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# European Resuscitation Council Guidelines 2021: Paediatric Life Support

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**Abstract**

These European Resuscitation Council Paediatric Life Support (PLS) guidelines, are based on the 2020 International Consensus on Cardiopulmonary Resuscitation Science with Treatment Recommendations. This section provides guidelines on the management of critically ill infants and children, before, during and after cardiac arrest.

**Keywords:** Resuscitation child, Infant, Paediatric, CPR, Basic life support, Advanced life support, Defibrillation, Pediatric, Respiratory failure, Circulatory failure, Shock, Oxygen, Cardiac arrest, Bag-mask ventilation

## Introduction and scope

Many of the underlying aetiologies and pathophysiological processes involved in critically ill children and infants differ from those in adults. Critical illness is less common in children and those responsible for its management might have limited experience. The available evidence is often scarce and/or extrapolated from adult literature. Differences in local healthcare organisation and resource availability can lead to significant variation in practice. The ERC Paediatric Life Support (PLS) writing group (PWG) acknowledges this and has tried to make guidelines unequivocal, yet contextual. When writing these guidelines, we focused not only on science, but equally on feasibility of education and implementation.[1]

We identified 80 questions needing review. Search strategies and results, as well as identified knowledge gaps, are described in detail in

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the appendix document to this guideline chapter (Appendix A) and will not be repeated here, providing only a summary of the evidence available and its implications for practice and research. In general, search strategies were in the form of 'rapid reviews' (RR) and these were updated in June 2020. [https://www.who.int/alliance-hpsr/resources/publications/rapid- review-guide/en/]. Where available, searches were primarily informed by reviews included in the International Liaison Committee on Resuscitation Consensus on Cardiopulmonary Resuscitation Science with Treatment Recommendations (ILCOR COSTR). For topics not covered or only partially covered by ILCOR, we explored both existing guidelines and systematic (SR) or narrative reviews (STEP 0) and additional clinical studies (both randomised controlled trials (RCT) and observational studies) directly related to the defined PICOST (Population – Intervention – Control – Outcomes – Setting – Times) (STEP 1). The quality of existing guidelines and SR was assessed using the AGREE II and AMSTAR II tool respectively.[2,3] For clinical studies, we reported results and limitations, yet did not systematically assess for certainty of the evidence. We also considered indirect evidence (STEP 2) from adult, animal, or non-clinical papers to inform our insights.

This ERC guideline chapter focuses on the management of critically ill infants and children, before, during and after cardiac arrest. It should be read in conjunction with other chapters, that focus on specific relevant topics, e.g. information on epidemiology, ethics, education, and certain special circumstances, pertaining to children.

The guidelines for resuscitation of newborn babies (transition at birth) are described in a separate chapter. The ERC PLS guidelines apply to **all other children**, be it neonates (within 4 weeks of being born), infants (up to one year of age) or children (from the age of 1 to 18 years).[4] From a practical perspective, adult guidelines can be used for anyone who appears to be an adult.

In the following text, unless otherwise specified, 'child' refers to both infants and children. We used the term 'healthcare provider' to identify those people who look after patients and should have a higher level of training than lay persons. We specifically used the term 'competent' provider to specify those providers with sufficient knowledge, skills, attitudes, expertise, and ongoing training to perform or lead a certain procedure or action to the level demanded by society. It is not always possible to define unequivocally what sufficient means and consider it the responsibility of the provider to reflect upon their competence.

There are relatively few major changes introduced in these guidelines compared to our guidelines in 2015. Key points to note include (Fig. 1):

- PLS guidelines apply to all children, aged 0–18 years, except for 'newborns at birth'. Patients who look adult can be treated as an adult.
- Oxygen therapy should be titrated to an $SpO_2$ of 94–98%. Until titration is possible, in children with signs of circulatory/respiratory failure where $SpO_2$ (or $PaO_2$) is impossible to measure, we advise to start high flow oxygen.
- For children with circulatory failure, give 1 or more fluid bolus(es) of 10 ml/kg. Reassess after each bolus to avoid fluid overload. Start vasoactive drugs early. Limit crystalloid boluses and as soon as available give blood products (whole blood or packed red cells with plasma and platelets) in case of haemorrhagic shock.
- Any person trained in paediatric BLS should use the specific PBLS algorithm.
- For PBLS providers, immediately after the 5 rescue breaths, proceed with chest compressions – unless there are clear signs of circulation. Single rescuers should first call for help (speakerphone) before proceeding. In case of sudden witnessed collapse, they should also try to apply an AED if directly accessible. If they have no phone available, they should perform 1 min of CPR before interrupting CPR.
- A single PBLS-trained provider preferably uses a two-thumb encircling technique for infant chest compression.
- For PALS providers, we emphasise even more the importance of actively searching for (and treating) reversible causes.
- 2-Person bag-mask ventilation is the first line ventilatory support during CPR for all competent providers. Only if a patient is intubated, we advise asynchronous ventilation and this at an age-appropriate rate (10–25 per minute).
- For PALS providers, when in doubt, consider the rhythm to be shockable.

These guidelines were drafted and agreed by the Paediatric Life Support Writing Group members. The methodology used for guideline development is presented in the Executive summary.[5] The guidelines were posted for public comment in October 2020. The feedback was reviewed by the writing group and the guidelines was updated where relevant. The Guideline was presented to and approved by the ERC General Assembly on 10th December 2020.

## Concise guideline for clinical practice

### Recognition and management of critically ill children

#### Assessment of the seriously ill or injured child

- Use the Paediatric Assessment Triangle or a similar quick-look tool for the early recognition of a child in danger.
- Follow the ABCDE approach
  - Perform the necessary interventions at each step of the assessment as abnormalities are identified.
  - Repeat your evaluation after any intervention or when in doubt.
- **A** is for Airway – establish and maintain airway patency.
- **B** is for Breathing – check
  - Respiratory rate (see Table 1; trends are more informative than single readings)
  - Work of breathing, e.g. retractions, grunting, nasal flaring, . . .
  - Tidal volume (TV) – air entry clinically (chest expansion; quality of cry) or by auscultation
  - Oxygenation (colour, pulse oximetry). Be aware that hypoxaemia can occur without other obvious clinical signs.
  - Consider capnography
  - Consider thoracic ultrasound
- **C** is for Circulation – check
  - Pulse rate (see Table 2; trends are more informative than single readings)
  - Pulse volume
  - Peripheral & end-organ circulation: capillary refill time (CRT), urinary output, level of consciousness. Be aware that CRT is not very sensitive. A normal CRT should not reassure providers.
  - Preload evaluation: jugular veins, liver span, crepitations
  - Blood Pressure (see Table 3)
  - Consider serial lactate measurements
  - Consider point-of-care cardiac ultrasound
- **D** is for **D**isability – check
  - Conscious level using the AVPU (Alert- Verbal-Pain-Unresponsive) score, (paediatric) Glasgow Coma Scale (GCS) total


**Fig. 1 – Main messages of the 2021 paediatric guidelines.**

score, or the GCS motor score. AVPU score of P or less, a Glasgow motor score of 4 and total GCS score of 8 or less define a level of consciousness where airway reflexes are unlikely to be preserved.

- Pupil size, symmetry, and reactivity to light.
- Presence of posturing or focal signs.
- Recognise seizures as a neurological emergency.
- Check blood glucose if altered consciousness and/or potential hypoglycaemia.
- Sudden unexplained neurological symptoms, particularly those persisting after resuscitation, warrant urgent neuroimaging.

## Management of the seriously ill or injured child

Whilst ABCDE is described in a stepwise manner, in practice, interventions are best carried out by multiple team members acting in parallel in a coordinated manner. **Teamwork** is important in the management of any seriously ill or injured child.

Key components of teamwork include:

- **Anticipate:** what to expect, allocate tasks, . . .
- **Prepare:** materials, checklists to support decision making, patient data, . . .
- **Choreography:** where to stand, how to access the child, effective team size, . . .

**Table 1 – Normal values for age: respiratory rate.**

| Respiratory rate for age | 1 month | 1 year | 2 year | 5 year | 10 year |
|---|---|---|---|---|---|
| Upper limit of normal range | 60 | 50 | 40 | 30 | 25 |
| Lower limit of normal range | 25 | 20 | 18 | 17 | 14 |

**Table 2 – Normal values for age: heart rate.**

| Heart rate for age | 1 month | 1 year | 2 year | 5 year | 10 year |
|---|---|---|---|---|---|
| Upper limit of normal range | 180 | 170 | 160 | 140 | 120 |
| Lower limit of normal range | 110 | 100 | 90 | 70 | 60 |

**Table 3 – Normal values for age: systolic and mean arterial blood pressure (MAP). Fifth (p5) and fiftieth (p50) percentile for age.**

| Blood pressure for age | 1 month | 1 year | 5 year | 10 year |
|---|---|---|---|---|
| p50 for systolic BP | 75 | 95 | 100 | 110 |
| p5 for systolic BP | 50 | 70 | 75 | 80 |
| p50 for MAP | 55 | 70 | 75 | 75 |
| p5 for MAP | 40 | 50 | 55 | 55 |

- **Communicate:** both verbal, and non-verbal. Use closed-loop communication and standardised communication elements (e.g. to count compression pauses, plan patient transfers). Keep non-essential communications 'as low as reasonably practicable'. Ensure a low-stress working environment. Implement a culture that strongly condemns inappropriate behaviour, be it from colleagues or family.
- **Interact:** Team members have pre-defined roles as per protocol and perform tasks in parallel. The team-leader (clearly recognisable) monitors team performance, prioritises tasks to achieve common goals and keeps the whole team informed. Hands-off leadership is preferred, if feasible. Shared situational awareness is considered crucial.

We describe below the '**first-hour**' management of different life- or organ-threatening emergencies in children, each of them potentially leading to cardiac arrest if not properly treated. Quite often children will present with a combination of problems that demand a far more individualised approach. Treatment recommendations in children often differ from those in adults but will also differ between children of different age and weight. To estimate a child's weight, either rely on the parents or caretakers or use a length-based method, ideally corrected for body-habitus (e.g. Pawper MAC). Use, whenever possible, decision aids providing pre-calculated dose advice for emergency drugs and materials.

## Management of respiratory failure: general approach (AB)

The transition from a compensatory state to decompensation may occur unpredictably. Therefore, any child at risk should be monitored to enable early detection and correction of any deterioration in their physiology. *Most airway procedures are considered aerosol-generating and thus require proper (risk-adjusted) personal protection equipment (PPE) in cases of presumed transmittable diseases.*

- Open the airway and keep it patent using
  - Adequate head and body alignment,
  - Head tilt  chin lift or jaw thrust,
  - Careful suctioning of secretions.

Awake children will likely assume their own optimal position.

- Consider oropharyngeal airway in the unconscious child, in whom there is no gag reflex.
  - Use the appropriate size (as measured from the central incisors to the angle of the mandible) and avoid pushing the tongue backward during insertion.
- Consider nasopharyngeal airway in the semi-conscious child
  - Avoid if there is a suspicion of a basal skull fracture or of coagulopathy.
  - The correct insertion depth should be sized from the nostrils to the tragus of the ear.
- In children with a **tracheostomy**,
  - Check patency of the tracheostomy tube and suctioning if needed.
  - In case of suspected blockage that cannot be solved by suctioning, immediately remove the tracheostomy tube, and insert a new one. If this is not possible, providers should have a (pre-defined) emergency plan for airway reestablishment.

- To support **oxygenation,** consider supplemental oxygen and/or positive end-expiratory pressure (PEEP).
  - Where it is possible to accurately measure $SpO_2$ (or partial oxygen pressure ($PaO_2$)): start oxygen therapy if $SpO_2 < 94\%$. The goal is to reach an $SpO_2$ of 94% or above, with as little supplemental $FiO_2$ (fraction of inspired oxygen) as possible. Sustained $SpO_2$ readings of 100% should generally be avoided (except for instance in pulmonary hypertension, CO intoxication). Do not give pre-emptive oxygen therapy in children without signs of or immediate risk for hypoxaemia or shock.

Specific recommendations exist for children with certain chronic conditions.
- Where it is impossible to accurately measure $SpO_2$ or $PaO_2$: start oxygen therapy at high $FiO_2$, based upon clinical signs of circulatory or respiratory failure, and titrate oxygen therapy as soon as $SpO_2$ and/or $PaO_2$ become available.
- Where possible, competent providers should consider either high-flow nasal cannula (HFNC) or non-invasive ventilation (NIV) in children with respiratory failure and hypoxaemia not responding to low-flow oxygen.
- Tracheal intubation and subsequent mechanical ventilation enable secure delivery of $FiO_2$ and PEEP. The decision to intubate should be balanced against the existing risks of the procedure and the available resources (see below).
- In hypoxaemic children despite high PEEP (>10 $cmH_2O$) and standard optimisation measures, consider permissive hypoxaemia (oxygenation goal lowered to $SpO_2$ 88–92%).

- To support **ventilation**, adjust respiratory rate (and expiratory time) and/or tidal volume [TV] according to age.
  - Use a TV of 6 to 8 ml/kg IBW (ideal body weight), considering among others physiological and apparatus dead space (especially in younger children). Apparatus dead space should be minimalised. Look for normal chest rise. Avoid hyperinflation, as well as hypoventilation. Aim for normocapnia. Seek early expert help.
  - In acute lung injury, consider permissive hypercapnia (pH >7.2), thus avoiding overly aggressive ventilation. Permissive hypercapnia is not recommended in pulmonary hypertension or severe traumatic brain injury (TBI).
  - Only use $ETCO_2$ or venous partial carbon dioxide pressure ($PvCO_2$) as a surrogate for arterial $PaCO_2$ when correlation has been demonstrated.

- **Bag-mask ventilation (BMV)** is the recommended first line method to support ventilation.
  - Ensure a correct head position and mask size and a proper seal between mask and face.
  - Use an appropriately sized bag for age. To provide adequate TV, the inspiratory time should be sufficiently long (approx. 1 s); avoid hyperinflation.
  - Use a 2-person approach, especially if ventilation is difficult or when there is a risk of disease transmission. Consider airway adjuncts.
  - If competent, consider early placement of a supraglottic airway (SGA) or a tracheal tube (TT) in cases where BMV does not improve oxygenation and/or ventilation or is anticipated to be prolonged.

- **Tracheal intubation(TI)** should only be performed by a competent provider, following a well-defined procedure, and having the necessary materials and drugs. The decision to intubate should always be balanced against the associated risk of the procedure.
  - The oral route for TI is preferable during emergencies.
  - External laryngeal manipulation should only be applied at the discretion of the provider performing the intubation.
  - Use cuffed tracheal tubes (TT) for PLS (except maybe in small infants). Monitor cuff inflation pressure and limit this according to manufacturer's recommendations (usually <20 to 25 $cmH_2O$).
  - Use appropriate medication to facilitate intubation and provide subsequent analgosedation in all children unless they are in cardiorespiratory arrest.
  - Monitor haemodynamics and $SpO_2$ during intubation and be aware that bradycardia and desaturation are late signs of hypoxia.
  - Avoid prolonged laryngoscopy and/or multiple attempts. Anticipate potential cardiorespiratory problems and plan an alternative airway management technique in case the trachea cannot be intubated.
  - Competent providers should consider the (early) use of videolaryngoscopy, in cases where direct laryngoscopy is expected to be difficult.
  - Once intubated, confirmation of proper TT position is mandatory. Evaluate clinically and by means of imaging. Use capnography in all intubated children for early detection of obstruction, mal- or displacement.

- **Supraglottic airways**– SGAs (such as I-gel, LMA) may be an alternative way to provide airway control and ventilation, although they do not totally protect the airway from aspiration. Easier to insert than a TT, an SGA should also only be inserted by a competent provider.

- Sudden rapid deterioration of a child being ventilated (via mask or TT) is a time- critical event that demands immediate action. Consider 'DOPES':
  - **D** stands for displacement (TT, mask)
  - **O** for obstruction (TT, airway circuit, airway – head position)
  - **P** for pneumothorax
  - **E** for equipment (oxygen, tubing, connections, valves)
  - **S** for stomach (abdominal compartment)

### Management of status asthmaticus

- Recognition of a severe asthma crisis is based upon clinical signs, brief history taking, as well as monitoring of $SpO_2$.
  - Lung function determination (PEF or PEV1) is of added value in children >6 years old, if this can be easily measured without delaying treatment.
  - Arterial blood gas analysis is not routine but might be informative when the child does not respond to treatment or deteriorates. Continue oxygen therapy when taking the sample. Due to compensation, $PaCO_2$ might initially be normal or decreased. Hypercapnia is a sign of decompensation.
  - A chest X-ray is not routine but might be indicated if an alternative diagnosis or a complication is suspected.
- Timely, aggressive and protocolised treatment is needed in case of status asthmaticus:
  - Provide a comfortable environment and body position. Avoid sedative drugs, even if there is agitation.
  - Give supplemental oxygen titrated to achieve a $SpO_2$ of 94–98%. Give oxygen at high dose if $SpO_2$ cannot be measured but only until titration is possible.
  - Use short-acting beta-2 agonists (SABA) via an inhaler with spacer (e.g. salbutamol 2–10 puffs) or nebuliser (e.g. salbutamol 2.5–5 mg (0.15 mg/kg)). Adjust doses to response and repeat as needed (up to continuously in the first hour). The effect of SABA begins within seconds and reaches a maximum at 30 min (half- life 2–4 h). Add short-acting anticholinergics (e.g. ipratropium bromide 0.25–0.5 mg) either nebulised or as an inhaler with spacer.

- Give systemic corticosteroids within the first hour, either oral or intravenously (IV). Providers are advised to use the corticoid they are most familiar with (e.g. prednisolone 1–2 mg/kg, with a maximum of 60 mg/day).
- Consider IV magnesium sulfate for severe and life-threatening asthma. Give a single dose of 50 mg/kg over 20 min (max 2 g). In children, isotonic magnesium sulfate might alternatively be used as nebulised solution (2.5 ml of 250 mmol/l; 150 mg).
- Additional drugs can be considered by competent providers e.g. IV ketamine, IV aminophylline etc. Providers should be aware that IV SABA carry a significant risk of electrolyte disorders, hyperlactatemia, and more importantly cardiovascular failure. If used, the child should be monitored carefully.
- Antibiotics are not recommended unless there is evidence of bacterial infection.
- There is no place for routine systemic or local adrenaline in asthma, but anaphylaxis should be excluded as an alternative diagnosis in all children with sudden onset of symptoms.
- If available, consider NIV or HFNC in children with status asthmaticus needing oxygenation support beyond standard $FiO_2$ and/or not responding to initial treatment.

### Management of anaphylaxis

- Early diagnosis of anaphylaxis is crucial and will guide further treatment:
  - *Acute onset of an illness (minutes to hours) with involvement of the skin, mucosal tissue, or both and at least one of the following:*
    - a *Respiratory compromise* e.g. *dyspnoea, wheeze-bronchospasm, stridor, reduced PEF, hypoxaemia*
    - b *Reduced blood pressure or associated symptoms of end-organ dysfunction* e.g. *collapse, syncope*
    - c *Severe gastrointestinal symptoms, especially after exposure to non-food allergens*

*OR*

  - *Acute onset (minutes to several hours) of hypotension or bronchospasm or laryngeal involvement after exposure to a known or probable allergen, even in the absence of typical skin involvement.*
- As soon as anaphylaxis is suspected, immediately administer **intramuscular (IM) adrenaline** (anterolateral mid-thigh, not subcutaneous). Provide further ABCDE care as needed: call for help, airway support, oxygen therapy, ventilatory support, venous access, repetitive fluid boluses and vasoactive drugs.
  - Early administration of IM adrenaline might also be considered for milder allergic symptoms in children with a history of anaphylaxis.
  - The dose for IM adrenaline is 0.01 mg/kg; this can be administered by syringe (1 mg/ml solution) but in most settings auto-injectable adrenaline will be the only form available (0.15 mg (<6 y) – 0.3 mg (6–12 y) – 0.5 mg (>12 y)).
  - If symptoms do not improve rapidly, give a second dose of IM adrenaline after 5–10 min.
  - In cases of refractory anaphylaxis competent physicians might consider the use of IV or intraosseous (IO) adrenaline. Be careful to avoid dosage errors.
- Prevent any further exposure to the triggering agent. In the case of a bee sting, remove the sting as quickly as possible.
- Recognise cardiac arrest and start standard CPR when indicated. Rescuers only having access to IM adrenaline might consider giving this when cardiac arrest has just occurred.
- Consider early TI in case of respiratory compromise. Anticipate airway oedema. Airway management in case of anaphylaxis can be very complicated and early support by highly competent physicians is mandatory.
- In addition to IM adrenaline, consider the use of:
  - Inhaled SABA (and/or inhaled adrenaline) for bronchospasm.
  - IV or oral H1 and H2 antihistamines to alleviate subjective symptoms (especially cutaneous symptoms).
  - Glucocorticosteroids (e.g. methylprednisolone 1–2 mg/kg) only for children needing prolonged observation.
  - Specific treatments related to the context.
- After treatment, further observe for potential late or biphasic symptoms. Those children who responded well to one dose of IM adrenaline without any other risk factor can generally be discharged after 4–8 h. Prolonged observation (12–24 h) is advised for children with a history of biphasic or protracted anaphylaxis or asthma, those who needed more than one dose of IM adrenaline or had a delay between symptoms and first adrenaline dose of more than 60 min.
- Efforts should be made to identify the potential trigger. Without delaying treatment, take blood samples for mast cell tryptase upon arrival and ideally 1–2 h later. Refer patients to a dedicated healthcare professional for follow-up. Every child who had an anaphylactic reaction should have auto-injectable adrenaline prescribed and receive instructions how to use it (both the child, if feasible, and their caregivers).

### Management of circulatory failure [C]

- Healthcare systems should implement context-specific protocols for the management of children with shock including strategies for early recognition and timely emergency treatment.
- The management of a child in circulatory failure needs to be tailored to the individual, considering aetiology, pathophysiology, age, context, comorbidities, and available resources. The transition from a compensated state to decompensation may be rapid and unpredictable. 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 others clinical signs, MAP, trends in lactate, urine output and if competent, ultrasound findings. Competent physicians might also measure advanced haemodynamic variables such as cardiac index, systemic vascular resistance, and central venous oxygen saturation ($ScvO_2$), but this is not a priority in the first hour of care.
- The management of a child in circulatory failure, in accordance with the ABCDE approach, should always include proper management of airway, oxygenation and ventilation.
- **Vascular Access:**
  - Peripheral IV lines are the first choice for vascular access. Competent providers might use ultrasound to guide cannulation. In case of an emergency, limit the time for placement to 5 min (2 attempts) at most. Use rescue alternatives 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 (ALS) providers should be competent in IO placement and have regular retraining in the different devices (and puncture sites) used in their setting. Provide proper analgesia

-in every child unless comatose. Use a properly sized needle. Most standard pumps will not infuse via IO, so use either manual infusion or a high- pressure bag. Confirm proper placement and monitor for extravasation which can lead to compartment syndrome.

