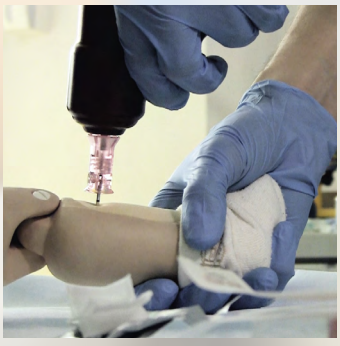
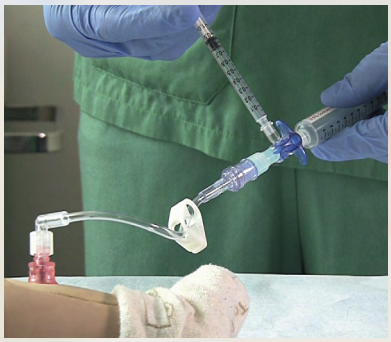
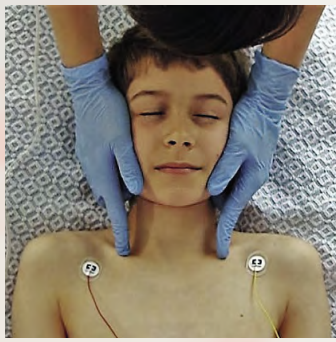
European Paediatric Advanced Life Support

ERC GUIDELINES 2021 EDITION

EUROPEAN RESUSCITATION COUNCIL

European Paediatric Advanced Life Support

ERC GUIDELINES 2021 EDITION

Edition 1

European Paediatric Advanced Life Support
Course Manual

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Contents

CHAPTER 0
ABOUT THE COURSE

The EPALS course aims to provide caregivers with the knowledge and skills for the management of the critically ill child during **the first hour** of illness, including the prevention and, if needed, treatment of paediatric cardiac arrest. Participants are generally team members or team leaders of advanced paediatric resuscitation teams. Emphasis is therefore also given to team management and non-technical skills.

Be aware of the scope of this course. If you only ever take responsibility for children during the first minutes of critical illness. awaiting a paediatric resuscitation team to arrive, the EPILS course may suit you better.

The content of this course is based upon the ERC 2021 guidelines, the content of the previous manual, existing evidence from literature, existing guidelines and expert consensus.

This manual should be read in conjunction with the virtual learning materials (VLE) available at the European Resuscitation Council (ERC) **'CoSy'** website. As it is, the ERC e-learning English version is considered the most complete and up to date, including a lot of background information, where this manual only contains the core learning content as it is known at the date of publication. *For this reason, you will find **QR codes** in this manual that directly link to the chapters and/or audiovisual materials within the VLE. You can click on them or scan these codes with for instance your mobile phone.*

If you receive this manual as part of your preparation for a relevant ERC course, you also have access to all relevant VLE e-learning materials via your CoSy account.

If you however bought this manual without being registered for a relevant ERC course, you might still gain access to the virtual materials by using the links and QR codes within this manual. The first time you do so, we will ask you to register to the platform and enter the following redeem code:

Sticker with redeem code to be added here.

To really train CPR and life support, you obviously need the knowledge (as provided by the given learning materials) but also should receive training in skills and importantly performance. We therefore invite you – if not already- to consider enrolling in a hands-on course. You can find a relevant course in your region via https://CoSy.erc.edu/en/sessions/calendar. Those completing a hands-on course also will receive an official ERC certificate.

0.1. IMPORTANT: LIFELONG LEARNING AND CERTIFICATE VALIDITY

Recertification & Lifelong Learning

With the launch of the new CoSy 2020, ERC has decided to better take into account the rapid decay in performance yet appreciating the difficult circumstances in which providers might work and the rules and regulations they need to comply with. ERC therefore decided to replace the end date of the certificate by a **deadline for recertification** via the ERC recertification program. This deadline for recertification is standard *2 year for advanced courses* (with a flexibility of up to 3 months). After this deadline, the only way to update your certificate is by redoing a full provider course.

To keep your certificate 'healthy', within the recertification program, ERC will demand you to do specific **'recertification'** activities at regular intervals. What these activities are is best found by going to your certificates in CoSy 2020 and clicking on the 'how to keep my certificates healthy' link.

! It might be that such recertification trajectory is not yet available in your country or for your course type and then the only way to update your certificate (date of last course) and keep access to all ERC learning materials is by doing a full provider course anew.

0.2. GLOSSARY

AED	Automated External Defibrillator
ALS	Advanced Life Support
BBB	Behaviour – Breathing – Body Colour
BE	Base Excess
BLS	Basic Life Support
BMV	Bag-Mask Ventilation
BP	Blood Pressure
CAT	Cardiac Arrest Team
CO	Cardiac Output
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPP	Cerebral Perfusion Pressure
CPR	Cardiopulmonary Resuscitation
ECG	Electrocardiography
EEG	Electroencephalography
EMS	Emergency Medical Service
$ETCO_2$	End Tidal Carbon Dioxide
FBAO	Foreign Body Airway Obstruction
FiO_2	Inspired Oxygen Fraction
GCS	Glasgow Coma Scale
HR	Heart Rate
ICP	Intracranial Pressure
IHCA	In-Hospital Cardiac Arrest
IO	Intraosseous Access
IV	Intravenous
J/kg	Joules Per Kilogram
L/min	Liters Per Minute
LMA	Laryngeal Mask Airway
MAP	Mean Arterial Pressure
Mcg/kg	Microgram Per Kilogram
MET	Medical Emergency Team
Ml/h	Milliliters Per Hour
Ml/kg	Milliliters Per Kilogram
O_2	Oxygen
OHCA	Out-Of-Hospital Cardiac Arrest
PaO_2	Partial Arterial Oxygen Content
PEA	Pulseless Electrical Activity
PEEP	Positive End Expiratory Pressure
PPE	Personal protection equipment
PICU	Paediatric Intensive Care Unit
PRC	Packed Red Cells
pVT	Pulseless Ventricular Tachycardia
ROSC	Return Of Spontaneous Circulation
RR	Respiratory Rate
RSI	Rapid Sequence Intubation
RSVP	Reason, Story, Vital Signs, Plan
SB	Standard Bicarbonate
SpO_2	Transcutaneous Arterial Oxygen Saturation
SV	Stroke Volume
SVR	Systemic Vascular Resistance
VF	Ventricular Fibrillation

In times of a pandemic...

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 **PPE** (personal protection equipment) 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 dedicated e-learning on CPR during the COVID-19 pandemic can be found in your CoSy account. The specific COVID-19 guideline text is also provided as background within the VLE.

CHAPTER 1
INTRODUCTION - CHILDREN DIFFER

The main focus of the EPALS/EPILS courses is on a systematic **[Airway (A), Breathing (B), Circulation (C), Disability (D), Environment - Exposure (E)]** approach to the immediate assessment and treatment of critically ill children and children in cardiorespiratory arrest.

The importance of both prevention and coordinated emergency care to improve outcome is illustrated in more detail by the **Paediatric Chain of Survival. We refer to the CoSy VLE for more information on this.**

CHILDREN DIFFER

Children have anatomical and physiological differences and suffer from a different spectrum of diseases and therefore warrant a distinct approach in comparison to adults.

It is of the utmost importance that healthcare professionals who take care of sick children are trained in the early recognition of any severely ill child and have the necessary knowledge and skills to deliver the appropriate emergency care. We specifically use the word **'competent'** to describe the level of knowledge, skills, attitudes, expertise, and ongoing training sufficient 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.

Except where specifically stated otherwise, the use of the word 'child' in the manual refers to both infants (< 1 year of age) and children (from the age of 1 to 18 years). From a practical perspective, adult guidelines can be used for anyone who appears to be an adult. A neonate is an infant within 4 weeks of being born, while a newborn refers to a neonate immediately after delivery.

Size & weight

One of the most obvious differences between infants, children and adults is their different size and weight. Weight is important because drugs and fluids are prescribed by body weight in paediatrics. Actual weight is however frequently unavailable in emergency situations. To estimate a child's weight, either rely on the parents or caretakers or use a length-based method (such as a Broselow tape), ideally

corrected for body-habitus (e.g. Pawper MAC). Use, whenever possible, decision aids providing pre-calculated dose advice for emergency drugs and materials. Whatever the method, it is essential that the caregiver is sufficiently familiar with it to use it quickly and accurately.

Airway

- The infant's head is usually large compared with the body, and in combination with the relatively large occiput, the head tends to become flexed on the neck when an unconscious child is in the supine position, causing airway obstruction. With increasing age, the head becomes relatively smaller, the neck lengthens and the larynx becomes more resistant to external pressure.
- The infant's face and mouth are small and the relatively *large tongue easily obstructs* the airway in the unconscious child. The floor of the mouth is also easily compressible and upper airway can be obstructed by pressure on soft tissues under the chin.
- The infant is a preferential *nose breather* for the first 6 months of life; therefore anything that causes nasal obstruction in newborns/infants (e.g., copious mucus secretions due to respiratory infections, anatomical abnormalities, equipment such as nasogastric tubes) can increase the work of breathing and lead to respiratory failure.
- (Adeno-)tonsillar hypertrophy is a relatively common finding in the age group between 2-6 years. It may contribute to upper airway obstruction (causing difficulties with bag-mask ventilation).
- The larynx is located at C2 in the infant compared with C4-C5 for older children and adults; the epiglottis is U-shaped, protruding towards the pharynx at an angle of 45°; the vocal cords are short. In children younger than 8 years, the narrowest section of the larynx is at the level of the subglottic cricoid cartilage. Especially in infants the narrow airway makes it particularly vulnerable to obstruction by e.g. oedema.

Some of these anatomical and physiological differences might render tracheal intubation in a child difficult.

Breathing

- The mechanics of breathing alter with age. The diaphragm is the main respiratory muscle in children and its downward movement in inspiration creates a vacuum that draws air through the upper airway and into the lungs. Mechanical obstacles to diaphragmatic contraction of abdominal origin (gastric distension, pneumoperitoneum, intestinal occlusion) or of pulmonary origin (hyperinflation, e.g., with bronchiolitis, asthma or foreign body inhalation) can lead to ineffective ventilation.
- The smaller lower airways of infants tend to collapse more easily when submitted to increased intrathoracic pressure because of forced expiratory effort.

- In the infant, the ribs are also soft and pliable and the intercostal muscles are relatively weak and ineffective compared to the diaphragm. In older children, the intercostal muscles are more developed and contribute significantly to the mechanics of ventilation; the ribs become ossified and act as secure supports as well as forming a rigid structure that is less likely to collapse in respiratory distress. This means that intercostal and sternal recession in older children is indicative of more serious respiratory compromise than it is in infants where it is often already present in an earlier stage.
- Due to higher metabolic rate and oxygen consumption, respiratory rate is higher in infants and young children than in adults.
- Work of breathing can account for up to 40 % of the cardiac output in children.
- Children have a smaller functional residual capacity and thus less respiratory reserve. Desaturation will occur much faster. This is even more obvious when in supine position.

Circulation

- The circulating volume of the neonate is 80 ml/kg, decreasing to 60-70 ml/kg in adulthood.
- Due to higher metabolic rate and higher cardiac output, heart rate is higher in children than in adults. As stroke volume cannot increase in the same way as in adults, cardiac output in infants and young children is mainly determined by heart rate.
- Blood pressure is lower in infants and small children than in larger children or adolescents.

PATHWAYS LEADING TO CARDIORESPIRATORY ARREST

Cardiac arrest in children is less likely due to primary cardiac disease **(primary cardiorespiratory arrest)**. This type of cardiac arrests is a lot more frequent in the adult population and has an acute and unpredictable onset reflecting intrinsic heart disease. *Immediate defibrillation* is generally required as often the terminal rhythm will be a shockable one (Ventricular Fibrillation [VF]- Pulseless Ventricular Tachycardia [pVT]). In these situations, every minute delay in defibrillation will significantly decrease the probability of returning to a spontaneous circulation.

Secondary cardiorespiratory arrest is much more common in children, reflecting the inability to deal with certain triggering injuries/illnesses. Cardiac arrest is here the consequence of severe *tissue hypoxia* causing myocardial dysfunction. Tissue hypoxia can arise from respiratory failure with inadequate oxygenation or from severe hypoperfusion as in circulatory failure. Initially the body activates adaptive physiological responses to protect the heart and the brain from hypoxia and compensate for the respiratory or circulatory failure. With the progression of failure or injury, however, the body fails to sustain these responses. This represents a

decompensated physiological state, either respiratory or circulatory depending on the underlying cause; both can also be present simultaneously. Respiratory and circulatory failure combine as the child's condition worsens, leading to cardiorespiratory failure and then cardiorespiratory arrest. The terminal rhythm will often be a non-shockable one: bradycardia - pulseless electrical activity [PEA] or asystole.

Table 1.1 Normal values of parameters for age

AGE	RESP. RATE / min (LOWER - UPPER LIMIT)	HEART RATE / min (LOWER - UPPER LIMIT)	BP Syst mmHg (p5 - p50)	BP MEAN mmHg (p5 - p50)
1 month	25 - 60	110 - 180	50 - 75	40 - 55
1 year	20 - 50	100 - 170	70 - 95	50 - 70
2 year	18 - 40	90 - 160	70 - 95	50 - 70
5 year	17 - 30	70 - 140	75 - 100	55 - 75
10 year	14 - 25	60 - 120	80 - 110	55 - 75

CHAPTER 2
RECOGNITION OF THE CRITICALLY ILL CHILD

Emergency assessment of severely ill children is often difficult. Complex information must be integrated, and treatment decisions have to be made in a compressed timeframe, sometimes by health care providers without a lot of experience with critically ill children. As in any medical emergency, a systematic and priority-based approach enhances reliability and improves communication and optimisation of teamwork.

For children of all ages, emergency assessment includes 4 sequential steps:

1. *First Observational Assessment or Quick Look*
2. *Primary Physiological Assessment by using the ABCDE approach*
3. *Secondary Clinical Assessment with a focused medical history and detailed physical examination*
4. *Tertiary Complementary Assessment with laboratory, imaging and other ancillary studies.*

Only steps 1 and 2 will be covered in this chapter (and in this course). The identification of potentially life- threatening conditions and the delivery of lifesaving treatment take place during these first two crucial steps. They are performed in a simultaneous and continuous manner in order to prevent further deterioration to cardiorespiratory arrest.

! **The most crucial element of this systematic approach is the principle that when a potentially life-threatening problem is identified immediate treatment is performed before moving on to the next step in the sequence: 'Treat as you go' approach.**

A FIRST OBSERVATIONAL ASSESSMENT: THE QUICK LOOK

The Quick Look assessment is a rapid way to decide (in a few seconds) if a child is *severely ill or not* and if they require *immediate lifesaving treatment & additional resources*. It is a hands–off across the room assessment that can be completed in less than 10 seconds using only visual and auditory clues, requiring no technical equipment nor undressing (apart from taking away a face mask).

The components of the Quick Look assessment can be memorized as **'BBB'**: [Behaviour – Breathing – Body colour]. Each component is evaluated separately using predefined findings. ***Any abnormality*** *noted denotes an unstable child who needs some immediate clinical intervention and a hands-on ABCDE primary assessment.*

- **BEHAVIOUR** includes assessment of muscle tone and mental status and reflects the adequacy of respiratory, circulatory and brain function. Abnormal signs include:
  - no spontaneous movement
  - unable to sit or stand
  - being less alert or engaged with clinician, parents or toys; being inconsolable
  - has a weak cry (nearly audible) …
- **BREATHING** describes the child's respiratory status, especially the degree to which the child must work in order to oxygenate and ventilate:
  - abnormal breathing sounds (snoring, muffled or hoarse speech, stridor, grunting, wheezing)
  - chest retractions
  - very irregular breathing…
- **BODY COLOUR** describes the child's circulatory function, primarily in terms of skin perfusion:
  - **pallor:** white or pale skin or mucous membranes
  - **mottling:** patchy skin discoloration due to various degrees of vasoconstriction
  - **cyanosis:** bluish discoloration of skin

PRIMARY ASSESSMENT: THE ABCDE APPROACH

When the quick hand-free general assessment shows one or more anomalies in any ill or injured child a standardised ABCDE evaluation is mandatory during which a complete assessment of **A**irway, **B**reathing, **C**irculation, mental status (**D**isability) and **E**xposure is made and appropriate stabilization measures performed. It is important to **repeat** periodically the primary assessment, particularly after an intervention to evaluate its effect, and after any major change in the patient's condition.

! **When a child was unresponsive at first impression, a brief check of responsiveness should be performed before starting with the airway assessment by gentle verbal or tactile stimulation to establish a more exact level of consciousness and identify potential cardiac arrest (unresponsive with absent or abnormal breathing).**

A = Airway

If air movement at the child's mouth or nose can be felt, if thoracic excursions are detected and normal breath sounds and/or normal speech is heard then the airway is likely patent. Visual chest expansion without effective air entry can occur with airway obstruction. Abnormal breath sounds (e.g. stridor, gurgling sounds) may indicate partial airway obstruction by something that is limiting normal air flow, such as secretions, oedema or a foreign body.

Children with a diminished level of consciousness are at risk of airway obstruction due to a decrease in pharyngeal muscle tone causing the tongue falling backwards and obstructing the airway.

Non-comatose children in respiratory distress will adopt a position to maximize their respiratory capacity. In upper airway obstruction they often adopt the "sniffing" position to optimize their upper airway patency.

! **If the airway is not patent or at risk, immediate interventions are necessary before proceeding to the breathing assessment: airway opening manoeuvres, suctioning, airway adjuncts....**

Once the airway has been opened:

Look, Listen, Feel to identify abnormal breathing *(In unconscious children) look for chest wall (& abdominal) movements, listen for breath sounds and noises at mouth & nose (or chest auscultation), feel for air flow at mouth & nose or use.* **If a child is unconscious with absent or abnormal breathing, presume it to be in cardiac arrest until proven otherwise…**

Figure 2.1 Look, Listen, Feel. Airway patency is evaluated by looking at the thorax for chest movement, listening for breath sounds and feeling air movement at the patient's mouth or nose.

