

Cardiorespiratory Arrest

Pauline M Cullen

Cardiorespiratory arrests in children are uncommon and their aetiology differs from those in adults. Progressive respiratory insufficiency accounts for 60% of all paediatric arrests. This may result from upper or lower airway disease (e.g. croup, bronchiolitis, pneumonia, asthma, foreign body aspiration) or respiratory depression caused, for example, by prolonged convulsions, raised intracranial pressure, neuromuscular disease or drug overdose. Other important causes include sepsis, dehydration and hypovolaemia.

Primary cardiac arrest in children is rare and ventricular fibrillation has been reported in less than 10% of cases. Many children have a relatively long 'pre-arrest' phase (i.e. cardiac arrest following prolonged physiological deterioration). Impending cardiopulmonary arrest may be averted by early recognition of the child's distress and prompt intervention. Once cardiac arrest occurs, the outcome is dismal with survival rates of 3–17%. Often the child is resuscitated only to die of multi-organ failure in the ICU or to survive with significant neurological impairment.

Guidelines for paediatric life support are published by several national organizations. The most recent recommendations are those of the International Liaison Committee on Resuscitation (ILCOR) in 1997 and the European Resuscitation Council in 1998. The cardiopulmonary resuscitation (CPR) algorithms described in this article are based on these guidelines. The CPR sequence and general resuscitative principles are similar for infants and children. An artificial line is generally drawn between infants (< 1 year) and children (1–8 years). Older children and teenagers should be resuscitated using adult algorithms and techniques.

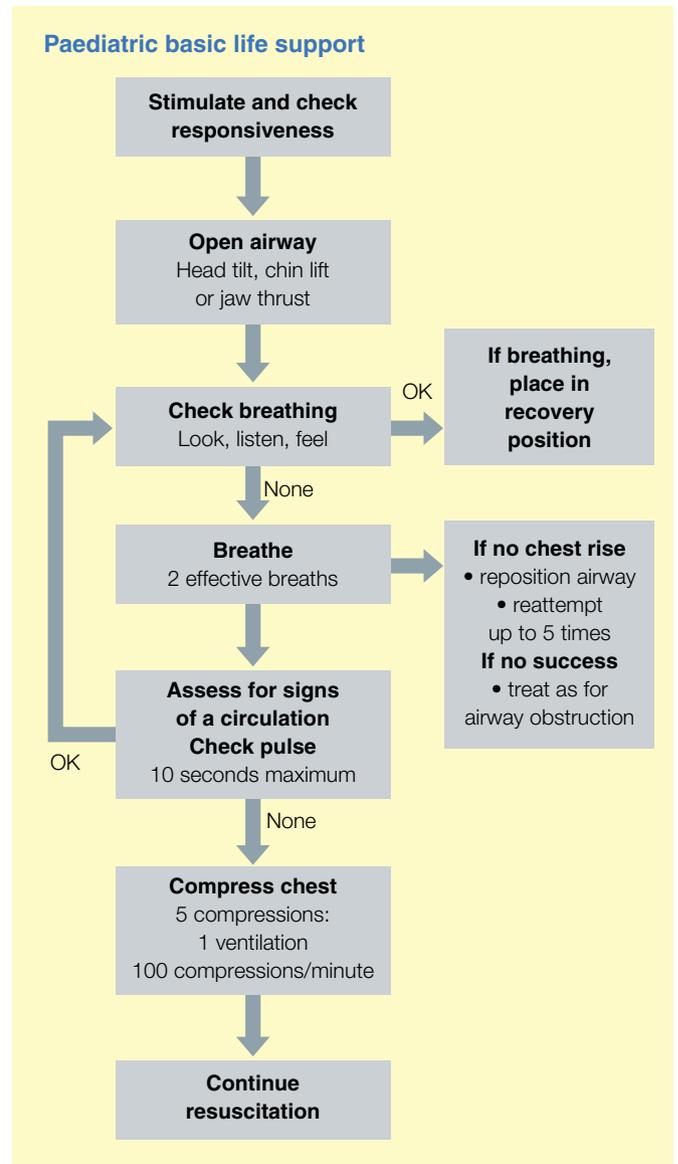
Basic life support

Basic life support (Figure 1) refers to maintenance of the airway and support of respiration and circulation without the use of equipment.