- **Fluid therapy:**
  - Give one or more early fluid bolus(es) of **10 ml/kg** in children with recognised shock. Repeated fluid boluses -up to 40–60 ml/kg- might be needed in the first hour of treatment of (septic) shock.
  - Reassess after each bolus and avoid repeated boluses in children who cease to show signs of decreased perfusion or show signs of fluid overload or cardiac failure. Combine clinical signs with biochemical values and if possible, imaging such as cardiac and lung ultrasound to assess the need for additional boluses. In case of repeated fluid boluses, consider vasoactive drugs and respiratory support early on. In settings where intensive care is not available, it seems prudent to be even more restrictive.
  - Use **balanced crystalloids** as first choice of fluid bolus, if available. If not, normal saline is an acceptable alternative. Consider albumin as second-line fluid for children with sepsis, especially in the case of malaria or dengue fever. In non-haemorrhagic shock, blood products are only needed when blood values fall below an acceptable minimum value.
  - Give rapid fluid boluses in children with **hypovolemic non-haemorrhagic shock**. Otherwise, fluid resuscitation of severely dehydrated children can generally be done more gradually (up to e.g. 100 ml/kg over 8 h).
  - In cases of **haemorrhagic shock,** keep crystalloid boluses to a minimum (max. 20 ml/kg). Consider early blood products -or if available, full blood- in children with severe trauma and circulatory failure, using a strategy that focuses on improving coagulation (using at least as much plasma as RBC and considering platelets, fibrinogen, other coagulation factors). Avoid fluid overload but try to provide adequate tissue perfusion awaiting definitive damage control and/or spontaneous haemostasis. Permissive hypotension (MAP at 5th percentile for age) can only be considered in children when there is no risk of associated brain injury.
  - Give **tranexamic acid** (TxA) in all children requiring transfusion after severe trauma -as soon as possible, within the first 3 h after injury- and/or life-threatening haemorrhage. Consider TxA in children with isolated moderate TBI (GCS 9–13) without pupillary abnormalities. Use a loading dose at 15–20 mg/kg (max. 1 g), followed by an infusion of 2 mg/kg/h for at least 8 h or until the bleeding stops (max. 1 g).
- **Vasoactive/Inotropic drugs:**
  - Start vasoactive drugs early, as a continuous infusion (diluted as per local protocol) via either a central or peripheral line, in children with circulatory failure when there is no improvement of the clinical state after multiple fluid boluses. Attention should be given to proper dilution, dosing and infusion management. Preferably use a dedicated line with proper flow, avoiding inadvertent boluses or sudden dose changes. Titrate these drugs based on a desired target MAP, which may differ with pathology, age and patient response; in an ICU setting other haemodynamic variables may also be taken into account.
  - Use either noradrenaline or adrenaline as first-line inoconstrictors and dobutamine or milrinone as first-line inodilators. Dopamine should be considered only in settings where neither adrenaline nor noradrenaline are available. All paediatric ALS providers should be competent in the use of these drugs during the first hour of stabilisation of a child in circulatory failure.
  - Also use vasoactive drugs in cases of hypovolemic shock, when fluid-refractory -especially when there is loss of sympathetic drive such as during anaesthesia-, as well as for children with hypovolemic shock and concomitant TBI. A sufficiently high MAP is needed to attain an adequate cerebral perfusion pressure (e.g. MAP above 50th percentile). Evaluate and, if necessary, support cardiac function.
- **Additional therapies in septic shock:**
  - Consider a first dose of stress-dose hydrocortisone (1–2 mg/kg) in children with septic shock, unresponsive to fluids and vasoactive support, regardless of any biochemical or other parameters.
  - Give stress-dose hydrocortisone in children with septic shock who also have acute or chronic corticosteroid exposure, hypothalamic-pituitary-adrenal axis disorders, congenital adrenal hyperplasia, or other corticosteroid- related endocrinopathies, or have recently been treated with ketoconazole or etomidate.
  - Start broad-spectrum antibiotics as soon as possible after initial ABCD management. Preferably, this is within the first hour of treatment. Obtain blood cultures (or blood samples for PCR) before starting, if this can be done without delaying therapy.
- **Obstructive shock in children:**
  - Tension pneumothorax requires immediate treatment by either emergency thoracostomy or needle thoracocentesis. Use ultrasound to confirm the diagnosis if this does not delay treatment. For both techniques, use the 4th or 5th intercostal space (ICS) slightly anterior to the midaxillary line as the primary site of entry. In children, the 2nd ICS midclavicular remains an acceptable alternative. Convert to standard chest tube drainage as soon as practically feasible.
  - Systems that do not implement immediate thoracostomy should at least consider thoracostomy as a rescue option in paediatric severe trauma and train their providers accordingly.
  - If available, use ultrasound to diagnose pericardial tamponade. Tamponade leading to obstructive shock demands immediate decompression by pericardiocentesis, thoracotomy or (re) sternotomy according to circumstances and available expertise. Depending on their context, systems should have protocols in place for this.
- **Unstable primary bradycardia:**
  - Consider atropine (20 mcg/kg; max. 0.5 mg per dose) only in bradycardia caused by increased vagal tone.
  - Consider emergency transthoracic pacing in selected cases with circulatory failure due to bradycardia caused by complete heart block or abnormal function of the sinus node. Early expert help is mandatory.
- **Unstable primary tachycardia:**
  - In children with decompensated circulatory failure due to either supraventricular (SVT) or ventricular tachycardia (VT), the first choice for treatment is *immediate synchronised electrical cardioversion* at a starting energy of 1 J/kg body weight. Double the energy for each subsequent attempt up to a maximum of 4 J/kg. If possible, this should be guided by expert help. For children who are not yet unconscious, use adequate analgosedation according to local protocol. Check for signs of life after each attempt.

- In children with a presumed SVT who are not yet decompensated, providers can try vagal manoeuvres (e.g. ice application, modified Valsalva techniques). If this has no immediate effect, proceed with IV adenosine. Give a rapid bolus of 0.1−0.2 mg/kg (max 6 mg) with immediate saline flush via a large vein; ensure a rhythm strip is running for later expert evaluation. Especially in younger children, higher initial doses are preferable. In case of persistent SVT, repeat adenosine after at least 1 min at a higher dose (0.3 mg/kg, max 12−18 mg). Be cautious with adenosine in children 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 through an additional pathway. In case the mechanism of the arrhythmia is not fully understood, wide QRS arrhythmia should be treated as VT. In a child 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, IV magnesium sulfate 50 mg/kg is indicated.

## Management of 'neurological' and other medical emergencies [D] [E]

Recognise and treat neurological emergencies quickly, because prognosis is worsened by secondary injury (due to e.g. hypoxia, hypotension) and treatment delays. In accordance with the ABCDE approach, such treatment includes proper management of airway, oxygenation and ventilation, and circulation.

### Status epilepticus

- Identify and manage underlying diagnoses and precipitant causes including hypoglycaemia, electrolyte disorders, intoxications, brain infections and neurological diseases, as well as systemic complications such as airway obstruction, hypoxaemia or shock.
- If convulsions persist for more than 5 min, give a first dose of a benzodiazepine. Immediate treatment should be considered in specific situations. Which benzodiazepine via which route to give will depend on the availability, context, social preference, and expertise of the providers. Non-IV benzodiazepines should be used if an IV line is not (yet) available. Adequate dosing is essential, we suggest:
  - IM midazolam 0.2 mg/kg (max 10 mg) or prefilled syringes: 5 mg for 13−40 kg, 10 mg > 40 kg); intranasal/buccal 0.3 mg/kg; IV 0.15 mg/kg (max 7.5 mg)
  - IV lorazepam 0.1 mg/kg (max 4 mg)
  - IV diazepam 0.2−0.25 mg/kg (max 10 mg)/rectal 0.5 mg/kg (max 20 mg)
- If convulsions persist after another 5 min, administer a second dose of benzodiazepine and prepare a long-acting second line drug for administration. Seek expert help.
- Not later than 20 min after convulsions started, give second line anti-epileptic drugs. The choice of drug will again depend on context, availability, and expertise of the provider. Adequate dosing is again essential:
  - Levetiracetam 40−60 mg/kg IV (recent papers suggest the higher dose; max. 4.5 g, over 15')
  - Phenytoin 20 mg/kg IV (max. 1.5 g, over 20 min; or alternatively phosphenytoin)
  - Valproic acid 40 mg/kg IV (max 3 g; over 15 min; avoid in cases of presumed hepatic failure or metabolic diseases − which can never be ruled out in infants and younger children-, as well as in pregnant teenagers).
  - Phenobarbital (20 mg/kg over 20 min) IV is a reasonable second-line alternative if none of the three recommended therapies are available.
- If convulsions continue, consider an additional second-line drug after the first second-line drug has been given.
- Not later than 40 min after convulsions started, consider anaesthetic doses (given by a competent provider) of either midazolam, ketamine, pentobarbital/thiopental, or propofol; preferably under continuous EEG monitoring. Prepare for adequate support of oxygenation, ventilation and perfusion as needed.
- Non-convulsive status epilepticus can continue after clinical convulsions cease; all children who do not completely regain consciousness need EEG monitoring and appropriate treatment.

### Hypoglycaemia

- Recognise hypoglycaemia using context, clinical signs, and measurement (50−70 mg/dl; 2.8−3.9 mmol/L), and promptly treat this. Also identify and treat any underlying cause. Specific dosage of IV glucose maintenance might be indicated in specific metabolic diseases.
- Mild asymptomatic hypoglycaemia may be treated with standard glucose administration, either by maintenance infusion glucose (6−8 mg/kg/min) or by oral rapid acting glucose (0.3 g/kg tablets or equivalent), followed by additional carbohydrate intake to prevent recurrence.
- Severe paediatric hypoglycaemia (<50 mg/dl (2.8 mmol/L) with neuroglycopenic symptoms) demands:
  - IV glucose 0.3 g/kg bolus; preferably as 10% (100 mg/ml; 3 ml/kg) or 20%-solution (200 mg/ml; 1.5 ml/kg)
  - When IV glucose is not available, providers may administer glucagon as temporary rescue, either IM or SC (0.03 mg/kg or 1 mg >25 kg; 0.5 mg <25 kg) or intranasally (3 mg; 4−16 y).
  - Retest blood glucose 10 min after treatment and repeat treatment if the response is inadequate. Reasonable targets are an increase of at least 50 mg/dl (2.8 mmol/L) and/or a target glycaemia of 100 mg/dL (5.6 mmol/L).
  - Start a glucose maintenance infusion (6−8 mg/kg/min) to reverse catabolism and maintain adequate glycaemia.

### Hypokalaemia

- For severe hypokalaemia (<2.5 mmol/L) in a pre-arrest state, give IV boluses of 1 mmol/kg (max 30 mmol) over at least 20 min to a monitored child and repeat until the serum potassium is above 2.5 mmol/L avoiding inadvertent hyperkalaemia. Also give IV magnesium sulfate 30−50 mg/kg.
- In all other cases, enteral potassium is preferred for those who tolerate enteral supplementation. The eventual dose should depend on the clinical presentation, the value measured and the expected degree of depletion.

### Hyperkalaemia

- To evaluate the severity of hyperkalaemia, consider the potassium value in the context of the underlying cause and contributing factors, and the presence of potassium-related ECG changes.

Eliminate or treat underlying causes and contributing factors as soon as possible.

- Tailor emergency treatment to the individual child. Consider early expert help. In children with acute symptomatic life- threatening hyperkalaemia give:
  - Calcium (e.g. calcium gluconate 10% 0.5 ml/kg max 20 ml) for membrane stabilisation. This works within minutes and the effect lasts 30−60 min.
  - Fast-acting insulin with glucose to redistribute potassium, which is effective after about 15 min, peaks at 30−60 min and lasts 4 −6 h (e.g. 0.1 U/kg insulin in a 1 IU insulin in 25 ml glucose 20% solution; there is no need for initial glucose when the initial glycaemia is >250 mg/dl (13.9 mmol/L)). Repeated dosing might be necessary. To avoid hypoglycaemia, once hyperkalaemia is treated, continue with a glucose maintenance infusion without insulin. Monitor blood glucose levels.
  - Nebulised beta-agonists at high dose (e.g. 5 times the bronchodilation dose), however be aware that the maximal effect is reached only after 90 min.
  - Sodium bicarbonate 1 mmol/kg IV (repeat as necessary) in case of a metabolic acidosis (pH < 7.2) and/or in cardiac arrest. The effect of sodium bicarbonate is slow (hours).
- Continue potassium redistribution measures until potassium removal treatments become effective. Potassium removal can be done by potassium binding agents, furosemide (in well-hydrated children with preserved kidney function) and/or dialysis.

### Hyperthermia

- In cases of **heat stroke** (i.e. a central body temperature ≥ 40 −40.5 °C with central nervous system (CNS) dysfunction):
  - Monitor central body temperature as soon as possible (rectal, oesophageal, bladder, intravascular).
  - Prehospital treatment consists of full ABCDE management and rapid aggressive cooling. Remove the child from the heat source. Undress and fan with cold air and mist. Apply ice packs. Provide early evaporative external cooling. Consider cold-water immersion for adolescents and young adults.
  - Further cooling in hospital can be done by placing the child on a cooling blanket; applying ice packs to the neck, axilla and groin or alternatively on the smooth skin surfaces of the cheeks, palms, and soles; and infusion of IV crystalloids at room temperature. Stop cooling measures once the core temperature reaches 38 °C. Benzodiazepines are suggested to avoid trembling, shivering or seizures during cooling measures. Classic antipyretic medications are ineffective.
  - All children with heat stroke should be admitted to a (paediatric) intensive care unit to maintain adequate monitoring and to treat associated organ dysfunction.

## Paediatric basic life support

The sequence of actions in paediatric BLS (PBLS) support will depend upon the level of training of the rescuer attending: those fully competent in PBLS (preferred algorithm), those trained only in adult BLS and those untrained (dispatcher- assisted lay rescuers).

### Sequence of actions in PBLS

- Ensure safety of rescuer and child. Check for responsiveness to verbal and tactile stimulation (Fig. 2). Ask bystanders to help.
- If the child does not respond, open the airway, and assess breathing for no longer than 10 s.
  - If you have difficulty opening the airway with head tilt − chin lift or specifically in cases of trauma, use a jaw thrust. If needed, add head tilt a small amount at a time until the airway is open.
  - In the first few minutes after a cardiac arrest a child may be taking slow infrequent gasps. If you have any doubt whether breathing is normal, act as if it is not normal.
  - Look for respiratory effort, listen and feel for movement of air from the nose and/or mouth. If there is effort but no air movement, the airway is not open.
  - In cases where there is more than one rescuer, a second rescuer should call the EMS immediately upon recognition of unconsciousness, preferably using the speaker function of a mobile phone.
- In the unresponsive child, if breathing is absent or abnormal: give five initial rescue breaths.
  - For infants, ensure a neutral position of the head. In older children, more extension of the head will be needed (head tilt).
  - Blow steadily into the child's mouth (or infant's mouth and nose) for about 1 second, sufficient to make the chest visibly rise.
  - If you have difficulty achieving an effective breath, the airway may be obstructed (see below): remove any visible obstruction. Do not perform a blind finger sweep. Reposition the head or adjust airway opening method. Make up to five attempts to achieve effective breaths, if still unsuccessful, move on to chest compressions.
  - Competent providers should use BMV with oxygen, when available, instead of expired air ventilation. In larger children when BMV is not available, competent providers can also use a pocket mask for rescue breaths.
  - If there is only one rescuer, with a mobile phone, he or she should call help first (and activate the speaker function) immediately after the initial rescue breaths. Proceed to the next step while waiting for an answer. If no phone is readily available perform 1 min of CPR before leaving the child.
  - In cases where PBLS providers are unable or unwilling to start with ventilations, they should proceed with compressions and add into the sequence ventilations as soon as these can be performed.
- Immediately proceed with 15 chest compressions, unless there are clear signs of circulation (such as movement, coughing). Rather than looking at each factor independently, focus on consistent good quality compressions as defined by:
  - Rate: 100−120 $min^{-1}$ for both infants and children.
  - Depth: depress the lower half of the sternum by at least one third of the anterior−posterior dimension of the chest. Compressions should never be deeper than the adult 6 cm limit (approx. an adult thumb's length).
  - Recoil: Avoid leaning. Release all pressure between compressions and allow for complete chest recoil.

When possible, perform compressions on a firm surface. Move the child only if this results in markedly better CPR conditions (surface, accessibility). Remove clothes only if they severely hinder chest compressions.

Preferably use a two-thumb encircling technique for chest compression in infants − be careful to avoid incomplete recoil. Single rescuers might alternatively use a two-finger technique.

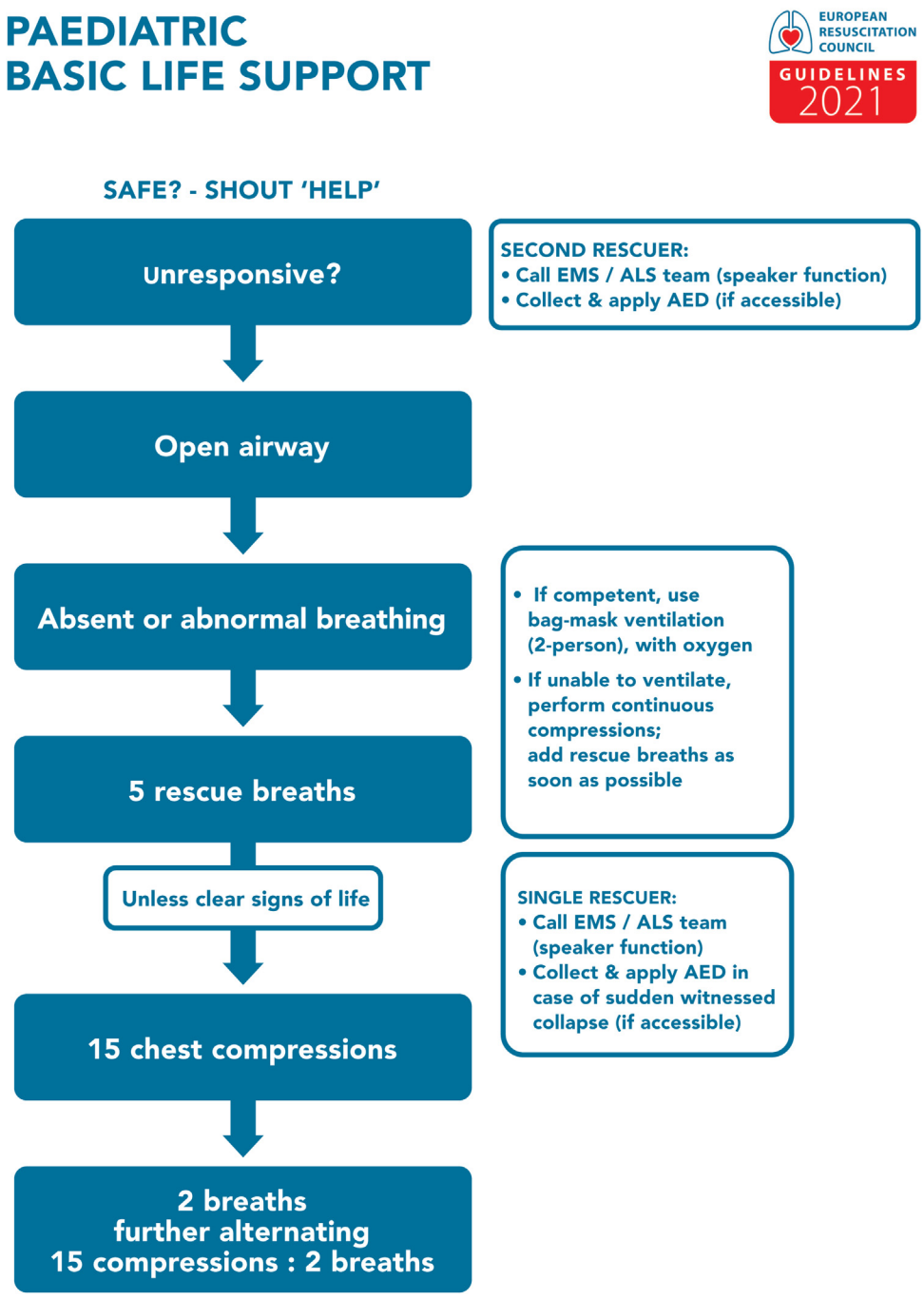


**Fig. 2 – Paediatric basic life support.**

In children older than 1 year, depending on size and hand span, use either a one-hand or two-hand technique. In case the one-hand technique is used, the other hand can be positioned to maintain an open airway throughout (or to stabilise the compression arm at the elbow).

- After 15 compressions, 2 rescue breaths should follow and then alternating (15:2 duty cycle). Do not interrupt CPR at any moment unless there are clear signs of circulation (movement, coughing) or when exhausted. Two or more rescuers should change the rescuer performing chest compressions frequently and the individual rescuer should switch hands (the hand compressing, the hand on top) or technique (one to 2-handed) to avoid fatigue.
- In case there are clear signs of life, but the child remains unconscious but not breathing normally, continue to support ventilation at a rate appropriate for age.

### Rescuers only trained in adult BLS

BLS providers who are untrained in PBLS, should follow the adult CPR algorithm with ventilations, as they were trained, adapting the techniques to the size of the child. If trained, they should consider

giving 5 initial rescue breaths before proceeding with compressions.

### Untrained lay rescuers

- Cardiac arrest is determined to have occurred based on the combination of being *unresponsive and absent or abnormal breathing*. As the latter is often difficult to identify or when there are concerns about safety (e.g. risk of viral transmission), rather than look-listen-feel, bystanders might also be guided by specific word descriptors or by feeling for respiratory movement.
- Bystander CPR should be started in all cases when feasible. The EMS dispatcher has a crucial role in assisting lay untrained bystanders to recognise CA and provide CPR. When bystander CPR is already in progress at the time of the call, dispatchers should probably only provide instructions when asked for or when issues with knowledge or skills are identified.
- The steps of the algorithm for paediatric dispatcher-assisted CPR are very similar to the PBLS algorithm. To decrease the number of switches, a 30:2 duty cycle might be preferable. If bystanders cannot provide rescue breaths, they should proceed with chest compressions only.

