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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 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/resour-ces/publications/rapid- review-guide/en/]. Where available, searches were primarily informed by reviews included in the International Liaison Committee on Resuscitation Consensus on Cardiopulmonary Resus-citation 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 (speaker-phone) 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 hypoxae-mia 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-Unrespon-sive) score, (paediatric) Glasgow Coma Scale (GCS) total

PAEDIATRIC*LIFE SUPPORT 2021

5 TOP MESSAGES

*0-18y, except newborns 'at birth'

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1. **Use ABCDE as common language**
- Work as a team – Be competent.

2. **Titrate oxygen therapy to SpO_2 94-98%**
- only if impossible to measure, start high flow O_2 based on signs of circulatory/respiratory failure.

3. **In 'shock', give 1 or more fluid bolus(es) of 10ml/kg of (preferably balanced) crystalloids (or blood products). Reassess after each bolus. Start vasoactive drugs early.**

4. **For basic life support, use the specific PBLS algorithm (ABC - 15:2) if you are trained to do so. Both improving the quality of CPR and limiting the hands-off time are considered crucial. Consider provider safety.**

5. **For advanced life support, use the specific PALS algorithm. Actively search for and treat reversible causes. Use 2-person BMV as the first line ventilatory support. Only if intubated, provide asynchronous ventilation at an age-dependent rate (10-25/').**

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 haemo-stasis. 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 inoconstric-tors 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 exper-tise. 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 hyper-kalaemia 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).
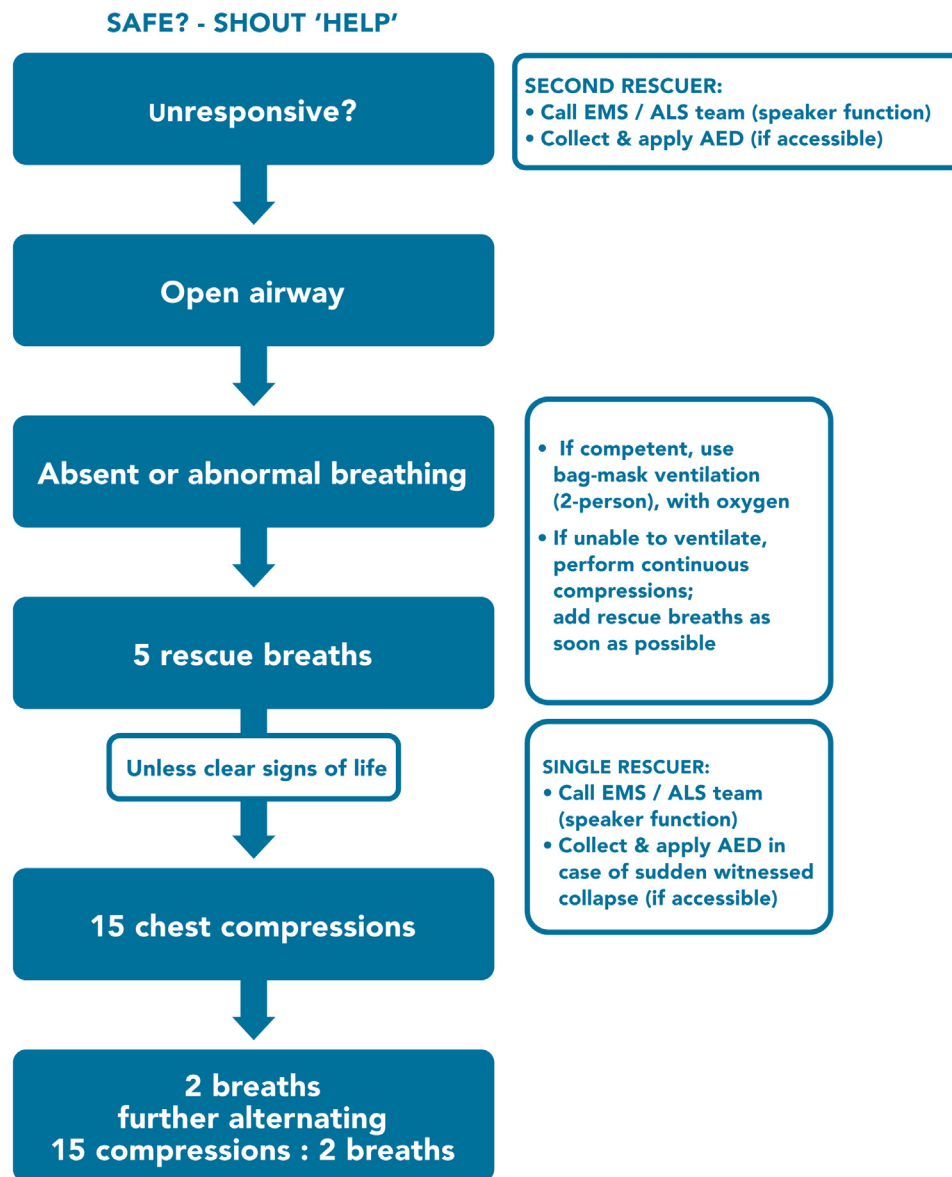
Sequence of actions in PBLS

- 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 compres-sions 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.

PAEDIATRIC BASIC LIFE SUPPORT

EUROPEAN RESUSCITATION COUNCIL
GUIDELINES 2021

SAFE? - SHOUT 'HELP'

Unresponsive?

SECOND RESCUER:
• Call EMS / ALS team (speaker function)
• Collect & apply AED (if accessible)

Open airway

Absent or abnormal breathing

• If competent, use bag-mask ventilation (2-person), with oxygen
• If unable to ventilate, perform continuous compressions; add rescue breaths as soon as possible

5 rescue breaths

Unless clear signs of life

SINGLE RESCUER:
• Call EMS / ALS team (speaker function)
• Collect & apply AED in case of sudden witnessed collapse (if accessible)

15 chest compressions

2 breaths
further alternating
15 compressions : 2 breaths

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.
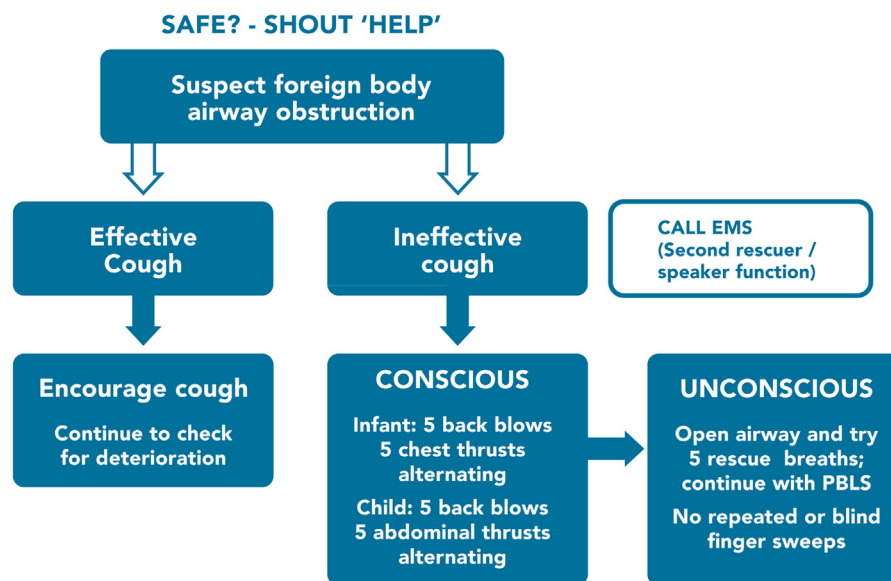
Paediatric advanced life support

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

PAEDIATRIC FOREIGN BODY AIRWAY OBSTRUCTION

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SAFE? - SHOUT 'HELP'

Suspect foreign body airway obstruction

Effective Cough → **Encourage cough** — Continue to check for deterioration

Ineffective cough → **CONSCIOUS**
Infant: 5 back blows 5 chest thrusts alternating
Child: 5 back blows 5 abdominal thrusts alternating

→ **UNCONSCIOUS**
Open airway and try 5 rescue breaths; continue with PBLS
No repeated or blind finger sweeps

CALL EMS (Second rescuer / speaker function)

If obstruction relieved: urgent medical follow-up

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)
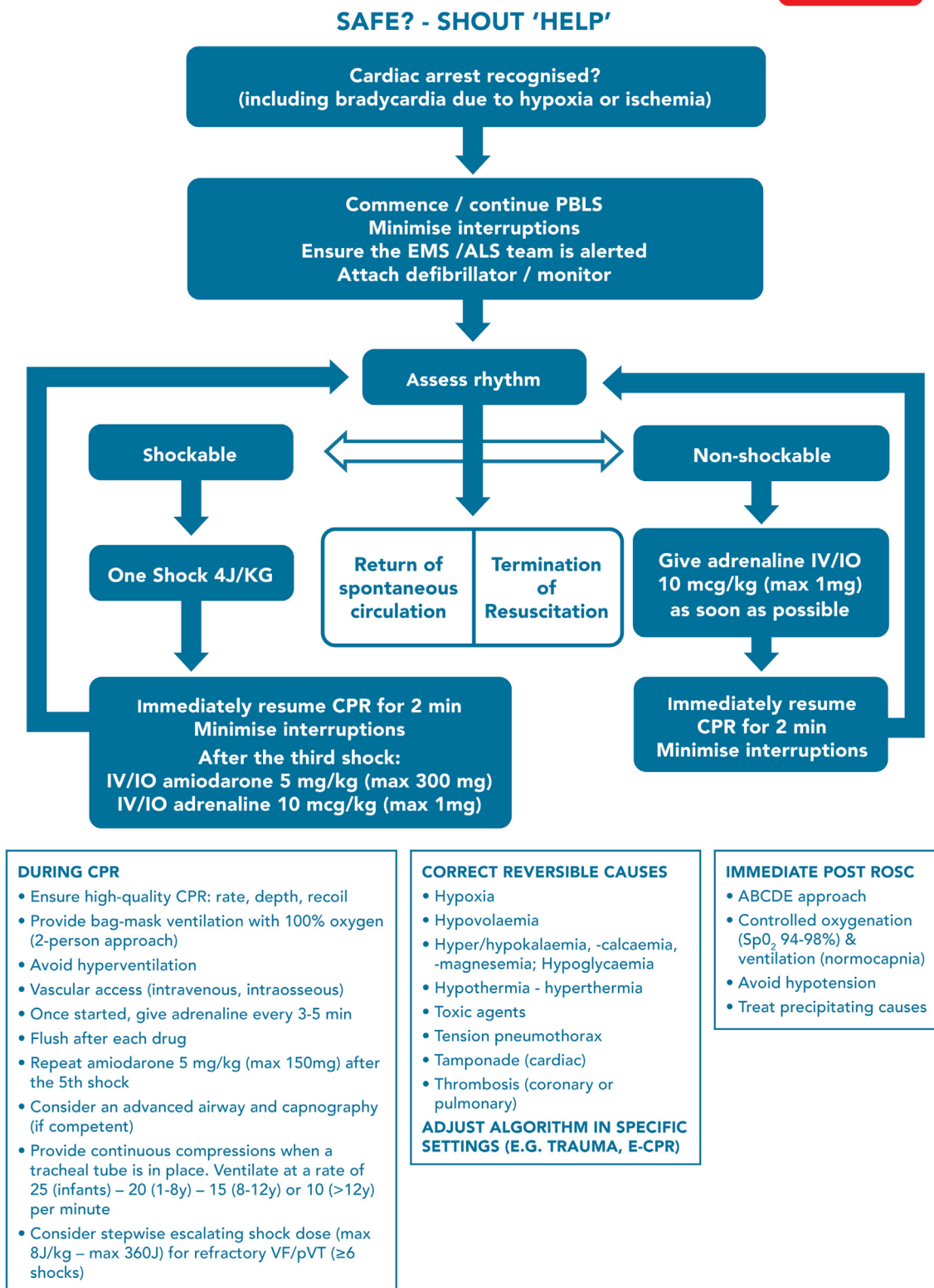 ■ There are criteria for withdrawing resuscitation (see the ERC guideline chapter on ethics).

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

PAEDIATRIC ADVANCED LIFE SUPPORT

EUROPEAN RESUSCITATION COUNCIL
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SAFE? - SHOUT 'HELP'

Cardiac arrest recognised?
(including bradycardia due to hypoxia or ischemia)

Commence / continue PBLS
Minimise interruptions
Ensure the EMS /ALS team is alerted
Attach defibrillator / monitor

Assess rhythm

Shockable

Non-shockable

One Shock 4J/KG

Return of spontaneous circulation | **Termination of Resuscitation**

Give adrenaline IV/IO 10 mcg/kg (max 1mg) as soon as possible

Immediately resume CPR for 2 min
Minimise interruptions
After the third shock:
IV/IO amiodarone 5 mg/kg (max 300 mg)
IV/IO adrenaline 10 mcg/kg (max 1mg)

Immediately resume CPR for 2 min
Minimise interruptions

DURING CPR
- Ensure high-quality CPR: rate, depth, recoil
- Provide bag-mask ventilation with 100% oxygen (2-person approach)
- Avoid hyperventilation
- Vascular access (intravenous, intraosseous)
- Once started, give adrenaline every 3-5 min
- Flush after each drug
- Repeat amiodarone 5 mg/kg (max 150mg) after the 5th shock
- Consider an advanced airway and capnography (if competent)
- Provide continuous compressions when a tracheal tube is in place. Ventilate at a rate of 25 (infants) – 20 (1-8y) – 15 (8-12y) or 10 (>12y) per minute
- Consider stepwise escalating shock dose (max 8J/kg – max 360J) for refractory VF/pVT (≥6 shocks)

CORRECT REVERSIBLE CAUSES
- Hypoxia
- Hypovolaemia
- Hyper/hypokalaemia, -calcaemia, -magnesemia; Hypoglycaemia
- Hypothermia - hyperthermia
- Toxic agents
- Tension pneumothorax
- Tamponade (cardiac)
- Thrombosis (coronary or pulmonary)

ADJUST ALGORITHM IN SPECIFIC SETTINGS (E.G. TRAUMA, E-CPR)

IMMEDIATE POST ROSC
- ABCDE approach
- Controlled oxygenation (SpO$_2$ 94-98%) & ventilation (normocapnia)
- Avoid hypotension
- Treat precipitating causes

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: Hypoxia; Hypovolemia; Hypo- or hyperkalaemia/-calcaemia/-magnesemia & hypoglycaemia; Hypo- or Hyperthermia; Tension pneumothorax; Tamponade; Thrombosis (Cardiac − Pulmonary); Toxic 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 cardio-pulmonary 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 pre-defined 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, multi-disciplinary 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 (prefera-bly 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. Takotsu-bo). 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 circum-stances.[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 simulta-neously 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. Adren-aline is also a beta-agonist. Finally, despite ongoing contro-versy, 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 bicarbon-ate 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 addi-tional 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. corticoste-roids). 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 hyper-thermia, 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. Imple-mentation 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, hyper-ammonaemia 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

($<24\,^{\circ}$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 adminis- tration 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 organisa- tional 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 normox- emia after ROSC (weak recommendation, very-low-quality evi- dence). 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 neuro- prognostication.[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

Acknowledgments

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.

REFERENCES

1. Soreide E, Morrison L, Hillman K, et al. The formula for survival in resuscitation. Resuscitation 2013;84:1487−93, doi:http://dx.doi.org/10.1016/j.resuscitation.2013.07.020.
2. Brouwers MC, Kho ME, Browman GP, et al. AGREE II: advancing guideline development, reporting and evaluation in health care. J Clin Epidemiol 2010;63:1308−11, doi:http://dx.doi.org/10.1016/j.jclinepi.2010.07.001.
3. Shea BJ, Hamel C, Wells GA, et al. AMSTAR is a reliable and valid measurement tool to assess the methodological quality of systematic reviews. J Clin Epidemiol 2009;62:1013−20.
4. Perkins GD, Olasveengen TM, Maconochie I, et al. European Resuscitation Council Guidelines for Resuscitation: 2017 update. Resuscitation 2018;123:43−50, doi:http://dx.doi.org/10.1016/j.resuscitation.2017.12.007.
5. Perkins GD, Graesner JT, Semeraro F, et al. European Resuscitation Council Guidelines 2021 − executive summary. Resuscitation 2021161:.
6. Edwards-Jackson N, North K, Chiume M, et al. Outcomes of in-hospital paediatric cardiac arrest from a tertiary hospital in a low-income African country. Paediatr Int Child Health 2020;40:11−5, doi:http://dx.doi.org/10.1080/20469047.2019.1570443.
7. Nolan JP, Monsieurs KG, Bossaert L, et al. European Resuscitation Council COVID-19 guidelines executive summary. Resuscitation 2020;153:45−55, doi:http://dx.doi.org/10.1016/j.resuscitation.2020.06.001.
8. Shen J, Sun J, Zhao D, et al. Characteristics of nosocomial infections in children screened for SARS-CoV-2 infection in China. Med Sci Monit 2020;26:e928835, doi:http://dx.doi.org/10.12659/MSM.928835.
9. Ludvigsson JF. Systematic review of COVID-19 in children shows milder cases and a better prognosis than adults. Acta Paediatr 2020;109:1088−95, doi:http://dx.doi.org/10.1111/apa.15270.
10. Dong Y, Mo X, Hu Y, et al. Epidemiology of COVID-19 among children in China. Pediatrics 2020145:, doi:http://dx.doi.org/10.1542/peds.2020- 0702.
11. Rauf A, Abu- Izneid T, Olatunde A, et al. COVID-19 pandemic: epidemiology, etiology, conventional and non- conventional therapies. Int J Environ Res Public Health 202017:, doi:http://dx.doi.org/10.3390/ijerph17218155.
12. Chao JY, Derespina KR, Herold BC, et al. Clinical characteristics and outcomes of hospitalized and critically ill children and adolescents with coronavirus disease 2019 at a Tertiary Care Medical Center in New York City. J Pediatr 2020223:, doi:http://dx.doi.org/10.1016/j.jpeds.2020.05.006 14−19 e2.
13. Garcia-Salido A, Leoz- Gordillo I, Martinez de Azagra-Garde A, et al. Children in critical care due to severe acute respiratory syndrome coronavirus 2 infection: experience in a Spanish Hospital. Pediatr Crit Care Med 2020;21:e576−80, doi:http://dx.doi.org/10.1097/PCC.0000000000002475.
14. Nehme Z, Namachivayam S, Forrest A, Butt W, Bernard S, Smith K. Trends in the incidence and outcome of paediatric out-of-hospital cardiac arrest: a 17-year observational study. Resuscitation 2018;128:43−50, doi:http://dx.doi.org/10.1016/j.resuscitation.2018.04.030.
15. Phillips RS, Scott B, Carter SJ, et al. Systematic review and meta-analysis of outcomes after cardiopulmonary arrest in childhood. PLOS ONE 2015;10:e0130327, doi:http://dx.doi.org/10.1371/journal.pone.0130327.
16. Gerein RB, Osmond MH, Stiell IG, Nesbitt LP, Burns S. What are the etiology and epidemiology of out-of-hospital pediatric cardiopulmonary arrest in Ontario, Canada? Acad Emerg Med 2006;13:653−8 (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=16670256).
17. Lee J, Yang WC, Lee EP, et al. Clinical survey and predictors of outcomes of pediatric out-of- hospital cardiac arrest admitted to the emergency department. Sci Rep 2019;9:7032, doi:http://dx.doi.org/10.1038/s41598-019-43020-0.
18. Goto Y, Funada A, Goto Y. Duration of prehospital cardiopulmonary resuscitation and favorable neurological outcomes for pediatric out-of-hospital cardiac arrests: a nationwide, population-based cohort study. Circulation 2016;134:2046−59, doi:http://dx.doi.org/10.1161/CIRCULATIONAHA.116.023821.
19. Matsui S, Sobue T, Irisawa T, et al. Poor long-term survival of out-of-hospital cardiac arrest in children. Int Heart J 2020;61:254−62, doi:http://dx.doi.org/10.1536/ihj.19-574.
20. Okubo M, Chan HK, Callaway CW, Mann NC, Wang HE. Characteristics of paediatric out-of-hospital cardiac arrest in the United States. Resuscitation 2020;153:227−33, doi:http://dx.doi.org/10.1016/j.resuscitation.2020.04.023.
21. Holmberg MJ, Ross CE, Fitzmaurice GM, et al. Annual incidence of adult and pediatric in-hospital cardiac arrest in the United States. Circ Cardiovasc Qual Outcomes 2019;12:e005580 (https://www.ncbi.nlm.nih.gov/pubmed/31545574).
22. Skellett S, Orzechowska I, Thomas K, Fortune PM. The landscape of paediatric in-hospital cardiac arrest in the United Kingdom National Cardiac Arrest Audit. Resuscitation 2020;155:165−71, doi:http://dx.doi.org/10.1016/j.resuscitation.2020.07.026.
23. Booth A, Moylan A, Hodgson J, et al. Resuscitation registers: how many active registers are there and how many collect data on paediatric cardiac arrests? Resuscitation 2018;129:70−5, doi:http://dx.doi.org/10.1016/j.resuscitation.2018.03.029.
24. Hamid MA, Chandna A, Siddiqui S, Fayyaz J. Pulse oximetry: a reliable and cost effective screening tool in children with pneumonia for developing countries. J Pak Med Assoc 2016;66:1015−8 (https://www.ncbi.nlm.nih.gov/pubmed/27524539).
25. Bamber AR, Mifsud W, Wolfe I, et al. Potentially preventable infant and child deaths identified at autopsy; findings and implications. Forensic Sci Med Pathol 2015;11:358−64, doi:http://dx.doi.org/10.1007/s12024-015-9681-9.
26. Hansmann A, Morrow BM, Lang HJ. Review of supplemental oxygen and respiratory support for paediatric emergency care in sub-Saharan Africa. Afr J Emerg Med 2017;7:S10−9, doi:http://dx.doi.org/10.1016/j.afjem.2017.10.001.
27. Mendelson J. Emergency department management of pediatric shock. Emerg Med Clin North Am 2018;36:427−40, doi:http://dx.doi.org/10.1016/j.emc.2017.12.010.
28. Davis AL, Carcillo JA, Aneja RK, et al. American college of critical care medicine clinical practice parameters for hemodynamic support of pediatric and neonatal septic shock. Crit Care Med 2017;45:1061−93, doi:http://dx.doi.org/10.1097/CCM.0000000000002425.
29. Rambaud-Althaus C, Althaus F, Genton B, D'Acremont V. Clinical features for diagnosis of pneumonia in children younger than 5 years: a systematic review and meta-analysis. Lancet Infect Dis 2015;15:439−50, doi:http://dx.doi.org/10.1016/S1473-3099(15)70017-4.
30. Opiyo N, English M. What clinical signs best identify severe illness in young infants aged 0−59 days in developing countries? A systematic review. Arch Dis Child 2011;96:1052−9, doi:http://dx.doi.org/10.1136/adc.2010.186049.

31. Acker SN, Ross JT, Partrick DA, Tong S, Bensard DD. Pediatric specific shock index accurately identifies severely injured children. J Pediatr Surg 2015;50:331−4, doi:http://dx.doi.org/10.1016/j.jpedsurg.2014.08.009.

32. Rousseaux J, Grandbastien B, Dorkenoo A, Lampin ME, Leteurtre S, Leclerc F. Prognostic value of shock index in children with septic shock. Pediatr Emerg Care 2013;29:1055−9, doi:http://dx.doi.org/10.1097/PEC.0b013e3182a5c99c.

33. Strutt J, Flood A, Kharbanda AB. Shock index as a predictor of morbidity and mortality in pediatric trauma patients. Pediatr Emerg Care 2019;35:132−7, doi:http://dx.doi.org/10.1097/PEC.0000000000001733.

34. Shah S, Kaul A, Jadhav Y, Shiwarkar G. Clinical outcome of severe sepsis and septic shock in critically ill children. Trop Doct 2020;50:186−90, doi:http://dx.doi.org/10.1177/0049475520914831.

35. G.K.F S, Wong HC, Ganapathy S, Ong GY. Oximetry-detected pulsus paradoxus predicts for severity in paediatric asthma. Arch Dis Child 2020;105:533−8, doi:http://dx.doi.org/10.1136/archdischild-2019-318043.

36. Fleming S, Gill P, Jones C, et al. The diagnostic value of capillary refill time for detecting serious illness in children: a systematic review and meta-analysis. PLOS ONE 2015;10:e0138155, doi:http://dx.doi.org/10.1371/journal.pone.0138155.

37. Scott HF, Deakyne SJ, Woods JM, Bajaj L. The prevalence and diagnostic utility of systemic inflammatory response syndrome vital signs in a pediatric emergency department. Acad Emerg Med 2015;22:381−9, doi:http://dx.doi.org/10.1111/acem.12610.

38. Brissaud O, Botte A, Cambonie G, et al. Experts' recommendations for the management of cardiogenic shock in children. Ann Intensive Care 2016;6:14, doi:http://dx.doi.org/10.1186/s13613-016- 0111-2.

39. Paul R. Recognition, diagnostics, and management of pediatric severe sepsis and septic shock in the emergency department. Pediatr Clin North Am 2018;65:1107−18, doi:http://dx.doi.org/10.1016/j.pcl.2018.07.012.

40. Blacklock C, Mayon- White R, Coad N, Thompson M. Which symptoms and clinical features correctly identify serious respiratory infection in children attending a paediatric assessment unit? Arch Dis Child 2011;96:708−14, doi:http://dx.doi.org/10.1136/adc.2010.206243.

41. Daw WJ, Kingshott RN, Elphick HE. Poor inter-observer agreement in the measurement of respiratory rate in children: a prospective observational study. BMJ Paediatr Open 2017;1:e000173, doi:http://dx.doi.org/10.1136/bmjpo-2017-000173.

42. Wang EE, Law BJ, Stephens D, et al. Study of interobserver reliability in clinical assessment of RSV lower respiratory illness: a Pediatric Investigators Collaborative Network for Infections in Canada (PICNIC) study. Pediatr Pulmonol 1996;22:23−7, doi:http://dx.doi.org/10.1002/(SICI)1099-0496(199607)22:1<23::AID-PPUL4>3.0.CO;2- L.

43. Kemper KJ, Benson MS, Bishop MJ. Interobserver variability in assessing pediatric postextubation stridor. Clin Pediatr (Phila) 1992;31:405−8, doi:http://dx.doi.org/10.1177/000992289203100705.

44. de Groot MG, de Neef M, Otten MH, van Woensel JBM, Bem RA. Interobserver agreement on clinical judgment of work of breathing in spontaneously breathing children in the pediatric intensive care unit. J Pediatr Intensive Care 2020;9:34−9, doi:http://dx.doi.org/10.1055/s-0039-1697679.

45. Balamuth F, Alpern ER, Grundmeier RW, et al. Comparison of two sepsis recognition methods in a pediatric emergency department. Acad Emerg Med 2015;22:1298−306, doi:http://dx.doi.org/10.1111/acem.12814.

46. Despins LA. Automated detection of sepsis using electronic medical record data: a systematic review. J Healthc Qual 2017;39:322−33, doi:http://dx.doi.org/10.1097/JHQ.0000000000000066.

47. Potes C, Conroy B, Xu-Wilson M, Newth C, Inwald D, Frassica J. A clinical prediction model to identify patients at high risk of hemodynamic instability in the pediatric intensive care unit. Crit Care 2017;21:282, doi:http://dx.doi.org/10.1186/s13054-017-1874- z.

48. Weiss SL, Peters MJ, Alhazzani W, et al. Surviving sepsis campaign international guidelines for the management of septic shock and sepsis-associated organ dysfunction in children. Pediatr Crit Care Med 2020;21:e52−e106, doi:http://dx.doi.org/10.1097/PCC.0000000000002198.

49. Fernandez A, Benito J, Mintegi S. Is this child sick? Usefulness of the Pediatric Assessment Triangle in emergency settings. J Pediatr 2017;93:60−7, doi:http://dx.doi.org/10.1016/j.jped.2017.07.002.

50. Horeczko T, Enriquez B, McGrath NE, Gausche-Hill M, Lewis RJ. The Pediatric Assessment Triangle: accuracy of its application by nurses in the triage of children. J Emerg Nurs 2013;39:182−9, doi:http://dx.doi.org/10.1016/j.jen.2011.12.020.

51. Gausche-Hill M, Eckstein M, Horeczko T, et al. Paramedics accurately apply the pediatric assessment triangle to drive management. Prehosp Emerg Care 2014;18:520−30, doi:http://dx.doi.org/10.3109/10903127.2014.912706.

52. Fernandez A, Ares MI, Garcia S, Martinez-Indart L, Mintegi S, Benito J. The validity of the pediatric assessment triangle as the first step in the triage process in a pediatric emergency department. Pediatr Emerg Care 2017;33:234−8, doi:http://dx.doi.org/10.1097/PEC.0000000000000717.

53. Fleming S, Thompson M, Stevens R, et al. Normal ranges of heart rate and respiratory rate in children from birth to 18 years of age: a systematic review of observational studies. Lancet 2011;377:1011−8, doi:http://dx.doi.org/10.1016/S0140-6736(10)62226-X.

54. O'Leary F, Hayen A, Lockie F, Peat J. Defining normal ranges and centiles for heart and respiratory rates in infants and children: a cross-sectional study of patients attending an Australian tertiary hospital paediatric emergency department. Arch Dis Child 2015;100:733−7, doi:http://dx.doi.org/10.1136/archdischild-2014- 307401.

55. Sepanski RJ, Godambe SA, Zaritsky AL. Pediatric vital sign distribution derived from a multi-centered emergency department database. Front Pediatr 2018;6:66, doi:http://dx.doi.org/10.3389/fped.2018.00066.

56. Nijman RG, Thompson M, van Veen M, Perera R, Moll HA, Oostenbrink R. Derivation and validation of age and temperature specific reference values and centile charts to predict lower respiratory tract infection in children with fever: prospective observational study. BMJ 2012;345:e4224, doi:http://dx.doi.org/10.1136/bmj.e4224.

57. Hagedoorn NN, Zachariasse JM, Moll HA. A comparison of clinical paediatric guidelines for hypotension with population-based lower centiles: a systematic review. Crit Care 2019;23:380, doi:http://dx.doi.org/10.1186/s13054-019-2653-9.

