Chapter 38

Principles of Paediatric Resuscitation

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Paediatric basic and advanced life support skills are essential for all anaesthetists. They may be needed occasionally in the operating room or more commonly when anaesthetists are members of clinical emergency/cardiac arrest teams. Data from the National Cardiac Arrest Audit in the United Kingdom (which collects data from in-hospital cardiac arrests [IHCA] attended by emergency teams) indicates that approximately 250 IHCA occur per year in children and infants in contrast to approximately 16,000 adult IHCA each year.

As cardiac arrest occurs less frequently in children than in adults, regular training is essential. Good teamwork is an important element of successful resuscitation, so an emphasis on this should be placed in simulation training and practice. The ideal interval for re-training is unknown, but it is likely that frequent top-ups, several times a year, are most effective.

Epidemiology

When resuscitating children and infants, the following definitions are used:

- A newborn is an infant just after birth.
- An infant is under the age of 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 paediatric guidelines are used in error in a young adult, little harm will ensue, as studies have shown that the paediatric causes of arrest continue into early adulthood.

Adults most commonly have primary cardiac arrests caused by a cardiac arrhythmia reflecting intrinsic heart disease; this is a sudden acute event. Arrest rhythms are commonly ventricular fibrillation (VF) and pulseless ventricular tachycardia (pVT), and they are managed with prompt defibrillation. Children and infants rarely present with primary cardiac arrest, although it can occur with congenital or acquired heart disease or inherited arrhythmia syndromes.

In children, most cardiac arrests are secondary and are caused by hypoxia associated with decompensated respiratory and/or circulatory failure, reflecting the limit of the body's ability to compensate for the effects of underlying illness or injury. Severe tissue hypoxia causes myocardial dysfunction, resulting in profound bradycardia, which typically deteriorates to asystole or pulseless electrical activity (PEA); hence cardiac arrest in children is more often referred to as cardiorespiratory arrest.

In the operating theatre, cardiac arrest in children is rare, most commonly due to respiratory causes, such as loss of airway, or cardiovascular causes such as hypovolaemia due to blood loss or hyperkalaemia associated with rapid blood transfusion. Children with pulmonary hypertension are also a high-risk group of patients. A combination of many factors can often be identified in perioperative cardiac arrest, including poor preoperative condition, inadequate assessment, inappropriate anaesthesia technique or human factors.

A secondary cardiorespiratory arrest in a ward setting is rarely a sudden event but follows a progressive deterioration. The body initially activates adaptive physiological responses compensating for the effects of the deterioration in vital organs (compensated respiratory or circulatory failure). These compensatory responses result in important signs and symptoms that can be recognised, thereby providing an opportunity to intervene before further deterioration. This pattern of deterioration can most easily be recognised and managed using the structured ABCDE (airway, breathing, circulation, disability, exposure) approach which is taught in resuscitation courses. Early intervention in the deteriorating child is crucial, as the outcome from secondary cardiorespiratory arrest is relatively poor in a ward setting.

Even if return of spontaneous circulation (ROSC) is achieved, morbidity and mortality after cardiorespiratory arrest remain high. Data from the Warwick University Out-of-Hospital Cardiac Arrest Outcomes (OHCAO) audit in the United Kingdom between 2014 and 2018 indicate approximately 570 out-of-hospital cardiac arrests (OHCA) per year in children with 9% survival to hospital discharge. Rates of ROSC and survival to hospital discharge after IHCA have improved over the past two decades, with 70% achieving ROSC and 54% of children surviving to hospital discharge. Cardiac arrest outcomes in theatre are better as children are closely monitored. However, many children continue to succumb to severe organ injury (e.g. brain, kidney) or multi-system organ failure 48–72 hours post-arrest.

Basic Life Support (BLS)

In the management of the collapsed child, several factors are important in maximising the chances of a good outcome. The most important is early recognition and appropriate intervention in children who exhibit signs of respiratory and/or circulatory compromise. Whilst this is essential, there will always be some children in whom respiratory and/or circulatory collapse cannot be prevented. For these children, early BLS, rapid activation of the in-hospital clinical emergency team and prompt, effective advanced life support is crucial in improving mortality and morbidity. The sequence is as shown in the algorithm (Figure 38.1).

BLS is the combination of manoeuvres and skills that provides recognition and management of a person in cardiac or respiratory arrest (without the use of technical adjuncts) and which 'buys time' until the child can receive more advanced treatment. The aim is to achieve sufficient oxygenation and perfusion to 'protect' the brain and other vital organs.

The sequence of actions in BLS is known as cardiopulmonary resuscitation (CPR). For optimum outcome, CPR should start as soon as possible by the first person on the scene. Although ventilation remains a particularly important component of CPR in children, rescuers who are unable or unwilling to provide breaths should be encouraged to perform at least compression-only CPR. A child is far more likely to be harmed if the rescuer does nothing.

Before starting BLS, it is important to remember the 3 S's:

- *Safety*

  Assess the situation and ensure the safety of the rescuer(s) and then the child. There may be a variety of hazards which the rescuer should be alert to whether the situation occurs within or outside the health care environment.

  All bodily fluids should be treated as potentially infectious; put on gloves as soon as practicable and use barrier devices for ventilation (e.g. pocket mask, bag mask ventilation [BMV]) if possible. Most airway procedures are considered aerosol generating and thus require proper (risk-adjusted) personal protection equipment (PPE) in cases of presumed transmittable diseases.

- *Stimulate*

  Establish the responsiveness of the unconscious child by tactile and verbal stimulation but never shake a child vigorously. If the child or infant is unresponsive, further assistance will be required.

- *Shout for assistance*

  Call for help or press the emergency buzzer and summon the clinical emergency team. In the United Kingdom and Europe, the cardiac arrest call number is 2222.

The following subsections describe the elements of the structured ABCDE approach.

A – Airway

Turn the child or infant supine. In the unconscious child, the tongue is likely to occlude their airway at least partly. This can usually be overcome by using a head-tilt and chin-lift manoeuvre or, if necessary, by performing a jaw thrust.

Head tilt and chin lift: place one hand on the forehead and gently tilt their head back. In infants, the head should be placed in a neutral position. For the child, a 'sniffing' position that causes some extension of the head on the neck will be required. The chin lift is performed by placing the fingertips of the rescuer's other hand on the bony part of the child's lower jaw and lifting the chin upwards. Take care not to compress the soft tissues under the child's jaw as this will occlude the airway.

