Advanced life support for children and pregnant mothers

Introduction
As described in Section 1.12 on basic life support, the pregnant mother in cardiac arrest has usually suffered from the same deranged pathophysiology as the arrested child (i.e. respiratory or circulatory collapse rather than a primarily cardiac event).

The ‘child’ type of cardiac arrest is seen in almost all children (excluding those rare arrhythmic events in children with congenital or acquired heart disease, and those in whom sudden, unexpected collapse is preceded by apparent normal respiratory and circulatory function), and in adults who have a terminal acute illness involving respiratory or circulatory pathology. This includes patients who have had convulsions, trauma (including drowning), poisoning, bleeding, sepsis, etc.

In addition, there is international agreement that, where possible, guidelines on resuscitation of patients with cardiac arrest should be simplified, as there is evidence that complex guidelines cause ‘provider paralysis’, resulting in no or poor life-saving effort being made.

In view of this, the Advanced Life Support Group (ALSG)/Maternal Child Health Advocacy International (MCAI) programme for resource-limited countries teaches a programme of basic life support (BLS) and advanced life support (ALS) for infants, children and pregnant mothers which reflects the known pathologies in these groups (i.e. respiratory and circulatory causes of cardiac arrest) and recognises that the clinicians who provide resuscitation attend patients of all ages.

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, child or mother who has a problem of the airway or breathing (see Section 1.11).

Airway: equipment and skills for opening and maintaining the airway
Essential airway and breathing equipment includes the following:
- face masks (ideally with reservoirs)
- airways, including laryngeal mask airways (LMAs) if anaesthetic skills are available
- self-inflating bag-valve-mask devices
- tracheal tubes, introducers and connectors
- laryngoscopes
- Magill’s forceps
- suction devices
- surgical airway packs for performing an emergency surgical airway.

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
There are two main types of pharyngeal airway, namely oropharyngeal (see Figures 1.13.1 and 1.13.2) and nasopharyngeal.

Airway: equipment and skills for opening and maintaining the airway
In the awake 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 incisors, then curved around the face, will reach the angle of the mandible. Too small an airway may be ineffective, and too large an airway may cause laryngospasm. Either may cause mucosal trauma or may worsen airway obstruction. Reassessment following placement is therefore a vital part of safe insertion of an airway device.

There are two methods for inserting an oropharyngeal airway in children, depending on whether the child is small or large. However, there is no specific age of transition from one to the other – the choice of method depends on practicality and the skills of the operator. The important point is not to push the tongue back by inserting the airway carelessly.

The twist technique is used for larger children and in pregnant mothers. With this technique the convex side of the airway is used to depress the tongue as the airway is pushed into the mouth. The airway should be inserted upside down until the tip has passed the soft palate, and then rotated through 180 degrees so that the natural curve of the Guedel airway follows the curve of the tongue and pharynx (see Figure 1.13.3).

![Figure 1.13.3 Oropharyngeal airway shown being inserted concave side up, then in place concave side down.](image)

However, in infants and small children, 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 a spatula and not by the convex side of the airway (see Figure 1.13.4).

![Figure 1.13.4 When inserting the airway without rotation, a tongue depressor can be helpful (not shown).](image)

Nasopharyngeal airways
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. 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. If it does not improve the airway as shown by improved breathing, then a reappraisal of the choice or size of airway is urgently required.

In pregnant mothers, the nasopharyngeal tube is not commonly used, because of the tendency for nasal mucosal bleeding to occur in pregnancy.

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. 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.

Tracheal tubes
Uncuffed tubes should be used during resuscitation, by operators who do not have paediatric anaesthetic experience, for children up to approximately 10 years of age. If the operator is familiar with cuffed tube placement, both cuffed and uncuffed tubes are acceptable for infants and children undergoing emergency intubation, but not for neonates. Up until the age of around 10 years, 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.

The appropriate size of an uncuffed tracheal tube is estimated as follows:

\[
\text{internal diameter (mm)} = \frac{(\text{age in years})}{4} + 4
\]

\[
\text{length (cm)} = \frac{(\text{age in years})}{2} + 12 \quad \text{for an oral tube}
\]

\[
\text{length (cm)} = \frac{(\text{age in years})}{2} + 15 \quad \text{for nasal tube}
\]
These formulae are appropriate for ages over 1 year. Neonates usually require a tube of internal diameter 3–3.5 mm, although preterm infants may need one of diameter 2.5 mm. Cuffed tubes should not be used in neonates.

