Resuscitation Council UK

Paediatric advanced life support Guidelines

Authors
Sophie Skellett
Ian Maconochie
Bob Bingham
Mark Worrall
Barnaby R Scholefield
Mae Johnson
Mike Page
Liesje Andre
Jonathan Wyllie
Andrew Lockey
Sue Hampshire
Published May 2021.

Key points

In managing the seriously ill or injured child and infant

Management of respiratory failure

- Where it is possible to accurately measure oxygen saturations (SpO_2), start oxygen therapy if SpO_2 < 94% (or for infants or children with chronic conditions at an SpO_2 3% below known baseline). The goal is to keep SpO_2 between 94-98% with as little supplemental oxygen as possible. When giving supplemental oxygen, sustained SpO_2 readings of 100% should generally be avoided (except in specific circumstances such as carbon monoxide poisoning). Do not give pre-emptive oxygen therapy to children and infants without signs of or immediate risk of hypoxaemia or shock.
- In children and infants with respiratory failure and/or hypoxaemia not responding to low-flow oxygen (but who continue to have adequate respiratory drive), competent providers should consider either humidified

high-flow nasal cannula oxygen (HFNC) or continuous positive airway pressure (CPAP)/non-invasive ventilation (NIV) support.

- Bag-mask ventilation (BMV) is the recommended first line method to support ventilation. A 2-person technique is recommended, especially if ventilation is difficult or when there is a risk of disease transmission. Consider airway adjuncts.
- In children and infants where BMV does not improve oxygenation and/or ventilation, or the requirement for ventilation is anticipated to be prolonged, competent providers should consider early use of a supraglottic airway (SGA) or tracheal intubation.
- For tracheal intubation, use cuffed tracheal tubes (TT) for paediatric life support (except in neonates where there is less evidence for their use). Monitor cuff inflation pressure and limit this according to manufacturer's recommendations (usually less than 20cm H_2O).
- Use capnography in all intubated children and infants for early detection of mal- or displacement of the tracheal tube.

Management of circulatory failure

- Healthcare systems should implement context specific protocols for the management of children and infants with shock (including septic shock), including strategies for early recognition and timely emergency treatment.
- No single finding can reliably identify the severity of the circulatory failure and/or be used as a goal for treatment. Reassess frequently and at least after every intervention. Consider among other clinical signs: mean arterial blood pressure, trends in lactate, urine output and if competent, ultrasound findings.
- Peripheral intravenous (IV) lines are the first choice for vascular access. In case of emergency, limit the time for placement to 5 minutes (2 attempts). Competent providers may use ultrasound to guide cannulation. Consider rescue alternatives (e.g. intraosseous route) for access earlier when the chances of success are considered minimal.
- For infants and children, the primary rescue alternative is intraosseous (IO) access. All paediatric advanced life support providers should be competent in IO placement and have regular retraining in the different devices (and puncture sites) used in their setting. Provide proper intraosseous analgesia before giving the first fluid bolus in every child and infant unless comatose. Confirm proper placement clinically and monitor for extravasation which can lead to compartment syndrome.
- Recommendations for fluid administration in shock for children and infants

in the UK healthcare system with intensive care availability are 10 mL kg^{-1} bolus, repeated up to 40-60 mL kg^{-1} in the first hour titrated to patient response with repeated re-assessment and discontinued if signs of fluid overload develop. Signs of fluid overload include hepatomegaly, bilateral basal lung crackles, and jugular venous distention.

- The optimal timing of intubation in septic shock is unclear but consensus opinion suggests that in the setting of fluid and inotrope resistant shock intubation is indicated even in the absence of respiratory failure.
- Use balanced isotonic crystalloids as first choice of fluid bolus, if available. If not, normal saline (0.9%) is an acceptable alternative.
- Give rapid fluid boluses in patients with hypovolaemic non-haemorrhagic shock.
- In haemorrhagic shock keep crystalloid boluses to a minimum (max 20 mL kg^{-1}). Consider early blood products in children and infants with severe trauma and circulatory failure, using a strategy that focuses on improving coagulation. Avoid fluid overload but try to provide adequate tissue perfusion awaiting definitive damage control (e.g. surgery) and/or spontaneous thrombosis. Permissive hypotension (mean arterial blood pressure (MAP) at 5th percentile for age) may be considered; however, its use is contraindicated in children and infants with associated brain injury (e.g. traumatic brain injury).

Blood pressure for age(mmHg)	1month	1year	5year	10 year
50th centilefor Systolic BP	75	95	100	110
5th centile for Systolic BP	50	70	75	80
50th centilefor meanarterial pressure(MAP)	55	70	75	75
5th centile for mean arterial blood pressure (MAP)	40	50	55	55