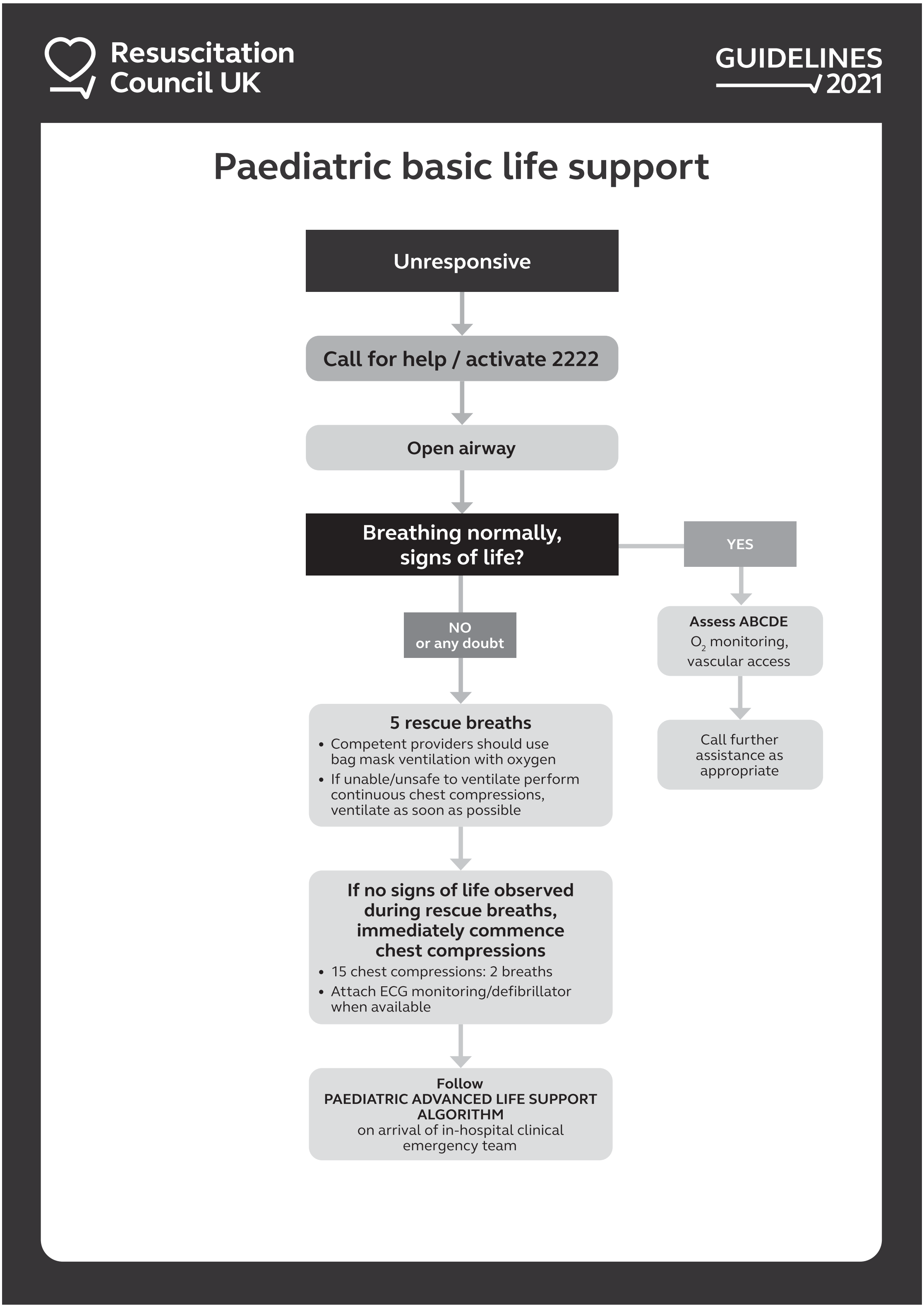

Figure 38.1 The BLS algorithm.

Jaw thrust: this is the preferred airway opening manoeuvre when cervical spine immobilisation is required. Place hands on either side of the child's head with two or three fingertips of both hands under both angles of the child's lower jaw. With thumbs resting gently on the child's cheeks, lift the jaw upwards. If neck injury is suspected, try to open the airway using jaw thrust alone. If this is unsuccessful, add head tilt gradually until the airway is open. Establishing an open airway takes priority over concerns about the cervical spine.

After airway opening, check in the child's mouth to ensure there is no obvious foreign body present. If one is seen and the rescuer is confident that they can remove it safely, this can be attempted; however, blind finger sweeps should never be performed.

B – Breathing

After opening the airway, the rescuer needs to assess the child for effective, normal breathing (see Table 38.1).

Keeping the airway open, look, listen and feel for normal breathing by putting your face close to the child's face and looking along the chest whilst simultaneously looking for signs of life (see Table 38.2). Studies have shown that feeling for a pulse is unreliable in determining the presence or absence of a circulation even for trained paediatric health care workers. The evaluation of circulation is now performed by looking for signs of life during the breathing assessment and during delivery of rescue breaths. If a health care worker wishes to also check for a pulse, this should be done simultaneously with the breathing assessment.

Table 38.1 Assessment of breathing during BLS

LOOK	For chest and abdominal movements
LISTEN	For airflow at the mouth and nose (+/–additional noises)
FEEL	For airflow at the mouth and nose

Table 38.2 Signs of life

Signs of life
Swallowing
Spontaneous movements
Vocalising
Coughing
Normal (not agonal) breathing

Look, listen and feel for no more than 10 seconds before deciding; if you have any doubts about whether the breathing is normal, act as if it is not normal.

If the child's breathing is *not* normal or absent:

- *Give five initial rescue breaths*: While performing the rescue breaths, note any gag or cough response to your action. These responses, or their absence, will form part of your ongoing assessment of signs of life.
- *Give rescue breaths for an infant*: Maintaining an open airway, cover the mouth and nose of the infant with your mouth, ensuring a good seal. Blow steadily into the infant's mouth and nose over one second, sufficient to make the chest rise. Take your mouth away and watch for the chest to fall as air comes out. Repeat this sequence four more times ensuring chest rise and fall.
- *Give rescue breaths for a child older than one year*: Maintaining an open airway, pinch the soft part of the nose closed with the index finger and thumb of your hand on their forehead. Open the mouth a little, but maintain a chin lift. Take a breath and place your lips around the mouth, ensuring a good seal. Blow steadily into their mouth over one second, sufficient to make the chest rise visibly. Take your mouth away and watch for the chest to fall as air comes out. Repeat this sequence four more times ensuring chest rise and fall.
- *Where equipment is immediately, accessible provide ventilation by BMV, using 100% oxygen as soon as this is available*: To provide an adequate seal to the mask, a two-person technique is advocated.
- *If a rescue breath is ineffective, consider airway obstruction or inadequate airway opening*: Try repositioning the head to open the airway or the addition of jaw thrust. Take up to five attempts to achieve an effective breath. If still unsuccessful, move on to chest compressions.

If there are signs of life after the rescue breaths, continue ventilations (12–30 breaths per minute) until the child starts breathing effectively on their own. Unconscious children and infants who are not in cardiac arrest and have normal breathing can have their airway kept open by either continued head tilt and chin lift or jaw thrust. If there is a perceived risk of vomiting, position the unconscious child in a recovery position and check for continued normal breathing once every minute.

C – Circulation

Following the rescue breaths, if there are no signs of life or you are unsure, immediately start high-quality chest compressions. Chest compressions are serial, rhythmic compressions of the anterior chest wall, intended to cause blood to flow to vital organ tissues.

To perform high-quality chest compressions (CC):

- CC rate: 100–120 per minute for both infants and children.
- Locate the xiphisternum and compress the sternum one finger's breadth above this.
- CC depth: depress the lower half of the sternum by at least one third of the anterior-posterior dimension of the chest (approximately 4 cm for an infant and 5 cm for a child), not deeper than 6 cm (adult).
- Release all pressure on the chest between compressions to allow for complete chest recoil; this optimises venous return and hence cardiac output generated by CC.
- Minimise pauses in CC so that 80% or more of the CPR cycle consists of CC. ROSC is linked to the generation of a coronary perfusion pressure of more than 15 mmHg during CPR.

Coronary perfusion pressure rises when the aortic end diastolic pressure generated by effective chest compressions rises. It takes six to eight compressions to build up sufficient aortic end diastolic pressure, and this will be lost immediately if the compressions stop.

After 15 chest compressions, tilt the head, lift the chin and give two rescue breaths. Continue CC and breaths in a ratio of 15:2. Perform compressions on a firm surface.