For cuffed tracheal tubes, the appropriate internal diameter for children aged 2 years or older is estimated as follows:

\[
\text{internal diameter (mm)} = \frac{\text{age in years}}{4} + 3.5.
\]

For infants of weight over 3 kg and up to 1 year in age a size 3 cuffed tube is usually acceptable, and for those aged 1–2 years a size 3.5 cuffed tube can generally be used.

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 prepare one a size smaller and one a size larger.

In the case of resuscitation in a young child 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.

In pregnant mothers, cuffed tubes must be used because of the high risk of gastric reflux in the pregnant patient causing aspiration of acidic gastric material and severe respiratory problems.

**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 and malleable 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 Selénder-type 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.

In pregnant mothers:

1. A 15 French bougie should be used for endotracheal tube sizes 6.0–11.0.
2. Lubricate the bougie with KY jelly.
3. Perform laryngoscopy. If the cords are not visible, identify landmarks to aid intubation.
4. Place the bougie into the pharynx and direct it into the larynx. If necessary, bend the bougie to negotiate the corner. Correct placement may be confirmed by detection of tracheal ‘clicks’ and ‘hold-up’ of the bougie (the absence of hold-up indicates oesophageal placement).
5. Hold the tube firmly in place and gently withdraw the bougie.
6. Remove the laryngoscope and confirm tube placement as usual.

**Tracheal tube connectors**

In pregnant mothers, 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.

The same standard system exists for children, including neonates.

**Magill’s forceps**

Magill’s forceps (see Figure 1.13.5) 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 supraglottic 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 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), 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 both adult and paediatric sizes. It may have a side hole, which can be occluded by a finger, allowing greater control over vacuum pressure.

**Tracheal suction catheters (see Figure 1.13.6)**

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).
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, surgical cricothyroidotomy and surgical tracheostomy) are described in Section 8.2.

Breathing: equipment and skills for helping the patient 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 patients:

- with respiratory distress (severe indrawing 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 children with dark skin)
- who are shocked
- who are fitting
- who are unconscious, with abnormal oxygen saturation (SaO₂) on a pulse oximeter.

Ideally, where the resources for this are available, oxygen therapy should be guided by pulse oximetry (see below). Give oxygen to children with an SaO₂ of < 94%, and aim to keep SaO₂ at 94–98% (except at high altitude, where normal oxygen saturation levels are lower). 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 available at all times. The two main sources of oxygen are cylinders and oxygen concentrators.

Oxygen cylinders contain compressed gas. A flow meter 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 (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 may be available. They 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.

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 (www.ogsi.com).

Oxygen delivery

A mask with a reservoir bag (see Figure 1.13.7) 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.

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 (with a delivery rate of up to 15 litres/minute) can be given. Hold the mask in place using the
elastic strap around the back of the head or, in the case of a young child, ask the mother to hold it as close as possible to the child’s face.

Nasal cannulae (also known as nasal prongs) (see Figure 1.13.8) are the preferred method of delivery in most circumstances, as they are safe, non-invasive, reliable and do not obstruct the nasal airway. Head boxes are not recommended, 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**

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:

- $\text{SaO}_2$ 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 child 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. The response to oxygen therapy in lung disease can be measured with the pulse oximeter, as the patient’s $\text{SaO}_2$ should increase (in patients with cyanotic heart disease, $\text{SaO}_2$ does not change when oxygen is given). The oxygen flow can be titrated using the pulse oximeter as a monitor to obtain a stable $\text{SaO}_2$ of 94–98% without giving too much oxygen. This is especially important in pre-term babies with respiratory disease (see Section 3.4).

**Assessment of oxygenation at and above sea level**

A systematic review in 2009 found an $\text{SpO}_2$ 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.