### Use of an automated external defibrillator (AED)

- In children with a CA, a lone rescuer should immediately start CPR as described above. In cases where the likelihood of a primary shockable rhythm is very high such as in sudden witnessed collapse, if directly accessible, he or she can rapidly collect and apply an AED (at the time of calling EMS). In case there is more than one rescuer, a second rescuer will immediately call for help and then collect and apply an AED (if feasible).
- Trained providers should limit the no-flow time when using an AED by restarting CPR 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 below 8 years. If such is not available, use a standard AED for all ages.

### PBLS in case of traumatic cardiac arrest (TCA)

- Perform bystander CPR when confronted with a child in CA after trauma, provided it is safe to do so. Try to minimise spinal movement as far as possible during CPR without hampering the process of resuscitation, which clearly has priority.
- Do not routinely apply an AED at the scene of paediatric TCA unless there is a high likelihood of shockable underlying rhythm such as after electrocution.
- Apply direct pressure to stop massive external haemorrhage if possible, using haemostatic dressings. Use a tourniquet (preferably manufactured but otherwise improvised) in case of an uncontrollable, life- threatening external bleeding.

### Recovery position

- Unconscious children who are not in CA and clearly have normal breathing, can have their airway kept open by either continued head tilt – chin lift or jaw thrust or, especially when there is a perceived risk of vomiting, by positioning the unconscious child in a recovery position.
- Once in recovery position, reassess breathing *every minute* to recognise CA as soon as it occurs (lay rescuers might need dispatcher guidance to do so).
- Avoid any pressure on the child's chest that may impair breathing and regularly change side to avoid pressure points (i.e. every 30 min).
- In unconscious trauma victims, open the airway using a jaw thrust, taking care to avoid spinal rotation.

### Paediatric foreign body airway obstruction (FBAO)

- Suspect FBAO -if unwitnessed- 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 might further alert the rescuer.
- As long as 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 (Fig. 3).
- If the child's coughing is (becoming) **ineffective** (decreasing consciousness, quiet cough, inability to breathe or vocalise, cyanosis), ask for bystander help and determine the child's conscious level. A second rescuer should call EMS, preferably by mobile phone (speaker function). A single trained rescuer should first proceed with rescue manoeuvres (unless able to call simultaneously with the speaker function activated).
- If the child is still conscious but has ineffective coughing, give back blows. If back blows do not relieve the FBAO, give chest thrusts to infants or abdominal thrusts to children. If the foreign body has not been expelled and the victim is still conscious, continue the sequence of back blows and chest (for infant) or abdominal (for children) thrusts. Do not leave the child.
- The aim is to relieve the obstruction with each thrust rather than to give many of them.
- 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, urgent medical follow up is mandatory.
- If the child with FBAO is, or becomes, unconscious, continue according to the paediatric BLS algorithm. Competent providers should consider the use of Magill forceps to remove a foreign body.

## Paediatric advanced life support

### Sequence of actions in PALS

Although the sequence of actions is presented stepwise, ALS is a team activity, and several interventions will be done in parallel. ALS teams should not only train in knowledge and skills but also in teamwork and the 'choreography' of ALS interventions (Fig. 4).

- *Commence and/or continue with paediatric BLS*. Recognition of CA can be done on clinical grounds or based on monitored vital signs (ECG, loss of $SpO_2$ and/or $ETCO_2$, loss of blood pressure etc.). Importantly, also start CPR in children who become bradycardic with signs of very low perfusion despite adequate respiratory support.
- If not already in place, apply cardiac monitoring as soon as possible using ECG-electrodes or self-adhesive defibrillator pads (or defibrillation paddles). *Differentiate between shockable and non-shockable cardiac rhythms*.
  - **Non-shockable** rhythms are pulseless electrical activity (PEA), bradycardia and asystole. If bradycardia (<60 per minute) is the

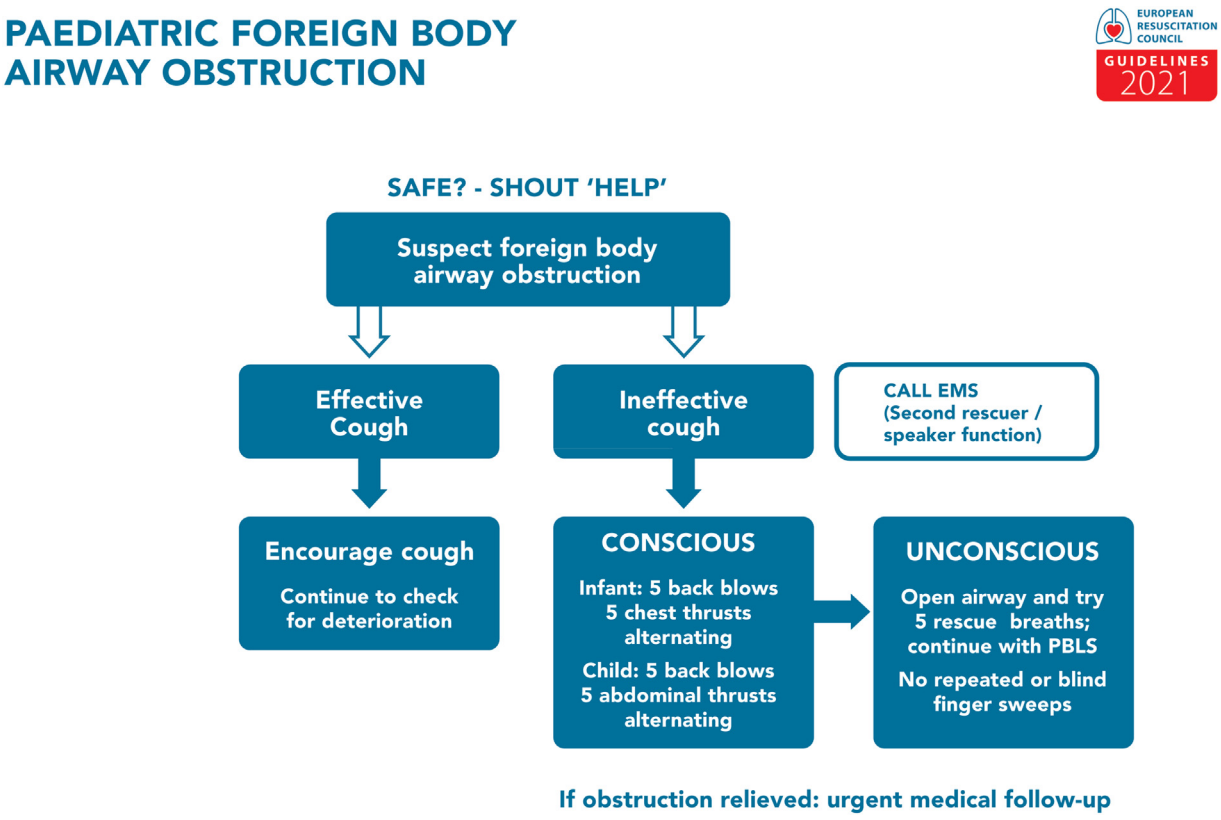


**Fig. 3 – Foreign body airway obstruction.**

result of hypoxia or ischaemia, CPR is needed even if there is still a detectable pulse. Therefore, providers should rather assess signs of life and not lose time by checking for a pulse. In the absence of signs of life, continue to provide high- quality CPR. Obtain vascular access and give adrenaline IV (10 mcg/kg, max 1 mg) as soon as possible. Flush afterwards to facilitate drug delivery. Repeat adrenaline every 3–5 min. In cases where it is likely to be difficult to obtain IV access, immediately go for IO access.

- **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.

  If using self-adhesive pads, continue chest compressions while the defibrillator is charging. Once charged, pause chest compressions, and ensure all rescuers are clear of the child. Minimise the delay between stopping chest compressions and delivery of the shock (<5 s). Give one shock (4 J/kg) and immediately resume CPR. Reassess the cardiac rhythm every 2 min (after the last shock) and give another shock (4 J/kg) if a shockable rhythm persists. Immediately after the third shock, give adrenaline (10 mcg/kg, max 1 mg) and amiodarone (5 mg/kg, max 300 mg) IV/IO. Flush after each drug. Lidocaine IV (1 mg/kg) might be used as an alternative to amiodarone by providers competent in its use. Give a second dose of adrenaline (10 mcg/kg, max 1 mg) and amiodarone (5 mg/kg, max 150 mg) after the 5th shock if the child still has a shockable rhythm. Once given, adrenaline should be repeated every 3–5 min.
  - Change the person doing compressions at least every 2 min. Watch for fatigue and/or suboptimal compressions and switch rescuers earlier if necessary.
  - CPR should be continued unless:
    - An organised potentially perfusing rhythm is recognised (upon rhythm check) and accompanied by signs of return of spontaneous circulation (ROSC), identified clinically (eye opening, movement, normal breathing) and/or by monitoring (etCO2, SpO2, blood pressure, ultrasound)
    - There are criteria for withdrawing resuscitation (see the ERC guideline chapter on ethics).

### Defibrillation during paediatric ALS

Manual defibrillation is the recommended method for ALS, but if this is not immediately available an AED can be used as alternative.

- Use 4 J/kg as the standard energy dose for shocks. It seems reasonable not to use doses above those suggested for adults (120–200 J, depending on the type of defibrillator). Consider escalating doses -stepwise increasing up to 8 J/Kg and max. 360 J- for refractory VF/pVT (i.e. more than 5 shocks needed).
- Defibrillation via self-adhesive pads has become the standard. If unavailable, the use of paddles (with preformed gel pads) is still considered an acceptable alternative yet demands specific alterations to the choreography of defibrillation. Charging should then be done on the chest directly, already pausing compressions at that stage. *Good planning before each action* will minimise hands-off time.

Pads should be positioned either in the antero-lateral (AL) or the antero- posterior (AP) position. Avoid contact between pads as this will

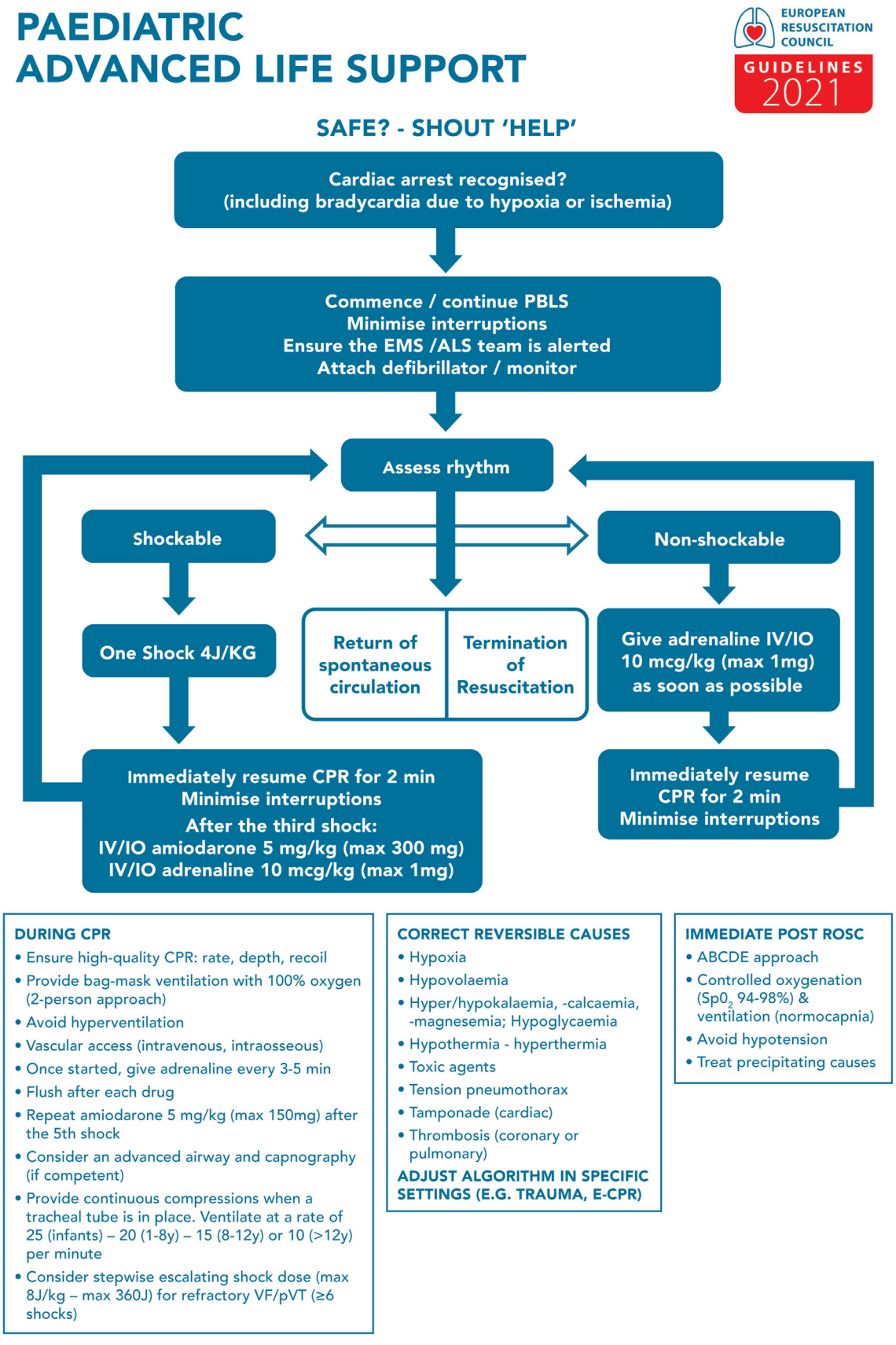


**Fig. 4 – Paediatric advanced life support.**

create charge arcing. In the AL position, one pad is placed below the right clavicle and the other in the left axilla. In the AP position the anterior pad is placed mid-chest immediately left to the sternum and the posterior in the middle of the back between the scapulae.

### Oxygenation and ventilation during paediatric ALS

- *Oxygenate and ventilate with BMV, using a high concentration of inspired oxygen (100%)*. Do not titrate FiO2 during CPR.
  - Consider insertion of an advanced airway (TT, SGA) in cases where CPR during transport or prolonged resuscitation is anticipated and a competent provider is present. Where it is impossible to ventilate by BMV, consider the early use of an advanced airway or rescue technique. Use $ETCO_2$ monitoring when an advanced airway is in place.
  - Always avoid hyperventilation (due to excessive rate and/or TV). However, also take care to ensure that lung inflation is adequate during chest compressions. TV can be estimated by looking at chest expansion.

- In cases of CPR with positive pressure ventilation via a TT, ventilations can be asynchronous and **chest compressions continuous** (only pausing every 2 min for rhythm check). In this case, ventilations should approximate to the lower limit of normal rate for age e.g. breaths/min: 25 (infants), 20 (>1 y), 15 (>8 y), 10 (>12 y).
- For children 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, TV and $FiO_2$ are appropriate for CPR. There is no evidence to support any specific level of PEEP during CPR. Ventilator dysfunction can itself be a cause of cardiac arrest.
- Once there is sustained ROSC, titrate $FiO_2$ to an $SpO_2$ of 94−98%. Competent providers should insert an advanced airway, if not already present, in children who do not regain consciousness or for other clinical indications.

### Measurable factors during ALS

- **Capnography** is mandatory for the monitoring of TT position. It however does not permit identification of selective bronchial intubation. When in place during CPR, it can help to rapidly detect ROSC. $ETCO_2$ values should not be used as quality indicator or target during paediatric ALS, nor as an indication for or against continuing CPR.
- **Invasive blood pressure** should only be considered as a target during paediatric ALS by competent providers for children with in-hospital CA [IHCA] where an arterial line is already in place. Blood pressure values should not be used to predict outcome.
- **Point of care ultrasound** can be used by competent providers to identify reversible causes of CA. 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** (of e.g. potassium, lactate, glucose, . . . ) can be used to identify reversible causes of cardiac arrest but should not be used for prognostication. Providers should be aware that the measured values may differ significantly, depending on the measurement technique and sampling site.

### Special circumstances – reversible causes

- The early identification and proper treatment of any reversible cause during CPR is a priority for all ALS providers. Use the mnemonic "4H4T" 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 (see above and the dedicated chapter on special circumstances within these guidelines).
- Providers should consider (as per protocol and if possible, 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).
- Specific conditions such as cardiac surgery, neurosurgery, trauma, drowning, sepsis, pulmonary hypertension also demand a specific approach. Importantly, the more widespread use of extracorporeal life support/CPR (ECLS/eCPR) has thoroughly redefined the whole concept of 'reversibility'.
  - Institutions performing cardiothoracic surgery in children should establish institution-specific algorithms for cardiac arrest after cardiothoracic surgery.
  - Standard ALS may be ineffective for children with CA and pulmonary hypertension (PHT). Actively search for reversible causes of increased pulmonary vascular resistance such as cessation of medication, hypercarbia, hypoxia, arrhythmias, cardiac tamponade, or drug toxicity. Consider specific treatments like pulmonary vasodilators.

### 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 finger or tube 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

- Adapt standard paediatric ALS actions for hypothermia (see also the chapter on special circumstances). Start standard CPR for all victims in CA. If continuous CPR is not possible and the child is deeply hypothermic (<28 °C), consider delayed or intermittent CPR.

- Any child who is considered to have any chance of a favourable outcome should ideally be transported as soon as possible to a (paediatric) reference centre with ECLS or cardiopulmonary bypass capacity.

### Extracorporeal life support

- E-CPR should be considered early for children with ED or 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 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 OHCA in cases of deep hypothermic arrest or when cannulation can be done prehospitally by a highly trained team, within a dedicated healthcare system.

### Post-resuscitation care

The eventual outcome of children 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 at or above the p50, taking into account the clinical signs, serum lactate and/or measures of cardiac output. Use the minimum necessary doses of parenteral fluids and vasoactive drugs to achieve this. Monitor all interventions and adjust continuously to the child's physiological responses.
- **Ventilation:** Provide a normal ventilatory rate and volume for the child's age, to achieve a normal $PaCO_2$. Try to avoid both hypocarbia and hypercarbia. In a few children the usual values for $PaCO_2$ and $PaO_2$ may deviate from the population normal values for age (e.g. in children with chronic lung disease or congenital heart conditions); aim to restore values to that child's normal levels. Do not use $ETCO_2$ 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 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 ($\leq$ 37.5°), maintain a specific set temperature, by means of, for instance, external cooling. Lower target temperatures (e.g. 34 °C) 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 higher target temperature, e.g. 36 °C.
- **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 and neuroimaging.

## Evidence informing the guidelines

The context of the regional healthcare system and specifically the availability of resources will highly influence practice and should always be considered when interpreting and implementing these guidelines.[6]

### COVID-19: impact on the recommendations within these guidelines

The COVID-19 pandemic emerged just as these guidelines were being drafted. This required specific changes to the CA algorithms, as well as to the care provided to the critically ill child. These changes were the topic of specific ERC guidelines on 'Resuscitation during the COVID pandemic' and will not be repeated here.[7]

Future guidelines will have to balance the aim of providing optimal treatment for the child with the epidemiology (of this and future viruses) and available resources. Assuring the safety of the rescuer has always been a priority in ERC guidelines but lack of evidence has made it difficult to precisely define the associated risks. Rescuers may value the benefit for the child more highly than their personal risk but should equally be aware of their responsibility towards their relatives, colleagues, and the wider community. In general, when there is a risk of transmission of a severe disease, rescuers should use appropriate personal protection equipment (PPE) before providing life support. Systems should be in place to facilitate this, and if extra time is required to achieve safe care this should be considered an acceptable part of the resuscitation process. Procedures and techniques that limit the risk of disease transmission (for instance by aerosol spread) are to be preferred.

A detailed discussion on COVID-19 in children is beyond the scope of the current guidelines. In general, children show milder disease and might be less contagious for others than adults.[8–10] However, this could be different for individual cases or with other viruses in the future.[11–13]

### Epidemiology of cardiac arrest in children

See the epidemiology section of the ERC Guidelines for more detail. Key points include:

- Paediatric OHCA is a relatively rare event, with a dismal prognosis. Rates of 30-day survival have improved recently but still vary between 5 and 10% overall. Less than half of these survivors have a favourable neurological outcome. Initial shockable rhythms are seen in 4–8.5% of reported cases, with far better outcomes (up to 50% survival). Infants make up 40–50% of all paediatric OHCA and their prognosis is much worse than older children. About 40–50% of all paediatric OHCA are presumed to be respiratory in nature. 'Sudden death of Infancy' is reported in 20–30%. Trauma-related cardiac arrest makes up 10–40% of the reported cohorts.[14–20]
- The incidence of paediatric IHCA has remained relatively unchanged over the last years. At least 50% of all cases appear to be non-pulseless events.[21] Survival to discharge is significantly

better than for OHCA, averaging 37.2% (95% CI 23.7; 53) in a systematic review of 16 datasets.[15] How this translates into favourable neurological outcome is less clear. A large cohort of IHCA study from the United Kingdom ($n$ = 1580, 2011–2018, 4.3% initial shockable rhythm) documented 69.1% ROSC and 54.2% unadjusted survival to discharge.[22] Good neurological outcome was seen in more than 70% of survivors.

- Overall, there is a lack of adequate 'global' data on the incidence, circumstances and outcome of paediatric CA. A less fragmented approach would improve the utility of registration data and eventually benefit children.[23]

## Signs of respiratory failure – signs of circulatory failure

In the absence of a recent COSTR, we based our advice on existing guidelines, reviews, and clinical data on the topic (APPENDIX RR 1 A.1 & 1 A.2). The recently published guidelines of the Surviving Sepsis Campaign on the management of septic shock in children were considered of high quality and largely informed our insights in all RRs concerning septic shock.[48]

Respiratory and cardiovascular emergencies together account for most of the paediatric morbidity and mortality worldwide, especially in infants and young children. Rapid recognition and proper treatment improve outcome.[24–28] Presenting symptoms are usually not specific to a particular illness, and no single finding can reliably measure severity nor differentiate the underlying aetiology.[29–35] Obvious signs of decompensation (decreased consciousness, hypotension) are generally late, closely preceding cardiorespiratory collapse. Early recognition and treatment is crucial, yet initial clinical signs of (compensated) failure are unreliable and there is significant interobserver variability, especially in young children.[27,30,36–44]

Proper assessment therefore demands an integrative approach, looking at clinical symptoms, but also considering additional information from history, biomarkers and/or imaging. Complex models using artificial intelligence do not necessarily perform better than clinical decision making by a competent bedside physician.[45–47] We deliberately do not differentiate between 'cold' and 'warm' shock as this is often difficult to appreciate clinically and might mislead clinicians.[48]

Quick first recognition of a child at risk ('five second hands- off' first assessment) is recommended using the Paediatric Assessment Triangle (PAT) or similar models.[49–52] Any abnormality should trigger a subsequent full stepwise pathophysiology driven **ABCDE** evaluation.