The best method for compressions varies slightly between infants and children:

- Infants:
  - Two-finger technique: Recommended for the lone rescuer. Place two fingers of one hand in the correct position on the sternum and depress it by at least one third of the depth of the infant's chest, approximately 4 cm.
  - Two-thumb encircling technique: Recommended for two rescuers and in-hospital resuscitation. There is evidence that this method delivers greater cardiac output than the two-finger technique. Place both thumbs flat, side-by-side, on the lower half of the sternum, with the tips pointing towards the infant's head. Spread the rest of both hands, with the fingers together, to encircle the lower part of the infant's rib cage with tips of the fingers supporting the infant's back. Press down on the lower sternum with your two thumbs to depress it at least one third of the depth of the infant's chest, approximately 4 cm. For small infants, you may need to overlap your thumbs to provide effective compressions.
- Chest compression in children aged over one year:
  - Place the heel of one hand over the lower half of the sternum. Lift the fingers to ensure that pressure is not applied over the child's ribs. Position yourself vertically above the child's chest and, with your arm straight, compress the sternum by at least one third of the depth of the chest, approximately 5 cm. In larger children, or for small rescuers, this may be achieved by using both hands with fingers interlocked.

Do not interrupt CPR at any moment unless there are clear signs of life (e.g. normal breathing, coughing). Two or more rescuers should alternate who is performing chest compressions frequently and/or switch hands to avoid fatigue.

Continue with this sequence, attaching electrocardiogram (ECG) monitoring/defibrillator when available, until the arrival of the clinical emergency team or until the child starts to show signs of life.

Advanced Life Support

Resuscitation is a continuous process from BLS to advanced life support (ALS). High-quality BLS is the essential foundation of resuscitation and must be continued even when experienced help arrives and appropriate equipment can be used to facilitate the delivery of advanced techniques. The anaesthetist is often a member of the clinical emergency team because of their advanced airway management skills. Good teamworking skills and excellent communication are required to achieve all the simultaneous interventions that are required to optimise outcomes. The sequence is shown in the ALS algorithm (Figure 38.2).

Whilst monitoring is attached, the team leader should confirm cardiac arrest with a short simultaneous check for breathing and signs of life, then immediately direct the team to recommence high-quality CPR.

Airway and Breathing

The team member tasked with airway and breathing, most often the anaesthetist, should ensure a patent airway by using an airway manoeuvre and provide ventilation, initially by BMV, using 100% oxygen. The concentration of inspired oxygen (FiO_2) should not be titrated 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.

The trachea should only be intubated by experienced personnel (anaesthetists, intensivists) if this can be performed with minimal interruption to chest compressions. Consider intubation if BMV is unsuccessful or becoming more difficult as the resuscitation progresses. A cuffed tracheal tube (TT) should be used, and placement must be confirmed by end-tidal carbon dioxide ($ETCO_2$) monitoring. Once positive pressure ventilation via a TT is being delivered, ventilations can be asynchronous and chest compressions continuous (only pausing every two 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

In the out-of-hospital setting, studies have suggested that ventilation with BMV rather than attempting tracheal intubation or use of a supraglottic airway (SGA) in the management of paediatric cardiac arrest is associated with better outcomes. In the in-hospital setting, there is insufficient evidence to make a definitive recommendation. Competent personnel may choose to insert an SGA as an alternative to intubation when BMV is unsuccessful; $ETCO_2$ monitoring should be used with an SGA.

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 and 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.

Circulation

Once cardiorespiratory arrest is confirmed and CPR recommenced, attach an ECG monitor to allow cardiac rhythm assessment to decide whether the child has a shockable or non-shockable cardiac arrest rhythm (done with no interruption to CPR).

Manual defibrillators can provide ECG monitoring via electrodes or via self-adhesive defibrillation pads. If using pads, place one on the chest wall just below the right clavicle, and one in the mid-axillary line (anterolateral [AL] position). In infants and small children, it may be best to apply the pads to the front (mid-chest immediately left of the sternum) and back (middle of the back between the scapulae) of the chest (antero-posterior [AP] position) if they cannot be adequately separated in the standard positions. There is no evidence to recommend the superiority of one pad position over the other, but the heart must be bracketed between the two 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; these may require AP pad placement. 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.

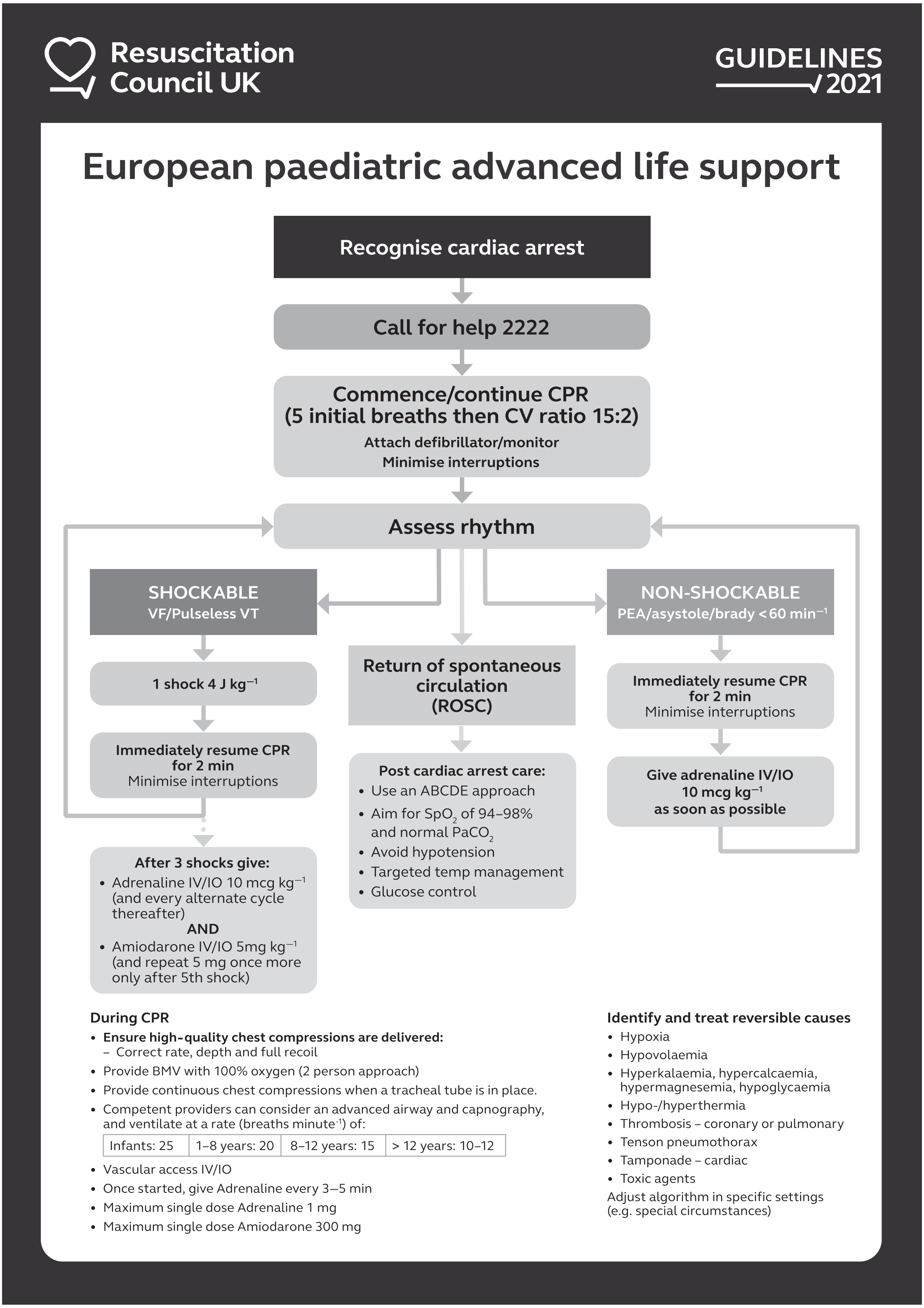

Figure 38.2 The ALS algorithm.