<table>
<thead>
<tr>
<th>Altitude</th>
<th>Location</th>
<th>n</th>
<th>Age</th>
<th>$\text{SpO}_2$ (%)</th>
<th>Author</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea level</td>
<td>UK</td>
<td>70</td>
<td>2–16 (mean, 8) years</td>
<td>Range, 95.8–100 Median, 99.5</td>
<td>Poets et al.</td>
<td>1993</td>
</tr>
<tr>
<td>Sea level</td>
<td>Peru</td>
<td>189</td>
<td>2 months to 5 years</td>
<td>Range, 96–100 Mean, 98.7</td>
<td>Reuland et al.</td>
<td>1991</td>
</tr>
<tr>
<td>1610 m</td>
<td>Colorado</td>
<td>150</td>
<td>&lt; 48 hours 3 months</td>
<td>95% CI, 88–97 Mean, 93 95% CI, 86–97 Mean, 92.2</td>
<td>Thilo et al.</td>
<td>1991</td>
</tr>
<tr>
<td>1670 m</td>
<td>Nairobi</td>
<td>87</td>
<td>7 days to 3 years</td>
<td>Range, 89.3–99.3 Mean, 95.7</td>
<td>Onyango et al.</td>
<td>1993</td>
</tr>
<tr>
<td>2640</td>
<td>Bogota</td>
<td>189</td>
<td>5 days to 2 years</td>
<td>Range, 84–100 Mean, 93.3</td>
<td>Lozano et al.</td>
<td>1992</td>
</tr>
<tr>
<td>2800</td>
<td>Colorado</td>
<td>72</td>
<td>3–670 days</td>
<td>Range, 88–97 Mean, 91.7</td>
<td>Nicholas et al.</td>
<td>1993</td>
</tr>
<tr>
<td>3100</td>
<td>Colorado</td>
<td>14</td>
<td>6 hours to 4 months 1 week to 4 months</td>
<td>Range, 81–91 Mean, 80.6±5.3 Mean, 86.1±4.6</td>
<td>Niemeyer et al.</td>
<td>1993</td>
</tr>
<tr>
<td>3658</td>
<td>Tibetb</td>
<td>15</td>
<td>6 hours to 4 months</td>
<td>Immigrant, 76–90 Indigenous, 86–94</td>
<td>Niemeyer et al.</td>
<td>1995</td>
</tr>
<tr>
<td>3750</td>
<td>Peru</td>
<td>153</td>
<td>2–60 months</td>
<td>Range, 81–97 Mean, 88.9</td>
<td>Reuland et al.</td>
<td>1991</td>
</tr>
</tbody>
</table>

Values given are those in quiet sleep.

*Ranges refer to those born to immigrant Chinese mothers and to those indigenous babies whose families have lived at that altitude for innumerable generations.*
Duration of oxygen therapy

Continue giving oxygen continuously until the patient is able to maintain an $\text{SaO}_2$ of 94% or higher in room air. When the patient is stable and improving, take them off oxygen for a few minutes. If the $\text{SaO}_2$ 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 1.13.9)

These face masks are used for either mouth-to-mask or, more commonly, 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. Children’s masks should be clear so that the child’s colour or the presence of vomit can be seen.

A pocket mask is a single-size clear plastic mask with an air-filled cushion rim designed for mouth-to-mask resuscitation. It can be supplied with a port for attaching it to an oxygen supply, and can be used in adults and children. It can be used upside down to ventilate infants.

Self-inflating bags (see Figure 1.13.10)

This is one of the most important pieces of equipment, allowing hand ventilation by face mask without a supply of gas. The two appropriate sizes are 500mL and 1600mL (the smaller size for infants under 1 year of age, and the larger size for children and mothers). There is also a 250mL 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 overridden if necessary for stiff, poorly compliant lungs by loosening the screw at the top.

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 98%) 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 3.2).

It is also important to clean the system after each patient.
Section 1.13

FIGURE 1.13.13 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 to try is to readjust the head-tilt/chin-lift position and try again. If this is not successful, the jaw-thrust manoeuvre should be tried (see Figure 1.13.13). Failure of both the head-tilt/chin-lift and jaw-thrust manoeuvres should lead to suspicion that 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 cases with a significant haemothorax or pneumothorax (particularly tension pneumothorax), ventilation may be compromised and insertion of a chest drain is mandatory (see Section 8.3).

Gastric tubes
Insertion of a gastric tube is essential after intubation, and may also relieve respiratory distress in spontaneously breathing patients 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 Section 5.2.B (on spacers and nebulisers), Section 8.3

SAFETY
Approach with care
Free from danger?

STIMULATE
Are you all right?