Initial approach and assessment of responsiveness

Before starting resuscitation it is important to evaluate the site for any danger or physical hazards. Only in extreme situations should the child be moved. The first step in any resuscitation is to assess the level of responsiveness. If the child does not respond to voice

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or gentle shaking, a rapid cardiopulmonary assessment should be performed (Figure 2). Assessment should take no longer than 10 seconds. Infants should not be shaken vigorously. If trauma is suspected, the cervical spine should be immobilized (see page 441). Resuscitation should start immediately and help should be summoned.

Airway

The tongue is the most common cause of airway obstruction in children. Simple head tilt, chin lift or jaw thrust manoeuvres may relieve the obstruction. Infants are primarily nose breathers; this is an inbuilt mechanism to overcome obstruction caused by a relatively large tongue. Only the jaw thrust procedure is recommended in suspected spinal injury. If a foreign body is obstructing the airway it should be removed carefully under direct vision. The blind finger sweep technique used in adults is not recommended because it may cause trauma and bleeding or displace the foreign body further into the trachea.

Rapid cardiopulmonary assessment

A Airway

- Patency

B Breathing

- Respiratory rate
- Work of breathing
- Stridor
- Wheeze
- Air entry
- Skin colour

C Circulation

- Heart rate
- Pulse volume
- Capillary refill
- Skin temperature
- Mental status

D Disability

- Conscious level
- Posture
- Pupils

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Breathing

The adequacy of breathing should be assessed by looking for chest movement, listening over the airway for breath sounds and feeling for exhaled air over the mouth and nose. If the child is not breathing despite an adequate airway, expired air ventilation should be started. The mouth of the rescuer should cover the nose and mouth of the infant. In the child, mouth-to-mouth expired air ventilation is recommended. A minimum of two, but up to five breaths, may be required for effective ventilation in the hypoxic child. The breaths should be delivered slowly, over 1–1.5 seconds, with a force sufficient to make the chest rise. By giving the breaths slowly, an adequate volume is delivered at the lowest possible pressure thereby avoiding gastric distension and possible regurgitation of gastric contents. If chest movement does not occur or is inadequate, the airway position should be readjusted and the possibility of a foreign body considered.

Circulation

Check the presence, rate and volume of the pulse. In infants, the brachial or femoral pulse is easiest to feel. In older children, the carotid should be palpated. It may be difficult to locate a pulse in a collapsed child owing to the intense vasoconstriction. If no detectable pulse is felt within 10 seconds or the rate is less than 60 beats/minute in an infant, chest compressions should be started.

The chest is compressed over the lower half of the sternum and the technique differs slightly between age groups.

- In infants, the chest is compressed using two fingers placed one finger's breadth below an imaginary line joining the nipples.
- In the child, the heel of the hand is used and positioned one finger's breadth up from the xiphisternum.

- In the child over 8 years, the two-handed compression technique is recommended.

The chest should be compressed to one-third its resting diameter at a rate of 100/minute. One breath should be given after each five compressions.

Airway obstruction from a foreign body

If upper airway obstruction due to foreign body aspiration is witnessed or strongly suspected, special measures to clear the airway must be undertaken (Figure 3). If the child is breathing spontaneously, their own efforts to clear the obstruction should be encouraged. Intervention is necessary only if these attempts are ineffective and respiration is inadequate. The manoeuvres suggested for removing impacted foreign bodies are:

- back blows
- chest thrusts
- abdominal thrusts.

A combination of back blows and chest thrusts are recommended for infants. Abdominal thrusts are not recommended because damage to the abdominal contents may occur. In children, back blows with alternate cycles of chest thrusts and abdominal thrusts are preferred. After each cycle, the mouth should be checked for the presence of a foreign body and ventilation attempted.