Rhythm Assessment

The majority of children and infants (>80%) will have a non-shockable rhythm:

- *Asystole* – no electrical activity of the heart, the ECG is a flat line.
- *PEA* – normal electrical complexes are present on the ECG, but there are no signs of life nor a palpable pulse.
- *Bradycardia <60/minute* – CPR should be started in children and infants who become bradycardic 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.

A few children and infants will have a shockable rhythm:

- VF
- pVT

Non-shockable (Asystole, PEA, Bradycardia)

- Pause chest compressions briefly to assess the cardiac rhythm on the monitor.
- If a non-shockable rhythm is diagnosed, immediately continue high-quality CPR.
- Obtain intravenous (IV) or intraosseous (IO) access and give 10 mcg kg^{-1} adrenaline (0.1 ml kg^{-1} of 1 in 10,000 solution) as soon as possible after a non-shockable rhythm is identified, preferably within three minutes of identification of cardiac arrest. The same dose of adrenaline should be repeated every three to five minutes (every other cycle) until ROSC is obtained or the rhythm changes and/or CPR is stopped.
- Continue CPR, only pausing briefly every two minutes to check for rhythm change.
  If organised electrical activity is seen, check for signs of life and a pulse. If there is ROSC, continue post-resuscitation care.
- Feeling for a pulse:
  - In a child aged over one 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.
- Consider any reversible causes of cardiorespiratory arrest (4H's and 4T's), and correct as found (see Table 38.3).
- If the patient is intubated, chest compressions can be continuous if this does not interfere with satisfactory ventilation. The ventilation rates during continuous chest compressions differ according to age, as noted in the 'Airway and Breathing' section.
- When performing chest compressions, choose a team member who will be able to deliver them most effectively. Use a rigid surface/back board so that chest compressions are more effective.
- Change the person performing chest compressions at least every two minutes. Watch for fatigue and/or suboptimal compressions and switch rescuers earlier if necessary.
- 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. Continue to measure $ETCO_2$ to monitor ventilation and confirm correct TT placement.

Shockable (VF/pVT)

- As soon as a shockable rhythm is identified, defibrillation should immediately be attempted (regardless of the ECG amplitude). If in doubt, consider the rhythm to be shockable.
- Continue CPR until a defibrillator is available; good team planning before each action will minimise hands-off time and improve the quality of CPR.
- Apply self-adhesive defibrillation pads in the anterolateral or anteroposterior position.
- Charge the defibrillator while another rescuer continues chest compressions.
- Once the defibrillator is charged, pause the chest compressions, ensure all rescuers are clear of the patient and deliver the shock. Minimise the delay between stopping CC and shock delivery (<5 seconds).
- Give one shock of 4 J kg^{-1} if using a manual defibrillator (do not exceed the adult starting dose, 150 J).
- Without reassessing the rhythm or feeling for a pulse, resume CC immediately. Even if the heart is cardioverted to a potential perfusing

Table 38.3 Identification and treatment of the reversible causes of cardiorespiratory arrest in children and infants (the 4Hs and 4Ts)

Cause	Consider	Identification	Treatment
H	Hypoxia	History/clinical exam +/– oxygen saturation (if trace picked up)	Ventilation and 100% FiO2
H	Hypovolaemia	History +/– POCUS*	Fluid bolus 10 mls/kg balanced 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)

Note: *POCUS = point of care ultrasound.

rhythm, the myocardium will be 'stunned' and the right ventricle distended with blood. By restarting CC immediately, coronary perfusion pressure will be maintained and help ventricular emptying.

- Consider and correct reversible causes (4Hs and 4Ts, Table 38.3).
- Continue CPR for two minutes, 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.
- Continue to repeat the cycle of shocks at 4J kg^{-1} followed by two minutes of CPR and a brief pause to assess the rhythm for as long as the child or infant remains in a shockable rhythm.
- Immediately after the third shock, whilst chest compressions are ongoing, give adrenaline 10 mcg kg^{-1} IV/IO (0.1 ml kg^{-1} of 1 in 10,000 solution) and 5 mg kg^{-1} amiodarone IV/IO (lidocaine 1 mg kg^{-1} may be used an alternative to amiodarone).
- The same adrenaline dose, 10 mcg kg^{-1} IV/IO, should then be given after every other shock (third, fifth, seventh, etc.) until ROSC. Amiodarone 5 mg kg^{-1} can be repeated once more after the fifth shock.
- Consider escalating the energy dose for the sixth shock in refractory VF/pVT. The 2021 guidelines suggest escalating to 8J kg^{-1} but without exceeding the maximum adult dose (360 J). In refractory VF/pVT, it is also suggested to try alternative pad placement (i.e. change AL to AP position).
- Change the person performing chest compressions at least every two minutes; watch for fatigue and/or suboptimal compressions and switch rescuers earlier if necessary. Team choreography is important.
- 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 support the team whilst reflecting on their clinical practice.

Automated External Defibrillators (AEDs)

AEDs are increasingly available in public places (supermarkets, swimming pools, cinemas, schools), and a national programme is under way in the United Kingdom to map AED locations so that the ambulance dispatcher (when 999 is called) can direct a rescuer to the nearest one available.

Trained providers should limit the no-flow time when using an AED by performing CPR up to the point of analysis (but not during, or the rhythm will not be correctly identified) and immediately after the shock delivery or no shock decision; pads should be applied with minimal or no interruption in CPR. If possible, use an AED with a paediatric attenuator in infants and children younger than eight years (e.g. energy reduced to 50–75 J). If this is not available, use a standard AED for all ages. There have been continuing reports of safe and successful use of AEDs in children less than eight years, demonstrating that AEDs can identify arrhythmias accurately in children and are extremely unlikely to advise a shock inappropriately.

Capnography

This is mandatory for all intubated patients, including children. Monitoring $ETCO_2$ with waveform capnography reliably confirms TT placement in a child or infant weighing more than 2 kg with a perfusing rhythm. The waveform will appear after four ventilated breaths and indicates that the TT is in the tracheobronchial tree, both in the presence of a perfusing rhythm and during CPR. It does not rule out intubation of a bronchus.

If there is no $ETCO_2$ trace during CPR, then TT placement must be checked. Assume 'No trace, wrong place'.

The $ETCO_2$ value reflects pulmonary blood flow, which in turn reflects cardiac output, so an attenuated $ETCO_2$ waveform or $ETCO_2$ value less than 2 kPa during CPR should direct the team to check the quality of CPR, particularly that of chest compressions, being delivered. A sudden rise in $ETCO_2$ can be an early indication of ROSC. 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 an SGA or during BMV.