LOOK for chest wall
(& abdominal) movements

LISTEN for breath sounds and noises
at the mouth and nose
(or chest auscultation)

FEEL for air flow at the mouth and nose

B = Breathing

Normal respiratory function requires the movement of gas into and out of the lungs and the adequate exchange of oxygen [O_2] **(oxygenation)** and carbon dioxide [CO_2] **(ventilation)** across the alveolar-capillary membrane.

After the airway has been assessed and the necessary interventions made to obtain airway patency, one should proceed to the **BREATHING assessment**. This is done by evaluating: *Respiratory rate, Work of breathing, Tidal volume, Oxygenation* (RWTO can be used as memory aid). By doing so, the respiratory status can be categorized as stable or as compensated or decompensated respiratory failure. **This categorisation should always be based on a constellation of findings and not on a single abnormal element.** Appropriate interventions should be started according to the degree of respiratory dysfunction and before proceeding to the assessment of the circulatory function.

- **Respiratory Rate [RR]** varies with age and other causes such as agitation or the presence of fever. It is therefore important to keep record of respiratory rate, as changes over time (trend) are more useful than a single value. Abnormalities can be classified as regular or irregular; too rapid (tachypnoea), too slow (bradypnoea), or absent (apnoea). A reduction of respiratory rate in an acutely ill child may indicate exhaustion and in this case is an ominous sign.
- **Work of Breathing:** Increased work of breathing in children manifests as: intercostal, sternal, and subcostal retraction (or recession), nasal flaring, head bobbing and contraction of the anterior chest wall muscles. Retractions (recessions) are easily observed in infants and young children owing to the high compliance of the chest wall. The degree of retraction gives an indication of the severity of the respiratory distress. In children older than 5 years, when the chest is less compliant, retractions indicate severe impairment of the child's respiratory function. *(an example of subcostal retractions is provided in the VLE, as well as more information on head bobbing & see-saw respiration).* A high-pitched inspiratory noise (stridor) is characteristic of a partial extrathoracic upper airway obstruction and is due to rapid, turbulent flow through a narrowed portion of the upper tracheal airway. Biphasic stridor (inspiratory and expiratory) indicates an obstruction at the upper tracheal level. When the site of obstruction is more distal (at the lower tracheal level), the noise becomes primarily expiratory. Wheezing (expiratory, prolonged noise audible by the ear or by the stethoscope) indicates lower airway narrowing, usually at the bronchial or bronchiolar level (intrathoracic). Grunting is mainly heard in neonates but sometimes in infants and young children. It is the result of exhaling against a partially closed glottis in an attempt to generate a positive end expiratory pressure [PEEP] and preserve the resting lung volume. Grunting is an unspecific but sensitive indicator of serious illness.

The degree of increased work of breathing is generally proportional to the severity of respiratory failure except in situations where there might be no signs of increased work of breathing such as central respiratory depression, neuromuscular diseases and exhaustion (decompensation of respiratory failure).

- **Tidal Volume:** Spontaneous tidal volume stays constant throughout life at around 7 ml/kg (ideal body weight). It can be qualitatively assessed by visual detection of chest expansion adequacy and by listening to air entry in all zones of the lungs (auscultation).

A 'silent' chest is an ominous sign that indicates a dramatically reduced tidal volume.

- **Oxygenation:** A clinical way of determining oxygenation is by evaluating the presence of central cyanosis (of the oral mucosa) indicative of hypoxemia. This is however an inconsistent and late sign of respiratory failure. It only appears when the O_2 saturation level is < 80 %. Importantly, its absence does not imply that O_2 levels are normal. Hypoxia may cause vasoconstriction and skin pallor that may mask cyanosis, or the patient may be severely anemic. Peripheral cyanosis limited to the extremities is usually due to circulatory insufficiency rather than to respiratory failure. Therefore, a more reliable way to determine oxygenation is by measuring the oxygen saturation with a pulse oximeter when respiratory failure is suspected, even in the absence of cyanosis. Pulse oximetry is an invaluable tool in the assessment and monitoring of respiratory failure and should be systematically used to measure the transcutaneous arterial oxygen saturation [SpO_2]. The reading should always be interpreted in the light of the inspired oxygen concentration – a reading of 95 % on air is not too concerning but it is a serious finding in a child on 60 % oxygen. Oximeters are less accurate when SpO_2 is less than 70 %, in low peripheral perfusion states (e.g. shock, hypothermia) and/or in the presence of carboxyhaemoglobin or methaemoglobin. Likewise, when the SpO_2 is 100 %, it becomes impossible to correlate this value with the partial arterial oxygen content [PaO_2], thus incorporating a risk of not detecting inadvertent hyperoxemia. Sustained SpO_2 readings of 100% should therefore generally be avoided (except for instance in pulmonary hypertension, CO intoxication).

Respiratory dysfunction will be accompanied by tachycardia (and eventually bradycardia). A changing level of consciousness is indicative of decompensation. When respiratory failure progresses, the child may initially become agitated (for instance fighting the oxygen mask) or drowsy. The final event will be loss of consciousness.

C = Circulation

Circulatory Failure / Shock is a clinical state in which blood flow and the delivery of tissue nutrients do not meet tissue metabolic demand. Failure to adequately deliver metabolic substrates (oxygen, glucose) and to remove cellular metabolites, leads to anaerobic metabolism, accumulation of lactic acid and cell injury. It progresses over a continuum of severity from compensated circulatory dysfunction to a decompensated state.

Compensated shock is the early phase of shock before the presence of hypotension. Signs of compensatory mechanisms to try to preserve normal perfusion of vital organs are present such as tachycardia, poor peripheral perfusion (cool extremities, prolonged capillary refill time), weak peripheral pulses and decreasing urinary output.

Decompensated shock is present when hypotension develops and vital organ (heart, brain) perfusion is compromised as manifested by decreased level of consciousness and weak central pulses.

Shock may occur with increased, normal or decreased cardiac output [CO] or blood pressure [BP]. Measurement of blood pressure is by itself of limited value in determining circulatory status, as blood pressure often remains normal in compensated shock, and only starts to drop when decompensation occurs. *The aim in the management of shock is to prevent the onset of decompensated shock, as this may lead to irreversible shock and death.*

After breathing has been assessed and the necessary interventions have been made to support oxygenation and ventilation, one should proceed to the **CIRCULATION assessment**. This is done by evaluating: *Pulse-Heart Rate, Peripheral Perfusion, Pulses volume, Blood Pressure and Preload* (**5P** can be used as memory aid). By doing so, the circulatory status can be categorized as normal or as compensated or decompensated circulatory failure (shock). It is important to integrate the signs of shock because **no single sign confirms the diagnosis.**

see the CoSy VLE for more information

The assessment of a child in shock is completed by detection of any arrhythmia on ECG monitoring. (Cardiac) ultrasound might help to assess haemodynamic variables and the impact of treatment. Appropriate interventions should be made based on the degree of circulatory dysfunction.

- **Pulse – Heart Rate:** Sinus tachycardia is a common response to e.g. anxiety, fever or pain but is also seen in hypoxia, hypercapnia or hypovolemia (non-specific but early sign). If the increase in heart rate fails to maintain adequate tissue oxygenation, hypoxia and acidosis result in bradycardia, which indicates that cardiorespiratory arrest is imminent.

Small infants have limited cardiac reserve; they increase their cardiac output primarily by increasing their heart rate, rather than stroke volume. They develop bradycardia as the first response to hypoxia; older children will initially develop tachycardia.

- **Peripheral Perfusion:** Systemic Vascular Resistance [SVR] may be estimated by examining capillary refill time, skin temperature and diastolic blood pressure [BP]. In the healthy child, the skin is warm, dry and pink from head to toe, unless the ambient temperature is low. Capillary refill time is used to estimate perfusion; if prolonged, it is an early sign of developing shock. It is evaluated after pressure is applied to an area of skin for 5 seconds (e.g. nailbed or presternal skin). After releasing the pressure, the colour should return in 2 seconds or less. When the capillary refill is evaluated, the limb should be at the level of the heart, or very slightly above, to avoid venous stasis. Decreased perfusion of skin is indicative of peripheral vasoconstriction, an early sign of shock. Be aware that CRT is not very sensitive and influenced by the ambient temperature. A normal CRT should not reassure providers. Mottling, pallor and peripheral cyanosis are other signs of poor skin perfusion seen when cardiac output decreases.
- **Pulses Volume:** Stroke volume may be evaluated by palpation of the pulse amplitude. As stroke volume decreases, pulse amplitude decreases. Comparison between distal and central pulses may be useful. Distal pulses can also be weakened by vasoconstriction due to fever, cold or anxiety. Diminishing central pulses are a warning sign of imminent cardiorespiratory arrest.
- **Preload:** Clinical assessment of preload helps to differentiate cardiogenic shock from other forms of shock. If the preload significantly increases -as in fluid overload or heart failure-, the liver enlarges, jugular veins become dilated and moist sounds (crackles) can be heard in the lungs.
- **Blood Pressure:** Whatever the type of shock, hypotension is a sign of physiological decompensation, and must be treated vigorously as cardiorespiratory failure and arrest may be imminent. Use a correct size of cuff when measuring non-invasive BP. Be aware that, especially in young children, repeated NIBP measurement can cause distress.

! **As it is Mean Arterial Pressure [MAP] rather than systolic BP that determines tissue perfusion, maintaining this MAP above an age-specific threshold is considered at least as important.**

Tachypnoea can be seen a compensatory mechanism of circulatory dysfunction.

Organ perfusion depends on cardiac output and perfusion pressure. The skin, the kidneys, and the brain best reflect the quality of organ perfusion. A decrease of the hourly urinary output (< 1 ml/kg/hour in infants; 0,5 ml/kg/h in children) is an indicator of inadequate renal perfusion in cases of shock and is a clinically useful way to monitor the progression of shock and the effectiveness of treatment.

Signs of cerebral hypoperfusion vary with the severity and the duration of the insult. When circulatory dysfunction induces significant changes in cerebral function the child has decompensated circulatory failure. *If the onset of cerebral hypoperfusion is abrupt as in an arrhythmia, the first signs may be loss of consciousness, seizures or dilated pupils. If hypoperfusion progresses more slowly, agitation, lethargy, drowsiness or irritability may be observed.*

D = Disability- Neurological problems

The brain and the heart are the two organs that are preferentially preserved by the compensatory mechanisms of respiratory or circulatory failure, hence *evaluating brain function is important to determine the child's physiological status.* Following appropriate management of ABC, and ideally before depressant drugs are given, an evaluation of the child's neurological status should be made.

Whilst both respiratory and circulatory problems may have central neurological effects, some neurological conditions (e.g. meningitis, stroke, status epilepticus or decompensated intracranial hypertension) may have respiratory, circulatory or other severe consequences. These conditions have to be identified during the primary assessment since they need to be treated immediately. Treatment delays worsen outcome.

Sudden unexplained neurological symptoms, particularly those persisting after resuscitation, warrant urgent neuroimaging.

How to assess brain function?

- **AVPU:** A rapid assessment of the child's consciousness: the painful stimulus is delivered by applying sternal or supra-orbital pressure. A child who is only responsive to painful stimulus has a significant degree of neurological derangement equivalent to a value of 8 (which is the cut-off to define 'Coma') on the Glasgow Coma Scale.

Table 2.1 AVPU score

Alert	Normal reaction
Verbal	Reaction after vocal stimulation
Pain	Only reaction after pain stimulus
Unresponsive	No reaction despite any stimulus

- **GLASGOW COMA SCALE [GCS] – POSTURE:** A more detailed alternative for rapid assessment is the use of the Glasgow Coma Scale [GCS] *(see VLE)*. The GCS is modified for use in children under 5 years, due to their relatively immature ability to communicate. A total value of 8 defines 'coma' - a level of consciousness where airway reflexes are unlikely to be preserved. Given the complexity of the total GCS, some advocate the use of merely the GCS Motor score as a valuable, more easy to remember alternative. This 6-level score contains nearly all the information content of the total GCS (including both pain reaction and posture). The pain stimulus should be delivered by pressing hard on the supra-orbital notch (beneath medial end of eyebrow) with your thumb, except for M4, which is tested by pressing hard on the flat nail surface with the barrel of a pencil. The best response should be scored when responses are unclear or asymmetrical. A motor score of 4 or less indicates 'coma'.

Table 2.2 The Glasgow Coma Motor Score

Motor	
M6	Obeys commands
M5	Localises to supraorbital pain (> 9 months of age) or withdraws to touch
M4	Withdraws from nailbed pain
M3	Flexion to supraorbital pain (decorticate)
M2	Extension to supraorbital pain (decerebrate)
M1	No response to supraorbital pain (flaccid)

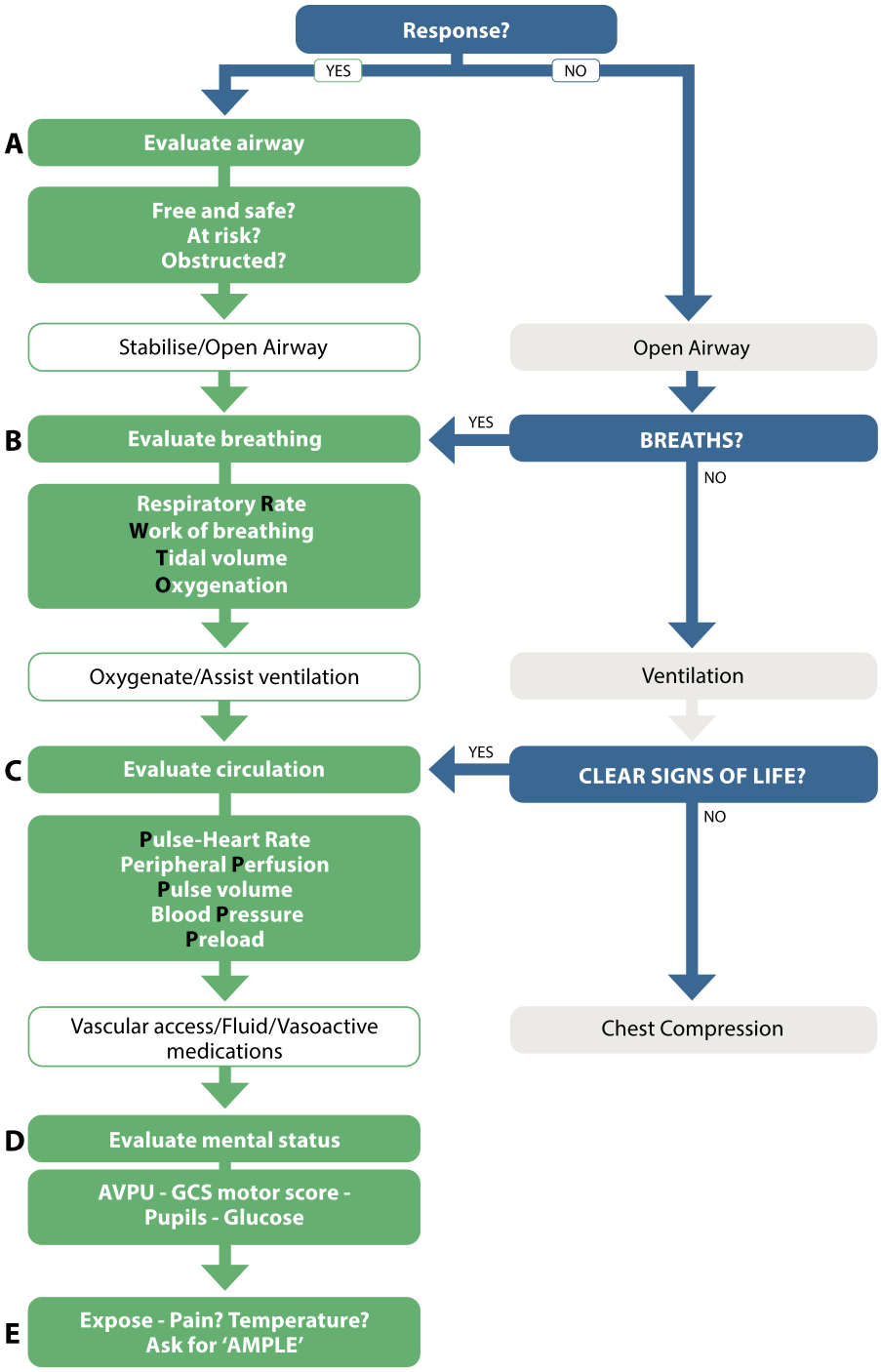
- **Pupils size / reactivity:** Size, symmetry and reactivity of the pupils can be affected by a number of things including cerebral lesions, congenital abnormalities and medications. A severely depressed mental status accompanied by pupillary abnormalities is indicative of intracranial hypertension and immediate treatment should be instituted accordingly.
- **DON'T EVER FORGET:** GLUCOSE – ALWAYS check blood glucose if altered consciousness and/or potential hypoglycaemia.

E = Environment- Exposure

During the last part of the primary assessment a quick evaluation is made if there are any clues to the patient's condition. Proper exposure of the child, with respect for their dignity, is necessary. Presence of fever, signs of trauma, skin rashes etc. should be observed. As children have more immature *temperature* regulation, it is important to avoid hypothermia. *Pain and discomfort* should be recognized and treated as soon as possible after the initial ABCDE stabilization. Search for clues in the environment to understand the problem/disease. A useful acronym to explore the circumstances of illness or injury is **AMPLE**:

- **A**llergy?
- **M**edication?
- **P**ast History?
- **L**ast Meal?
- **E**nvironment/exposure?