58. Haque IU, Zaritsky AL. Analysis of the evidence for the lower limit of systolic and mean arterial pressure in children. Pediatr Crit Care Med 2007;8:138−44, doi:http://dx.doi.org/10.1097/01.PCC.00002 57039.32593.DC [in Eng].

59. Eytan D, Goodwin AJ, Greer R, Guerguerian AM, Laussen PC. Heart rate and blood pressure centile curves and distributions by age of hospitalized critically ill children. Front Pediatr 2017;5:52, doi:http://dx.doi.org/10.3389/fped.2017.00052.

60. Jackson LV, Thalange NK, Cole TJ. Blood pressure centiles for Great Britain. Arch Dis Child 2007;92:298−303, doi:http://dx.doi.org/10.1136/adc.2005.081216.

61. Xi B, Zong X, Kelishadi R, et al. Establishing international blood pressure references among nonoverweight children and adolescents aged 6 to 17 years. Circulation 2016;133:398−408, doi:http://dx.doi.org/10.1161/CIRCULATIONAHA.115.017936.

62. Duke T, Blaschke AJ, Sialis S, Bonkowsky JL. Hypoxaemia in acute respiratory and non-respiratory illnesses in neonates and children in a developing country. Arch Dis Child 2002;86:108−12, doi:http://dx.doi.org/10.1136/adc.86.2.108.

63. Salyer JW. Neonatal and pediatric pulse oximetry. Respir Care 2003;48:386−96 [discussion 397−8]. (https://www.ncbi.nlm.nih.gov/pubmed/12667266).

64. Tobin MJ, Laghi F, Jubran A. Why COVID-19 silent hypoxemia is baffling to physicians. Am J Respir Crit Care Med 2020;202:356–60, doi:http://dx.doi.org/10.1164/rccm.202006- 2157CP.

65. Weber MW, Usen S, Palmer A, Jaffar S, Mulholland EK. Predictors of hypoxaemia in hospital admissions with acute lower respiratory tract infection in a developing country. Arch Dis Child 1997;76:310–4, doi: http://dx.doi.org/10.1136/adc.76.4.310.

66. Aubertin G, Marguet C, Delacourt C, et al. Recommendations for pediatric oxygen therapy in acute and chronic settings: needs assessment, implementation criteria, prescription practices and follow-up. Arch Pediatr 2012;19:528–36, doi:http://dx.doi.org/ 10.1016/j.arcped.2012.02.016.

67. Carruthers DM, Harrison BD. Arterial blood gas analysis or oxygen saturation in the assessment of acute asthma? Thorax 1995;50:186 –8, doi:http://dx.doi.org/10.1136/thx.50.2.186.

68. Kobayashi M, Fukuda S, Takano KI, Kamizono J, Ichikawa K. Can a pulse oxygen saturation of 95% to 96% help predict further vital sign destabilization in school-aged children? A retrospective observational study. Medicine (Baltimore) 2018;97:e11135, doi: http://dx.doi.org/10.1097/MD.0000000000011135.

69. Shah SN, Bachur RG, Simel DL, Neuman MI. Does this child have pneumonia? The rational clinical examination systematic review. JAMA 2017;318:462–71, doi:http://dx.doi.org/10.1001/ jama.2017.9039.

70. Ozdemir A, Dogruel D, Yilmaz O. Oxygen saturation/minute heart rate index: simple lung function test for children. Pediatr Int 2017;59:209–12, doi:http://dx.doi.org/10.1111/ped.13081.

71. Crocker ME, Hossen S, Goodman D, et al. Effects of high altitude on respiratory rate and oxygen saturation reference values in healthy infants and children younger than 2 years in four countries: a cross-sectional study. Lancet Glob Health 2020;8:e362–73, doi:http://dx. doi.org/10.1016/S2214-109X(19)30543-1.

72. Abramo TJ, Wiebe RA, Scott S, Goto CS, McIntire DD. Noninvasive capnometry monitoring for respiratory status during pediatric seizures. Crit Care Med 1997;25:1242–6, doi:http://dx.doi.org/ 10.1097/00003246- 199707000-00029.

73. Langhan ML, Shabanova V, Li FY, Bernstein SL, Shapiro ED. A randomized controlled trial of capnography during sedation in a pediatric emergency setting. Am J Emerg Med 2015;33:25–30, doi: http://dx.doi.org/10.1016/j.ajem.2014.09.050.

74. Moses JM, Alexander JL, Agus MS. The correlation and level of agreement between end-tidal and blood gas pCO2 in children with respiratory distress: a retrospective analysis. BMC Pediatr 2009;9:20, doi:http://dx.doi.org/10.1186/1471-2431-9-20.

75. Abramo TJ, Wiebe RA, Scott SM, Primm PA, McIntyre D, Mydler T. Noninvasive capnometry in a pediatric population with respiratory emergencies. Pediatr Emerg Care 1996;12:252–4, doi:http://dx.doi. org/10.1097/00006565- 199608000-00004.

76. Langhan ML, Emerson BL, Nett S, et al. End-tidal carbon dioxide use for tracheal intubation: analysis from the national emergency airway registry for children (NEAR4KIDS) registry. Pediatr Crit Care Med 2018;19:98–105, doi:http://dx.doi.org/10.1097/ PCC.0000000000001372.

77. Phillips JS, Pangilinan LP, Mangalindan ER, Booze JL, Kallet RH. A comparison of different techniques for interfacing capnography with adult and pediatric supplemental oxygen masks. Respir Care 2017;62:78–85, doi:http://dx.doi.org/10.4187/respcare.05111.

78. Saunders R, Struys M, Pollock RF, Mestek M, Lightdale JR. Patient safety during procedural sedation using capnography monitoring: a systematic review and meta- analysis. BMJ Open 2017;7:e013402, doi:http://dx.doi.org/10.1136/bmjopen-2016 -013402.

79. Langhan ML, Chen L, Marshall C, Santucci KA. Detection of hypoventilation by capnography and its association with hypoxia in children undergoing sedation with ketamine. Pediatr Emerg Care 2011;27:394–7, doi:http://dx.doi.org/10.1097/ PEC.0b013e318217b538.

80. Yang JT, Erickson SL, Killien EY, Mills B, Lele AV, Vavilala MS. Agreement between arterial carbon dioxide levels with end-tidal carbon dioxide levels and associated factors in children

hospitalized with traumatic brain injury. JAMA Netw Open 2019;2: e199448, doi:http://dx.doi.org/10.1001/ jamanetworkopen.2019.9448.

81. Scott HF, Brou L, Deakyne SJ, Kempe A, Fairclough DL, Bajaj L. Association between early lactate levels and 30-day mortality in clinically suspected sepsis in children. JAMA Pediatr 2017;171:249–55, doi:http://dx.doi.org/10.1001/ jamapediatrics.2016.3681.

82. Scott HF, Donoghue AJ, Gaieski DF, Marchese RF, Mistry RD. The utility of early lactate testing in undifferentiated pediatric systemic inflammatory response syndrome. Acad Emerg Med 2012;19:1276 –80, doi:http://dx.doi.org/10.1111/acem.12014.

83. Miescier MJ, Lane RD, Sheng X, Larsen GY. Association between initial emergency department lactate and use of vasoactive medication in children with septic shock. Pediatr Emerg Care 2019;35:455–60, doi:http://dx.doi.org/10.1097/ PEC.0000000000000981.

84. Yan HP, Lu XL, Qiu J, Liu PP, Zuo C, Zhu YM. Value of blood lactic acid in evaluating disease severity and prognosis in children with sepsis. Zhongguo Dang Dai Er Ke Za Zhi 2016;18:506–10 (https:// www.ncbi.nlm.nih.gov/pubmed/27324538).

85. Scott HF, Brou L, Deakyne SJ, Fairclough DL, Kempe A, Bajaj L. Lactate clearance and normalization and prolonged organ dysfunction in pediatric sepsis. J Pediatr 2016170:, doi:http://dx.doi. org/10.1016/j.jpeds.2015.11.071 149–55 e1–4.

86. Britton PN, Eastwood K, Paterson B, et al. Consensus guidelines for the investigation and management of encephalitis in adults and children in Australia and New Zealand. Intern Med J 2015;45:563 –76, doi:http://dx.doi.org/10.1111/imj.12749.

87. Kneen R, Michael BD, Menson E, et al. Management of suspected viral encephalitis in children – Association of British Neurologists and British Paediatric Allergy, Immunology and Infection Group national guidelines. J Infect 2012;64:449–77, doi:http://dx.doi.org/10.1016/j. jinf.2011.11.013.

88. Thompson M, Van den Bruel A, Verbakel J, et al. Systematic review and validation of prediction rules for identifying children with serious infections in emergency departments and urgent-access primary care. Health Technol Assess 2012;16:1–100, doi:http://dx.doi.org/ 10.3310/hta16150.

89. Da Dalt L, Parri N, Amigoni A, et al. Italian guidelines on the assessment and management of pediatric head injury in the emergency department. Ital J Pediatr 2018;44:7, doi:http://dx.doi. org/10.1186/s13052-017- 0442-0.

90. Medley TL, Miteff C, Andrews I, et al. Australian Clinical Consensus Guideline: the diagnosis and acute management of childhood stroke. Int J Stroke 2019;14:94–106, doi:http://dx.doi.org/10.1177/ 1747493018799958.

91. Chou R, Totten AM, Carney N, et al. Predictive utility of the total glasgow coma scale versus the motor component of the glasgow coma scale for identification of patients with serious traumatic injuries. Ann Emerg Med 201770:, doi:http://dx.doi.org/10.1016/j. annemergmed.2016.11.032 143–157 e6.

92. Nuttall AG, Paton KM, Kemp AM. To what extent are GCS and AVPU equivalent to each other when assessing the level of consciousness of children with head injury? A cross-sectional study of UK hospital admissions. BMJ Open 2018;8:e023216, doi:http://dx.doi.org/ 10.1136/bmjopen-2018-023216.

93. Hoffmann F, Schmalhofer M, Lehner M, Zimatschek S, Grote V, Reiter K. Comparison of the AVPU scale and the pediatric GCS in prehospital setting. Prehosp Emerg Care 2016;20:493–8, doi:http:// dx.doi.org/10.3109/10903127.2016.1139216.

94. Van de Voorde P, Sabbe M, Rizopoulos D, et al. Assessing the level of consciousness in children: a plea for the Glasgow Coma Motor subscore. Resuscitation 2008;76:175–9, doi:http://dx.doi.org/ 10.1016/j.resuscitation.2007.07.007.

95. Borgialli DA, Mahajan P, Hoyle Jr. JD, et al. Performance of the pediatric glasgow coma scale score in the evaluation of children with blunt head trauma. Acad Emerg Med 2016;23:878–84, doi:http://dx. doi.org/10.1111/acem.13014.

96. DiBrito SR, Cerullo M, Goldstein SD, Ziegfeld S, Stewart D, Nasr IW. Reliability of Glasgow Coma Score in pediatric trauma patients. J Pediatr Surg 2018;53:1789−94, doi:http://dx.doi.org/10.1016/j.jpedsurg.2017.12.027.

97. Ladner TR, Mahdi J, Gindville MC, et al. Pediatric acute stroke protocol activation in a children's hospital emergency department. Stroke 2015;46:2328−31, doi:http://dx.doi.org/10.1161/STROKEAHA.115.009961.

98. DeLaroche AM, Sivaswamy L, Farooqi A, Kannikeswaran N. Pediatric stroke clinical pathway improves the time to diagnosis in an emergency department. Pediatr Neurol 2016;65:39−44, doi:http://dx.doi.org/10.1016/j.pediatrneurol.2016.09.005.

99. Yock-Corrales A, Mackay MT, Mosley I, Maixner W, Babl FE. Acute childhood arterial ischemic and hemorrhagic stroke in the emergency department. Ann Emerg Med 2011;58:156−63, doi:http://dx.doi.org/10.1016/j.annemergmed.2010.10.013.

100. Gumer LB, Del Vecchio M, Aronoff S. Strokes in children: a systematic review. Pediatr Emerg Care 2014;30:660−4, doi:http://dx.doi.org/10.1097/PEC.0000000000000218.

101. Mackay MT, Monagle P, Babl FE. Brain attacks and stroke in children. J Paediatr Child Health 2016;52:158−63, doi:http://dx.doi.org/10.1111/jpc.13086.

102. Guedj R, Chappuy H, Titomanlio L, et al. Risk of bacterial meningitis in children 6 to 11 months of age with a first simple febrile seizure: a retrospective, cross-sectional, observational study. Acad Emerg Med 2015;22:1290−7, doi:http://dx.doi.org/10.1111/acem.12798.

103. Najaf-Zadeh A, Dubos F, Hue V, Pruvost I, Bennour A, Martinot A. Risk of bacterial meningitis in young children with a first seizure in the context of fever: a systematic review and meta-analysis. PLOS ONE 2013;8:e55270, doi:http://dx.doi.org/10.1371/journal.pone.0055270.

104. Joffe AR, Anton NR, Burkholder SC. Reduction in hospital mortality over time in a hospital without a pediatric medical emergency team: limitations of before-and-after study designs. Arch Pediatr Adolesc Med 2011;165:419−23, doi:http://dx.doi.org/10.1001/archpediatrics.2011.47.

105. Thomas-Jones E, Lloyd A, Roland D, et al. A prospective, mixed-methods, before and after study to identify the evidence base for the core components of an effective Paediatric Early Warning System and the development of an implementation package containing those core recommendations for use in the UK: Paediatric early warning system − utilisation and mortality avoidance- the PUMA study protocol. BMC Pediatr 2018;18:244, doi:http://dx.doi.org/10.1186/s12887-018-1210- z.

106. Bortcosh W, Shaahinfar A, Sojar S, Klig JE. New directions in point-of-care ultrasound at the crossroads of paediatric emergency and critical care. Curr Opin Pediatr 2018;30:350−8, doi:http://dx.doi.org/10.1097/MOP.0000000000000621.

107. Singh Y, Tissot C, Fraga MV, et al. International evidence-based guidelines on Point of Care Ultrasound (POCUS) for critically ill neonates and children issued by the POCUS Working Group of the European Society of Paediatric and Neonatal Intensive Care (ESPNIC). Crit Care 2020;24:65, doi:http://dx.doi.org/10.1186/s13054-020-2787-9.

108. Marin JR, Abo AM, Arroyo AC, et al. Pediatric emergency medicine point-of-care ultrasound: summary of the evidence. Crit Ultrasound J 2016;8:16, doi:http://dx.doi.org/10.1186/s13089-016-0049- 5.

109. Balk DS, Lee C, Schafer J, et al. Lung ultrasound compared to chest X-ray for diagnosis of pediatric pneumonia: a meta-analysis. Pediatr Pulmonol 2018;53:1130−9, doi:http://dx.doi.org/10.1002/ppul.24020.

110. Orso D, Ban A, Guglielmo N. Lung ultrasound in diagnosing pneumonia in childhood: a systematic review and meta-analysis. J Ultrasound 2018;21:183−95, doi:http://dx.doi.org/10.1007/s40477-018-0306- 5.

111. Potter SK, Griksaitis MJ. The role of point- of-care ultrasound in pediatric acute respiratory distress syndrome: emerging evidence for its use. Ann Transl Med 2019;7:507, doi:http://dx.doi.org/10.21037/atm.2019.07.76.

112. Ozkaya AK, Baskan Vuralkan F, Ardic S. Point-of-care lung ultrasound in children with non-cardiac respiratory distress or tachypnea. Am J Emerg Med 2019;37:2102−6, doi:http://dx.doi.org/10.1016/j.ajem.2019.05.063.

113. Lissaman C, Kanjanauptom P, Ong C, Tessaro M, Long E, O'Brien A. Prospective observational study of point-of-care ultrasound for diagnosing pneumonia. Arch Dis Child 2019;104:12−8, doi:http://dx.doi.org/10.1136/archdischild-2017-314496.

114. Harel-Sterling M, Diallo M, Santhirakumaran S, Maxim T, Tessaro M. Emergency department resource use in pediatric pneumonia: point-of-care lung ultrasonography versus chest radiography. J Ultrasound Med 2019;38:407−14, doi:http://dx.doi.org/10.1002/jum.14703.

115. Jones BP, Tay ET, Elikashvili I, et al. Feasibility and safety of substituting lung ultrasonography for chest radiography when diagnosing pneumonia in children: a randomized controlled trial. Chest 2016;150:131−8, doi:http://dx.doi.org/10.1016/j.chest.2016.02.643.

116. Berce V, Tomazin M, Gorenjak M, Berce T, Lovrencic B. The usefulness of lung ultrasound for the aetiological diagnosis of community-acquired pneumonia in children. Sci Rep 2019;9:17957, doi:http://dx.doi.org/10.1038/s41598-019-54499-y.

117. Lovrenski J, Petrovic S, Balj-Barbir S, Jokic R, Vilotijevic- Dautovic G. Stethoscope vs. ultrasound probe − which is more reliable in children with suspected pneumonia? Acta Med Acad 2016;45:39−50, doi:http://dx.doi.org/10.5644/ama2006-124.155.

118. Gravel CA, Monuteaux MC, Levy JA, Miller AF, Vieira RL, Bachur RG. Interrater reliability of pediatric point-of-care lung ultrasound findings. Am J Emerg Med 2020;38:1−6, doi:http://dx.doi.org/10.1016/j.ajem.2019.01.047.

119. Lin MJ, Gurley K, Hoffmann B. Bedside ultrasound for tracheal tube verification in pediatric emergency department and ICU patients: a systematic review. Pediatr Crit Care Med 2016;17:e469−76, doi:http://dx.doi.org/10.1097/PCC.0000000000000907.

120. Mori T, Nomura O, Hagiwara Y, Inoue N. Diagnostic accuracy of a 3-point ultrasound protocol to detect esophageal or endobronchial mainstem intubation in a pediatric emergency department. J Ultrasound Med 2019;38:2945−54, doi:http://dx.doi.org/10.1002/jum.15000.

121. Klugman D, Berger JT. Echocardiography and focused cardiac ultrasound. Pediatr Crit Care Med 2016;17:S222−4, doi:http://dx.doi.org/10.1097/PCC.0000000000000815.

122. Long E, Oakley E, Duke T, Babl FE, Paediatric Research in Emergency Departments International C. Does respiratory variation in inferior vena cava diameter predict fluid responsiveness: a systematic review and meta-analysis. Shock 2017;47:550−9, doi:http://dx.doi.org/10.1097/SHK.0000000000000801.

123. Orso D, Paoli I, Piani T, Cilenti FL, Cristiani L, Guglielmo N. Accuracy of ultrasonographic measurements of inferior vena cava to determine fluid responsiveness: a systematic review and meta-analysis. J Intensive Care Med 2020;35:354−63, doi:http://dx.doi.org/10.1177/0885066617752308.

124. Long E, O'Brien A, Duke T, Oakley E, Babl FE, Pediatric Research in Emergency Departments International C. Effect of fluid bolus therapy on extravascular lung water measured by lung ultrasound in children with a presumptive clinical diagnosis of sepsis. J Ultrasound Med 2019;38:1537−44, doi:http://dx.doi.org/10.1002/jum.14842.

125. Ricci F, Aquilani R, Radico F, et al. Role and importance of ultrasound lung comets in acute cardiac care. Eur Heart J Acute Cardiovasc Care 2015;4:103−12, doi:http://dx.doi.org/10.1177/2048872614553166.

126. Holmes JF, Gladman A, Chang CH. Performance of abdominal ultrasonography in pediatric blunt trauma patients: a meta-analysis. J Pediatr Surg 2007;42:1588−94, doi:http://dx.doi.org/10.1016/j.jpedsurg.2007.04.023.

127. Holmes JF, Kelley KM, Wootton-Gorges SL, et al. Effect of abdominal ultrasound on clinical care, outcomes, and resource use among children with blunt torso trauma: a randomized clinical trial. JAMA 2017;317:2290−6, doi:http://dx.doi.org/10.1001/jama.2017.6322.

128. Schoneberg C, Tampier S, Hussmann B, Lendemans S, Waydhas C. Diagnostic management in paediatric blunt abdominal trauma – a systematic review with metaanalysis. Zentralbl Chir 2014;139:584–91, doi:http://dx.doi.org/10.1055/s-0032-1328645.

129. Greif R, Bhanji F, Bigham BL, et al. Education, implementation, and teams: 2020 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Resuscitation 2020;156:A188–239, doi:http://dx.doi.org/10.1016/j.resuscitation.2020.09.014.

130. Weinstock P, Halamek LP. Teamwork during resuscitation. Pediatr Clin North Am 2008;55:1011–24, doi:http://dx.doi.org/10.1016/j.pcl.2008.04.001 xi–xii.

131. Cheng A, Duff JP, Kessler D, et al. Optimizing CPR performance with CPR coaching for pediatric cardiac arrest: a randomized simulation-based clinical trial. Resuscitation 2018;132:33–40, doi:http://dx.doi.org/10.1016/j.resuscitation.2018.08.021.

132. Sherman JM, Chang TP, Ziv N, Nager AL. Barriers to effective teamwork relating to pediatric resuscitations: perceptions of pediatric emergency medicine staff. Pediatr Emerg Care 2020;36:e146–50, doi:http://dx.doi.org/10.1097/PEC.0000000000001275.

133. Coolen E, Draaisma J, Loeffen J. Measuring situation awareness and team effectiveness in pediatric acute care by using the situation global assessment technique. Eur J Pediatr 2019;178:837–50, doi:http://dx.doi.org/10.1007/s00431-019-03358-z.

134. Lammers RL, Willoughby- Byrwa M, Fales WD. Errors and error-producing conditions during a simulated, prehospital, pediatric cardiopulmonary arrest. Simul Healthc 2014;9:174–83, doi:http://dx.doi.org/10.1097/SIH.0000000000000013.

135. Taylor KL, Ferri S, Yavorska T, Everett T, Parshuram C. A description of communication patterns during CPR in ICU. Resuscitation 2014;85:1342–7, doi:http://dx.doi.org/10.1016/j.resuscitation.2014.06.027.

136. Grimsley EA, Cochrane NH, Keane RR, Sumner BD, Mullan PC, O'Connell KJ. A pulse check on leadership and teamwork: an evaluation of the first 5 minutes of emergency department resuscitation during pediatric cardiopulmonary arrests. Pediatr Emerg Care 2019, doi:http://dx.doi.org/10.1097/PEC.0000000000001923.

137. AlSohime F, NurHussen A, Temsah MH, et al. Factors that influence the self-reported confidence of pediatric residents as team leaders during cardiopulmonary resuscitation: a national survey. Int J Pediatr Adolesc Med 2018;5:116–21, doi:http://dx.doi.org/10.1016/j.ijpam.2018.07.001.

138. Delaloye NJ, Tobler K, O'Neill T, et al. Errors during resuscitation: the impact of perceived authority on delivery of care. J Patient Saf 2020;16:73–8, doi:http://dx.doi.org/10.1097/PTS.0000000000000359.

139. Fernandez Castelao E, Russo SG, Riethmuller M, Boos M. Effects of team coordination during cardiopulmonary resuscitation: a systematic review of the literature. J Crit Care 2013;28:504–21, doi:http://dx.doi.org/10.1016/j.jcrc.2013.01.005.

140. Riskin A, Bamberger P, Erez A, et al. Expressions of gratitude and medical team performance. Pediatrics 2019143:, doi:http://dx.doi.org/10.1542/peds.2018-2043.

141. Krage R, Zwaan L, Tjon Soei Len L, et al. Relationship between non-technical skills and technical performance during cardiopulmonary resuscitation: does stress have an influence? Emerg Med 2017;34:728–33, doi:http://dx.doi.org/10.1136/emermed-2016-205754.

142. Johnson SL, Haerling KA, Yuwen W, Huynh V, Le C. Incivility and clinical performance, teamwork, and emotions: a randomized controlled trial. J Nurs Care Qual 2020;35:70–6, doi:http://dx.doi.org/10.1097/NCQ.0000000000000407.

143. Maconochie IK, Aickin R, Hazinski MF, et al. Pediatric life support: 2020 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Resuscitation 2020;156:A120–55, doi:http://dx.doi.org/10.1016/j.resuscitation.2020.09.013.

144. Wells M, Goldstein LN, Bentley A, Basnett S, Monteith I. The accuracy of the Broselow tape as a weight estimation tool and a drug-dosing guide – a systematic review and meta-analysis. Resuscitation 2017;121:9–33, doi:http://dx.doi.org/10.1016/j.resuscitation.2017.09.026.

145. Wells M, Goldstein LN, Bentley A. The accuracy of emergency weight estimation systems in children – a systematic review and meta-analysis. Int J Emerg Med 2017;10:29, doi:http://dx.doi.org/10.1186/s12245-017-0156- 5.

146. Young KD, Korotzer NC. Weight estimation methods in children: a systematic review. Ann Emerg Med 201668:, doi:http://dx.doi.org/10.1016/j.annemergmed.2016.02.043 441–451 e10.

147. Matson KL, Horton ER, Capino AC. Advocacy committee for the pediatric pharmacy advocacy g. medication dosage in overweight and obese children. J Pediatr Pharmacol Ther 2017;22:81–3, doi:http://dx.doi.org/10.5863/1551-6776-22.1.81.

148. Rodriguez JJ, Higuita- Gutierrez LF, Carrillo Garcia EA, Castano Betancur E, Luna Londono M, Restrepo Vargas S. Meta-analysis of failure of prehospital endotracheal intubation in pediatric patients. Emerg Med Int 2020;2020:7012508, doi:http://dx.doi.org/10.1155/2020/7012508.

149. Harshman J, Roy M, Cartotto R. Emergency care of the burn patient before the burn center: a systematic review and meta-analysis. J Burn Care Res 2019;40:166–88, doi:http://dx.doi.org/10.1093/jbcr/iry060.

150. Garner AA, Bennett N, Weatherall A, Lee A. Success and complications by team composition for prehospital paediatric intubation: a systematic review and meta-analysis. Crit Care 2020;24:149, doi:http://dx.doi.org/10.1186/s13054-020-02865-y.

151. Miller KA, Nagler J. Advances in emergent airway management in pediatrics. Emerg Med Clin North Am 2019;37:473–91, doi:http://dx.doi.org/10.1016/j.emc.2019.03.006.

152. Stein ML, Park RS, Kovatsis PG. Emerging trends, techniques, and equipment for airway management in pediatric patients. Paediatr Anaesth 2020;30:269–79, doi:http://dx.doi.org/10.1111/pan.13814.

153. Sun F, Wang Y, Ma S, et al. Clinical consensus of emergency airway management. J Thorac Dis 2017;9:4599–606, doi:http://dx.doi.org/10.21037/jtd.2017.10.79.

154. Engelhardt T, Fiadjoe JE, Weiss M, et al. A framework for the management of the pediatric airway. Paediatr Anaesth 2019;29:985–92, doi:http://dx.doi.org/10.1111/pan.13716.

155. Scott A, Chua O, Mitchell W, Vlok R, Melhuish T, White L. Apneic oxygenation for pediatric endotracheal intubation: a narrative review. J Pediatr Intensive Care 2019;8:117–21, doi:http://dx.doi.org/10.1055/s-0039- 1678552.

156. Youngquist S, Gausche- Hill M, Burbulys D. Alternative airway devices for use in children requiring prehospital airway management: update and case discussion. Pediatr Emerg Care 2007;23:250–8, doi:http://dx.doi.org/10.1097/PEC.0b013e31803f7552 quiz 259–61.

157. Else SDN, Kovatsis PG. A narrative review of oxygenation during pediatric intubation and airway procedures. Anesth Analg 2020;130:831–40, doi:http://dx.doi.org/10.1213/ANE.0000000000004403.

158. Long E, Barrett MJ, Peters C, Sabato S, Lockie F. Emergency intubation of children outside of the operating room. Paediatr Anaesth 2020;30:319–30, doi:http://dx.doi.org/10.1111/pan.13784.

159. Fiadjoe J, Nishisaki A. Normal and difficult airways in children: "What's New" – current evidence. Paediatr Anaesth 2020;30:257–63, doi:http://dx.doi.org/10.1111/pan.13798.

160. Schreiber S, Ronfani L, Ghirardo S, et al. Nasal irrigation with saline solution significantly improves oxygen saturation in infants with bronchiolitis. Acta Paediatr 2016;105:292–6, doi:http://dx.doi.org/10.1111/apa.13282.

161. Sun J, Li XH, Zuo YX. Comparison of Incidence of hypoxia during modified rapid sequence induction and an alternative technique: a prospective randomized controlled trial. Int J Clin Exp Med 2015;8:16231–7 (https://www.ncbi.nlm.nih.gov/pubmed/26629138).

162. Heschl S, Meadley B, Andrew E, Butt W, Bernard S, Smith K. Efficacy of pre-hospital rapid sequence intubation in paediatric traumatic brain injury: a 9-year observational study. Injury 2018;49:916−20, doi: http://dx.doi.org/10.1016/j.injury.2018.02.013.

163. Lawrason Hughes A, Murray N, Valdez TA, Kelly R, Kavanagh K. Development of the Connecticut Airway Risk Evaluation (CARE) system to improve handoff communication in pediatric patients with tracheotomy. JAMA Otolaryngol Head Neck Surg 2014;140:29−33, doi:http://dx.doi.org/10.1001/jamaoto.2013.5550.

164. Matettore A, Ramnarayan P, Jones A, et al. Adverse tracheal intubation- associated events in pediatric patients at nonspecialist centers: a multicenter prospective observational study. Pediatr Crit Care Med 2019;20:518−26, doi:http://dx.doi.org/10.1097/PCC.0000000000001923.

165. Hernandez MC, Antiel RM, Balakrishnan K, Zielinski MD, Klinkner DB. Definitive airway management after prehospital supraglottic rescue airway in pediatric trauma. J Pediatr Surg 2018;53:352−6, doi:http://dx.doi.org/10.1016/j.jpedsurg.2017.10.004.

166. Simons T, Soderlund T, Handolin L. Radiological evaluation of tube depth and complications of prehospital endotracheal intubation in pediatric trauma: a descriptive study. Eur J Trauma Emerg Surg 2017;43:797−804, doi:http://dx.doi.org/10.1007/s00068-016-0758-2.

167. Hansen M, Meckler G, Lambert W, et al. Patient safety events in out-of-hospital paediatric airway management: a medical record review by the CSI-EMS. BMJ Open 2016;6:e012259, doi:http://dx.doi.org/10.1136/bmjopen-2016-012259.