- Give tranexamic acid (TxA) to all children and infants requiring transfusion after severe trauma and/or significant haemorrhage, as soon as possible (ideally within 3 hours of injury).
- Children and infants with a febrile illness and no signs of shock should not receive fluid bolus therapy.
- In children and infants with persistent decompensated circulatory failure after multiple fluid boluses, vasoactive drugs should be started early, as a continuous infusion via either a central or peripheral line.
- Use either noradrenaline or adrenaline as first line vasoactive drugs (dopamine is no longer recommended but can be used if adrenaline and noradrenaline are not available). Paediatric ALS providers should be competent in the use of these drugs during the first hour of stabilisation of a child or infant in circulatory failure.
- In suspected septic shock, start broad spectrum antibiotics as soon as possible after initial ABCDE assessment. Ideally this is within the first hour of treatment. Obtain blood cultures before starting antibiotics, if this can be done without delaying therapy.
- In children and infants with decompensated circulatory failure due to either supraventricular (SVT) or ventricular tachycardia (VT), the first choice for treatment is immediate cardioversion at a starting energy of 1 J kg^{-1} body weight. Double the energy to 2 J kg^{-1} if the initial electric cardioversion is

unsuccessful. Consider up to 4 Jkg^{-1}, but this should be guided by expert help. For children and infants who are conscious, use adequate analgesia and sedation (e.g. intranasal or intramuscular ketamine) with airway management. If an intravenous (IV) line can be rapidly sited IV analgesia and sedation (e.g. IV ketamine) can be used but IV access attempts **must not** delay cardioversion.

- In children and infants with a presumed SVT who are not yet decompensated, providers can try vagal manoeuvres (ice immersion, Valsalva techniques). If this has no immediate effect, proceed with IV adenosine:
  - **Neonates (birth to 28 days of life):** adenosine IV 150 micrograms kg^{-1}, then increase dose in steps of 50-100 micrograms kg^{-1} every 1-2 minutes if required, dose to be repeated until tachycardia terminated or maximum single dose of 300 micrograms kg^{-1} given (BNFc).
  - **Infants 1 month-11 months of age:** adenosine IV 150 micrograms kg^{-1}, then increase dose in steps of 50-100 micrograms kg^{-1} every 1-2 minutes if required, dose to be repeated until tachycardia terminated or maximum single dose of 500 micrograms kg^{-1} given (BNFc).
  - **Children 12 months to 11 years of age:** adenosine IV 100 micrograms kg^{-1} then increased in steps of 50-100 micrograms kg^{-1} every 1-2 minutes if required, dose to be repeated until tachycardia terminated or maximum single dose of 500 micrograms kg^{-1} (max 12 mg) given (BNFc).
  - **Children 12-17 years of age:** adenosine IV 3mg, followed by 6 mg after 1-2 minutes if required, followed by 12 mg after 1-2 minutes if required (British National Formulary for children (BNFc)).
  - Each dose of adenosine should be given intravenously by rapid bolus followed by immediate saline flush in a large vein as close to the heart as possible (the heart is the site of action); ensure a rhythm strip is recording for later expert evaluation. Be cautious with adenosine in children and infants with known sinus node disease, pre-excited atrial arrhythmias, heart transplant or severe asthma. In such cases, or when there is no prolonged effect of adenosine, competent providers (with expert consultation) might give alternative medications.
- Wide QRS tachycardias can be either VT or SVT with bundle branch block aberration, or antegrade conduction. In case the mechanism of the arrhythmia is not fully understood, wide QRS arrhythmia should be treated as VT. In a patient who is haemodynamically stable, the response to vagal manoeuvres may provide insight into the mechanism responsible for the

arrhythmia and competent providers (with expert help) can subsequently try pharmacological treatment. Even in stable patients, electrical cardioversion should always be considered. In case of Torsade de pointes VT, magnesium IV 25–50 mg kg^{-1} (max. per dose 2 g), to be given over 10–15 minutes, dose may be repeated once if necessary (consult local protocol) (BNFc).

In managing a child or infant in cardiorespiratory arrest

- The resuscitation team must continuously pay attention to the quality of cardiopulmonary resuscitation they are delivering, ensuring it is of high quality:
  - chest compressions of the correct depth and rate
  - chest compression fraction of 80% or greater
  - full recoil of the chest at the end of each chest compression.
- Once a tracheal tube is in place, continuous chest compressions should be given. In this case, ventilations should approximate to the lower limit of normal rate for age:
  - Infants: 25 breaths per minute
  - Children 1-8 years old: 20 breaths per minute
  - Children 8-12 years old: 15 breaths per minute
  - Children > 12 years old: 10-12 breaths per minute
- End tidal carbon dioxide monitoring should be used if the child or infant has a TT or SGA inserted, to ensure correct airway placement in all situations including cardiac arrest.
- In the non-shockable algorithm, there is increased emphasis on the administration of adrenaline as soon as possible.

In post-resuscitation care

- Avoid hypoxia, hypotension and fever in children and infants who have return of spontaneous circulation (ROSC) following cardiac arrest.
- Targeted temperature management of children post-ROSC should comprise active treatment with either normothermia or mild hypothermia and continuous invasive temperature monitoring.

Introduction

Guidelines 2021 are based on the International Liaison Committee on

Resuscitation 2020 Consensus on Science and Treatment Recommendations for Advanced Life Support and the European Resuscitation Council Guidelines for Resuscitation (2021) Advanced Life Support. Refer to the ERC guidelines publications for supporting reference material.

Management of cardiac arrest in patients with known or suspected COVID-19 is not specifically included in these guidelines, but is covered within RCUK's COVID-19 guidance which is accessible from the RCUK website.

The process used to produce the Resuscitation Council UK Guidelines 2021 has been previously accredited, and is pending reaccreditation by the National Institute for Health and Care Excellence. The guidelines process includes:

- Systematic reviews with grading of the certainty of evidence and strength of recommendations. This led to the International Liaison Committee on Resuscitation (ILCOR) Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations.
- 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.