Figure 2.2 The systematic assessment and treatment of a critically ill child



CHAPTER 3
AIRWAY & BREATHING

A FREE AIRWAY

Airway obstruction is common during paediatric resuscitation. It may be the primary cause of cardiorespiratory failure (e.g. foreign body aspiration) or a consequence of the underlying disease process (e.g. hypoxia, trauma), which leads to decreased consciousness. In unconscious children, the tongue can fall backwards and cause airway occlusion. This airway obstruction must be recognised and managed immediately to prevent hypoxic damage. Chest movement does not guarantee that the airway is clear.

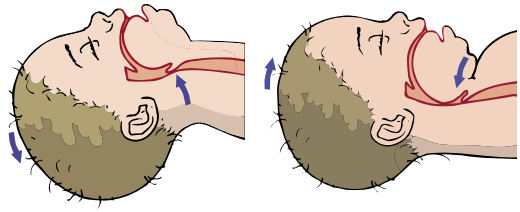
Airway management

If a sick or injured child is breathing effectively and spontaneously, they should be supported in a position of comfort - preferably the position they naturally assume to optimize airway patency. The child must not be forced to lie down or adopt a position they do not like, as stress and anxiety will increase oxygen consumption and/or a supine position may aggravate airway obstruction. All actions should be carried out calmly. (Humidified) oxygen, if needed, should be administered in a manner the child will tolerate. The parents should be encouraged to stay with the child.

In an **unconscious child** with or without spontaneous breathing, the airway must be optimised immediately as there is a risk that the tongue will fall backwards and obstruct the airway. Adequate oxygenation and ventilation can and will only be achieved once the airway is patent. Airway opening initially means positioning the head and performing either *a head tilt and chin lift or a jaw-thrust* manoeuvre. A correct position of the head is related to both age and individual characteristics. Younger children tend to need a more neutral head position while more extension is needed in older children. Both hyperextension and flexion can result in airway obstruction.

! **Do not apply pressure on the soft tissue under the jaw, as this can worsen airway obstruction.**

Figure 3.1 Both hyperextension and flexion can result in airway obstruction



Hyperextension Flexion

HEAD TILT - CHIN LIFT: Approach the child from the side and if necessary turn him carefully on his back. Place one hand on the child's forehead and gently tilt the head back. In infants the head should be placed in a neutral position (the axis of the ear aligned with the axis of the thorax). For the child, more extension of the head is required (*"sniffing"* position). The chin lift is performed by placing the fingertips of the rescuer's other hand on the bony part of the child's lower jaw and lift the chin upwards.

JAW THRUST: Jaw Thrust is the method of choice in case of presumed cervical spine injury. From behind the child, one rescuer places his hands on either side of the child's head. Two or three fingertips of both hands should be placed under both angles of the child's jaw, lifting it upwards, while the thumbs rest gently on the cheeks. The rescuer's elbows should rest on the surface that the child is laid on to support the manoeuvre.

Figure 3.2 Airway opening: Head tilt-chin lift

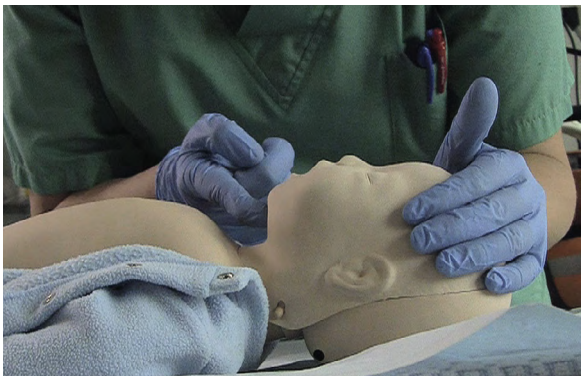
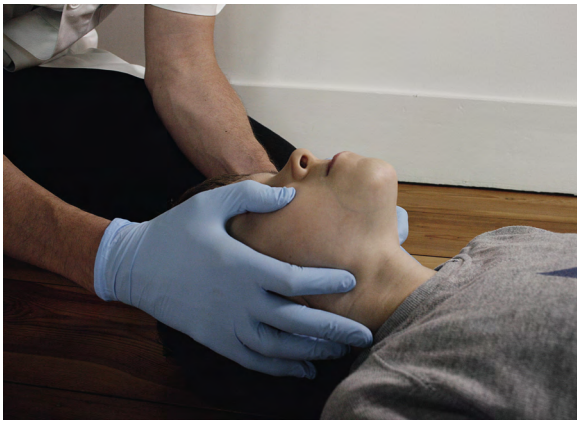


Figure 3.3 Airway opening: jaw-thrust. Method of choice in case of presumed cervical spine injury

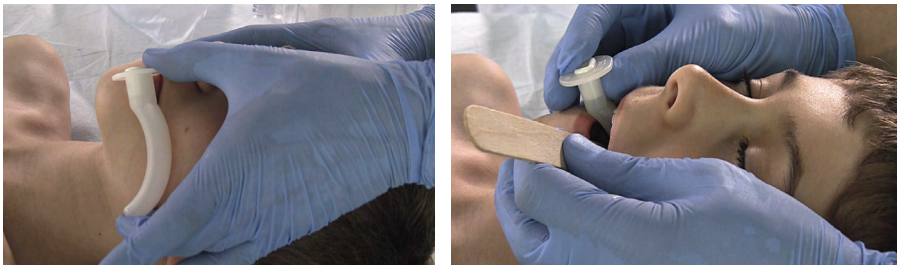


Airway equipment & airway opening adjuncts

- **SUCTIONING:** The child may be unable to clear secretions, vomit or blood in the upper airway and suction is then required. Rigid and large bore suction catheters (e.g. Yankauer) are particularly useful for removing vomit and copious or thick secretions. Flexible suction catheters are more appropriate for small children or infants, and may be less traumatic; however, they have a limited suction ability and may obstruct easily. Airway suction must be carried out *cautiously* if the child has an intact gag reflex as it may induce vomiting and subsequent aspiration or laryngospasm. Prolonged suctioning in infants should be avoided as it can also lead to bradycardia by vagal nerve stimulation. Whenever possible, suction of the airway should be performed under direct visualization, increasing its effectiveness and decreasing the risk of trauma. The use of a Y- piece or a side hole that can be occluded intermittently helps to control suction pressure.
- **OROPHARYNGEAL AIRWAYS (MAYO CANNULA OR GUEDEL):** They prevent the soft tissues of the neck and tongue from occluding the upper part of the airway. Different sizes are available, from 00 (premature infant) to 4-5 (adult). It is important to use a correctly sized cannula as one of incorrect size can lead to trauma, laryngospasm or worsening of the obstruction. The correctly sized airway reaches from the central incisors to the angle of the mandible, when laid on the child's face. *If in doubt between two sizes, start by trying the smaller one*. Re-assess after insertion. The oropharyngeal airway must be inserted with care and without excessive force to avoid damage to the soft palate. It can be inserted directly over the tongue (concavity down) using a tongue depressor or a laryngoscope blade to push the tongue towards the floor of the mouth. This has the advantage of allowing visualization of the oropharynx and some control over placement. The rim of the airway should rest on the child's incisors. Once placed, do not further fixate the oropharyngeal airway by for instance taping.

In older children, it can also be inserted with the tip up (concavity up) until the soft palate is reached and then rotating through 180° before pushing further down.

Figure 3.4 Oropharyngeal airway: sizing and insertion technique

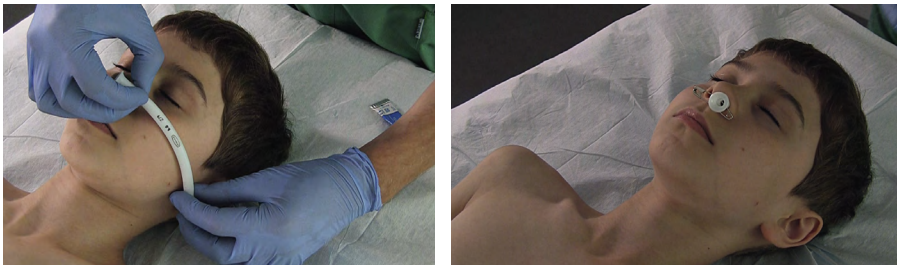


Oropharyngeal airways should only be inserted in comatose patients. In semi-conscious or conscious children, they are often not tolerated and may cause vomiting or laryngospasm. Insertion of an oropharyngeal airway does not eliminate the risk of aspiration of stomach contents. Following insertion of the oropharyngeal airway, the child's airway patency must be reassessed and oxygen or ventilation delivered appropriately.

- **NASOPHARYNGEAL AIRWAYS:** are made of flexible rubber or silicon and designed to open a channel from the nostril to the pharynx. The smaller pediatric sizes are not widely available, but shortened tracheal tubes (never cut the distal smooth extremity of the tube) may be used (a safety pin should be passed through the outer end of the tube to prevent it from passing into the nostril). The correct length of the tube is determined by measuring the distance from the tip of the child's nose to the tragus of their ear, and it should fit into the nostril without causing blanching.

  The airway must be well lubricated before insertion; insert while gently rotating the tube posteriorly along the floor of the nose (in vertical direction in a supine child). Do not direct the tube upward or this will cause trauma and bleeding. Nasopharyngeal airways are better tolerated than oropharyngeal airways by conscious children.

Figure 3.5 Nasopharyngeal airway: sizing and insertion technique



It may be the airway adjunct of choice in a (semi-)conscious self-ventilating patient with obvious upper airway compromise due to swelling of the tongue. They are contraindicated if a basal skull fracture is suspected or in cases of severe coagulopathy -unless there is no safe alternative to open the airway-. They do not protect from aspiration of stomach contents. Following insertion of the nasopharyngeal airway, the child's airway patency must be reassessed and oxygen delivered appropriately.

Most airway procedures are considered aerosol-generating and thus require proper (risk- adjusted) personal protection equipment (PPE) in cases of presumed transmittable diseases.

For more information we refer to the CoSy VLE.

OXYGENATION & VENTILATION

Within the common ABCDE language, the B stands for 'breathing' which incorporates both **oxygenation** (uptake of oxygen 02 in the blood) and **ventilation** (removal of carbon dioxide CO_2 from blood).

In childhood, recognition and support of respiratory or/and circulatory failure are more important than making a precise diagnosis of the disease. However, in certain circumstances, knowledge of specific disease processes may help to appropriately manage the disease and improve the outcome. Some of these conditions demand certain specific emergency actions. We will further describe these in a separate lesson.

To support oxygenation, consider supplemental oxygen and/or positive end-expiratory pressure (PEEP).

OXYGEN DELIVERY: In seriously ill or injured children, who have any sign of compensated or decompensated respiratory or circulatory failure, oxygen must be administered as soon as it is available. Oxygen should be delivered initially at the highest available concentration. It can be supplied from a wall or portable source, through a flowmeter capable of delivering 15 l/min. Ideally, it should be humidified, to prevent the drying of secretions, and warmed to prevent hypothermia and bronchospasm. The method used to deliver the oxygen should be selected according to the child's condition and device tolerance. Oxygen saturation levels should be monitored by pulse oximeter.

Once it is possible to accurately measure SpO_2, oxygen therapy should be titrated to a SpO_2 of 94-98%. Give as little supplemental FiO_2 (fraction of inspired oxygen) as practicable to reach this goal. Sustained SpO_2 readings of 100% should generally be avoided. Do not give pre-emptive oxygen therapy in children without signs of or immediate risk for hypoxaemia

or shock. In smoke inhalation (carbon monoxide [CO] or cyanide) or severe anaemia prolonged delivery of 100 % FiO_2 is advised. In children with pre-existing cardiac disease or other chronic underlying conditions, consider oxygen therapy in view of the underlying condition, the baseline SpO_2 (if known) and the intercurrent disease process. Early expert advice is warranted. Concerns about oxygen toxicity should never prevent high-flow oxygen from being given during the initial resuscitation of a child.

In children with respiratory failure and hypoxaemia not responding to low-flow oxygen, where possible, competent providers should consider either high-flow nasal cannula (HFNC) or non-invasive ventilation (NIV). Tracheal intubation and subsequent mechanical ventilation enable secure delivery of FiO_2 and PEEP. The decision to intubate should however be balanced against the existing risks of the procedure and the available resources *(see below)*.

In hypoxaemic children despite high PEEP (>10) and standard optimisation measures, consider permissive hypoxaemia (oxygenation goal lowered to SpO_2 88-92%).

There are different ways to deliver oxygen, more detail is given in the **CoSy VLE**. The most used ones are:

- **Blow-by oxygen:** unthreatening and thus well-tolerated. Parents can be encouraged to waft oxygen from the supply tubing over their child's nose and mouth. The FiO_2 that can be delivered is obviously low, so it is only suitable in mild, compensated respiratory failure.
- **Nasal prongs** are available in different sizes, suitable for newborn to adult and best suited for mildly ill children or ward use. Oxygen delivery depends mainly on flow, nasal resistance and extent of nasal breathing. Oxygen flows > 4 L/min are irritating and do not further increase oxygen levels. It is usually not possible to achieve FiO_2 > 40 % with nasal prongs. Ideally the oxygen is both humidified and warmed.
    - **High-flow nasal canulae** are able to give high FiO_2 by using high flow (give to 1-2L/kg/min) optimal humidified oxygen through (specific) nasal prongs. These devices are presumed to provide accurate oxygen supply with greater patient comfort and to a lesser degree a low-level positive airway pressure.
- **A simple oxygen mask without reservoir bag** only delivers oxygen concentrations of up to 60 % (depending on oxygen flow and the child's minute volume) as room air enters through inspiratory holes, mixing with the supplied oxygen. To avoid rebreathing, oxygen flow must be at least 4 L/min.
- **An oxygen mask with a reservoir bag** is the first choice in managing the seriously ill child who is breathing spontaneously. This mask itself is equipped with one-way valves between reservoir and mask and valves that cover the expiratory holes. These valves guarantee maximal oxygen delivery during inspiration, allow exhalation and prevent rebreathing. Absence of one of or both these valves results in decreased oxygen delivery (allowing air to enter

during inspiration). Provided that there is a good facemask fit, it provides oxygen concentrations of 90 % or higher. The flow of oxygen must always be sufficiently high to avoid reservoir collapse during inspiration (e.g. 12-15 L/min).

- Devices for invasive or non-invasive ventilatory support are able to deliver FiO_2 from 21 to 100 %. In that way they do not only support ventilation but are also able to improve oxygenation. Importantly these devices are also able to provide **PEEP**. As PEEP is crucial for the sustained opening of alveoli in sick lungs – thus improving gas exchange-, providing a higher PEEP can improve oxygenation where FiO_2 alone would fail to do so.

VENTILATORY SUPPORT: In a child with inadequate breathing, the maintenance of a patent airway is the first priority. Once this is achieved, if breathing remains inadequate, ventilation must be supported. This is best achieved by connecting a self-inflating bag to a facemask, a tracheal or tracheostomy tube or a supraglottic device.

- The ventilatory **rate** provided will *depend on the age of the child and the clinical circumstances*.
- The tidal **volume** delivered should produce a visible chest expansion and breath sounds on auscultation. 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. Hyperventilation might decrease cerebral and coronary perfusion and should be avoided, both in terms of rate, tidal volume and peak inspiratory pressure. Hypoventilation could lead to hypercapnia, atelectasis and finally hypoxia.

Continuous monitoring (pulse oximetry, capnography) of children with respiratory insufficiency must be started as soon as possible.

Bag-mask ventilation (BMV) is the recommended first line method to support ventilation. Every healthcare professional potentially caring for critically ill children should be able to perform it correctly. Even when tracheal intubation is considered necessary, BMV is rapidly available for use and can ensure effective ventilation for most children until expert help arrives. Optimal BMV demands adequate training and regular retraining.

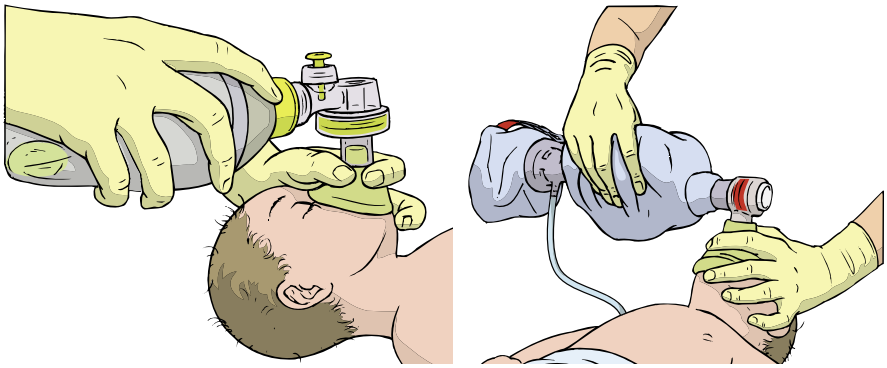
For a detailed description of the technique of BMV we refer to the CoSy VLE.

Whilst the operating principle of a self-inflating bag is simple, it requires some skill (and thus practice) to use one safely and effectively. Hypoventilation can occur with a poor technique (e.g. inadequate mask seal or incorrect head positioning) and is likely to have a negative effect on the outcome.

To achieve the best possible ventilation, the optimal position of the airway must be sought. This frequently implies repositioning the head and neck to try to find the best position and to keep it that way during ventilation. The most frequent reason for inadequate BMV is inadequate airway opening.

- In infants the neutral position is best for airway opening, with two fingers lifting the jaw and taking care not to compress the soft tissues. Hyperextension of the neck will increase airway obstruction.
- In children over 1 year old, some degree of extension of the neck should be added. Lifting the chin with two or three fingers may also be helpful. Placing an adequately sized roll under the neck may help to open properly the airway, provided there is no clear risk of cervical spine injury. Two hands must be used to provide BMV. The mask is held with one hand using the E clamp – C clamp technique with simultaneous airway opening: E is formed by placing the 3rd, 4th, and 5th fingers on the mandible, C by the thumb and index on the mask. The other hand squeezes the bag.