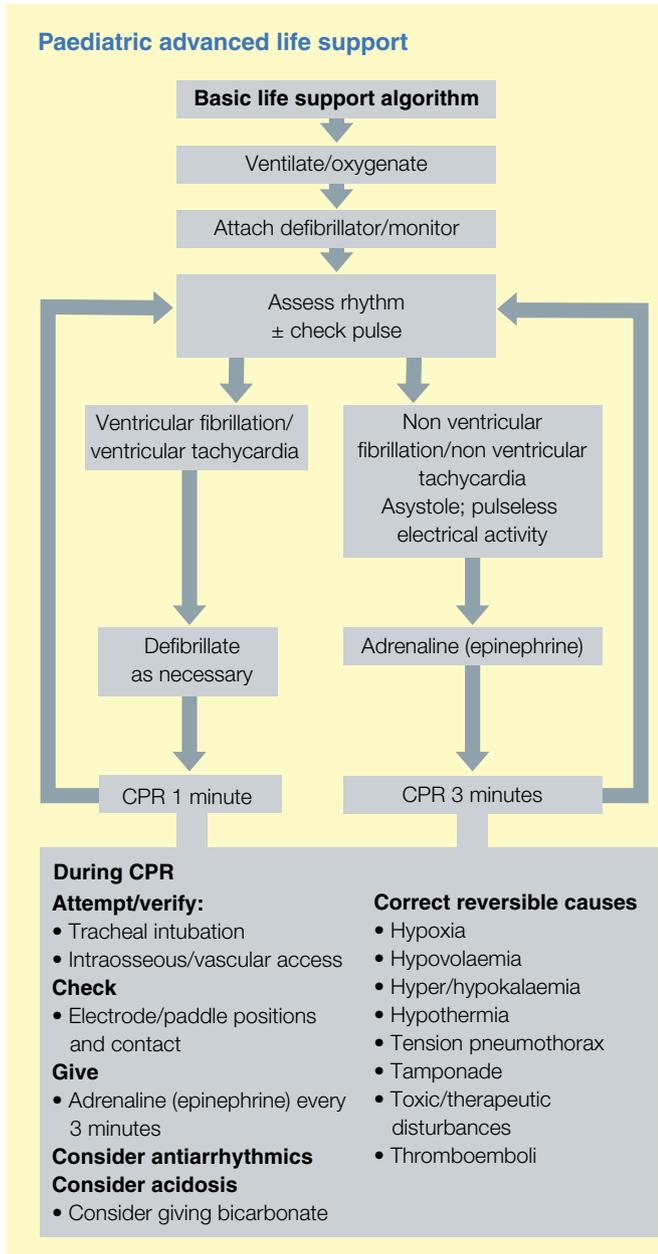
Advanced life support

As soon as skilled help and equipment arrive, advanced life support should be started (Figures 4 and 5). The aim of advanced life support is to restore spontaneous cardiac activity. Asystole is presumed to be the primary arrhythmia because ventricular fibrillation has been documented in less than 10% of paediatric cardiac arrests. Monitoring equipment (including a pulse oximeter, ECG and end-tidal carbon dioxide analyser) should be attached as soon as possible. The priorities are to secure the airway and provide adequate oxygenation and ventilation followed by vascular access and drug administration.

The choking infant or child



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Airway and ventilation

A secure airway and effective ventilation are vital in advanced life support. Respiratory failure is the primary cause of paediatric cardiac arrest, therefore the highest available oxygen concentration should be given immediately by bag, valve mask ventilation. An oropharyngeal airway may be used to aid airway management in the short term.

Tracheal intubation is the most effective method of securing the paediatric airway during CPR. It allows optimum ventilation, protects the airways from aspiration of gastric contents, and provides a route for drug administration. Intubation should be achieved rapidly. Any attempt lasting longer than 30 seconds should be abandoned and the child’s lungs reoxygenated before further attempts are made. The position of the tracheal tube should be checked and the tube secured to prevent dislodgement or displacement. The place of the laryngeal mask airway in paediatric resuscitation has yet to be established.