SHOUT
for help

Airway-opening manoeuvres

Look, listen, feel

5 rescue breaths

Check for signs of life
Check pulse
Take no more than 10 seconds

CPR
15 chest compressions: 2 ventilations

VF/ pulseless VT
Assess rhythm
Asystole/ PEA
Non-shockable

FIGURE 1.13.14 Initial approach to cardiac arrest. CPR, cardiopulmonary resuscitation; VF, ventricular fibrillation; VT, ventricular tachycardia; PEA, pulseless electrical activity.
Circulation: equipment and skills for maintaining the circulation
Details of how to undertake the following procedures are covered in Section 8.4:
- peripheral venous cannulation
- blood sampling from an IV catheter
- intraosseous cannulation and infusion
- cutdown long saphenous venous cannulation
- insertion of central venous catheters
- needle pericardiocentesis.

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 (see Figure 1.13.14).

Four cardiac arrest rhythms can occur:
1. asystole
2. pulseless electrical activity (including electromechanical dissociation)
3. ventricular fibrillation
4. pulseless ventricular tachycardia.

These are divided into two groups. Asystole and pulseless electrical activity, which do not require defibrillation, are called ‘non-shockable’ rhythms. Ventricular fibrillation and pulseless ventricular tachycardia, which do require defibrillation, are called ‘shockable’ rhythms.

Non-shockable cardiac arrest
Asystole
This is the most common cardiac arrest rhythm in infants and children, and in pregnant mothers. 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 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 1.13.15). 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.

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 complexes that normally produce a pulse (see Figure 1.13.16). PEA is treated in the same way as asystole, and is often a pre-asystolic state.

PEA in children and pregnant mothers is often due to major trauma, often with an identifiable and reversible cause such as severe hypovolaemia, tension pneumothorax or pericardial tamponade. PEA is also seen in hypothermic patients and in those with electrolyte abnormalities. It may be seen after massive pulmonary thromboembolus.

Management of asystole/PEA in children and pregnant mothers
The first essential step is to establish ventilations and chest compressions effectively. Ensure a patent airway, initially using an airway manoeuvre to open the airway and 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:ventilation ratio of 15:2. 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 middle of 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, give adrenaline 10 micrograms/kilogram (0.1 mL of 1:10 000 solution/kg) intravenously or intra-osseously in children and 1 mg IV in pregnant mothers. Adrenaline increases coronary artery perfusion, enhances the contractile state of the heart and stimulates spontaneous contractions. The drug is best given through a central line, 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 (2–5 mL).

If there are signs of life, check rhythm
If there is perfusable rhythm, check pulse
If possible, intubate
Assess rhythm
Continue CPR
ROSC
Post cardiac arrest treatment

FIGURE 1.13.15 ECG appearance of asystole.

FIGURE 1.13.16 Pulseless electrical activity (PEA) in a child with no pulse or signs of life.

FIGURE 1.13.17 Algorithm for the treatment of non-shockable (asystole and PEA) rhythms in children. Doses of drugs used in pregnancy are given in the text above. CPR, cardiopulmonary resuscitation; IV, intravenous; IO, intra-osseous; ROSC, return of spontaneous circulation.
If available, and as soon as is feasible, a skilled and experienced operator should intubate the patient'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 10–12 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 1.13.17.

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 below), 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 monitor. 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 12–20 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 children and 1 mg IV in pregnant mothers.

In pregnant mothers, if there is asystole or a slow heart rate (< 60 beats/minute), give atropine 3 mg IV just once to counteract any excessive vagal tone.

Reversible causes of cardiac arrest

The causes of cardiac arrest in childhood and pregnancy 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. In the trauma setting, cardiac arrest may be caused by severe hypovolaemia, tension pneumothorax or pericardial tamponade.

It is often appropriate to give an early IV bolus of Ringer-lactate or Hartmann's solution (10 mL/kg in a child and 500 mL to 1 litre in a mother, depending on her weight), as this will be supportive in cases related to severe hypovolaemia. In addition, however, a tension pneumothorax and/or pericardial tamponade require 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, tension pneumothorax and pericardial tamponade 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. Hypoxia is a prime cause of cardiac arrest in childhood, and its reversal is key to successful resuscitation.
2. Hypovolaemia may be significant in arrests associated with trauma, gastroenteritis, pregnancy-related haemorrhage, anaphylaxis and sepsis. It requires infusion of crystalloid, and in the case of haemorrhage, blood should be given.
3. Hyperkalaemia, hypokalaemia, hypocalcaemia, acidemia, hypermagnesaemia (following excess magnesium sulphate in eclampsia) and other metabolic abnormalities may be suggested by the patient’s underlying condition (e.g. renal failure, eclampsia), tests taken during the resuscitation or clues from the ECG. Intravenous calcium (0.2 mL/kg of 10% calcium gluconate in children and 10 mL of 10% calcium gluconate in pregnant mothers) is indicated in cases of magnesium overdose, hyperkalaemia and hypocalcaemia.
4. Hypothermia is associated with drowning incidents and requires particular care. A low-reading thermometer must be used to detect it (see Section 7.3.E).
5. Tension pneumothorax and cardiac Tamponade are especially associated with PEA and are often found in trauma cases.
6. Toxic substances, resulting either from accidental or deliberate overdose or from an iatrogenic mistake, may require specific antidotes.
7. Thromboembolic phenomena (pulmonary or amniotic fluid) in pregnancy.

