

Guidelines: Paediatric advanced life support

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1. The guideline process

- The process used to produce the Resuscitation Council UK Guidelines 2015 has been accredited by the National Institute for Health and Care Excellence. The guidelines process includes:
- Systematic reviews with grading of the quality of evidence and strength of recommendations. This led to the 2015 International Liaison Committee on Resuscitation (ILCOR) Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. 1,2
- The involvement of stakeholders from around the world including members of the public and cardiac arrest survivors.
- Details of the guidelines development process can be found in the Resuscitation Council UK Guidelines Development Process Manual. [link to Guidelines development process manual]
- These Resuscitation Council UK Guidelines have been peer reviewed by the Executive Committee of Resuscitation Council UK, which comprises 25 individuals and includes lay representation and representation of the key stakeholder groups.

2. Summary of changes in paediatric advanced life support since the 2010 Guidelines

In managing the seriously ill child:

- If there are no signs of septic shock, children with a febrile illness should receive fluid with caution followed by reassessment. In some forms of septic shock, restricted fluid therapy with isotonic crystalloid may be more beneficial than the liberal use of fluids.
- For cardioversion of a supraventricular tachycardia (SVT), the initial dose has been revised to 1 J kg^{-1} .

In the paediatric cardiac arrest algorithm:

- Many of the features are common with adult practice.

In post-resuscitation care:

- Prevent fever in children who have return of spontaneous circulation (ROSC) from an out-of-hospital cardiac arrest.
- Targeted temperature management of children post-ROSC should comprise treatment with either normothermia or mild hypothermia.

3. Introduction

The causes of cardiorespiratory arrest in children differ from those in adults in that most paediatric arrests arise from decompensated respiratory or circulatory failure (i.e. they are predominantly secondary cardiorespiratory arrests).³⁻⁷ Although in adulthood, primary arrests resulting from arrhythmias are more common, many young adults have similar causes to children (e.g. trauma, drowning and poisoning), meaning that respiratory failure is also common in this population.⁸⁻¹¹

Cardiorespiratory arrest generally has a poor outcome in children hence the identification of the seriously ill or injured child is an absolute priority. Directed interventions at the compensated or decompensated stages of illness/injury can be life-saving and prevent progression to cardiorespiratory arrest. Any unwell child or infant should be assessed in a systematic manner to identify the extent of any physiological disruption and interventions started to correct the situation.

The order of assessment and intervention for any seriously ill or injured child

follows the ABCDE principles:

- **A**irway (Ac for airway and cervical spine stabilisation for the injured child).
- **B**reathing.
- **C**irculation (with haemorrhage control in the injured child).
- **D**isability (level of consciousness and neurological status).
- **E**xposure to ensure full examination (whilst respecting the child's dignity and ensuring body temperature conservation).

Interventions are made at each step in the assessment as abnormalities are identified. The next step of the assessment is not started until the preceding abnormality has been treated and corrected if possible (the exception to this is the child presenting with life-threatening haemorrhage after serious injury when circulatory interventions will be made simultaneously with assessment and management of airway and breathing).

4. Summoning expert advice

Summoning a paediatric rapid response team (RRT) or medical emergency team (MET) may reduce the risk of respiratory and/or cardiac arrest in hospitalised children. This team should include at least one clinician with paediatric expertise and one specialist nurse. They should be called to evaluate a potentially critically ill child who is not already in a paediatric intensive care unit (PICU) or paediatric emergency department (ED).^{2,12,13}

5. The sequence of actions in cardiopulmonary resuscitation (CPR)

1. Establish basic life support

See [paediatric BLS section](#).

2. Oxygenate, ventilate, and start chest compression:

- Ensure a patent airway by using an airway manoeuvre described in the Paediatric basic life support section.
- Provide ventilation initially by bag-mask, using high-concentration inspired

oxygen as soon as this is available.

- Intubate the trachea only if this can be performed by an experienced operator with minimal interruption to chest compressions. Tracheal intubation will both control the airway and enable chest compression to be given continuously, thus improving coronary perfusion pressure.
- Use a compression rate of 100–120 min⁻¹.
- If the child has been intubated and compressions are uninterrupted, ensure that ventilation is adequate and use a slow ventilation rate of approximately 10–12 min⁻¹.