168. Goto T, Gibo K, Hagiwara Y, et al. Factors associated with first-pass success in pediatric intubation in the emergency department. West J Emerg Med 2016;17:129−34, doi:http://dx.doi.org/10.5811/westjem.2016.1.28685.

169. Mortimer T, Burzynski J, Kesselman M, Vallance J, Hansen G. Apneic oxygenation during rapid sequence intubation in critically ill children. J Pediatr Intensive Care 2016;5:28−31, doi:http://dx.doi.org/10.1055/s-0035-1568149.

170. Fiadjoe JE, Nishisaki A, Jagannathan N, et al. Airway management complications in children with difficult tracheal intubation from the Pediatric Difficult Intubation (PeDI) registry: a prospective cohort analysis. Lancet Respir Med 2016;4:37−48, doi:http://dx.doi.org/10.1016/S2213-2600(15)00508-1.

171. Li S, Rehder KJ, Giuliano Jr. JS, et al. Development of a quality improvement bundle to reduce tracheal intubation-associated events in pediatric ICUs. Am J Med Qual 2016;31:47−55, doi:http://dx.doi.org/10.1177/1062860614547259.

172. Johnson M, Miskovic A, Ray S, et al. The nasopharyngeal airway: estimation of the nares-to-mandible and nares-to-tragus distance in young children to assess current clinical practice. Resuscitation 2019;140:50−4, doi:http://dx.doi.org/10.1016/j.resuscitation.2019.04.039.

173. Garcia-Marcinkiewicz AG, Adams HD, Gurnaney H, et al. A retrospective analysis of neuromuscular blocking drug use and ventilation technique on complications in the pediatric difficult intubation registry using propensity score matching. Anesth Analg 2020;131:469−79, doi:http://dx.doi.org/10.1213/ANE.0000000000004393.

174. Ramgopal S, Button SE, Owusu-Ansah S, et al. Success of pediatric intubations performed by a critical care transport service. Prehosp Emerg Care 2020;24:683−92, doi:http://dx.doi.org/10.1080/10903127.2019.1699212.

175. Hansen M, Lambert W, Guise JM, Warden CR, Mann NC, Wang H. Out-of-hospital pediatric airway management in the United States. Resuscitation 2015;90:104−10, doi:http://dx.doi.org/10.1016/j.resuscitation.2015.02.018.

176. Conway JA, Kharayat P, Sanders Jr. RC, et al. Ketamine use for tracheal intubation in critically ill children is associated with a lower occurrence of adverse hemodynamic events. Crit Care Med 2020;48:e489−97, doi:http://dx.doi.org/10.1097/CCM.0000000000004314.

177. Galvez JA, Acquah S, Ahumada L, et al. Hypoxemia, bradycardia, and multiple laryngoscopy attempts during anesthetic induction in

infants: a single-center, retrospective study. Anesthesiology 2019;131:830−9, doi:http://dx.doi.org/10.1097/ALN.0000000000002847.

178. Overmann KM, Boyd SD, Zhang Y, Kerrey BT. Apneic oxygenation to prevent oxyhemoglobin desaturation during rapid sequence intubation in a pediatric emergency department. Am J Emerg Med 2019;37:1416−21, doi:http://dx.doi.org/10.1016/j.ajem.2018.10.030.

179. Crulli B, Loron G, Nishisaki A, Harrington K, Essouri S, Emeriaud G. Safety of paediatric tracheal intubation after non-invasive ventilation failure. Pediatr Pulmonol 2016;51:165−72, doi:http://dx.doi.org/10.1002/ppul.23223.

180. Neubrand TL, Alletag M, Woods J, Mendenhall M, Leonard J, Schmidt SK. Breathing easier: decreasing tracheal intubation-associated adverse events in the pediatric ED and urgent care. Pediatr Qual Saf 2019;4:e230, doi:http://dx.doi.org/10.1097/pq9.0000000000000230.

181. Mokhateb-Rafii T, Bakar A, Gangadharan S, et al. Hemodynamic impact of oxygen desaturation during tracheal intubation among critically ill children with cyanotic and noncyanotic heart disease. Pediatr Crit Care Med 2019;20:19−26, doi:http://dx.doi.org/10.1097/PCC.0000000000001766.

182. Parker MM, Nuthall G, Brown 3rd C, et al. Relationship between adverse tracheal intubation associated events and PICU outcomes. Pediatr Crit Care Med 2017;18:310−8, doi:http://dx.doi.org/10.1097/PCC.0000000000001074.

183. van Sambeeck SJ, van Kuijk SMJ, Kramer BW, Vermeulen PM, Vos GD. Endotracheal intubation skills of pediatricians versus anesthetists in neonates and children. Eur J Pediatr 2019;178:1219−27, doi:http://dx.doi.org/10.1007/s00431-019-03395-8.

184. Li S, Hsieh TC, Rehder KJ, et al. Frequency of desaturation and association with hemodynamic adverse events during tracheal intubations in PICUs. Pediatr Crit Care Med 2018;19:e41−50, doi: http://dx.doi.org/10.1097/PCC.0000000000001384.

185. Daigle CH, Fiadjoe JE, Laverriere EK, et al. Difficult bag-mask ventilation in critically ill children is independently associated with adverse events. Crit Care Med 2020;48:e744−52, doi:http://dx.doi.org/10.1097/CCM.0000000000004425.

186. Emami P, Czorlich P, Fritzsche FS, et al. Observed versus expected mortality in pediatric patients intubated in the field with Glasgow Coma Scale scores <9. Eur J Trauma Emerg Surg 2019;45:769−76, doi:http://dx.doi.org/10.1007/s00068-018-01065- 2.

187. Vukovic AA, Hanson HR, Murphy SL, Mercurio D, Sheedy CA, Arnold DH. Apneic oxygenation reduces hypoxemia during endotracheal intubation in the pediatric emergency department. Am J Emerg Med 2019;37:27−32, doi:http://dx.doi.org/10.1016/j.ajem.2018.04.039.

188. Lee JH, Nuthall G, Ikeyama T, et al. Tracheal intubation practice and safety across international PICUs: a report from national emergency airway registry for children. Pediatr Crit Care Med 2019;20:1−8, doi: http://dx.doi.org/10.1097/PCC.0000000000001782.

189. Algie CM, Mahar RK, Tan HB, Wilson G, Mahar PD, Wasiak J. Effectiveness and risks of cricoid pressure during rapid sequence induction for endotracheal intubation. Cochrane Database Syst Rev 2015;CD011656, doi:http://dx.doi.org/10.1002/14651858.CD011656.pub2.

190. Kojima T, Harwayne- Gidansky I, Shenoi AN, et al. Cricoid pressure during induction for tracheal intubation in critically ill children: a report from national emergency airway registry for children. Pediatr Crit Care Med 2018;19:528−37, doi:http://dx.doi.org/10.1097/PCC.0000000000001531.

191. Kojima T, Laverriere EK, Owen EB, et al. Clinical impact of external laryngeal manipulation during laryngoscopy on tracheal intubation success in critically ill children. Pediatr Crit Care Med 2018;19:106−14, doi:http://dx.doi.org/10.1097/PCC.0000000000001373.

Sun Y, Lu Y, Huang Y, Jiang H. Pediatric video laryngoscope versus direct laryngoscope: a meta- analysis of randomized controlled trials.

192. Paediatr Anaesth 2014;24:1056–65, doi:http://dx.doi.org/10.1111/pan.12458.

193. Lingappan K, Arnold JL, Fernandes CJ, Pammi M. Videolaryngoscopy versus direct laryngoscopy for tracheal intubation in neonates. Cochrane Database Syst Rev 2018;6: CD009975, doi:http://dx.doi.org/10.1002/14651858.CD009975.pub3.

194. Abdelgadir IS, Phillips RS, Singh D, Moncreiff MP, Lumsden JL. Videolaryngoscopy versus direct laryngoscopy for tracheal intubation in children (excluding neonates). Cochrane Database Syst Rev 2017;5:CD011413, doi:http://dx.doi.org/10.1002/14651858.CD011413.pub2.

195. Sola C, Saour AC, Macq C, Bringuier S, Raux O, Dadure C. Children with challenging airways: what about GlideScope((R)) video-laryngoscopy? Anaesth Crit Care Pain Med 2017;36:267–71, doi:http://dx.doi.org/10.1016/j.accpm.2016.10.005.

196. Grunwell JR, Kamat PP, Miksa M, et al. Trend and outcomes of video laryngoscope use across PICUs. Pediatr Crit Care Med 2017;18:741 –9, doi:http://dx.doi.org/10.1097/PCC.0000000000001175.

197. Park R, Peyton JM, Fiadjoe JE, et al. The efficacy of GlideScope(R) videolaryngoscopy compared with direct laryngoscopy in children who are difficult to intubate: an analysis from the paediatric difficult intubation registry. Br J Anaesth 2017;119:984–92, doi:http://dx.doi.org/10.1093/bja/aex344.

198. Kaji AH, Shover C, Lee J, et al. Video versus direct and augmented direct laryngoscopy in pediatric tracheal intubations. Acad Emerg Med 2020;27:394–402, doi:http://dx.doi.org/10.1111/acem.13869.

199. Gupta A, Kamal G, Gupta A, Sehgal N, Bhatla S, Kumar R. Comparative evaluation of CMAC and Truview picture capture device for endotracheal intubation in neonates and infants undergoing elective surgeries: a prospective randomized control trial. Paediatr Anaesth 2018;28:1148–53, doi:http://dx.doi.org/10.1111/pan.13524.

200. Sinha R, Ray BR, Sharma A, et al. Comparison of the C-MAC video laryngoscope size 2 Macintosh blade with size 2 C-MAC D-Blade for laryngoscopy and endotracheal intubation in children with simulated cervical spine injury: a prospective randomized crossover study. J Anaesthesiol Clin Pharmacol 2019;35:509–14, doi:http://dx.doi.org/10.4103/joacp.JOACP_106_18.

201. Vadi MG, Roddy KJ, Ghazal EA, Um M, Neiheisel AJ, Applegate 2nd RL. Comparison of the GlideScope Cobalt(R) and Storz DCI(R) video laryngoscopes in children younger than 2 years of age during manual in-line stabilization: a randomized trainee evaluation study. Pediatr Emerg Care 2017;33:467–73, doi:http://dx.doi.org/10.1097/PEC.0000000000000607.

202. Kim JE, Kwak HJ, Jung WS, Chang MY, Lee SY, Kim JY. A comparison between McGrath MAC videolaryngoscopy and Macintosh laryngoscopy in children. Acta Anaesthesiol Scand 2018;62:312–8, doi:http://dx.doi.org/10.1111/aas.13043.

203. Jones P. The therapeutic value of atropine for critical care intubation. Arch Dis Child 2016;101:77–80, doi:http://dx.doi.org/10.1136/archdischild-2014- 308137.

204. Quintard H, l'Her E, Pottecher J, et al. Experts' guidelines of intubation and extubation of the ICU patient of French Society of Anaesthesia and Intensive Care Medicine (SFAR) and French-speaking Intensive Care Society (SRLF): In collaboration with the pediatric Association of French-speaking Anaesthetists and Intensivists (ADARPEF), French-speaking Group of Intensive Care and Paediatric emergencies (GFRUP) and Intensive Care physiotherapy society (SKR). Ann Intensive Care 2019;9:13, doi:http://dx.doi.org/10.1186/s13613-019-0483-1.

205. Jones P, Peters MJ, Pinto da Costa N, et al. Atropine for critical care intubation in a cohort of 264 children and reduced mortality unrelated to effects on bradycardia. PLOS ONE 2013;8:e57478, doi:http://dx.doi.org/10.1371/journal.pone.0057478.

206. Jones P, Ovenden N, Dauger S, Peters MJ. Estimating 'lost heart beats' rather than reductions in heart rate during the intubation of critically-ill children. PLOS ONE 2014;9:e86766, doi:http://dx.doi.org/10.1371/journal.pone.0086766.

207. Gill H, Thoresen M, Smit E, et al. Sedation management during therapeutic hypothermia for neonatal encephalopathy: atropine premedication for endotracheal intubation causes a prolonged increase in heart rate. Resuscitation 2014;85:1394–8, doi:http://dx.doi.org/10.1016/j.resuscitation.2014.07.002.

208. Litman RS, Weissend EE, Shibata D, Westesson PL. Developmental changes of laryngeal dimensions in unparalyzed, sedated children. Anesthesiology 2003;98:41–5, doi:http://dx.doi.org/10.1097/00000542- 200301000-00010.

209. Kneyber MCJ, de Luca D, Calderini E, et al. Recommendations for mechanical ventilation of critically ill children from the Paediatric Mechanical Ventilation Consensus Conference (PEMVECC). Intensive Care Med 2017;43:1764–80, doi:http://dx.doi.org/10.1007/s00134-017-4920- z.

210. Tosif S, Duke T. Evidence to support oxygen guidelines for children with emergency signs in developing countries: a systematic review and physiological and mechanistic analysis. J Trop Pediatr 2017;63:402–13, doi:http://dx.doi.org/10.1093/tropej/fmw100.

211. Rojas-Reyes MX, Granados Rugeles C, Charry-Anzola LP. Oxygen therapy for lower respiratory tract infections in children between 3 months and 15 years of age. Cochrane Database Syst Rev 2014; CD005975, doi:http://dx.doi.org/10.1002/14651858.CD005975.pub3.

212. Grandville B, Petak F, Albu G, Bayat S, Pichon I, Habre W. High inspired oxygen fraction impairs lung volume and ventilation heterogeneity in healthy children: a double-blind randomised controlled trial. Br J Anaesth 2019;122:682–91, doi:http://dx.doi.org/10.1016/j.bja.2019.01.036.

213. Patel B, Khine H, Shah A, Sung D, Medar S, Singer L. Randomized clinical trial of high concentration versus titrated oxygen use in pediatric asthma. Pediatr Pulmonol 2019;54:970–6, doi:http://dx.doi.org/10.1002/ppul.24329.

214. Peters MJ, Jones GAL, Wiley D, et al. Conservative versus liberal oxygenation targets in critically ill children: the randomised multiple-centre pilot Oxy-PICU trial. Intensive Care Med 2018;44:1240–8, doi:http://dx.doi.org/10.1007/s00134-018-5232- 7.

215. von der Weid L, Gehri M, Camara B, Thiongane A, Pascual A, Pauchard JY. Clinical signs of hypoxaemia in children aged 2 months to 5 years with acute respiratory distress in Switzerland and Senegal. Paediatr Int Child Health 2018;38:113–20, doi:http://dx.doi.org/10.1080/20469047.2017.1390828.

216. Jones GAL, Ramnarayan P, Raman S, et al. Protocol for a randomised pilot multiple centre trial of conservative versus liberal oxygenation targets in critically ill children (Oxy-PICU). BMJ Open 2017;7:e019253, doi:http://dx.doi.org/10.1136/bmjopen-2017 -019253.

217. Maitland K, Kiguli S, Opoka RO, et al. Children's Oxygen Administration Strategies Trial (COAST): a randomised controlled trial of high flow versus oxygen versus control in African children with severe pneumonia. Wellcome Open Res 2017;2:100, doi:http://dx.doi.org/10.12688/wellcomeopenres.12747.2.

218. Ramnarayan P, Lister P, Dominguez T, et al. FIRST-line support for Assistance in Breathing in Children (FIRST-ABC): a multicentre pilot randomised controlled trial of high-flow nasal cannula therapy versus continuous positive airway pressure in paediatric critical care. Crit Care 2018;22:144, doi:http://dx.doi.org/10.1186/s13054-018-2080-3.

219. Durand P, Guiddir T, Kyheng C, et al. A randomised trial of high-flow nasal cannula in infants with moderate bronchiolitis. Eur Respir J 202056:, doi:http://dx.doi.org/10.1183/13993003.01926-2019.

220. Williams AM, Abramo TJ, Shah MV, et al. Safety and clinical findings of BiPAP utilization in children 20kg or less for asthma exacerbations. Intensive Care Med 2011;37:1338–43, doi:http://dx.doi.org/10.1007/s00134-011-2238-9.

221. Essouri S, Laurent M, Chevret L, et al. Improved clinical and economic outcomes in severe bronchiolitis with pre-emptive nCPAP ventilatory strategy. Intensive Care Med 2014;40:84–91, doi:http://dx.doi.org/10.1007/s00134-013-3129-z.

222. Abadesso C, Nunes P, Silvestre C, Matias E, Loureiro H, Almeida H. Non-invasive ventilation in acute respiratory failure in children. Pediatr Rep 2012;4:e16, doi:http://dx.doi.org/10.4081/pr.2012.e16.

223. Vitaliti G, Vitaliti MC, Finocchiaro MC, et al. Randomized comparison of helmet CPAP versus high-flow nasal cannula oxygen in pediatric respiratory distress. Respir Care 2017;62:1036−42, doi:http://dx.doi.org/10.4187/respcare.05384.

224. Korang SK, Feinberg J, Wetterslev J, Jakobsen JC. Non-invasive positive pressure ventilation for acute asthma in children. Cochrane Database Syst Rev 2016;9:CD012067, doi:http://dx.doi.org/10.1002/14651858.CD012067.pub2.

225. Combret Y, Prieur G, LER P, Medrinal C. Non-invasive ventilation improves respiratory distress in children with acute viral bronchiolitis: a systematic review. Minerva Anestesiol 2017;83:624−37, doi:http://dx.doi.org/10.23736/S0375- 9393.17.11708-6.

226. Ballestero Y, De Pedro J, Portillo N, Martinez-Mugica O, Arana- Arri E, Benito J. Pilot clinical trial of high-flow oxygen therapy in children with asthma in the emergency service. J Pediatr 2018194:, doi:http://dx.doi.org/10.1016/j.jpeds.2017.10.075 204−10 e3.

227. Luo J, Duke T, Chisti MJ, Kepreotes E, Kalinowski V, Li J. Efficacy of high-flow nasal cannula vs standard oxygen therapy or nasal continuous positive airway pressure in children with respiratory distress: a meta-analysis. J Pediatr 2019215:, doi:http://dx.doi.org/10.1016/j.jpeds.2019.07.059 199−208 e8.

228. O'Brien S, Craig S, Babl FE, et al. 'Rational use of high-flow therapy in infants with bronchiolitis. What do the latest trials tell us?.' A paediatric research in emergency departments international collaborative perspective. J Paediatr Child Health 2019;55:746−52, doi:http://dx.doi.org/10.1111/jpc.14496.

229. Mikalsen IB, Davis P, Oymar K. High flow nasal cannula in children: a literature review. Scand J Trauma Resusc Emerg Med 2016;24:93, doi:http://dx.doi.org/10.1186/s13049-016-0278-4.

230. Vahlkvist S, Jurgensen L, la Cour A, Markoew S, Petersen TH, Kofoed PE. High flow nasal cannula and continuous positive airway pressure therapy in treatment of viral bronchiolitis: a randomized clinical trial. Eur J Pediatr 2020;179:513−8, doi:http://dx.doi.org/10.1007/s00431-019-03533-2.

231. Gc VS, Franklin D, Whitty JA, et al. First-line oxygen therapy with high-flow in bronchiolitis is not cost saving for the health service. Arch Dis Child 2020;105:975−80, doi:http://dx.doi.org/10.1136/archdischild-2019-318427.

232. Figueroa L, Laffaye F. Early use of continuous positive airway pressure in the treatment of moderate to severe acute lower respiratory tract infections among patients younger than 2 years old. Arch Argent Pediatr 2017;115:277−81, doi:http://dx.doi.org/10.5546/aap.2017.eng.277.

233. Chisti MJ, Salam MA, Smith JH, et al. Bubble continuous positive airway pressure for children with severe pneumonia and hypoxaemia in Bangladesh: an open, randomised controlled trial. Lancet 2015;386:1057−65, doi:http://dx.doi.org/10.1016/S0140-6736(15)60249-5.

234. Mandelzweig K, Leligdowicz A, Murthy S, Lalitha R, Fowler RA, Adhikari NKJ. Non-invasive ventilation in children and adults in low- and low- middle income countries: a systematic review and meta-analysis. J Crit Care 2018;47:310−9, doi:http://dx.doi.org/10.1016/j.jcrc.2018.01.007.

235. Balfour-Lynn RE, Marsh G, Gorayi D, Elahi E, LaRovere J. Non-invasive ventilation for children with acute respiratory failure in the developing world: literature review and an implementation example. Paediatr Respir Rev 2014;15:181−7, doi:http://dx.doi.org/10.1016/j.prrv.2014.02.002.

236. Richards M, Le Roux D, Cooke L, Argent A. The influence of high flow nasal cannulae on the outcomes of severe respiratory disease in children admitted to a regional hospital in South Africa. J Trop Pediatr 2020;66:612−20, doi:http://dx.doi.org/10.1093/tropej/fmaa024.

237. Yurtseven A, Turan C, Erseven E, Saz EU. Comparison of heated humidified high-flow nasal cannula flow rates (1-L.kg.min(-1) vs 2-L.kg.min (-1)) in the management of acute bronchiolitis. Pediatr Pulmonol 2019;54:894−900, doi:http://dx.doi.org/10.1002/ppul.24318.

238. Kotoda M, Hishiyama S, Mitsui K, et al. Assessment of the potential for pathogen dispersal during high-flow nasal therapy. J Hosp Infect 2020;104:534−7, doi:http://dx.doi.org/10.1016/j.jhin.2019.11.010.

239. Kobayashi H, Takimoto T, Kitaoka H, Kijima T. Aerosol spread with use of high-flow nasal cannulae: a computational fluid dynamics analysis. J Hosp Infect 2020;106:204−5, doi:http://dx.doi.org/10.1016/j.jhin.2020.06.010.

240. Kochanek PM, Tasker RC, Bell MJ, et al. Management of pediatric severe traumatic brain injury: 2019 consensus and guidelines-based algorithm for first and second tier therapies. Pediatr Crit Care Med 2019;20:269−79, doi:http://dx.doi.org/10.1097/PCC.0000000000001737.

241. Kim GJ, Newth CJL, Khemani RG, Wong SL, Coates AL, Ross PA. Does size matter when calculating the "correct" tidal volume for pediatric mechanical ventilation?.: A hypothesis based on FVC. Chest 2018;154:77−83, doi:http://dx.doi.org/10.1016/j.chest.2018.04.015.

242. Bilharz JR, Wheeler CR, Walsh BK, Smallwood CD. A comparative analysis of ideal body weight methods for pediatric mechanical ventilation. Respir Care 2018;63:1079−84, doi:http://dx.doi.org/10.4187/respcare.06021.

243. Lee JH, Jung H, Jang YE, et al. Manual vs pressure-controlled facemask ventilation during the induction of general anesthesia in children: a prospective randomized controlled study. Paediatr Anaesth 2019;29:331−7, doi:http://dx.doi.org/10.1111/pan.13594.

244. Mumma JM, Durso FT, Dyes M, Dela Cruz R, Fox VP, Hoey M. Bag valve mask ventilation as a perceptual-cognitive skill. Hum Factors 2018;60:212−21, doi:http://dx.doi.org/10.1177/0018720817744729.

245. Kroll M, Das J, Siegler J. Can altering grip technique and bag size optimize volume delivered with bag-valve-mask by emergency medical service providers? Prehosp Emerg Care 2019;23:210−4, doi:http://dx.doi.org/10.1080/10903127.2018.1489020.

246. Becker HJ, Langhan ML. Can providers use clinical skills to assess the adequacy of ventilation in children during bag-valve mask ventilation? Pediatr Emerg Care 2020;36:e695−9, doi:http://dx.doi.org/10.1097/PEC.0000000000001314.

247. Williams DC, Cheifetz IM. Emerging approaches in pediatric mechanical ventilation. Expert Rev Respir Med 2019;13:327−36, doi:http://dx.doi.org/10.1080/17476348.2019.1586536.

248. Smallwood CD, Davis MD. Year in review 2018: pediatric mechanical ventilation. Respir Care 2019;64:855−63, doi:http://dx.doi.org/10.4187/respcare.07029.

249. Conti G, Piastra M. Mechanical ventilation for children. Curr Opin Crit Care 2016;22:60−6, doi:http://dx.doi.org/10.1097/MCC.0000000000000271.

250. Pediatric Acute Lung Injury Consensus Conference G. Pediatric acute respiratory distress syndrome: consensus recommendations from the pediatric acute lung injury consensus conference. Pediatr Crit Care Med 2015;16:428−39, doi:http://dx.doi.org/10.1097/PCC.0000000000000350.

251. Pearsall MF, Feldman JM. When does apparatus dead space matter for the pediatric patient? Anesth Analg 2014;118:776−80, doi:http://dx.doi.org/10.1213/ANE.0000000000000148.

252. Siegler J, Kroll M, Wojcik S, Moy HP. Can EMS providers provide appropriate tidal volumes in a simulated adult-sized patient with a pediatric-sized bag-valve-mask? Prehosp Emerg Care 2017;21:74−8, doi:http://dx.doi.org/10.1080/10903127.2016.1227003.

253. van Vonderen JJ, Witlox RS, Kraaij S, te Pas AB. Two-minute training for improving neonatal bag and mask ventilation. PLOS ONE 2014;9:e109049, doi:http://dx.doi.org/10.1371/journal.pone.0109049.

254. Khoury A, Hugonnot S, Cossus J, et al. From mouth-to-mouth to bag-valve-mask ventilation: evolution and characteristics of actual devices–a review of the literature. Biomed Res Int 2014 2014;762053, doi:http://dx.doi.org/10.1155/2014/762053.

255. Balamuth F, Kittick M, McBride P, et al. Pragmatic pediatric trial of balanced versus normal saline fluid in sepsis: the PRoMPT BOLUS

randomized controlled trial pilot feasibility study. Acad Emerg Med 2019;26:1346−56, doi:http://dx.doi.org/10.1111/acem.13815.

256. Parker MJ, Thabane L, Fox-Robichaud A, et al. A trial to determine whether septic shock-reversal is quicker in pediatric patients randomized to an early goal-directed fluid-sparing strategy versus usual care (SQUEEZE): study protocol for a pilot randomized controlled trial. Trials 2016;17:556, doi:http://dx.doi.org/10.1186/s13063-016-1689-2.

257. Inwald DP, Butt W, Tasker RC. Fluid resuscitation of shock in children: what, whence and whither? Intensive Care Med 2015;41:1457−9, doi:http://dx.doi.org/10.1007/s00134-015-3905- z.

258. Inwald DP, Canter R, Woolfall K, et al. Restricted fluid bolus volume in early septic shock: results of the fluids in shock pilot trial. Arch Dis Child 2019;104:426−31, doi:http://dx.doi.org/10.1136/archdischild-2018-314924.

259. Gaensbauer JT, Birkholz M, Smit MA, Garcia R, Todd JK. Epidemiology and clinical relevance of toxic shock syndrome in US children. Pediatr Infect Dis J 2018;37:1223−6, doi:http://dx.doi.org/10.1097/INF.0000000000002002.

260. Weiss SL, Fitzgerald JC, Pappachan J, et al. Global epidemiology of pediatric severe sepsis: the sepsis prevalence, outcomes, and therapies study. Am J Respir Crit Care Med 2015;191:1147−57, doi:http://dx.doi.org/10.1164/rccm.201412-2323OC.

261. Maitland K, Kiguli S, Opoka RO, et al. Mortality after fluid bolus in African children with severe infection. N Engl J Med 2011;364:2483−95, doi:http://dx.doi.org/10.1056/NEJMoa1101549.

262. Tripathi A, Kabra SK, Sachdev HP, Lodha R. Mortality and other outcomes in relation to first hour fluid resuscitation rate: a systematic review. Indian Pediatr 2015;52:965−72, doi:http://dx.doi.org/10.1007/s13312-015-0754-3.

263. Levin M, Cunnington AJ, Wilson C, et al. Effects of saline or albumin fluid bolus in resuscitation: evidence from re-analysis of the FEAST trial. Lancet Respir Med 2019;7:581−93, doi:http://dx.doi.org/10.1016/S2213-2600(19) 30114-6.

264. Long E, Babl FE, Oakley E, Sheridan B, Duke T, Pediatric Research in Emergency Departments International C. Cardiac index changes with fluid bolus therapy in children with sepsis-an observational study. Pediatr Crit Care Med 2018;19:513−8, doi:http://dx.doi.org/10.1097/PCC.0000000000001534.

265. Chang R, Holcomb JB. Choice of fluid therapy in the initial management of sepsis, severe sepsis, and septic shock. Shock 2016;46:17−26, doi:http://dx.doi.org/10.1097/SHK.0000000000000577.

266. Lewis SR, Pritchard MW, Evans DJ, et al. Colloids versus crystalloids for fluid resuscitation in critically ill people. Cochrane Database Syst Rev 2018;8:CD000567, doi:http://dx.doi.org/10.1002/14651858.CD000567.pub7.

267. Medeiros DN, Ferranti JF, Delgado AF, de Carvalho WB. Colloids for the initial management of severe sepsis and septic shock in pediatric patients: a systematic review. Pediatr Emerg Care 2015;31:e11−6, doi:http://dx.doi.org/10.1097/PEC.0000000000000601.

268. Emrath ET, Fortenberry JD, Travers C, McCracken CE, Hebbar KB. Resuscitation with balanced fluids is associated with improved survival in pediatric severe sepsis. Crit Care Med 2017;45:1177−83, doi:http://dx.doi.org/10.1097/CCM.0000000000002365.

269. Weiss SL, Keele L, Balamuth F, et al. Crystalloid fluid choice and clinical outcomes in pediatric sepsis: a matched retrospective cohort study. J Pediatr 2017182:, doi:http://dx.doi.org/10.1016/j.jpeds.2016.11.075 304−310 e10.

270. Antequera Martin AM, Barea Mendoza JA, Muriel A, et al. Buffered solutions versus 0.9% saline for resuscitation in critically ill adults and children. Cochrane Database Syst Rev 2019;7:CD012247, doi:http://dx.doi.org/10.1002/14651858.CD012247.pub2.

271. Ranjit S, Ramanathan G, Ramakrishnan B, Kissoon N. Targeted interventions in critically ill children with severe dengue. Indian J Crit Care Med 2018;22:154−61, doi:http://dx.doi.org/10.4103/ijccm.IJCCM_413_17.

272. Singh M, Sankar J, Kumar A, Kumar UV, Lodha R, Kabra SK. Predictors of mortality in children admitted to the pediatric intensive care unit with acute gastroenteritis with severe dehydration. Indian J Pediatr 2019;86:1142−5, doi:http://dx.doi.org/10.1007/s12098-019-03094-0.