Figure 3.6 BMV: E clamp – C clamp



Bag mask ventilation in a child (the bag is squeezed during inspiration).

Chest expansion should be carefully observed to monitor the efficacy of ventilation. Auscultation is also useful if one person is available to do it. Excessive ventilation (in terms of high tidal volume, ventilation rate and/or airway pressure) is harmful. In cardiorespiratory arrest, hyperventilation increases thoracic pressure and decreases coronary and cerebral perfusion, so it may compromise survival. It may also compromise cardiac output, distend the stomach, cause air trapping and leaks. In patients with head injuries, hyperventilation may compromise neurological outcome.

The use of an oro- or nasopharyngeal airway to maintain airway patency is frequently necessary during BMV.

To provide adequate tidal volume, the inspiratory time should be sufficiently long (approx. 1 second).

A two-person technique, with one person maintaining the airway -providing a bimanual jaw-thrust- and holding the mask in place whilst the other squeezes the

bag, may help to overcome difficulty in achieving an airtight seal or if higher pressure is needed. This is especially of value during CPR, where the rescuer performing compressions will then also be the one squeezing the bag. A two-person technique is also advocated when there is a risk of aerogenic disease transmission.

Face masks

Sized facemasks used with a bag are available in a variety of sizes and two types: anatomic and circular. They must be capable of providing a good seal over the mouth and the nose, whilst ensuring it is not applied over the eye. Circular masks, in soft plastic, silicon or with an inflatable rim, provide a good seal in infants and small children. Anatomic masks should be used for older children and adults. The preferred mask is transparent (allowing rapid detection of secretions/vomiting and observation of the child's central color) a*nd should have the lowest possible dead space.* A small leak is not necessarily problematic if there is adequate chest rise.

Self-inflating bags

are widely available and easy to handle. The operating principle is simple: while pressure is applied to the bag by the resuscitator's hand, air flows through a one-way valve to the mask and hence to the patient. When this pressure is relieved, the bag automatically inflates, due to its elasticity, with air entering through another port from the reservoir. During this phase (expiration) the first valve closes to prevent rebreathing and exhaled air comes out through an exhalation valve near the mask. These bags must have an independent oxygen supply and a reservoir. **Some bags include *an additional PEEP valve* (limiting flow during expiration thus increasing end- expiratory pressure) which further improves oxygenation.**

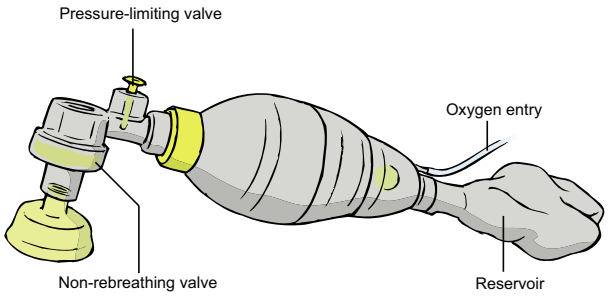
Self-inflating bags come in three sizes: 250 ml, 450-500 ml, and 1600-2000 ml. *The smallest is ineffective for resuscitation even for term newborns, as a relatively high pressure is required for the first breaths.* In general, although many different types of bags exist commercially, the two smaller sizes are equipped with a pressure-limiting valve, preset at 35-40 mm Hg to prevent lungs from being damaged by excessive pressure.

During resuscitation, higher than usual pressures may be needed and it may be necessary to override the pressure-limiting valve (position of the airway should be checked before disabling the valve). This should of course be done cautiously.

Most self-inflating bags do not support spontaneous breathing because oxygen is provided only when the bag is squeezed and thus the non-rebreathing valve opens. The child's own spontaneous effort will often not generate sufficient pressure to open the valve. Children who are breathing spontaneously therefore better receive oxygen by other methods, such as a mask with a reservoir bag.

Self-inflating bags can malfunction if the valves are incorrectly mounted, for instance after cleaning, and so should be checked regularly. Healthcare providers should be able to quickly and correctly disassemble, check and reassemble a self-inflating bag if needed.

Figure 3.7 Self-inflating bags



Self-inflating bag (500 ml) with reservoir (highest FiO_2)

Oxygen Reservoir

Without the reservoir it is almost impossible to deliver > 50-60 % FiO_2, but with a large enough reservoir the delivered oxygen concentration can reach > 90 % depending on the given oxygen flow and the applied minute ventilation.

TRACHEAL INTUBATION

Intubation is **not a priority skill** for all healthcare professionals that take care of children. It is a difficult skill to learn and to perform in children and requires practice, not only on manikins, but also in for instance the operating theatre under the supervision of an anaesthetist. Repeated and/or prolonged attempts at intubation can worsen the child's condition AND SHOULD BE AVOIDED. BMV is often preferable to maintain adequate oxygenation and ventilation of the patient while waiting for someone with appropriate experience of advanced airway management.

We provide more background information in the CoSy VLE. The most important things to remember are:

- Morbidity and even mortality can result from the incorrect placement of the tracheal tube or from hypoxia resulting from repeated or prolonged attempts at tube placement. Attempts to intubate (max. 3 attempts) should in general not exceed 30 seconds each. If bradycardia or hypoxia occurs during intubation, the procedure should be interrupted and the patient ventilated with BMV and oxygen. Ideally an assistant monitors timing, observes SpO_2 and heart rate and gives notice. Rescue plans should be in place for when intubation fails.
- Except maybe for small infants, cuffed tracheal tubes should be used for emergencies in children (cuff inflation pressure should be monitored and kept under 25 cm H_2O).

- Although nasal placement may be more secure (in particular in neonates and small infants) if a long intubation period is foreseen, oral intubation is faster and less complicated, and thus is preferred during resuscitation.
- Adequate preparation of the intubation procedure is crucial to avoid inadvertent problems. A difficult airway should always be anticipated and when expected appropriate equipment and personnel must be available before proceeding.
- Intubation of a child in cardiorespiratory arrest does not require sedation or analgesia, but all other emergency situations do.
- The endotracheal position of the tube should be checked by a combination of several methods because no single method is 100 % reliable under all circumstances:
    - Visually passing of the tube beyond the vocal cords on laryngoscopy
    - Symmetrical chest wall movement during positive pressure ventilation
    - Absence of gastric distension or air entry into the stomach on auscultation
    - Equal air entry on bilateral auscultation in axillae and chest apices
    - Mist in the tube during the expiratory phase of ventilation
    - Capnometry/-graphy if the child has a perfusing rhythm
    - Improvement or stabilization of SpO_2 and heart rate towards the age-expected value
    - Chest X-ray, Ultrasound
- Use capnography in all intubated children for early detection of obstruction, mal- or displacement. Be aware that bradycardia and desaturation are late signs of hypoxia.
- Once correct position is confirmed, secure the tube with tape after drying or cleaning the skin with gauze and adhesive solution, if required.

If the condition of an intubated patient suddenly deteriorates, rapidly consider several possibilities, which are easily recalled by the acronym **"DOPES"**. Other reasons for deterioration or inadequate ventilation exist but these are most often less sudden: tube too small with a significant leak, tidal volume given too low, pressure-limiting valve active with low compliance lungs...

Table 3.1

D	**D**isplacement: accidental extubation, tube in right main bronchus…
O	**O**bstruction: of e.g. the tube, the heat & moisture exchanger or the respirator pipes
P	**P**neumothorax (& other pulmonary disorders such as bronchospasm, pulmonary hypertension)
E	**E**quipment: source of gas, bag, connector-tubing, ventilator
S	**S**tomach: distension can alter diaphragm mechanics

DIFFICULT AIRWAY MANAGEMENT

An alternative plan for airway management, in case of intubation failure, must be **considered in advance**. In general, going back to a previous technique that did work (e.g. BMV) is the best strategy. Expert help must be summoned whenever possible.

BE AWARE that most situations of 'cannot intubate, cannot ventilate' can be managed by overcoming an anatomical or functional airway obstruction such as by better airway positioning, use of SGA, sufficient analgosedation and optionally neuromuscular blocking agents...

More information on rescue strategies such as videolaryngoscopy, the use of a supraglottic airway or very rarely cricothyroidotomy is given in the CoSy VLE.

MONITORING OXYGENATION & VENTILATION

Pulse oximetry

Clinical recognition of hypoxia may be difficult and is usually late and unreliable. Pulse oximetry enables continuous evaluation of the peripheral oxygen saturation and is an important non-invasive method of monitoring the child in respiratory failure and, in fact, any severely ill or injured child. It provides an early indication of hypoxia, and should be used during stabilisation and transport of the critically ill child. Accurate readings are based upon the relative amount of oxygen bound to haemoglobin and require an adequate pulsatile peripheral blood flow and red blood cells; therefore they will be *unreliable or unreadable in cardiorespiratory arrest or shock with severely reduced peripheral perfusion or in CO poisoning, methaemoglobinemia or severe anaemia.* Any condition that causes significantly reduced peripheral perfusion (e.g. cold extremities, rising fever) may affect pulse oximetry readings and must be considered if a good reading is impossible to obtain.

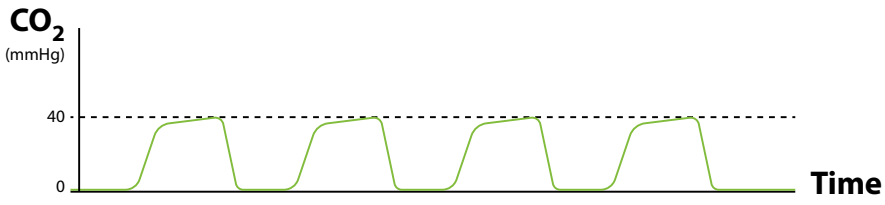
End Tidal Carbon Dioxide ($ETCO_2$)

Monitoring exhaled carbon dioxide is recommended to confirm tube placement and guide ventilation in neonates, infants and in children. After six ventilations to wash out any carbon dioxide in the oesophagus and stomach, $ETCO_2$ can be presumed to be from the lungs. Very low or absent $ETCO_2$ then indicates misplacement of the tube, particularly if gastric distension occurs. However, detection of $ETCO_2$ does not replace careful bilateral auscultation and a chest X-ray to confirm tube position in the trachea rather than in the right main bronchus.

In cardiorespiratory arrest, failure to detect $ETCO_2$ does not imply that the tracheal tube is misplaced, because these children may have very low pulmonary blood flow. Therefore, if no $ETCO_2$ is detected during cardiorespiratory arrest, tube position must be confirmed by clinical assessment and/or direct laryngoscopy. Similarly, it may also be very low in cases of low cardiac output (especially in infants). During CPR, capnography may be the first indicator of return of spontaneous circulation (trend rather than threshold values).

In a post-resuscitation setting, titration of mechanical ventilation towards normocapnia is very important. $ETCO_2$ may not correlate fully with true arterial CO_2. As such, as soon as possible, arterial PCO_2 needs to be measured to guide ventilation and to avoid both hypo- and hypercapnia. Capnography detects tracheal tube dislodgement more rapidly than pulse oximetry (except in the case of bronchial placement of the tube).

Figure 3.8 Capnography waveform. The value of end tidal CO_2 can be seen on the Y-axis.



CHAPTER 4
CIRCULATION

Shock, or circulatory failure, is a clinical state in which blood flow and/or delivery of tissue nutrients fail to meet metabolic demand and is defined *as the inadequate perfusion of the tissues of the body*. Failure to adequately deliver metabolic substrates (oxygen, glucose) and to remove cellular metabolites will lead to anaerobic metabolism, accumulation of lactic acid and cell injury. Shock may be described as being compensated or decompensated.

Shock is treated according to the ABCDE principles, with **fluid** administration being part of the "C" phase of resuscitation. As the type & quantity of fluid and the speed of infusion are dependent on the type of shock, special attention is needed towards the early recognition of the different types of shock. Fluid resuscitation volumes may need to be limited in cardiogenic shock since the problem lies with the heart's ability to pump circulating blood volume. **Vasoactive and/or inotropic medication** may also be needed depending on the type of shock. It must be emphasized that fluid resuscitation must always be accompanied by careful monitoring of signs of fluid overload.

As part of the circulation assessment, the electrocardiogram (ECG) should also be monitored. It confirms the presence of cardiac arrhythmias, and monitors changes in heart rate due to either the evolution of the condition or in response to therapy.

The management of a child in circulatory failure needs to be tailored to the individual, considering etiology, 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.

There are several types of shock. Most often, the initial recognition and support of respiratory or/and circulatory failure is more important than the precise diagnosis. However, in certain circumstances, knowledge of specific pathophysiological processes may help to appropriately manage the disease and improve the outcome. Some of these types of shock types demand certain specific emergency actions and this will be described in later lessons.

- **Hypovolemic shock** is the most common type in children and occurs when a large volume of fluid is lost from the intravascular space without sufficient replacement e.g. in diarrhoea with dehydration, excessive vomiting, trauma with haemorrhage, burns > 10 % BSA body surface area, diabetic ketoacidosis, etc.
- Septic, anaphylactic and neurogenic shocks are known as types of **distributive shock**. Septic and anaphylactic shock are characterized by a combination of vasodilatation and an increase in capillary permeability into the interstitium (surrounding tissues). In neurogenic shock, loss of vascular tone means that blood pressure remains low despite large volumes of fluid resuscitation. As other complications of fluid overload can arise in time, the judicious use of inotropes to improve vascular tone is required and the total fluid volume given carefully monitored.
- In **cardiogenic shock,** circulatory failure is the result of an impaired pump function, which can occur because of decreased contractility of the heart muscle resulting from myocarditis or cardiomyopathy. **Obstructive shock** in turn is seen when there is an obstruction to flow in and out of the heart (decreased filling of the heart cavities (preload) and decreased stroke volume). This can be caused by several conditions: pericardial tamponade, tension pneumothorax, dynamic hyperinflation, massive pulmonary embolism, abdominal compartment syndrome… Finally, whilst rhythm abnormalities are often the result of an acute illness, several of these arrhythmias cause subsequent circulatory failure themselves.
- **Dissociative shock** may be seen in conditions where there is insufficient oxygen carried by the blood (haemoglobin), thus leading to anaerobic conditions and acidosis (e.g. CO or cyanide poisoning or severe anaemia).

EMERGENCY VASCULAR ACCESS

The establishment of circulatory access is essential within the first few minutes of resuscitation and following the recognition of signs of shock. It may be achieved via peripheral intravenous [IV] or intraosseous route [IO]. IO access has all the advantages of a central venous access but is considerably easier and faster to achieve. *The IO route is the primary rescue alternative in emergencies when peripheral IV placement fails (max. 5 minutes, two attempts) or is considered too difficult. IO might be the first choice in cardiorespiratory arrest and in decompensated shock states.*

Once circulatory access is secured, relevant blood samples should be taken if possible e.g. blood gas, lactate, glucose, electrolytes, full blood count, coagulation and blood cultures. These samples should ideally be taken before the administration of fluids, providing this does not delay the delivery of adrenaline or other resuscitation drugs/ fluids. Fluid boluses can be delivered by syringe or infusion as appropriate and the given volume recorded. Any medication administered during resuscitation is flushed through into the circulation by a bolus of at least 5 ml of 0.9 % saline (up to 10 ml if infused by a peripheral vein or in the leg). Rapid fluid boluses cannot be given by drip. Use a pressure bag or push fluid in using 50ml syringes.

Urgent intravenous or intraosseous access is definitely preferred over central venous access or the tracheal route for giving drugs. Central venous access in a shocked child demands experience and, even in experienced hands, takes more time than peripheral or IO access. A peripheral vein may be used if it is easily seen or can be felt under the skin and appears to be of good size. Common sites for peripheral intravenous access in children are the back of the hand, dorsum of the feet and antecubital fossa. When these are not easy to identify, the long saphenous or external jugular veins might be considered. The use of scalp veins during resuscitation is not advisable due to the risk of extravasation and potential tissue necrosis. Peripheral venous access demands some skill and experience but once obtained it can be used for most to all resuscitative fluids and drugs. *Assess the size of the vein and insert the largest possible cannula, then secure in place.*

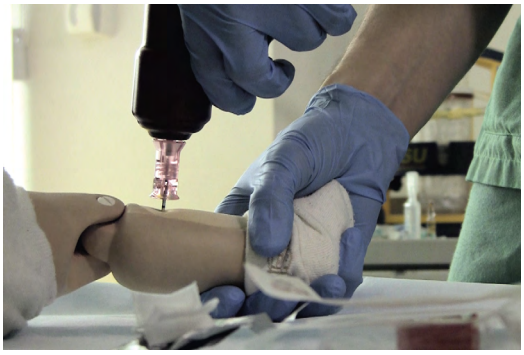
Competent providers might use ultrasound to facilitate peripheral intravenous access.

Intraosseous access

IO is a fast and easy way of obtaining circulatory access and is the route of choice in cases of cardiorespiratory arrest and decompensated shock. Peripheral venous access may be attempted in case of cardiorespiratory arrest or decompensated shock, but if there is any potential difficulty or delay, then IO access should take precedence. Drugs, fluids or blood-derived products that can be given by the peripheral intravenous route can also be given via the IO route. Large boluses of fluids can be injected using manual pressure (syringe) or a pressure bag, but not by a simple drip or other low pressure means. To reach desired flow rates incrementally increase infusion pressure, using caution. It may take up to 300 mmHg to achieve desired rates. The intraosseous infusion is best replaced by a standard venous access once the child is stabilised.

Figure 4.1 Trochar IO needle

Figure 4.2 Semi-automatic IO device



Different types of needles are designed for intraosseous infusion.

See the CoSy VLE for more information.