3. Attach a defibrillator or monitor:

- Assess and monitor the cardiac rhythm.
- If using a defibrillator, place one defibrillator pad or paddle on the chest wall just below the right clavicle, and one in the mid-axillary line. Pads for children should be 8–12 cm in size, and 4.5 cm for infants. In infants and small children it may be best to apply the pads to the front and back of the chest if they cannot be adequately separated in the standard positions.
- The defibrillator pads may be used to assess the rhythm, when in monitoring mode.

4. Assess rhythm and check for signs of life:

- Look for signs of life, which include responsiveness, coughing, spontaneous movements and normal breathing.
- Assess the rhythm on the monitor:
 - Non-shockable (asystole or pulseless electrical activity (PEA)) OR
 - Shockable – ventricular fibrillation (VF) or pulseless ventricular tachycardia (pVT).

5A. Non-shockable (asystole or PEA):

This is the more common finding in children.

- **Perform continuous CPR:**
 - Continue to ventilate with high-concentration oxygen.
 - If ventilating with bag-mask give 15 chest compressions to 2 ventilations.

- Use a compression rate of 100–120 min⁻¹.
- If the patient is intubated, chest compressions can be continuous as long as this does not interfere with satisfactory ventilation.
- Once the child's trachea has been intubated and compressions are uninterrupted use a ventilation rate of approximately 10–12 min⁻¹.
Note: Once there is return of spontaneous circulation (ROSC), the ventilation rate should be 12–20 min⁻¹. Measure end-tidal carbon dioxide (CO₂) to monitor ventilation and ensure correct tracheal tube placement.
- Give adrenaline:
 - If vascular access has been established, give adrenaline 10 mcg kg⁻¹ (0.1 mL kg⁻¹ of 1 in 10,000 solution).
 - If there is no circulatory access, obtain intraosseous (IO) access.
- Continue CPR, only pausing briefly every 2 min to check for rhythm change.
 - Give adrenaline 10 mcg kg⁻¹ every 3–5 min (i.e. every other loop), while continuing to maintain effective chest compression and ventilation without interruption.
- Consider and correct reversible causes (4Hs and 4Ts):
 - Hypoxia
 - Hypovolaemia
 - Hyper/hypokalaemia, metabolic
 - Hypothermia
 - Thromboembolism (coronary or pulmonary)
 - Tension pneumothorax
 - Tamponade (cardiac)
 - Toxic/therapeutic disturbance

5B. Shockable (VF/pVT)

This is less common in children but may occur as a secondary event and is likely when there has been a witnessed and sudden collapse. It is seen more often in the intensive care unit and cardiac ward.

- **Continue CPR until a defibrillator is available - as 5A above**
- **Defibrillate the heart:**
 - Charge the defibrillator while another rescuer continues chest compressions.
 - Once the defibrillator is charged, pause the chest compressions, quickly ensure that all rescuers are clear of the patient and then

deliver the shock. This should be planned before stopping compressions.

- Give 1 shock of 4 J kg^{-1} if using a manual defibrillator.
- If using an AED for a child of less than 8 years, deliver a paediatric-attenuated adult shock energy.
- If using an AED for a child over 8 years, use the adult shock energy.

• **Resume CPR:**

- Without reassessing the rhythm or feeling for a pulse, resume CPR immediately, starting with chest compression.
- Consider and correct reversible causes (4Hs and 4Ts).

• **Continue CPR for 2 min, then pause briefly to check the monitor:**

- If still VF/pVT, give a second shock (with same energy level and strategy for delivery as the first shock).

• **Resume CPR:**

- Without reassessing the rhythm or feeling for a pulse, resume CPR immediately, starting with chest compression.

• **Continue CPR for 2 min, then pause briefly to check the monitor:**

- If still VF/pVT, give a third shock (with same energy level and strategy for delivery as the previous shock).

• **Resume CPR:**

- Without reassessing the rhythm or feeling for a pulse, resume CPR immediately, starting with chest compression.
- Give adrenaline 10 mcg kg^{-1} and amiodarone 5 mg kg^{-1} after the third shock, once chest compressions have resumed.
- Repeat adrenaline every alternate cycle (i.e. every 3–5 min) until ROSC.
- Repeat amiodarone 5 mg kg^{-1} one further time, after the fifth shock if still in a shockable rhythm.

