to look at their baby, hold, dress and even take a photograph of him or her. They may be afraid and need your encouragement to touch their baby.
It is not helpful to take the body away before the mother has had time to see her baby. This is the only time she will ever have with him or her, and the memories she has are important to help her to accept the reality of what has happened.

*How can professionals help each other?*
It is difficult to know what to say to a grieving family, and we all feel inadequate when faced with this uncomfortable task.
Most professionals will themselves have had the experience of loss and grief and some will have had a baby who died. Seeing someone else's grief can remind us of our own loss, and make us reluctant to involve ourselves, but awareness of our own feelings will help us to care for families.
As a team of professionals, we should be able to offer each other support and understanding. It is not a weakness to want to share difficult experiences, and we can learn from each other. We need to try to make time to do this.
It is not necessary to be a 'trained counsellor' to help parents when their baby dies, but we do know for certain that the way we behave with them will make a difference to how they feel later about this sad event.
We can all learn to be gentle, to listen well and to give time to the bereaved family.

*14th June 2018 from Dr. Alison Earley MBBS FRCP FRCPCH DTM&H. Consultant* ***paediatrician and MCAI volunteer in the advanced neonatal training programme, Liberia.***