This guideline applies to all infants and children, excluding only newborn infants

- A newborn is an infant just after birth.
- A neonate is an infant under 1 month.
- An infant is under 1 year.
- A child is between 1 year and 18 years of age.
- The differences between adult and paediatric resuscitation are largely based on differing aetiology. if the rescuer believes the victim to be a child then they should use the paediatric guidelines.
- If a misjudgement is made, and the child turns out to be a young adult, little harm will accrue as studies of aetiology have shown that the paediatric causes of arrest continue into early adulthood.
- It is necessary to differentiate between infants (under 1 year of age) and children, as there are some important differences between these two groups.

The causes of cardiorespiratory arrest in children and infants

differ from those in adults

- Most paediatric arrests arise from decompensated respiratory or circulatory failure causing hypoxia (i.e. they are predominantly secondary cardiorespiratory arrests).
- Cardiorespiratory arrest generally has a poor outcome in children and infants, hence the identification of the seriously ill or injured child and infant is an absolute priority.
- Directed interventions at the compensated or decompensated stages of illness/injury can be lifesaving 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 (plus 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).
- The ABCDE principles guide the order of importance of assessment and intervention in each system.
- Interventions are made at each step as abnormalities are identified with these being addressed in the ABCDE order. Although the sequence of actions is presented stepwise, ALS is a team activity, and several interventions will be done in parallel (for example, in a child or infant with life threatening haemorrhage when circulatory assessment and interventions will be made simultaneously with assessment and management of airway and breathing).
- ALS teams should not only train in knowledge and skills but also in teamwork and the 'choreography' of ALS interventions.

Clinical Response systems

- Evidence from a large randomised trial indicated that whilst the implementation of a paediatric early warning score system does not affect mortality, it does reduce the number of critical incidents associated with

deterioration on the wards. So, whilst early warning scores are useful as part of the overall clinical response system there must be a focus on improving health carers' ability to recognise and intervene for patients with deteriorating illness.

- Summoning a paediatric rapid response team (RRT) or medical emergency team (MET) as an additional part of the clinical response system may reduce the risk of respiratory and/or cardiac arrest in hospitalised children and infants.
- 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).

The sequence of actions in cardiopulmonary resuscitation (CPR)

Establish basic life support (BLS)

- Commence and/or continue CPR as per paediatric BLS.
- Recognition of cardiac arrest (CA) can be done on clinical grounds or based on monitored vital signs (e.g. electrocardiogram (ECG), loss of oxygen saturations (SpO_2) and/or end-tidal carbon dioxide trace ($ETCO_2$), loss of blood pressure).
- Importantly, also start CPR in children who become bradycardic (heart rate $< 60\ min^{-1}$) with signs of inadequate perfusion despite adequate respiratory support.
- See Paediatric BLS section.

Oxygenate, ventilate, and start chest compressions

- Ensure a patent airway by using an airway manoeuvre described in the paediatric BLS section.
- Provide ventilation initially by bag-mask ventilation (BMV), using high-concentration inspired oxygen 100% as soon as this is available. Do not titrate the concentration of inspired oxygen during CPR. To provide an adequate seal of the mask a two-person technique is advocated.
- If BMV can be successfully performed, then continue with this mode of

ventilation. A team member with the necessary skills to safely provide an advanced airway should be summoned but **only** intubate the trachea if this can be performed with minimal interruption to chest compressions. Intubation should also be considered if BMV is unsuccessful or becoming more difficult as the resuscitation progresses). Confirm tracheal tube (TT) placement by $ETCO_2$ monitoring.

- Once positive pressure ventilation via a TT is being delivered, ventilations can be asynchronous and **chest compressions continuous** (only pausing every 2 minutes for rhythm check). In this case, ventilations should approximate to the lower limit of normal rate for age:
  - Infants: 25 breaths per minute
  - Children 1-8 years old: 20 breaths per minute
  - Children 8-12 years old: 15 breaths per minute
  - Children >12 years old: 10-12 breaths per minute
- If BMV is unsuccessful and a team member with the necessary skills to safely intubate the child or infant is not yet present, a competent provider may use a supraglottic airway (SGA) as an alternative.
- Once a TT or SGA is in place $ETCO_2$ monitoring should be used.
- Use a chest compression rate of 100–120 min^{-1}.
- For children or infants already on a mechanical ventilator, either disconnect the ventilator and ventilate by means of a self-inflating bag or continue to ventilate with the mechanical ventilator. In the latter case, ensure that the ventilator is in a volume-controlled mode, that triggers and limits are disabled, and ventilation rate, tidal volume (TV) and fraction of inspired oxygen (FiO_2) are appropriate for CPR. There is no evidence to support any specific level of positive end expiratory pressure (PEEP) during CPR. Ventilator dysfunction can itself be a cause of cardiac arrest.
- Once there is sustained return of spontaneous circulation (ROSC), titrate the FiO_2 to an SpO_2 of 94-98%. In children and infants who do not regain consciousness or for other clinical indications, an advanced airway may be required. Team members with the necessary skills to insert an advanced airway will be required (drugs may be needed at this point to assist).

Attach a defibrillator or monitor

- Assess and monitor the cardiac rhythm via ECG electrodes or defibrillator self-adhesive pads (this is preferred but if not available may use defibrillator paddles).
- If using a defibrillator for a child, place one defibrillator pad or paddle on the chest wall just below the right clavicle, and one in the mid-axillary line

(antero-lateral position).