• **Continue giving shocks every 2 min, continuing compressions during charging of the defibrillator and minimising the breaks in chest compression as much as possible.**

- After each 2 min of uninterrupted CPR, pause briefly to assess the rhythm: If still VF/pVT:
 - Continue CPR with the shockable (VF/pVT) sequence.
- If asystole:
 - Continue CPR and switch to the non-shockable (asystole or PEA) sequence as above.
- 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 rate of $<60 \text{ min}^{-1}$), and there are no other signs of life, continue CPR and continue as for the non-shockable sequence above.

If defibrillation was successful but VF/pVT recurs, resume the CPR sequence and defibrillate. Give an amiodarone bolus (unless two doses have already been given) and start a continuous infusion of the drug.

Important note

Uninterrupted, high quality CPR is vital. Chest compression and ventilation should be interrupted only for defibrillation. Chest compression is tiring for providers and the team leader should repeatedly assess and feedback on the quality of the compressions. To prevent fatigue, change providers should every two minutes. This will mean that the team can deliver effective high quality CPR so improving the chances of survival.^{2,14}

Figure 1. Paediatric advanced life support algorithm

6. Explanatory notes

Tracheal tubes

Recent studies continue to show no greater risk of complications for children younger than 8 years when cuffed, rather than uncuffed, tracheal tubes are used in the operating room and intensive care unit. Cuffed tracheal tubes are as safe as uncuffed tubes for infants (except neonates) and children if rescuers use the correct tube size, cuff inflation pressure, and verify tube position. The use of cuffed tubes increases the chance of selecting the correct size at the first attempt. Under certain circumstances (e.g. poor lung compliance, high airway resistance, and facial burns) cuffed tracheal tubes may be preferable.¹⁵

Alternative airways

Although bag-mask ventilation remains the recommended first line method for achieving airway control and ventilation in children, the laryngeal mask airway (LMA) is an acceptable airway device for providers trained in its use. It is

particularly helpful in airway obstruction caused by supraglottic airway abnormalities or if bag-mask ventilation is not possible. Other supraglottic airways (SGA) (e.g. i-gel) which have been successful in children's anaesthesia may also be useful, but there are few data on the use of these devices in paediatric emergencies. Supraglottic airways do not totally protect the airway from aspiration of secretions, blood or stomach contents, and therefore close observation is required as their use is associated with a higher incidence of complications in small children compared with older children or adults.

Capnography

Monitoring end-tidal CO₂ with waveform capnography reliably confirms tracheal tube placement in a child weighing more than 2 kg with a perfusing rhythm and must be used after intubation and during transport of an intubated child. The presence of a capnographic waveform for more than four ventilated breaths indicates that the tube is in the tracheobronchial tree, both in the presence of a perfusing rhythm and during CPR. Capnography does not rule out intubation of a bronchus. The absence of exhaled CO₂ during CPR does not guarantee tube misplacement because a low or absent end-tidal CO₂ may reflect low or absent pulmonary blood flow.

Capnography may also provide information on the efficiency of chest compressions and a sudden rise in the end-tidal CO₂ can be an early indication of ROSC. Try to improve chest compression quality if the end-tidal CO₂ remains below 2 kPa as this may indicate low cardiac output and low pulmonary blood flow. Be careful when interpreting end-tidal CO₂ values after giving adrenaline or other vasoconstrictor drugs when there may be a transient decrease in end-tidal CO₂, or after the use of sodium bicarbonate when there may be a transient increase in the end-tidal values. Current evidence does not support the use of a threshold end-tidal CO₂ value as an indicator for stopping the resuscitation attempt.

7. Drugs used in CPR

Below, you'll find detailed information on the different drugs used in CPR.

Adrenaline

This is an endogenous catecholamine with potent alpha, beta₁, and beta₂ adrenergic actions. Adrenaline induces vasoconstriction, increases coronary and cerebral perfusion pressure and enhances myocardial contractility. Although firm evidence for its effectiveness is lacking, it is thought to stimulate spontaneous contractions, and increases the intensity of VF so increasing the likelihood of successful defibrillation.

The recommended IV/IO dose of adrenaline in children is 10 micrograms kg⁻¹. Subsequent doses of adrenaline are given every 3–5 min. Do not use higher doses of intravascular adrenaline in children because this may worsen outcome.
16

Amiodarone

Amiodarone is a membrane-stabilising anti-arrhythmic drug that increases the duration of the action potential and refractory period in atrial and ventricular myocardium. Atrioventricular conduction is also slowed and a similar effect occurs in accessory pathways. Amiodarone has a mild negative inotropic action. The hypotension that occurs with IV amiodarone is related to the rate of delivery and is due more to the solvent (Polysorbate 80 and benzyl alcohol) - which causes histamine release - than the drug itself.