### Respiratory rate, heart rate, blood pressure

Values considered as normal or abnormal for different age groups in paediatric textbooks and PLS manuals were recently questioned in several studies and SR including large datasets of healthy children as well as children seen in the ED. It seems the simple dichotomy of normal/abnormal does not reflect precisely enough the commonly seen variations among children.[53–61] Recently derived centile graphs better represent the variations between different age groups, but their use in clinical practice and impact on outcomes require verification. Previous 'normal values' as described in textbooks clearly do not match the ranges presented in recent studies and we therefore propose some corrections, to avoid under- and over- triage. Importantly, none of these values taken in isolation has sufficient test performance and should always be considered in relation to other signs and symptoms. Each of them might be influenced by conditions such as fever, anxiety or pain. Overall, trends are more informative than single readings.

### Pulse oximetry

Hypoxaemia is often present in sick children,[62] both in respiratory and non-respiratory illness (e.g. sepsis) and is a major risk factor for death regardless of the diagnosis. Early identification of hypoxaemia helps in the assessment of severity and allows for proper treatment.[63] Clinical signs may underestimate the degree of hypoxaemia and 'silent hypoxaemia' has been described in e.g. adult COVID-19 patients.[64] While measurement of $PaO_2$ is considered the gold standard, pulse oximetry provides a rapid non-invasive way of assessing oxaemia and is the standard of care for continuous monitoring of oxygenation.[24,26,65] Robust data on 'normal' values distribution in children are surprisingly scarce. An $SpO_2$ of 95% has been cited as a lower cut-off value.[66] Different studies and reviews seem to suggest similar.[67–70] Given the lack of strong evidence and in view of consistency between different RR and ease of teaching, the PWG continues to advise 94–98% as the 'normal range'. Many factors (including altitude, technical limitations, quality of perfusion, carbon monoxide, during sleep) must be considered when interpreting pulse oximetry values, and this knowledge should be part of any training in PLS.[71]

### Non-invasive end-tidal $ETCO_2$/capnography

Arterial $PaCO_2$ and other ABG parameters are considered the gold standard for assessing ventilation. Capillary or venous ABG can also be used in the absence of arterial access. Venous $PvCO_2$ is higher than arterial $PaCO_2$ but generally correlates with $PaCO_2$. Unlike $PaO_2$, normal values of $PaCO_2$ (35–45 mmHg; 1 kPa = 7.5 mmHg approx.) are well defined and do not change with age. Non-invasive $ETCO_2$ devices are increasingly used in both pre-hospital and in-hospital care. Several studies show reasonable correlation between $ETCO_2$ and $PaCO_2$. Capnography is the preferred method of $ETCO_2$ measurements in intubated children but should also be considered in spontaneously breathing children who for instance undergo deep procedural sedation or present in acute respiratory failure.[72–76] High flow oxygen might lead to artificially lower $ETCO_2$ values.[77] The addition of $ETCO_2$ to visual assessment and pulse oximetry was associated with a significant reduction in desaturation and/or hypoventilation during procedural sedation.[73,78] $ETCO_2$ changes appear minutes before desaturation could be identified by pulse oximetry.[79] $ETCO_2$ should not be used as a surrogate for $PaCO_2$ when aiming for normocapnia as part of neuroprotective care.[80]

### Serum lactate

The evidence for monitoring serum lactate in children with circulatory failure is limited. Early hyperlactataemia is associated with critical illness, but organ dysfunction can equally occur in those with normal lactate values.[81–84] Moreover, lactate can increase for other reasons than cellular dysoxia and thus neither is a specific measure of dysoxia or organ dysfunction. Use trends in blood lactate values, in addition to clinical assessment, to guide resuscitation of children with septic shock.[48,85] A persistent elevation in blood lactate may indicate incomplete haemodynamic resuscitation.

### Central venous oxygen saturation ($ScvO_2$)

Continuous or intermittent measurement of $ScvO_2$ was considered a crucial part of early goal-directed therapy and identified as potentially beneficial in previous guidelines. The PWG could however not find sufficient evidence to suggest for or against its use in children with septic shock. The use of ScvO2 requires a central line which might detract from other 'first hour' priorities. Advanced haemodynamic

variables might be of value to guide the ongoing resuscitation of children with septic shock beyond the first hour.[28,48]

## Signs of neurological impairment

Early recognition and treatment of neurological emergencies is of particular importance (Appendix RR 1A.3). Prognosis is often related to secondary injury due to associated hypoxaemia or ischaemia. Treatment delays worsen outcome.[86–88] For the management of some of these emergencies we also refer to dedicated guidelines.[87,89,90]

Both level of consciousness, presence of posturing and pupil size, symmetry and light reactivity inform prognosis but are insufficient to allow definite prognostication.

### Level of consciousness

The Glasgow Coma Scale (GCS) is commonly used to describe a patient's level of consciousness and trend over time. Its use in children is complicated. Several studies confirmed near equal performance of simplified scores.[91–96] AVPU is easy and correlates well with the total GCS in children older than five years. The limited levels between alert and fully unresponsive hamper its discriminative power. The GCS motor score has more levels than AVPU and seems to have almost the same information content as the total GCS. It can be used at all ages.

### Stroke

Stroke is among the top ten causes of death in children and more than half of survivors have long-term impairments. Stroke in children is uncommon and thus easily mistaken for more common conditions, such as migraine or intoxication. Early recognition of stroke is crucial, as any delay in treatment will affect outcome. Red flags include sudden onset of severe headache or focal neurological deficits, but stroke in children can also often present as an altered mental state or seizures. Adult stroke recognition tools have limited performance in children and are not recommended. Children presenting with sudden onset of any of the above symptoms are at high risk of stroke and should undergo immediate neurological assessment and consideration of urgent neuroimaging.[90,97–101]

### Meningitis/encephalitis

The diagnosis of encephalitis requires a high level of suspicion, especially in infants.[86,87,102] Delays in diagnosis and treatment are associated with worse outcomes. Immediate lumbar puncture is recommended only after initial stabilisation and in the absence of contraindications (such as impaired consciousness, signs of intracranial hypertension or coagulation abnormalities). In children with a first febrile seizure, the pooled prevalence of bacterial meningitis is low, and diagnosis is mostly clinical for children above the age of 6 months. The utility of routine lumbar puncture in children with an apparent first febrile seizure is low.[103]

## Paediatric early warning scores (PEWS) – medical emergency teams (MET) – rapid response teams (RRT)

The topics of PEWS, MET and RRT were explored by ILCOR as a scoping review (PLS 818) and an evidence update (EvUp) respectively (PLS 397). The PLS taskforce concluded that the implementation of PEWS and the use of paediatric MET/RRT systems should be part of an overall clinical response system. They acknowledged the potential cost and impact on resources of implementing such systems. They also identified multiple difficulties in research on PEWS.[104] The results of a large cluster RCT examining the impact of implementing PEWS and paediatric track and trigger tools are awaited.[105]

## Point-of-care ultrasound imaging (POCUS) in critically ill children

The available evidence suggests POCUS to be an effective method for both rapid diagnosis and procedure guidance in a variety of paediatric emergencies (Appendix RR 1C).[106,107] Technology continues to evolve, and ongoing research is extending the use of POCUS to new clinical scenarios. Formal training is needed to standardise and expand its use. Guidelines for the practice of POCUS in paediatric emergencies have been published.[108]

### POCUS and the lung

Recent publications highlight the added value of lung POCUS in paediatric respiratory failure.[109–118] POCUS has at least similar sensitivity and specificity to chest X-ray for diagnosing childhood pneumonia and might have better cost- and time-effectiveness, depending on the context of its use. POCUS is more accurate for pleural effusions or pneumothorax and helps guide needle thoracocentesis and thoracostomy. It has also been described as an adjunct tool for confirmation of correct tracheal tube placement but the evidence in children is limited.[119,120]

### POCUS for circulatory failure

With adequate training, the accuracy of cardiac US performed by non-cardiologists seems particularly good.[121] Paediatricians and paediatric emergency physicians with focused training were able to accurately diagnose pericardial effusions, cardiac contractility abnormalities, and left ventricular enlargement. Further potential uses include the detection of cardiac tamponade, dilated cardiomyopathy, congenital heart disease and infective endocarditis.

In adults, POCUS has also been advocated as a guide to the treatment of shock, but evidence in children is limited. In a systematic review, respiratory variation in inferior vena cava (IVC) diameter performed only moderately (pooled specificity 0.73) in predicting fluid responsiveness.[122] Importantly, a negative ultrasound could not be used to rule out fluid responsiveness (pooled sensitivity 0.63). Standard measurements of the IVC/aorta in children are not well established for all age groups and serial exams may therefore be more useful to guide resuscitation.[110,123] Lung US might have a role in guiding fluid therapy in paediatric sepsis. The number of B-lines on lung US seems to correlate with extra-vascular lung water in children.[124,125]

### Extended FAST examination (E-FAST) in paediatric trauma

Evidence for E-FAST US in children is far more limited than in adults, and equally conflicting. Abdominal US seems to have only modest sensitivity for the detection of hemoperitoneum.[126–128] Based on the available evidence, the PWG does not advise FAST as the sole diagnostic test to rule out the presence of intra-abdominal bleeding. FAST examination may be incorporated into other aspects of trauma evaluation to improve the accuracy of the test. Observational data demonstrated that a FAST examination has limited impact on abdominal CT use in injured children at very low (<1%) and very high risk (>10%) of intra-abdominal injury. However, use of FAST in children considered to have 1–10% risk of intra-abdominal injury decreased abdominal CT use. One small study found that when combined with transaminase values >100 IU/

L the specificity of the FAST was 98%, suggesting that a negative FAST and transaminases <100 IU/L could be an indication for patient observation instead of abdominal CT scanning. Extended FAST includes US of heart and lung which has a much higher accuracy and information content.

### Teamwork

The 2020 ILCOR COSTR suggested specific team training as part of ALS training for healthcare providers (weak recommendation, very low certainty of evidence).[129] We specifically looked at the impact on outcome from a 'team-based' approach and likewise what 'proper' teamwork should constitute (team effectiveness) (appendix RR 2).

Despite the large amount of literature, the evidence base for teamwork is limited. Earlier papers indicated that lack of teamwork and communication failures are important reasons for medical errors and adverse outcomes.[130] Based on this and the identified literature in the RR, the PWG advises a team-based approach to the acute treatment of critically ill children. We emphasise the importance of a structured implementation strategy for those not already using this and an ongoing evaluation of effectiveness for those who already use team-based approach. A team-based approach has many defining factors and is more than just bringing different professionals together in the same room.[131–139] Ideally, written protocols should exist for children in all departments where they might present. New team members should ideally be trained in teamwork and the specific existing protocols, establishing shared mental models. This continuous education process should be an integral part of the implementation protocols for a team-based approach.

In addition, the PWG wants to highlight the potential negative impact on performance of rudeness and other external stressors.[140–142] All team members, especially the team leader, should work to establish a culture that condemns rude behaviour.

Finally, the PWG agrees with the ILCOR EIT437 COSTR that suggests a relationship between exposure and outcome.[129] They suggested that EMS systems: (1) monitor exposure of their clinical personnel to resuscitation and (2) implement strategies, where possible, to address low exposure or ensure that treating teams have members with recent exposure (weak recommendation, very-low certainty of evidence).

### Drug calculation tools and rules

The PWG largely based its insights on the 2020 ILCOR EvUp PLS 420,[143] three additional SRs,[144–146] and one guideline,[147] and identified the need for a change in the current advice with regard to weight estimation methods (appendix RR 3). The dosing of emergency drugs requires a functional estimate of the child's weight. Parental estimates are usually more accurate than estimates by health professionals. Length-based methods, such as the Broselow tape, are also accurate but tend to underestimate weight in populations with a high incidence of obesity. Systems including a correction for body-habitus (e.g. Pawper) are more accurate. Such systems often include a pre-calculated dose advice for emergency drugs which has been shown to reduce administration errors. Care provider estimates and age-based formulas are inaccurate and therefore not advised. Finally, although the pharmacokinetics of some drugs (e.g. fentanyl, propofol, midazolam) vary between obese and non-obese children, there is too much variation between medications and individuals to advocate any specific strategy to correct for this.

### Airway management in critically ill children

We included in our analysis one guideline,[48] three SRs,[148–150] nine narrative reviews,[151–159] two RCTs,[160,161] and 27 observational papers (appendix RR 4.1).[162–188]

Overall, the evidence available in children is weak, being based mainly on observational (registry) data. Evidence from adult studies or from the operating room should be considered as indirect. Importantly, as practice and team composition vary broadly between regions and settings, one cannot draw universal conclusions.

Evidence suggests that TI by providers with limited experience influences outcome. This is even more so in complex settings (e.g. small child, haemodynamic instability). Despite that about 5% of EMS encountered children need an airway management procedure, individual provider exposure is often less than needed. Each of the existing techniques for advanced airway management (TT with or without videolaryngoscopy, SGA, BMV with optional airway adjunct) has its own advantages and disadvantages and competent operators should be knowledgeable of these. Importantly, as far as reasonably possible, teams should prepare in a structured and timely way before performing any airway procedure. This preparation includes consideration of 'rescue' and 'fallback' procedures.

Despite a suggestion of worse outcome in certain settings, for many healthcare providers, TI remains the preferred way of managing the airway of a critically ill or injured child, regardless of the context. The risk of failed or incorrect positioned TI in children is significantly higher than in adults. Multiple TI attempts are associated with increased risk of hypoxaemia, desaturations, adverse haemodynamic events and subsequent morbidity and mortality. The number of attempts should therefore be limited before considering alternative airway management. Providers should always evaluate the balance between presumed benefit and risk of harm when considering TI, and not solely decide based on predefined dogmatic rules (e.g. GCS ≤8, burn percentage) nor without first considering alternatives. In children, difficult airways are rarely because of their anatomy but usually related to physiological and situational difficulties (e.g. failing to prepare).[158] Conditions may be optimised by standardising equipment and its location, use of checklists, multidisciplinary team training in both technical and non-technical aspects of emergency TI, and regular audit of performance.

For many settings, BMV appears to be at least non-inferior to TI. It is a far easier skill to master and should be taught to all providers involved in the care of critically ill children. To optimise efficiency, providers can either use a 2-person technique and/or use an airway adjunct. Most difficulties with mask ventilation can be overcome by recognising and treating anatomical airway obstructions (e.g. using airway adjuncts or a SGA) or functional ones (e.g. muscle paralysis). Avoid muscle paralysis in children with mucopolysaccharidosis, airway masses/foreign bodies or external airway compression but in many other settings such agents allow for controlled ventilation before TI and fewer adverse events. Difficult BMV should not prompt a rushed TI but should serve as a red flag for more thorough preparation.

A front of neck airway (FONA) in children should only be attempted as a last resort in a "cannot oxygenate-cannot intubate" situation. It is difficult to gain sufficient expertise for this situation, especially given the variability of anatomy at different ages. In most cases, needle cricothyroidotomy with jet ventilation is used. Surgical cricothyroidotomy procedures are extremely rare. There is no evidence that a quicker decision to use FONA would increase the overall survival without neurological impairment. Importantly, "cannot oxygenate-cannot intubate" situations might themselves result from previous

suboptimal airway management and repeated TI attempts and therefore most authors emphasise the importance of other difficult airway techniques before using FONA.

### The use of $ETCO_2$ during intubation

The 2020 ILCOR EvUp (PLS 385) confirmed the earlier recommendation to use $ETCO_2$ for intubated children with a perfusing cardiac rhythm in all settings.[143] In view of that and considering the potential harm of dis- or misplaced TT, we consider capnography an essential tool for TT confirmation in children, but proper evaluation of TT position should also include clinical evaluation and either ultrasound or X-ray (appendix RR 4.2).

### The use of cricoid pressure for intubation

The 2020 ILCOR EvUp (PLS 376) confirmed the earlier recommendation to discontinue cricoid pressure if it impedes ventilation or interferes with the speed or ease of intubation.[143] We further considered one SR[189] and two overlapping clinical studies (appendix RR 4.3).[190,191] We could not find sufficient evidence to recommend the use of cricoid pressure to prevent regurgitation or aspiration during rapid sequence or emergent TI in children. It might impair airway handling in children and infants in the emergency setting.

### Videolaryngoscopy

The available evidence for the use of videolaryngoscopy in critically ill children is limited (appendix RR 4.4). Primary endpoints in most studies were time to intubate or TT first pass success rate. Some SRs suggest an increased risk of prolonged intubation time and unsuccessful intubation with videolaryngoscopy.[192–194] More recent RCT and observational papers suggest a benefit, but the evidence remains conflicting.[195–202] Importantly, such a benefit will strongly depend on who is performing the intubation, which technique and device is used and for which indication. Those who plan to use it should be properly trained. Many devices exist which differ in technique but there is no evidence that one is superior to another. Considering this, the PWG cannot advise for or against the use of videolaryngoscopy over direct laryngoscopy in the emergency setting. The decision to use videolaryngoscopy and for which indication remains at the discretion of the competent physician performing the procedure. It should be considered earlier in cases where direct laryngoscopy is expected to be difficult such as with manual in-line stabilisation of the cervical spine.

### The use of atropine for intubation

A 2020 ILCOR EvUp (PLS 821) did not find any new evidence to enable a recommendation.[143] Bradycardia occurs during intubation, presumably because of either hypoxia or vagal stimulation due to laryngoscopy. This temporary bradycardia is accompanied by vasoconstriction and will normally respond to re-oxygenation and removal of the vagal stimulation. However, several induction drugs also induce bradycardia that may be accompanied by vasodilation, leading to 'unstable bradycardia'. In the context of a child with for instance sepsis this bradycardia induces low cardiac output and hypoperfusion, which can be potentially fatal.[203] In young children the incidence of dysrhythmias may be reduced when atropine is included in the drugs used for emergency intubation.[204] The use of atropine decreases the incidence of bradycardia during intubation of both neonates and older children but the consequences of such bradycardia are unclear.[205–207]

Atropine may be used for the intubation of critically ill children (1 month – 8 years) to decrease the incidence of bradycardia and dysrhythmias especially in younger children, when suxamethonium is used, and/or when vasodilation is present (appendix RR 4.5).

### The use of cuffed tracheal tubes

A 2020 ILCOR EvUp (PLS 412) did not find any new evidence to change the 2010 'equivocal' recommendation.[143] The PWG agrees with the specific insights of the authors of this EvUp who argue in favour of the exclusive use of cuffed TT for paediatric ALS "*in an effort to reduce tube selection errors, improve capnography accuracy, have less need of TT change, reliable TV delivery and/or pressure, reduction in sore throat, reduced risk of aspiration and standardise practice* (appendix RR 4.7). MRI images have shown the cricoid ring in children to be elliptical, rather than circular as traditionally taught.[208] Therefore, there may still be a leak around a perfectly sized circular uncuffed tracheal tube while the TT causes increased pressure on other areas of the tracheal mucosa. If cuffed tracheal tubes are used, cuff inflation pressure should be monitored and limited according to manufacturer's recommendations. The traditional rules for TT selection per age were made for uncuffed tubes and thus likely overestimate the optimal size of cuffed TT.

## The use of supplementary oxygen in the management of critically ill or injured children

Our RR identified three guidelines,[28,66,209] 2 SRs,[210,211] three RCTs,[212–214] and one observational study[215] on the topic (appendix RR 5.1). The results of both the Oxy-PICU trial and the COAST trial are likely to further inform our guidelines but are not yet available.[216,217] The use of supplemental oxygen before TI, in cardiac arrest and post-ROSC is reported separately. Supplementary oxygen has been a mainstay in the treatment of virtually any critically ill or injured child untill recently. Growing concerns about the potential negative impact of hyperoxygenation on outcome has led to changing guidelines in adults and neonates. The PWG recognises the risk of inadvertent hypoxaemia with an overly conservative approach to oxygen therapy, especially in situations where continuous monitoring is difficult such as prehospital or in shock states. However, too much supplementary oxygen caries an undefined risk and is also costly, especially in resource-limited environments. Importantly, while the evidence base is limited, any guideline about supplemental oxygen will need to consider the local situation. Oxygen can be delivered in many ways. The provider needs to be aware of the oxygen concentration delivering capacity of the device, the $FiO_2$ requirements and the acceptability of the device to the child. In children with specific chronic conditions or existing cardiac disease, oxygen therapy should be tailored to the underlying condition, the baseline $SpO_2$ (if known) and the intercurrent disease process. Early expert advice is warranted. Far less frequent than in adults, high-concentrated oxygen can also lead to hypoventilation in some children with chronic conditions.[213]

### Non-invasive ventilation and high-flow nasal cannula (HFNC)

In the absence of a specific COSTR on this topic, we performed a RR (appendix RR 5.2). The results of the large multicentre RCT 'FIRST ABC' comparing HFNC to nasal CPAP in the paediatric critical care setting are not yet available.[218]

Invasive ventilation can be damaging to the lungs, carries an increased risk of secondary infections, is more costly and demands

more analgosedation. Non- invasive ventilation on the other hand is sometimes poorly tolerated by children, requires that children still have sufficient respiratory drive and might carry a risk of delaying appropriate care. Nasal CPAP and HFNC improve the work of breathing and oxygenation by increasing distending pressure and allowing reliable delivery of high concentrations of warm humidified oxygen. HFNC appears to improve alveolar ventilation but does not actively increase TV. Both HFNC and NIV seem easy and safe to implement.[219–230] There is currently insufficient evidence, especially when also considering the potential impact on resources, to advise for or against their use in hypoxaemia due to non-pulmonary causes nor in compensated respiratory failure without hypoxaemia.[231] The decision to use HFNC or NIV in these groups of children is typically taken in an advanced care setting, by a critical care provider. In children with respiratory failure and hypoxaemia (due to e.g. bronchiolitis, pneumonia), NIV or HFNC may improve outcome and prevent further deterioration. This is especially important in low-resource settings where there is often no access to high-quality intensive care.[232–236] Start HFNC or CPAP in infants with bronchiolitis and hypoxaemia not responding to low-flow oxygen.[228] Very low certainty evidence suggests that a flow of 1 L/kg/min might be as effective as 2 L/kg/min.[237] Although HFNC might not increase the risk of droplet and contact infection,[238] it likely increases aerosol dispersal[239] and, in settings where this might be a problem, we advise the use of HFNC only under conditions of guaranteed airborne protection.