Shockable cardiac arrest

These arrhythmias are less common in children and in pregnant mothers, but either of them may be expected in patients with sudden collapse, hypothermia, poisoning by tricyclic antidepressants, or cardiac disease. The protocol for ventricular fibrillation (VF) (see Figure 1.13.18) and pulseless ventricular tachycardia (pVT) (see Figure 1.13.19) is the same, and is shown in Figure 1.13.20.

A sudden witnessed collapse is also suggestive of a VF/pVT episode.

FIGURE 1.13.18 An episode of ventricular fibrillation.

FIGURE 1.13.19 Ventricular tachycardia.
paediatric attenuation pads. The choice of defibrillator available, its use should be considered, preferably with a recommended. However, if an AED is the only defibrillator which can be adjusted to give the correct shock is used with the AED (if available).

Under 8 years, attenuated paediatric paddles should be monophasic in well-sited places. One electrode is placed over the apex in the mid-axillary line, while the other is placed immediately below the clavicle just to the right of the sternum. If the paddles are too large, one should be placed on the upper back, below the left scapula, and the other should be placed on the front, to the left of the sternum.

Automated external defibrillators (AEDs) are now commonplace in well-resourced countries. The standard adult shock is used for children over 8 years of age. For children under 8 years, attenuated paediatric paddles should be used with the AED (if available).

For infants under 1 year of age, a manual defibrillator which can be adjusted to give the correct shock is recommended. However, if an AED is the only defibrillator available, its use should be considered, preferably with paediatric attenuation pads. The choice of defibrillation for infants in decreasing order of preference is as follows:

1. manual defibrillator
2. AED with dose attenuator
3. AED without dose attenuator.

Many AEDs can detect VF/VT in children of all ages, and differentiate between ‘shockable’ and ‘non-shockable’ rhythms with a high degree of sensitivity and specificity.

If the shock fails to defibrillate, attention must revert to supporting coronary and cerebral perfusion as in asystole. Although the procedures for stabilising the airway and obtaining circulatory access are now described sequentially, they should be undertaken simultaneously under the direction of a resuscitation team leader.

The airway should be secured, the patient ventilated with high-flow oxygen, and effective chest compressions continued at a rate of 100–120 per minute, with a compression depth of at least one-third of the antero-posterior diameter of the chest, and a ratio of 15 compressions to 2 ventilations. As soon as is feasible, a skilled and experienced operator should intubate the child’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 10–12 breaths per minute. It is important for the team leader to check that the ventilations remain adequate when chest compressions are continuous. Obtain circulatory access. Whenever venous access is not readily available, intra-osseous access should be considered early on in children, as it is rapid and effective. Central venous lines provide more secure long-term access, but they offer no advantages compared with IO or peripheral IV access. In each case any drug is followed by a crystalloid flush (2–5 mL).

Two minutes after the first shock, pause the chest compressions briefly to check the monitor. If VF/VT is still present, give a second shock of 4 joules/kg and immediately resume CPR, commencing with chest compressions. Consider and correct reversible causes (the 4Hs and 4Ts) while continuing CPR for a further 2 minutes.

Pause briefly to check the monitor. If the rhythm is still VF/VT, give a third shock of 4 joules/kg.

Once chest compressions have resumed, give adrenaline 10 micrograms/kg in children and 1 mg in pregnant mothers IV and amiodarone 5 mg/kg in children and 300 mg in pregnant mothers intravenously or intra-osseously, flushing after each drug.

After completion of the 2 minutes of CPR, pause briefly to check the monitor and if the rhythm is still VF/VT give an immediate fourth shock of 4 joules/kg and resume CPR.