273. Qadori M, Flem E, Bekkevold T, et al. Hypoglycaemia was common in acute gastroenteritis in a prospective hospital-based study, but electrolyte imbalances were not. Acta Paediatr 2018;107:1455−60, doi:http://dx.doi.org/10.1111/apa.14318.

274. Vonasek BJ, Chiume M, Crouse HL, et al. Risk factors for mortality and management of children with complicated severe acute malnutrition at a tertiary referral hospital in Malawi. Paediatr Int Child Health 2020;40:148−57, doi:http://dx.doi.org/10.1080/20469047.2020.1747003.

275. Alam NH, Ashraf H, Ahmed T, Jahan N, Gyr N. Randomised trial showed that rapid rehydration of severely malnourished children with dehydrating diarrhoea was as safe and effective as slow rehydration. Acta Paediatr 2020;109:1473−84, doi:http://dx.doi.org/10.1111/apa.15134.

276. Houston KA, Gibb J, Olupot-Olupot P, et al. Gastroenteritis aggressive versus slow treatment for rehydration (GASTRO): a phase II rehydration trial for severe dehydration: WHO plan C versus slow rehydration. BMC Med 2019;17:122, doi:http://dx.doi.org/10.1186/s12916-019-1356- z.

277. Iro MA, Sell T, Brown N, Maitland K. Rapid intravenous rehydration of children with acute gastroenteritis and dehydration: a systematic review and meta-analysis. BMC Pediatr 2018;18:44, doi:http://dx.doi.org/10.1186/s12887-018-1006-1.

278. Polites SF, Moody S, Williams RF, et al. Timing and volume of crystalloid and blood products in pediatric trauma: An Eastern Association for the Surgery of Trauma multicenter prospective observational study. J Trauma Acute Care Surg 2020;89:36−42, doi:http://dx.doi.org/10.1097/TA.0000000000002702.

279. Schauer SG, April MD, Becker TE, Cap AP, Borgman MA. High crystalloid volumes negate benefit of hemostatic resuscitation in pediatric wartime trauma casualties. J Trauma Acute Care Surg 2020;89:S185−91, doi:http://dx.doi.org/10.1097/TA.0000000000002590.

280. Elkbuli A, Zajd S, Ehrhardt Jr. JD, McKenney M, Boneva D. Aggressive crystalloid resuscitation outcomes in low-severity pediatric trauma. J Surg Res 2020;247:350−5, doi:http://dx.doi.org/10.1016/j.jss.2019.10.009.

281. Polites SF, Nygaard RM, Reddy PN, et al. Multicenter study of crystalloid boluses and transfusion in pediatric trauma-When to go to blood? J Trauma Acute Care Surg 2018;85:108−12, doi:http://dx.doi.org/10.1097/TA.0000000000001897.

282. Magoteaux SR, Notrica DM, Langlais CS, et al. Hypotension and the need for transfusion in pediatric blunt spleen and liver injury: an ATOMAC+ prospective study. J Pediatr Surg 2017;52:979−83, doi:http://dx.doi.org/10.1016/j.jpedsurg.2017.03.021.

283. Nadler R, Mozer- Glassberg Y, Gaines B, Glassberg E, Chen J. The Israel Defense Forces experience with freeze- dried plasma for the resuscitation of traumatized pediatric patients. J Trauma Acute Care Surg 2019;87:1315−20, doi:http://dx.doi.org/10.1097/TA.0000000000002477.

284. Haltmeier T, Benjamin E, Gruen JP, et al. Decreased mortality in patients with isolated severe blunt traumatic brain injury receiving higher plasma to packed red blood cells transfusion ratios. Injury 2018;49:62−6, doi:http://dx.doi.org/10.1016/j.injury.2017.07.035.

285. Long B, April MD. Does administration of hypertonic solutions improve mortality in hemorrhagic shock compared with isotonic solutions? Ann Emerg Med 2018;71:529−31, doi:http://dx.doi.org/10.1016/j.annemergmed.2017.11.025.

286. Phillips R, Acker SN, Shahi N, et al. The ABC-D score improves the sensitivity in predicting need for massive transfusion in pediatric trauma patients. J Pediatr Surg 2020;55:331−4, doi:http://dx.doi.org/10.1016/j.jpedsurg.2019.10.008.

287. Figueiredo S, Taconet C, Harrois A, et al. How useful are hemoglobin concentration and its variations to predict significant hemorrhage in the early phase of trauma? A multicentric cohort study. Ann Intensive Care 2018;8:76, doi:http://dx.doi.org/10.1186/s13613-018-0420- 8.

288. Brinck T, Handolin L, Lefering R. The effect of evolving fluid resuscitation on the outcome of severely injured patients: an 8-year experience at a tertiary trauma center. Scand J Surg 2016;105:109 −16, doi:http://dx.doi.org/10.1177/1457496915586650.

289. Wang CH, Hsieh WH, Chou HC, et al. Liberal versus restricted fluid resuscitation strategies in trauma patients: a systematic review and meta-analysis of randomized controlled trials and observational studies*. Crit Care Med 2014;42:954−61, doi:http://dx.doi.org/10.1097/CCM.0000000000000050.

290. Albreiki M, Voegeli D. Permissive hypotensive resuscitation in adult patients with traumatic haemorrhagic shock: a systematic review. Eur J Trauma Emerg Surg 2018;44:191−202, doi:http://dx.doi.org/10.1007/s00068-017-0862- y.

291. Tran A, Yates J, Lau A, Lampron J, Matar M. Permissive hypotension versus conventional resuscitation strategies in adult trauma patients with hemorrhagic shock: a systematic review and meta-analysis of randomized controlled trials. J Trauma Acute Care Surg 2018;84:802 −8, doi:http://dx.doi.org/10.1097/TA.0000000000001816.

292. Owattanapanich N, Chittawatanarat K, Benyakorn T, Sirikun J. Risks and benefits of hypotensive resuscitation in patients with traumatic hemorrhagic shock: a meta-analysis. Scand J Trauma Resusc Emerg Med 2018;26:107, doi:http://dx.doi.org/10.1186/s13049-018-0572- 4.

293. Dittrich MHM, Hosni ND, de Carvalho WB. Association between fluid creep and infection in burned children: a cohort study. Burns 2020;46:1036−42, doi:http://dx.doi.org/10.1016/j.burns.2020.02.003.

294. Granfeldt A, Avis SR, Lind PC, et al. Intravenous vs. intraosseous administration of drugs during cardiac arrest: a systematic review. Resuscitation 2020;149:150−7, doi:http://dx.doi.org/10.1016/j.resuscitation.2020.02.025.

295. Jousi M, Laukkanen- Nevala P, Nurmi J. Analysing blood from intraosseous access: a systematic review. Eur J Emerg Med 2019;26:77−85, doi:http://dx.doi.org/10.1097/MEJ.0000000000000569.

296. Ohchi F, Komasawa N, Mihara R, Minami T. Comparison of mechanical and manual bone marrow puncture needle for intraosseous access; a randomized simulation trial. Springerplus 2015;4:211, doi:http://dx.doi.org/10.1186/s40064-015-0982-y.

297. El-Nawawy AA, Omar OM, Khalil M. Intraosseous versus intravenous access in pediatric septic shock patients admitted to alexandria university pediatric intensive care unit. J Trop Pediatr 2018;64:132 −40, doi:http://dx.doi.org/10.1093/tropej/fmx061.

298. Maxien D, Wirth S, Peschel O, et al. Intraosseous needles in pediatric cadavers: rate of malposition. Resuscitation 2019;145:1−7, doi:http://dx.doi.org/10.1016/j.resuscitation.2019.09.028.

299. Al-Shibli A, Lim R, Poonai N, Istasy V, Lin K, Kilgar J. Determination of the pretibial soft tissue thickness in children: are intraosseous infusion needles long enough? Pediatr Emerg Care 2020;36:39−42, doi:http://dx.doi.org/10.1097/PEC.0000000000002019.

300. Mori T, Takei H, Sasaoka Y, Nomura O, Ihara T. Semi-automatic intraosseous device (EZ-IO) in a paediatric emergency department. J Paediatr Child Health 2020;56:1376−81, doi:http://dx.doi.org/10.1111/jpc.14940.

301. Harcke HT, Curtin RN, Harty MP, et al. Tibial intraosseous insertion in pediatric emergency care: a review based upon postmortem computed tomography. Prehosp Emerg Care 2020;24:665−71, doi:http://dx.doi.org/10.1080/10903127.2019.1698682.

302. Szarpak L, Ladny JR, Dabrowski M, et al. Comparison of 4 pediatric intraosseous access devices: a randomized simulation study. Pediatr Emerg Care 2020;36:e568−72, doi:http://dx.doi.org/10.1097/PEC.0000000000001587.

303. Hamed RK, Hartmans S, Gausche-Hill M. Anesthesia through an intraosseous line using an 18-gauge intravenous needle for emergency pediatric surgery. J Clin Anesth 2013;25:447−51, doi:http://dx.doi.org/10.1016/j.jclinane.2013.03.013.

304. Kalechstein S, Permual A, Cameron BM, et al. Evaluation of a new pediatric intraosseous needle insertion device for low-resource settings. J Pediatr Surg 2012;47:974−9, doi:http://dx.doi.org/10.1016/j.jpedsurg.2012.01.055.

305. Isayama K, Nakatani T, Tsuda M, Hirakawa A. Current status of establishing a venous line in CPA patients by Emergency Life-Saving Technicians in the prehospital setting in Japan and a proposal for intraosseous infusion. Int J Emerg Med 2012;5:2, doi:http://dx.doi.org/10.1186/1865-1380-5- 2.

306. Hansen M, Meckler G, Spiro D, Newgard C. Intraosseous line use, complications, and outcomes among a population-based cohort of children presenting to California hospitals. Pediatr Emerg Care 2011;27:928−32, doi:http://dx.doi.org/10.1097/PEC.0b013e3182307a2f.

307. Sunde GA, Heradstveit BE, Vikenes BH, Heltne JK. Emergency intraosseous access in a helicopter emergency medical service: a retrospective study. Scand J Trauma Resusc Emerg Med 2010;18:52, doi:http://dx.doi.org/10.1186/1757-7241-18- 52.

308. Bielski K, Szarpak L, Smereka J, Ladny JR, Leung S, Ruetzler K. Comparison of four different intraosseous access devices during simulated pediatric resuscitation. a randomized crossover manikin trial. Eur J Pediatr 2017;176:865−71, doi:http://dx.doi.org/10.1007/s00431-017-2922-z.

309. Pifko EL, Price A, Busch C, et al. Observational review of paediatric intraosseous needle placement in the paediatric emergency department. J Paediatr Child Health 2018;54:546−50, doi:http://dx.doi.org/10.1111/jpc.13773.

310. Johnson M, Inaba K, Byerly S, et al. Intraosseous infusion as a bridge to definitive access. Am Surg 2016;82:876−80 (https://www.ncbi.nlm.nih.gov/pubmed/27779964).

311. Oksan D, Ayfer K. Powered intraosseous device (EZ-IO) for critically ill patients. Indian Pediatr 2013;50:689−91, doi:http://dx.doi.org/10.1007/s13312-013-0192-z.

312. Reuter-Rice K, Patrick D, Kantor E, Nolin C, Foley J. Characteristics of children who undergo intraosseous needle placement. Adv Emerg Nurs J 2015;37:301−7, doi:http://dx.doi.org/10.1097/TME.0000000000000077.

313. Lee SH, Frey M, Kerrey BT, Zhang Y, Byczkowski T, Geis GL. A video-based, case-control study of factors associated with intraosseous catheterization during pediatric resuscitation. Ann Emerg Med 2020;75:755−61, doi:http://dx.doi.org/10.1016/j.annemergmed.2019.09.005.

314. Abramson TM, Alreshaid L, Kang T, Mailhot T, Omer T. FascIOtomy: ultrasound evaluation of an intraosseous needle causing compartment syndrome. Clin Pract Cases Emerg Med 2018;2:323 −5, doi:http://dx.doi.org/10.5811/cpcem.2018.8.38854.

315. Tsung JW, Blaivas M, Stone MB. Feasibility of point-of- care colour Doppler ultrasound confirmation of intraosseous needle placement during resuscitation. Resuscitation 2009;80:665−8, doi:http://dx.doi.org/10.1016/j.resuscitation.2009.03.009.

316. Oulego-Erroz I, Munoz- Lozon A, Alonso-Quintela P, Rodriguez-Nunez A. Comparison of ultrasound guided brachiocephalic and internal jugular vein cannulation in critically ill children. J Crit Care 2016;35:133−7, doi:http://dx.doi.org/10.1016/j.jcrc.2016.05.010.

317. Gallagher RA, Levy J, Vieira RL, Monuteaux MC, Stack AM. Ultrasound assistance for central venous catheter placement in a pediatric emergency department improves placement success rates. Acad Emerg Med 2014;21:981−6, doi:http://dx.doi.org/10.1111/acem.12460.

318. Stinson HR, Viteri S, Koetter P, et al. Early experience with a novel strategy for assessment of sepsis risk: the shock huddle. Pediatr Qual Saf 2019;4:e197, doi:http://dx.doi.org/10.1097/pq9.0000000000000197.

319. Wulff A, Montag S, Marschollek M, Jack T. Clinical decision-support systems for detection of systemic inflammatory response syndrome, sepsis, and septic shock in critically ill patients: a systematic review. Methods Inf Med 2019;58:e43−57, doi:http://dx.doi.org/10.1055/s-0039-1695717.

320. Pepper DJ, Natanson C, Eichacker PQ. Evidence underpinning the centers for medicare & medicaid services' severe sepsis and septic

shock management bundle (SEP-1). Ann Intern Med 2018;168:610 −2, doi:http://dx.doi.org/10.7326/L18- 0140.

321. Barboza CL, Valete CO, da Silva AR. Bundle adherence of intravenous antibiotic fluid resuscitation and vasopressor in children with severe sepsis or septic shock. Indian J Crit Care Med 2020;24:128−32, doi:http://dx.doi.org/10.5005/jp-journals-10071-23336.

322. Balamuth F, Weiss SL, Fitzgerald JC, et al. Protocolized treatment is associated with decreased organ dysfunction in pediatric severe sepsis. Pediatr Crit Care Med 2016;17:817−22, doi:http://dx.doi.org/10.1097/PCC.0000000000000858.

323. Workman JK, Ames SG, Reeder RW, et al. Treatment of pediatric septic shock with the surviving sepsis campaign guidelines and PICU patient outcomes. Pediatr Crit Care Med 2016;17:e451−8, doi:http://dx.doi.org/10.1097/PCC.0000000000000906.

324. Lane RD, Funai T, Reeder R, Larsen GY. High reliability pediatric septic shock quality improvement initiative and decreasing mortality. Pediatrics 2016138:, doi:http://dx.doi.org/10.1542/peds.2015-4153.

325. Hebert A, Boucher MP, Guimont C, Weiss M. Effect of measuring vital signs on recognition and treatment of septic children. Paediatr Child Health 2017;22:13−6, doi:http://dx.doi.org/10.1093/pch/pxw003.

326. Paul R, Melendez E, Wathen B, et al. A quality improvement collaborative for pediatric sepsis: lessons learned. Pediatr Qual Saf 2018;3:e051, doi:http://dx.doi.org/10.1097/pq9.0000000000000051.

327. Evans IVR, Phillips GS, Alpern ER, et al. Association between the New York sepsis care mandate and in- hospital mortality for pediatric sepsis. JAMA 2018;320:358−67, doi:http://dx.doi.org/10.1001/jama.2018.9071.

328. Samransamruajkit R, Limprayoon K, Lertbunrian R, et al. The utilization of the surviving sepsis campaign care bundles in the treatment of pediatric patients with severe sepsis or septic shock in a resource-limited environment: a prospective multicenter trial. Indian J Crit Care Med 2018;22:846−51, doi:http://dx.doi.org/10.4103/ijccm.IJCCM_367_18.

329. Kortz TB, Axelrod DM, Chisti MJ, Kache S. Clinical outcomes and mortality before and after implementation of a pediatric sepsis protocol in a limited resource setting: a retrospective cohort study in Bangladesh. PLOS ONE 2017;12:e0181160, doi:http://dx.doi.org/10.1371/journal.pone.0181160.

330. Lane RD, Olson J, Reeder R, et al. Antibiotic timing in pediatric septic shock. Hosp Pediatr 2020;10:311−7, doi:http://dx.doi.org/10.1542/hpeds.2019- 0250.

331. Kyo M, Ohshimo S, Kosaka T, Fujita N, Shime N. Impact of inappropriate empiric antimicrobial therapy on mortality in pediatric patients with bloodstream infection: a retrospective observational study. J Chemother 2019;31:388−93, doi:http://dx.doi.org/10.1080/1120009X.2019.1623362.

332. van Paridon BM, Sheppard C, GG G, Joffe AR, Alberta Sepsis N. Timing of antibiotics, volume, and vasoactive infusions in children with sepsis admitted to intensive care. Crit Care 2015;19:293, doi:http://dx.doi.org/10.1186/s13054-015-1010-x.

333. Carapetis JR, Jacoby P, Carville K, Ang SJ, Curtis N, Andrews R. Effectiveness of clindamycin and intravenous immunoglobulin, and risk of disease in contacts, in invasive group a streptococcal infections. Clin Infect Dis 2014;59:358−65, doi:http://dx.doi.org/10.1093/cid/ciu304.

334. Weiss SL, Fitzgerald JC, Balamuth F, et al. Delayed antimicrobial therapy increases mortality and organ dysfunction duration in pediatric sepsis. Crit Care Med 2014;42:2409−17, doi:http://dx.doi.org/10.1097/CCM.0000000000000509.

335. Fusco NM, Parbuoni KA, Morgan JA. Time to first antimicrobial administration after onset of sepsis in critically ill children. J Pediatr Pharmacol Ther 2015;20:37−44, doi:http://dx.doi.org/10.5863/1551-6776-20.1.37.
Han M, Fitzgerald JC, Balamuth F, et al. Association of delayed antimicrobial therapy with one-year mortality in pediatric sepsis.

336. Shock 2017;48:29−35, doi:http://dx.doi.org/10.1097/SHK.0000000000000833.

337. Li Q, Cheng J, Wu Y, et al. Effects of delayed antibiotic therapy on outcomes in children with streptococcus pneumoniae sepsis. Antimicrob Agents Chemother 201963:, doi:http://dx.doi.org/10.1128/AAC.00623- 19.

338. Tran P, Dowell E, Hamilton S, et al. Two blood cultures with age-appropriate volume enhance suspected sepsis decision-making. Open Forum Infect Dis 2020;7:ofaa028, doi:http://dx.doi.org/10.1093/ofid/ofaa028.

339. Ventura AM, Shieh HH, Bousso A, et al. Double-blind prospective randomized controlled trial of dopamine versus epinephrine as first-line vasoactive drugs in pediatric septic shock. Crit Care Med 2015;43:2292−302, doi:http://dx.doi.org/10.1097/CCM.0000000000001260.

340. Ramaswamy KN, Singhi S, Jayashree M, Bansal A, Nallasamy K. Double-blind randomized clinical trial comparing dopamine and epinephrine in pediatric fluid- refractory hypotensive septic shock. Pediatr Crit Care Med 2016;17:e502−12, doi:http://dx.doi.org/10.1097/PCC.0000000000000954.

341. Wen L, Xu L. The efficacy of dopamine versus epinephrine for pediatric or neonatal septic shock: a meta-analysis of randomized controlled studies. Ital J Pediatr 2020;46:6, doi:http://dx.doi.org/10.1186/s13052-019-0768- x.

342. Masarwa R, Paret G, Perlman A, Reif S, Raccah BH, Matok I. Role of vasopressin and terlipressin in refractory shock compared to conventional therapy in the neonatal and pediatric population: a systematic review, meta-analysis, and trial sequential analysis. Crit Care 2017;21:1, doi:http://dx.doi.org/10.1186/s13054-016-1589- 6.

343. Lampin ME, Rousseaux J, Botte A, Sadik A, Cremer R, Leclerc F. Noradrenaline use for septic shock in children: doses, routes of administration and complications. Acta Paediatr 2012;101:e426−30, doi:http://dx.doi.org/10.1111/j.1651- 2227.2012.02725.x.

344. Michel J, Hofbeck M, Spiller G, Renk H, Kumpf M, Neunhoeffer F. Safety and efficacy of terlipressin in pediatric distributive shock: a retrospective analysis in 20 children. Paediatr Drugs 2017;19:35−41, doi:http://dx.doi.org/10.1007/s40272-016-0199-8.

345. Patregnani JT, Sochet AA, Klugman D. Short-term peripheral vasoactive infusions in pediatrics: where is the harm? Pediatr Crit Care Med 2017;18:e378−81, doi:http://dx.doi.org/10.1097/PCC.0000000000001230.

346. Morin L, Kneyber M, Jansen NJG, et al. Translational gap in pediatric septic shock management: an ESPNIC perspective. Ann Intensive Care 2019;9:73, doi:http://dx.doi.org/10.1186/s13613-019-0545- 4.

347. Ranjit S, Natraj R, Kandath SK, Kissoon N, Ramakrishnan B, Marik PE. Early norepinephrine decreases fluid and ventilatory requirements in pediatric vasodilatory septic shock. Indian J Crit Care Med 2016;20:561−9, doi:http://dx.doi.org/10.4103/0972-5229.192036.

348. Ferguson LP, Thiru Y, Staffa SJ, Guillen Ortega M. Reducing cardiac arrests in the PICU: initiative to improve time to administration of prearrest bolus epinephrine in patients with cardiac disease. Crit Care Med 2020;48:e542−9, doi:http://dx.doi.org/10.1097/CCM.0000000000004349.

349. Gamper G, Havel C, Arrich J, et al. Vasopressors for hypotensive shock. Cochrane Database Syst Rev 2016;2:CD003709, doi:http://dx.doi.org/10.1002/14651858.CD003709.pub4.

350. Misir A, Mehrotra S. Fluid and medication considerations in the traumatized patient. Curr Pediatr Rev 2018;14:9−27, doi:http://dx.doi.org/10.2174/1573396313666170815101504.

351. Health RCoPaC. Major trauma and the use of tranexamic acid in children Evidence statement Royal College of Paediatrics and Child Health. 2012 (https://www.rcem.ac.uk/docs/External Guidance/).

352. Patel J, Prajapati M, Patel H, Gandhi H, Deodhar S, Pandya H. Topical and low-dose intravenous tranexamic acid in cyanotic cardiac surgery. Asian Cardiovasc Thorac Ann 2017;25:118−22, doi:http://dx.doi.org/10.1177/0218492316688416.

353. O'Neil ER, Schmees LR, Resendiz K, Justino H, Anders MM. Inhaled tranexamic acid as a novel treatment for pulmonary hemorrhage in critically ill pediatric patients: an observational study. Crit Care Explor 2020;2:e0075, doi:http://dx.doi.org/10.1097/CCE.0000000000000075.

354. Maeda T, Michihata N, Sasabuchi Y, et al. Safety of tranexamic acid during pediatric trauma: a nationwide database study. Pediatr Crit Care Med 2018;19:e637−42, doi:http://dx.doi.org/10.1097/PCC.0000000000001724.

355. Eckert MJ, Wertin TM, Tyner SD, Nelson DW, Izenberg S, Martin MJ. Tranexamic acid administration to pediatric trauma patients in a combat setting: the pediatric trauma and tranexamic acid study (PED-TRAX). J Trauma Acute Care Surg 2014;77:852−8, doi:http://dx.doi.org/10.1097/TA.0000000000000443 [discussion 858].

356. Lin CY, Shuhaiber JH, Loyola H, et al. The safety and efficacy of antifibrinolytic therapy in neonatal cardiac surgery. PLOS ONE 2015;10:e0126514, doi:http://dx.doi.org/10.1371/journal.pone.0126514.

357. Zhang Y, Wang R, Wang YH, et al. Effects of tranexamic acid on the blood conservation and the long- term prognosis in pediatric patients undergoing repair for tetralogy of fallot. Zhonghua Yi Xue Za Zhi 2019;99:3564−7, doi:http://dx.doi.org/10.3760/cma.j.issn.0376-2491.2019.45.007.

358. Crash- trial collaborators, Shakur H, Roberts I, et al. Effects of tranexamic acid on death, vascular occlusive events, and blood transfusion in trauma patients with significant haemorrhage (CRASH-2): a randomised, placebo-controlled trial. Lancet 2010;376:23−32, doi:http://dx.doi.org/10.1016/S0140-6736(10)60835-5.

359. collaborators C-t. Effects of tranexamic acid on death, disability, vascular occlusive events and other morbidities in patients with acute traumatic brain injury (CRASH-3): a randomised, placebo-controlled trial. Lancet 2019;394:1713−23, doi:http://dx.doi.org/10.1016/S0140-6736(19) 32233-0.

360. Menon K, McNally D, Choong K, Sampson M. A systematic review and meta-analysis on the effect of steroids in pediatric shock. Pediatr Crit Care Med 2013;14:474−80, doi:http://dx.doi.org/10.1097/PCC.0b013e31828a8125.

361. El-Nawawy A, Khater D, Omar H, Wali Y. Evaluation of early corticosteroid therapy in management of pediatric septic shock in pediatric intensive care patients: a randomized clinical study. Pediatr Infect Dis J 2017;36:155−9, doi:http://dx.doi.org/10.1097/INF.0000000000001380.

362. Wong HR, Cvijanovich NZ, Anas N, et al. Endotype transitions during the acute phase of pediatric septic shock reflect changing risk and treatment response. Crit Care Med 2018;46:e242−9, doi:http://dx.doi.org/10.1097/CCM.0000000000002932.

363. Wong HR, Atkinson SJ, Cvijanovich NZ, et al. Combining prognostic and predictive enrichment strategies to identify children with septic shock responsive to corticosteroids. Crit Care Med 2016;44:e1000−3, doi:http://dx.doi.org/10.1097/CCM.0000000000001833.

364. Nichols B, Kubis S, Hewlett J, Yehya N, Srinivasan V. Hydrocortisone therapy in catecholamine-resistant pediatric septic shock: a pragmatic analysis of clinician practice and association with outcomes. Pediatr Crit Care Med 2017;18:e406−14, doi:http://dx.doi.org/10.1097/PCC.0000000000001237.

365. Menon K, McNally JD, Choong K, et al. A cohort study of pediatric shock: frequency of corticosteriod use and association with clinical outcomes. Shock 2015;44:402−9, doi:http://dx.doi.org/10.1097/SHK.0000000000000355.

366. Atkinson SJ, Cvijanovich NZ, Thomas NJ, et al. Corticosteroids and pediatric septic shock outcomes: a risk stratified analysis. PLOS ONE 2014;9:e112702, doi:http://dx.doi.org/10.1371/journal.pone.0112702.

367. Cooney L, Hawcutt D, Sinha I. The evidence for intravenous theophylline levels between 10−20mg/l in children suffering an acute exacerbation of asthma: a systematic review. PLOS ONE 2016;11:e0153877, doi:http://dx.doi.org/10.1371/journal.pone.0153877.

368. Cooney L, Sinha I, Hawcutt D. Aminophylline dosage in asthma exacerbations in children: a systematic review. PLOS ONE 2016;11:e0159965, doi:http://dx.doi.org/10.1371/journal.pone.0159965.

369. Mathew JL. Systematic review on efficacy of magnesium (intravenous or nebulized) for acute asthma episodes in children: evidence-based medicine viewpoint. Indian Pediatr 2017;54:133−6, doi:http://dx.doi.org/10.1007/s13312-017-1016-3.

370. Vezina K, Chauhan BF, Ducharme FM. Inhaled anticholinergics and short-acting beta(2)-agonists versus short-acting beta2-agonists alone for children with acute asthma in hospital. Cochrane Database Syst Rev 2014;CD010283, doi:http://dx.doi.org/10.1002/14651858.CD010283.pub2.

371. Knightly R, Milan SJ, Hughes R, et al. Inhaled magnesium sulfate in the treatment of acute asthma. Cochrane Database Syst Rev 2017;11:CD003898, doi:http://dx.doi.org/10.1002/14651858.CD003898.pub6.

372. Keeney GE, Gray MP, Morrison AK, et al. Dexamethasone for acute asthma exacerbations in children: a meta- analysis. Pediatrics 2014;133:493−9, doi:http://dx.doi.org/10.1542/peds.2013-2273.

373. Silva Pde S, Barreto SS. Noninvasive ventilation in status asthmaticus in children: levels of evidence. Rev Bras Ter Intensiva 2015;27:390−6, doi:http://dx.doi.org/10.5935/0103-507X.20150065.

374. Liu X, Yu T, Rower JE, Campbell SC, Sherwin CM, Johnson MD. Optimizing the use of intravenous magnesium sulfate for acute asthma treatment in children. Pediatr Pulmonol 2016;51:1414−21, doi:http://dx.doi.org/10.1002/ppul.23482.

375. Hon KLE, Leung AKC. Medications and recent patents for status asthmaticus in children. Recent Pat Inflamm Allergy Drug Discov 2017;11:12−21, doi:http://dx.doi.org/10.2174/1872213X11666170130143524.

376. Pardue Jones B, Fleming GM, Otillio JK, Asokan I, Arnold DH. Pediatric acute asthma exacerbations: evaluation and management from emergency department to intensive care unit. J Asthma 2016;53:607−17, doi:http://dx.doi.org/10.3109/02770903.2015.1067323.

377. Tiwari A, Guglani V, Jat KR. Ketamine versus aminophylline for acute asthma in children: a randomized, controlled trial. Ann Thorac Med 2016;11:283−8, doi:http://dx.doi.org/10.4103/1817- 1737.191874.

378. Cronin JJ, McCoy S, Kennedy U, et al. A randomized trial of single-dose oral dexamethasone versus multidose prednisolone for acute exacerbations of asthma in children who attend the emergency department. Ann Emerg Med 201667:, doi:http://dx.doi.org/10.1016/j.annemergmed.2015.08.001 593−601 e3.

379. Paniagua N, Lopez R, Munoz N, et al. Randomized trial of dexamethasone versus prednisone for children with acute asthma exacerbations. J Pediatr 2017191:, doi:http://dx.doi.org/10.1016/j.jpeds.2017.08.030 190−196 e1.