### Ventilation

We identified three recent guidelines[48,209,240] and six observational studies,[241–246] as well as several additional older studies or papers with indirect evidence on this topic (appendix RR 6). Details of mechanical ventilation and PICU management are beyond the scope of these guidelines but see existing recent reviews.[247–250]

Minute ventilation is influenced by both TV and respiratory rate. A TV of 6–8 ml/kg ideal body weight, taking into account (apparatus) dead space, is an appropriate initial target.[209,250,251] Apparatus dead space can be reduced by using appropriate child circuits and reduction of swivels. Adequacy of TV can be estimated by observing chest rise and measuring $paCO_2$ trend.

Adjust ventilation to achieve a normal arterial $paCO_2$ in children who have normal lungs. However, in acutely ill children aiming for normal might require overly aggressive ventilation. In this case, permissive hypercapnia can be considered standard practice unless there is pulmonary hypertension or severe TBI.

Self-inflating bags are preferred over anaesthetic bags for ventilation for all providers not specifically trained in the use of an anaesthetic bag. Self-inflating bags should be properly sized to enable sufficient TV while avoiding overinflation and inadvertent gastric insufflation. Existing bags vary from 180–240 ml (neonatal), 450–650 ml (paediatric) and 1300–1600 ml (adult). Providers should be aware that one- handed compression of an 'adult' bag can easily generate volumes above 500 ml.[245,252] BMV is easy and the mainstay of initial ventilatory support but is not without risks and demands providers to be properly (re)trained.[253,254]

A one-handed BMV technique gives the provider the freedom to use the other hand but increases the risk of leak. We therefore advocate a two-person approach in all cases where either there is difficulty in providing an adequate seal or there is a risk of infectious disease transmission via aerosols. In the latter case, one should also apply a viral filter between bag and mask.[7]

During resuscitation, ventilation can also be provided by mouth-to-mouth or mouth-to mouth and nose. This is less efficient than BMV and does not enable additional oxygenation. Moreover, it does not protect the rescuer from infectious disease transmission and the fear of which might be a barrier for rescuers to provide ventilations in the first place.

### Fluid therapy for circulatory failure

This RR concerns the use of fluid resuscitation during the first hour of shock, once recognised and as part of a general approach to a child in shock (appendix RR 7.1). Later fluid therapy might also impact outcome but is beyond the scope of this review. We included the 2020 ILCOR EvUp on fluid bolus for septic shock (PLS1534) and the scoping review on graded volume resuscitation for traumatic shock (PLS 400), as well as several guidelines, SR and clinical studies on topic.[143] Results from both the SQUEEZE and the ProMPT bolus trial are currently still awaited.[255,256]

It is difficult to study individual interventions in the multifaceted approach to sepsis. As a result of equivocal guidelines based on very low certainty evidence and contextual in nature, large variations in practice currently exist and these do not serve the individual child well. Early goal directed therapy (EGDT) has been the mainstay of the worldwide Surviving Sepsis campaigns but more recent RCTs have shown that this strategy does not improve outcome.

Shock is not one disease but the end stage of many different pathologies and there are many subtypes (hypovolaemic, cardiogenic, obstructive, distributive, and dissociative). Moreover, circulatory failure is a spectrum and the result of many concomitant processes related to both the causal agent and the host response. Treatment should be individualised, taking into consideration the underlying aetiology and pathophysiology, age, context, comorbidities, and available resources.[257] A strategy of frequent re-assessment and careful, but concise treatment steps seems prudent.

#### Presumed septic shock

Although septic shock still generates significant mortality and morbidity in infants and children globally, its prevalence and presentation are changing due to vaccination, comorbidity, and the incidence of immune suppression.[258–260] Treatment strategies and outcomes of specific types of septic shock (e.g. toxic shock, neutropenic) vary considerably. Until recently, early aggressive fluid resuscitation was considered the most important intervention for septic shock in children, despite this being based on very low certainty evidence. Publication of the FEAST trial challenged this strategy.[261] There is ongoing discussion about the general applicability of the FEAST results and how these should inform our practice.[262,263] Most existing protocols would still advise repeated boluses of fluid at 20 ml/kg during the first hour of paediatric septic shock to counteract presumed hypovolemia due to transcapillary leak.[28,257] The recently updated Surviving Sepsis Campaign guidelines advocate 10–20 ml/kg boluses with a maximum of 40–60 ml/kg in the first hour in situations where there is ICU availability. When there is no access to ICU, fluid boluses are still advised but only in the case of hypotension (10–20 ml/kg up to 40 ml/kg in the first hour).

Current evidence suggests that a more restrictive approach to fluid resuscitation is at least as effective and might decrease side effects. Even a single fluid bolus can influence respiratory function. Perfusion improves in the first hour after a fluid bolus, but this effect does not persist.[124,263,264] Identifying children in distributive shock who need fluid is challenging, as other reasons of tissue dysoxia will generate a

similar clinical picture. Even more challenging is identifying which children are fluid responsive. Clinical signs, combined with biochemical values (pH, lactate), give an acceptable test performance when combined but not when considered individually. Ultrasound evaluation of fluid responsiveness is gaining interest but the evidence supporting it in children is lacking. On the other hand, echocardiography guidance might help to recognise myocardial dysfunction and hypovolemia early.

In view of the above, the PWG advises smaller fluid boluses, namely 10 ml/kg. This smaller volume enables faster reassessment but does not necessarily limit the total amount of fluid to be given in the first hour of treatment. An individual child might still need volumes of up to 40−60 ml/kg to treat shock. In case of repeated fluid boluses, early consideration of vasoactive or inotropic drugs and respiratory support is crucial. In settings where these options are not readily available, it seems prudent to be even more restrictive. Equally important is the type of fluid used.[28,263,265] There seems to be consensus on avoiding synthetic colloids and the current data on hypertonic solutions is too limited to permit a practice recommendation. The general advice advocating the use of crystalloids as first-line fluid still stands. Crystalloids are effective, inexpensive and are widely available.[266,267] The evidence base for balanced crystalloids (e.g. Lactated Ringer's) is limited. Systematic reviews on the topic show no more than a trend towards a better outcome.[268–270] However, normal saline (NS) induces hyperchloraemic acidosis and might be associated with a worse outcome.[263] Considering the limited extra cost, the PWG would therefore consider balanced crystalloids the first choice (and NS an acceptable alternative). Albumin appears to be at least equivalent to crystalloids in terms of outcome but should be second-line due to the higher cost.[48] Specific diseases (e.g. dengue, cerebral malaria) might benefit from earlier use of albumin 4.5% as a resuscitation fluid.[28,271]

Shock is defined by the degree of cellular dysoxia generated; haemoglobin has an important role and higher transfusion goals may be appropriate when there is cardiovascular compromise. There is insufficient evidence to advocate a single cut-off value for transfusion and the trend may also be important. Repeated crystalloid boluses will inevitably lead to haemodilution as may underlying pathophysiological mechanisms.

Septic shock affects the integrity of the endothelial glycocalyx and the microvasculature. It also activates and consumes coagulation factors and often induces diffuse intravascular coagulation in children who already have suboptimal coagulation caused by acidosis and dilution. There is insufficient evidence to advocate the prophylactic use of plasma for all children in septic shock, but we would suggest its early use in cases of presumed diffuse intravascular coagulation and worsening coagulopathy.

### Cardiogenic shock

Cardiogenic shock can be either primary or secondary to other types of shock. The diagnosis is based on both clinical signs and echocardiography. Once confirmed, the general approach is to avoid fluid resuscitation. However, children with proven preload insufficiency on echocardiographic, clinical, or biochemical grounds, due to, for instance, low intake or associated sepsis, might benefit from cautious fluid resuscitation.[38]

### Hypovolemic non-haemorrhagic shock

As the primary mechanism of circulatory failure in hypovolemic shock is fluid loss, the mainstay of treatment is fluid resuscitation. However, depending on the underlying aetiology, consider also co-existing distributive or cardiogenic shock. Treatment focuses on electrolyte disorders and possible severe hypoalbuminemia or hypoglycaemia, which might cloud the clinical assessment.[272,273]

Severe acute gastroenteritis can lead to severe dehydration (>10% body weight loss) and hypovolemic shock. Whilst its incidence is decreasing in many countries, severe acute gastroenteritis remains an important cause of paediatric mortality worldwide. Mortality is highest in children with severe comorbidity, including those that have severe malnutrition. The identification of children with severe dehydration/hypovolemic shock from acute gastroenteritis is not always easy and the degree often overestimated. Considering the setting where acute gastroenteritis with severe dehydration frequently occurs (limited resources, with comorbidity) and the very limited existing evidence, a 'non-bolus' approach to IV fluid resuscitation is advisable, except when associated with septic shock. Such an approach is probably also reasonable for children with severe malnutrition.[274–277]

### Haemorrhagic shock

Blood loss not only generates a decrease in circulating volume but also in blood components. The aim of therapy – apart from restitution of blood volume – is to stop the bleeding via direct or indirect pressure or by surgery or interventional radiology. Coagulopathy due to consumption, blood loss, dilution from fluid therapy, acidosis from hypoperfusion and/or hyperchloraemia, and hypothermia is pivotal in the pathophysiology of trauma-related mortality.

Consider giving blood products early during the fluid resuscitation of children with severe trauma using a strategy that focuses on improving coagulation.[278–285] Fluid resuscitation is guided by specific endpoints (MAP, lactate, Hb, clinical assessment, pH, coagulation) to avoid fluid overload yet still provide adequate tissue perfusion.[286–288] Adult data suggest that overly aggressive fluid resuscitation worsens outcome and supports a more restrictive approach including permissive hypotension.[289–292] However, severe paediatric trauma is often associated with TBI, in which restrictive resuscitation might be deleterious. Even in children with no risk of associated brain injury, a minimal MAP above p5 is needed to avoid brain hypoperfusion.

### Burn fluid management

Burn injury is a specific type of trauma where fluid loss is related to skin loss. Standard fluid regimens are 'preventive' in nature and beyond the scope of these guidelines.[293] Importantly, early circulatory failure should alert the clinician to look for other causes for shock than burn fluid loss.

## Vascular access

For many paediatric emergencies, not being able to obtain reliable vascular access will impact outcome, although the evidence supporting this is uncertain. Importantly, obtaining vascular access in children is often difficult with risks of repeated attempts or failure and associated complications (e.g. extravasation). Deciding upon the proper technique will depend upon ease of use and timely effectiveness but, especially in areas with less resources, also availability and cost. Whatever technique used, those performing it should be competent in its use. For this RR, we considered two recent SRs,[294,295] one guideline,[28] 2 RCT,[296,297] and 19 clinical studies (appendix RR 7.2).[298–313]

Peripheral intravenous lines are still considered first-line as they are cheap, easy to use and effective, with a low risk of complications. Some authors suggest the use of either electro-optical visual aids or

ultrasonography to facilitate the procedure, but evidence is limited, and both are operator dependent. Providers should not lose time in obtaining peripheral access when there is an urgent need and should be aware that multiple attempts might generate distress. There is no clear evidence to suggest the optimal immediate rescue procedures if peripheral IV cannulation fails, but if a provider considers the chances of success of peripheral IV access to be minimal, they should use such rescue procedures even earlier.

For infants and children, the primary rescue alternative is intraosseous (IO) access. This has almost the same functionality as (central) intravenous access, although there are some doubts about delivery of certain drugs (e.g. adenosine) and about reliability of blood sampling. In general, ABO-typing, pH and sodium are considered reliable, and to a lesser degree glucose and bicarbonate. Intraosseous can be a bridge to IV, until peripheral IV access can be achieved. Intraosseous access is painful, especially when infusing fluids, and analgesia (e.g. IO lidocaine, intranasal fentanyl, or ketamine) should be given to every child unless they are deeply comatose. Different devices are available and perform differently in terms of ease of use, success rate, cost, and risk for complications. Manual IO-devices primarily have a place in very young children or in low-resource settings. In infants, reports suggest one can even use a 18G needle (and optionally a reusable needle holder). Power-driven IO-devices are generally fast and easy to use. They have a significantly higher cost than manual devices and still carry a risk of misplacement (too shallow or too deep) Choosing the properly sized needle is therefore important. Overall, the complication rate for IO is low but providers should watch for extravasation, with a risk of compartment syndrome, and infection. Correct needle position can be evaluated clinically or potentially by colour doppler ultrasound.[314,315]

Many different puncture sites exist, and each of them has specific indications and/or contra-indications and require a specific technique and training. Importantly, flow differs depending on the puncture site e.g. placement in the humeral head allows for higher flows. Although a central venous line provides secure and multifunctional access, its placement is generally slower, carries a risk of comorbidity, is more operator dependent and less cost-effective. In settings where it is feasible, use ultrasound to guide placement of a central venous line, especially for the internal jugular or axillary routes.[316,317] Venous cut-down has largely been abandoned.

### Care bundles in the management of paediatric shock

The use of care bundles in the management of paediatric septic shock is central to the 2014 ACCCM guidelines and advocated in the more recent surviving sepsis campaign guidelines (appendix RR 8.1).[28,48] Systematic screening of acutely unwell children using a 'recognition bundle' can be tailored to the type of patients, resources, and procedures within each institution. Clinical decision- support systems and electronic medical record-based sepsis recognition tool might be of specific help, but the supporting evidence is very limited.[318,319] The success of multiple interventions applied simultaneously (a 'bundle') is not necessarily evidence that each individual intervention is necessary for the bundle's effectiveness.[320] Some of these interventions may even induce harm and/or merely increase costs.

While many different observational studies showed a positive impact on outcome of care bundle implementation, this effect was far less in other studies.[318,321–329] Reasons for such differences are not always easy to identify, but might be related to selection bias, differences in implementation strategies or differences in care of control populations. Importantly, protocols should be tailored to the local reality.

### Timing of antibiotics in sepsis

We identified two guidelines[28,48] and 10 observational studies on this issue (appendix RR 8.2).[321,330–338] Antibiotics are a necessary part of sepsis treatment and early (first hour) empiric broad-spectrum antibiotics are advocated in international guidelines. Consider local resistance patterns, antecedents, co-morbidity, and the presumed source when selecting antibiotics. Unless meningitis has been ruled out, the chosen antibiotic(s) should be able to cross the blood-brain barrier. The indications for lumbar puncture are beyond the scope of this RR but in the case of septic shock, it is generally sufficient to obtain blood cultures before starting antibiotics. Outcome might be worse if antibiotics are delayed for more than 3 h after recognition of sepsis.

### Vasoactive/inotropic drugs in critically ill or injured children

#### Vasoactive/inotropic drugs in distributive shock

A 2020 ILCOR scoping review (PLS 1604) included two RCTs but did not find sufficient evidence to suggest a change in recommendation.[143,339,340] Both RCTs compared adrenaline and dopamine in paediatric septic patients with fluid-refractory shock. Both have several limitations making their usage for clinical guidelines development difficult. Moreover, they were performed in low-to-middle-income countries and their applicability in higher resource settings was questioned. To inform our insights we further considered two guidelines,[28,48] two SR,[341,342] and five observational studies (appendix RR 8.3A).[343–347]

The new Surviving Sepsis Campaign Guidelines 2020 recommend noradrenaline or adrenaline as first line vasoactive agents over dopamine (weak recommendation based on low certainty evidence) but could not find sufficient evidence to recommend one above the other, suggesting to base the choice on individual child physiology, clinician preference, and local system factors. Once echocardiography or other advanced monitoring is available, selection of vasoactive therapy might be driven by individual patient pathophysiology.

There is insufficient evidence to identify the criteria for starting vasoactive drugs in children with septic shock. Knowing that excessive fluid resuscitation can lead to increased mortality in critically ill children, we suggest early use of vasoactive drugs in children with shock, especially when there is no clear improvement of the clinical state after multiple fluid boluses (e.g. 40 ml/kg). Given their overall safety profile, we suggest starting with either noradrenaline or adrenaline, depending on local practices and infusing via either a central or a peripheral line. Dopamine should only be considered in settings where neither adrenaline nor noradrenaline is available. If there is any evidence of cardiac dysfunction, an inodilator might be added.

As with fluid, vasoactive drugs should be initiated and titrated based upon consideration of multiple factors (including MAP, lactate and clinical signs). Re- evaluate repeatedly and at least after every treatment change. Vasoactive drugs are typically given as a continuous infusion. Boluses of vasoactive medications should be given only in (pre-) arrest situations, but competent physicians might consider small boluses of a vasoconstrictor to treat acute hypotension in specific settings (e.g. medication induced). Evidence guiding this practice is lacking.

### Vasoactive/inotropic drugs in cardiogenic shock

A 2020 ILCOR EvUp (PLS 418) did not find sufficient evidence to suggest a change in recommendation.[143] We additionally considered two guidelines (appendix RR 8.3B).[28,38] Vasoactive drugs are only one part of the treatment options for cardiogenic shock. Treatment choices are aetiology-driven and early consideration of mechanical support is recommended.

Given the current absence of direct paediatric evidence, we cannot advise for or against the use of any specific vasoactive drug. The decision which vasoactive drugs to use as first- or second-line is complex and there are likely to be differences between patient groups in terms of both aetiology and haemodynamic responses. The treatment strategy should therefore be tailored to the individual child and titrated to specific targets. Good knowledge of the activity and effects of each of the vasoactive drugs at different doses is imperative and should guide treatment choices. For this we also refer to the two existing paediatric guidelines which advocate noradrenaline as first-line inoconstrictor and dobutamine or milrinone as first-line inodilators.

A recent before-after cohort study suggests a strongly positive impact on outcome of bolus adrenaline (1 mcg/kg) in paediatric cardiac ICU patients developing hypotension, although this was part of an overall quality improvement initiative and the results might have been influenced by other covariables.[348]

### Vasoactive/inotropic drugs in hypovolemic shock (8.3C)

We identified one SR[349] and one narrative review[350] on this topic (appendix RR 8.3C). Given the current absence of direct paediatric evidence, our advice is only based on indirect evidence from adult papers and pathophysiological reasoning. While the initial phase of hypovolemic shock is most often characterised by a marked increase in systemic vascular resistance, this response can be lost once decompensation occurs or sedative drugs are given. Vasopressors could then be used to ensure adequate perfusion pressure. As they can increase afterload, it is prudent to also assess cardiac function when starting these drugs. Vasopressors also permit decreased fluid administration and may reduce inflammatory reactions. Although 'permissive hypotension' might be considered in children with isolated penetrating trauma without TBI, there is insufficient evidence to advocate this in any other situation. Importantly for TBI, a sufficiently high mean arterial pressure is needed to attain minimal levels of cerebral perfusion pressure (e.g. MAP $>$ 50th percentile).

## Tranexamic acid TxA

Severe bleeding in children is most caused by trauma and/or emergency surgery. It is beyond the scope of the current review to consider the use of tranexamic acid in elective surgery or non-life-threatening problems. For the topic of critical bleeding, we identified one guideline,[351] one RCT[352] and six observational studies (appendix RR 8.3D).[353–357]

### TxA in traumatic bleeding

Adult evidence strongly suggests that TxA reduces mortality in trauma patients with bleeding without increasing the risk of adverse events.[358] TxA should be given as early as possible and within 3 h of injury, as later treatment was ineffective and may be harmful. Limited evidence from paediatric studies seems to suggest similar results. Overall TxA seems cost-effective and safe. It has been used in children for a long time, without identifying important side-effects even at much higher doses. There is some concern about post-administration seizures, but this seems to be rare with the doses used for trauma. No specific dose-finding studies are available, but the (derived) dosing scheme proposed in literature seems reasonable.

For the specific subpopulation of isolated TBI, paediatric data are even more limited. However, considering the results of the CRASH-3 trial and the reasoning above, consider giving TxA to children with isolated moderate TBI (GCS 9–13) without pupillary abnormalities.[359] The results of CRASH-3 were equivocal for patients in coma, but this might be due to them being unsalvageable. CRASH-3 enrolled only adults without major extracranial bleeding. Where a significant extracranial haemorrhage cannot be excluded, the PWG suggests acting as above and giving TxA regardless.

### TxA in non-traumatic bleeding

Intravenous and inhaled TxA has been reported to improve outcome in children with pulmonary bleeding. Given that mucosal surfaces are rich in fibrinolytic enzymes, the use of TxA for bleeding in such areas might be as effective as in trauma. No paediatric studies are currently available to support this. Considering the safety profile and potential effectiveness, we suggest using TxA in paediatric non-traumatic life-threatening bleeding.

## Corticosteroids for shock

Our RR, which informed the 2020 ILCOR EvUp (PLS 413), included two guidelines,[28,48] one SR,[360] 1 RCT,[361] and five observational studies (appendix RR 8.4).[362–366] All these studies had small sample sizes and major risk of selection bias. Study populations, timings and type and doses of steroids all differed between different populations. We could not identify sufficient evidence to change the 2010 ILCOR treatment recommendation: *stress-dose corticosteroids may be considered in children with septic shock unresponsive to fluids and requiring (moderate to high dose) vasoactive support, regardless of any biochemical or other parameters.* Stress-dose hydrocortisone is always indicated for specific populations at risk such as hypothalamic-pituitary- adrenal axis disorders. Preliminary research further suggests there might be other specific subpopulations that would benefit or experience harm from steroid administration. However, these subpopulations cannot yet be identified at the bedside.

## Paediatric status asthmaticus

Asthma still causes significant morbidity and even mortality in children globally. Timely aggressive and protocolised treatment for status asthmaticus is required. We consider here only the emergency 'first hour' management (appendix RR 9).

We identified one guideline (ginasthma.org), eight SRs,[224,367–373] three narrative reviews,[374–376] nine RCTs,[213,226,377–383] and five observational studies,[384–388] published in the last 5 years. Older papers were considered when informative.[389–394] The search update June 2020 additionally revealed one guideline,[395] 3 SR,[396–398] one narrative review,[399] 1 RCT[400] and four observational trials.[401–404] We evaluated the guidelines published by the Global Initiative for Asthma (ginasthma.org) and those of the French paediatric emergency societies to be of high quality (AGREE II) and largely based our insights on them.[395]

Recognition of a severe asthma crisis is primarily based on clinical signs, brief history, and oxygen saturation. Hypoxaemia is a sign of decompensated respiratory failure. It might induce agitation or decreased perception of breathlessness. Differential diagnosis

includes pneumonia, pneumothorax, cardiac failure, laryngeal obstruction, pulmonary embolism, foreign body aspiration and anaphylaxis.