After a further 2 minutes of CPR, pause briefly to check the monitor and if the rhythm is still shockable, give an immediate fifth shock of 4 joules/kg.

Once chest compressions have resumed, give a second dose of adrenaline 10 micrograms/kg and a second dose of amiodarone 5 mg/kg intravenously or intra-osseously in children and 1 mg of adrenaline IV and 150 mg amiodarone in pregnant mothers. An amiodarone infusion can be continued if there is refractory VF/VT of 900 mg over 24 hours in adults and 15 mg/kg over 24 hours in children.

After completion of the 2 minutes of CPR, pause briefly before the next shock to check the monitor. Continue giving shocks every 2 minutes, minimising the pauses in CPR as

![Algorithm for the treatment of shockable (VF and pVT) rhythms in children. Doses of drugs and size of shock used in pregnancy are given in the text below. CPR, cardiopulmonary resuscitation; IV, intravenous; IO, intra-osseous; ROSC, return of spontaneous circulation.](image-url)
much as possible. Give adrenaline after every alternate shock (i.e. every 4 minutes) and continue to seek and treat reversible causes.

**Note:** After each 2 minutes of uninterrupted CPR, pause briefly to assess the rhythm on the monitor.

In addition, if at any stage there are signs of life, such as regular respiratory effort, coughing or eye opening, stop CPR and check the monitor.

- If the rhythm is still VF/VT, continue with the sequence as described above.
- If the rhythm is asystole, change to the asystole/PEA sequence.
- If organised electrical activity is seen, check for signs of life and a pulse. If there is ROSC, continue post-resuscitation care. If there is no pulse (or a pulse of < 60 beats/minute) and no other signs of life, continue the asystole/PEA sequence.

In VT or VF that does not respond to the above sequence, and where there is no evidence of previous administration of magnesium for eclampsia, consider giving magnesium sulphate 25–50 mg/kg up to a maximum of 2 grams in children and an 8 mmol IV bolus (4 mL of 50% magnesium sulphate) in pregnant mothers.

**Sodium bicarbonate**

If VF/VT is due to tricyclic antidepressant overdose or hyperkalaemia, sodium bicarbonate may be helpful. Give 1 mmol/kg (1 mL/kg of an 8.4% solution or 2 mL/kg of a 4.2% solution) in children, and give 50 mmol in pregnant mothers.

**Amiodarone**

Amiodarone is the treatment of choice in shock-resistant ventricular fibrillation and pulseless ventricular tachycardia. The dose of amiodarone for VF/pulseless VT is 5 mg/kg via rapid IV/IO bolus in children, and 300 mg IV in pregnant mothers.

**Lidocaine** is an alternative to amiodarone if the latter is unavailable. The dose is 1 mg/kg IV or IO in children and 100 mg as an IV bolus in pregnant mothers.

It is DC shock that converts the heart back to a perfusing rhythm, not the drug. The purpose of the anti-arrhythmic drug is to stabilise the converted rhythm, and the purpose of adrenaline is to improve myocardial oxygenation by increasing coronary perfusion pressure. Adrenaline also increases the vigour and intensity of ventricular fibrillation, which increases the success rate of defibrillation.

**Precordial thump**

A precordial thump may be given in monitored patients in whom the onset of VT or VF is witnessed, if there are several clinicians present and if the defibrillator is not immediately to hand. However, it is rarely effective, and early activation of emergency services and obtaining an AED are more appropriate. Start CPR as soon as possible.

**Drugs used in non-shockable and 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 from hyperoxia. Pulse oximetry should be used to monitor and adjust for oxygen requirement after a successful resuscitation. Saturations should be maintained in the range 94–98%. **Always ensure that oxygen delivery is discontinued during defibrillation shocks, to avoid the risks of explosions and fire.**

**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. It renders the myocardium more susceptible to defibrillation.

The initial IV or IO dose is 10 micrograms/kg (0.1 mL/kg of 1 in 10,000 solution) in children and 1 mg (1 mL of 1 in 1000 solution) in pregnant mothers. In children 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 (2–5 mL).

**Sodium bicarbonate**

Good basic life support is more effective than alkalising agents, which may be considered if spontaneous circulation has not returned after the first or second dose of adrenaline. Sodium bicarbonate is recommended in the treatment of patients with VT/VF due to hyperkalaemia and tricyclic antidepressant overdose (see above).