380. Alangari AA, Malhis N, Mubasher M, et al. Budesonide nebulization added to systemic prednisolone in the treatment of acute asthma in children: a double-blind, randomized, controlled trial. Chest 2014;145:772−8, doi:http://dx.doi.org/10.1378/chest.13- 2298.

381. Muchao FP, Souza JM, Torres HC, et al. Albuterol via metered-dose inhaler in children: lower doses are effective, and higher doses are safe. Pediatr Pulmonol 2016;51:1122−30, doi:http://dx.doi.org/10.1002/ppul.23469.

382. Arulparithi CS, Babu TA, Ravichandran C, et al. Efficacy of nebulised budesonide versus oral prednisolone in acute severe asthma. Indian J Pediatr 2015;82:328−32, doi:http://dx.doi.org/10.1007/s12098-014-1498-0.

383. Iramain R, Castro- Rodriguez JA, Jara A, et al. Salbutamol and ipratropium by inhaler is superior to nebulizer in children with severe acute asthma exacerbation: randomized clinical trial. Pediatr Pulmonol 2019;54:372−7, doi:http://dx.doi.org/10.1002/ppul.24244.

384. Cundiff KM, Gerard JM, Flood RG. Critical care interventions for asthmatic patients admitted from the emergency department to the pediatric intensive care unit. Pediatr Emerg Care 2018;34:385−9, doi:http://dx.doi.org/10.1097/PEC.0000000000001163.

385. Hudgins JD, Neuman MI, Monuteaux MC, Porter J, Nelson KA. Provision of guideline-based pediatric asthma care in us emergency departments. Pediatr Emerg Care 2019, doi:http://dx.doi.org/10.1097/PEC.0000000000001706.

386. Golden C, Xu M, Estrada CM, Arnold DH. Clinical outcomes after bilevel positive airway pressure treatment for acute asthma exacerbations. JAMA Pediatr 2015;169:186−8, doi:http://dx.doi.org/10.1001/jamapediatrics.2014.2767.

387. Rehder KJ. Adjunct therapies for refractory status asthmaticus in children. Respir Care 2017;62:849−65, doi:http://dx.doi.org/10.4187/respcare.05174.

388. Wisecup S, Eades S, Hashmi SS, Samuels C, Mosquera RA. Diastolic hypotension in pediatric patients with asthma receiving continuous albuterol. J Asthma 2015;52:693−8, doi:http://dx.doi.org/10.3109/02770903.2014.1002566.

389. Male I, Richter H, Seddon P. Children's perception of breathlessness in acute asthma. Arch Dis Child 2000;83:325−9, doi:http://dx.doi.org/10.1136/adc.83.4.325.

390. Cates CJ, Welsh EJ, Rowe BH. Holding chambers (spacers) versus nebulisers for beta-agonist treatment of acute asthma. Cochrane Database Syst Rev 2013;CD000052, doi:http://dx.doi.org/10.1002/14651858.CD000052.pub3.

391. Watts K, Chavasse RJ. Leukotriene receptor antagonists in addition to usual care for acute asthma in adults and children. Cochrane Database Syst Rev 2012;CD006100, doi:http://dx.doi.org/10.1002/14651858.CD006100.pub2.

392. Griffiths B, Ducharme FM. Combined inhaled anticholinergics and short-acting beta2-agonists for initial treatment of acute asthma in children. Cochrane Database Syst Rev 2013;CD000060, doi:http://dx.doi.org/10.1002/14651858.CD000060.pub2.

393. Edmonds ML, Milan SJ, Camargo Jr. CA, Pollack CV, Rowe BH. Early use of inhaled corticosteroids in the emergency department treatment of acute asthma. Cochrane Database Syst Rev 2012;12:CD002308, doi:http://dx.doi.org/10.1002/14651858.CD002308.pub2.

394. Jat KR, Chawla D. Ketamine for management of acute exacerbations of asthma in children. Cochrane Database Syst Rev 2012;11:CD009293, doi:http://dx.doi.org/10.1002/14651858.CD009293.pub2.

395. Le Conte P, Terzi N, Mortamet G, et al. Management of severe asthma exacerbation: guidelines from the Societe Francaise de Medecine d'Urgence, the societe de reanimation de langue francaise and the french group for pediatric intensive care and emergencies. Ann Intensive Care 2019;9:115, doi:http://dx.doi.org/10.1186/s13613-019-0584- x.

396. Wei J, Lu Y, Han F, Zhang J, Liu L, Chen Q. Oral dexamethasone vs. oral prednisone for children with acute asthma exacerbations: a systematic review and meta-analysis. Front Pediatr 2019;7:503, doi:http://dx.doi.org/10.3389/fped.2019.00503.

397. Murphy KR, Hong JG, Wandalsen G, et al. Nebulized inhaled corticosteroids in asthma treatment in children 5 years or younger: a systematic review and global expert analysis. J Allergy Clin Immunol Pract 2020;8:1815−27, doi:http://dx.doi.org/10.1016/j.jaip.2020.01.042.

398. Liedtke AG, Lava SAG, Milani GP, et al. Selective ss2-adrenoceptor agonists and relevant hyperlactatemia: systematic review and meta-analysis. J Clin Med 20199:, doi:http://dx.doi.org/10.3390/jcm9010071.

399. Kwon JW. High-flow nasal cannula oxygen therapy in children: a clinical review. Clin Exp Pediatr 2020;63:3−7, doi:http://dx.doi.org/10.3345/kjp.2019.00626.

400. Katsunuma T, Fujisawa T, Maekawa T, et al. Low-dose l-isoproterenol versus salbutamol in hospitalized pediatric patients with severe acute exacerbation of asthma: a double-blind, randomized controlled trial. Allergol Int 2019;68:335−41, doi:http://dx.doi.org/10.1016/j.alit.2019.02.001.

401. Graff DM, Stevenson MD, Berkenbosch JW. Safety of prolonged magnesium sulfate infusions during treatment for severe pediatric status asthmaticus. Pediatr Pulmonol 2019;54:1941−7, doi:http://dx.doi.org/10.1002/ppul.24499.

402. Messer AF, Sampayo EM, Mothner B, et al. Continuous albuterol in pediatric acute care: study demonstrates safety outside the intensive care unit. Pediatr Qual Saf 2019;4:e225, doi:http://dx.doi.org/10.1097/pq9.0000000000000225.

403. Boeschoten S, de Hoog M, Kneyber M, Merkus P, Boehmer A, Buysse C. Current practices in children with severe acute asthma across European PICUs: an ESPNIC survey. Eur J Pediatr 2020;179:455−61, doi:http://dx.doi.org/10.1007/s00431-019-03502- 9.

404. Kapuscinski CA, Stauber SD, Hutchinson DJ. Escalation in therapy based on intravenous magnesium sulfate dosing in pediatric patients with asthma exacerbations. J Pediatr Pharmacol Ther 2020;25:314−9, doi:http://dx.doi.org/10.5863/1551-6776-25.4.314.

405. Lott CT, Alfonzo AA, Barelli A, González-Salvado V, Hinkelbein J, Nolan JP, et al. European resuscitation council guidelines 2021: cardiac arrest in special circumstances. Resuscitation 2021161:.

406. Muraro A, Roberts G, Worm M, et al. Anaphylaxis: guidelines from the European academy of allergy and clinical immunology. Allergy: Eur J Allergy Clin Immunol 2014;69:1026−45, doi:http://dx.doi.org/10.1111/all.12437.

407. Simons FE, Ardusso LR, Bilo MB, et al. International consensus on (ICON) anaphylaxis. World Allergy Organ J 2014;7:9, doi:http://dx.doi.org/10.1186/1939-4551-7-9.

408. Simons FE, Ebisawa M, Sanchez-Borges M, et al. 2015 update of the evidence base: World Allergy Organization anaphylaxis guidelines. World Allergy Organ J 2015;8:32, doi:http://dx.doi.org/10.1186/s40413-015-0080- 1.

409. Shaker MS, Wallace DV, Golden DBK, et al. Anaphylaxis-a 2020 practice parameter update, systematic review, and Grading of Recommendations, Assessment, Development and Evaluation (GRADE) analysis. J Allergy Clin Immunol 2020;145:1082−123, doi:http://dx.doi.org/10.1016/j.jaci.2020.01.017.

410. Sicherer SH, Simons FER. Section on a, immunology. epinephrine for first-aid management of anaphylaxis. Pediatrics 2017139:, doi:http://dx.doi.org/10.1542/peds.2016- 4006.

411. Halbrich M, Mack DP, Carr S, Watson W, Kim H. CSACI position statement: epinephrine auto-injectors and children <15kg. Allergy Asthma Clin Immunol 2015;11:20, doi:http://dx.doi.org/10.1186/s13223-015- 0086-9.

412. Lieberman P, Nicklas RA, Randolph C, et al. Anaphylaxis–a practice parameter update 2015. Ann Allergy Asthma Immunol 2015;115:341−84, doi:http://dx.doi.org/10.1016/j.anai.2015.07.019.

413. Campbell RL, Li JT, Nicklas RA, Sadosty AT, Members of the Joint Task F, Practice Parameter W. Emergency department diagnosis and treatment of anaphylaxis: a practice parameter. Ann Allergy Asthma Immunol 2014;113:599−608, doi:http://dx.doi.org/10.1016/j.anai.2014.10.007.

414. Atanaskovic-Markovic M, Gomes E, Cernadas JR, et al. Diagnosis and management of drug-induced anaphylaxis in children: an EAACI position paper. Pediatr Allergy Immunol 2019;30:269−76, doi:http://dx.doi.org/10.1111/pai.13034.

415. Turner PJ, Worm M, Ansotegui IJ, et al. Time to revisit the definition and clinical criteria for anaphylaxis? World Allergy Organ J 2019;12:100066, doi:http://dx.doi.org/10.1016/j.waojou.2019.100066.

416. Resuscitation AaNZCo. First Aid Management of Anaphylaxis. Australian Resuscitation Council. (https://resus.org.au/editorial-changes- guidelines/).

417. Liyanage CK, Galappatthy P, Seneviratne SL. Corticosteroids in management of anaphylaxis; a systematic review of evidence. Eur Ann Allergy Clin Immunol 2017;49:196−207, doi:http://dx.doi.org/10.23822/EurAnnACI.1764-1489.15.

418. Pourmand A, Robinson C, Syed W, Mazer-Amirshahi M. Biphasic anaphylaxis: a review of the literature and implications for emergency management. Am J Emerg Med 2018;36:1480−5, doi:http://dx.doi.org/10.1016/j.ajem.2018.05.009.

419. Alqurashi W, Ellis AK. Do corticosteroids prevent biphasic anaphylaxis? J Allergy Clin Immunol Pract 2017;5:1194−205, doi:http://dx.doi.org/10.1016/j.jaip.2017.05.022.

420. Wang Y, Allen KJ, Suaini NHA, McWilliam V, Peters RL, Koplin JJ. The global incidence and prevalence of anaphylaxis in children in the general population: a systematic review. Allergy: Eur J Allergy Clin Immunol 2019;74:1063−80, doi:http://dx.doi.org/10.1111/all.13732.

421. Posner LS, Camargo Jr. CA. Update on the usage and safety of epinephrine auto-injectors, 2017. Drug Healthc Patient Saf 2017;9:9 −18, doi:http://dx.doi.org/10.2147/DHPS.S121733.

422. Tanno LK, Alvarez- Perea A, Pouessel G. Therapeutic approach of anaphylaxis. Curr Opin Allergy Clin Immunol 2019;19:393−401, doi: http://dx.doi.org/10.1097/ACI.0000000000000539.

423. Anagnostou K. Anaphylaxis in children: epidemiology, risk factors and management. Curr Pediatr Rev 2018;14:180−6, doi:http://dx. doi.org/10.2174/1573396314666180507115115.

424. Farbman KS, Michelson KA. Anaphylaxis in children. Curr Opin Pediatr 2016;28:294−7, doi:http://dx.doi.org/10.1097/ MOP.0000000000000340.

425. Simons FE, Sampson HA. Anaphylaxis: unique aspects of clinical diagnosis and management in infants (birth to age 2 years). J Allergy Clin Immunol 2015;135:1125−31, doi:http://dx.doi.org/10.1016/j. jaci.2014.09.014.

426. Gabrielli S, Clarke A, Morris J, et al. Evaluation of prehospital management in a canadian emergency department anaphylaxis cohort. J Allergy Clin Immunol Pract 20197:, doi:http://dx.doi.org/ 10.1016/j.jaip.2019.04.018 2232−8 e3.

427. Krmpotic K, Weisser C, O'Hanley A, Soder C. Incidence and outcomes of severe anaphylaxis in paediatric patients in Atlantic Canada. J Pediatr Intensive Care 2019;8:113−6, doi:http://dx.doi. org/10.1055/s-0039-1683869.

428. Maa T, Scherzer DJ, Harwayne-Gidansky I, et al. Prevalence of Errors in Anaphylaxis in Kids (PEAK): a multicenter simulation-based study. J Allergy Clin Immunol Pract 20208:, doi:http://dx.doi.org/ 10.1016/j.jaip.2019.11.013 1239−46 e3.

429. Choi YJ, Kim J, Jung JY, Kwon H, Park JW. Underuse of epinephrine for pediatric anaphylaxis victims in the emergency department: a population-based study. Allergy Asthma Immunol Res 2019;11:529 −37, doi:http://dx.doi.org/10.4168/aair.2019.11.4.529.

430. Cohen N, Capua T, Pivko D, Ben-Shoshan M, Benor S, Rimon A. Trends in the diagnosis and management of anaphylaxis in a tertiary care pediatric emergency department. Ann Allergy Asthma Immunol 2018;121:348−52, doi:http://dx.doi.org/10.1016/j.anai.2018.06.033.

431. Ruiz Oropeza A, Lassen A, Halken S, Bindslev-Jensen C, Mortz CG. Anaphylaxis in an emergency care setting: a one year prospective study in children and adults. Scand J Trauma Resusc Emerg Med 2017;25:111, doi:http://dx.doi.org/10.1186/s13049-017-0402- 0.

432. Michelson KA, Monuteaux MC, Neuman MI. Glucocorticoids and hospital length of stay for children with anaphylaxis: a retrospective study. J Pediatr 2015167:, doi:http://dx.doi.org/10.1016/j. jpeds.2015.05.033 719−24 e1−3.

433. Fleming JT, Clark S, Camargo Jr. CA, Rudders SA. Early treatment of food-induced anaphylaxis with epinephrine is associated with a lower risk of hospitalization. J Allergy Clin Immunol Pract 2015;3:57−62, doi:http://dx.doi.org/10.1016/j.jaip.2014.07.004.

434. van der Valk JPM, Berends I, Gerth van Wijk R, et al. Small percentage of anaphylactic reactions treated with epinephrine during food challenges in Dutch children. Ann Allergy Asthma Immunol 2018;120:300−3, doi:http://dx.doi.org/10.1016/j.anai.2017.08.018.

435. Ninchoji T, Iwatani S, Nishiyama M, et al. Current situation of treatment for anaphylaxis in a japanese pediatric emergency center. Pediatr Emerg Care 2018;34:e64−7, doi:http://dx.doi.org/10.1097/ PEC.0000000000000691.

436. Dubus JC, Le MS, Vitte J, et al. Use of epinephrine in emergency department depends on anaphylaxis severity in children. Eur J Pediatr 2019;178:69−75, doi:http://dx.doi.org/10.1007/s00431-018- 3246-3.

437. Sidhu N, Jones S, Perry T, et al. Evaluation of anaphylaxis management in a pediatric emergency department. Pediatr Emerg Care 2016;32:508−13, doi:http://dx.doi.org/10.1097/ PEC.0000000000000864.

438. Robinson M, Greenhawt M, Stukus DR. Factors associated with epinephrine administration for anaphylaxis in children before arrival to the emergency department. Ann Allergy Asthma Immunol 2017;119:164−9, doi:http://dx.doi.org/10.1016/j.anai.2017.06.001.

439. Latimer AJ, Husain S, Nolan J, et al. Syringe administration of epinephrine by emergency medical technicians for anaphylaxis. Prehosp Emerg Care 2018;22:319−25, doi:http://dx.doi.org/ 10.1080/10903127.2017.1392667.

440. Cristiano LM, Hiestand B, Caldwell JW, et al. Prehospital administration of epinephrine in pediatric anaphylaxis − a statewide perspective. Prehosp Emerg Care 2018;22:452−6, doi:http://dx.doi. org/10.1080/10903127.2017.1399184.

441. Carrillo E, Hern HG, Barger J. Prehospital administration of epinephrine in pediatric anaphylaxis. Prehosp Emerg Care 2016;20:239−44, doi:http://dx.doi.org/10.3109/ 10903127.2015.1086843.

442. Andrew E, Nehme Z, Bernard S, Smith K. Pediatric anaphylaxis in the prehospital setting: incidence, characteristics, and management. Prehosp Emerg Care 2018;22:445−51, doi:http://dx.doi.org/ 10.1080/10903127.2017.1402110.

443. Kim L, Nevis IF, Tsai G, et al. Children under 15kg with food allergy may be at risk of having epinephrine auto-injectors administered into bone. Allergy Asthma Clin Immunol 2014;10:40, doi:http://dx.doi.org/ 10.1186/1710-1492-10- 40.

444. Topal E, Bakirtas A, Yilmaz O, et al. Anaphylaxis in infancy compared with older children. Allergy Asthma Proc 2013;34:233−8, doi:http:// dx.doi.org/10.2500/aap.2013.34.3658.

445. Grabenhenrich LB, Dolle S, Moneret-Vautrin A, et al. Anaphylaxis in children and adolescents: the European anaphylaxis registry. J Allergy Clin Immunol 2016137:, doi:http://dx.doi.org/10.1016/j. jaci.2015.11.015 1128−37 e1.

446. Loprinzi Brauer CE, Motosue MS, Li JT, et al. Prospective validation of the NIAID/FAAN criteria for emergency department diagnosis of anaphylaxis. J Allergy Clin Immunol Pract 2016;4:1220−6, doi:http:// dx.doi.org/10.1016/j.jaip.2016.06.003.

447. Mintegi S, Azkunaga B, Prego J, et al. International epidemiological differences in acute poisonings in pediatric emergency departments. Pediatr Emerg Care 2019;35:50−7, doi:http://dx.doi.org/10.1097/ PEC.0000000000001031.

448. Avau B, Borra V, Vanhove AC, Vandekerckhove P, De Paepe P, De Buck E. First aid interventions by laypeople for acute oral poisoning. Cochrane Database Syst Rev 2018;12:CD013230, doi:http://dx.doi. org/10.1002/14651858.CD013230.

449. Mintegi S, Dalziel SR, Azkunaga B, et al. International variability in gastrointestinal decontamination with acute poisonings. Pediatrics 2017140:, doi:http://dx.doi.org/10.1542/peds.2017-0006.

450. Quinn N, Palmer CS, Bernard S, Noonan M, Teague WJ. Thoracostomy in children with severe trauma: an overview of the paediatric experience in Victoria, Australia. EMA − Emerg Med Australas 2020;32:117−26, doi:http://dx.doi.org/10.1111/1742- 6723.13392.

451. Terboven T, Leonhard G, Wessel L, et al. Chest wall thickness and depth to vital structures in paediatric patients − implications for prehospital needle decompression of tension pneumothorax. Scand J Trauma Resusc Emerg Med 2019;27:45, doi:http://dx.doi.org/ 10.1186/s13049-019-0623-5.

452. Leonhard G, Overhoff D, Wessel L, et al. Determining optimal needle size for decompression of tension pneumothorax in children − a CT-based study. Scand J Trauma Resusc Emerg Med 2019;27:90, doi: http://dx.doi.org/10.1186/s13049-019-0671- x.

808. American College of Surgeons Committee on Trauma. Advanced Trauma Life Support® Student Course Manual. 10th Edition Chicago, US: American College of Surgeons; 2018 ISBN 78-0- 9968262-3-5.

453. Pelland-Marcotte MC, Tucker C, Klaassen A, et al. Outcomes and risk factors of massive and submassive pulmonary embolism in children: a retrospective cohort study. Lancet Haematol 2019;6:e144 −53, doi:http://dx.doi.org/10.1016/S2352-3026(18)30224-2.

454. Morgan JK, Brown J, Bray RM. Resilience as a moderating factor between stress and alcohol-related consequences in the Army National Guard. Addict Behav 2018;80:22−7, doi:http://dx.doi.org/10.1016/j.addbeh.2018.01.002.

455. Belsky J, Warren P, Stanek J, Kumar R. Catheter-directed thrombolysis for submassive pulmonary embolism in children: a case series. Pediatr Blood Cancer 2020;67:e28144, doi:http://dx.doi.org/10.1002/pbc.28144.

456. Akam-Venkata J, Forbes TJ, Schreiber T, et al. Catheter-directed therapy for acute pulmonary embolism in children. Cardiol Young 2018;1−7, doi:http://dx.doi.org/10.1017/S1047951118002135.

457. Kayashima K. Factors affecting survival in pediatric cardiac tamponade caused by central venous catheters. J Anesth 2015;29:944−52, doi:http://dx.doi.org/10.1007/s00540-015-2045-5.

458. Jat KR, Lodha R, Kabra SK. Arrhythmias in children. Indian J Pediatr 2011;78:211−8, doi:http://dx.doi.org/10.1007/s12098-010-0276-x.

459. Baruteau AE, Perry JC, Sanatani S, Horie M, Dubin AM. Evaluation and management of bradycardia in neonates and children. Eur J Pediatr 2016;175:151−61, doi:http://dx.doi.org/10.1007/s00431-015-2689-z.

460. Eisa L, Passi Y, Lerman J, Raczka M, Heard C. Do small doses of atropine (<0.1mg) cause bradycardia in young children? Arch Dis Child 2015;100:684−8, doi:http://dx.doi.org/10.1136/archdischild-2014-307868.

461. Brugada J, Blom N, Sarquella-Brugada G, et al. Pharmacological and non-pharmacological therapy for arrhythmias in the pediatric population: EHRA and AEPC-Arrhythmia Working Group joint consensus statement. Europace 2013;15:1337−82, doi:http://dx.doi.org/10.1093/europace/eut082.

462. Brugada J, Katritsis DG, Arbelo E, et al. 2019 ESC Guidelines for the management of patients with supraventricular tachycardia the task force for the management of patients with supraventricular tachycardia of the European Society of Cardiology (ESC). Eur Heart J 2020;41:655−720, doi:http://dx.doi.org/10.1093/eurheartj/ehz467.

463. BET 1: Intraosseous adenosine for the termination of paroxysmal supraventricular tachycardia in children. Emerg Med 2014;31:604−5, doi:http://dx.doi.org/10.1136/emermed-2014-203947.1.

464. Quail MA, Till J. Question 3 Does a higher initial dose of adenosine improve cardioversion rates in supraventricular tachycardia? Arch Dis Child 2012;97:177−9, doi:http://dx.doi.org/10.1136/archdischild-2011- 301079.

465. Campbell M, Buitrago SR. BET 2: Ice water immersion, other vagal manoeuvres or adenosine for SVT in children. Emerg Med 2017;34:58−60, doi:http://dx.doi.org/10.1136/emermed-2016-206487.2.

466. Richardson C, Silver ES. Management of supraventricular tachycardia in infants. Paediatr Drugs 2017;19:539−51, doi:http://dx.doi.org/10.1007/s40272-017-0254-0.

467. Bronzetti G, Brighenti M, Mariucci E, et al. Upside-down position for the out of hospital management of children with supraventricular tachycardia. Int J Cardiol 2018;252:106−9, doi:http://dx.doi.org/10.1016/j.ijcard.2017.10.120.

468. Gill BU, Bukhari SN, Rashid MA, Saleemi MS, Zaffar MZ. Comparing the efficacy of intravenous adenosine and verapamil in termination of acute paroxysmal supra ventricular tachycardia. J Ayub Med Coll Abbottabad 2014;26:29−31 (https://www.ncbi.nlm.nih.gov/pubmed/25358211).

469. Clausen H, Theophilos T, Jackno K, Babl FE. Paediatric arrhythmias in the emergency department. Emerg Med 2012;29:732−7, doi:http://dx.doi.org/10.1136/emermed-2011-200242.

470. Chrysostomou C, Morell VO, Wearden P, Sanchez-de-Toledo J, Jooste EH, Beerman L. Dexmedetomidine: therapeutic use for the termination of reentrant supraventricular tachycardia. Congenit Heart Dis 2013;8:48−56, doi:http://dx.doi.org/10.1111/j.1747-0803.2012.00669.x.

471. Moffett BS, Lupo PJ, delaUz CM, et al. Efficacy of digoxin in comparison with propranolol for treatment of infant supraventricular tachycardia: analysis of a large, national database. Cardiol Young 2015;25:1080−5, doi:http://dx.doi.org/10.1017/S1047951114001619.

472. Qureshi AU, Hyder SN, Sheikh AM, Sadiq M. Optimal dose of adenosine effective for supraventricular tachycardia in children. J Coll Physicians Surg Pak 2012;22:648−51, doi:http://dx.doi.org/10.2012/JCPSP.648651.

473. Chu PY, Hill KD, Clark RH, Smith PB, Hornik CP. Treatment of supraventricular tachycardia in infants: analysis of a large multicenter database. Early Hum Dev 2015;91:345−50, doi:http://dx.doi.org/10.1016/j.earlhumdev.2015.04.001.

474. Diaz-Parra S, Sanchez- Yanez P, Zabala-Arguelles I, et al. Use of adenosine in the treatment of supraventricular tachycardia in a pediatric emergency department. Pediatr Emerg Care 2014;30:388−93, doi:http://dx.doi.org/10.1097/PEC.0000000000000144.

475. Morello ML, Khoury PR, Knilans TK, et al. Risks and outcomes of direct current cardioversion in children and young adults with congenital heart disease. Pacing Clin Electrophysiol 2018;41:472−9, doi:http://dx.doi.org/10.1111/pace.13315.

476. Lewis J, Arora G, Tudorascu DL, Hickey RW, Saladino RA, Manole MD. Acute management of refractory and unstable pediatric supraventricular tachycardia. J Pediatr 2017181:, doi:http://dx.doi.org/10.1016/j.jpeds.2016.10.051 177−82 e2.

477. Kim JH, Jung JY, Lee SU, Park JW, Choi JY. Delayed adenosine therapy is associated with the refractory supraventricular tachycardia in children. Am J Emerg Med 2020;38:2291−6, doi:http://dx.doi.org/10.1016/j.ajem.2019.10.018.

478. Weberding NT, Saladino RA, Minnigh MB, et al. Adenosine administration with a stopcock technique delivers lower-than-intended drug doses. Ann Emerg Med 2018;71:220−4, doi:http://dx.doi.org/10.1016/j.annemergmed.2017.09.002.

479. Palatinus JA, Lieber SB, Joyce KE, Richards JB. Extracorporeal membrane oxygenation support for hypokalemia- induced cardiac arrest: a case report and review of the literature. J Emerg Med 2015;49:159−64, doi:http://dx.doi.org/10.1016/j.jemermed.2015.02.046.

480. Rehman Siddiqu NU, Merchant Q, Hasan BS, et al. Comparison of enteral versus intravenous potassium supplementation in hypokalaemia in paediatric patients in intensive care post cardiac surgery: open-label randomised equivalence trial (EIPS). BMJ Open 2017;7:e011179, doi:http://dx.doi.org/10.1136/bmjopen-2016-011179.

481. Amirnovin R, Lieu P, Imperial-Perez F, Taketomo C, Markovitz BP, Moromisato DY. Safety, efficacy, and timeliness of intravenous potassium chloride replacement protocols in a pediatric cardiothoracic intensive care unit. J Intensive Care Med 2020;35:371−7, doi:http://dx.doi.org/10.1177/0885066617752659.

482. Knudson JD, Lowry AW, Price JF, Moffett BS. Response to intravenous potassium chloride supplementation in pediatric cardiac intensive care patients. Pediatr Cardiol 2013;34:887−92, doi:http://dx.doi.org/10.1007/s00246-012-0565-4.

483. Varallo FR, Trombotto V, Lucchetta RC, Mastroianni PC. Efficacy and safety of the pharmacotherapy used in the management of hyperkalemia: a systematic review. Pharm Pract (Granada) 2019;17:1361, doi:http://dx.doi.org/10.18549/PharmPract.2019.1.1361.

484. Depret F, Peacock WF, Liu KD, Rafique Z, Rossignol P, Legrand M. Management of hyperkalemia in the acutely ill patient. Ann Intensive Care 2019;9:32, doi:http://dx.doi.org/10.1186/s13613-019-0509-8.

485. Chime NO, Luo X, McNamara L, Nishisaki A, Hunt EA. A survey demonstrating lack of consensus on the sequence of medications for treatment of hyperkalemia among pediatric critical care providers. Pediatr Crit Care Med 2015;16:404−9, doi:http://dx.doi.org/10.1097/PCC.0000000000000384.

486. Howard-Quijano KJ, Stiegler MA, Huang YM, Canales C, Steadman RH. Anesthesiology residents' performance of pediatric resuscitation during a simulated hyperkalemic cardiac arrest. Anesthesiology 2010;112:993−7, doi:http://dx.doi.org/10.1097/ALN.0b013e3181d31fbe.

487. Arnholt AM, Duval- Arnould JM, McNamara LM, Rosen MA, Singh K, Hunt EA. Comparatively evaluating medication preparation sequences for treatment of hyperkalemia in pediatric cardiac arrest: a prospective, randomized, simulation-based study. Pediatr Crit Care Med 2015;16:e224−30, doi:http://dx.doi.org/10.1097/PCC.0000000000000497.

488. Lee J, Moffett BS. Treatment of pediatric hyperkalemia with sodium polystyrene sulfonate. Pediatr Nephrol 2016;31:2113−7, doi:http://dx.doi.org/10.1007/s00467-016-3414-5.

489. Abraham MB, Jones TW, Naranjo D, et al. ISPAD clinical practice consensus guidelines 2018: assessment and management of hypoglycemia in children and adolescents with diabetes. Pediatr Diabetes 2018;19:178−92, doi:http://dx.doi.org/10.1111/pedi.12698.

490. Weston PJ, Harris DL, Battin M, Brown J, Hegarty JE, Harding JE. Oral dextrose gel for the treatment of hypoglycaemia in newborn infants. Cochrane Database Syst Rev 2016;CD011027, doi:http://dx.doi.org/10.1002/14651858.CD011027.pub2.