Physiological CPR

Several recent studies have looked at monitoring of certain physiological responses during CPR, in the critical care or highly monitored setting, that may be used to direct further resuscitative efforts. Parameters studied include invasively measured diastolic blood pressure, $ETCO_2$ and cerebral near-infrared spectroscopy (NIRS). There is some evidence that generation of diastolic blood pressures of $\geq$25 mmHg in infants and $\geq$30 mmHg in children during CPR may improve the chances of ROSC. Whilst this shows promise for the future, evidence is currently insufficient to recommend routine use.

Point of Care Tests

- Bedside ultrasound (US) may be used by those trained in its use to identify certain reversible causes of cardiac arrest (e.g. cardiac tamponade, pneumothorax), but evidence of benefit on outcome is limited. Most importantly, the use of US should not increase hands-off time or impact the quality of CPR; image acquisition is best done during pauses for rhythm check and/or for ventilations.
- Blood gas analysis may be used to identify reversible causes of cardiac arrest and help direct additional treatments in certain conditions (e.g. hyperkalaemia).

Transcutaneous Pacing

Pacing is not effective for the management of children and infants in asystole. Nor is it 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 useful in selected cases of bradycardia caused by complete heart block or abnormal function of the sinus node, and in these situations emergency transthoracic pacing may be life-saving.

Extracorporeal Life Support (ECLS)

For some children and infants with decompensated cardiorespiratory failure (e.g. severe refractory septic shock or cardiomyopathy or myocarditis with 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. 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 ECLS capacity.

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 IHCA and a presumed reversible cause when conventional ALS does not promptly lead to ROSC. E-CPR has also been used in the management of children with OHCA in cases of hypothermic cardiac arrest or when cannulation can be done pre-hospitally by a highly trained team, within a dedicated health care system. Whilst this is not yet widely available in the United Kingdom, practice is increasing.

Management of Cardiac Arrest in Specific Disease States

Trauma: Start standard CPR with particular attention to external haemorrhage control, including the use of tourniquets in exsanguinating injury to the extremities; potential need for bilateral thoracostomies (or needle thoracocentesis); and IO/IV access and fluid resuscitation (if possible, with blood or blood products), as well as the use of the pelvic binder in blunt trauma. CC are performed simultaneously with these interventions depending on the available personnel and procedures. Effective CPR must be prioritised over cervical spine immobilisation.

Hypothermic arrest: Start standard BLS and assess the heart rhythm. Muscle rigidity in hypothermia will make CC and ventilations more difficult to perform. Hypothermia reduces the effectiveness of defibrillation and resuscitation drugs. If the rhythm is shockable, attempt defibrillation, but if this is unsuccessful continue CC until core temperature $>30^{\circ}$C when drugs and defibrillation are more likely to be effective. Drugs given when the core temperature is $<30^{\circ}$C may accumulate with resultant toxicity when re-warmed. Never stop resuscitation and diagnose death until the patient has been re-warmed to at least 32°C or cannot be re-warmed despite active measures. In some cases, hypothermia can exert a protective effect on the brain and vital organs, and intact neurological recovery can occur even after prolonged cardiac arrest if deep hypothermia develops before asphyxia. Consider E-CPR where facilities are available to support this.

Septic shock: There is no evidence to suggest alterations to standard CPR are of benefit.

Single-ventricle circulation: There is no evidence to suggest alterations to standard CPR 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.

Hemi-Fontan/Fontan circulation: There is no evidence to suggest alterations to standard CPR are of benefit. For the seriously ill child or infant, hypercarbia achieved by hypoventilation may be beneficial to increase oxygenation and cardiac output. Hypovolaemia is poorly tolerated, and intravenous fluid administration may be necessary. 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 E-CPR 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 the use of inhaled nitric oxide or aerosolised prostacyclin (PGI2). For children and infants with PHT receiving postoperative care, respiratory management and monitoring should be directed towards avoiding hypoxia and acidosis.

Prognostic and Family Considerations

There is little evidence to suggest a fixed length of time for CPR after which ongoing efforts are futile, but if there has been no ROSC after 30 minutes of unsuccessful CPR, the team leader should consider stopping the resuscitation. This decision should be made on an individual basis for each child or infant and should consider various factors.

Poor prognostic factors include:

- Unwitnessed arrest
- Prolonged interval from collapse to initiation of CPR
- Asystole as the first arrest rhythm
- Blunt trauma

Good prognostic factors include:

- Witnessed arrest with prompt bystander CPR
- Short periods of CPR
- A shockable rhythm
- Arrest with hypothermia or immersion in cold water

Many parents want to be present during a resuscitation attempt so they can see that everything possible is being done for their child or infant. Studies indicate that being with their child is comforting to the parents and helps them to gain a realistic view of attempted resuscitation and death. Additionally, bereaved families who have been present at the event show less anxiety and depression several months after the death. 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.

Post-resuscitation Care

A child or infant who is successfully resuscitated may suffer from post–cardiac arrest syndrome. This is comprised of multiple organ failure (resulting from hypoxia and ischaemia during cardiac arrest), the effects of the subsequent reperfusion injury and effects from precipitating pathology. It is seen most often in children who remain comatose post-ROSC. Each patient may be affected differently depending on pre-arrest comorbidities, duration of the ischaemic insult and cause of the cardiorespiratory arrest.

A significant percentage of resuscitated children may ultimately die or survive with serious neurological sequelae. Therefore, the main goal of post-resuscitation care is to maintain oxygenation and perfusion to vital organs to prevent secondary organ injury (e.g. hypoxic-ischaemic brain injury, ischaemic myocardial damage, hypoxic pulmonary damage [acute lung injury], acute kidney injury, coagulopathy). For children and infants who have had a cardiorespiratory arrest, the initial step is ROSC, but this is only the first step in the continuous process of resuscitation management.

The ABCDE approach must be followed, and ongoing care of the child who remains comatose post-ROSC is best delivered in a paediatric intensive care unit (PICU). This may require specialist transport. Children who have suffered perioperative cardiac arrest should not be extubated at the end of surgery and should be transferred to the PICU for continuing care.

Airway and breathing: In children and infants who do not regain consciousness within 10 minutes of ROSC and for some other clinical indications (e.g. transfer to PICU, CT scan), intubation may be required, if not already undertaken. This will also allow subsequent control of ventilation: hypoxia, hypercarbia and hypocarbia should all be avoided to prevent the deleterious effects on the brain.

If a child wakes but does not return to a fully alert state, analgesia, sedation and muscle relaxants will be required; these will reduce oxygen consumption, facilitate ventilation and help to prevent complications. Neuromuscular blockade may also be needed to facilitate ventilation and prevent shivering during targeted temperature management (discussed later in this section).

A cuffed TT should be used and the cuff pressure monitored. In the non-theatre setting, tracheal intubation should be performed by competent and experienced personnel (usually anaesthetists) following well-defined protocols, having all necessary equipment and drugs at hand, anticipating problems and having a plan B if intubation fails. Capnography is mandatory for all intubated children, and a chest X-ray should be performed to confirm correct placement of TT (between T2 and T3).

Once intubated, children and infants will require gastric decompression with a gastric tube; this is usually via the nasogastric route unless there is a history of head injury when an orogastric tube should be used in case of basal skull fracture. Once there is sustained ROSC, titrate the FiO_2 to an SpO_2 of 94–98%.