- In infants and small children, it may be best to apply the pads to the front (mid chest immediately left to the sternum) and back (middle of the back between the scapulae) of the chest if they cannot be adequately separated in the standard positions (antero-posterior position). There is no evidence to recommend the superiority of one pad position over the other, but the heart must be bracketed between the 2 pads.
- Use the largest size pads that fit the chest without touching each other. Pads for children should be 8–12 cm in size, and 4.5 cm for infants.
- Avoid contact between the pads as this will create charge arcing if defibrillation is needed.
- Some defibrillators have pads fitted with feedback devices which will help monitor the quality of CPR delivered, measuring depth and rate of chest compressions. The devices store the data from resuscitation efforts and can be used to debrief teams after resuscitation episodes. There is evidence that guideline compliant CPR and event debriefs can improve resuscitation outcomes.

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 and decide if the rhythm is:
  - **Non-shockable -** asystole, pulseless electrical activity (PEA), bradycardia*, or:
  - **Shockable** – ventricular fibrillation (VF) or pulseless ventricular tachycardia (pVT).

*CPR should be started in children who become bradycardic (< 60 min^{-1}) with signs of inadequate perfusion despite adequate respiratory support. Hence providers should rather assess signs of life and not lose time by checking for a pulse.

Non-shockable (asystole, PEA, bradycardia):

This is the more common finding in children.

- **Perform CPR:**
  - Continue to ventilate with 100% oxygen.
  - If ventilating with BMV 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 if this

does not interfere with satisfactory ventilation.
    - When performing chest compressions, choose a team member who will be able to deliver them most effectively and use a rigid surface/back board so that chest compressions are more effective.
    - Once the child's trachea has been intubated and compressions are uninterrupted ventilations should approximate to the lower limit of normal rate for age:
        - Infants: 25 breaths per minute
        - Children 1-8 years old: 20 breaths per minute
        - Children 8-12 years old: 15 breaths per minute
        - Children >12 years old: 10-12 breaths per minute

Note: Once there is ROSC, the ventilation rate should be a normal physiological age dependent respiratory rate which may then be adjusted to meet the goals of post resuscitation care. Measure end-tidal carbon dioxide ($ETCO_2$) to monitor ventilation and ensure correct TT placement.

- **Give adrenaline:**
    - If vascular access has been established, give IV adrenaline 10 micrograms kg^{-1} (0.1 mL kg^{-1} of 1 in 10,000 solution).
    - If there is no intravenous access, obtain intraosseous (IO) access.
    - **The first dose of adrenaline should be given as soon as possible,** preferably within 3 minutes of identification of cardiac arrest (for non-shockable rhythms).
- **Continue CPR, only pausing briefly every 2 min to check for rhythm change.**
    - Give IV adrenaline 10 micrograms kg^{-1} (0.1 mL kg^{-1} of 1 in 10,000 solution) every 3–5 min (every other cycle), while continuing to maintain effective chest compression and ventilation without interruption.
- **Change the person performing chest compressions at least every 2 minutes.**
    - Watch for fatigue and/or suboptimal compressions, and switch rescuers earlier if necessary.
- **Consider and correct reversible causes (4 Hs and 4 Ts):**
    - Hypoxia
    - Hypovolaemia
    - Hyper/hypokalaemia, metabolic
    - Hypothermia/hyperthermia
    - Thromboembolism (coronary or pulmonary)

    - Tension pneumothorax
    - Tamponade (cardiac)
    - Toxic/therapeutic disturbance.
- **After each 2 min of uninterrupted CPR, pause briefly to assess the rhythm:**
    - **If asystole:**
        - Continue CPR using non shockable sequence
    - **If VF/pVT:**
        - Continue CPR and switch to the shockable (VF/pVT) sequence as below.
    - **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 min^{-1}), and there are no other signs of life, continue CPR and continue as for the non-shockable sequence above.
    - Feeling for a pulse:
        - In a child aged over 1 year – feel for the carotid pulse in the neck.
        - In an infant – feel for the brachial pulse on the inner aspect of the upper arm.
        - For both infants and children, the femoral pulse in the groin (mid-way between the anterior superior iliac spine and the symphysis pubis) can also be used.

Shockable (VF/pVT)

- Shockable rhythms are pulseless ventricular tachycardia (pVT) and ventricular fibrillation (VF).
- As soon identified, defibrillation should immediately be attempted (regardless of the ECG amplitude). If in doubt, consider the rhythm to be shockable.
- Shockable rhythms are less common in children but may occur as a secondary event and are more likely when there has been a witnessed and sudden collapse.
- It is seen more often in the intensive care unit and cardiac ward or in adolescents on the sporting field.
- Good team planning before each action will minimise hands-off time and improve the quality of CPR.
- Continue CPR until a defibrillator is available.

Defibrillate the heart (as soon as possible)

- Apply defibrillation pads (self-adhesive pads are standard) in the antero-lateral or antero-posterior position.
- 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. Minimise the delay between stopping chest compressions and delivery of the shock (<5 seconds).
- Give **1 shock** of 4 J kg^{-1} if using a manual defibrillator. It seems reasonable not to use doses above those suggested for adults
- If using an AED for a child of less than 8 years, preferably deliver a paediatric attenuated adult shock energy (50-75 J) if an attenuator is available. If one is not available use a standard AED which will deliver adult shock energy doses.
- If using an AED for a child over 8 years, use the adult shock energy.
- If using paddles charging should be done with paddles on the chest, pausing compressions at that stage.