There are several potential IO insertion sites. The choice of which one to use will depend on the patient's age, size, ability to locate landmarks, specific clinical environment, contra-indications etc. An IO should never be placed in a bone that has been punctured in the last 48 hours, nor in a fractured bone. Any bone that is located upstream of major venous bleeding should not be used during resuscitation.

Sites include the following:

- **Proximal tibia:** anteromedial surface of the tibia 2-3 cm below the the distal border of the patella (medial to the tuberosity): younger children.
- **Distal Femur:** 1 cm proximal to the superior border of the patella and 1-2 cm medial to the midline: neonates, infants. It is important to immobilise the leg at the knee to avoid dislodgement.
- **Distal Tibia:** medial aspect of the tibia 3 cm above the medial malleolus: alternative site in older children.
- **Proximal Humerus:** Latero-anterior aspect of the greater tubercle of the humerus: adolescents; older children; when high fluid volumes are necessary; in conscious patients. It is important tot immobilise the arm to avoid abduction and resulting dislodgement.

All of the above sites avoid the growth plates of the long bones. The needle is placed through the periosteum and cortex into the medullary cavity. Aspirate blood or flush normal saline to confirm correct positioning.

See the CoSy VLE for a detailed description on technique.

To assure adequate flow rates the IO catheter should be gently but smoothly flushed with an initial fluid bolus of 5 ml (infants and young children) up to 10 ml (older children) of 0.9 % Saline. It is also important to flush (5-10 ml 0.9 % Saline) after all medications given.

In contrast to the actual placement which is generally well tolerated, intraosseous fluid administration may be very painful. IO access is feasible in a conscious child but proper analgesia should be given before any medication or fluids. Administer into the marrow 0.5 mg/kg preservative- and adrenaline-free lidocaine (2 % = 20 mg/ml) over 1-2 min and allow it to work 60 seconds before giving the initial flush.

Although complications are rare, they can be serious. Proper technique and consistent site evaluation are imperative.

Extravasation is one of the most common IO complications and may be minor or severe with serious consequences. Check for swelling near or on the opposite side of the insertion site, discoloration, pain and distal symptoms that may indicate extravasation. If there is any concern, stop injecting fluid into the marrow and recheck placement site with aspiration (and ability to flush). Actual extravasation into a fascial compartment may compromise the blood supply to limb and give rise to a compartment syndrome. An extravasation of certain medications can also cause soft tissue damage.

Other rare complications *(see also VLE)* include embolism, infection, fracture and skin necrosis.

FLUIDS IN RESUSCITATION

Fluids are given in resuscitation to restore circulatory volume and ensure that vital organs are adequately perfused. This is essential to allow the exchange of oxygen and carbon dioxide and for normal metabolic conditions to be maintained.

Isotonic crystalloids are recommended as the initial resuscitation fluid for infants and children with any type of circulatory failure. Fluids are usually given as **10 ml/kg** bolus IV or IO. The child must then be reassessed and if signs of shock remain, a second bolus of 10 ml/kg of fluid is given (max. 500 ml per bolus). Repeated fluid boluses -up to 40-60 ml/kg- might be needed in the first hour of treatment of (septic) shock.

Consider albumin as second-line fluid for children with sepsis, especially in the case of malaria or dengue fever. If not for 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. 100ml/kg over 8h).

In cases of haemorrhagic shock, keep crystalloid boluses to a minimum (max. 20 ml/kg). Consider early blood products -or if available, full blood- in children with severe trauma and circulatory failure, using a strategy that focuses on improving coagulation (using at least as much plasma as RBC and considering platelets, fibrinogen, other coagulation factors). Avoid fluid overload but try to provide adequate tissue perfusion awaiting definitive damage control and/or spontaneous haemostasis. Permissive hypotension (MAP at 5th percentile for age) can only be considered in children when there is no risk of associated brain injury.

Overall, it is important that the underlying cause for fluid bolus requirement is diagnosed and treated. The child's ABCDE status should be reassessed continuously, and if there is evidence of compensated or decompensated shock, extra fluid bolus(es) can be considered.

With ongoing shock despite fluid therapy and/or when signs of decompensation of the pump function (hepatomegaly, crepitations, jugular vein distension) are found, support by means of inotropes and/or vasopressors should be instituted as soon as possible. Fluids might still be needed but should be given more cautiously.
In children with febrile illness not (or no longer) showing signs of circulatory failure, a cautious approach to fluid therapy should be used, with frequent reassessment of the child.

Crystalloids are used to replace fluid lost and to correct any electrolyte deficiencies. Crystalloids are preferred as first line resuscitation fluids because they are generally safe, readily available, efficient in increasing circulating volume, and inexpensive. Often large volumes may be needed to correct the circulatory deficit; this may be poorly tolerated in cases of underlying cardiac or respiratory disease, as pulmonary oedema may occur. Therefore fluid resuscitation must be performed with constant ABC evaluation and monitoring. Examples of isotonic crystalloids include: Normal saline (0.9 %), Ringer's lactate, Hartmann's solution and Plasmalyte….

Glucose solutions should never be used for volume expansion as they can cause hyperglycaemia, which leads to osmotic diuresis. This increases urine production and increases circulatory volume loss. It is best to consider glucose solutions as a drug, used in case there is (a risk of) hypoglycaemia.

Balanced Crystalloids such as Ringer's lactate or Plasmalyte are considered first choice for fluid bolus.

Colloids have long been believed to stay longer within the vascular compartment and thus be more efficient in increasing circulatory volume than crystalloids. Recent findings point out that this difference is far less than previously thought. Moreover colloids, both human and synthetic, are more expensive and allergic reactions can occur. Importantly, (semi-)synthetic colloids have been associated with detrimental effects on renal function, coagulation and mortality and their use should be abandoned (outside clinical trials).

Human albumin solutions (5 or 4.5 %) might still have a place in the resuscitation of children. They are an acceptable choice as an adjuvant volume expander in septic shock but contraindicated in patients with traumatic brain injury. Hypertonic albumin (20 %) may also be indicated in critically ill children with hypoalbuminemia or oliguria, but this is beyond the scope of this manual.

Blood products should always be used with caution because of their cost, relative sparseness and potential side-effects (infectious, inflammatory…). They should only be considered in case of (presumed) low red blood cells or platelets or coagulation abnormalities. Thresholds to consider transfusion must be balanced against

both aetiology and circumstances. It is important to acknowledge that in septic shock anaemia, thrombocytopenia and prolonged coagulation occur, due to both consumption and dilution. The timely addition of blood products during resuscitation of a child in septic shock might influence outcome. In cases of haemorrhagic shock, due to massive blood loss as in e.g. trauma, blood products are even more crucial as failure to correct coagulation, thrombocytopenia and anaemia will result in ongoing haemorrhage and tissue hypoxia. *Any child with presumed haemorrhagic shock after trauma who has not responded to 20 ml/kg of crystalloid needs blood products as soon as possible.*

Services should organize themselves to be able to have blood products (including Fresh Frozen Plasma) at hand for these occasions. In general, blood products are given according to blood group (type-specific). For packed red cells [PRC], units are ideally cross-matched with a patient's sample to avoid inadvertent antibody reactions. However, in profound haemorrhagic shock, uncross-matched Group O Rhesus-negative blood and/or Group AB Fresh Frozen Plasma must be given while awaiting more specific blood products. Do not give red blood cells together with glucose or calcium-containing fluids in the same line as haemolysis occurs.

DRUGS IN RESUSCITATION & SHOCK

Administration of medications is often essential in the management of circulatory failure and likewise cardiorespiratory arrest. As indicated above, the optimum access routes are the intraosseous and the intravenous route. For the intravenous route the difference between centrally and peripherally administered drugs is probably less important in children than in the adult and both routes permit appropriate delivery of medications. In specific cases, if there is spontaneous circulation, intramuscular or mucosal administration of certain drugs may be an alternative. The tracheal route is no longer recommended for any situation.

During resuscitation, especially in cases of shock, drugs should be followed immediately by a normal saline **flush** (2 to 10 ml) to ensure their delivery into the central circulation. Drug interactions should be taken into account and certain drugs will ideally be given through a dedicated line (e.g. continuous catecholamines, phenytoin...). *Glucose-containing solution should be avoided during resuscitation unless for confirmed hypoglycaemia.*

We underneath describe the most important features of some of the more important resuscitation drugs.

Further background information can be found in the CoSy VLE.

- **ADRENALINE:** remains the drug of choice in cardiorespiratory arrest. Adrenaline is given as soon as possible and then every 3-5 minutes of CPR in non-shockable algorithms; in the shockable algorithm it is given after the third shock and then every 3-5 minutes. The dose remains the same, regardless of the duration of cardiorespiratory arrest: *10 mcg/kg or 0.1 ml/kg of a 1:10 000 solution (1 mg diluted to 10 ml) with a maximum single dose of 1 mg*. The intravenous and intraosseous routes are both effective for the administration of adrenaline. Higher doses of adrenaline are not recommended routinely, as these do not improve survival or neurological outcome after cardiopulmonary arrest. The half-life of adrenaline is short (2 min) and doses are repeated until the desired effect is achieved or resuscitation is abandoned.

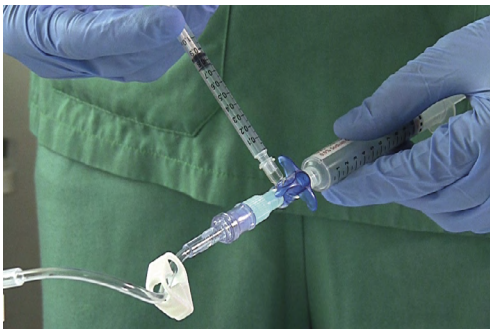
  Once spontaneous circulation is restored, a continuous infusion of adrenaline or another drug may be needed to support the heart. Catecholamines, such as adrenaline, are inactivated by alkaline solutions and should never be given simultaneously through the same line as sodium bicarbonate. If both these medications are to be used, their administration should be separated by a bolus of normal saline (5-10 ml). As the action of catecholamines may be depressed by acidosis, careful attention to oxygenation, ventilation and circulation is essential (ABCDE).

  Continuous adrenaline should be administered through a secure peripheral intravenous line or through an intraosseous route or central intravenous access. If adrenaline infiltrates surrounding tissues, it may cause local ischaemia and tissue injury. High dose infusion rates may also produce excessive vasoconstriction and compromise blood flow in the extremities, the bowel and the kidneys. Adrenaline causes tachycardia and may produce or exacerbate instances of ventricular ectopics.

- **ADENOSINE:** is used in supraventricular tachycardia (if not in decompensated shock). It is rapidly metabolised by red blood cells and its half-life is only 10 seconds. It should therefore be injected rapidly as close to the heart as possible, via central or upper limb peripheral intravenous route, and immediately followed by a rapid bolus of normal saline (10 ml). A three-way tap may be useful for this purpose. The effectiveness of intraosseous administration is less well established. If used, the proximal humerus is probably the preferred location and sufficient flush mandatory.

  The standard dose is 0.1 - 0.2 mg/kg (maximum dose 6 mg). Especially in younger children, higher initial doses are preferable. In case of persistent SVT, repeat adenosine after at least 1 minute at a higher dose (0.3 mg/kg, max 12-18 mg).

Figure 4.3 Adenosine administration



- **AMIODARONE:** is given together with adrenaline in the treatment of defibrillation refractory shockable rhythms (after the third shock and the fifth shock). In defibrillation-refractory shockable rhythms 5 mg/kg by intravenous bolus is recommended (max. first dose 300 mg, max. second dose 150 mg); this may be repeated up to 15 mg/kg/day. It is also indicated for supraventricular and ventricular tachycardia and
- ventricular ectopics post-cardiac surgery (as a continuous infusion over 20-30 minutes, not in bolus).
- **ATROPINE:** is indicated for bradycardia caused by increased vagal tone. The standard IV/IO dose is 20 mcg/kg (max 0.5 mg/dose; higher doses might be needed in case of cholinergic drug toxicity).
- **SODIUM BICARBONATE:** Studies have shown that the routine administration of sodium bicarbonate in cardiorespiratory arrest fails to improve the outcome. It might still be considered in prolonged cardiorespiratory arrest after ABCDE's are properly managed with the opening of the airway, 100 % oxygen, assisted ventilation and restoration of effective systemic perfusion by chest compression, the administration of fluids, and the use of intravenous or intraosseous adrenaline (although the evidence for its use is lacking).

  Sodium bicarbonate is indicated in *hyperkalaemia when accompanied with acidosis or in the management of tricyclic antidepressant drug overdose.* A first dose is given as 1 mEq/kg (= 1 mmol/kg = 1 ml/kg of 8.4 % solution = 2 ml/kg of a 4.2 % solution).
- **CALCIUM:** is only recommended for the treatment of documented hypocalcemia, hyperkalaemia, hypermagnesaemia, or for an overdose of calcium channel blockers. Hypocalcemia is frequently seen, it should actively been searched for in septic patients who need repeated fluid boluses or trauma patients needing multiple blood transfusions.

  Rapid calcium injection may induce brady-arrhythmias and asystole in patients treated with digoxin. The dose should be infused by slow intravenous injection

(calcium gluconate 10 % 0.5 ml/kg (max 20 ml); calcium chloride 10 % 0.2 ml/kg (max. 10 ml)) preferably via a central access, as calcium may produce chemical burns if it leaks into the surrounding tissues.

- **GLUCOSE:** Infants have high glucose requirements and low glycogen storage. During periods of increased energy requirements, e.g. when in coma, shock and respiratory failure, infants can readily become hypoglycaemic. It is therefore necessary to monitor blood glucose concentrations closely. As hypoglycaemia is a cause of seizures or coma, any child who presents with fits or coma must have a bedside measurement of his blood glucose level as soon as possible. Glucose is a major energy substrate of myocardial cells; hence myocardial contractility may be depressed in hypoglycaemia. *Clinical signs of hypoglycaemia and shock may have certain similarities, namely: agitation or decreased consciousness, hypotension, tachycardia, decreased peripheral perfusion, and sweating.*

  Careful control and measurement of blood glucose is essential in the management of any ill or injured child and can be measured at the bedside. For documented hypoglycaemia, a bolus of 3 ml/kg of dextrose 10 % (100 mg/ml) (or 1.5 ml/kg D20%) is the recommended dose.

- **NALOXONE:** is a fast acting (2 minutes after injection) opioid antagonist with duration of action up to 45 minutes. It is indicated in cases of opioid poisoning.
- **VASOACTIVE DRUGS:** Inotropes and vasopressors are administered as a salt solution in a continuous infusion, properly diluted, by intraosseous or central venous access. When monitored carefully, infusion via a secure peripheral line is equally acceptable. 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.

  The most used inotropes are dobutamine (and milrinone), while noradrenaline is most often used as vasopressor. Adrenaline (and dopamine) can be used both for their inotropic and vasopressor effect, depending on the dose given. Each of these vasoactive drugs has their own effects and side-effects, which should be known to their user. Dopamine should be considered only in settings where neither adrenaline nor noradrenaline are available.

Suggestions for calculation rules are provided in the CoSy VLE as background information.

Overall, the *constant concentration method* is considered the safest one to use in emergencies. Intelligent pumps allow for easy programming and safe, efficient use.

CHAPTER 5
BASIC LIFE SUPPORT OF INFANT & CHILD

BLS is indicated in all children who are unresponsive and not breathing normally. It must be initiated as soon as possible and preferably by those witnessing the event. Its main objective is to achieve sufficient oxygenation to 'protect' the brain and other vital organs. Ideally, all citizens should possess BLS knowledge and skills. The sequence of actions in BLS is known as cardiopulmonary resuscitation (CPR). BLS is more effective when the rescuer is proficient in its delivery, but even suboptimal CPR gives a better result than no CPR at all.

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 only trained in 'adult' BLS and those untrained (dispatcher-assisted lay rescuers). Healthcare providers will occasionally start BLS alone but would normally work in a **team**. In a team certain actions may be done in parallel.