The dose is 1 mmol/kg in children (1 mL/kg of an 8.4% solution or 2 mL/kg of 4.2% solution), and 50 mmol in pregnant mothers.

- Sodium bicarbonate must not be given in the same intravenous line as calcium, otherwise precipitation will occur.
- Sodium bicarbonate inactivates adrenaline and dopamine, so the line must be flushed with Ringer-lactate or Hartmann’s solution if these drugs are subsequently given.
- Sodium bicarbonate must not be given via the intratracheal route.

**Glucose**

Hypoglycaemia is defined as a glucose concentration of less than 2.5 mmol/litre (45 mg/dL).

All patients, but especially infants and preschool children, 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 in children or 100 mL of 25% glucose in pregnant mothers, preferably IV if not enterally (via a gastric tube). Make 100 mL of 25% glucose by adding 50 mL of 50% glucose to 50 mL of Ringer-lactate or Hartmann’s solution. If blood glucose levels can be measured, avoid hypoglycaemia (maintain blood glucose concentration below 12 mmol/litre).

**Cardiac arrest and cardiopulmonary resuscitation in the obstetric patient**

**Background**

Cardiac arrest in late pregnancy or during delivery is rare, and maternal survival rates are very low (3–33% in published series). The cause of the arrest is not often reversed, and the physiological changes present in late pregnancy hinder effective CPR.

Cardiac arrest in the mother results in absent uterine...
perfusion, and the fetus will also die. Even when CPR is ideal, it is not possible to generate a cardiac output of more than 30%.

**Causes**

These include the following:
- massive haemorrhage
- pulmonary embolism
- trauma
- amniotic fluid embolism
- severe infection
- local anaesthetic toxicity.

**Physiological changes of pregnancy that relate to cardiopulmonary resuscitation**

- Pregnant mothers more easily develop hypoxaemia.
- The enlarged uterus along with the resultant upward displacement of the abdominal viscera decreases lung compliance.
- The most serious physiological change is aorto-caval compression in the supine position. It is essential that CPR is performed in the left lateral position in any pregnant woman where the uterus is a significant intra-abdominal mass (usually after 20 weeks’ gestation). During closed-chest cardiac compression the best cardiac output that can be achieved is between one-fourth and one-third of normal. Although many factors contribute to this, poor venous return to the heart is of paramount importance. At term the vena cava is completely occluded in 90% of supine pregnant patients. This results in a decrease in cardiac stroke volume of as much as 70%. It is helpful to manually displace the uterus to the left in advanced pregnancy (see Figure 1.13.21).
- Caesarean section performed early in resuscitation greatly improves the effectiveness of maternal resuscitation.

**Perimortem Caesarean section**

- Caesarean section should be performed as soon as possible, as described in Section 1.12 on basic life support. This will immediately relieve the vena cava obstruction and increase the likelihood of survival for both infant and mother. CPR must be continued throughout the procedure until spontaneous and effective cardiac activity occurs.
- Assisted ventilation may have to be continued for a longer period of time. Some infants have survived when delivered after 20 minutes of maternal resuscitation.
- Without Caesarean section, less than 10% of mothers who arrest in hospital will survive to discharge. Removal of the infant improves maternal circulation during resuscitation, and cardiac output immediately increases by 20–25%.

Perform the Caesarean section with a midline vertical incision, or whatever method the operator is most familiar with, and remove the baby as fast as possible. Remove lateral tilt when the baby is delivered.

**When to stop resuscitation**

Local guidelines should be in place. Resuscitation efforts are unlikely to be successful, and cessation can be considered, if there is no return of spontaneous circulation at any time after 20 minutes of life support and in the absence of recurring or refractory VF/VT. The exceptions are patients with a history of poisoning or a primary hypothermic insult, in whom prolonged attempts may occasionally be successful. Prolonged external cardiac compressions during which central (femoral or arterial) pulses were felt have successfully resuscitated patients with tricyclic antidepressant overdose.

The presence of the parents at the child’s side during resuscitation enables them to gain a realistic understanding of the efforts made to save their child’s life. In general, family members should be offered the opportunity to be present during the resuscitation of their child.

The most important points can be summarised as follows:

- A staff member (if available) must be designated as the parents’ support and interpreter of events at all times.
- The team leader, not the parents, decides when it is appropriate to stop the resuscitation.
- If the presence of the parents is impeding the progress of the resuscitation, they should be sensitively asked to leave.
- The team needs a debriefing session to support staff and reflect on practice.