Advanced life support

- Perform basic life support algorithm
- Ventilate the lungs with 100% oxygen
- Establish a secure airway by intubating the trachea
- Establish reliable vascular access
- Administer adrenaline (epinephrine) every 3–5 minutes
- If resuscitation attempts exceed 15 minutes, consider giving sodium bicarbonate
- Correct reversible causes

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Circulation

Rapid vascular access is critical in paediatric resuscitation for drug and fluid administration. In small children this may be difficult owing to the extreme vasoconstriction. The intravenous or intraosseous routes are preferred for drug delivery.

Intravenous access: the choice of venous access is determined by the skill of the resuscitator and the relative risks of the procedure. In practice, the largest, most accessible vein that does not require the interruption of CPR is used. Attempts at peripheral venous cannulation should be limited to 90 seconds. Useful central venous routes during resuscitation include the femoral and external jugular veins. The internal jugular and subclavian routes require interruption of external cardiac compressions and are prone to serious complications in young children. Drugs administered centrally act more rapidly than those administered peripherally.

Alternative routes of drug and fluid administration: when rapid venous access is impossible an intraosseous cannula should be inserted. This is relatively easy to perform, safe and usually rapidly achieved (see page 452). Drugs and fluids can be administered by this route and gain rapid access to the central circulation.

The trachea is often intubated early in the resuscitation and is a useful alternative route for drug administration. It is best used when there has been, or is likely to be, a significant delay in establishing venous access. Lipid-soluble drugs, adrenaline (epinephrine), atropine, lidocaine (lignocaine), naloxone and diazepam are suitable for this route. Animal studies suggest that peak plasma concentrations of drugs are significantly lower than those achieved by intravenous administration, hence a tenfold increase in the adrenaline (epinephrine) dose is recommended for the tracheal route. Depot storage of adrenaline (epinephrine) in the lungs may cause prolonged post-arrest hypertension.

Drug and fluid therapy

Adrenaline (epinephrine) is the most useful drug during paediatric CPR. The α -adrenergic action increases systemic vascular resistance, elevates aortic diastolic pressure and thereby improves coronary perfusion. The recommended initial dose is 0.01 mg/kg,

intravenously or intraosseously, or 0.1 mg/kg by the tracheal route. Because the outcome of asystolic arrest in children is poor and a beneficial effect of higher dose adrenaline (epinephrine) has been demonstrated in some studies, second and all subsequent doses should be 0.1 mg/kg regardless of route of administration. As the action of adrenaline (epinephrine) is short lived, it should be repeated every 3–5 minutes during resuscitation. If there is no return of spontaneous cardiac activity after two doses, despite adequate CPR, the outlook is likely to be dismal.

Sodium bicarbonate: after the initial treatment of cardiac arrest (ventilation, chest compression, adrenaline (epinephrine)), severe acidosis is treated with sodium bicarbonate. Its use remains controversial because it has not been shown to improve survival. Nevertheless, during prolonged resuscitation (i.e. over 15 minutes), sodium bicarbonate, 1 meq/kg, may be administered intravenously or intraosseously.

Other drugs: neither calcium chloride nor atropine is recommended in the treatment of asystole or pulseless electrical activity.

Fluids: expansion of the circulating blood volume is vital in children who are hypovolaemic secondary to fluid loss or fluid maldistribution. The intravascular fluid of choice is isotonic crystalloid. An initial bolus of 20 ml/kg is given and repeated until there is an improvement in circulatory status.