In the treatment of shockable rhythms, give an initial IV bolus dose of amiodarone 5 mg kg⁻¹ after the third defibrillation. Repeat the dose after the fifth shock if still in VF/pVT. If defibrillation was successful but VF/pVT recurs, amiodarone can be repeated (unless two doses have already been given) and a continuous infusion started.

Amiodarone can cause thrombophlebitis when injected into a peripheral vein and, ideally, should be delivered via a central vein. If central venous access is unavailable (likely at the time of cardiac arrest) and so it has to be given peripherally, flush it liberally with 0.9% sodium chloride or 5% glucose.

One recent observational study in children showed that ECG resolution and survival to discharge was similar in a group treated with lidocaine instead of amiodarone but the evidence was not sufficiently robust to recommend a change in practice.¹⁷

Atropine

Atropine is effective in increasing heart rate when bradycardia is caused by excessive vagal tone (e.g. after insertion of nasogastric tube). The dose is 20 mcg kg⁻¹. There is no evidence that atropine has any benefit in asphyxial bradycardia or asystole and its routine use has been removed from the ALS algorithms.

Magnesium

This is a major intracellular cation and serves as a cofactor in many enzymatic reactions. Magnesium treatment is indicated in children with documented hypomagnesaemia or with polymorphic VT (torsade de pointes), regardless of cause.

Calcium

Calcium plays a vital role in the cellular mechanisms underlying myocardial contraction. However, high plasma concentrations achieved after intravenous injection may be harmful to the ischaemic myocardium and may also impair cerebral recovery. The routine administration of calcium during cardiac arrest has been associated with increased mortality and it should be given only when specifically indicated (e.g. in hyperkalaemia, hypocalcaemia and in overdose of calcium-channel-blocking drugs).¹⁸

Sodium bicarbonate

Cardiorespiratory arrest results in combined respiratory and metabolic acidosis, caused by cessation of pulmonary gas exchange and the development of anaerobic cellular metabolism respectively. The best treatment for acidaemia in cardiac arrest is a combination of effective chest compression and ventilation (high quality CPR). Administration of sodium bicarbonate generates carbon dioxide, which diffuses rapidly into the cells, exacerbating intracellular acidosis if it is not rapidly cleared via the lungs. It also has the following detrimental effects:

- It produces a negative inotropic effect on an ischaemic myocardium.

- It presents a large, osmotically active, sodium load to an already compromised circulation and brain.
- It produces a shift to the left in the oxygen dissociation curve, further inhibiting release of oxygen to the tissues.

The routine use of sodium bicarbonate in CPR is not recommended.^{19,20} It may be considered in prolonged arrests, and it has a specific role in hyperkalaemia and the arrhythmias associated with tricyclic antidepressant overdose.

Fluids in CPR

Hypovolaemia is a potentially reversible cause of cardiac arrest. If hypovolaemia is suspected, give IV or IO fluids rapidly (20 mL kg⁻¹ boluses). In the initial stages of resuscitation there are no clear advantages in using colloid solutions, whatever the aetiology, so use isotonic saline solutions for initial volume resuscitation. Do not use dextrose-based solutions for volume replacement – these will be redistributed rapidly away from the intravascular space and will cause hyponatraemia and hyperglycaemia, which may worsen neurological outcome.²¹

8. Post-resuscitation care

Oxygen

In neonates there is evidence that hyperoxaemia can be detrimental and room air is recommended for use during initial resuscitation of the newborn (see Resuscitation and support of transition of babies at birth). In the older child there is no evidence for any such advantages, so 100% oxygen should be used for initial resuscitation. After ROSC, titrate the inspired oxygen, using pulse oximetry, to achieve an oxygen saturation of 94–98%. In situations where dissolved oxygen plays an important role in oxygen transport such as smoke inhalation (carbon monoxide poisoning) and severe anaemia, maintain a high inspired oxygen (FiO₂).

Carbon dioxide

In children who do not recover consciousness immediately following ROSC, controlled ventilation may help prevent further secondary brain injury (from

cerebral oedema or ischaemia) as blood pH and PaCO₂ levels influence cerebral blood flow. The usual target range for PaCO₂ in this setting is 4.5–5.0 kPa, however, the target value for the PaCO₂ should be towards the anticipated value for the individual patient as the ‘normal value’ for a child with a chronic respiratory disorder may exceed the quoted ranges based on children without adaptive physiology.