Circulation: Continuous re-assessment to ensure haemodynamic stability and prevent further organ failure is important. A stunned myocardium will not tolerate fluid overload, so judicious use of fluid is indicated. Each bolus should be 10 ml kg^{-1} of balanced isotonic fluid, given when there are signs of circulatory failure; 0.9% saline is an acceptable alternative. Clinical assessment of the child's circulation (heart rate, blood pressure, capillary refill time, peripheral temperature, core temperature and urine output) is important and will aid in the evaluation of any treatment response. Re-assessment should look for signs of effectiveness of fluid administration and for signs of fluid overload, which include basal lung crepitations, an expanding liver edge and in older children a raised jugular venous pressure. Use of vasoactive medications (adrenaline and noradrenaline) should be used when fluid-resistant shock exists or the child develops signs of fluid overload. Noradrenaline and adrenaline may be started as peripheral IV infusions (or given IO) but are best given via a central vein if access can be achieved. An arterial line is optimal, as it will allow monitoring of blood gases and continuous blood pressure. An early echocardiogram is helpful in assessing heart function. Serial lactate measurements may also indicate the effectiveness of circulatory interventions. The ideal goal for blood pressure (BP) post-ROSC is unknown, but BP should not be allowed to fall below the fifth centile for age at any point; aim for a mean or systolic blood pressure between the fifth and 50th centile for age. Urine output is a marker of end-organ perfusion, so it reflects circulatory status and should be monitored (>1 ml kg^{-1} h^{-1} in children and >2 ml kg^{-1} h^{-1} in infants).

Disability: An assessment of neurological status should be performed early to obtain a post-resuscitation baseline, help identify neurological deficits and aid in predicting prognosis. The conscious level should be assessed with either the AVPU or Glasgow Coma Scale scoring systems. Pupil reactivity, posturing and focal signs should also be noted and regularly recorded. Most children who die after ROSC do so from neurological injury, so efforts need to be directed at protecting the brain from secondary injury. Secondary brain injury can be minimised by:

- Avoiding hypoxia, hypocapnia and hypercapnia; providing adequate oxygen and ventilation, keeping $PaCO_2$ between 4.5 kPa and 6.0 kPa.
- Avoiding and treating hypotension with fluids and vasoactive medications; keeping BP between the fifth and 50th centile for age.
- Recognising and promptly treating seizures, as these are associated with a worse outcome; begin continuous EEG monitoring as soon as possible and check blood glucose.
- Correcting glucose and electrolyte abnormalities.
- Monitoring and promptly treating signs of raised ICP (using 3% saline or mannitol).
- Targeted temperature management (TTM): after ROSC, TTM involves strict control of temperature to avoid hyperthermia (>37.5°C) and severe hypothermia (<32°C) and is mandatory. Hyperthermia post-ROSC is common within the first 48 hours and worsens brain injury. Fever should be treated aggressively with anti-pyretics and active cooling. Two large paediatric randomised controlled trials (Therapeutic Hypothermia after Pediatric Cardiac Arrest [THAPCA] trials) compared mild therapeutic hypothermia (TH, 32–34°C) with therapeutic normothermia (TN, 36.8°C, controlled to prevent temperatures above 37.5°C) following in-hospital and out-of-hospital cardiorespiratory arrest. In both the out-of-hospital and in-hospital groups, there was no significant difference in survival or one-year functional outcome between the two different temperature groups (TH and TN). It may be that the avoidance of fever confers a better outcome and is the important goal in TTM for patients following cardiorespiratory arrest. The optimal duration of TTM is unknown, and different centres use 24, 48 or 72 hours.

Exposure: The child or infant will need to be (at least briefly) fully exposed to facilitate a full examination. This may aid in diagnosis and inform specific management (e.g. the purpuric rash of meningococcaemia may prompt treatment with broad-spectrum antibiotics if not already given).

Resuscitation of the Acutely Unwell Child

The transition from a compensatory state to decompensation may occur unpredictably in children. Therefore, any acutely unwell child should be monitored in the right setting to enable early recognition and appropriate intervention to correct any deterioration in their physiology. Health care systems should implement strategies for early recognition and management of deteriorating children and infants in their institutions, including context-specific guidance, for example children with septic shock.

Assessment and Management of Respiratory and Circulatory Failure Follows the ABCDE Approach

Assess the respiratory status by evaluating:

- The child's level of responsiveness: hypoxia causes agitation and eventually loss of consciousness.

- Respiratory rate (RR) adjusted for age and in context: pain, fever and anxiety will all increase RR, so trends are more informative than single values.
- SpO_2.
- Work of breathing: subcostal and intercostal recession, tracheal tug, head bobbing, chest excursion.
- Air entry on auscultation of the chest.
- The presence of additional noises: stridor, wheeze.

Assess the child's circulatory status by evaluating:

- The pulse rate: trends are more informative than single readings.
- Pulse volume.
- Peripheral and end-organ circulation: capillary refill time (CRT), urinary output, level of consciousness.
- Preload evaluation: jugular veins, liver span, lung crepitations.
- Blood pressure.
- Serial lactate measurements.

It is important to remember that no single finding can reliably identify the severity of the circulatory failure and/or be used as a goal for treatment. Attach an ECG monitor to assess cardiac rhythm in acutely unwell children.

All children need to be reassessed frequently and at least after every intervention.

Most drugs and fluids are administered to children based on their weight. In the emergency department, if the weight of the child is not yet known, the weight of the child should be obtained, in order of preference, by:

- Asking the caregiver for a recent weight
- Using a body length tape with pre-calculated drug doses (Sandell, Broselow)
- Using a paediatric emergency drug chart, such as provided on the European Paediatric Advanced Life Support course
- Using an age-based weight calculation formula:
  - For the age group between 1 and 10 years, the following formula provides an approximation of weight:
    weight (kg) = (age in years + 4) × 2.
  - This formula will underestimate the weight of overweight children, but for most resuscitation drugs, dosage is based on lean body mass (care must be taken to avoid exceeding adult drug doses).
  - An infant weighs approximately 3 kg at birth and 10 kg at one year of age.

Airway

- Open the airway and keep it patent using head-tilt/chin-lift or jaw-thrust manoeuvres and perform careful suctioning of any secretions.
- Awake children will usually assume their own optimal position; do not try and lie them down or agitate them, as this will make them cry, causing turbulent airflows resulting in increased airway resistance, worsening hypoxia.
- Consider an oropharyngeal airway (Guedel) in the unconscious child, in whom there is no gag reflex, to optimise the airway. Use the appropriate size, measured from the central incisors to the angle of the mandible, and avoid pushing the tongue backwards during insertion.
- Consider a nasopharyngeal airway in the semi-conscious child for airway optimisation (unless the child has a coagulopathy or basal skull fracture). The correct insertion depth should be sized from the nostrils to the tragus of the ear.
- In children and infants with a tracheostomy, respiratory distress may be caused by obstruction of the tracheostomy tube, leading to ineffective ventilation. Check the patency of the tube by suctioning. If a suction catheter cannot be passed, the tracheostomy tube should be removed immediately and replaced. If a clean tube is not available, ventilation via BMV should be given at the tracheostomy stoma site until the tube is cleaned and replaced. If the child's upper airway is patent, it may be possible to provide BMV via the mouth and nose using a conventional bag and mask whilst the tracheal stoma site is occluded. Rarely tracheal intubation via the tracheostomy with a classical endotracheal tube may be needed. It is important that each child/infant with a tracheostomy has an emergency box which includes spare tubes and a pre-defined emergency plan for airway re-establishment.
- Needle cricothyroidotomy is an emergency technique indicated in cases of upper-airway obstruction (e.g. laryngeal obstruction by

oedema, foreign body or major facial trauma) when an emergency surgical airway is not available. It should only be undertaken when ventilation by BMV or a supraglottic airway device and TT intubation have failed. (See Chapter 22.)