Treatment algorithms

Non-ventricular fibrillation/non-ventricular tachycardia: asystole and pulseless electrical activity are the most common rhythms in childhood cardiac arrest. Profound bradycardia should be treated in the same way as asystole. The drug of choice is adrenaline (epinephrine), 0.01 mg/kg, intravenous or intraosseous or 0.1 mg/kg via the tracheal route. This should be followed by 3 minutes of CPR. If the child does not respond to the initial dose of adrenaline (epinephrine), another dose of 0.1 mg/kg should be given. All subsequent doses should be the higher dose of 0.1 mg/kg intravenous or intraosseous.

Any underlying reversible cause of the arrest should be treated and resuscitation should not be abandoned until reasonable attempts have been made to do so. Reversible causes of pulseless electrical activity include:

- hypovolaemia
- tension pneumothorax
- cardiac tamponade
- drug overdose
- electrolyte imbalance.

Ventricular fibrillation and ventricular tachycardia are relatively uncommon in infants and children; they are treated by defibrillation. The recommended sequence is to give two rapid defibrillatory shocks of 2 joules/kg, followed by a single shock of 4 joules/kg. If the initial third shock fails, CPR should be continued for 1 minute and adrenaline (epinephrine), 0.01 mg/kg, given. The heart is then defibrillated with three further shocks at 4 joules/kg. The cycle of defibrillation and 1 minute of CPR is repeated until defibrillation is achieved. In children there is often an underlying cause and correction of hypothermia, drug overdose and electrolyte imbalance should be considered.

Post-arrest stabilization

Following a cardiac arrest, children are often poorly perfused, hypotensive and very acidotic. Most require continuing pharmacological support to maintain blood pressure and improve tissue perfusion. Management is similar to the general management of critically ill infants and children in cardiogenic shock. The goals are rapid restoration of blood pressure, effective organ perfusion, and correction of hypoxia and acidosis. Normocapnic ventilation should be continued until cardiorespiratory stability is achieved.

Cerebral resuscitation aims to provide a sufficient supply of oxygenated blood to the brain to meet its demands. Hypoglycaemia and hyperglycaemia should be avoided, and factors that increase cerebral oxygen requirements (e.g. hyperthermia, inadequate analgesia, seizures) should be treated. Mild hypothermia (34°C) is beneficial after global brain ischaemia. In animal studies, lowering brain temperature from 36° to 33°C with local cranial cooling during the first hour of post-ischaemic recirculation improves neuronal survival. The protective effect of mild hypothermia is presumably multifactorial as it cannot be explained by the modest reduction in oxygen consumption. The clinical impact of mild hypothermia on long-term outcome remains to be tested. It is probably wise to avoid aggressive rewarming of patients in the early post-arrest period. Cerebral resuscitative strategies such as thiopental (thiopentone), calcium channel blockers and steroids do not improve outcome.

Outcome

The combined mortality and morbidity rate of children who are pulseless on arrival in the accident and emergency department approaches 100%. Children who have a delayed response to resuscitation have little chance of surviving without neurological damage. The length of resuscitation is another predictor of outcome. Prolonged resuscitation requiring more than two doses of adrenaline (epinephrine) leads to a dismal outcome and attempts beyond 25 minutes are unsuccessful. Respiratory arrest alone is associated with a better outcome. The most effective treatment of cardiorespiratory arrest is prevention. The early recognition and aggressive treatment of impending cardiac or respiratory failure in children is essential. ◆

FURTHER READING

- Advanced Life Support Group. *Advanced Paediatric Life Support Manual*. 3rd ed. London: BMJ Books, 2001.
- Paediatric Advanced Life Support: An Advisory Statement by the Paediatric Life Support Working Group of the International Liaison Committee on Resuscitation. *Resuscitation* 1997; **34**: 115–27.
- Ushay M H. Pharmacology of Pediatric Resuscitation. *Ped Clin N Am* 1997; **44**: 207–29.
- Zaritsky A L. Recent Advances in Pediatric Cardiopulmonary Resuscitation and Advanced Life Support. *New Horizons* 1998; **6**: 201–11.
- Ziderman D A. Paediatric and Neonatal Life Support. *Br J Anaesth* 1997; **79**: 188–97.