! **For the purposes of BLS, an infant is a child up to 1 year, and a child is generally considered to be between 1 year of age and 18y of age. However, if the rescuer believes the victim to be an adult, they can decide to use 'adult' guidelines.**

For the majority of children who suffer cardiorespiratory arrest, the recommended sequence of events is based on two main facts:

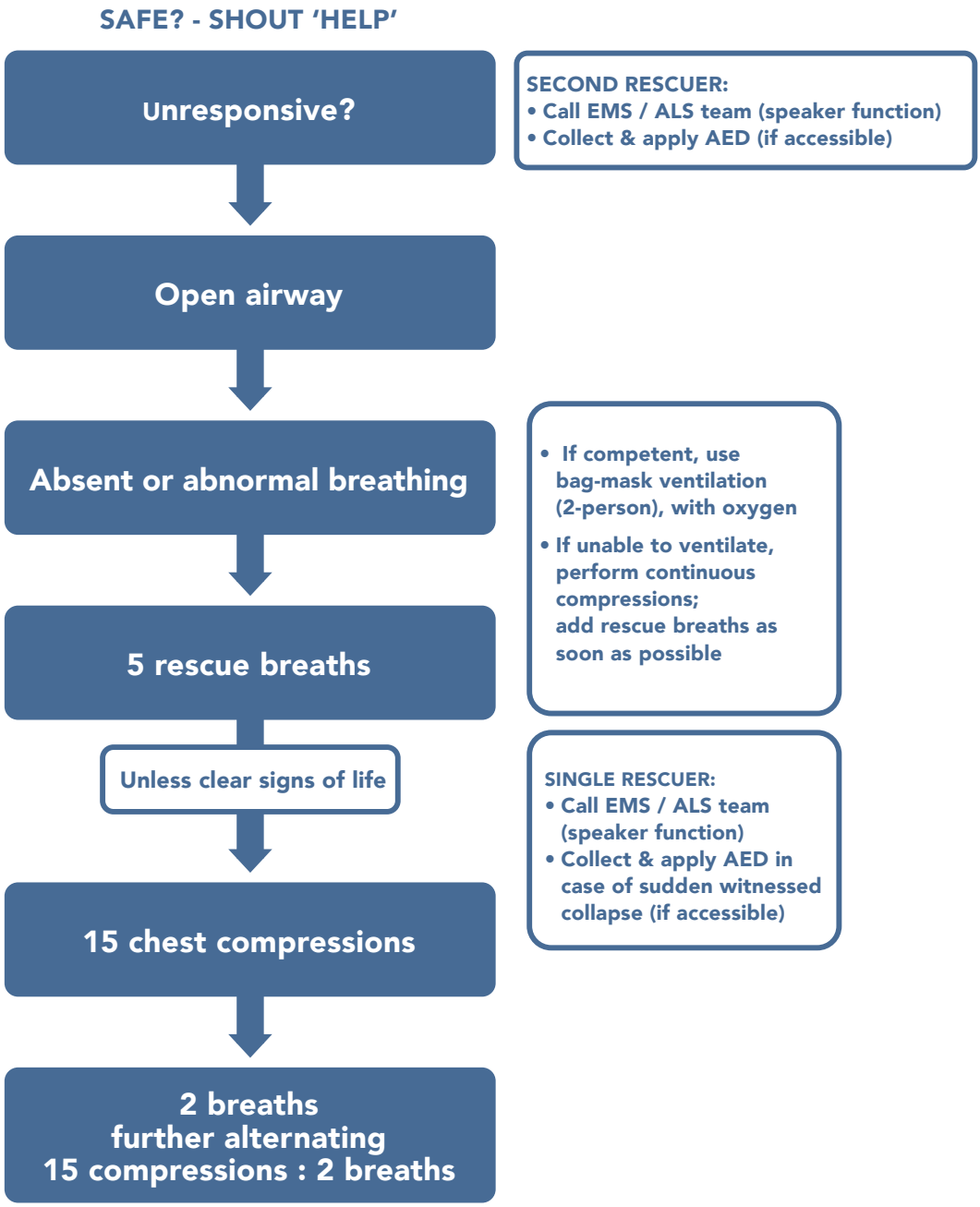
- The majority of paediatric arrests are hypoxic in origin (and/or as a consequence of the child's limited functional residual capacity) and therefore the priority is to open and maintain the airway and immediately provide oxygen (by means of rescue breaths).
- The most common cardiac arrhythmia encountered in paediatric arrests is severe bradycardia deteriorating into asystole. Hence effective BLS including assisted breathing is more important than rapid access to a defibrillator.

! **In the case of a lone rescuer, it is vital that BLS is commenced as soon as possible by administering rescue breaths and then immediately after the rescue breaths summon assistance. Preferably this is done with a mobile phone put on speaker, while continuing the BLS sequence. If no phone is readily available, perform one minute of CPR before leaving the child. If more than one rescuer is present, once unconsciousness is confirmed, one of them should immediately seek further assistance by activating the appropriate EMS team or the in-hospital cardiac arrest team, while the other(s) initiates BLS.**

Figure 5.1

PAEDIATRIC BASIC LIFE SUPPORT

EUROPEAN RESUSCITATION COUNCIL GUIDELINES 2021



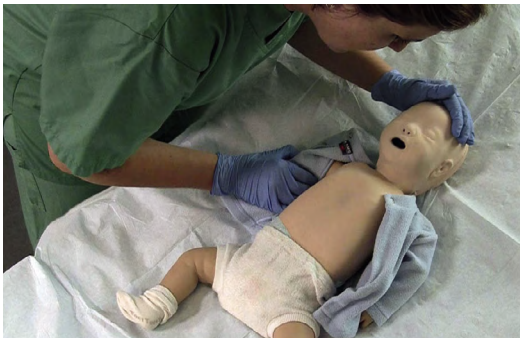
STEPWISE APPROACH TO BASIC LIFE SUPPORT

1. **SAFETY / STIMULATE:** In all emergencies it is essential to quickly assess the situation and to ensure the safety of first the rescuer(s) and then the child. Although potential hazards may be different, this is equally important whether the situation occurs in the hospital environment or outside. All bodily fluids should be treated as potentially infectious. *Put on appropriate personal protection equipment [PPE] as soon as feasible and use BMV devices to deliver ventilation whenever possible.*

   On approaching the child, and before touching him, the rescuer should rapidly look for any clues as to what may have caused the emergency. This may affect the way the child is managed.

   It is important to establish the responsiveness of the apparently unconscious child by **both verbal and tactile stimulation,** as he may not be in a critical condition. An appropriate way to do this is to stabilise the child's head, placing one hand on the forehead and then using the other hand to either gently shake his arm or tug his hair. At the same time, loudly call out the child's name, tell him to 'wake up' or ask him 'are you alright?'. Never shake a child. If the child responds by moving, crying or talking, his clinical status and any potential dangers should be assessed and, if necessary, assistance sought.

Figure 5.2 'Stimulate' as part of the BLS sequence



+ SHOUT FOR HELP: Shout for help if you think there might be other bystanders nearby, otherwise immediately start BLS.

+ FIRM FLAT SURFACE: In general, do not move the child unless this results in markedly better CPR conditions (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.

2. **OPEN AIRWAY:** In the unconscious child, the tongue is likely to (partly) occlude the airway. Therefore, the rescuer must first open the airway. This can be done by performing a head tilt-chin lift.

   Turn the child carefully onto their back. Open their airway by placing your hand on their forehead and gently tilting the head back. At the same time, use your fingertip(s) under the point of the child's chin, to lift the chin. Do not push on the soft tissues under the chin as this may obstruct the airway.

   In infants, the head should be placed in a neutral position (eyes looking perpendicularly at the ceiling, long axis of ear aligned with that of the thorax). In older children, more extension of the head will be required.

   In case of inadequate airway opening or presumed cervical trauma the jaw-thrust manoeuvre is preferred. If jaw thrust alone does not enable adequate airway patency, add head tilt a small amount at a time until the airway is open. Jaw thrust is only feasible if more than one rescuer is available.

   Whichever method of airway opening is adopted, the rescuer should also have a quick look into the mouth to ensure there is no obvious foreign body present. If a foreign body is visible and the rescuer is confident that he can remove it with one single finger sweep, this can be attempted. "Blind" finger sweeps must never be performed.

   Once the airway (A) has been opened and assessed, the rescuer should move on to the next step.

3. **ASSESS BREATHING:** After opening the airway, the rescuer needs to assess the child for effective spontaneous breathing. The best way to do this is to 'look, listen and feel'. The rescuer positions his cheek a few centimetres above the child's mouth and nose, and looks along the child's body. The maximum time allowed *for this manoeuvre should be 10 seconds (preferably less).*

   When there is a clear risk of disease transmission, such as by aerosol, rescuers are advised to avoid approaching the nose and mouth of the child, but rather assess breathing visually, and optionally, by placing a hand on the belly.

   - If the child is breathing spontaneously and effectively, the airway is kept open whilst more assistance is summoned. If there is no suspicion of cervical spine injury, the child should be placed in the recovery position whilst further assistance is awaited. If the rescuer is alone, he must activate the EMS himself.
   - **If the child is not breathing effectively or only gasping, the rescuer must deliver rescue breaths.** Gasping or agonal breathing is infrequent or irregular breaths that must not be confused with normal breathing.

4. **RESCUE BREATHS: Five initial rescue breaths** should be given whilst maintaining the airway open. The aim of rescue breaths is to deliver oxygen to the child's lungs. Each breath should be delivered slowly, over approximately 1 second. This maximises the amount of oxygen delivered to the child's lungs and minimises the potential for gastric distension. Allow sufficient time to exhale. *The rescuer must take a breath between each rescue breath to optimise the O_2 and minimise the CO_2 they deliver to the child.*

   The effectiveness of the rescue breaths can only be determined by observing the rise and fall of the chest. The rescuer must adapt the pressure and volume of their own exhaled breath to the characteristics of the child, to ensure that chest movement is seen with each breath delivered. While performing rescue breaths note any gag or cough response as these can be part of the subsequent assessment of 'signs of life'.

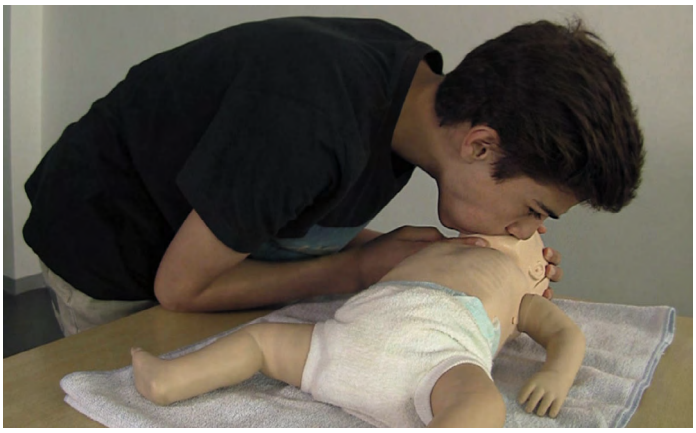
   If chest movement is not seen with any rescue breath, the rescuer must reassess the child's airway (reposition the head, remove any visible obstruction, try a jaw-thrust) and ensure he has an adequate seal between his mouth and the child's face before attempting to deliver the next breath. However, no more than five breaths should be given.

   If despite repositioning the airway and having a good seal, the rescuer is still unable to achieve movement of the child's chest, the likelihood of a foreign body obstructing the airway should be considered and the rescuer should proceed directly to chest compression *(See Foreign Body Airway Obstruction [FBAO] algorithm).*

   If within an healthcare environment, appropriate emergency equipment should be taken to the scene as soon as possible.

- **Infants: Mouth to mouth-and-nose technique:**
  Ensure a neutral position of the head. As an infant's head - when unconscious - is usually flexed when supine, this may require some extension (a thin layer of rolled towel under the upper part of the body may help to maintain the position) and a chin lift. Take a breath and cover the mouth and nose of the infant with your mouth, making sure you have a good seal. If the nose and mouth cannot be covered together in the older infant, the rescuer may attempt to seal only the infant's nose or mouth with their own mouth (if the nose is used, close the lips to prevent air escape). Blow steadily into the infant's mouth and nose for about 1 second, sufficient to make the chest visibly rise. Maintain head position and chin lift, take your mouth away from the victim and watch for his chest to fall as air comes out. Take another breath (at some distance of the child's mouth) and repeat this sequence five times.

Figure 5.3 Infants: mouth to mouth-and-nose technique



- **Child: Mouth-to-mouth technique:**
  Ensure head tilt and chin lift. Pinch the soft part of the nose closed with the index finger and thumb of your hand on his forehead. Allow the mouth to open but maintain chin lift. Take a breath and place your lips around the mouth, making sure that you have a good seal. Blow steadily into the mouth for about 1 second, watching for chest rise. Maintain head tilt and chin lift, take your mouth away from the victim and watch for his chest to fall as air comes out. Take another breath (at some distance of the child's mouth) and repeat this sequence five times.

Figure 5.4 Child: mouth-to-mouth technique

HEALTHCARE PROVIDERS....

BLS can be executed without any adjuncts. However, as expired air ventilation provides only 16-17 % of oxygen, oxygen should be administered as soon as possible to the child in cardiorespiratory arrest. The trained healthcare provider must provide BMV with oxygen, as soon as the necessary equipment becomes available.

It is important to start ventilation in children in cardiac arrest as soon as possible. Healthcare providers may deliver mouth-to-mouth rescue breaths awaiting appropriately sized equipment however infectious risk must be considered and in cases where PBLS providers are unable or unwilling to start with ventilations (e.g. BMV not directly available), they should proceed with compressions and add into the sequence ventilations as soon as these can be performed.

Pocket masks exist for mouth-to-mask ventilation. These mask are usually anatomically shaped, single-sized (that may be suitable for larger children and adolescents), with an air-filled cushion rim and sometimes an oxygen port. They often need to be held with two hands to achieve a good seal and allow adequate insufflation of the lung by mouth-to-mask ventilation. However, it should be noted that without a viral/bacterial filter they do not confer an appropriate protection against infectious diseases and that the one size does not fit all infants and children.

5. **ASSESS FOR 'SIGNS OF LIFE':** After rescue breaths are delivered, whilst calling EMS with the phone on speaker mode, **immediately continue with chest compressions unless there are clear signs of life:** [movement, coughing or normal breathing]. Gasps or infrequent, irregular breaths are abnormal. Pulse check as such is unreliable and it is the complete picture of how the patient appears that should guide BLS requirement.

   If there are clear signs of life, the rescuer should reassess the child's breathing. If breathing is still inadequate, then rescue breathing should be continued at the physiological respiratory rate for age. The child's breathing and circulation should be frequently reassessed and BLS continued appropriately until either the EMS team arrives to take over, or until the child starts to breathe spontaneously. Only if effective spontaneous breathing is clearly established and there is no suspicion of cervical spine trauma, the child can be placed in a safe, 'recovery position'.

6. **CHEST COMPRESSIONS:**
   To be delivered effectively, the child must be placed supine on a hard, flat surface, maintaining the head in a position that keeps the airway open. Only move the child if this results in markedly better CPR conditions. Remove clothes only if they severely hinder chest compressions. The rate of delivery of chest compressions should be **100-120 times per minute**. The objective of chest compression is to depress the chest **at least 1/3 of the anteroposterior**

diameter, with equal time spent in compression and relaxation. Compressions should never exceed the adult 6 cm limit (approx. an adult thumb's length).

The quality of chest compressions provided is directly related to the child's outcome. Thus, the delivery of chest compression must be performed as effectively as possible. **Push hard and fast. Minimise interruptions.** After each compression, release all the pressure on the chest and **allow full recoil** without losing contact between your hands and the sternum (avoid leaning). The Compression:Ventilation ratio for use in children of all ages is **15:2.**

For the sake of simplicity, rescuers only trained in adult CPR can use a C:V ratio of 30:2 in line with what they were trained. If feasible, they should also deliver 5 initial rescue breaths before summoning help. Providers unable or unwilling to provide mouth-to-mouth ventilation should be encouraged to at least perform compression-only CPR.

In all infants and children, deliver chest compressions over the lower half of the sternum. In order to avoid compressing the upper abdomen, locate the xiphisternum at the angle where the lower costal margins meet and compress one finger's breadth above this point.

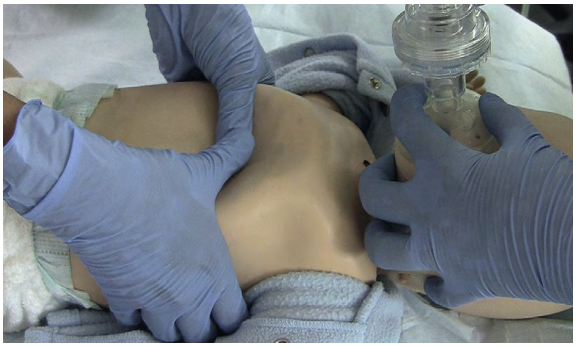
- **INFANT CHEST COMPRESSIONS: The two-thumb encircling technique is the recommended for infant chest compression, even for a single rescuer.** There is evidence that this method delivers greater cardiac output than the two- finger technique. However rescuers must take care to avoid incomplete recoil.

  To use the two-thumb encircling technique the rescuer positions himself at the infant's side/feet, places both thumbs on top of one another over the lower half of the infant's sternum (as above). Thumbs may also be side by side in case of small hands. The rescuer's hands should be positioned to encircle the infant's chest and afford support to the infant's back. Deliver compressions as described above. Single rescuers might still consider to use a two-finger technique as an alternative for infant chest compression: The rescuer should then place two (or three) fingers of one hand (preferably index and middle finger) over the lower half of the sternum as above.

Figure 5.5 Infant chest compression: two-finger technique

Chest compression in infant: two-finger technique

Figure 5.6 Infant chest compression: two-thumb encircling technique



Chest compression in infant: two-thumb encircling technique

- **CHILD CHEST COMPRESSIONS:** Depending on the size of child and the hand span of the rescuer, he or she can use either a two-thumb encircling, a one-hand or two-hand technique.

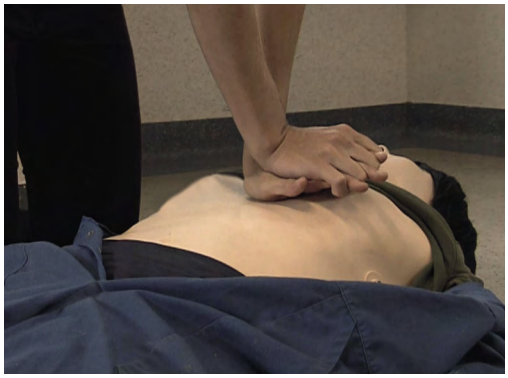
  For the one-hand technique, the rescuer positions himself at the child's side and places the heel of one hand directly on the long axis of the lower half of the sternum. The fingers should be raised off the child's chest so that only the heel of the hand is exerting pressure on the child's chest. The rescuer positions his shoulders directly over the child's chest, keeps his arm locked straight at the elbow at 90 degrees to the chest surface, and uses his body weight to depress the sternum by at least one third of the resting chest diameter.

  The other hand can be positioned to maintain an open airway throughout or to stabilise the compression arm at the elbow. During the relaxation phase following each chest compression the pressure is completely released, but the hand stays in position on the chest wall.

If it is difficult to achieve a compression depth of at least 1/3 of the anteroposterior diameter of the chest, the rescuer should use 2 hands. The second one should be placed on top of the 1st and the fingers locked together, but off the chest wall.

Figure 5.7 Child chest compression

Figure 5.8 Child chest compression: 2 hands



Chest compression in a small child: one-hand technique

7. REASSESS...

In the event that there is no phone readily available the single rescuer will need to interrupt CPR *after one minute* and leave the child to alarm EMS. If the victim is an infant or very small child the rescuer might be able to carry him safely while looking for a phone.