As there is virtually no CO_2 removal, this technique only provides temporary oxygenation until a definitive airway can be provided, that is, tracheal intubation or a tracheostomy. Expert help must be sought as soon as possible.

Breathing

- Start oxygen therapy if SpO_2 <94%.
- For infants or children with chronic conditions, use a threshold of SpO_2 3% below known baseline.
- Maintain SpO_2 94–98 % with as little supplemental oxygen as possible.
- Avoid sustained SpO_2 readings of 100% except when it is known to be beneficial, such as for carbon monoxide poisoning or pulmonary hypertension. There is no benefit to giving oxygen if SpO_2 is within range.
- If SpO_2 cannot be monitored, use 100% oxygen for children and infants with signs and symptoms of respiratory and/or circulatory failure and titrate the oxygen as soon as possible.
- Consider either high-flow humidified nasal cannula oxygen or non-invasive ventilation (NIV) for children with respiratory failure and hypoxaemia not responding to low-flow oxygen.
- For high-flow humidified nasal cannula oxygen, flows of 2 l kg^{-1} min^{-1} are commonly used for children up to 12 kg, plus 0.5 l kg^{-1} min^{-1} for each kilogram thereafter to a maximum of 50 l min^{-1}.
- BMV is the recommended first line method to support ventilation. It is important to use an appropriately sized bag for age to support the tidal volume delivered whilst avoiding hyperinflation.
- If BMV is ineffective or ventilation will be prolonged, progress to tracheal intubation. An SGA will not be well tolerated in child with intact pharyngeal reflexes.
- Tracheal intubation provides a secure airway, and this together with subsequent mechanical ventilation enables secure delivery of both oxygen and positive end expiratory pressure (which will help improve oxygenation). Personnel experienced in airway management should intubate children and infants. Cuffed TTs should be used (except in small infants) with monitoring of cuff inflation pressures.
- All equipment and drugs should be pre-prepared, and the use of a checklist is advised.
- Plans for failure of intubation also need to be reviewed before the procedure.
- Confirm the TT position is correct by clinical assessment, auscultation of the lung with air entry in all areas, capnography and chest X-ray.
- When initiating mechanical ventilation, use a tidal volume appropriate for the size and weight of the child (5–7 ml kg^{-1}) and adjust respiratory rate and expiratory time according to age and pathology. Look for normal chest rise. Avoid hyperinflation as well as hypoventilation.
- Only use $ETCO_2$ as a surrogate for arterial $PaCO_2$ when correlation has been demonstrated.
- If the condition of a child being ventilated via mask, SGA or TT suddenly deteriorates, consider the following causes, best recalled using the acronym DOPES:
  - D stands for displacement of airway device.
  - O for obstruction (TT, airway circuit, airway, head position).
  - P for pneumothorax.
  - E for equipment problem (oxygen, tubing, connections, valves).
  - S for stomach (distention can alter diaphragm mechanics).

Circulation

- Peripheral IV lines are the first choice for vascular access in children who remain responsive to pain. In an emergency, limit the time for placement to five minutes (two attempts).
- For infants and children, the primary rescue alternative is IO access. Health care workers who may encounter an acutely unwell child should be competent in IO placement and have regular retraining in the different devices and

puncture sites used in their workplace. IO infusion is painful, so appropriate intraosseous analgesia will be required before giving the first fluid bolus in every child and infant, unless comatose. Confirm placement clinically and monitor for extravasation, which can lead to compartment syndrome.

- Children and infants with a febrile illness and no signs of shock should not receive fluid bolus therapy.
- Recommendations for fluid administration in shock for children and infants in the UK health care 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 reassessment and discontinued if signs of fluid overload develop. Signs of fluid overload include hepatomegaly, bilateral basal lung crackles and jugular venous distention.
- Use balanced isotonic crystalloids as first choice of fluid bolus (Hartmann's, Ringer's, Plasmalyte, Normosol); if these are not available, 0.9% saline is an acceptable alternative.
- Consensus opinion suggests that in the setting of fluid- and inotrope-resistant septic shock intubation is indicated even in the absence of respiratory failure.
- In suspected septic shock, start broad-spectrum antibiotics as soon as possible after initial ABCDE assessment, ideally within the first hour of treatment, and obtain blood cultures before starting, if this can be done without delaying therapy.
- In haemorrhagic shock, keep crystalloid boluses to a minimum (maximum 20 ml kg^{-1}), and give blood products early to children with severe trauma and circulatory failure (use a strategy that focuses on improving coagulation). Avoid fluid overload, but try to provide adequate tissue perfusion whilst awaiting definitive damage control and/or spontaneous thrombosis.
- Give tranexamic acid 15 mg kg^{-1} loading dose (maximum 1 g) over 10 minutes followed by 2 mg kg^{-1} per hour to all children and infants requiring blood transfusion after severe trauma and/or significant haemorrhage, as soon as possible (within three hours).
- 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).
- **Unstable bradycardia**: Only consider atropine in children where bradycardia is caused by increased vagal tone.
- **Unstable tachycardia**: 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 J kg^{-1}, guided by expert help. If the child or infant is still conscious, use adequate analgesia and sedation (e.g. intranasal or intramuscular ketamine) with airway management. If an IV line can be rapidly sited, IV analgesia and sedation (e.g. ketamine) can be used, but IV access attempts must not delay cardioversion. In children and infants with presumed SVT with good compensation, vagal manoeuvres (ice immersion, Valsalva techniques) can be tried. If this has no immediate effect, proceed with IV or IO adenosine. The dose depends on age; for a child 1–11 years, for example, the dose is 100 mg kg^{-1}, increased in steps of 50–100 mg kg^{-1} every one to two minutes if required, the dose to be repeated until tachycardia terminated or maximum single dose of 500 micrograms kg^{-1} (maximum 12 mg) given. An initial dose of 150 micrograms kg^{-1} is used in infants. In children over 12 years, the initial dose is 3 mg, increasing to 6 mg, then 12 mg. 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 an ECG rhythm strip is recording to evaluate response and for later expert evaluation (exercise caution with adenosine if there is known sinus node disease, pre-excited atrial arrhythmias, heart transplant or severe asthma). Even in stable patients, electrical cardioversion should always be considered.

In case of Torsade de pointes VT, magnesium IV 25–50 mg kg^{-1} (maximum 2 g) should be given over 10–15 minutes; the dose may be repeated once if necessary (check local protocols).

Foreign Body Airway Obstruction (FBAO)

A child will react immediately to a foreign body in the airway by coughing to try to expel it. If the child can still cough effectively, this must be encouraged, as a spontaneous cough is not only safer but probably more effective than any manoeuvre. If coughing is absent or becoming ineffective, the child's airway is at risk of complete obstruction, and immediate intervention is required.

Most choking events occur during play or feeding and are therefore frequently witnessed. If unwitnessed, FBAO should be suspected when the onset of respiratory symptoms (coughing, gagging, stridor, distress) is very sudden and there are no other signs of illness; a history of eating or playing with small items immediately before the onset of symptoms will alert the rescuer. The management is shown in the algorithm (Figure 38.3).

If the child is coughing effectively (fully responsive, loud cough, taking a breath before coughing, still crying or speaking), no manoeuvre is necessary. Encourage the child to cough and continue monitoring the child's condition.

If the child's coughing is or becomes ineffective (decreasing consciousness, quiet cough, inability to breathe or vocalise, cyanosis), ask for help and determine the child's conscious level.