491. De Buck E, Borra V, Carlson JN, Zideman DA, Singletary EM, Djarv T. First aid glucose administration routes for symptomatic hypoglycaemia. Cochrane Database Syst Rev 2019;4:CD013283, doi:http://dx.doi.org/10.1002/14651858.CD013283.pub2.

492. Kim SY. Endocrine and metabolic emergencies in children: hypocalcemia, hypoglycemia, adrenal insufficiency, and metabolic acidosis including diabetic ketoacidosis. Ann Pediatr Endocrinol Metab 2015;20:179−86, doi:http://dx.doi.org/10.6065/apem.2015.20.4.179.

493. Rostykus P, Kennel J, Adair K, et al. Variability in the treatment of prehospital hypoglycemia: a structured review of EMS protocols in the United States. Prehosp Emerg Care 2016;20:524−30, doi:http://dx.doi.org/10.3109/10903127.2015.1128031.

494. Remick K, Redgate C, Ostermayer D, Kaji AH, Gausche- Hill M. Prehospital glucose testing for children with seizures: a proposed change in management. Prehosp Emerg Care 2017;21:216−21, doi:http://dx.doi.org/10.1080/10903127.2016.1218979.

495. Walsh BM, Gangadharan S, Whitfill T, et al. Safety threats during the care of infants with hypoglycemic seizures in the emergency department: a multicenter, simulation-based prospective cohort study. J Emerg Med 201753:, doi:http://dx.doi.org/10.1016/j.jemermed.2017.04.028 467−74 e7.

496. Sherr JL, Ruedy KJ, Foster NC, et al. Glucagon nasal powder: a promising alternative to intramuscular glucagon in youth with type 1 diabetes. Diabetes Care 2016;39:555−62, doi:http://dx.doi.org/10.2337/dc15-1606.

497. Singletary EM, Zideman DA, Bendall JC, et al. 2020 international consensus on first aid science with treatment recommendations. Resuscitation 2020;156:A240−82, doi:http://dx.doi.org/10.1016/j.resuscitation.2020.09.016.

498. Lipman GS, Gaudio FG, Eifling KP, Ellis MA, Otten EM, Grissom CK. Wilderness medical society clinical practice guidelines for the prevention and treatment of heat illness: 2019 update. Wilderness Environ Med 2019;30:S33−46, doi:http://dx.doi.org/10.1016/j.wem.2018.10.004.

499. Tate RC, Selde W. Heat trap. How to treat vehicular hyperthermia in children. JEMS 201338: 36−8, 40, 42. (https://www.ncbi.nlm.nih.gov/pubmed/24159737).

500. Rosenberg H, Pollock N, Schiemann A, Bulger T, Stowell K. Malignant hyperthermia: a review. Orphanet J Rare Dis 2015;10:93, doi:http://dx.doi.org/10.1186/s13023-015-0310-1.

501. Jardine DS. Heat illness and heat stroke. Pediatr Rev 2007;28:249−58, doi:http://dx.doi.org/10.1542/pir.28-7-249.

502. Nelson P, Litman RS. Malignant hyperthermia in children: an analysis of the North American malignant hyperthermia registry. Anesth Analg 2014;118:369−74, doi:http://dx.doi.org/10.1213/ANE.0b013e3182a8fad0.

503. Adato B, Dubnov- Raz G, Gips H, Heled Y, Epstein Y. Fatal heat stroke in children found in parked cars: autopsy findings. Eur J Pediatr 2016;175:1249−52, doi:http://dx.doi.org/10.1007/s00431-016-2751-5.

504. Natsume J, Hamano SI, Iyoda K, et al. New guidelines for management of febrile seizures in Japan. Brain Dev 2017;39:2−9, doi:http://dx.doi.org/10.1016/j.braindev.2016.06.003.

505. Glauser T, Shinnar S, Gloss D, et al. Evidence-based guideline: treatment of convulsive status epilepticus in children and adults: report of the guideline committee of the American epilepsy society. Epilepsy Curr 2016;16:48−61, doi:http://dx.doi.org/10.5698/1535-7597-16.1.48.

506. Health NSW. Infants and Children − Acute Management of Seizures. New South Wales Health. (Accessed 07 June 2018, at https://www1.health.nsw.gov.au/pds/ActivePDSDocuments/GL2018_015.pdf).

507. Li L, Zhang Y, Jia L, et al. Levetiracetam versus phenytoin for the treatment of established status epilepticus: a systematic review and meta-analysis of randomized controlled trials. Seizure 2020;78:43−8, doi:http://dx.doi.org/10.1016/j.seizure.2020.03.002.

508. Chen D, Bian H, Zhang L. A meta-analysis of levetiracetam for randomized placebo-controlled trials in patients with refractory epilepsy. Neuropsychiatr Dis Treat 2019;15:905−17, doi:http://dx.doi.org/10.2147/NDT.S188111.

509. Sanchez Fernandez I, Gainza- Lein M, Lamb N, Loddenkemper T. Meta-analysis and cost-effectiveness of second-line antiepileptic drugs for status epilepticus. Neurology 2019;92:e2339−48, doi:http://dx.doi.org/10.1212/WNL.0000000000007503.

510. Brigo F, Bragazzi NL, Bacigaluppi S, Nardone R, Trinka E. Is intravenous lorazepam really more effective and safe than intravenous diazepam as first-line treatment for convulsive status epilepticus? A systematic review with meta-analysis of randomized controlled trials. Epilepsy Behav 2016;64:29−36, doi:http://dx.doi.org/10.1016/j.yebeh.2016.09.020.

511. Ortiz de la Rosa JS, Ladino LD, Rodriguez PJ, Rueda MC, Polania JP, Castaneda AC. Efficacy of lacosamide in children and adolescents with drug- resistant epilepsy and refractory status epilepticus: a systematic review. Seizure 2018;56:34−40, doi:http://dx.doi.org/10.1016/j.seizure.2018.01.014.

512. Uppal P, Cardamone M, Lawson JA. Outcomes of deviation from treatment guidelines in status epilepticus: a systematic review. Seizure 2018;58:147−53, doi:http://dx.doi.org/10.1016/j.seizure.2018.04.005.

513. Au CC, Branco RG, Tasker RC. Management protocols for status epilepticus in the pediatric emergency room: systematic review article. J Pediatr 2017;93:84−94, doi:http://dx.doi.org/10.1016/j.jped.2017.08.004.

514. Zhao ZY, Wang HY, Wen B, Yang ZB, Feng K, Fan JC. A Comparison of Midazolam, Lorazepam, and Diazepam for the treatment of status epilepticus in children: a network meta-analysis. J Child Neurol 2016;31:1093−107, doi:http://dx.doi.org/10.1177/0883073816638757.

515. Trinka E, Hofler J, Zerbs A, Brigo F. Efficacy and safety of intravenous valproate for status epilepticus: a systematic review. CNS Drugs 2014;28:623−39, doi:http://dx.doi.org/10.1007/s40263-014-0167-1.

516. Strzelczyk A, Zollner JP, Willems LM, et al. Lacosamide in status epilepticus: systematic review of current evidence. Epilepsia 2017;58:933−50, doi:http://dx.doi.org/10.1111/epi.13716.

517. Jain P, Sharma S, Dua T, Barbui C, Das RR, Aneja S. Efficacy and safety of anti-epileptic drugs in patients with active convulsive seizures when no IV access is available: systematic review and meta-analysis. Epilepsy Res 2016;122:47−55, doi:http://dx.doi.org/10.1016/j.eplepsyres.2016.02.006.

518. McTague A, Martland T, Appleton R. Drug management for acute tonic-clonic convulsions including convulsive status epilepticus in children. Cochrane Database Syst Rev 2018;1:CD001905, doi:http://dx.doi.org/10.1002/14651858.CD001905.pub3.

519. Alshehri A, Abulaban A, Bokhari R, et al. Intravenous versus nonintravenous benzodiazepines for the cessation of seizures: a systematic review and meta-analysis of randomized controlled trials. Acad Emerg Med 2017;24:875−83, doi:http://dx.doi.org/10.1111/acem.13190.

520. Sanchez Fernandez I, Goodkin HP, Scott RC. Pathophysiology of convulsive status epilepticus. Seizure 2019;68:16−21, doi:http://dx.doi.org/10.1016/j.seizure.2018.08.002.

521. Ciccone O, Mathews M, Birbeck GL. Management of acute seizures in children: a review with special consideration of care in resource-limited settings. Afr J Emerg Med 2017;7:S3−9, doi:http://dx.doi.org/10.1016/j.afjem.2017.09.003.

522. Silverman EC, Sporer KA, Lemieux JM, et al. Prehospital care for the adult and pediatric seizure patient: current evidence-based recommendations. West J Emerg Med 2017;18:419−36, doi:http://dx.doi.org/10.5811/westjem.2016.12.32066.

523. Lawton B, Davis T, Goldstein H, Tagg A. An update in the initial management of paediatric status epilepticus. Curr Opin Pediatr 2018;30:359−63, doi:http://dx.doi.org/10.1097/MOP.0000000000000616.

524. Stredny CM, Abend NS, Loddenkemper T. Towards acute pediatric status epilepticus intervention teams: do we need "Seizure Codes"? Seizure 2018;58:133−40, doi:http://dx.doi.org/10.1016/j.seizure.2018.04.011.

525. Smith DM, McGinnis EL, Walleigh DJ, Abend NS. Management of status epilepticus in children. J Clin Med 20165:, doi:http://dx.doi.org/10.3390/jcm5040047.

526. Kapur J, Elm J, Chamberlain JM, et al. Randomized trial of three anticonvulsant medications for status epilepticus. N Engl J Med 2019;381:2103−13, doi:http://dx.doi.org/10.1056/NEJMoa1905795.

527. Alansari K, Barkat M, Mohamed AH, Al Jawala SA, Othman SA. Intramuscular versus buccal midazolam for pediatric seizures: a randomized double-blinded trial. Pediatr Neurol 2020;109:28−34, doi:http://dx.doi.org/10.1016/j.pediatrneurol.2020.03.011.

528. Vignesh V, Rameshkumar R, Mahadevan S. Comparison of Phenytoin, Valproate and Levetiracetam in pediatric convulsive status epilepticus: a randomized double-blind controlled clinical trial. Indian Pediatr 2020;57:222−7 (https://www.ncbi.nlm.nih.gov/pubmed/32198861).

529. Chamberlain JM, Kapur J, Shinnar S, et al. Efficacy of levetiracetam, fosphenytoin, and valproate for established status epilepticus by age group (ESETT): a double-blind, responsive-adaptive, randomised controlled trial. Lancet 2020;395:1217−24, doi:http://dx.doi.org/10.1016/S0140-6736(20)30611-5.

530. Chamberlain DB, Chamberlain JM. Making sense of a negative clinical trial result: a bayesian analysis of a clinical trial of lorazepam and diazepam for pediatric status epilepticus. Ann Emerg Med 2017;69:117−24, doi:http://dx.doi.org/10.1016/j.annemergmed.2016.08.449.

531. Portela JL, Garcia PC, Piva JP, et al. Intramuscular midazolam versus intravenous diazepam for treatment of seizures in the pediatric emergency department: a randomized clinical trial. Med Intensiva 2015;39:160−6, doi:http://dx.doi.org/10.1016/j.medin.2014.04.003.

532. Singh K, Aggarwal A, Faridi MMA, Sharma S. IV Levetiracetam versus IV phenytoin in childhood seizures: a randomized controlled trial. J Pediatr Neurosci 2018;13:158−64, doi:http://dx.doi.org/10.4103/jpn.JPN_126_17.

533. Khajeh A, Yaghoubinia F, Yaghoubi S, Fayyazi A, Miri Aliabad G. Comparison of the effect of phenobarbital versus sodium valproate in management of children with status epilepticus. Iran J Child Neurol 2018;12:85−93 (https://www.ncbi.nlm.nih.gov/pubmed/30279711).

534. Lyttle MD, Rainford NEA, Gamble C, et al. Levetiracetam versus phenytoin for second-line treatment of paediatric convulsive status epilepticus (EcLiPSE): a multicentre, open-label, randomised trial. Lancet 2019;393:2125−34, doi:http://dx.doi.org/10.1016/S0140-6736(19)30724-X.

535. Birbeck GL, Herman ST, Capparelli EV, et al. A clinical trial of enteral Levetiracetam for acute seizures in pediatric cerebral malaria. BMC Pediatr 2019;19:399, doi:http://dx.doi.org/10.1186/s12887-019-1766-2.

Wani G, Imran A, Dhawan N, Gupta A, Giri JI. Levetiracetam versus phenytoin in children with status epilepticus. J Family Med Prim Care

536. 2019;8:3367−71, doi:http://dx.doi.org/10.4103/jfmpc.jfmpc_750_19.

537. Silbergleit R, Elm JJ. Levetiracetam no better than phenytoin in children with convulsive status epilepticus. Lancet 2019;393:2101−2, doi:http://dx.doi.org/10.1016/S0140-6736(19)30896-7.

538. Momen AA, Azizi Malamiri R, Nikkhah A, et al. Efficacy and safety of intramuscular midazolam versus rectal diazepam in controlling status epilepticus in children. Eur J Paediatr Neurol 2015;19:149−54, doi:http://dx.doi.org/10.1016/j.ejpn.2014.11.007.

539. Welch RD, Nicholas K, Durkalski-Mauldin VL, et al. Intramuscular midazolam versus intravenous lorazepam for the prehospital treatment of status epilepticus in the pediatric population. Epilepsia 2015;56:254−62, doi:http://dx.doi.org/10.1111/epi.12905.

540. Burman RJ, Ackermann S, Shapson-Coe A, Ndondo A, Buys H, Wilmshurst JM. A comparison of parenteral phenobarbital vs. parenteral phenytoin as second-line management for pediatric convulsive status epilepticus in a resource-limited setting. Front Neurol 2019;10:506, doi:http://dx.doi.org/10.3389/fneur.2019.00506.

541. Noureen N, Khan S, Khursheed A, et al. Clinical efficacy and safety of injectable levetiracetam versus phenytoin as second-line therapy in the management of generalized convulsive status epilepticus in children: an open-label randomized controlled trial. J Clin Neurol 2019;15:468−72, doi:http://dx.doi.org/10.3988/jcn.2019.15.4.468.

542. Dalziel SR, Borland ML, Furyk J, et al. Levetiracetam versus phenytoin for second-line treatment of convulsive status epilepticus in children (ConSEPT): an open-label, multicentre, randomised controlled trial. Lancet 2019;393:2135−45, doi:http://dx.doi.org/10.1016/S0140-6736(19)30722-6.

543. Chiarello D, Duranti F, Lividini A, et al. Clinical characterization of status epilepticus in childhood: a retrospective study in 124 patients. Seizure 2020;78:127−33, doi:http://dx.doi.org/10.1016/j.seizure.2020.03.019.

544. Wang T, Wang J, Dou Y, et al. Clinical characteristics and prognosis in a large paediatric cohort with status epilepticus. Seizure 2020;80:5−11, doi:http://dx.doi.org/10.1016/j.seizure.2020.04.001.

545. Sanchez Fernandez I, Abend NS, Agadi S, et al. Time from convulsive status epilepticus onset to anticonvulsant administration in children. Neurology 2015;84:2304−11, doi:http://dx.doi.org/10.1212/WNL.0000000000001673.

546. Lee YJ, Yum MS, Kim EH, Ko TS. Intravenous levetiracetam versus phenobarbital in children with status epilepticus or acute repetitive seizures. Korean J Pediatr 2016;59:35−9, doi:http://dx.doi.org/10.3345/kjp.2016.59.1.35.

547. Incecik F, Horoz OO, Herguner OM, et al. Intravenous levetiracetam in critically ill children. Ann Indian Acad Neurol 2016;19:79−82, doi:http://dx.doi.org/10.4103/0972-2327.167702.

548. Johnson PN, Nguyen A, Neely SB, Johnson M. Intramuscular lorazepam for status epilepticus in children with complex medical and physical disabilities. Ann Pharmacother 2017;51:656−62, doi:http://dx.doi.org/10.1177/1060028017706522.

549. Santhanam I, Yoganathan S, Sivakumar VA, Ramakrishnamurugan R, Sathish S, Thandavarayan M. Predictors of outcome in children with status epilepticus during resuscitation in pediatric emergency department: a retrospective observational study. Ann Indian Acad Neurol 2017;20:142−8, doi:http://dx.doi.org/10.4103/aian.AIAN_369_16.

550. Nishiyama M, Nagase H, Tomioka K, et al. Fosphenytoin vs. continuous midazolam for pediatric febrile status epilepticus. Brain Dev 2018;40:884−90, doi:http://dx.doi.org/10.1016/j.braindev.2018.08.001.

551. Ulusoy E, Duman M, Turker HD, et al. The effect of early midazolam infusion on the duration of pediatric status epilepticus patients. Seizure 2019;71:50−5, doi:http://dx.doi.org/10.1016/j.seizure.2019.06.011.

552. Theusinger OM, Schenk P, Dette-Oltmann K, Mariotti S, Baulig W. Treatment of seizures in children and adults in the emergency medical system of the city of Zurich, Switzerland − Midazolam vs.

Diazepam − a retrospective analysis. J Emerg Med 2019;57:345 −53, doi:http://dx.doi.org/10.1016/j.jemermed.2019.05.036.

553. Tasker RC, Goodkin HP, Sanchez Fernandez I, et al. Refractory status epilepticus in children: intention to treat with continuous infusions of Midazolam and Pentobarbital. Pediatr Crit Care Med 2016;17:968−75, doi:http://dx.doi.org/10.1097/PCC.0000000000000900.

554. Shtull-Leber E, Silbergleit R, Meurer WJ. Pre-hospital midazolam for benzodiazepine-treated seizures before and after the rapid anticonvulsant medication prior to arrival trial: a national observational cohort study. PLOS ONE 2017;12:e0173539, doi:http://dx.doi.org/10.1371/journal.pone.0173539.

555. Gurcharran K, Grinspan ZM. The burden of pediatric status epilepticus: epidemiology, morbidity, mortality, and costs. Seizure 2019;68:3−8, doi:http://dx.doi.org/10.1016/j.seizure.2018.08.021.

556. Isguder R, Guzel O, Ceylan G, Yilmaz U, Agin H. A comparison of intravenous levetiracetam and valproate for the treatment of refractory status epilepticus in children. J Child Neurol 2016;31:1120 −6, doi:http://dx.doi.org/10.1177/0883073816641187.

557. Olasveengen TM, Mancini ME, Perkins GD, et al. Adult basic life support: international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Resuscitation 2020;156:A35−79, doi:http://dx.doi.org/10.1016/j.resuscitation.2020.09.010.

558. Zhan L, Yang LJ, Huang Y, He Q, Liu GJ. Continuous chest compression versus interrupted chest compression for cardiopulmonary resuscitation of non-asphyxial out-of-hospital cardiac arrest. Cochrane Database Syst Rev 2017;3:CD010134, doi:http://dx.doi.org/10.1002/14651858.CD010134.pub2.

559. Maeda T, Yamashita A, Myojo Y, Wato Y, Inaba H. Augmented survival of out-of-hospital cardiac arrest victims with the use of mobile phones for emergency communication under the DA- CPR protocol getting information from callers beside the victim. Resuscitation 2016;107:80−7, doi:http://dx.doi.org/10.1016/j.resuscitation.2016.08.010.

560. Steensberg AT, Eriksen MM, Andersen LB, et al. Bystander capability to activate speaker function for continuous dispatcher assisted CPR in case of suspected cardiac arrest. Resuscitation 2017;115:52−5, doi:http://dx.doi.org/10.1016/j.resuscitation.2017.04.002.

561. Mortensen RB, Hoyer CB, Pedersen MK, Brindley PG, Nielsen JC. Comparison of the quality of chest compressions on a dressed versus an undressed manikin: a controlled, randomised, cross-over simulation study. Scand J Trauma Resusc Emerg Med 2010;18:16, doi:http://dx.doi.org/10.1186/1757-7241-18 -16.

562. Birkenes TS, Myklebust H, Kramer-Johansen J. Time delays and capability of elderly to activate speaker function for continuous telephone CPR. Scand J Trauma Resusc Emerg Med 2013;21:40, doi:http://dx.doi.org/10.1186/1757-7241-21-40.

563. Eisenberg Chavez D, Meischke H, Painter I, Rea TD. Should dispatchers instruct lay bystanders to undress patients before performing CPR? A randomized simulation study. Resuscitation 2013;84:979−81, doi:http://dx.doi.org/10.1016/j.resuscitation.2012.12.010.

564. Tobin JM, Ramos WD, Greenshields J, et al. Outcome of conventional bystander cardiopulmonary resuscitation in cardiac arrest following drowning. Prehosp Disaster Med 2020;35:141−7, doi:http://dx.doi.org/10.1017/S1049023X20000060.

565. Naim MY, Burke RV, McNally BF, et al. Association of bystander cardiopulmonary resuscitation with overall and neurologically favorable survival after pediatric out-of-hospital cardiac arrest in the united states: a report from the cardiac arrest registry to enhance survival surveillance registry. JAMA Pediatr 2017;171:133−41, doi:http://dx.doi.org/10.1001/jamapediatrics.2016.3643.

566. Fukuda T, Ohashi- Fukuda N, Kobayashi H, et al. Conventional versus compression-only versus no-bystander cardiopulmonary resuscitation for pediatric out-of-hospital cardiac arrest. Circulation 2016;134:2060−70, doi:http://dx.doi.org/10.1161/CIRCULATIONAHA.116.023831.

567. Sutton RM, Reeder RW, Landis WP, et al. Ventilation rates and pediatric in-hospital cardiac arrest survival outcomes. Crit Care Med 2019;47:1627−36, doi:http://dx.doi.org/10.1097/CCM.0000000000003898.

568. Derkenne C, Jost D, Thabouillot O, et al. Improving emergency call detection of out-of-hospital cardiac arrests in the greater paris area: efficiency of a global system with a new method of detection. Resuscitation 2020;146:34−42, doi:http://dx.doi.org/10.1016/j.resuscitation.2019.10.038.

569. Donoghue AJ, Kou M, Good GL, et al. Impact of personal protective equipment on pediatric cardiopulmonary resuscitation performance: a controlled trial. Pediatr Emerg Care 2020;36:267−73, doi:http://dx.doi.org/10.1097/PEC.0000000000002109.

570. De Maio VJ, Osmond MH, Stiell IG, et al. Epidemiology of out-of-hospital pediatric cardiac arrest due to trauma. Prehosp Emerg Care 2012;16:230−6, doi:http://dx.doi.org/10.3109/10903127.2011.640419.

571. Vassallo J, Webster M, Barnard EBG, Lyttle MD, Smith JE, Peruki. Epidemiology and aetiology of paediatric traumatic cardiac arrest in England and Wales. Arch Dis Child 2019;104:437−43, doi:http://dx.doi.org/10.1136/archdischild-2018-314985.

572. Deasy C, Bray J, Smith K, et al. Paediatric traumatic out-of-hospital cardiac arrests in Melbourne, Australia. Resuscitation 2012;83:471−5, doi:http://dx.doi.org/10.1016/j.resuscitation.2011.11.009.

573. Barnard EBG, Sandbach DD, Nicholls TL, Wilson AW, Ercole A. Prehospital determinants of successful resuscitation after traumatic and non-traumatic out-of- hospital cardiac arrest. Emerg Med 2019;36:333−9, doi:http://dx.doi.org/10.1136/emermed-2018-208165.

574. Lu CH, Fang PH, Lin CH. Dispatcher-assisted cardiopulmonary resuscitation for traumatic patients with out-of-hospital cardiac arrest. Scand J Trauma Resusc Emerg Med 2019;27:97, doi:http://dx.doi.org/10.1186/s13049-019-0679- 2.

575. Balhara KS, Bustamante ND, Selvam A, et al. Bystander assistance for trauma victims in low- and middle-income countries: a systematic review of prevalence and training interventions. Prehosp Emerg Care 2019;23:389−410, doi:http://dx.doi.org/10.1080/10903127.2018.1513104.

576. Lin CH, Chiang WC, Ma MH, Wu SY, Tsai MC, Chi CH. Use of automated external defibrillators in patients with traumatic out-of-hospital cardiac arrest. Resuscitation 2013;84:586−91, doi:http://dx.doi.org/10.1016/j.resuscitation.2012.09.028.

577. Tibballs J, Weeranatna C. The influence of time on the accuracy of healthcare personnel to diagnose paediatric cardiac arrest by pulse palpation. Resuscitation 2010;81:671−5, doi:http://dx.doi.org/10.1016/j.resuscitation.2010.01.030 [in Eng].

578. O'Connell KJ, Keane RR, Cochrane NH, et al. Pauses in compressions during pediatric CPR: Opportunities for improving CPR quality. Resuscitation 2019;145:158−65, doi:http://dx.doi.org/10.1016/j.resuscitation.2019.08.015.

579. Donoghue A, Berg RA, Hazinski MF, Praestgaard AH, Roberts K, Nadkarni VM. Cardiopulmonary resuscitation for bradycardia with poor perfusion versus pulseless cardiac arrest. Pediatrics 2009;124:1541−8, doi:http://dx.doi.org/10.1542/peds.2009-0727 [in Eng]. peds.2009-0727 [pii].

580. Considine J, Gazmuri RJ, Perkins GD, et al. Chest compression components (rate, depth, chest wall recoil and leaning): a scoping review. Resuscitation 2020;146:188−202, doi:http://dx.doi.org/10.1016/j.resuscitation.2019.08.042.

581. Manrique G, Gonzalez A, Iguiniz M, et al. Quality of chest compressions during pediatric resuscitation with 15:2 and 30:2 compressions-to-ventilation ratio in a simulated scenario. Sci Rep 2020;10:6828, doi:http://dx.doi.org/10.1038/s41598-020-63921-9.

582. Gregson RK, Cole TJ, Skellett S, Bagkeris E, Welsby D, Peters MJ. Randomised crossover trial of rate feedback and force during chest compressions for paediatric cardiopulmonary resuscitation. Arch Dis Child 2017;102:403−9, doi:http://dx.doi.org/10.1136/archdischild-2016-310691.

583. Kandasamy J, Theobald PS, Maconochie IK, Jones MD. Can real-time feedback improve the simulated infant cardiopulmonary resuscitation performance of basic life support and lay rescuers? Arch Dis Child 2019;104:793−801, doi:http://dx.doi.org/10.1136/archdischild-2018-316576.

584. Cheng A, Hunt EA, Grant D, et al. Variability in quality of chest compressions provided during simulated cardiac arrest across nine pediatric institutions. Resuscitation 2015;97:13−9, doi:http://dx.doi.org/10.1016/j.resuscitation.2015.08.024.

585. Zimmerman E, Cohen N, Maniaci V, Pena B, Lozano JM, Linares M. Use of a metronome in cardiopulmonary resuscitation: a simulation study. Pediatrics 2015;136:905−11, doi:http://dx.doi.org/10.1542/peds.2015- 1858.

586. Lin Y, Cheng A, Grant VJ, Currie GR, Hecker KG. Improving CPR quality with distributed practice and real-time feedback in pediatric healthcare providers − a randomized controlled trial. Resuscitation 2018;130:6−12, doi:http://dx.doi.org/10.1016/j.resuscitation.2018.06.025.

587. Haque IU, Udassi JP, Udassi S, Theriaque DW, Shuster JJ, Zaritsky AL. Chest compression quality and rescuer fatigue with increased compression to ventilation ratio during single rescuer pediatric CPR. Resuscitation 2008;79:82−9, doi:http://dx.doi.org/10.1016/j.resuscitation.2008.04.026 [in Eng]. S0300-9572(08)00463-2 [pii].

588. Sutton RM, Reeder RW, Landis W, et al. Chest compression rates and pediatric in-hospital cardiac arrest survival outcomes. Resuscitation 2018;130:159−66, doi:http://dx.doi.org/10.1016/j.resuscitation.2018.07.015.

589. Braga MS, Dominguez TE, Pollock AN, et al. Estimation of optimal CPR chest compression depth in children by using computer tomography. Pediatrics 2009;124:e69−74, doi:http://dx.doi.org/10.1542/peds.2009- 0153 [in Eng]. 124/1/e69 [pii].

590. Kao PC, Chiang WC, Yang CW, et al. What is the correct depth of chest compression for infants and children? A radiological study. Pediatrics 2009;124:49−55, doi:http://dx.doi.org/10.1542/peds.2008-2536 [in Eng]. 124/1/49 [pii].

591. Skogvoll E, Nordseth T, Sutton RM, et al. Factors affecting the course of resuscitation from cardiac arrest with pulseless electrical activity in children and adolescents. Resuscitation 2020;152:116−22, doi:http://dx.doi.org/10.1016/j.resuscitation.2020.05.013.

592. Lin CY, Hsia SH, Lee EP, Chan OW, Lin JJ, Wu HP. Effect of audiovisual cardiopulmonary resuscitation feedback device on improving chest compression quality. Sci Rep 2020;10:398, doi:http://dx.doi.org/10.1038/s41598-019-57320- y.

593. Donoghue AJ, Myers S, Kerrey B, et al. Analysis of CPR quality by individual providers in the pediatric emergency department. Resuscitation 2020;153:37−44, doi:http://dx.doi.org/10.1016/j.resuscitation.2020.05.026.

594. Jones SI, Jeffers JM, Perretta J, et al. Closing the gap: optimizing performance to reduce interruptions in cardiopulmonary resuscitation. Pediatr Crit Care Med 2020;21:e592−8, doi:http://dx.doi.org/10.1097/PCC.0000000000002345.

595. Rodriguez SA, Sutton RM, Berg MD, et al. Simplified dispatcher instructions improve bystander chest compression quality during simulated pediatric resuscitation. Resuscitation 2014;85:119−23, doi:http://dx.doi.org/10.1016/j.resuscitation.2013.09.003.

596. Kim YH, Lee JH, Cho KW, et al. Verification of the optimal chest compression depth for children in the 2015 american heart association guidelines: computed tomography study. Pediatr Crit Care Med 2018;19:e1−6, doi:http://dx.doi.org/10.1097/PCC.0000000000001369.

597. Austin AL, Spalding CN, Landa KN, et al. A randomized control trial of cardiopulmonary feedback devices and their impact on infant chest compression quality: a simulation study. Pediatr Emerg Care 2020;36:e79−84, doi:http://dx.doi.org/10.1097/PEC.0000000000001312.