Despite being first-line treatment, the actual evidence for short-acting beta-2 agonists (SABA) in severe crises is limited. High-dose inhaled SABA are relatively safe, although they do cause certain side effects (cardiovascular, electrolyte disorders, hyperlactatemia, hypotension). They might also induce transient hypoxaemia because of increased ventilation-perfusion mismatch. Short-acting anticholinergics, particularly ipratropium bromide, seem to have added value although the evidence is conflicting. Systemic steroids are indicated within the first hour. Oral steroids are as effective as intravenous. They require at least 4 h to produce clinical improvement. The evidence is too limited to advocate one steroid over another. The evidence for high dose inhaled steroids in a severe crisis is less clear but seems to suggest a benefit. Intravenous magnesium sulfate might be of added value for a severe crisis, with few side effects. In children, isotonic magnesium sulfate might also be used as nebulised solution. There is no evidence for an added benefit of intravenous SABA, nor for a specific dosing scheme. IV SABA carry an inherent risk of electrolyte disorders, hyperlactatemia, and most importantly cardiovascular failure. Limited and conflicting evidence exist for many other therapies (IV ketamine, aminophylline, Helium, isoflurane, leukotriene receptor antagonists, ICS-LABA, macrolides, monoclonal antibodies) and each of them should only be used by physicians competent in their use. Antibiotics are not recommended unless there is proven bacterial infection. NIV or HFNC might be considered in children with status asthmaticus remaining hypoxic with standard oxygen therapy and/or not responding to initial treatment. The available evidence on NIV or HFNC is conflicting and, especially in children with asthma exacerbations not meeting respiratory failure guidelines, these therapies may be associated with greater resource utilisation without evidence of improved outcome. Their use should never delay the decision to intubate when indicated. Severe exhaustion, deteriorating consciousness, poor air entry, worsening hypoxaemia and/or hypercapnia, and cardiopulmonary arrest are indications for intubation. Mechanical ventilation of a child with status asthmaticus is extremely challenging. Due to high airway resistance, there is a risk of gastric distension, pneumothorax, and dynamic hyperinflation with decreased venous return. This in turn might lead to cardiovascular collapse.

## Anaphylaxis

We also refer to the 2021 ERC guideline chapter on special circumstances.[405] Our RR identified 11 guidelines,[406–416] four SRs,[417–420] five narrative reviews,[421–425] as well as 21 observational studies (appendix RR 10).[426–446]

Anaphylaxis is life-threatening and requires immediate treatment. The incidence of anaphylaxis in children varies worldwide, ranging from 1 to 761/100,000 person-year. One-third have had a previous episode. Food items are the most frequent trigger in children (2/3), followed by insect venom and drugs (antibiotics, NSAIDs). Food anaphylaxis can cause respiratory arrest 30–35 min after contact, insect bites can produce shock very early (10–15 min), and anaphylaxis from medications usually occurs in a few minutes. No 'acute' death has been reported occurring more than 6 h after contact with the trigger. Biphasic reactions occur in up to 15% of cases and mostly where there was more than one dose of epinephrine required or a delay between the onset of anaphylaxis symptoms and the administration of epinephrine >60 min. Early diagnosis of anaphylaxis is crucial and will guide further treatment; for this we refer to the 2019 WAO criteria for diagnosis.[415] For the proposed emergency treatment, we essentially refer to the existing guidelines from relevant societies. We did not find any additional evidence but also considered issues of education and implementation in making our advice.

In addition to IM adrenaline, several supportive treatment options are proposed, based on limited evidence: inhaled beta-agonists and/or adrenaline for bronchospasm; IV Glucagon for children receiving beta-blockers; IV or oral H1 and/or H2 antihistamines to alleviate subjective symptoms (especially cutaneous). Corticosteroids might have a positive impact on late respiratory symptoms but otherwise there is no evidence of any effect on biphasic reactions or other outcomes. Corticosteroids are not without side effects and therefore should only be considered in children who need prolonged observation. Specific treatments might be considered in relation to the identified trigger and context (e.g. methylene blue).

## Severe intoxications

Paediatric emergency consultations for intoxications are frequent, although there is significant variation in incidence between regions.[447] A Cochrane review could not identify sufficient evidence to advise for or against specific first aid treatments for oral poisoning.[448] There is large geographic variation in the use of different decontamination techniques.[449]

It is important to consult an expert early. For further information we refer to the chapter on special circumstances within the 2020 guidelines.[405] In appendix, we report on some of the more important paediatric papers on the topic (appendix RR 11–RR 33.1).

## Obstructive shock (12.1)

Obstructive shock is a topic in the 2021 chapter on special circumstances.[405] We refer to appendix RR 12.1 and also to RR 34 on traumatic cardiac arrest and RR 33.1 on '4H4T'. There is no clear evidence for any recommendation regarding decompression of a tension pneumothorax in small children. Most data come from adult literature. Especially in small children the risk of iatrogenic injury to vital structures by needle decompression is high. The 4th intercostal space (ICS) at the anterior axillary line (AAL) offers a smaller chest wall thickness. Deviations from the correct angle of entry are accompanied by a higher risk of injury to intrathoracic structures at the second ICS.[450–452] In line with adult guidelines, we prefer the 4th (or 5th) ICS slightly anterior of the midaxillary line as the primary site of insertion, but the 2nd ICS midclavicular is still an acceptable alternative.[452a] There is insufficient evidence to suggest immediate thoracostomy over needle thoracocentesis as the first-line intervention in children with traumatic cardiac arrest, tension pneumothorax and massive haemothorax. Needle thoracocentesis seems easier to learn and faster to perform but might be less efficient.[450] However, systems that do not implement immediate thoracostomy should at least consider it as a rescue option. If immediately available, ultrasound should be used for confirmation of a pneumothorax, to measure chest wall thickness and confirm lack of underlying vital structures (e.g. the heart) before puncture and hence minimise depth of needle insertion and reduce the risk of injuring vital structures.

Pulmonary embolism may be more common than previously reported in adolescent sudden cardiac arrest.[453] Early recognition, high-quality CPR, and treatment with thrombolytic therapy resulted in

good survival in patients with pulmonary embolism.[454] Evidence does not exist on dose and timing of thrombolytic therapy in children. Catheter- directed therapy seems to be effective and safe for sub-massive and massive pulmonary embolism in children when instituted in a timely fashion.[455,456]

There are no comparative studies focusing on the treatment of cardiac tamponade. Weak evidence shows that survival improved when tamponade is detected early and treated promptly emphasising the importance of echocardiography.[457] Pericardiocentesis (preferably ultrasound-guided) should only be considered if immediate thoracotomy or (re) sternotomy is not possible (expert consensus).

### Atropine or pacing for unstable bradycardia

We included two narrative reviews[458,459] and one observational study[460] but found no new evidence to support changes to the ILCOR 2010 recommendations (appendix RR 13.1–13.2). If bradycardia is the consequence of decompensated respiratory or circulatory failure then this needs to be treated, rather than the bradycardia itself. Futile at best, atropine in hypoxic bradycardia could even be harmful as the temporary increase in heart rate might increase oxygen demand. Moreover, decreasing the parasympathetic drive might worsen those pathologies that are primary catecholamine-mediated (e.g. Takotsubo). An indication for atropine in bradycardia caused by increased vagal tone might still exist.

Historically, a minimum dose of atropine of 100 mcg has been recommended to avoid paradoxical decreases in heart rate supposed to occur with lower dosages. A recent observational study in infants did not confirm this for doses as low as 5 mcg/kg. A significant increase in heart rate was seen within 5 min of this low dose, tachycardia developed in half of all children and lasted for a few minutes. Moreover, several neonatal publications highlighted the potential for overdose in children weighing less than 5 kg if a minimum dose of 100 mcg was given.

Concerning emergency pacing the ILCOR paediatric taskforce could not identify any evidence and thus still recommended as in 2010: "*in selected cases of bradycardia caused by complete heart block or abnormal function of the sinus node, emergency transthoracic pacing may be lifesaving. Pacing is not helpful in children with bradycardia secondary to a post-arrest hypoxic/ischaemic myocardial insult or respiratory failure. Pacing also was not shown to be effective in the treatment of asystole in children*".[143]

### Unstable tachycardia

The 2020 ILCOR EvUp (PLS 379 & 409) did not find sufficient evidence to suggest a change in recommendation.[143] The ILCOR PLS taskforce specifically noted the importance of expert consultation before using procainamide or amiodarone for supraventricular tachycardia SVT. See the European Society of Cardiology ESC guidelines for in-depth information about subtypes, diagnosis and treatment options.[461,462] Our search identified an additional three narrative reviews,[463–466] two RCTs[467,468] and nine observational studies (appendix RR 13.3).[469–477] Different approaches to treatment are suggested for children who are haemodynamically unstable (decompensated) versus stable and/or have either narrow or wide QRS tachycardia.

Intravenous adenosine is the first-line treatment for narrow QRS tachycardia in children who are not yet in a decompensated state. Starting doses of 0.1 mg/kg for children and 0.15 mg/kg for infants are generally advised. Providers should consider a higher initial dose (0.2 mg/kg), especially in younger children.[464,472] Younger age is associated with decreased response to the first dose of adenosine and increased odds of adenosine- refractory SVT (Lewis 2017 177).[476] Use of a stopcock in small children may also lead to sub-therapeutic dosing.[478] There is insufficient evidence for or against the use of an intra-osseous access for adenosine delivery, but the IV route is preferable. Once decompensated, emergency electrical cardioversion is the preferred option and services should have a protocol in place for this procedure, including the use of analgosedation (e.g. IV/IO or intranasal ketamine, midazolam or fentanyl) for children who are still conscious.

Alternative medications include calcium channel blockers, beta-blockers, flecainide, digoxin, amiodarone, dexmedetomidine and ibutilide. Each of these medications has specific side effects and contraindications and should be used by competent providers, after expert consultation. Verapamil might provoke severe hypotension in younger children.

### Hypokalaemia

Hypokalaemia is a topic in the 2021 chapter on special circumstances.[405] We further included in our RR one narrative review,[479] one RCT[480] and two observational studies (appendix RR 14.1).[481,482] We found no new studies on the treatment of hypokalaemia in paediatric cardiac arrest. Studies on the treatment of hypokalaemia in intensive care settings are limited to cardiac patients and differ significantly in treatment threshold and dosage. Overall, enteral potassium seems to be equally effective to parenteral. Hyperkalaemia after treatment is rarely reported. Concomitant repletion of magnesium stores will facilitate more rapid correction of hypokalaemia and is strongly recommended in cases of severe hypokalaemia.

### Hyperkalaemia

For hyperkalaemia we again refer to the 'special circumstances' chapter.[405] We identified in our search one SR,[483] one narrative review,[484] and four observational studies (appendix RR 14.2).[485–488] Although the evidence base is limited, especially in children with cardiac arrest, a clear treatment algorithm is important to ensure consistent and effective interventions and avoid dosing errors or inadvertent side effects.

Children have specific underlying causes of hyperkalaemia and these should be considered early as they might alert the clinician to recognise hyperkalaemia and inform the therapeutic approach. Identification and treatment of all contributing factors of hyperkalaemia should, as far as possible, be performed simultaneously with the acute pharmacological treatment. This latter consists of:

- Membrane stabilisation with a calcium salt. Hypertonic saline might also provide membrane stabilisation but there is no evidence in children and the potential for side-effects is higher. Sodium bicarbonate, when indicated, has a similar effect.
- Potassium redistribution: Fast-acting insulin in a glucose infusion – to avoid hypoglycaemia – is usually effective after 15 min and lasts for 4–6 h. Repeated dosing might be necessary. There are different dosing regimens in the literature but no evidence to make strong recommendations for any one regimen. The effectiveness of inhaled beta-agonists has been described in adult and neonatal observational studies, but not for children specifically. The proposed dose is significantly

higher (4−8 times) than that for bronchodilation. The effect of nebulised beta-agonists is maximal only after 90 min. A peak effect is reached significantly earlier (30 min) with IV beta-agonists as a single bolus but the potential side effects are significant and dangerous and we suggest their use only in resistant hyperkalaemia and (imminent) cardiac arrest. Adrenaline is also a beta-agonist. Finally, despite ongoing controversy, we suggest the use of sodium bicarbonate in the emergency treatment of children with hyperkalaemia and metabolic acidosis (pH < 7.2) and/or in cardiac arrest. Give repeated doses of 1 mEq/kg to correct pH and concomitantly shift potassium intracellularly. The effect of sodium bicarbonate is slow (hours) but consistent and sodium might further stabilise the cell membrane.

- Potassium removal: Continue potassium redistribution measures until potassium removal treatments can be started. Dialysis is the most efficient treatment option but might not be readily available. Watch for post-dialysis rebound. Furosemide increases urinary potassium excretion. It is mostly indicated in well-hydrated children with preserved kidney function. Its effect is far less clear when there is also renal impairment. Potassium-binding agents like sodium polystyrene sulfonate (SPS in sorbitol) have not been studied prospectively in children. In adults, there are concerns regarding safety of SPS. Newer drugs might be safer and efficient but are unstudied in children.

### Hypoglycaemia

We identified one guideline,[489] 2 SRs,[490,491] one narrative review,[492] as well as four observational studies (appendix RR 15).[493−496] The ILCOR First Aid taskforce specifically performed a COSTR on the methods of glucose administration for hypoglycaemia.[497]

The threshold at which hypoglycaemia becomes harmful is uncertain and might depend on age, cause, and rate of onset. Standard threshold values have been defined in the literature at 50−70 mg/dl (2.8−3.9 mmol/L). While 70 mg/dl should alert physicians (considering symptoms and the risk of further decrease), a value of 50 mg/dl, especially if combined with neuroglycopaenic symptoms, is an absolute indication for prompt treatment. Systems should evaluate the test performance of their point-of-care tests when developing protocols.

Considering the pathophysiology, existing guidelines, and additional very low certainty evidence, we suggest an IV bolus of glucose for severe paediatric hypoglycaemia. Whereas adult protocols use 50% glucose, for children we advise the use of less hypertonic solutions in view of causticity and risk of dosing errors. In situations where IV glucose is not feasible, glucagon can be administered as temporary rescue, either IM or SC or intranasally. Start a maintenance infusion of glucose to reverse catabolism and maintain adequate glycaemia.

Less severe hypoglycaemia can be treated with standard glucose administration, without a glucose bolus or glucagon. This can be either by maintenance infusion or by oral glucose, followed by additional carbohydrates to prevent recurrence.

In both severe and non-severe hypoglycaemia, the underlying cause should be resolved when possible. This might include removing the trigger or administering additional treatments (e.g. corticosteroids). Severe hypoglycaemia might directly or indirectly lead to cardiac arrest. Although reversal of hypoglycaemia might not necessarily improve long-term outcomes in children who are in cardiac arrest, non-reversal of severe hypoglycaemia will cause brain damage and likely prevent ROSC. Therefore, it seems logical to include hypoglycaemia as one of the 4H, actively search for it, specifically in children at risk (metabolic, septic, intoxicated), and treat it when found.

### Hyperthermia

We identified two guidelines (MHAUS.org 2019),[498] three narrative reviews[499−501] and two observational studies (appendix RR 17.1).[502,503] The ILCOR First Aid taskforce specifically performed a COSTR on the First Aid Cooling Techniques for Heat Stroke and Exertional Hyperthermia.[497] Fever, hyperthermia, malignant hyperthermia, heat exhaustion and heat stroke are all distinct concepts with specific definitions. Fever is generally a beneficial physiological mechanism to fight infection and is not associated with long-term neurological complications. Heat-related illness and malignant hyperthermia both demand specific management (https://www.mhaus.org/healthcare-professionals/mhaus- recommendations/).

For severe heat-related illness, rapid recognition, assessment, cooling, and advanced planning are key to minimise the risk of morbidity and mortality. Symptoms associated with different heat related illnesses are similar. Although their distinction is not clear, children with elevated body temperature and CNS abnormalities should be treated as victims of heat stroke, which can be a life-threatening event.

### Status epilepticus

We report on only the emergency first-hour management, excluding further treatment for super-refractory status epilepticus [SE] or evidence on specific aetiologies (appendix RR 18). We included three guidelines,[504−506] 13 SRs,[507−519] six narrative reviews,[520−525] 15 RCT[526−542] and 13 non-RCT clinical studies.[543−556]

The incidence of paediatric SE is roughly 20 per 100,000 children per year, with an overall mortality of 3%. Prognosis is related to age, seizure duration and underlying cause. Despite mounting evidence that early treatment of SE is more effective and safer, both the initial and subsequent treatment is often delayed. Delayed treatment leads to decreased response to treatment, longer seizures, greater need of continuous infusions, potential brain injury and increased in-hospital mortality.

The current operational definition of SE includes seizures that have not stopped spontaneously within 5 min, as the likelihood of spontaneous cessation after this interval is low. Timely aggressive treatment of SE requires implementation of strict protocols. Implementation strategies should focus both on training of all professionals involved, as well as regular audit of performance and protocol adherence.

Time points in the algorithm represent maximum times before implementing the relevant step, but, depending on the cause and severity, children may go through the phases faster or even skip the second phase and move rapidly to the third phase, especially in sick or intensive care unit patients. Identify and manage underlying precipitant causes early on including metabolic derangements (e.g. hypoglycaemia, electrolyte disorders) and other causes (e.g. neurological, cardiological, metabolic, intoxications), as well as the systemic complications caused by underlying aetiology or treatment that could result in secondary brain injury.

Benzodiazepines are the initial therapy of choice, given their demonstrated efficacy, safety, and tolerability. Which benzodiazepine

to use via which route will depend on the availability, context, social preference, and expertise as there is no strong evidence to prefer one over the other. A first-line benzodiazepine (at least a first dose) can also be administered by properly trained lay caregivers or first responders. Although IV benzodiazepines are generally considered easy to administer and effective, in cases where there is not yet an IV-line, other routes might be preferable to avoid delay. A very recent RCT suggests intramuscular midazolam to be more efficient than buccal midazolam.[527] Although IV phenobarbital is effective and well tolerated, its slower rate of administration makes it an alternative initial therapy rather than the drug of first choice. Adequate dosing of the chosen benzodiazepine is essential for early SE cessation.

The approach in resource-limited settings is similar, considering potential differences in underlying aetiology and co-morbidity. Administration of more than two doses of benzodiazepine is associated with an increased risk of respiratory failure and subsequent death in settings where ventilation is not available.

A timely transition from first-line drugs to other anti-epileptic drugs could contribute to reducing treatment resistance in convulsive SE. IV Phenytoin/fosphenytoin, valproic acid and levetiracetam have been proposed for step 2. Where most protocols still include phenytoin as drug of choice, recent evidence favours levetiracetam in view of both cost-effectiveness, ease of use and safety profile. Valproic acid has similar response rates but is teratogenic and there is an associated risk of acute encephalopathy, related to hepatic abnormalities, hyperammonaemia and/or metabolic underlying diseases. Especially in infants and younger children this warrants extreme caution. IV phenobarbital is a reasonable alternative if none of the three above mentioned therapies are available. Here too, adequate dosing is essential. In resource-limited settings, when parenteral formulations of long-acting anti-epileptic drugs are not available, the use of enteral formulations delivered nasogastrically is feasible and potentially effective. Oral levetiracetam syrup has excellent bioavailability and produces therapeutic serum levels within approximately 1 h of delivery.

Recent papers also describe the use of lacosamide in paediatric SE. While lacosamide seems safe and effective, the evidence is currently too limited for widespread use.

Additional rescue medications should be considered for prolonged SE (step 3, no later than at 40 min). It is acceptable and potentially effective to use one of the second-line drugs not yet given immediately after the first second-line drug is given, as this might prevent the need for and thus complications of anaesthesia and intubation. Alternatively, depending on aetiology, vital signs and circumstances, anaesthetic doses of midazolam, pentobarbital/thiopental, ketamine or propofol can be considered, ideally with continuous EEG monitoring. Healthcare providers should be thoroughly familiar with the properties of each of these drugs when using them.

Non-convulsive SE can occur after cessation of visible seizures in convulsive SE, especially if the underlying cause is an acute central nervous system infection. EEG monitoring after treatment of CSE is essential for the recognition of persistent seizures. Early recognition and treatment of non-convulsive SE is advocated because it may influence outcome.

### Recognition of cardiac arrest – sequence of PBLS – duty cycle – bystander CPR

Although the ILCOR BLS taskforce advised in favour of commencing CPR with compressions (CAB), the paediatric taskforce maintained clinical equipoise. In a separate COSTR the PLS taskforce had already suggested that *bystanders provide CPR with ventilation for infants and children younger than 18 years with OHCA (weak recommendation, very low quality evidence) and that if bystanders can't provide rescue breaths as part of CPR for infants and children younger than 18 years with OHCA (Good Practice statement), they should at least provide chest compressions.*[4] The ILCOR PLS taskforce also recommended that emergency dispatchers provide CPR instructions for paediatric CA when no bystander CPR is in progress (strong recommendation, low certainty evidence).[143] The ILCOR BLS taskforce further recommended that lay persons initiate CPR in children or adults for presumed CA without concerns of harm to patients not in CA (strong recommendation, very low certainty evidence).[557] A Cochrane review on continuous chest compressions for non-asphyxial OHCA identified only one paediatric study.[558] Our RR additionally included some manikin studies as 'indirect' evidence (appendix RR 19.1,19.4, and 19.5).[559–563] We also refer to the RR on pulse check RR 19.7 and RR 25 on CPR for bradycardia.

The majority of paediatric cardiac arrests are caused by hypoxaemia or ischaemia and oxygen reserves are most often depleted by the time arrest occurs. The added value of ventilation in this context has been advocated repeatedly.[564] The PLS 2020 COSTR recommends bystanders provide CPR with ventilation for paediatric OHCA.[143] The taskforce identified in a subsequent search two additional papers (very-low certainty evidence) that found no difference in survival and neurological outcomes with compression-only CPR in children (older than infants), but did not consider this sufficient evidence to change their recommendation.[565,566] In a multicenter cohort study, higher ventilation rates during CPR were associated with improved outcome.[567]

Unconscious children with an obstructed airway might experience ventilatory arrest. Spontaneous breathing may be restored with simple airway opening and a few positive pressure breaths. Such children have an excellent outcome but might not be captured in CA registries, unless chest compressions are started before airway opening.