Resume CPR

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

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

- If still VF/pVT, give a second shock (with same energy level 4J kg^{-1} 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 compressions.

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

- If still VF/pVT, give a third shock (with same energy level 4J kg^{-1} 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 compressions.
- Give adrenaline 10 micrograms kg^{-1} (0.1 mL kg^{-1} of 1 in 10,000 solution) and amiodarone 5 mg kg^{-1} (or lidocaine 1 mg kg^{-1} may be used an alternative to amiodarone for providers competent in its use) after the third shock after chest compressions have resumed.
- Repeat adrenaline 10 micrograms kg^{-1} (0.1 mL kg^{-1} of 1 in 10,000 solution) every alternate cycle (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

- Continue compressions during charging of the defibrillator and minimise the breaks in chest compression as much as possible.

Change the person performing chest compressions at least every 2 minutes

- Watch for fatigue and/or suboptimal compressions and switch rescuers earlier if necessary.

Consider and correct reversible causes (4 Hs and 4 Ts):

- Hypoxia
- Hypovolaemia
- Hyper/hypokalaemia, metabolic
- Hypothermia/hyperthermia
- Thromboembolism (coronary or pulmonary)
- Tension pneumothorax
- Tamponade (cardiac)
- Toxic/therapeutic disturbance

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.

    - Consider escalating energy doses after seeking expert help for the 6th shock in refractory VF/pVT.
- **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 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.
- CPR should be continued unless:
    - an organised perfusing rhythm is recognised and confirmed by a clinical assessment indicating signs of life (ROSC)
    - there are criteria for withdrawing resuscitation.
- 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 (this has been shown to improve practice).

Additional PALS notes

Tracheal tubes (TT)

- Cuffed TT are recommended in paediatric advanced life support (except in neonates where there is less evidence for their use).
- Cuffed TT are as safe as uncuffed tubes for infants and children if rescuers use the correct tube size, monitor cuff inflation pressure, and verify tube position via CXR.
- The use of cuffed TT 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 TT may be preferable.

Alternative airways

- Although BMV remains the recommended first line method for achieving

airway control and ventilation in children, supraglottic devices (e.g. LMA and i-gel) are an acceptable airway device for providers trained in their use.

- They are particularly helpful in airway obstruction caused by supraglottic airway abnormalities or if BMV is not possible.
- 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

- Use with TT:
  - Monitoring $ETCO_2$ with waveform capnography reliably confirms tracheal tube placement in a child or infant weighing more than 2 kg with a perfusing rhythm and must be used after intubation and during transport of an intubated child or infant.
  - The presence of a capnographic waveform (which will appear after 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 CO_2 during CPR should prompt providers to check tracheal tube placement **‘no trace, wrong place’.** An attenuated CO_2 waveform, however, may reflect low or absent pulmonary blood flow; providers should check quality of chest compressions delivered.
  - Capnography may provide information on the efficiency of chest compressions and a sudden rise in the $ETCO_2$ can be an early indication of ROSC.
  - Try to improve chest compression quality if the $ETCO_2$ remains below 2 kPa as this may indicate low cardiac output and low pulmonary blood flow.
  - Be careful when interpreting $ETCO_2$ values after giving adrenaline or other vasoconstrictor drugs when there may be a transient decrease in $ETCO_2$, 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 $ETCO_2$ value as an indicator for stopping the resuscitation attempt.
- Capnography may also be useful for monitoring ventilation when using SGAs or during BMV.

Transcutaneous pacing

- In selected cases of bradycardia caused by complete heart block or abnormal function of sinus node, emergency transthoracic pacing may be lifesaving.
- Pacing is not helpful in children or infants with bradycardia secondary to post cardiac arrest hypoxic/ischaemic myocardial insult or in bradycardia secondary to respiratory failure.
- Pacing is not effective in the treatment of asystole in children and infants.

Physiological monitoring during CPR to guide therapy

- Monitoring of certain physiological responses during CPR may be used to direct further resuscitative efforts, so called ‘individualised CPR’ in the critical care or highly monitored setting.
- Physiological monitoring may be beneficial, but evidence is currently insufficient to recommend routine use.
- Parameters studied include invasively measured diastolic blood pressure, end tidal carbon dioxide and cerebral near infrared spectroscopy (NIRS).
- **Point of care ultrasound (POCUS):**
  - Can be used by competent providers to identify reversible causes of CA but evidence of benefit on outcome is limited.
  - Its use should not increase hands-off time or impact quality of CPR.
  - Image acquisition is best done during pauses for rhythm check and/or for ventilations; the team should plan and anticipate (choreography) to make the most of the available seconds for imaging.
- **Point of care serum values:**
  - Include serum sodium, potassium, lactate, ionised calcium and magnesium.
  - May be used to identify reversible causes of cardiac arrest but should not be used for prognostication.