598. Enriquez D, Firenze L, Fernandez Diaz J, et al. Changes in the depth of chest compressions during cardiopulmonary resuscitation in a pediatric simulator. Arch Argent Pediatr 2018;116:e730−5, doi:http://dx.doi.org/10.5546/aap.2018.eng.e730.

599. Oh JH, Kim SE, Kim CW, Lee DH. Should we change chest compression providers every 2min when performing one-handed chest compressions? EMA − Emerg Med Australas 2015;27:108 −12, doi:http://dx.doi.org/10.1111/1742-6723.12364.

600. Niles DE, Nishisaki A, Sutton RM, et al. Improved retention of chest compression psychomotor skills with brief "Rolling Refresher" training. Simul Healthc 2017;12:213−9, doi:http://dx.doi.org/10.1097/SIH.0000000000000228.

601. Morgan RW, Landis WP, Marquez A, et al. Hemodynamic effects of chest compression interruptions during pediatric in-hospital cardiopulmonary resuscitation. Resuscitation 2019;139:1−8, doi:http://dx.doi.org/10.1016/j.resuscitation.2019.03.032.

602. Dezfulian C, Fink EL. How bad is it to fail at pushing hard and fast in pediatric cardiopulmonary resuscitation? Pediatr Crit Care Med 2018;19:495−6, doi:http://dx.doi.org/10.1097/PCC.0000000000001529.

603. Kim MJ, Lee HS, Kim S, Park YS. Optimal chest compression technique for paediatric cardiac arrest victims. Scand J Trauma Resusc Emerg Med 2015;23:36, doi:http://dx.doi.org/10.1186/s13049-015-0118- y.

604. Mayrand KP, Fischer EJ, Ten Eyck RP. A simulation-based randomized controlled study of factors influencing chest compression depth. West J Emerg Med 2015;16:1135−40, doi:http://dx.doi.org/10.5811/westjem.2015.9.28167.

605. Millin MG, Bogumil D, Fishe JN, Burke RV. Comparing the two-finger versus two-thumb technique for single person infant CPR: a systematic review and meta-analysis. Resuscitation 2020;148:161−72, doi:http://dx.doi.org/10.1016/j.resuscitation.2019.12.039.

606. Lee JE, Lee J, Oh J, et al. Comparison of two-thumb encircling and two-finger technique during infant cardiopulmonary resuscitation with single rescuer in simulation studies: a systematic review and meta-analysis. Medicine (Baltimore) 2019;98:e17853, doi:http://dx.doi.org/10.1097/MD.0000000000017853.

607. Douvanas A, Koulouglioti C, Kalafati M. A comparison between the two methods of chest compression in infant and neonatal resuscitation. A review according to 2010 CPR guidelines. J Matern Fetal Neonatal Med 2018;31:805−16, doi:http://dx.doi.org/10.1080/14767058.2017.1295953.

608. Lee KH, Kim EY, Park DH, et al. Evaluation of the 2010 American Heart Association Guidelines for infant CPR finger/thumb positions for chest compression: a study using computed tomography. Resuscitation 2013;84:766−9, doi:http://dx.doi.org/10.1016/j.resuscitation.2012.11.005 [in Eng].

609. Lee SH, Cho YC, Ryu S, et al. A comparison of the area of chest compression by the superimposed-thumb and the alongside-thumb techniques for infant cardiopulmonary resuscitation. Resuscitation 2011;82:1214−7, doi:http://dx.doi.org/10.1016/j.resuscitation.2011.04.016.

610. Park M, Oh WS, Chon SB, Cho S. Optimum chest compression point for cardiopulmonary resuscitation in children revisited using a 3D coordinate system imposed on CT: a retrospective, cross-sectional study. Pediatr Crit Care Med 2018;19:e576−84, doi:http://dx.doi.org/10.1097/PCC.0000000000001679.

611. Jang HY, Wolfe H, Hsieh TC, et al. Infant chest compression quality: a video-based comparison of two- thumb versus one-hand technique in the emergency department. Resuscitation 2018;122:36−40, doi:http://dx.doi.org/10.1016/j.resuscitation.2017.11.044.

612. Lim JS, Cho Y, Ryu S, et al. Comparison of overlapping (OP) and adjacent thumb positions (AP) for cardiac compressions using the encircling method in infants. Emerg Med 2013;30:139−42, doi:http://dx.doi.org/10.1136/emermed-2011- 200978 [in Eng].

613. Jung JY, Kwak YH, Kwon H, et al. Effectiveness of finger-marker for maintaining the correct compression point during paediatric resuscitation: a simulation study. Am J Emerg Med 2017;35:1303−8, doi:http://dx.doi.org/10.1016/j.ajem.2017.04.003.

614. Jiang J, Zou Y, Shi W, et al. Two-thumb-encircling hands technique is more advisable than 2- finger technique when lone rescuer performs cardiopulmonary resuscitation on infant manikin. Am J Emerg Med 2015;33:531−4, doi:http://dx.doi.org/10.1016/j.ajem.2015.01.025.

615. Yang D, Kim KH, Oh JH, Son S, Cho J, Seo KM. Development and evaluation of a new chest compression technique for cardiopulmonary resuscitation in infants. Pediatr Cardiol 2019;40:1217−23, doi:http://dx.doi.org/10.1007/s00246-019-02135-x.

616. Ladny JR, Smereka J, Rodriguez-Nunez A, Leung S, Ruetzler K, Szarpak L. Is there any alternative to standard chest compression techniques in infants? A randomized manikin trial of the new "2-thumb-fist" option. Medicine (Baltimore) 2018;97:e9386, doi:http://dx.doi.org/10.1097/MD.0000000000009386.

617. Rodriguez-Ruiz E, Martinez- Puga A, Carballo-Fazanes A, Abelairas-Gomez C, Rodriguez-Nunez A. Two new chest compression methods might challenge the standard in a simulated infant model. Eur J Pediatr 2019;178:1529−35, doi:http://dx.doi.org/10.1007/s00431-019-03452-2.

618. Rodriguez-Ruiz E, Guerra Martin V, Abelairas-Gomez C, et al. A new chest compression technique in infants. Med Intensiva 2019;43:346−51, doi:http://dx.doi.org/10.1016/j.medin.2018.04.010.

619. Jo CH, Cho GC, Lee CH. Two-thumb encircling technique over the head of patients in the setting of lone rescuer infant CPR occurred during ambulance transfer: a crossover simulation study. Pediatr Emerg Care 2017;33:462−6, doi:http://dx.doi.org/10.1097/PEC.0000000000000833.

620. Na JU, Choi PC, Lee HJ, Shin DH, Han SK, Cho JH. A vertical two-thumb technique is superior to the two-thumb encircling technique for infant cardiopulmonary resuscitation. Acta Paediatr 2015;104:e70−5, doi:http://dx.doi.org/10.1111/apa.12857.

621. Pellegrino JL, Bogumil D, Epstein JL, Burke RV. Two-thumb-encircling advantageous for lay responder infant CPR: a randomised manikin study. Arch Dis Child 2019;104:530−4, doi:http://dx.doi.org/10.1136/archdischild-2018-314893.

622. Tsou JY, Kao CL, Chang CJ, Tu YF, Su FC, Chi CH. Biomechanics of two- thumb versus two-finger chest compression for cardiopulmonary resuscitation in an infant manikin model. Eur J Emerg Med 2020;27:132−6, doi:http://dx.doi.org/10.1097/MEJ.0000000000000631.

623. Kim YS, Oh JH, Kim CW, Kim SE, Lee DH, Hong JY. Which fingers should we perform two-finger chest compression technique with when performing cardiopulmonary resuscitation on an infant in cardiac arrest? J Korean Med Sci 2016;31:997−1002, doi:http://dx.doi.org/10.3346/jkms.2016.31.6.997.

624. Nasiri E, Nasiri R. A comparison between over-the-head and lateral cardiopulmonary resuscitation with a single rescuer by bag-valve mask. Saudi J Anaesth 2014;8:30−7, doi:http://dx.doi.org/10.4103/1658- 354X.125923.

625. Cheong SA, Oh JH, Kim CW, Kim SE, Lee DH. Effects of alternating hands during in-hospital one- handed chest compression: a randomised cross-over manikin trial. EMA − Emerg Med Australas 2015;27:567−72, doi:http://dx.doi.org/10.1111/1742-6723.12492.

626. Oh JH, Kim CW, Kim SE, Lee DH, Lee SJ. One-handed chest compression technique for paediatric cardiopulmonary resuscitation: dominant versus non-dominant hand. Emerg Med 2015;32:544−6, doi:http://dx.doi.org/10.1136/emermed-2014-203932.

627. Lee SY, Hong JY, Oh JH, Son SH. The superiority of the two-thumb over the two-finger technique for single-rescuer infant cardiopulmonary resuscitation. Eur J Emerg Med 2018;25:372−6, doi:http://dx.doi.org/10.1097/MEJ.0000000000000461.

628. Lee SS, Lee SD, Oh JH. Comparison between modified and conventional one-handed chest compression techniques for child cardiopulmonary resuscitation: a randomised, non-blind, cross-over simulation trial. J Paediatr Child Health 2019;55:1361−6, doi:http://dx.doi.org/10.1111/jpc.14422.

629. Kherbeche H, Exer N, Schuhwerk W, Ummenhofer W, Osterwalder J. Chest compression using the foot or hand method: a prospective, randomized, controlled manikin study with school children. Eur J Emerg Med 2017;24:262−7, doi:http://dx.doi.org/10.1097/MEJ.0000000000000335.

630. Smereka J, Szarpak L, Ladny JR, Rodriguez-Nunez A, Ruetzler K. A novel method of newborn chest compression: a randomized crossover simulation study. Front Pediatr 2018;6:159, doi:http://dx.doi.org/10.3389/fped.2018.00159.

631. Park JW, Jung JY, Kim J, et al. A novel infant chest compression assist device using a palm rather than fingers: a randomized crossover trial. Prehosp Emerg Care 2019;23:74−82, doi:http://dx.doi.org/10.1080/10903127.2018.1471559.

632. Jung WJ, Hwang SO, Kim HI, et al. 'Knocking-fingers' chest compression technique in infant cardiac arrest: single-rescuer manikin study. Eur J Emerg Med 2019;26:261−5, doi:http://dx.doi.org/10.1097/MEJ.0000000000000539.

633. Smereka J, Szarpak L, Rodriguez-Nunez A, Ladny JR, Leung S, Ruetzler K. A randomized comparison of three chest compression techniques and associated hemodynamic effect during infant CPR: a randomized manikin study. Am J Emerg Med 2017;35:1420−5, doi:http://dx.doi.org/10.1016/j.ajem.2017.04.024.

634. Lopez-Herce J, Almonte E, Alvarado M, et al. Latin American Consensus for Pediatric Cardiopulmonary Resuscitation 2017: Latin American Pediatric Critical Care Society Pediatric Cardiopulmonary Resuscitation Committee. Pediatr Crit Care Med 2018;19:e152−6, doi:http://dx.doi.org/10.1097/PCC.0000000000001427.

635. Rossano JW, Jones WE, Lerakis S, et al. The use of automated external defibrillators in infants: a report from the American Red Cross Scientific Advisory Council. Pediatr Emerg Care 2015;31:526−30, doi:http://dx.doi.org/10.1097/PEC.0000000000000490.

636. Hoyt Jr. WJ, Fish FA, Kannankeril PJ. Automated external defibrillator use in a previously healthy 31-day-old infant with out-of-hospital cardiac arrest due to ventricular fibrillation. J Cardiovasc Electrophysiol 2019;30:2599−602, doi:http://dx.doi.org/10.1111/jce.14125.

637. Johnson MA, Grahan BJ, Haukoos JS, et al. Demographics, bystander CPR, and AED use in out-of-hospital pediatric arrests. Resuscitation 2014;85:920−6, doi:http://dx.doi.org/10.1016/j.resuscitation.2014.03.044.

638. Mitani Y, Ohta K, Yodoya N, et al. Public access defibrillation improved the outcome after out-of- hospital cardiac arrest in school-age children: a nationwide, population-based, Utstein registry study in Japan. Europace 2013;15:1259−66, doi:http://dx.doi.org/10.1093/europace/eut053.

639. Swor R, Grace H, McGovern H, Weiner M, Walton E. Cardiac arrests in schools: assessing use of automated external defibrillators (AED) on school campuses. Resuscitation 2013;84:426−9, doi:http://dx.doi.org/10.1016/j.resuscitation.2012.09.014.

640. Nagata T, Abe T, Noda E, Hasegawa M, Hashizume M, Hagihara A. Factors associated with the clinical outcomes of paediatric out-of-hospital cardiac arrest in Japan. BMJ Open 2014;4:e003481, doi:http://dx.doi.org/10.1136/bmjopen-2013 -003481.

641. Hunt EA, Duval- Arnould JM, Bembea MM, et al. Association between time to defibrillation and survival in pediatric in-hospital cardiac arrest with a first documented shockable rhythm. JAMA Netw Open 2018;1:e182643, doi:http://dx.doi.org/10.1001/jamanetworkopen.2018.2643.

642. Tsuda T, Geary EM, Temple J. Significance of automated external defibrillator in identifying lethal ventricular arrhythmias. Eur J Pediatr 2019;178:1333−42, doi:http://dx.doi.org/10.1007/s00431-019-03421 -9.

643. El-Assaad I, Al-Kindi SG, McNally B, et al. Automated external defibrillator application before EMS arrival in pediatric cardiac arrests. Pediatrics 2018142:, doi:http://dx.doi.org/10.1542/peds.2017-1903.

644. Goto Y, Funada A, Goto Y. Subsequent shockable rhythm during out-of-hospital cardiac arrest in children with initial non-shockable rhythms: a nationwide population-based observational study. J Am Heart Assoc 20165:, doi:http://dx.doi.org/10.1161/JAHA.116.003589.

645. Pundi KN, Bos JM, Cannon BC, Ackerman MJ. Automated external defibrillator rescues among children with diagnosed and treated long QT syndrome. Heart Rhythm 2015;12:776−81, doi:http://dx.doi.org/10.1016/j.hrthm.2015.01.002.

646. Griffis H, Wu L, Naim MY, et al. Characteristics and outcomes of AED use in pediatric cardiac arrest in public settings: the influence of neighborhood characteristics. Resuscitation 2020;146:126−31, doi:http://dx.doi.org/10.1016/j.resuscitation.2019.09.038.

647. Rehn M, Hyldmo PK, Magnusson V, et al. Scandinavian SSAI clinical practice guideline on pre-hospital airway management. Acta Anaesthesiol Scand 2016;60:852−64, doi:http://dx.doi.org/10.1111/aas.12746.

648. Borra V, Avau B, De Paepe P, Vandekerckhove P, De Buck E. Is placing a victim in the left lateral decubitus position an effective first aid intervention for acute oral poisoning? A systematic review. Clin Toxicol (Phila) 2019;57:603−16, doi:http://dx.doi.org/10.1080/15563650.2019.1574975.

649. Hyldmo PK, Vist GE, Feyling AC, et al. Is the supine position associated with loss of airway patency in unconscious trauma patients? A systematic review and meta-analysis. Scand J Trauma Resusc Emerg Med 2015;23:50, doi:http://dx.doi.org/10.1186/s13049-015-0116- 0.

650. Hyldmo PK, Vist GE, Feyling AC, et al. Does turning trauma patients with an unstable spinal injury from the supine to a lateral position increase the risk of neurological deterioration?—A systematic review. Scand J Trauma Resusc Emerg Med 2015;23:65, doi:http://dx.doi.org/10.1186/s13049-015- 0143-x.

651. Freire-Tellado M, Navarro- Paton R, Pavon-Prieto MDP, Fernandez-Lopez M, Mateos- Lorenzo J, Lopez-Forneas I. Does lying in the recovery position increase the likelihood of not delivering cardiopulmonary resuscitation? Resuscitation 2017;115:173−7, doi:http://dx.doi.org/10.1016/j.resuscitation.2017.03.008.

652. Navarro-Paton R, Freire- Tellado M, Fernandez-Gonzalez N, Basanta-Camino S, Mateos- Lorenzo J, Lago-Ballesteros J. What is the best position to place and re-evaluate an unconscious but normally breathing victim? A randomised controlled human simulation trial on children. Resuscitation 2019;134:104−9, doi:http://dx.doi.org/10.1016/j.resuscitation.2018.10.030.

653. Fukushima H, Imanishi M, Iwami T, et al. Abnormal breathing of sudden cardiac arrest victims described by laypersons and its association with emergency medical service dispatcher-assisted cardiopulmonary resuscitation instruction. Emerg Med 2015;32:314−7, doi:http://dx.doi.org/10.1136/emermed-2013-203112.

654. Hyldmo PK, Horodyski M, Conrad BP, et al. Does the novel lateral trauma position cause more motion in an unstable cervical spine injury than the logroll maneuver? Am J Emerg Med 2017;35:1630−5, doi:http://dx.doi.org/10.1016/j.ajem.2017.05.002.

655. Hyldmo PK, Horodyski MB, Conrad BP, et al. Safety of the lateral trauma position in cervical spine injuries: a cadaver model study. Acta Anaesthesiol Scand 2016;60:1003−11, doi:http://dx.doi.org/10.1111/aas.12714.

656. Julliand S, Desmarest M, Gonzalez L, et al. Recovery position significantly associated with a reduced admission rate of children with loss of consciousness. Arch Dis Child 2016;101:521−6, doi:http://dx.doi.org/10.1136/archdischild-2015-308857.

657. Del Rossi G, Dubose D, Scott N, et al. Motion produced in the unstable cervical spine by the HAINES and lateral recovery positions. Prehosp Emerg Care 2014;18:539−43, doi:http://dx.doi.org/10.3109/10903127.2014.916019.

658. Cheng J, Liu B, Farjat AE, Routh J. National estimations of airway foreign bodies in children in the United States, 2000 to 2009. Clin Otolaryngol 2019;44:235−9, doi:http://dx.doi.org/10.1111/coa.13261.

659. Redding JS. The choking controversy: critique of evidence on the Heimlich maneuver. Crit Care Med 1979;7:475−9 (https://www.ncbi.nlm.nih.gov/pubmed/477356).
Langhelle A, Sunde K, Wik L, Steen PA. Airway pressure with chest compressions versus Heimlich manoeuvre in recently dead

660. adults with complete airway obstruction. Resuscitation 2000;44:105−8.

661. Vilke GM, Smith AM, Ray LU, Steen PJ, Murrin PA, Chan TC. Airway obstruction in children aged less than 5 years: the prehospital experience. Prehosp Emerg Care 2004;8:196−9.

662. Heimlich HJ, Patrick EA. The Heimlich maneuver. Best technique for saving any choking victim's life. Postgrad Med 199087:, doi:http://dx.doi.org/10.1080/00325481.1990.11716329 38−48, 53.

663. Chillag S, Krieg J, Bhargava R. The Heimlich maneuver: breaking down the complications. South Med J 2010;103:147−50, doi:http://dx.doi.org/10.1097/SMJ.0b013e3181c99140.

664. Dunne CL, Peden AE, Queiroga AC, Gomez Gonzalez C, Valesco B, Szpilman D. A systematic review on the effectiveness of anti-choking suction devices and identification of research gaps. Resuscitation 2020;153:219−26, doi:http://dx.doi.org/10.1016/j.resuscitation.2020.02.021.

665. Kleinman ME, Chameides L, Schexnayder SM, et al. Part 14: pediatric advanced life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation 2010;122:S876−908, doi:http://dx.doi.org/10.1161/CIRCULATIONAHA.110.971101.

666. de Caen AR, Maconochie IK, Aickin R, et al. Part 6: Pediatric basic life support and pediatric advanced life support: 2015 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Circulation 2015;132:S177−203, doi:http://dx.doi.org/10.1161/CIR.0000000000000275.

667. Maconochie IK, Bingham R, Eich C, et al. European Resuscitation Council Guidelines for Resuscitation 2015: Section 6. Paediatric life support. Resuscitation 2015;95:223−48, doi:http://dx.doi.org/10.1016/j.resuscitation.2015.07.028.

668. Nadkarni VM, Larkin GL, Peberdy MA, et al. First documented rhythm and clinical outcome from in-hospital cardiac arrest among children and adults. JAMA 2006;295:50−7.

669. Gilhooley C, Burnhill G, Gardiner D, Vyas H, Davies P. Oxygen saturation and haemodynamic changes prior to circulatory arrest: implications for transplantation and resuscitation. J Intensive Care Soc 2019;20:27−33, doi:http://dx.doi.org/10.1177/1751143718764541.

670. Morgan RW, Reeder RW, Meert KL, et al. Survival and hemodynamics during pediatric cardiopulmonary resuscitation for bradycardia and poor perfusion versus pulseless cardiac arrest. Crit Care Med 2020;48:881−9, doi:http://dx.doi.org/10.1097/CCM.0000000000004308.

671. Khera R, Tang Y, Girotra S, et al. Pulselessness after initiation of cardiopulmonary resuscitation for bradycardia in hospitalized children. Circulation 2019;140:370−8, doi:http://dx.doi.org/10.1161/CIRCULATIONAHA.118.039048.

672. Fraser J, Sidebotham P, Frederick J, Covington T, Mitchell EA. Learning from child death review in the USA, England, Australia, and New Zealand. Lancet 2014;384:894−903, doi:http://dx.doi.org/10.1016/S0140-6736(13)61089-2.

673. Bhalala US, Balakumar N, Zamora M, Appachi E. Hands-on defibrillation skills of pediatric acute care providers during a simulated ventricular fibrillation cardiac arrest scenario. Front Pediatr 2018;6:107, doi:http://dx.doi.org/10.3389/fped.2018.00107.

674. Tibballs J, Carter B, Kiraly NJ, Ragg P, Clifford M. External and internal biphasic direct current shock doses for pediatric ventricular fibrillation and pulseless ventricular tachycardia. Pediatr Crit Care Med 2011;12:14−20, doi:http://dx.doi.org/10.1097/PCC.0b013e3181dbb4fc.

675. Ristagno G, Yu T, Quan W, Freeman G, Li Y. Comparison of defibrillation efficacy between two pads placements in a pediatric porcine model of cardiac arrest. Resuscitation 2012;83:755−9, doi:http://dx.doi.org/10.1016/j.resuscitation.2011.12.010.

676. Weisfeldt ML. A three phase temporal model for cardiopulmonary resuscitation following cardiac arrest. Trans Am Clin Climatol Assoc 2004;115:115−22 [discussion 122]. (https://www.ncbi.nlm.nih.gov/pubmed/17060961).

677. Society of Thoracic Surgeons Task Force on Resuscitation After Cardiac S. The society of thoracic surgeons expert consensus for the resuscitation of patients who arrest after cardiac surgery. Ann Thorac Surg 2017;103:1005−20, doi:http://dx.doi.org/10.1016/j. athoracsur.2016.10.033.

678. Soar JBB, Carli P, Couper K, Deakin CD, Djarv T, Lott C, et al. European Resuscitation Council Guidelines 2021: advanced life support. Resuscitation 2021;161.

679. Fukuda T, Ohashi- Fukuda N, Kobayashi H, et al. Public access defibrillation and outcomes after pediatric out- of-hospital cardiac arrest. Resuscitation 2017;111:1−7, doi:http://dx.doi.org/10.1016/j. resuscitation.2016.11.010.

680. Mercier E, Laroche E, Beck B, et al. Defibrillation energy dose during pediatric cardiac arrest: Systematic review of human and animal model studies. Resuscitation 2019;139:241−52, doi:http://dx.doi. org/10.1016/j.resuscitation.2019.04.028.

681. Hoyme DB, Zhou Y, Girotra S, et al. Improved survival to hospital discharge in pediatric in-hospital cardiac arrest using 2Joules/ kilogram as first defibrillation dose for initial pulseless ventricular arrhythmia. Resuscitation 2020;153:88−96, doi:http://dx.doi.org/ 10.1016/j.resuscitation.2020.05.048.

682. Deakin CD, Morley P, Soar J, Drennan IR. Double (dual) sequential defibrillation for refractory ventricular fibrillation cardiac arrest: a systematic review. Resuscitation 2020;155:24−31, doi:http://dx.doi. org/10.1016/j.resuscitation.2020.06.008.

683. Huang Y, He Q, Yang LJ, Liu GJ, Jones A. Cardiopulmonary resuscitation (CPR) plus delayed defibrillation versus immediate defibrillation for out-of-hospital cardiac arrest. Cochrane Database Syst Rev 2014;9:CD009803, doi:http://dx.doi.org/10.1002/ 14651858.CD009803.pub2.

684. Bradley SM, Liu W, Chan PS, et al. Defibrillation time intervals and outcomes of cardiac arrest in hospital: retrospective cohort study from Get With The Guidelines-Resuscitation registry. BMJ 2016;353: i1653, doi:http://dx.doi.org/10.1136/bmj.i1653.

685. Roh YI, Jung WJ, Hwang SO, et al. Shorter defibrillation interval promotes successful defibrillation and resuscitation outcomes. Resuscitation 2019;143:100−5, doi:http://dx.doi.org/10.1016/j. resuscitation.2019.08.022.

686. Brugger H, Durrer B, Elsensohn F, et al. Resuscitation of avalanche victims: evidence-based guidelines of the international commission for mountain emergency medicine (ICAR MEDCOM): intended for physicians and other advanced life support personnel. Resuscitation 2013;84:539−46, doi:http://dx. doi.org/10.1016/j.resuscitation.2012.10.020 [Practice Guideline Review].

687. Saczkowski RS, Brown DJA, Abu-Laban RB, Fradet G, Schulze CJ, Kuzak ND. Prediction and risk stratification of survival in accidental hypothermia requiring extracorporeal life support: an individual patient data meta-analysis. Resuscitation 2018;127:51−7, doi:http:// dx.doi.org/10.1016/j.resuscitation.2018.03.028.

688. Bauman BD, Louiselle A, Nygaard RM, et al. Treatment of hypothermic cardiac arrest in the pediatric drowning victim, a case report, and systematic review. Pediatr Emerg Care 2019, doi:http:// dx.doi.org/10.1097/PEC.0000000000001735.

689. Sepehripour AH, Gupta S, Lall KS. When should cardiopulmonary bypass be used in the setting of severe hypothermic cardiac arrest? Interact Cardiovasc Thorac Surg 2013;17:564−9, doi:http://dx.doi. org/10.1093/icvts/ivt208.

690. Dunne B, Christou E, Duff O, Merry C. Extracorporeal-assisted rewarming in the management of accidental deep hypothermic cardiac arrest: a systematic review of the literature. Heart Lung Circ 2014;23:1029−35, doi:http://dx.doi.org/10.1016/j. hlc.2014.06.011.

691. Paal P, Gordon L, Strapazzon G, et al. Accidental hypothermia-an update: the content of this review is endorsed by the International Commission for Mountain Emergency Medicine (ICAR MEDCOM). Scand J Trauma Resusc Emerg Med 2016;24:111, doi:http://dx.doi. org/10.1186/s13049-016-0303- 7.

692. Best RR, Harris BHL, Walsh JL, Manfield T. Pediatric drowning: a standard operating procedure to aid the prehospital management of pediatric cardiac arrest resulting from submersion. Pediatr Emerg Care 2020;36:143−6, doi:http://dx.doi.org/10.1097/ PEC.0000000000001169.

693. Strapazzon G, Plankensteiner J, Mair P, et al. Prehospital management and outcome of avalanche patients with out-of-hospital cardiac arrest: a retrospective study in Tyrol, Austria. Eur J Emerg Med 2017;24:398−403, doi:http://dx.doi.org/10.1097/ MEJ.0000000000000390.

694. Svendsen OS, Grong K, Andersen KS, Husby P. Outcome after rewarming from accidental hypothermia by use of extracorporeal circulation. Ann Thorac Surg 2017;103:920−5, doi:http://dx.doi.org/ 10.1016/j.athoracsur.2016.06.093.

695. Mentzelopoulos SD, Couper K, Van de Voorde P, et al. European Resuscitation Council Guidelines 2021: ethics of resuscitation and end of life decisions. Resuscitation 2021161:.

696. Patel JK, Kataya A, Parikh PB. Association between intra- and post-arrest hyperoxia on mortality in adults with cardiac arrest: a systematic review and meta-analysis. Resuscitation 2018;127:83 −8, doi:http://dx.doi.org/10.1016/j.resuscitation.2018.04.008.

697. Soar J, Maconochie I, Wyckoff MH, et al. 2019 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Resuscitation 2019;145:95−150, doi:http://dx.doi.org/10.1016/j. resuscitation.2019.10.016.

698. Okubo M, Komukai S, Izawa J, et al. Prehospital advanced airway management for paediatric patients with out-of-hospital cardiac arrest: a nationwide cohort study. Resuscitation 2019;145:175−84, doi:http://dx.doi.org/10.1016/j.resuscitation.2019.09.007.

699. Fukuda T, Sekiguchi H, Taira T, et al. Type of advanced airway and survival after pediatric out-of-hospital cardiac arrest. Resuscitation 2020;150:145−53, doi:http://dx.doi.org/10.1016/j. resuscitation.2020.02.005.

700. Lopez J, Fernandez SN, Gonzalez R, Solana MJ, Urbano J, Lopez-Herce J. Different respiratory rates during resuscitation in a pediatric animal model of asphyxial cardiac arrest. PLOS ONE 2016;11: e0162185, doi:http://dx.doi.org/10.1371/journal.pone.0162185.

701. Gonzalez R, Pascual L, Sava A, Tolon S, Urbano J, Lopez-Herce J. Ventilation during cardiopulmonary resuscitation in children: a survey on clinical practice. World J Pediatr 2017;13:544−50, doi:http://dx. doi.org/10.1007/s12519-017-0061- 2.

702. Aufderheide TP, Sigurdsson G, Pirrallo RG, et al. Hyperventilation-induced hypotension during cardiopulmonary resuscitation. Circulation 2004;109:1960−5 (http://www.ncbi.nlm.nih.gov/entrez/ query.fcgi? cmd=Retrieve&db=PubMed&dopt=Citation&list_ uids=15066941).

703. Yannopoulos D, Tang W, Roussos C, Aufderheide TP, Idris AH, Lurie KG. Reducing ventilation frequency during cardiopulmonary resuscitation in a porcine model of cardiac arrest. Respir Care 2005;50:628−35 [in Eng].

704. Lapid FM, O'Brien CE, Kudchadkar SR, et al. The use of pressure-controlled mechanical ventilation in a swine model of intraoperative pediatric cardiac arrest. Paediatr Anaesth 2020;30:462−8, doi:http:// dx.doi.org/10.1111/pan.13820.