Otherwise **BLS should only be stopped when:**

- The child exhibits signs of life.
- Other rescuers (EMS) take over resuscitation.
- The safety of the rescuer can no longer be guaranteed.
- The rescuer becomes too exhausted to continue.

TRAUMATIC CARDIAC ARREST:

Basic life support should equally be performed in children with cardiac arrest as a result of a severe trauma, provided it is safe for the provider to do so. Try to minimise spinal movement as much as possible without however hampering the process of CPR, which clearly has priority. Do not routinely apply an AED unless there is a high likelihood of a shockable underlying rhythm such as after electrocution. Apply direct pressure to stop massive external bleeding (using if possible haemostatic dressings). Use a tourniquet in case of uncontrollable life- threatening external bleeding (preferably manufactured).

NOW BRING IN THE AED...

Automated External Defibrillators [AED] are devices that use voice and visual prompts to guide lay rescuers and health care professionals to attempt defibrillation in a safe manner. The AED analyses the victim's ECG and determines the need for, and then if appropriate, delivers an asynchronous electrical shock (with a predefined amount of Joules).

Some AEDs combine guidance for defibrillation with guidance for the delivery of optimal chest compressions. In semi-automated models (the most frequently available), the shock delivery requires the rescuer to follow the AED prompts and press the relevant button. This ensures safety of the procedure. Some of the models available to healthcare professional also have the facility for the rescuer to override the device and deliver a shock independently of any prompting by the machine. For trained healthcare professionals this is preferable.

If a child over 25 kg (or 8 years) requires defibrillation, a standard 'adult' AED should be used. However, if possible, **an AED with an attenuating device should be used in children less than 8 years.** This delivers a lower energy (typically 50-75 joules) rather than the standard (150-200 joules if biphasic). If neither an attenuator device nor a manually adjustable defibrillator are readily available however, an unmodified 'adult' AED may be used in these children.

The use of an AED should not delay or impair the delivery of good quality CPR. In cases where there are two or more rescuers, CPR should not be interrupted while the adhesive electrode pads are being placed. Trained providers should limit the no-flow time by performing CPR up to the point of analysis and immediately after the shock delivery or no shock decision. They should however remain 'hands-off' during both analysis, charging and shock. A lone rescuer should only collect and apply an AED (at the time of calling EMS) in cases where the likelihood of a primary shockable rhythm is very high (e.g. sudden witnessed collapse) and the AED easily accessible.

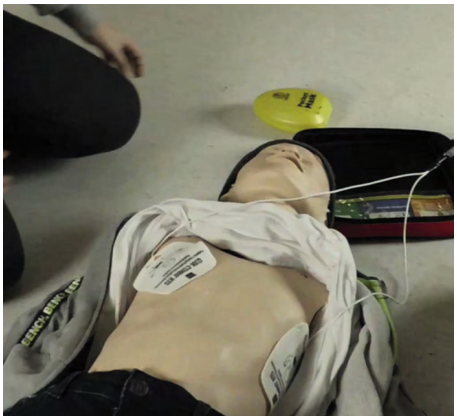
BLS algorithm with AED

Below we provide you a step-by-step algorithm. In the **CoSy VLE**, we provide you with an explanatory video about the use of an AED, as well as one further video about paediatric BLS with AED in-hospital and one about out-of-hospital sudden witnessed collapse.

1. Make sure the rescuer, the victim, and any bystander are safe. Commence appropriate BLS. If two or more rescuers are present, one continues BLS while the other summons help and gets the **AED** if available on the scene. The lone rescuer should collect the AED - at the time of calling EMS- when the likelihood of a primary shockable rhythm is very high (e.g. sudden witnessed collapse) and the AED easily accessible.
2. **Switch on** the AED. End CPR cycle with compressions. Follow the spoken/visual directions.

3. **AED pads** are placed as follows: one to the right of the sternum, below the clavicle and the other in the mid-axillary line on the left side of the chest. To improve efficiency, this second pad should be positioned with its long axis vertical. Alternatively, pads can also be positioned as shown on the AED pads. The pads should be smoothed onto the skin in order to ensure no air is trapped as this will reduce efficiency. Although the pads are labelled right and left (or have a picture of correct placement), it does not matter if they are reversed. *Therefore if an error is made, the pads should not be removed and replaced, as this wastes time and may also cause loss of adherence when the pads are reattached.* If more than one rescuer is present, BLS should be continued while this is carried out. **Ensure that nobody touches the victim while the AED is analysing the rhythm.**

Figure 5.9 Anterolateral position of defibrillation pads



4. **If a shock is indicated:** ensure that nobody touches the victim and then push the shock button as indicated. Afterwards, immediately resume appropriate BLS. If no shock is indicated: immediately resume appropriate BLS.
5. **Continue** as directed by the voice/visual prompts. Continue CPR until one or more of the following occurs:

    - Further help arrives and takes over
    - The victim starts to breathe normally
    - You become exhausted.

Figure 5.10 Anterioposterior position of defibrillation pads

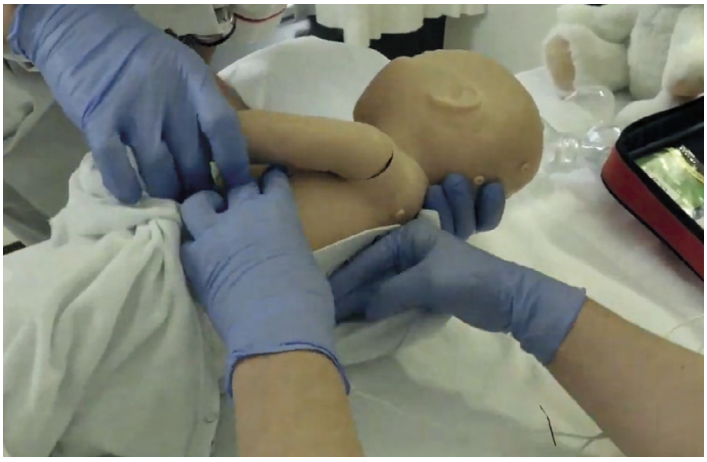


Figure 5.11 Anterioposterior position of defibrillation pads

Safe & effective use of an AED:

Do not touch the victim nor the wires connected to the pads during analysis, charging or delivery of a shock. Also ensure no one else touches the victim or his immediate surroundings (e.g. a bed). Touching the victim during analysis may cause movements that interfere with the victim's rhythm recognition and may delay delivery of a shock. Make sure the environment is safe (e.g. avoid kneeling in immediate surrounding water). Shout "stand clear" and check visually that no one is in contact with the victim.

AED defibrillation pads should not be touching each other (danger of charge arching). If they are too large they should be positioned **anterioposterior** instead, with one pad midchest left of the sternum and the other in the middle of the upper back between the scapulae. Alternatively, pads can also be positioned as shown on the AED pads.

Some victims may have a wet chest, for example following rescue from water. Quickly wipe the chest dry before attaching the AED pads to the chest.

Some victims have a heart *pacemaker* fitted. These are usually visible under the skin of the chest wall, just below the left collarbone (clavicula). Sometimes they are situated under the right collarbone instead of under the left one. Small children also may have pacemakers placed under the abdominal wall/skin. Ensure that the AED pads are not placed on top of this pacemaker, but just aside or below. Remove any metal jewelry that might come into contact with the AED pads. Pads should be kept clear of irremovable jewelry, if possible, including that used with body piercing.

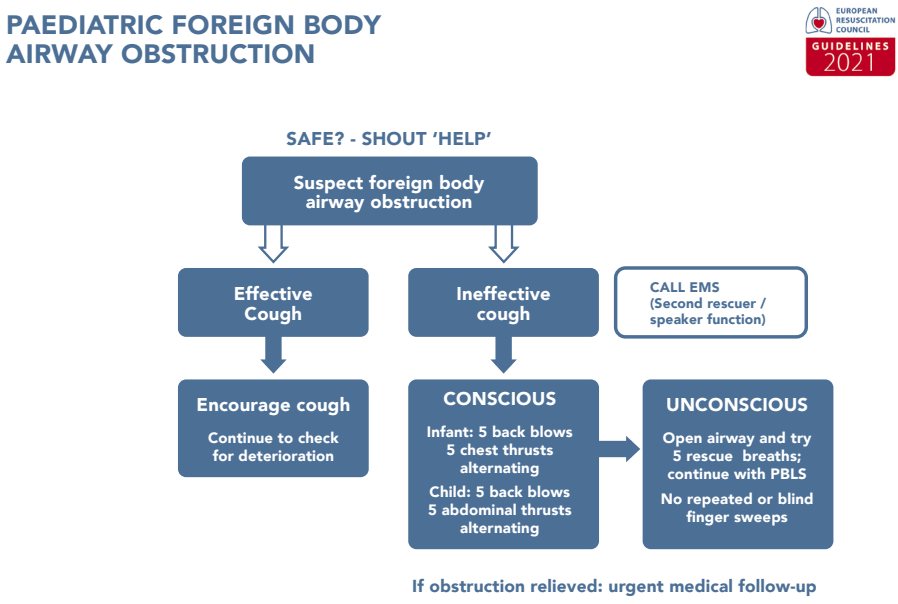
FOREIGN BODY AIRWAY OBSTRUCTION

When a foreign body enters the airway, the child reacts immediately by coughing in an attempt to expel it. *A spontaneous cough is likely to be more effective and safer than any manoeuvre a rescuer may perform.* However, if coughing is absent or ineffective and the object completely obstructs the airway, the child will rapidly become hypoxic. **Active interventions to relieve choking are therefore only required when coughing becomes ineffective but at that stage, they need to be done immediately and confidently.**

The majority of choking events in infants and children occur during play or eating and are therefore frequently witnessed by a caregiver, which permits interventions to be initiated rapidly if required. Choking is characterised by the sudden onset of respiratory distress associated with coughing, gagging, or stridor. Similar signs and symptoms may also be associated with other causes of airway obstruction such as laryngitis or epiglottitis, which require different management.

In the CoSy VLE we provide a video with more details on the algorithm and the rescue maneuvers for foreign body airway obstruction.

Figure 5.12 Choking algorithm



1. If the child or infant is coughing effectively, no external manoeuvre is necessary. Encourage the child to cough and monitor them continuously. Ask for help.
2. If the child's or infant's coughing is, or is becoming, ineffective, shout for help immediately and determine the consciousness 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.

Rescue maneuvers in a child or infant with choking who is still conscious but has an ineffective cough:

- Administer back blows.
- If back blows do not relieve the obstruction, and the child is still conscious, chest thrusts to infants or abdominal thrusts (Heimlich) to children must be administered. These manoeuvres create an 'artificial cough' to increase intra-thoracic pressure and dislodge the foreign body. Abdominal thrusts must not be used in infants.
- Afterwards reassess the child.
- If the object has not been expelled, and the victim is still conscious, the sequence of back blows and thrusts should be continued. Do not leave the child at this stage.

- If the object is expelled successfully, the child's clinical condition should be reassessed. It is possible that part of the object may remain in the respiratory tract and cause complications. If there is any doubt, medical assistance should be sought. Abdominal thrusts may cause internal injuries, therefore a medical practitioner should carefully examine all such victims afterwards.

Back Blows in an infant

The rescuer should support the infant in a head-downwards, prone position, to enable gravity to assist removal of the foreign body. A seated or kneeling rescuer should be able to support the infant safely across his lap. The infant's head must be supported by placing the thumb of one hand at the angle of the lower jaw, and one or two fingers from the same hand at the same point on the other side of the jaw. Care must be taken not to compress the soft tissues under the infant's jaw, as this will exacerbate the airway obstruction. Up to 5 sharp back blows should be delivered with the heel of one hand in the middle of the back between the child's shoulder blades. The aim is to relieve the obstruction with each blow rather than to give all five.

Figure 5.13 Back blows in an infant

Back Blows in a child

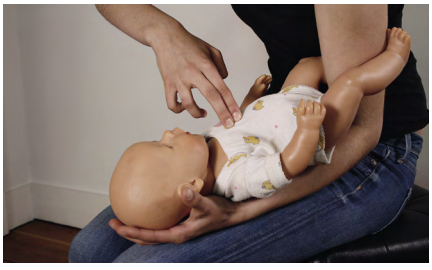
Back blows are more effective if the child is positioned head down. A small child may be placed across the rescuer's lap as with an infant. If this is not possible, support the child in a forward-leaning position and deliver the back blows from behind.

Figure 5.14 Back blows in a child

Chest Thrusts Infant

The rescuer should turn the infant into a head-downwards supine position. This is achieved safely by placing the free arm along the infant's back and encircling the occiput with the hand. The infant is supported down the rescuer's arm, which is placed down (or across) his thigh. The landmark for chest compression (lower sternum approximately a finger's breadth above the xiphisternum) should be identified on the infant's sternum. Up to five chest thrusts should be delivered. These are similar to chest compressions but sharper in nature and delivered at a slower rate.

Figure 5.15 Chest thrusts in an infant



Abdominal Thrusts Child

The rescuer stands or kneels behind the child and places his arms under the child's arms and encircles the child's torso. The rescuer should clench one of his fist and place it, with the thumb against the abdominal wall, between the umbilicus and xiphisternum. Grasping his fist with the other hand, the rescuer must pull sharply inwards and upwards to give up to 5 abdominal thrusts. The aim is to relieve the obstruction with each thrust rather than to give all five. Care should be taken not to apply pressure to the xiphoid process or to the lower rib cage as this may result in abdominal trauma.

Figure 5.16 Back blows in an infant

Rescue maneuvers in a child or infant with choking who is unconscious:

Place the child on a firm, flat surface.

- **Airway:** Open the mouth and look for any obvious object. If one is seen, make an attempt to remove it with a single finger sweep. Do not attempt blind or repeated finger sweeps, as these can impact the object more deeply into the pharynx and cause injury.
- **Rescue breaths:** Open the airway and attempt five rescue breaths. Assess the effectiveness of each breath; if a breath does not make the chest rise, reposition the head before making the next attempt. If there is no response (moving,

coughing, spontaneous breaths) single rescuers should call EMS at this stage (ideally by mobile phone on speaker, if not already) and then immediately proceed to:

- **Chest compression:** If there are no clear signs of life after the five breaths, proceed directly to chest compression.
- If it appears that the obstruction has been relieved, open and check the airway as above. Deliver rescue breaths if the child is not breathing.
- If the child regains consciousness and exhibits spontaneous effective breathing, place him in a safe 'recovery' position and monitor breathing and conscious level whilst awaiting the arrival of an EMS team.

! Emergency laryngoscopy and the use of a (Magill) forceps to remove a supraglottic foreign body is indicated when the airway is completely obstructed and basic foreign body removal manoeuvres fail to resolve the obstruction. This however demands specific skill training.

RECOVERY POSITION

The unresponsive child who is breathing spontaneously should be placed in a safe position, lying on their side, unless contraindicated (e.g. suspected cervical spine injury). The purpose of this is to ensure that the tongue does not fall backwards occluding the airway, and to reduce the risk of pulmonary aspiration of vomit or secretions. It is especially valuable when there are multiple victims. In unconscious trauma victims, it is probably better to keep the airway open by a continued jaw thrust, if possible.

! The use of this safety position should be balanced against the risk of not-recognizing a cardiac arrest. One should NOT place a child in recovery position when there is any doubt about 'normal breathing'. Once in recovery position, reassess breathing every minute to recognise CA as soon as it occurs (lay rescuers might need dispatcher guidance to do this).

There is no universally accepted "recovery" position but the general principles are based on ensuring that the child:

- Is in as near a true lateral position as possible.
- Has a patent airway maintained.
- Can be easily observed and monitored.
- Is in a stable position and cannot roll over (in small infant this may require the placement of a rolled-up towel or blanket behind their back).
- Can freely drain secretions/vomit/blood from their mouth.

- Has no pressure on their chest that may impede breathing. Regularly change sides to avoid pressure points.
- Can be turned easily onto their back for BLS if required.

Figure 5.17 Recovery position

In the CoSy VLE we further provide a description of how a victim can be put in recovery position.

CHAPTER 6

ADVANCED LIFE SUPPORT: ALGORITHM & VIDEO

(SEE ONLINE CONTENT)

CHAPTER 6.2
ADVANCED LIFE SUPPORT IN DETAIL

The distinction between BLS and Advanced Life Support [ALS] is somewhat artificial. The process of resuscitation started with BLS (chest compressions and ventilations) must be continued until return of spontaneous circulation [ROSC], then followed by adequate post-resuscitation care (paediatric chain of survival). The arrival of an ALS Team -be it a 112 Emergency Medical Services [EMS] pre-hospital team or a Medical Emergency Team [MET] or Cardiac Arrest Team [CAT] in-hospital- permits the use of appropriate equipment and facilitates the delivery of more advanced techniques. *All clinical staff within a healthcare facility should be able to immediately recognise cardiorespiratory arrest, commence appropriate resuscitation and summon an ALS team as appropriate.*

Staff will be trained to different levels according to local policies: some would be trained only in BLS or in BLS with bag and mask ventilation (and AED) whilst others would be expected to manage airway, breathing, circulation with more advanced techniques. All clinical areas where children are likely to be cared for should be equipped with resuscitation material to help with the management of a clinical emergency. *This should be regularly checked and maintained.* By employing standardised resuscitation equipment hospital-wide, healthcare providers and MET/CAT will be familiar with it wherever they have to manage a child.

In addition, hospitals should have policies for:

- calling criteria and composition of a dedicated MET team
- criteria for and audit of resuscitation skills and ongoing resuscitation training of all the different staff groups involved.

We describe some early warning signs in the CoSy VLE.