In making these recommendations we also considered that:

- Mobile phones are ubiquitous and most emergency calls are currently by mobile phone. Limited evidence suggests about 60% of callers can put their mobile phone on speaker.
- For adult CPR, the ILCOR BLS taskforce recommends that the lone bystander with a mobile phone first dials the EMS, activates the speaker or other hands-free option on the mobile phone, and then immediately begins CPR (strong recommendation, very-low-certainty of evidence).[557]
- Removing clothes did not seem to influence quality of CPR in two simulation studies but induced a delay of about 30 s.
- The identification of 'abnormal breathing' is not always easy in case of dispatcher-assisted CPR and adding specific word descriptors might improve recognition. Some groups suggest in adults the use of the 'hand on belly' method.[568] These methods are especially relevant in cases where there are issues of safety in approaching the victim's mouth and nose (e.g. viral transmission). The standard 'look, listen, feel' method should be avoided in these cases.[7]
- There is no evidence to support nor refute the existing guideline advocating five initial rescue breaths. Considering the impact on education and implementation, we therefore continue to recommend this approach.
- Adequate ventilation demands a sufficient long inspiratory time (1 s) and an adequate tidal volume (chest rise). To do so, there must

be a good seal between mouth of the rescuer (or mask) and the mouth/mouth-nose of the child (if needed, closing nose or lips to avoid air escape). When available, competent providers should use (2- person) BMV – preferably with oxygen – instead of expired air ventilation. In larger children when BMV is not available, competent providers can also use a pocket mask for rescue breaths.

All three discriminants of the formula of survival (science, education, and implementation) are important and we recommend that only those trained specifically in paediatric BLS use the paediatric specific guidelines. The duty cycle advocated in the 2015 guidelines for children was 15:2 and there is no reason to change this. Short pauses for rhythm check and a switch of the rescuer performing compressions to minimise fatigue should be scheduled every 2 min. In cases where there is a risk of earlier fatigue (e.g. when wearing full PPE for COVID-19) more rapid switching might be reasonable.[569]

### BLS in traumatic cardiac arrest

Most of the evidence found on this topic was indirect (appendix RR 19.6). We identified four observational studies and refer to the ILCOR first aid COSTR on external bleeding and spinal motion restriction.[497,570–573] Paediatric traumatic cardiac arrest [TCA] is rare and has a poor outcome. Of 21,710 children in the UK TARN database, 0.6% sustained TCA.[571] Overall, 30-day survival was 5.4% ((95% CI 2.6 to 10.8%), $n = 7$). In one TCA cohort initial recorded rhythms were shockable in only 3.5%.[570] Most TCAs were unwitnessed (49.5%), and less than 20% of children received chest compressions by bystanders. 19.5% achieved ROSC in the field, 9.8% survived the first 24 h, and 5.7% survived to discharge. Unlike those sustaining blunt trauma or strangulation, most TCA patients who survived the first 24 h after penetrating trauma or drowning were discharged alive. We could not find studies investigating a relationship between a specific sequence of BLS actions and outcome for TCA. Dispatcher-assisted CPR (DA-CPR) seemed not to be associated with achieving sustained ROSC.[574] TCA cases were less likely to have dispatcher recognition of cardiac arrest, dispatcher initiation of bystander CPR or any dispatcher delivery of CPR instructions. Improved DA-CPR protocols for TCA should be studied and validated.

Overall, bystander CPR was performed in 20–35% of paediatric TCAs.[572] Bystander interventions varied greatly, mainly depending on situational factors and the type of medical emergency. In one cohort survivors had triple the rate of bystander CPR than non-survivors.[570] This survival advantage for bystander CPR may be even greater for trauma victims in low- and middle-income countries where posture change and airway opening by bystanders reduces mortality.[575] We advise performing bystander CPR for paediatric TCA provided it is safe to do so. The bystander should minimise spinal movement as far as possible without hampering the process of resuscitation.

There are no data exploring the individual components of CPR. Among 424 adults with TCA, there was no significant difference in sustained ROSC between AED and non-AED groups.[576] Shockable rhythms are rare in paediatric TCA. Adult TCA guidelines also de-emphasise the importance of defibrillation. Therefore, we do not encourage the routine use of AEDs at the scene of paediatric TCA unless there is a high likelihood of a shockable underlying rhythm.

Massive haemorrhage is one cause of TCA. The initial treatment for external massive bleeding is direct pressure - if possible, using haemostatic dressings. The ILCOR first aid taskforce suggested that if life-threatening external bleeding is amenable to the application of a tourniquet, first aid providers should use a tourniquet in preference to direct manual pressure alone.[497] A manufactured tourniquet is preferred to an improvised tourniquet (weak recommendations, very low certainty of evidence).

### Pulse check

We identified two observational studies and refer to RR 32.3 on the use of ultrasound during CPR.[577,578] No studies compared manual pulse check with 'signs of life' in a RCT design (appendix RR 19.7). 'Signs of life' were implemented as part of the guidelines because of concern about false negatives and thus not providing CPR where it was needed. Starting CPR in those not needing it is off less concern not least because CPR-induced injury is rare in infants and children. Some data indicate that providing CPR to children with 'non-pulseless' bradycardia and severely impaired perfusion improves outcome.[579]

The identification of pulseless CA and ROSC in advanced life support relies on evaluation of circulation, including the manual palpation of pulses. Although experienced health care providers perform better than inexperienced providers, the risk of both type 1 and type 2 error and prolonged CPR pauses is still significant. The detection of circulation therefore should also include other intra-arrest parameters such as $ETCO_2$, blood pressure and $SpO_2$ (or possibly ultrasound).

### Chest compressions: rate – depth – recoil

The 2020 COSTR PLS 1605 on chest compression depth identified insufficient evidence to change existing recommendations.[143] In addition to a related scoping review,[580] we also report on six RCTs[581–586] and 15 observational studies (appendix RR 21.1).[587–601]

Evidence suggests that outcome is related to the quality of chest compressions, including hands-off time. Several factors should be considered, ideally in an integrated way. Instead of considering the average of each factor, focus on consistent good quality compressions meaning a high percentage of compressions that are good:

- Rate: the 2015 guidelines recommended a rate of 100–120 $min^{-1}$ for all infants and children. Excessive rates are not uncommon in children and might impact outcome.[602,603] Very low certainty evidence suggests slightly slower rates (80–100) are associated with a higher rate of survival to hospital discharge and survival with favourable neurological outcome.[588] The current guideline is unchanged.
- Depth: a certain depth is needed to generate blood pressure and perfusion, but over-compression might worsen outcome. The 2015 guidelines recommended *depressing the lower sternum by at least one third of the anterior–posterior (AP) dimension of the chest (infant 4 cm, child 5 cm*). In older, larger children however, this 1/3 of the AP dimension might often generate a compression depth of more than 6 cm (adult limit). Also, the 2015 target is often not reached and there is a risk that compression will be too shallow if there is too much concern about over-compression.[595] Visually determining depth in cm is near impossible (and so only informative for feedback devices). We therefore continue to recommend depressing the lower sternum by one third of the AP dimension of the chest. For larger children, compressions should never be deeper than the adult 6 cm limit (approx. an adult thumb's length). Positioning the arm 90° to the chest and using a step stool

are modifiable factors facilitating improved chest compression depth.[604]
- Recoil and leaning: this might impact outcome by hampering venous return. There is no evidence to suggest a relation between rate, depth and recoil but be aware of the risk of insufficient recoil when performing CPR.
- Hands-off time: indirect evidence from adults suggests that it is important to limit the hands-off time as much as possible.

Visual feedback helps to keep compression rates within the correct range, but applied force remains widely variable. Feedback devices might positively influence the quality of CPR, but current evidence is still equivocal. Until further data (from e.g. the multicenter PediResQ study) become available, we align our advice with the ILCOR BLS COSTR which suggests against routine implementation of real-time CPR feedback devices as a stand-alone measure to improve resuscitation outcome, without more comprehensive quality improvement initiatives (weak recommendation, very low quality of evidence).[557] In systems currently using real-time CPR feedback devices, they suggest these devices may continue to be used given that there is no evidence suggesting significant harm (weak recommendation, very low quality of evidence).

The ILCOR BLS taskforce also evaluated the impact of a firm surface for chest compressions.[557] They made the following recommendation: "*We suggest performing chest compressions on a firm surface when possible (weak recommendation, very low certainty evidence). During in-hospital cardiac arrest, we suggest, where a bed has a CPR mode which increases mattress stiffness, it should be activated (weak recommendation, very low certainty of evidence). During in-hospital cardiac arrest, we suggest against moving a patient from a bed to floor, to improve chest compression depth (weak recommendation, very low certainty of evidence). During in-hospital cardiac arrest, we suggest in favour of either a backboard (when already implemented in routine practice) or no-backboard strategy (if not yet part of current practice), to improve chest compression depth, (Conditional recommendation, very low certainty of evidence).*"

There is a lack of studies in OHCA and in children. Providers should avoid inadequate compression depth due to soft surfaces and either change the surface or adjust the compression force. In general, children can be more easily moved to improve CPR quality (firm surface, accessibility to the victim). Moving the child should be balanced against the risk of injury, delay, more confined space (if moved to the floor) or losing monitoring or IV access.

### Chest compressions: method

We identified three SRs,[605–607] four observational studies[608–611] and 24 (randomised) manikin studies (appendix RR 21.2).[599,603,612–631]

The method of chest compression influences the attainment of set goals for rate, depth and recoil. The level of certainty of the available evidence for different compression methods is very limited.

For infants, previous guidelines advised using two fingers (TF) for a single and a two-thumb encircling technique (TTET) for two rescuers. Compression location should be the lower half of the sternum. However, the standard TF technique is associated with suboptimal compression quality and early fatigue. The TTET consistently performs better, even for the single rescuer, and hands-off times are little different compare to the TF technique, although there is an identified risk of incomplete recoil (to be considered when teaching). The TF technique should only be considered for untrained rescuers (supported by dispatcher CPR or those only trained in adult BLS), where a TTET might be too difficult to explain ad hoc.

The 2015 paediatric ERC guidelines advised that the thumbs should be side by side and non-overlapping when using the TTET. This differed from the 2015 neonatal guidelines that advised placing one thumb on top of the other (superimposed). We advise using the latter method, if possible, based on weak evidence suggesting the superimposed thumb technique to generate a higher perfusion pressure and less liver compression.

New techniques to improve the quality of CPR have recently been explored. None of these have been validated in children. Preliminary results from manikin studies suggest these methods are at least as effective as standard techniques.[632] The modified vertical two-thumb technique might be especially useful for providers with smaller hands.[633] These new methods should be considered only as 'rescue' alternatives for providers trained in their use when standard methods become too tiring or are difficult to perform.

The optimal compression position for infants was set in the 2015 guidelines at the lower half of the sternum. To avoid compression of other organs, it was advised to stay one-finger width above the xiphisternum. Recent data from CT studies suggest that this advice still holds. One study highlighted the value of position aids (marker stickers) to improve quality of CPR.[613]

For children older than 1 year, rescuers can use either one-handed or two-handed CPR. There is insufficient evidence to change the 2015 guideline and advise one technique over another. The attainment of the set goals should define which technique is used. If the one-handed technique is used the other hand can be positioned to maintain an open airway throughout or to stabilise the compression arm at the elbow.

Standard guidelines advise changing the person doing compressions every 2 min. However, regardless of the technique fatigue and decreasing quality can occur after just 60 to 90 s. Rescuers should be alert to fatigue and switch hands, technique or rescuer when necessary to maintain optimal compressions.

### The use of an automated external defibrillator [AED] as part of PBLS

We identified one guideline,[634] one SR,[635] one narrative review[636] and 11 observational studies (appendix RR 22).[14,637–646]

Early defibrillation in patients with CA and a shockable rhythm increases the high likelihood of ROSC and a subsequent good neurological outcome in children and adults. However, in children with a primary non-shockable rhythm, the use of the AED might increase no-flow time and divert attention from other interventions which influence outcome.

During BLS it is impossible to determine the underlying rhythm before attaching an AED or other monitor, thus rescuers must rely on contextual evidence for the decision to use an AED. Alternatively, an AED can be attached in all children. The likelihood of a shockable rhythm is much higher in older children, children with specific medical conditions or a sudden witnessed collapse; but shockable rhythms can also occur in other cases, even in the very young. A small proportion of children with an initial non-shockable rhythm will have a subsequent shockable rhythm (0.5–2%). There is insufficient evidence to change existing recommendations. For treatment of out-of-hospital VF/pulseless VT in children under 8 years of age the recommended method of shock delivery is, in order of preference: (1)

manual defibrillator, (2) AED with dose attenuator and (3) AED without dose attenuator. If there is any delay in the availability of the preferred device, use the device that is available. The majority of existing AEDs deliver a standard dose of 120–200 J (biphasic) and with a paediatric attenuator the dose is usually 50 J. The algorithm of an AED used for small children should have demonstrated high specificity and sensitivity for detecting shockable rhythms in infants.

While continuing to emphasise the importance of rescue breaths and high-quality chest compressions we advise the use of AEDs in all children if feasible (i.e. more than one rescuer, AED accessible). Lone rescuers should not interrupt CPR to collect an AED unless there is a high likelihood of a primary shockable rhythm (such as in sudden witnessed collapse) and the AED directly available.

These recommendations are for trained providers. CPR provided by untrained bystanders is typically guided by EMS dispatchers. The risk of prolonged no-flow time and suboptimal CPR quality is higher when untrained bystanders use an AED even with dispatcher assistance. Although there is no specific literature supporting this recommendation, it is our opinion that an AED should primarily be advised as part of dispatcher-assisted CPR in those cases where the likelihood of a primary shockable rhythm is very high (as in sudden witnessed collapse or when there are specific 'cardiac' antecedents), and there is an AED nearby and accessible.

### Recovery position

In making our recommendation, we considered the ILCOR First Aid COSTR on the topic,[497] as well as one guideline[647] three SRs,[648–650] two RCTs,[651,652] and five observational studies (appendix RR 23).[653–657] The recovery position has been advised for use in unconscious non-trauma patients without advanced airway support, who are not in cardiac arrest. If performed properly, it improves airway patency and reduces the risk of aspiration compared to the supine position. In one cohort study, the recovery position was associated with a significant decrease in hospital admission.[656] In cardiopulmonary arrest, children almost immediately lose consciousness but can have breathing movements for up to 2 min after arrest. The lateral recovery position might hinder the early detection of abnormal breathing. To prevent this, rescuers should be taught to repeatedly assess breathing. Changing the recommendation of re-evaluating the victim from 'regularly' to 'every minute' significantly increased the likelihood of detecting CA.[652] In the case of untrained lay people, EMS dispatchers should therefore stay in contact with rescuers until the EMS arrives.

The overall evidence is very limited, and it remains unclear whether this advice applies to all situations and types of rescuer. In cases of pregnancy and in intoxicated children, a left lateral position is preferable.[648] In situations where there is a high risk of hypoxic respiratory arrest or impending CA, it is probably advisable to just continue head tilt – chin lift or jaw thrust in the supine position. For the specific case of unconscious trauma victims, one must also balance the harm of decreased airway patency against the risk of secondary spinal injury. The evidence is equivocal about the potential for harm of lateral rotation in trauma. Mandatory in-line stabilisation requires several rescuers to place and maintain the child in a recovery position.

### Foreign body airway obstruction [FBAO]

FBAO causes thousands of deaths yearly, particularly in vulnerable populations that have difficulty protecting their airway, such as children.[658] Rapid bystander interventions can significantly improve survival. Age-specific manoeuvres for FBAO have been part of resuscitation guidelines for more than 25 years. However, despite FBAO being an important health problem, and many anecdotal reports of successful airway clearance, the evidence supporting these guidelines is conflicting and of very low certainty (appendix RR 24).[659–663] A dedicated 2020 COSTR BLS368 provided treatment recommendations.[557]

We do not recommend the use of existing anti-choking devices in the first aid of a choking child. The immediate use of such a device might distract bystanders from performing the recommended steps of the current algorithm in a timely way. In the absence of evidence of safety, certain risks to children cannot be ruled out. Such devices could interfere with the ability to cough in conscious children and might cause damage to upper airway structures or encourage aspiration of gastric contents. There will also be a considerable cost associated with widespread implementation of such devices. We acknowledge the lack of evidence and the need for additional research, especially in victims who are no longer coughing efficiently or are unconscious.[664] In situations where conventional manoeuvres have failed, an anti-choking device might be an adjunct to standard treatment. However, at present, this should be in the context of formal evaluation in a study setting.

### Chest compression for children not in cardiac arrest

Despite a lack of evidence, previous guidelines recommended that bradycardia with signs of poor perfusion, even with a palpable pulse, should be treated by immediate CPR (appendix RR 25).[665–667] In one study, in 18% of children who received CPR, compressions were started at the early stage of non-pulseless bradycardia before the child became pulseless, whereas this only applied to 2% of adults receiving CPR.[668] Survival to discharge after pulseless non-shockable events was better in children (24%) than in adults (11%) and this might have been attributable to an early aggressive approach in children with bradycardia with poor perfusion.

Outcomes from hypoxic cardiac arrest are clearly worse than those of arrests of primary cardiac origin. It is likely that children with an hypoxic cardiac arrest have already suffered severe hypoxic brain damage by the time of circulatory arrest. In arrested heart organ donors, after withdrawal of life-sustaining care, the first observed physiological steps are desaturation and hypoperfusion.[669] This phase preceding terminal bradycardia may last between a few minutes and 3 h. After the onset of bradycardia somatic death usually occurs in a few minutes.

Several recent studies showed that children who received CPR for bradycardia with pulses and poor perfusion had better outcomes than children who suffered immediate asystole or PEA.[579,670,671] Altogether, outcomes were the best in the population of children who became bradycardic, received CPR but never became pulseless. The longer the time between the initiation of CPR for bradycardia with pulse and poor perfusion and the actual loss of pulse, the lower the chance of survival.

We put higher value on the potential for improved outcome by early CPR than the low potential risk of harm of inadvertent CPR. It is often impossible to identify the point at which the pulse is truly lost and waiting for pulselessness (or loss of $SpO_2$ trace, blood pressure values etc.) will only cause delay.

There are currently no studies on the impact of chest compressions on survival in children with very low-flow shock states without bradycardia (e.g. supraventricular tachycardia).

### Pads versus paddles for defibrillation

The ILCOR COSTR EvUp (PLS 378−426) did not identify sufficient evidence to change the current guidelines (appendix RR 26.1).[143,672−675] In those settings where self- adhesive pads are unavailable, paddles are an acceptable alternative. Paddles might also be used for the first defibrillation if the application of self-adhesive pads is taking too long. As in 2015, defibrillation paddles can be used to determine a rhythm if monitor leads or self-adhesive pads are not immediately available.

We could not identify any high-certainty evidence favouring either the anterio-posterior (AP) or the antero-lateral (AL) position. The previous GL suggested '*If the paddles are too large and there is a danger of charge arcing across the paddles, one should be placed on the upper back, below the left scapula and the other on the front, to the left of the sternum*'.[667] However, other sources suggest a slightly different position, based on anatomy and pathophysiology. Acknowledging this and in view of consistency, for the AP position we advise placing the anterior pad mid-chest immediately next to the sternum and the posterior pad mid-back between the scapulae. Very low certainty evidence suggests that the AP position might be at least as effective as the AL position. The AP position is difficult to use with paddles. In case of shock-resistant VF/pVT and an initial AL position of self-adhesive pads, consider changing these to an AP position.

### Stacked shocks

The PWG did not identify any new evidence to change the existing recommendations that favour a single-shock strategy followed by immediate CPR (appendix RR 26.2). However, in a setting with monitoring attached and a defibrillator immediately ready for use, immediate defibrillation −before starting CPR − following the witnessed onset of VF/pVT is possible and potentially beneficial. The heart is believed to be more readily defibrillated in this phase.[676] If an immediate defibrillation attempt is unsuccessful, outcome may be improved by a second and if needed third attempt before commencing CPR. Considering this and the relatively limited time delay of a '3 shocks first' approach − despite very limited evidence − we advise using a 'stacked' shock approach for those children who are monitored and have a defibrillator immediately ready for use at the moment of a 'witnessed' VF/pVT.[677,678] This 'stacked shock' approach has also been advised during ALS for patients with COVID 19 where rescuers are not yet wearing appropriate personal protection.[7] In case of a stacked shock approach, IV amiodarone is given immediately after the 3 initial shocks, whilst adrenaline will only be given after 4 min.

### Dose and timing of defibrillation

Shockable rhythms are not infrequent in children (4−10%) and their prognosis is better than other rhythms (appendix RR 26.3).[679] The primary determinant of survival from VF/pVT CA is the time to defibrillation. Secondary VF is present at some point in up to 27% of in-hospital resuscitation events and has a much poorer prognosis than primary VF.

**Energy dose**: There are inconsistent data about the optimal energy dose for shockable rhythms in children. The ILCOR PLS 405 scoping review did not identify sufficient new evidence to alter their recommendation.[143] In the SR of Mercier et al. ROSC was frequently achieved (≥85%) with energy dose ranging from 2 to 7 J/kg.[680] The ideal energy dose for safe and effective defibrillation remains unknown. The defibrillation threshold in children varies according to body weight and appears to be higher in infants. A recent registry-based study suggested better outcome for first shock energy doses of around 2 J/kg in paediatric IHCA with primary shockable rhythms.[681] However, this study did not report on many important co-variables which might have affected the outcome such as reasons for protocol violations, CPR quality, duration, no-flow time and number of shocks. Sample sizes were also too small for strong conclusions.

Doses higher than 4 J/kg have defibrillated children effectively with negligible side effects.[680] Animal studies suggest myocardial damage and subsequent reduced myocardial function with doses above 10 J/Kg. Adult data and guidelines suggest a first dose of 120−200 J (depending on the type of waveform) with escalating doses for refractory or recurrent VF. Adult guidelines also suggest attempting defibrillation in any VF regardless of amplitude, even if this is judged to be 'fine' or close to asystole.[678]

Given the lack of evidence and taking into consideration issues of implementation and education we continue to recommend 4 J/kg as standard energy dose. It seems reasonable not to use doses above those suggested for adults and to consider stepwise escalating doses for refractory VF/pVT (i.e. failure to respond to initial defibrillation and antiarrhythmic medications).[682] A lower energy dose for the first shock (2 J/kg) might be a reasonable alternative for primary shockable rhythms. If no manual defibrillator is available, use an AED that can recognise paediatric shockable rhythms (appendix RR22).

**Timing** of charging and rhythm checks: it is unclear in adults whether immediate defibrillation or a short period of CPR before defibrillation is superior.[683] The ILCOR BLS taskforce suggests a short period of CPR until the defibrillator is ready for analysis and/or defibrillation in unmonitored CA (weak recommendation, low-certainty evidence).[557] They also suggest immediate resumption of chest compressions after shock delivery (weak recommendation, very-low-certainty evidence). If there is alternative physiological evidence of ROSC, chest compressions can be paused briefly for rhythm analysis.