705. Kjaergaard B, Bavarskis E, Magnusdottir SO, et al. Four ways to ventilate during cardiopulmonary resuscitation in a porcine model: a randomized study. Scand J Trauma Resusc Emerg Med 2016;24:67, doi:http://dx.doi.org/10.1186/s13049-016-0262-z.

706. Tan D, Xu J, Shao S, et al. Comparison of different inspiratory triggering settings in automated ventilators during cardiopulmonary resuscitation in a porcine model. PLOS ONE 2017;12:e0171869, doi: http://dx.doi.org/10.1371/journal.pone.0171869.

707. Kill C, Hahn O, Dietz F, et al. Mechanical ventilation during cardiopulmonary resuscitation with intermittent positive-pressure ventilation, bilevel ventilation, or chest compression synchronized ventilation in a pig model. Crit Care Med 2014;42:e89−95, doi:http:// dx.doi.org/10.1097/CCM.0b013e3182a63fa0.

708. Kill C, Galbas M, Neuhaus C, et al. Chest compression synchronized ventilation versus intermittent positive pressure ventilation during cardiopulmonary resuscitation in a pig model. PLOS ONE 2015;10:e0127759, doi:http://dx.doi.org/10.1371/journal.pone.0127759.

709. Schaller SJ, Altmann S, Unsworth A, et al. Continuous chest compressions with a simultaneous triggered ventilator in the Munich Emergency Medical Services: a case series. Ger Med Sci 2019;17:Doc06, doi:http://dx.doi.org/10.3205/000272.

710. Mendler MR, Maurer M, Hassan MA, et al. Different techniques of respiratory support do not significantly affect gas exchange during cardiopulmonary resuscitation in a newborn piglet model. Neonatology 2015;108:73–80, doi:http://dx.doi.org/10.1159/000381416.

711. Mendler MR, Weber C, Hassan MA, Huang L, Mayer B, Hummler HD. Tidal volume delivery and endotracheal tube leak during cardiopulmonary resuscitation in intubated newborn piglets with hypoxic cardiac arrest exposed to different modes of ventilatory support. Neonatology 2017;111:100–6, doi:http://dx.doi.org/10.1159/000447663.

712. Salas N, Wisor B, Agazio J, Branson R, Austin PN. Comparison of ventilation and cardiac compressions using the Impact Model 730 automatic transport ventilator compared to a conventional bag valve with a facemask in a model of adult cardiopulmonary arrest. Resuscitation 2007;74:94–101, doi:http://dx.doi.org/10.1016/j.resuscitation.2006.01.023.

713. Hurst Vt, West S, Austin P, Branson R, Beck G. Comparison of ventilation and chest compression performance by bystanders using the Impact Model 730 ventilator and a conventional bag valve with mask in a model of adult cardiopulmonary arrest. Resuscitation 2007;73:123–30, doi:http://dx.doi.org/10.1016/j.resuscitation.2006.07.027.

714. Allen SG, Brewer L, Gillis ES, Pace NL, Sakata DJ, Orr JA. A turbine-driven ventilator improves adherence to advanced cardiac life support guidelines during a cardiopulmonary resuscitation simulation. Respir Care 2017;62:1166–70, doi:http://dx.doi.org/10.4187/respcare.05368.

715. Grieco DL, L JB, Drouet A, et al. Intrathoracic airway closure impacts CO2 signal and delivered ventilation during cardiopulmonary resuscitation. Am J Respir Crit Care Med 2019;199:728–37, doi:http://dx.doi.org/10.1164/rccm.201806- 1111OC.

716. Holmberg MJ, Nicholson T, Nolan JP, et al. Oxygenation and ventilation targets after cardiac arrest: a systematic review and meta-analysis. Resuscitation 2020;152:107–15, doi:http://dx.doi.org/10.1016/j.resuscitation.2020.04.031.

717. Andersen LW, Berg KM, Saindon BZ, et al. Time to epinephrine and survival after pediatric in-hospital cardiac arrest. JAMA 2015;314:802–10, doi:http://dx.doi.org/10.1001/jama.2015.9678.

718. Meert K, Telford R, Holubkov R, et al. Paediatric in-hospital cardiac arrest: factors associated with survival and neurobehavioural outcome one year later. Resuscitation 2018;124:96–105, doi:http://dx.doi.org/10.1016/j.resuscitation.2018.01.013.

719. Hoyme DB, Patel SS, Samson RA, et al. Epinephrine dosing interval and survival outcomes during pediatric in-hospital cardiac arrest. Resuscitation 2017;117:18–23, doi:http://dx.doi.org/10.1016/j.resuscitation.2017.05.023.

720. Raymond TT, Praestgaard A, Berg RA, Nadkarni VM, Parshuram CS, American Heart Association's Get With The Guidelines-Resuscitation I. The association of hospital rate of delayed epinephrine administration with survival to discharge for pediatric nonshockable in-hospital cardiac arrest. Pediatr Crit Care Med 2019;20:405–16, doi:http://dx.doi.org/10.1097/PCC.0000000000001863.

721. Bellamy D, Nuthall G, Dalziel S, Skinner JR. Catecholaminergic polymorphic ventricular tachycardia: the cardiac arrest where epinephrine is contraindicated. Pediatr Crit Care Med 2019;20:262–8, doi:http://dx.doi.org/10.1097/PCC.0000000000001847.

722. Lin YR, Li CJ, Huang CC, et al. Early epinephrine improves the stabilization of initial post- resuscitation hemodynamics in children with non-shockable out-of-hospital cardiac arrest. Front Pediatr 2019;7:220, doi:http://dx.doi.org/10.3389/fped.2019.00220.

723. Lin YR, Wu MH, Chen TY, et al. Time to epinephrine treatment is associated with the risk of mortality in children who achieve sustained ROSC after traumatic out-of-hospital cardiac arrest. Crit Care 2019;23:101, doi:http://dx.doi.org/10.1186/s13054-019-2391-z.

724. Hansen M, Schmicker RH, Newgard CD, et al. Time to epinephrine administration and survival from nonshockable out-of-hospital cardiac arrest among children and adults. Circulation 2018;137:2032–40, doi:http://dx.doi.org/10.1161/CIRCULATIONAHA.117.033067.

725. Fukuda T, Kondo Y, Hayashida K, Sekiguchi H, Kukita I. Time to epinephrine and survival after paediatric out-of-hospital cardiac arrest. Eur Heart J Cardiovasc Pharmacother 2018;4:144–51, doi:http://dx.doi.org/10.1093/ehjcvp/pvx023.

726. Lin YR, Syue YJ, Buddhakosai W, et al. Impact of different initial epinephrine treatment time points on the early postresuscitative hemodynamic status of children with traumatic out-of- hospital cardiac arrest. Medicine (Baltimore) 2016;95:e3195, doi:http://dx.doi.org/10.1097/MD.0000000000003195.

727. Wall JJ, Iyer RV. Catecholaminergic polymorphic ventricular tachycardia. Pediatr Emerg Care 2017;33:427–31, doi:http://dx.doi.org/10.1097/PEC.0000000000001156.

728. Soar J, Perkins GD, Maconochie I, et al. European Resuscitation Council Guidelines for resuscitation: 2018 update – antiarrhythmic drugs for cardiac arrest. Resuscitation 2019;134:99–103, doi:http://dx.doi.org/10.1016/j.resuscitation.2018.11.018.

729. Holmberg MJ, Ross CE, Atkins DL, et al. Lidocaine versus amiodarone for pediatric in-hospital cardiac arrest: an observational study. Resuscitation 2020;149:191–201, doi:http://dx.doi.org/10.1016/j.resuscitation.2019.12.033.

730. Mok YH, Loke AP, Loh TF, Lee JH. Characteristics and risk factors for mortality in paediatric in-hospital cardiac events in singapore: retrospective single centre experience. Ann Acad Med Singap 2016;45:534–41 (https://www.ncbi.nlm.nih.gov/pubmed/28062881).

731. Lasa JJ, Alali A, Minard CG, et al. Cardiopulmonary resuscitation in the pediatric cardiac catheterization laboratory: a report from the American Heart Association's Get With the Guidelines-Resuscitation Registry. Pediatr Crit Care Med 2019;20:1040–7, doi:http://dx.doi.org/10.1097/PCC.0000000000002038.

732. Writer H. Cardiorespiratory arrest in children (out of hospital). BMJ Clin Evid 2010 2010 (https://www.ncbi.nlm.nih.gov/pubmed/21406131).

733. Wu ET, Li MJ, Huang SC, et al. Survey of outcome of CPR in pediatric in-hospital cardiac arrest in a medical center in Taiwan. Resuscitation 2009;80:443–8, doi:http://dx.doi.org/10.1016/j.resuscitation.2009.01.006 [in Eng]. S0300-9572(09)00017-3 [pii].

734. Del Castillo J, Lopez- Herce J, Canadas S, et al. Cardiac arrest and resuscitation in the pediatric intensive care unit: a prospective multicenter multinational study. Resuscitation 2014;85:1380–6, doi:http://dx.doi.org/10.1016/j.resuscitation.2014.06.024.

735. Wolfe HA, Sutton RM, Reeder RW, et al. Functional outcomes among survivors of pediatric in-hospital cardiac arrest are associated with baseline neurologic and functional status, but not with diastolic blood pressure during CPR. Resuscitation 2019;143:57–65, doi:http://dx.doi.org/10.1016/j.resuscitation.2019.08.006.

736. Matamoros M, Rodriguez R, Callejas A, et al. In-hospital pediatric cardiac arrest in Honduras. Pediatr Emerg Care 2015;31:31–5, doi:http://dx.doi.org/10.1097/PEC.0000000000000323.

737. Lopez-Herce J, del Castillo J, Canadas S, Rodriguez-Nunez A, Carrillo A, Spanish Study Group of Cardiopulmonary Arrest in C. In-hospital pediatric cardiac arrest in Spain. Rev Esp Cardiol (Engl Ed) 2014;67:189–95, doi:http://dx.doi.org/10.1016/j.rec.2013.07.017.

738. Raymond TT, Stromberg D, Stigall W, Burton G, Zaritsky A. American Heart Association's Get With The Guidelines-Resuscitation I. Sodium bicarbonate use during in-hospital pediatric pulseless cardiac arrest − a report from the American Heart Association Get With The Guidelines((R))- Resuscitation. Resuscitation 2015;89:106−13, doi:http://dx.doi.org/10.1016/j.resuscitation.2015.01.007.

739. Berg RA, Reeder RW, Meert KL, et al. End-tidal carbon dioxide during pediatric in-hospital cardiopulmonary resuscitation. Resuscitation 2018;133:173−9, doi:http://dx.doi.org/10.1016/j.resuscitation.2018.08.013.

740. Stine CN, Koch J, Brown LS, Chalak L, Kapadia V, Wyckoff MH. Quantitative end- tidal CO2 can predict increase in heart rate during infant cardiopulmonary resuscitation. Heliyon 2019;5:e01871, doi:http://dx.doi.org/10.1016/j.heliyon.2019.e01871.

741. Yates AR, Sutton RM, Reeder RW, et al. Survival and cardiopulmonary resuscitation hemodynamics following cardiac arrest in children with surgical compared to medical heart disease. Pediatr Crit Care Med 2019;20:1126−36, doi:http://dx.doi.org/10.1097/PCC.0000000000002088.

742. Berg RA, Sutton RM, Reeder RW, et al. Association between diastolic blood pressure during pediatric in- hospital cardiopulmonary resuscitation and survival. Circulation 2018;137:1784−95, doi:http://dx.doi.org/10.1161/CIRCULATIONAHA.117.032270.

743. Caglar A, Er A, Ulusoy E, et al. Cerebral oxygen saturation monitoring in pediatric cardiopulmonary resuscitation patients in the emergency settings: a small descriptive study. Turk J Pediatr 2017;59:642−7, doi:http://dx.doi.org/10.24953/turkjped.2017.06.004.

744. Abramo TJ, Meredith M, Jaeger M, et al. Cerebral oximetry with blood volume index in asystolic pediatric cerebrospinal fluid malfunctioning shunt patients. Am J Emerg Med 201432:, doi:http://dx.doi.org/10.1016/j.ajem.2014.04.007 1439 e1−7.

745. Pasquier M, Hugli O, Paal P, et al. Hypothermia outcome prediction after extracorporeal life support for hypothermic cardiac arrest patients: the HOPE score. Resuscitation 2018;126:58−64, doi:http://dx.doi.org/10.1016/j.resuscitation.2018.02.026.

746. Hilmo J, Naesheim T, Gilbert M. "Nobody is dead until warm and dead": prolonged resuscitation is warranted in arrested hypothermic victims also in remote areas—a retrospective study from northern Norway. Resuscitation 2014;85:1204−11, doi:http://dx.doi.org/10.1016/j.resuscitation.2014.04.029.

747. Wollenek G, Honarwar N, Golej J, Marx M. Cold water submersion and cardiac arrest in treatment of severe hypothermia with cardiopulmonary bypass. Resuscitation 2002;52:255−63.

748. Huang SC, Wu ET, Wang CC, et al. Eleven years of experience with extracorporeal cardiopulmonary resuscitation for paediatric patients with in-hospital cardiac arrest. Resuscitation 2012;83:710−4, doi:http://dx.doi.org/10.1016/j.resuscitation.2012.01.031 [Research Support, Non-U.S. Gov't; in Eng].

749. De Mul A, Nguyen DA, Doell C, Perez MH, Cannizzaro V, Karam O. Prognostic evaluation of mortality after pediatric resuscitation assisted by extracorporeal life support. J Pediatr Intensive Care 2019;8:57−63, doi:http://dx.doi.org/10.1055/s-0038- 1667012.

750. Pasquier M, Rousson V. Qualification for extracorporeal life support in accidental hypothermia: the HOPE score. Ann Thorac Surg 2020, doi:http://dx.doi.org/10.1016/j.athoracsur.2020.06.146.

751. Dunning J, Fabbri A, Kolh PH, et al. Guideline for resuscitation in cardiac arrest after cardiac surgery. Eur J Cardiothorac Surg 2009;36:3−28, doi:http://dx.doi.org/10.1016/j.ejcts.2009.01.033 [in Eng]. S1010-7940(09)00074-8 [pii].

752. Tsou PY, Kurbedin J, Chen YS, et al. Accuracy of point-of-care focused echocardiography in predicting outcome of resuscitation in cardiac arrest patients: a systematic review and meta- analysis. Resuscitation 2017;114:92−9, doi:http://dx.doi.org/10.1016/j.resuscitation.2017.02.021.

753. Bhananker SM, Ramamoorthy C, Geiduschek JM, et al. Anesthesia-related cardiac arrest in children: update from the Pediatric Perioperative Cardiac Arrest Registry. Anesth Analg 2007;105:344−50, doi:http://dx.doi.org/10.1213/01.ane.0000268712.00756.dd.

754. Spyres MB, Farrugia LA, Kang AM, et al. The toxicology investigators consortium case registry—the 2018 annual report. J Med Toxicol 2019;15:228−54, doi:http://dx.doi.org/10.1007/s13181-019-00736-9.

755. Larach MG, Rosenberg H, Gronert GA, Allen GC. Hyperkalemic cardiac arrest during anesthesia in infants and children with occult myopathies. Clin Pediatr (Phila) 1997;36:9−16, doi:http://dx.doi.org/10.1177/000992289703600102.

756. Carreiro S, Miller S, Wang B, Wax P, Campleman S, Manini AF. Clinical predictors of adverse cardiovascular events for acute pediatric drug exposures. Clin Toxicol (Phila) 2020;58:183−9, doi:http://dx.doi.org/10.1080/15563650.2019.1634272.

757. Morgan RW, Fitzgerald JC, Weiss SL, Nadkarni VM, Sutton RM, Berg RA. Sepsis-associated in-hospital cardiac arrest: epidemiology, pathophysiology, and potential therapies. J Crit Care 2017;40:128−35, doi:http://dx.doi.org/10.1016/j.jcrc.2017.03.023.

758. Workman JK, Bailly DK, Reeder RW, et al. Risk factors for mortality in refractory pediatric septic shock supported with extracorporeal life support. ASAIO J 2020;66:1152−60, doi:http://dx.doi.org/10.1097/MAT.0000000000001147.

759. Sole A, Jordan I, Bobillo S, et al. Venoarterial extracorporeal membrane oxygenation support for neonatal and pediatric refractory septic shock: more than 15 years of learning. Eur J Pediatr 2018;177:1191−200, doi:http://dx.doi.org/10.1007/s00431-018-3174- 2.

760. Torres-Andres F, Fink EL, Bell MJ, Sharma MS, Yablonsky EJ, Sanchez-de-Toledo J. Survival and long-term functional outcomes for children with cardiac arrest treated with extracorporeal cardiopulmonary resuscitation. Pediatr Crit Care Med 2018;19:451−8, doi:http://dx.doi.org/10.1097/PCC.0000000000001524.

761. Barbaro RP, Paden ML, Guner YS, et al. Pediatric extracorporeal life support organization registry international report 2016. ASAIO J 2017;63:456−63, doi:http://dx.doi.org/10.1097/MAT.0000000000000603.

762. Shin HJ, Song S, Park HK, Park YH. Results of extracorporeal cardiopulmonary resuscitation in children. Korean J Thorac Cardiovasc Surg 2016;49:151−6, doi:http://dx.doi.org/10.5090/kjtcs.2016.49.3.151.

763. Oberender F, Ganeshalingham A, Fortenberry JD, et al. Venoarterial extracorporeal membrane oxygenation versus conventional therapy in severe pediatric septic shock. Pediatr Crit Care Med 2018;19:965−72, doi:http://dx.doi.org/10.1097/PCC.0000000000001660.

764. Weiss SL, Balamuth F, Hensley J, et al. The epidemiology of hospital death following pediatric severe sepsis: when, why, and how children with sepsis die. Pediatr Crit Care Med 2017;18:823−30, doi:http://dx.doi.org/10.1097/PCC.0000000000001222.

765. Cunningham A, Auerbach M, Cicero M, Jafri M. Tourniquet usage in prehospital care and resuscitation of pediatric trauma patients-Pediatric Trauma Society position statement. J Trauma Acute Care Surg 2018;85:665−7, doi:http://dx.doi.org/10.1097/TA.0000000000001839.

766. American College of Surgeons Committee on T, American College of Emergency Physicians Pediatric Emergency Medicine C, National Association of Ems P, American Academy of Pediatrics Committee on Pediatric Emergency M, Fallat ME. Withholding or termination of resuscitation in pediatric out-of- hospital traumatic cardiopulmonary arrest. Pediatrics 2014;133:e1104−16, doi:http://dx.doi.org/10.1542/peds.2014- 0176.

767. Zwingmann J, Mehlhorn AT, Hammer T, Bayer J, Sudkamp NP, Strohm PC. Survival and neurologic outcome after traumatic out-of-hospital cardiopulmonary arrest in a pediatric and adult population: a systematic review. Crit Care 2012;16:R117, doi:http://dx.doi.org/10.1186/cc11410.

768. Donoghue AJ, Nadkarni V, Berg RA, et al. Out-of-hospital pediatric cardiac arrest: an epidemiologic review and assessment of current knowledge. Ann Emerg Med 2005;46:512−22.

769. Alqudah Z, Nehme Z, Alrawashdeh A, Williams B, Oteir A, Smith K. Paediatric traumatic out-of-hospital cardiac arrest: a systematic

review and meta-analysis. Resuscitation 2020;149:65–73, doi:http://dx.doi.org/10.1016/j.resuscitation.2020.01.037.

770. Moore L, Champion H, Tardif PA, et al. Impact of trauma system structure on injury outcomes: a systematic review and meta-analysis. World J Surg 2018;42:1327–39, doi:http://dx.doi.org/10.1007/s00268-017-4292- 0.

771. Puzio T, Murphy P, Gazzetta J, Phillips M, Cotton BA, Hartwell JL. Extracorporeal life support in pediatric trauma: a systematic review. Trauma Surg Acute Care Open 2019;4:e000362, doi:http://dx.doi.org/10.1136/tsaco-2019- 000362.

772. Tan BK, Pothiawala S, Ong ME. Emergency thoracotomy: a review of its role in severe chest trauma. Minerva Chir 2013;68:241–50 (https://www.ncbi.nlm.nih.gov/pubmed/23774089).

773. Allen CJ, Valle EJ, Thorson CM, et al. Pediatric emergency department thoracotomy: a large case series and systematic review. J Pediatr Surg 2015;50:177–81, doi:http://dx.doi.org/10.1016/j.jpedsurg.2014.10.042.

774. Moskowitz EE, Burlew CC, Kulungowski AM, Bensard DD. Survival after emergency department thoracotomy in the pediatric trauma population: a review of published data. Pediatr Surg Int 2018;34:857–60, doi:http://dx.doi.org/10.1007/s00383-018-4290-9.

775. Bennett M, Kissoon N. Is cardiopulmonary resuscitation warranted in children who suffer cardiac arrest post trauma? Pediatr Emerg Care 2007;23:267–72, doi:http://dx.doi.org/10.1097/PEC.0b013e3180403088.

776. Cameron A, Erdogan M, Lanteigne S, Hetherington A, Green RS. Organ donation in trauma victims: a systematic review and meta-analysis. J Trauma Acute Care Surg 2018;84:994–1002, doi:http://dx.doi.org/10.1097/TA.0000000000001886.

777. Shibahashi K, Sugiyama K, Hamabe Y. Pediatric out-of- hospital traumatic cardiopulmonary arrest after traffic accidents and termination of resuscitation. Ann Emerg Med 2020;75:57–65, doi:http://dx.doi.org/10.1016/j.annemergmed.2019.05.036.

778. Brindis SL, Gausche- Hill M, Young KD, Putnam B. Universally poor outcomes of pediatric traumatic arrest: a prospective case series and review of the literature. Pediatr Emerg Care 2011;27:616–21, doi:http://dx.doi.org/10.1097/PEC.0b013e31822255c9.

779. Matos RI, Watson RS, Nadkarni VM, et al. Duration of cardiopulmonary resuscitation and illness category impact survival and neurologic outcomes for in-hospital pediatric cardiac arrests. Circulation 2013;127:442–51, doi:http://dx.doi.org/10.1161/circulationaha.112.125625 [in Eng].

780. Duron V, Burke RV, Bliss D, Ford HR, Upperman JS. Survival of pediatric blunt trauma patients presenting with no signs of life in the field. J Trauma Acute Care Surg 2014;77:422–6, doi:http://dx.doi.org/10.1097/TA.0000000000000394.

781. Noje C, Bembea MM, Nelson McMillan KL, et al. A national survey on interhospital transport of children in cardiac arrest. Pediatr Crit Care Med 2019;20:e30–6, doi:http://dx.doi.org/10.1097/PCC.0000000000001768.

782. Wieck MM, Cunningham AJ, Behrens B, et al. Direct to operating room trauma resuscitation decreases mortality among severely injured children. J Trauma Acute Care Surg 2018;85:659–64, doi:http://dx.doi.org/10.1097/TA.0000000000001908.

783. Michelson KA, Hudgins JD, Monuteaux MC, Bachur RG, Finkelstein JA. Cardiac arrest survival in pediatric and general emergency departments. Pediatrics 2018141:, doi:http://dx.doi.org/10.1542/peds.2017- 2741.

784. Moore HB, Moore EE, Bensard DD. Pediatric emergency department thoracotomy: a 40-year review. J Pediatr Surg 2016;51:315–8, doi:http://dx.doi.org/10.1016/j.jpedsurg.2015.10.040.

785. Schauer SG, Hill GJ, Connor RE, Oh JS, April MD. The pediatric resuscitative thoracotomy during combat operations in Iraq and Afghanistan – a retrospective cohort study. Injury 2018;49:911–5, doi:http://dx.doi.org/10.1016/j.injury.2018.01.034.

786. Flynn-O'Brien KT, Stewart BT, Fallat ME, et al. Mortality after emergency department thoracotomy for pediatric blunt trauma: analysis of the National Trauma Data Bank 2007–2012. J Pediatr

Surg 2016;51:163–7, doi:http://dx.doi.org/10.1016/j.jpedsurg.2015.10.034.

787. Capizzani AR, Drongowski R, Ehrlich PF. Assessment of termination of trauma resuscitation guidelines: are children small adults? J Pediatr Surg 2010;45:903–7, doi:http://dx.doi.org/10.1016/j.jpedsurg.2010.02.014.

788. Zwingmann J, Lefering R, TraumaRegister DGU, et al. Outcome and risk factors in children after traumatic cardiac arrest and successful resuscitation. Resuscitation 2015;96:59–65, doi:http://dx.doi.org/10.1016/j.resuscitation.2015.07.022.

789. McLaughlin C, Zagory JA, Fenlon M, et al. Timing of mortality in pediatric trauma patients: a National Trauma Data Bank analysis. J Pediatr Surg 2018;53:344–51, doi:http://dx.doi.org/10.1016/j.jpedsurg.2017.10.006.

790. Alqudah Z, Nehme Z, Williams B, Oteir A, Bernard S, Smith K. A descriptive analysis of the epidemiology and management of paediatric traumatic out-of-hospital cardiac arrest. Resuscitation 2019;140:127–34, doi:http://dx.doi.org/10.1016/j.resuscitation.2019.05.020.

791. Kaestner M, Schranz D, Warnecke G, Apitz C, Hansmann G, Miera O. Pulmonary hypertension in the intensive care unit. Expert consensus statement on the diagnosis and treatment of paediatric pulmonary hypertension. The European Paediatric Pulmonary Vascular Disease Network, endorsed by ISHLT and DGPK. Heart 2016102:, doi:http://dx.doi.org/10.1136/heartjnl-2015- 307774 ii57–66.

792. Marino BS, Tabbutt S, MacLaren G, et al. Cardiopulmonary resuscitation in infants and children with cardiac disease: a scientific statement from the American Heart Association. Circulation 2018;137:e691–782, doi:http://dx.doi.org/10.1161/CIR.0000000000000524.

793. Morgan RW, Topjian AA, Wang Y, et al. Prevalence and outcomes of pediatric in-hospital cardiac arrest associated with pulmonary hypertension. Pediatr Crit Care Med 2020;21:305–13, doi:http://dx.doi.org/10.1097/PCC.0000000000002187.

794. Loaec M, Himebauch AS, Kilbaugh TJ, et al. Pediatric cardiopulmonary resuscitation quality during intra-hospital transport. Resuscitation 2020;152:123–30, doi:http://dx.doi.org/10.1016/j.resuscitation.2020.05.003.

795. Anton-Martin P, Moreira A, Kang P, Green ML. Outcomes of paediatric cardiac patients after 30minutes of cardiopulmonary resuscitation prior to extracorporeal support. Cardiol Young 2020;30:607–16, doi:http://dx.doi.org/10.1017/S1047951120000591.

796. Morell E, Rajagopal SK, Oishi P, Thiagarajan RR, Fineman JR, Steurer MA. Extracorporeal membrane oxygenation in pediatric pulmonary hypertension. Pediatr Crit Care Med 2020;21:256–66, doi:http://dx.doi.org/10.1097/PCC.0000000000002127.

797. Melvan JN, Davis J, Heard M, et al. Factors associated with survival following extracorporeal cardiopulmonary resuscitation in children. World J Pediatr Congenit Heart Surg 2020;11:265–74, doi:http://dx.doi.org/10.1177/2150135120902102.

798. Esangbedo ID, Brunetti MA, Campbell FM, Lasa JJ. Pediatric extracorporeal cardiopulmonary resuscitation: a systematic review. Pediatr Crit Care Med 2020;21:e934–43, doi:http://dx.doi.org/10.1097/PCC.0000000000002373.

799. Kido T, Iwagami M, Yasunaga H, et al. Outcomes of paediatric out-of-hospital cardiac arrest according to hospital characteristic defined by the annual number of paediatric patients with invasive mechanical ventilation: a nationwide study in Japan. Resuscitation 2020;148:49–56, doi:http://dx.doi.org/10.1016/j.resuscitation.2019.12.020.

800. Amagasa S, Kashiura M, Moriya T, et al. Relationship between institutional case volume and one-month survival among cases of paediatric out-of-hospital cardiac arrest. Resuscitation 2019;137:161–7, doi:http://dx.doi.org/10.1016/j.resuscitation.2019.02.021.

801. Gupta P, Tang X, Gall CM, Lauer C, Rice TB, Wetzel RC. Epidemiology and outcomes of in-hospital cardiac arrest in critically ill children across hospitals of varied center volume: a multi-center

analysis. Resuscitation 2014;85:1473−9, doi:http://dx.doi.org/
10.1016/j.resuscitation.2014.07.016.

802. Stub D, Nichol G. Hospital care after resuscitation from out-of-
hospital cardiac arrest: the emperor's new clothes? Resuscitation
2012;83:793−4, doi:http://dx.doi.org/10.1016/j.
resuscitation.2012.03.034.

803. Topjian AA, Telford R, Holubkov R, et al. The association of early
post-resuscitation hypotension with discharge survival following
targeted temperature management for pediatric in- hospital cardiac
arrest. Resuscitation 2019;141:24−34, doi:http://dx.doi.org/
10.1016/j.resuscitation.2019.05.032.

804. Laverriere EK, Polansky M, French B, Nadkarni VM, Berg RA,
Topjian AA. Association of duration of hypotension with survival after
pediatric cardiac arrest. Pediatr Crit Care Med 2020;21:143−9, doi:
http://dx.doi.org/10.1097/PCC.0000000000002119.

805. Topjian AA, Sutton RM, Reeder RW, et al. The association of
immediate post cardiac arrest diastolic hypertension and survival
following pediatric cardiac arrest. Resuscitation 2019;141:88−95,
doi:http://dx.doi.org/10.1016/j.resuscitation.2019.05.033.

806. Topjian AA, Telford R, Holubkov R, et al. Association of early
postresuscitation hypotension with survival to discharge after
targeted temperature management for pediatric out-of- hospital
cardiac arrest: secondary analysis of a randomized clinical trial.
JAMA Pediatr 2018;172:143−53, doi:http://dx.doi.org/10.1001/
jamapediatrics.2017.4043.

807. Lopez-Herce J, del Castillo J, Matamoros M, et al. Post return of
spontaneous circulation factors associated with mortality in pediatric
in-hospital cardiac arrest: a prospective multicenter multinational
observational study. Crit Care 2014;18:607, doi:http://dx.doi.org/
10.1186/s13054-014-0607- 9.