If the child or infant is still conscious but has ineffective coughing, give five back blows. Back blows are intended to loosen the object for the child to be able to then expel it. If back blows do not relieve the airway obstruction and the child is still conscious, then chest thrusts or abdominal thrusts should be given; five chest thrusts for infants and five abdominal thrusts for children. Thrusts increase the intrathoracic pressure, which will facilitate the expulsion of the foreign body. Following chest or abdominal thrusts, reassess the infant or child.

If the foreign body has still not been expelled and the child/infant remains conscious, continue the sequence of five back blows and five chest (for infant) or five abdominal (for children) thrusts. The aim is to relieve the obstruction with each thrust rather than to complete the sequence. Do not use abdominal thrusts (Heimlich manoeuvre) for infants.

If the object is expelled successfully, assess the child's clinical condition. It is possible that part of the object may remain in the respiratory tract and cause complications. If there is any doubt or if the victim was treated with abdominal thrusts, the child needs further medical review in hospital.

If the infant/child with foreign body airway obstruction is, or becomes, unconscious, move to treatment with the paediatric BLS algorithm.

Back blows for an infant:

- Support the infant in a head-downwards, prone position to enable gravity to assist. A seated or kneeling rescuer should be able to support the infant across their lap.
- Support the infant's head by placing the thumb of one hand at the angle of the lower jaw and one or two fingers from the same hand at the same point on the other side of the jaw. Do not compress the soft tissues under the infant's jaw, as this will exacerbate the airway obstruction.
- Deliver up to five sharp back blows with the heel of one hand in the middle of the back between the shoulder blades.

Back blows for a child over one year:

- Back blows are more effective if the child is positioned head-down. A small child may be placed across the rescuer's lap as with an infant. If this is not possible, support the child in a forward-leaning position and deliver the back blows from behind.
- Deliver up to five sharp back blows with the heel of one hand in the middle of the back between the shoulder blades.

Chest thrusts for infants:

- Turn the infant into a head-downwards supine position. Place your free arm along the infant's back and encircle the occiput with your hand. This will be easiest whilst the rescuer is sitting and their arm supporting the infant's back can rest on their thigh.
- Identify the landmark for chest compression (the lower sternum approximately a finger's breadth above the xiphisternum).

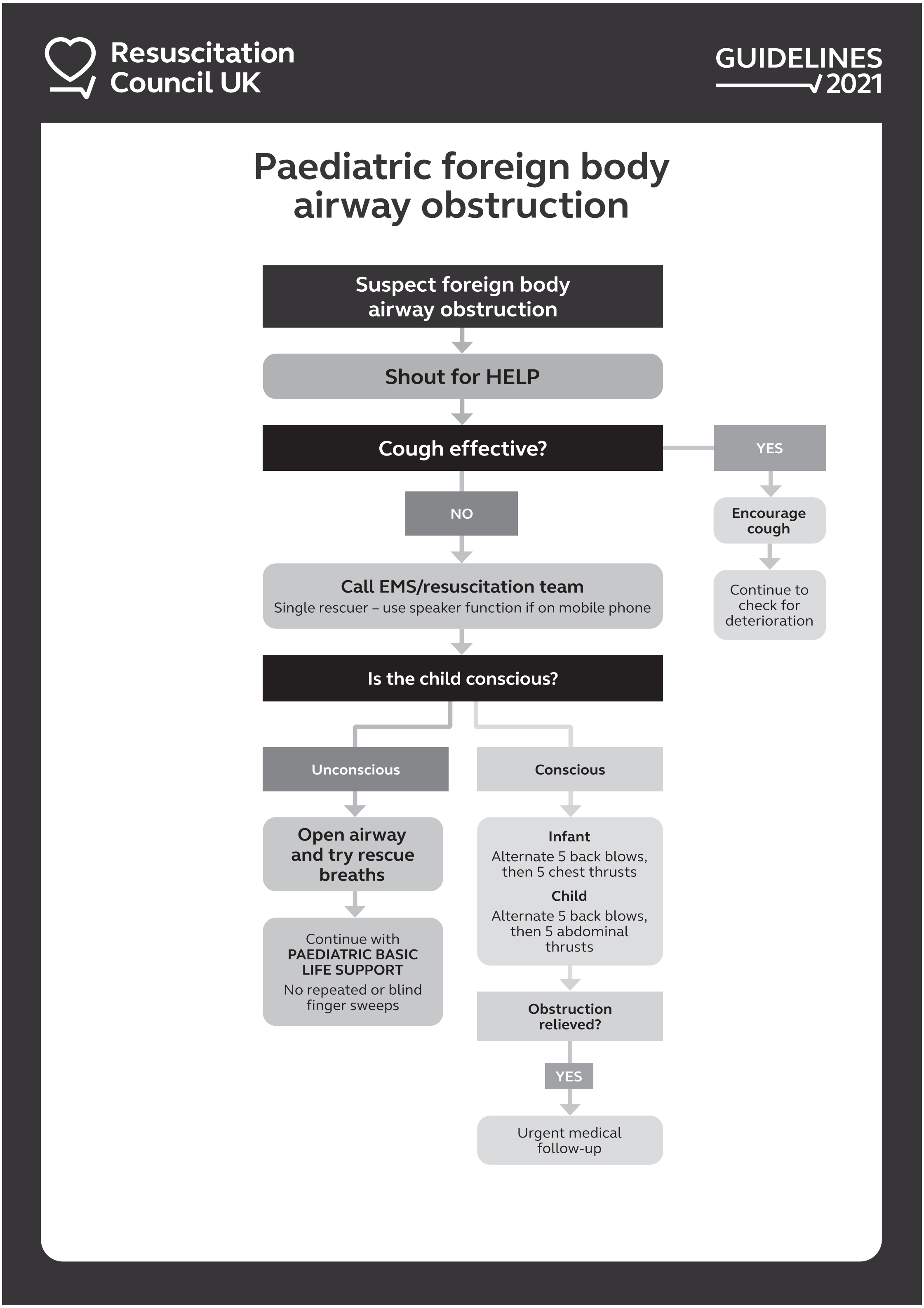

Figure 38.3 The FBAO algorithm.

- Deliver up to five chest thrusts, comparable to chest compressions but sharper in nature and delivered at a slower rate.

Abdominal thrusts for children over one year:

- Stand or kneel behind the child. Place your arms under the child's arms and encircle their torso.
- Clench your fist and place it between the umbilicus and xiphisternum.
- Grasp your fist with the other hand and pull sharply inwards and upwards.
- Repeat up to four more times. Ensure that pressure is not applied to the xiphoid process or the lower rib cage, as this may cause abdominal trauma.

In recent years, several anti-choking devices have become available on the market. A recent systematic review (with broad study inclusion criteria) looking at these devices identified only a small case series of manikin and cadaver studies, which were limited to a single device type. No reports of harm were identified, but their limited use in clinical practice means it is too early to conclude that their use is harm-free. The review recommended the need for further research before device use can be supported in practice.

Key Points

- Children and infants most often have a secondary cardiorespiratory arrest.
- Evaluation of the acutely unwell child with a systematic ABCDE approach will allow early intervention and help prevent deterioration to cardiorespiratory arrest.
- Teamwork is essential to good outcomes; regular training and simulation practice are recommended.
- High-quality CPR is essential to maximise chances of ROSC.
- In cardiorespiratory arrest, signs of life are used to evaluate circulation, as pulse detection is poor even in trained health care workers.
- Good post-ROSC care is important. Avoid hyperoxia and hypo- and hyperventilation, employ TTM and avoid fever (>37.5°C).

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