Reversible causes

- The early identification and proper treatment of any reversible cause during CPR is a priority for all ALS providers.
- Use the mnemonic “4 H 4 T” to remember what to actively look for:
  - **H**ypoxia
  - **H**ypovolemia

    - **H**ypo- or hyperkalaemia / -calcaemia / -magnesemia & hypoglycaemia
    - **H**ypo- or Hyperthermia
    - **T**ension pneumothorax
    - **T**amponade
    - **T**hrombosis (Cardiac – Pulmonary)
    - **T**oxic Agents
- Unless otherwise specified, the specific treatment for each of these causes is the same in CA as in acute life-threatening disease.
- Providers should consider (with expert help) specific treatments for intoxications with high-risk medications (e.g. beta-blockers, tricyclic antidepressants, calcium channel blockers, digitalis, or insulin).
- For certain life-threatening intoxications extracorporeal treatments should be considered early on and these patients should be transferred to a centre that can perform these in children, ideally before cardiovascular or neurological failure occurs (based upon the context of the intoxication rather than the actual symptoms).

	Consider	Identification	Treatment
H	Hypoxia	History/clinical exam +/-oxygen saturation (if trace picked up)	Ventilation and 100% FiO_2
H	Hypovolaemia	History +/- POCUS*	Fluid bolus 10 mL kg^{-1} isotonic crystalloid; blood products (major haemorrhage)
H	Hyper/hypokalaemia	History + blood gas analysis:	Correction/reduction of metabolic derangement
H	Hypothermia/ Hyperthermia	History + core temperature:	External (e.g. blanket), internal (e.g. cold/warm fluids, extracorporeal circuit) techniques
T	Thromboembolism	History +/- POCUS* (e.g. dilated right ventricle)	IV thrombolysis
T	Tension Pneumothorax	Examine symmetrical air entry +/- POCUS*	Needle thoracocentesis/ thoracostomy (trauma)
T	Tamponade (cardiac)	History +/- POCUS* (e.g. pericardial fluid collection).	Needle pericardiocentesis/ thoracotomy (trauma)
T	Toxic/ therapeutic disturbance	History / ECG	Specific toxic treatment (e.g. Sodium bicarbonate for tri-cyclic drug poisoning)

*POCUS: point of care ultrasound – if competent operator available.

Cardiac Arrest in special circumstances

CPR during specific conditions such as cardiac surgery, neurosurgery, trauma, drowning, sepsis, pulmonary hypertension demand a specific approach. Additionally, the use of extracorporeal life support (ECLS) for CA refractory to conventional CPR (E-CPR) is increasing the support options for children in CA. Institutions performing cardiothoracic surgery in children should establish institution-specific algorithms for cardiac arrest after cardiothoracic surgery.

Traumatic Cardiac Arrest (TCA)

- In case of TCA, start standard CPR while searching for and treating any of the reversible causes of paediatric TCA:
  - airway opening and ventilation with oxygen
  - external haemorrhage control including the use of tourniquets in exsanguinating injury to the extremities
  - bilateral thoracostomy (or needle thoracocentesis)
  - IO/IV access and fluid resuscitation (if possible, with full blood or blood products), as well as the use of the pelvic binder in blunt trauma.
- Chest compressions are performed simultaneously with these interventions depending on the available personnel and procedures. Based on the mechanism of injury, correction of reversible causes might precede adrenaline administration.
- Consider emergency department (ED) thoracotomy in paediatric TCA patients with penetrating trauma with or without signs of life on ED arrival. In some EMS systems, highly competent professionals might also consider pre-hospital thoracotomy for these patients (or for children with selected blunt injury).

Hypothermic Arrest

- Start standard CPR for all victims in CA.
- If continuous CPR is not possible and the child or infant is deeply hypothermic (< 28° C), consider delayed or intermittent CPR.
- Any child or infant who is considered to have any chance of a favourable outcome should ideally be transported as soon as possible to a paediatric centre with extracorporeal life support (ECLS) or cardiopulmonary bypass capacity.

Extracorporeal Life Support (ECLS)

- Extracorporeal cardiopulmonary resuscitation (E-CPR) is the implementation

of veno-arterial extracorporeal membrane oxygenation (VA-ECMO) in a patient with refractory cardiac arrest.

- E-CPR should be considered early for children and infants with in-hospital cardiac arrest (IHCA) and a (presumed) reversible cause when conventional ALS does not promptly lead to ROSC, in a healthcare context where expertise, resources and sustainable systems are available to rapidly initiate ECLS.
- For specific subgroups of children and infants with decompensated cardiorespiratory failure (e.g. severe refractory septic shock or cardiomyopathy or myocarditis and refractory low cardiac output), pre-arrest use of ECLS can be beneficial to provide end-organ support and prevent cardiac arrest. IHCA shortly prior to or during cannulation should not preclude ECLS initiation.
- Competent providers might also decide to perform E-CPR for out-of hospital cardiac arrest (OHCA) in cases of hypothermic cardiac arrest or when cannulation can be done prehospitally by a highly trained team, within a dedicated healthcare system (whilst this is not yet widely available in the UK, practice is increasing).

Septic shock

- There is no evidence to suggest alterations to standard CA algorithm are of benefit.

Single ventricle circulation:

- There is no evidence to suggest alterations to standard CA algorithm are of benefit for children and infants with single ventricle anatomy after stage 1 repair.
- Prior to repair infants with shock due to elevated pulmonary to systemic flow ratio may benefit from inducing mild hypercarbia (reducing ventilation rate and/or tidal volume if ventilated or giving opioids without muscle relaxants).

Hemi-Fontan/Fontan circulation:

- There is no evidence to suggest alterations to standard CA algorithm are of benefit.
- For the seriously ill child or infant, hypercarbia achieved by hypoventilation may be beneficial to increase oxygenation and cardiac output.