The interval between defibrillation attempts is set at 2 min, as in the 2015 guidelines.[667] This is based on expert opinion. There are studies that show improved outcome with a more rapid second attempt, but this is insufficient evidence to change the current guideline, especially when considering the impact on education and implementation.[684,685]

### Hypothermic cardiac arrest

The standard paediatric ALS actions should be adapted to adjust for the hypothermic state of the victim. For details, we refer to the chapter on special circumstances within these guidelines.[405] We considered the BLS 2020 COSTR on drowning,[557] as well as one guideline,[686] four SRs,[687−690] two narrative reviews,[691,692] and two observational studies (appendix RR 27).[693,694] Estimating the potential for survival with good neurological outcome in children after hypothermic arrest is difficult. No single parameter has sufficient test performance to do so. The adage 'no child can be declared dead if not warm' does not necessarily apply for those children with prolonged submersion/burial times, a lethal injury, a fully frozen body, or an unmanageable airway. However, none of these alone was 100% predictive and specifically in children prolonged submersion times in ice cold water have been associated with survival. Importantly, the presented evidence suggests a far worse prognosis for those children with preceding or associated asphyxia. Although not always easy to identify in the pre-hospital environment, one should carefully consider the mechanism and circumstances, and the first measured core body temperature

(<24 °C is more likely primary hypothermic). Additionally, the team should also consider the potential risks for the rescuers, the expected use of resources and the potential for harm to the victim.[695]

Any child with severe hypothermia who is considered to have any chance of favourable outcome (whether in CA or not) should ideally be transported as soon as possible to a centre with ECLS or CPB capacity for children. In hypothermic children emergency median sternotomy seems the preferable technique for vascular access. If not accessible continuous veno-venous haemofiltration or peritoneal lavage might be alternatives but seem to be associated with far less favourable outcomes.

### $FiO_2$ during CPR

The ILCOR 2020 COSTR PLS 396 did not identify sufficient evidence to change their 2005 recommendation to use 100% oxygen.[143] Although there is increasing evidence of a detrimental effect of hyperoxia on survival in critically ill adults, including those admitted with ROSC after CPR, clear evidence for an effect of oxygen titration during CRP in patients of any age is lacking (appendix RR 28). Hyperoxia during CPR is not clearly associated with increased mortality.[696]

### Advanced airway during ALS

Considering the published 2019 COSTR and two additional recent observational studies,[697–699] we advise the standard use of BMV during OHCA (appendix RR 29.1). Intubation or SGA placement might be performed once ROSC has been achieved. Competent airway operators might consider placement of an advanced airway in cases where CPR during transport or prolonged resuscitation is anticipated. Despite the lack of evidence, for consistency, we advise a similar approach for IHCA. However, when a competent professional attends an IHCA, early placement of an advanced airway might be considered.

### Ventilation strategy during ALS

In addition to the related ILCOR 2020 EvUp,[143] we included four observational studies and several papers with indirect evidence (appendix RR 29.3).[588,699–701]

Overall, the evidence base in favour of 'sub- physiological' ventilation rates is weak and suffers from severe indirectness. Early papers highlighted the potential harm caused by over-ventilation during CPR in adults.[702,703] However, the rates used to define hyperventilation in adult research and guidelines might not be applicable to children.

The importance of ventilation as part of the paediatric CPR algorithm is discussed in RR 19.4 and RR 29.3. Furthermore, one observational study – be it with only 47 subjects – suggests that low respiratory rates may be associated with less favourable outcomes especially for those children with bradycardia and poor perfusion.[567] One paediatric animal study found no differences in ROSC rates between ventilation rates of 10, 20 and 30 $min^{-1}$ but the highest rate was associated with higher $PaO_2$ levels.[700] This paper raised a concern that lower $PaCO_2$ values may result in reduced cerebral oxygen delivery, as the NIRS values tended to be lower in the 30 breaths per minute group. From a pathophysiological perspective, there is a fear that positive pressure breaths would inhibit passive venous return into the thorax due to increased intrathoracic pressure, and/or inadvertent PEEP. However, it is not known at what rate for age this might become an issue in children. A recent paper using a porcine infant asphyxia model of CA demonstrated that pressure-controlled ventilation at a rate of 20/min with an $FIO_2$ of 1.0 provided adequate oxygenation and restored normocapnia.[704]

Given the above and considering issues of education and implementation, we advise using minute volumes that are closer to those used for ventilation of any critically ill child.

There are no studies in children on the optimum ventilation strategy. What evidence there is, is derived from animal studies, manikin simulations and questionnaire surveys. Animal studies mainly used a porcine model of VF cardiac arrest and so did not address the asphyxial pathophysiology of paediatric resuscitation. One study showed that apnoeic oxygenation was equivalent to positive pressure ventilation with a mechanical ventilator in maintaining oxygenation in a VF arrest model.[705] A further study examined the effect of ventilator settings on blood gases and coronary perfusion pressure during CPR and demonstrated that trigger settings should be disabled.[706] Three adult studies examined chest compression synchronised ventilation modes and concluded that they offer advantages during CPR, but it is unclear how this translates into paediatric practice.[707–709] More relevant to paediatric resuscitation, is a newborn piglet study which demonstrated that the use of a self-inflating bag, a T-piece resuscitator or a mechanical ventilator all had similar effects on gas exchange.[710] The same group highlighted the leak around an uncuffed TT during CPR, which increased with PEEP.[711] Various manikin studies showed how the use of ventilator systems during adult CPR freed up hands for other necessary tasks.[712–714]

There are no data to inform the use of PEEP. It is known that intrathoracic airway closure occurs during CPR and that PEEP could potentially reverse this.[715] However, there is also concern that PEEP would raise the intrathoracic pressure and inhibit venous return during compressions. Low PEEP is likely to reduce oxygenation in children already requiring high PEEP before CA.

Finally, there might not be a need for five initial rescue breaths in children already ventilated before cardiac arrest, but providers should check that ventilations before cardiac arrest were adequate -and for instance not themselves the reason for cardiac arrest- before deciding to omit the first rescue breaths.

### Adrenaline during ALS

We considered the 2020 PLS COSTR 1541,[143] as well as some additional non-RCTs for our RR (appendix RR 30).[716–726] A shorter time to first administration of adrenaline is associated with more favourable outcomes in children for both IHCA and OHCA, a time to first dose of adrenaline of less than 3 min being the most favourable. No subgroup analyses between shockable and non-shockable CA rhythms could be performed. A cut-off of 5 min for the interval between adrenaline doses in paediatric IHCA was favourable for ROSC, survival to hospital discharge, and 12-month survival. However, if the cut-off interval was set as 3 min, more frequent administration of adrenaline tended to be harmful for 12-month survival.

Similar to adult data, the time to first adrenaline dose in traumatic CA seems to have different effects: a shorter time (<15 min) to first dose compared with a longer time was associated with significantly higher ROSC, but not with improved survival at discharge or better neurological outcome. Furthermore, early adrenaline administration was a risk factor for mortality in an haemorrhagic shock subgroup.

In line with the PLS COSTR 1541, we recommend administering the first dose of adrenaline for non-shockable rhythms as early as possible after collapse – if possible, within 3 min. Given the lack of evidence concerning dose interval, we continue to advise an interval of 3–5 min. Avoid an interval shorter than 3 min. In case of trauma, we put less emphasis on early adrenaline and advice rescuers to first consider treatment for reversible causes. In shockable rhythms, in line with the 2015 paediatric guidelines, we recommend giving a first dose of adrenaline after the third shock (about 4–5 min after start of CPR).[667] Although rare, avoid adrenaline in catecholaminergic polymorphic VT as this will aggravate the arrhythmia and worsen outcome.[727]

Finally, other vasoactive drugs (like vasopressin, terlipressin, milrinone or noradrenaline) have all been used in CA both in studies and in reports of clinical practice. The evidence for or against their use remains very weak and we would currently only advise their use in research settings.

### The use of amiodarone or lidocaine during ALS

This was topic of a 2018 ILCOR COSTR PLS 825 and published in the ERC 2018 update.[728] The 2015 recommendations about the use of amiodarone or lidocaine remained unchanged. Either amiodarone or lidocaine can be used in the treatment of paediatric shock- refractory VF/pVT. Clinicians should use the drug with which they are familiar. A recent retrospective comparative cohort study (GWTG-R) did not find any difference in outcome for either drug (appendix RR 30.2).[729]

### Atropine during ALS

We did not identify any relevant paediatric studies or recent indirect evidence supporting the use of atropine in children in CA (appendix RR 31.1). For other use and dosing we refer to the related RR.

### Magnesium

We did not identify any relevant paediatric studies or recent indirect evidence supporting an alteration in the 2015 ERC guideline which advised that magnesium should not be given routinely during CA (appendix RR 31.2).[667] Magnesium treatment is indicated in the child with documented hypomagnesaemia or with torsade de pointes VT regardless of the cause.

### Calcium

We identified two observational studies,[730,731] that gave no reason to alter the recommendations made in 2010: *the routine use of calcium for infants and children with cardiopulmonary arrest is not recommended in the absence of hypocalcemia, calcium channel blocker overdose, hypermagnesaemia, or hyperkalaemia*. (appendix RR 31.3).[143]

### Bicarbonate

Since 2010, one narrative review[732] and nine observational trials were published describing the association between the administration of sodium bicarbonate (or THAM) and outcomes in paediatric CA (appendix RR 31.4).[14,730,733–738] Whilst these studies are likely to be confounded by the association between administration of sodium bicarbonate and longer CPR duration, none provide any evidence to change the recommendation that bicarbonate should not be given routinely in paediatric CA.

The previous guidelines recommended that bicarbonate may be considered in cases of prolonged CA, severe metabolic acidosis, haemodynamic instability, co-existing hyperkalaemia and tricyclic antidepressant drug overdose. We however did not find any evidence to support the use of sodium bicarbonate in prolonged CA beyond the latter two indications.

### Intra-arrest parameters to guide CPR

Recommendations were primarily based on the related 2020 ILCOR PLS scoping reviews.[143] Given the limited evidence found, these reviews also considered adult and animal data, taking into account the serious indirectness of these (appendix 32.1, 32.2, 32.3, 32.4 and 32.6).

#### $ETCO_2$

The 2020 ILCOR PLS scoping review identified two observational studies.[739,740] $ETCO_2$ is thought to relate to cardiac output and perfusion. However, in one study it was not associated with diastolic blood pressure nor with any pre-defined outcomes.[739] This might be because $ETCO_2$ is also affected by minute volume and ventilation: perfusion matching. This study was only descriptive in nature, in a very selected population and at no point evaluated the outcomes associated with $ETCO_2$-directed CPR.

The level of certainty of the available paediatric evidence is too low to make any recommendation for or against the use of $ETCO_2$ to guide resuscitation efforts in children with CA. More specifically, there is no single $ETCO_2$ value that can be used as an indicator to terminate CPR, nor is there a single value that can be used as a target during CPR or as an indicator to continue or discontinue CPR.

#### Blood pressure

The 2020 ILCOR PLS scoping review identified three observational studies.[735,741,742] Adequate myocardial and brain tissue perfusion is fundamental to outcome and blood pressure could be useful as a clinically measurable surrogate for this. The current evidence is of very low certainty due to study design, sample size and selection bias, but suggests a possible relation between diastolic BP and the child's outcome. Only IHCA events were studied because of the need for invasive BP monitoring. Although one study identified optimal ROC curve thresholds for test performance, and thresholds below which no child survived,[742] the evidence is too limited to consider diastolic BP on its own sufficient to identify CPR futility or to predict favourable outcome. The level of certainty of the available evidence is too low to make any recommendation for or against the use of diastolic blood pressure to guide resuscitation efforts in children with cardiac arrest. However, for those children with IHCA where an arterial line is already in place and within settings that allow for proper implementation, haemodynamic-directed CPR might be considered.

#### POCUS

In their 2020 scoping review PLS 814 the ILCOR paediatric Taskforce warned against rapid implementation of POCUS in paediatric practice without sufficient evidence, despite its great potential and widespread acceptance. Acquisition and interpretation of images in children is more complex, especially in children with pre-existing heart disease. Furthermore, there are significant material and training costs which

might be important in low-resource settings. We suggest the use of POCUS by competent healthcare providers, when feasible, to identify reversible causes of cardiac arrest (4H4T). POCUS may also have role in identifying the presence of perfusion, but currently this should be only in the context of research. POCUS should currently not be used for prognostication.

### Near-infrared spectroscopy NIRS

The related 2020 ILCOR PLS identified two small observational studies.[743,744] The adult literature is more extensive, but the level of certainty is still low (serious indirectness presumed). At present, there is no consensus on a cut-off threshold of regional cerebral oxygen saturation ($rSO_2$) that can be used as an indicator of futility, nor is there a single $rSO_2$ value that can be used as a target during CPR or an argument to continue CPR. Adult literature suggests that a trend in $rSO_2$ is the most useful prognostic indicator, although this has not yet been validated in adults or children.

### Lactate or potassium

We identified two SRs,[687,688] one guideline [686] and seven relevant non-RCT studies.[694,745–750]

Intra-arrest potassium measurement is indicated for the exclusion of hyperkalaemia as a potential reversible cause of CA. However, there is insufficient evidence for making a statement about its use as a prognostication factor in children with CA. Even extreme hyperkalaemia should not impede CPR and ECLS in children.

Elevated lactate values are associated with worse short- and long-term outcomes in critically ill children, children with IHCA as well as in children treated with ECLS; they do not alone enable early prognostication. It should be noted that IO lactate samples might be higher during CA than in arterial and venous samples (evidence from animal studies only).

## Reversible causes of paediatric cardiac arrest: 4H4T

For most topics we refer to the dedicated RR within this document. In this paragraph, we highlight the potential reversibility and/or treatment options of certain pathologies. To do so we identified two guidelines,[677,751] one SR,[752] eight observational studies and several background papers (appendix RR 33.1).[485–487,738,753–756]

Although there might be other causes of CA that could be considered reversible – some sources propose 5 or even 6 Hs and Ts – we prefer to keep the '4H4T' mnemonic, in view of both consistency with the adult guidelines and ease of education.[678] We added hyperthermia (see RR 17.1) and hypoglycaemia (see RR 15) and deleted acidosis as reversible cause (see RR 31.4). Specific conditions such as cardiac surgery, neurosurgery, trauma, sepsis, and pulmonary hypertension demand a specific approach and importantly, the more widespread use of eCPR changes the concept of reversibility (see RR 33.3).

Institutions performing cardiothoracic surgery in children should establish institution-specific algorithms for CA in paediatric patients after cardiothoracic surgery. It is highly probable that this very specific group of patients will benefit from a different sequence of actions. There are two recent guidelines that can serve as an example for the development of such an algorithm from The Society of Thoracic Surgeons and the European Association for Cardio-Thoracic Surgery.[677]

### Cardiac arrest in septic children

We considered one SR[757] and 10 non-RCT studies (appendix RR 33.2).[734,758–764] Severe sepsis and septic shock are known risk factors for paediatric CA. Sepsis-associated IHCA has a bad outcome and prevention is the most crucial step. Different strategies can be used to prevent sepsis associated IHCA including the use of ECMO in refractory septic shock. No recommendations to deviate from the standard PALS algorithm can be made based on the currently available evidence. Early consideration and treatment of possible reversible causes is highly encouraged. IHCA occurring shortly before or during ECMO cannulation should not preclude ECMO initiation in paediatric patients with refractory septic shock as studies suggests that these children possibly benefit most from ECLS. Using high flows (greater than 150 mL/kg/min) might improve outcomes. Should ECPR be considered as a rescue therapy for septic IHCA the ECMO team must be activated early after initiation of PALS based on institution-specific protocols.

### Traumatic cardiac arrest

Our RR identified two guidelines,[765,766] 10 SRs,[767–776] 17 observational studies,[450,571,777–790] and a lot of papers with indirect evidence (appendix RR 34).

Paediatric TCA has a poor prognosis. Children with TCA who arrest after ED admission have better outcomes than those who arrest in the field. Strategies for improving early resuscitation can potentially change outcome. In case of paediatric TCA, resuscitation should be initiated in the absence of signs of irreversible death. Prolonged resuscitative efforts in children after blunt injury in whom CPR was ongoing for more than 15 min before arrival at the ED (or pre-hospital initiation of advanced CPR techniques) and who have fixed pupils are probably not beneficial and termination of resuscitation may be considered.

There is insufficient evidence to recommend for or against any specific sequence of actions in paediatric TCA. However, the early reversal of some of the reversible causes might yield more ROSC during pre-hospital care. Given this and the dire prognosis of paediatric TCA with standard care, we advise the pre-hospital near-immediate use of a bundle of interventions aimed specifically at reversible causes. Chest compressions should, if possible, be performed simultaneously with other interventions depending on the available personnel. Treatment of assumed reversible causes, based on mechanism of injury, might precede adrenaline administration.

Consider ED thoracotomy in paediatric TCA patients with penetrating trauma with or without signs of life on arrival to ED as this may improve survival of these children. Highly competent professionals in settings where the procedure has already been implemented might also consider pre-hospital thoracotomy for these children.

Current evidence shows no benefit (or even worse outcome) of thoracotomy in children after blunt injuries and this intervention is not generally recommended. In very selected blunt injury patients, based on thorough assessment, highly competent professionals might nevertheless identify an indication for emergency thoracotomy. Children with TCA should preferably be transported directly to a major trauma centre designated for children (or both children and adults) based on the local trauma system policy (expert consensus).

### Pulmonary hypertension

We refer to the ILCOR 2020 EvUp PLS 56[143] and the high-quality scientific statement by the American Heart Association on CPR in children with cardiac disease, as well as the specific guideline on intensive care treatment of PHT in children by the European Paediatric Pulmonary Vascular disease Network (appendix RR 35).[791,792] Consider the possibility of PHT in children with IHCA, who have a predefined risk for it.[793] Once cardiac arrest develops in a child with PHT, chest compressions and resuscitation drugs might be ineffective in generating pulmonary blood flow, left ventricular filling, and cardiac output. It is extremely important to search for and treat possible reversible causes of increased pulmonary vascular resistance, including inadvertent interruption in PHT therapy, hypercarbia, hypoxia, arrhythmia, cardiac tamponade, or drug toxicity. Maintain normocarbia and ensure adequate oxygenation. For the initial treatment of pulmonary hypertensive crises, oxygen administration and induction of alkalosis through hyperventilation or alkali administration can be useful while pulmonary- specific vasodilators are administered. There is no high-certainty evidence that alkali administration improves outcome, and excessive ventilation during resuscitation might also be harmful – positive-pressure ventilation will decrease systemic venous return, right ventricular filling, and cardiac output generated during chest compressions. If high-quality CPR remains ineffective despite provision of specific therapy, including pulmonary vasodilators, rapid consideration of ECLS might offer a chance of survival, either as a bridge to heart/lung transplantation or to permit recovery from the inciting factor.

### Extracorporeal eCPR

In line with the ILCOR 2019 COSTR update on the use of eCPR in children, we advise considering eCPR for children with ED- or IHCA with a presumed or confirmed reversible cause where conventional ALS does not promptly lead to ROSC (weak recommendation, very low certainty evidence).[697] An essential precondition is the organisational setting i.e. *with a strong institution-based commitment to sustaining a resuscitation system that includes eCPR with appropriate quality improvement systems*. To make a realistic choice about the use of eCPR, systems should also consider the evidence on cost-efficiency (see chapter on ethics).[695] Given the high resources needed and the fact that outcome is related to time to initiation and quality of CPR before initiation, the indications for eCPR in OHCA are very limited (appendix RR 33.3).[794–798]

### Management post-ROSC

Evidence on the impact of treating centre characteristics (or more broadly regional healthcare organisation) on outcome of children with ROSC after IHCA or OHCA is conflicting and difficult to interpret because of many confounders.[129,799–801] This should be a research priority. Pending further data, it is preferable to admit children who have been resuscitated from CA to a facility with the necessary competences and resources for proper post-ROSC neuroprotective care, organ- and/or life supporting treatments, comprehensive neurological assessment and psychosocial support.[802]

### Blood pressure

The ILCOR paediatric taskforce performed an EvUp (PLS 820) on this topic.[143] The authors identified five observational studies supporting the conclusion that post-CA hypotension less than the 5th percentile for age is associated with worse outcomes (appendix RR 36.1).[803–807] One paper demonstrated that hypertension immediately after CA is associated with improved survival. However, children who require higher doses of vasopressor support have lower rates of survival to hospital discharge.

### Oxygenation & ventilation

The paediatric ILCOR taskforce performed a SR on oxygenation and ventilation targets after ROSC (appendix RR 36.2).[143] They suggest that rescuers measure $PaO_2$ after ROSC and target a value appropriate to the specific condition of the child. In the absence of specific patient data, rescuers should target normoxemia after ROSC (weak recommendation, very-low-quality evidence). Rescuers should also measure $PaCO_2$ after ROSC and target normocapnia (weak recommendation, very-low-certainty evidence). Adjustments to the target $PaCO_2$ should be considered for specific populations where normocapnia may not desirable (e.g. chronic lung disease with chronic hypercapnia, single ventricle physiology). It is unclear if a strategy of permissive mild hypercapnia could be beneficial in ventilated children with respiratory failure.

### Targeted temperature management

In line with the ILCOR 2019 COSTR update on targeted temperature management (TTM) in children after ROSC,[697] TTM should be used for children who achieve ROSC (appendix RR 36.3). Although potentially of benefit, lower goals for TTM (e.g. 34 °C) demand appropriate systems of paediatric neurocritical care and should only be used in settings where these are in place. Whether certain temperature goals are more appropriate for certain subgroups is not supported by evidence and thus at the discretion of the attending team. This is also the case for the duration of TTM (24 to 72 h).

### Prognostication

An ILCOR 2020 EvUp evaluated the role of EEG in neuroprognostication.[143] Although EEG background patterns seem associated with neurological outcomes, the authors concluded that neither the presence or absence of any single factor predicts with high accuracy survival or survival with favourable neurological outcome. Biological markers measured within the first 24 h such as elevated blood lactate, or blood pH, or base excess may be indicative, but cut-off values remain unknown. Neuroimaging using CT, EEG, or biological markers may be promising in the future (appendix RR 36.6).

## Conflict of interest

FH reports speaker honorarium from ZOLL.
IM reports his role as Associate editor BMJ Open Paediatrics.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.resuscitation.2021.02.015.

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