Intravascular fluids and inotropes

Following ROSC, the use of fluids and/or inotropes to avoid hypotension is recommended in context of trying to ensure adequate tissue perfusion.²²

Rescue and post-ROSC use of extracorporeal membrane oxygenation (ECMO)

Extracorporeal circulatory techniques such as ECMO may be of benefit to patients with cardiac origins to their cardiorespiratory arrest in a setting where it can be instituted rapidly. The benefit to patients who have other causes for their arrest is unclear.²

Prognostic factors for outcomes of resuscitation

No single prognostic factor is sufficiently reliable to inform decisions about the termination of a resuscitation attempt or the likely outcome. Factors that should influence any decisions include the circumstances of the arrest, initial rhythm, duration of resuscitation and other features such as presence of hypothermia and severe metabolic derangement. Comatose children with ROSC receiving mechanical ventilation who fulfil neurological criteria for death, or in whom withdrawal of life-sustaining treatments is planned should be considered as potential organ donors.

Therapeutic hypothermia

Initial trials of therapeutic hypothermia (TH) in adults following cardiac arrest showed improvement in survival and neurological outcome.^{23,24} However, subsequent studies failed to replicate these findings. A recent study comparing a target temperature of 33°C with 36°C in comatose adults resuscitated from out-of-hospital cardiac arrest (OHCA) showed no difference in neurological outcome.²⁵

The Therapeutic Hypothermia After Pediatric Cardiac Arrest (THAPCA) study was

a large randomised controlled trial that compared mild TH (32–34°C) with therapeutic normothermia (36.8°C) (both groups received active temperature control) for comatose children who survived OHCA.²⁶ The trial did not show any significant difference in survival or 1-year functional outcome between the two groups (it was powered to show an absolute risk difference of 15–20%). There was a tendency toward better outcomes at the lower temperature ranges. There was no difference in the incidence of infection, bleeding, or serious arrhythmias between the two groups hence TH appears to be safe.

A child who has ROSC, but remains comatose after cardiorespiratory arrest, may benefit either from being cooled to a core temperature of 32–34°C (TH) or having their core temperature actively maintained at 36.8°C for at least 24 h post arrest. Do not actively rewarm a successfully resuscitated child with hypothermia unless the core temperature is below 32°C. Following a period of mild hypothermia, rewarm the child slowly at 0.25–0.5°C h⁻¹.

Blood glucose control

Neonatal, child and adult data show that both hyperglycaemia and hypoglycaemia are associated with poor outcome after cardiorespiratory arrest, but it is uncertain if this is causative or merely an association. Closely monitor plasma glucose concentrations in any ill or injured child including after cardiorespiratory arrest. Do not give glucose-containing fluids during CPR except for treatment of hypoglycaemia.

Hyperglycaemia and hypoglycaemia should be avoided following ROSC but tight glucose control has not shown survival benefits when compared with moderate glucose control in adults and increased the risk of hypoglycaemia in neonates, children and adults.

9. Parental presence

Many parents would want to be present during a resuscitation attempt; they can see that everything possible is being done for their child. Reports show that being at the side of the child is comforting to the parents or carers and helps them to gain a realistic view of attempted resuscitation and death. Bereaved families who have been present in the resuscitation room show less anxiety and depression several months after the death.

Parental presence in the resuscitation room may also encourage healthcare providers' professional behaviour and facilitate their understanding of the child in the context of his/her family.

A dedicated staff member should be present with the parents at all times to explain the process in an empathetic and sympathetic manner. They can also ensure that the parents do not interfere with the resuscitation process or distract the resuscitation team. If the presence of the parents is impeding the progress of the resuscitation, they should be gently asked to leave. When appropriate, physical contact with the child should be allowed.

The resuscitation team leader should decide when to stop the resuscitation; this should be expressed with sensitivity and understanding. After the event, debriefing of the team should be conducted, to express any concerns and to allow the team to reflect on their clinical practice in a supportive environment.

10. Acknowledgements

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11. Accreditation of the 2015 Guidelines

NICE has accredited the process used by Resuscitation Council UK to produce its Guidelines development Process Manual. Accreditation is valid for 5 years from March 2015. More information on accreditation can be viewed at

<https://www.nice.org.uk/about/what-we-do/accreditation>.

12. References

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