- Negative pressure ventilation, if available, may be beneficial for hemi-Fontan, bidirectional Glenn or Fontan circulations by increasing cardiac output.
- It is reasonable to consider ECPR early in situations of refractory CA.

Pulmonary hypertension (PHT)

- If a child or infant with PHT suffers a cardiac arrest, then standard CPR should be performed; it may be beneficial to attempt to correct hypercarbia. Additionally, consider use of inhaled nitric oxide or aerosolised prostacyclin (PGI_2).
- For children and infants with PHT receiving post-operative care respiratory management and monitoring should be directed towards avoiding hypoxia and acidosis.

Drugs and Fluids used in CPR

Body weight estimations

- In order of preference:
  - Use the child/infant's body weight for drug calculations if known.
  - Use a body length tape with pre-calculated drug doses.
  - Use a paediatric emergency drug chart.
  - Use an age-based weight calculation formula (e.g. weight in kg = (age in years + 4) x 2) up to age 10 years.
- For obese patients use ideal body weight and do not use actual weight to avoid drug toxicity.
- Beware of exceeding the adult doses of drugs and fluids in older children.

Intravenous or intraosseous access

- Intraosseous (IO) access is an acceptable route of vascular access in infants and children with cardiac arrest.
- IO access should also be considered in the care of critically ill children and infants whenever IV access is not readily available.

Adrenaline

- This is an endogenous catecholamine with potent alpha, beta-1, and beta-2

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.
- For non-shockable rhythms give adrenaline as soon as access is established, preferably within 3 minutes of identification of cardiac arrest.
- For shockable rhythms give the initial dose of adrenaline immediately after the third shock and then after alternate shocks (5th, 7th, 9th etc).
- The recommended IV/IO dose of adrenaline in children is 10 mcg kg^{-1} (0.1mL kg^{-1} of 1 in 10,000 solution).
- Subsequent doses of adrenaline are given every 3–5 minutes. There is a lack of evidence to suggest the ideal time interval of repeat adrenaline doses but **do not** administer them more frequently than every 3-5 minutes and **do not** use higher doses of IV adrenaline in children because this may worsen outcome.

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 may occur with IV amiodarone is related to the rate of delivery and the solvent (Polysorbate 80 and benzyl alcohol - which causes histamine release). Delivery rate is hence important in patients who have a perfusing rhythm and amiodarone should be infused slowly over longer than 20 minutes when given in the setting of ventricular tachycardia with a pulse or supraventricular tachycardia (preferably with expert paediatric cardiology advice) to avoid bradycardia and cardiac arrest.
- 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 (for dose and how to make up infusion see BNFc).
- 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 must be given peripherally, flush it liberally with 0.9% sodium chloride or 5% glucose.

- Amiodarone dose (BNFc):
  - Neonate 5 mg kg^{-1} IV in VF/pVT dose to be given over at least 3 minutes.
  - Child 5 mg kg^{-1} IV in VF/pVT (max per dose 300 mg), dose to be given over at least 3 minutes.

Lidocaine

- Lidocaine is a class 1B anti-arrhythmic drug which blocks sodium channels, shortening the cardiac action potential and decreasing the rate of contractions of the heart.
- Dose is age dependent (BNFc):
  - **Neonate:** IV injection 0.5-1 mg kg^{-1} followed immediately by IV infusion of 0.6-3 mg kg^{-1} $hour^{-1}$ OR 0.5-1 mg kg^{-1} doses repeated at intervals of not less than 5 minutes if infusion not immediately available following initial injection until infusion can be initiated; maximum 3 mg kg^{-1} per course.
  - **Child 1 month – 11 years:** IV injection 0.5^{-1} mg kg^{-1} followed immediately by IV infusion 0.6-3 mg kg^{-1} hour-1 OR 0.5-1 mg kg^{-1} repeated at intervals of not less than 5 minutes if infusion not immediately available following initial injection until infusion can be initiated; maximum 3 mg kg^{-1} per course.
  - **Child 12-17 years:** Initially IV injection 50-100 mg, followed by IV infusion of 120 mg, dose to be given over 30 minutes; then by IV infusion 240 mg, dose to be given over 2 hours; then by IV infusion 60 mg $hour^{-1}$. Reduce dose further if infusion is continued beyond 24 hours. If infusion not immediately available following initial injection dose may be repeated at intervals of not less than 5 minutes (to a maximum 300 mg dose in 1 hour) until infusion can be initiated.
- Evidence shows that either amiodarone or lidocaine may be used for treatment of paediatric shock resistant VF or pVT.

Atropine

- Atropine is effective in increasing heart rate when bradycardia is caused by excessive vagal tone (e.g. after insertion of nasogastric tube).

- Dose (BNFc):
  - **Neonates and Child 1 month -11 years:** IV 20 mcg kg^{-1}.
  - **Child 12-17 years:** IV 300-600 mcg, larger doses may be used in emergencies.
- There is no evidence that atropine has any benefit in asphyxial bradycardia or asystole or has a role in emergency intubations 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.
- Dose magnesium in Torsades de pointes:
  - Child IV 25-50 mg-1 kg^{-1} (max per dose 2 g) to be given over 10-15 minutes, dose may be repeated once if necessary (consult local protocols)

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, hypermagnesaemia and in overdose of calcium-channel-blocking drugs).
- Dose calcium gluconate in acute hypocalcaemia and in hyperkalaemia (for prevention arrhythmias) by slow intravenous injection (BNFc):
  - **Neonate:** 0.11 mmol kg^{-1} for one dose to be given over 5-10 minutes; some units use a dose of 0.46 mmol kg^{-1} (2 ml kg^{-1} calcium gluconate 10%).
  - **Child:** 0.11 mmol kg^{-1} to be given over 5-10 minutes, maximum 4.5 mmol (20 mL calcium gluconate 10%).

Sodium bicarbonate

- The routine use of sodium bicarbonate in CPR is not recommended.
- 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.
- 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 (10 mL kg^{-1} boluses).
- Use balanced crystalloids or 0.9% saline for initial volume resuscitation; in serious injury blood and blood products may be indicated.
- 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.

Parental presence

- Many parents would want to be present during a resuscitation attempt so they can see that everything possible is being done for their child or infant.
- Reports show that being at the side of the child or infant 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 at the event 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 or infant in the context of their family.
- A dedicated staff member should always stay with the parents 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.
- When appropriate, physical contact with the child or infant 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.

Termination of resuscitation

- There is no evidence to recommend a specific time period after which further resuscitation efforts are futile.
- There are increasing reports of survival to hospital discharge with good neurological outcome in children and infants who have been resuscitated for longer than 20 minutes (not including hypothermic CA).
- Factors that should influence any decision to stop resuscitation efforts include the circumstances of the arrest, initial rhythm, duration of resuscitation and other features such as presence of hypothermia and severe metabolic derangement.

Post-cardiac arrest care (PCAC)

- PCAC is required for children and infants who remain comatose after ROSC.
- The eventual outcome of children and infants following ROSC depends on many factors, some of which may be amenable to treatment. Secondary injury to vital organs might be caused by ongoing cardiovascular failure

from the precipitating pathology, post-ROSC myocardial dysfunction, reperfusion injury, or ongoing hypoxaemia.

- **Haemodynamic:** Avoid post-ROSC hypotension (i.e. MAP < 5th percentile for age). Aim for a blood pressure between 5th and 50th centile then titrate medications as needed, considering the effect on clinical signs, serum lactate and/or measures of cardiac output (including maintaining good cerebral perfusion). Use the minimum necessary doses of parenteral fluids and vasoactive drugs to achieve this. Monitor all interventions and adjust continuously to the child or infant's physiological responses.

Blood pressure for age (mmHg)	**1 month**	**1 year**	**5 year**	**10 year**
50th centile for Systolic BP	75	95	100	110
5th centile for Systolic BP	50	70	75	80
50th centile for mean arterial pressure (MAP)	55	70	75	75
5th centile for mean arterial blood pressure (MAP)	40	50	55	55

- **Ventilation:** Provide a normal ventilatory rate and tidal volume for the child or infant's age, to achieve a normal $PaCO_2$. (4.5-6 kPa). Avoid both hypocarbia and hypercarbia which may have harmful effects. In a few children or infants, the usual values for $PaCO_2$ and PaO_2 may deviate from the population normal values for age (e.g. in children or infants with chronic lung disease or congenital heart conditions); aim to restore values to that child or infant's normal levels. Do not use $ETCO_2$ alone as a surrogate for $PaCO_2$ when aiming for normocapnia as part of neuroprotective care unless there is a proven correlation.

- Oxygenation: Titrate FiO_2 to achieve normoxaemia (PaO_2 10 to 13 kPa.) or, if arterial blood gas is not available, maintain SpO_2 in the range of 94–98%. Maintain high FiO_2 in presumed carbon monoxide poisoning or severe anaemia.
- Use targeted temperature management TTM: Avoid fever (≥ 37.5°C), maintain a specific set temperature, using continuous core temperature monitoring and an external cooling blanket (preferred would be an automated servo-controlled feedback cooling blanket). Lower target temperatures (e.g. 33°C (32-34°C), therapeutic hypothermia) demand appropriate systems of paediatric critical care and should only be used in settings with the necessary expertise. Alternatively, the attending team can aim for a normal target temperature (e.g. 36.5°C (36 – 37.2°C), normothermia).
- **Glucose control:** monitor blood glucose and avoid both hypo- and hyperglycaemia. Be aware that tight glucose control may be harmful, due to a risk of inadvertent hypoglycaemia.
- Although several factors are associated with outcome after cardiopulmonary arrest, no single factor can be used in isolation for prognostication. Providers should use multiple variables in the pre-, intra-, and post-CA phases in an integrated way, including biological markers, electroencephalogram (EEG), somatosensory evoked potentials (SSEP) and neuroimaging (MRI brain).
- Comatose children and infants 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 and referred to the specialist organ donation team.
- After resuscitation for sudden unexplained cardiac arrest a careful history should be taken (syncope, seizures, unexplained accidents/drowning or family history of sudden death) to determine if there is a possibility of inheritable heart disease and a specialist review of any prior ECGs should take place.
- Additionally, if the patient does not survive, a postmortem should take place with tissue analysis for any channelopathies and the family referred to an expert in cardiac rhythm disturbances/ inherited cardiac disease.

References

ERC Guidelines 2021: https://cprguidelines.eu/

Related content

EPALS (European Paediatric Advanced Life Support)

Downloads

Paediatric ALS Algorithm 2021 38.58 KB

Paediatric Cardiac Arrhythmias Algorithm 2021 53.49 KB

Pediatric Emergency Drug Chart 46.21 KB