MANUAL DEFIBRILLATORS

Manual defibrillators have several advantages over AEDs and therefore manual defibrillators capable of delivering the full energy requirements from neonates upwards, must be readily available in all healthcare settings, even if AEDs are located nearby. These advantages include:

- arrhythmia diagnosis and if needed, rapid shock delivery with less hands-off time than waiting on rhythm analysis by an AED

- additional treatment possibilities, such as synchronised cardioversion and external pacing
- ability to alter energy levels
- continuous ECG monitoring

Manual defibrillators are therefore the preferred method for defibrillation during ALS, however, if not available, also in ALS rescuers should use an AED.

> *Defibrillation is the passage of electrical current across the myocardium with the intention of causing a global depolarisation of the myocardium and restoration of organised spontaneous electrical activity. The energy dosage should cause minimal myocardial injury. The electrical current depends on the selected energy (Joules) and resistance to flow of current (thoracic impedance). If impedance is high, the energy must be increased.*
>
> *Factors determining thoracic impedance are: paddle/pad size, conduction interface between paddle and skin, number and time interval of previous shocks, positioning of the paddles on the chest wall, paddle electrode pressure on the chest, chest wall thickness and obesity*
>
> *Defibrillators are either automatically (AED) or manually operated, and may be capable of delivering either monophasic or biphasic shocks. Monophasic defibrillators are no longer manufactured but many remain in use. They deliver a unipolar (one way) current. Biphasic defibrillators seem more effective and are gradually replacing monophasic ones. Biphasic defibrillators deliver currents that flow first in a positive and then in the reverse direction, during specified durations. First-shock efficacy for VF/VT is better with biphasic than with monophasic waveform. Biphasic waves also produce less post-shock cardiac dysfunction.*

The ideal energy dose for safe and effective defibrillation in children is unknown. Based on the available evidence, it is currently advised to select an energy dose of **4 Joules/kg** for all shocks when using a manual defibrillator, monophasic or biphasic. The maximum dose for the first shock is 200 J (biphasic) and 360 J (monophasic).

In cases of refractory VF/pVT i.e. more than 5 shocks needed, escalating doses -stepwise increasing up to 8 J/Kg and max. 360 J- for refractory VF/pVT might be considered.

Safety during defibrillation

Although the safety risks are far less than previously believed, especially when the rescuer is wearing gloves, it is still wise to consider the following points:

- Remove any free-flowing oxygen devices (e.g. oxygen mask, nasal cannula, disconnected tubing) and place them at least 1 meter away from the child. Ventilation bags or ventilator tubing connected to a tracheal tube should be left connected.

- Dry surfaces – Be aware of wet clothing or wet surfaces; wipe the patient's chest dry if necessary before defibrillation.
- Contact – Ensure that nobody is in either direct or indirect contact with the patient. This includes the patient bed/trolley and IV fluids.
- Ensure that the pads/paddles are not in contact with metal (e.g., jewelry) or devices such as transdermal medication or diathermy pads.
- Care must be taken when placing defibrillation pads/paddles on patients who have cardiac pacemakers or implantable cardioverter-defibrillators (ICD). They should,as far as possible, be placed at least 12 cm from the pacemaker site to minimise the risk of burns on the myocardium; this may necessitate anterior-posterior placement in children.

Ensure that operators are familiar with the equipment and that clear safety instructions are issued by them to the whole team/any bystanders. Any defibrillator should be tested regularly, as per local policy.

Self -adhesive pads (or paddles)

Self-adhesive defibrillation pads are safe, effective, and generally preferable to standard defibrillator paddles. They have similar transthoracic impedance to paddles but facilitate more rapid shock delivery in ongoing resuscitation attempts and decrease hands-off time. Pads have a limited shelf life and should not be used beyond the expiry date as they could become dry and impair defibrillation.

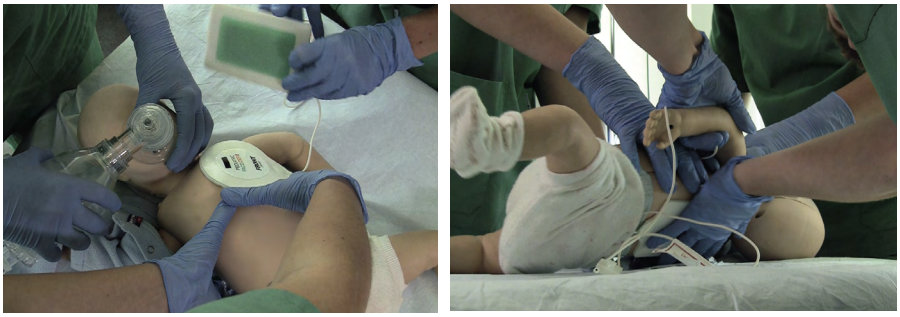
When **manual paddles** are used, they require separate non-adhesive defibrillation gel pads to be applied to the chest wall to ensure good contact and reduction of transthoracic impedance. These tend to fall off during chest compressions and need to be repositioned. Additionally, they can lead to spurious asystole on ECG analysis as the gel polarises and becomes less effective as a conducting agent. This phenomenon is not seen with self-adhesive gel pads. Electrode gel can also be used for manual defibrillation with paddles. However, this is less preferable, as it can become smeared across the patient's chest during chest compressions and lead to arcing of the electrical current. Ultrasound gel (which is a poor conductor), saline-soaked gauze (which has variable conductivity and the risk of arcing between the paddles), and alcohol-soaked gauze (risk of burns) must be avoided.

The paddles should bracket the heart to permit the current to flow across it. Usually, one paddle is placed just below the right clavicle and the other in the left axilla. Alternatively, pads can also be positioned anterio-posterior. 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.

When using defibrillator paddles, the largest possibly available should be chosen to permit maximal contact with the chest wall. However, paddles or any type of gel pads must not come in contact with each other. When delivering the shock via paddles, firm pressure should be exerted on the paddles to ensure good contact.

In general, infant paddles (approximately 4.5 cm diameter) are required for children weighing < 10 kg. If infant paddles are unavailable, an anterior - posterior placement of the paddles may be required.

Figure 6.1 Self-adhesive pads

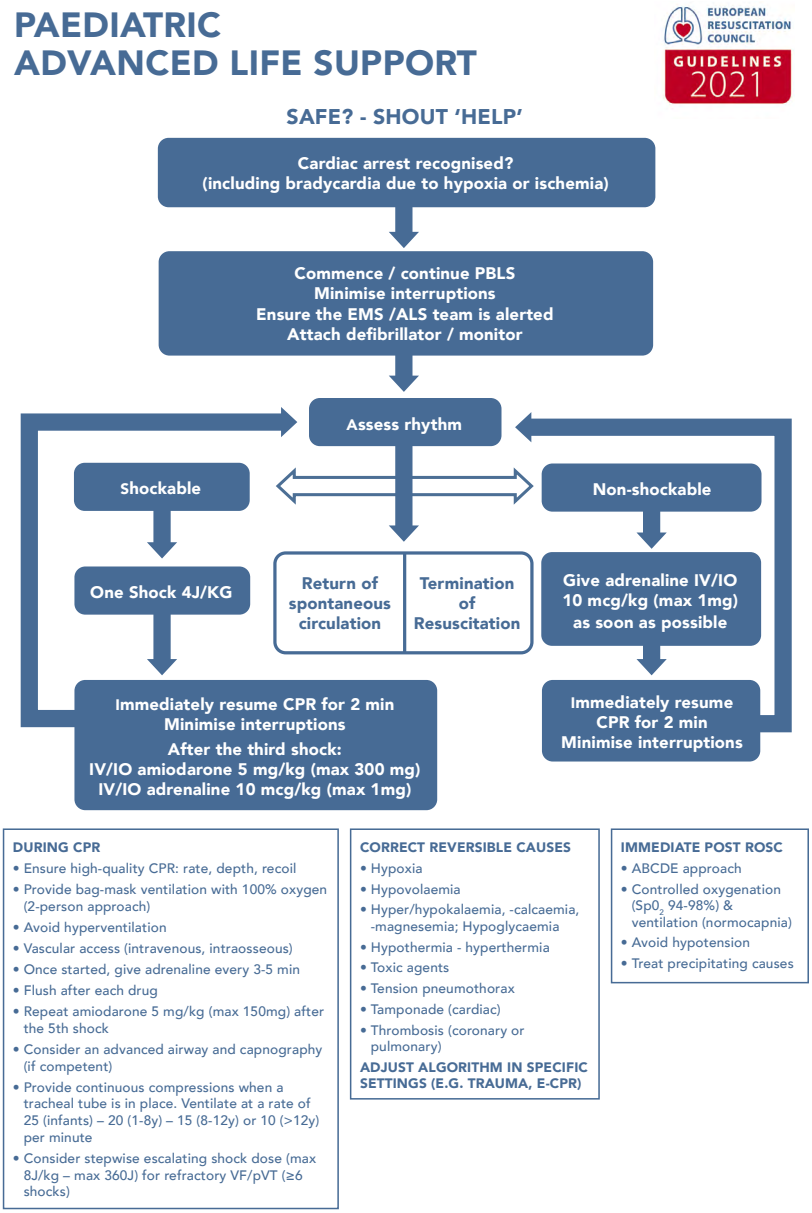


In the CoSy VLE we provide a video further describing the use of a defibrillator as part of the advanced life support algorithm.

A STEPWISE APPROACH TO ADVANCED LIFE SUPPORT...

Underneath we provide the overall algorithm on Paediatric Advanced Life Support. In the CoSy VLE we also show you a video that demonstrates the full algorithm.

Figure 6.2 Paediatric Advanced Life Support



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.

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 (even if there is still a detectable pulse).

Regardless of the setting, the approach to a sick child should ensure firstly the safety of rescuers. They should employ personal protective measures as soon as practicable (e.g. gloves, aprons, face masks, eye protection…).

A single rescuer must not leave the collapsed child but immediately initiate resuscitation as appropriate and ensure that further help is summoned. Within a clinical area, there are usually staff nearby who can be alerted to the situation either by the first responder shouting for help and/or using an emergency call button system. As soon as the second rescuer arrives, this person should be sent to summon further assistance in line with local policy (activate MET or CAT). On his return or on arrival of other staff members, simultaneous interventions can be undertaken according to their skills. If not already in place, monitoring and/or AED pads should be attached.

- **AIRWAY (A):** the airway should be opened. The rescuer should check for normal and effective breathing. Suction –if available- should be performed briefly if needed to clear any secretions in the upper airway before performing ventilation.
- **BREATHING (B):** if the child is not breathing or making only agonal gasps, initial rescue breaths should be delivered by the most appropriate method available (e.g. mouth to mouth technique or preferably BMV (with oxygen)). When two rescuers perform BLS and are trained in the use of BMV, the rescuer delivering the BMV should be positioned behind the child's head. The second rescuer should be positioned at the child's side or feet to perform chest compressions if indicated.
- **CIRCULATION (C):** Unless there are clear signs of circulation, chest compressions must be initiated. Awaiting the cardiac arrest team, rescuers should alternate in order to avoid fatigue and hence decreasing quality of compressions. To minimise 'no flow' time, rescuers should minimise interruptions by changing roles in a timely manner to avoid periods where no resuscitation is being performed (e.g. for two rescuers: after a series of chest compressions, the rescuer will move to the ventilation position and reposition the mask whilst the other rescuer will immediately resume to chest compression). Attention should be given at all times to the quality of CPR.

STEP 2: RHYTHM RECOGNITION

Whilst CPR is performed, the next step is to identify the child's cardiac rhythm and therefore an ECG monitor or a defibrillator must be attached to the patient. The priority is deciding whether the cardiac rhythm is **shockable or not**, in order to determine the next steps in the management of the cardiorespiratory arrest.
If an AED is used, the rhythm is not displayed and the machine will guide the rescuers through the appropriate sequence of actions.

The commonest initial cardiorespiratory arrest rhythms in children are non-shockable rhythms: pulseless electrical activity [PEA], bradycardia (<60/min) and asystole. Shockable cardiorespiratory arrest rhythms: pulseless Ventricular Tachycardia [pVT] and Ventricular Fibrillation [VF] are less common in children. When they do occur it is often in children with underlying cardiac disease. The priority of management for shockable rhythms is early defibrillation.

PEA and pVT are potentially perfusing rhythms. The need for CPR in these rhythms is identified by the absence of signs of life (and optionally a central pulse).

Asystole

is characterised by the total absence of effective electrical and mechanical activity in the heart. Asystole can be simulated by an artifact (e.g. detached electrodes). *A prompt check of equipment, gain and selected ECG lead/paddle, is essential to eliminate these possible artifacts.*

Figure 6.3 Pulseless Electrical Activity: in a patient with no signs of life

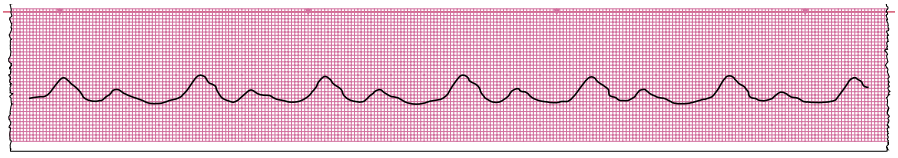


Figure 6.4 Pulseless Electrical Activity: severe bradycardia in a patient with no signs of life

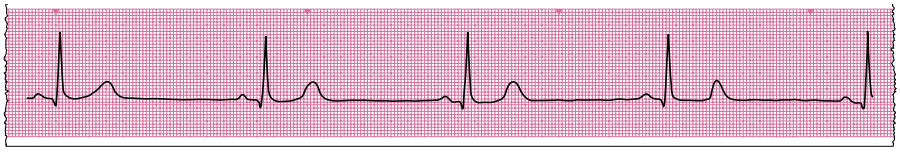


Figure 6.5 Asystole

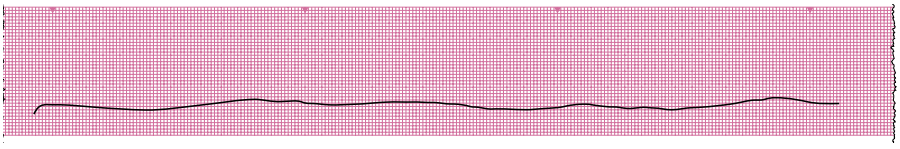


Figure 6.6 Pulseless Ventricular Tachycardia in a patient with no signs of life

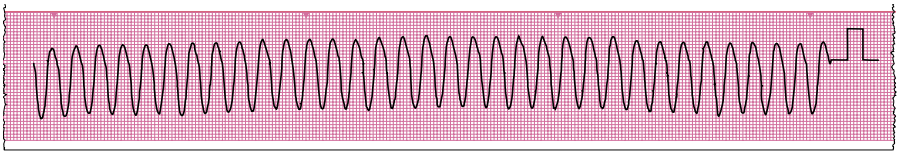


Figure 6.7 Ventricular Fibrillation coarse

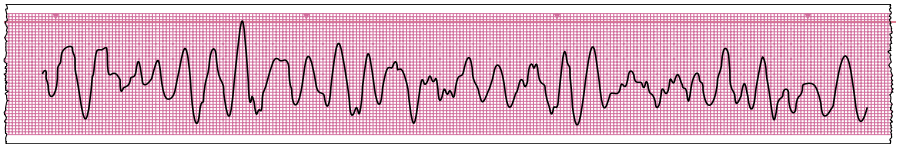
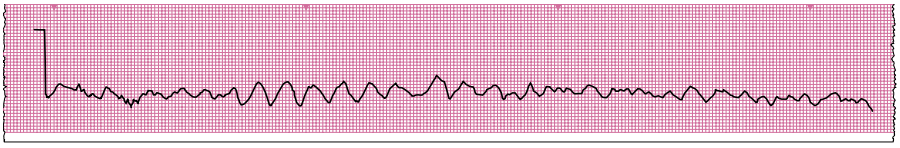


Figure 6.8 Ventricular Fibrillation fine



Pulseless electrical activity

PEA: is defined by an organised electrical activity in the absence of signs of life. The ECG may show any variation of regular QRS complexes but they will degenerate rapidly into slow and broad complexes. All cardiac arrest rhythms, but particularly PEA may be due to an underlying reversible cause. It is essential that treatable causes are identified and managed appropriately.

Severe bradycardia

Severe bradycardia is often the terminal rhythm following hypoxia or ischaemia, degenerating into asystole. A very shallow central pulse with a very low frequency (< 60/min) may still be palpable at this stage but the child is apnoeic or gasping and shows an absence of signs of life. It must be treated as a non-shockable arrest rhythm.

Of course, severe bradycardia <60 / min also happens in children with a perfusing rhythm (in case of e.g. AV nodal block, intoxication...): *see further lesson on specific paediatric emergencies*.

2.4. Pulseless ventricular tachycardia

pVT is characterised by a ventricular rate of 120-400 beats/minute, with regular broad QRS complexes but no signs of life (or no palpable pulses). It is managed the same way as VF meaning: effective CPR and defibrillation. This rhythm is uncommon in children.

Ventricular fibrillation

VF is a chaotic, disorganised, irregular series of depolarisations in which waves and complexes are clearly abnormal. Ventricular systole does not occur, so there is no cardiac output. VF is sometimes described as coarse or fine VF depending on the amplitude of the complexes. **When the rhythm is clearly VF, defibrillation should be performed without delay.** VF may occur with severe hypoxia, heart diseases, electrolyte disorders or drug toxicity (e.g., digoxin).

When there is a doubt whether a rhythm is a fine VF or an asystole, rescuers should consider the rhythm to be shockable.

STEP 3: AS SOON AS POSSIBLE..

The most important determinant of survival in these rhythms is **prompt defibrillation**. Defibrillation should be performed as soon as a defibrillator becomes available (regardless of the ECG amplitude). Ventilation, oxygenation, chest compression, and vascular access should be quickly instituted but without delaying defibrillation.

Minimise interruptions in chest compressions by planning actions before they are performed. *If possible, minimise rescuer fatigue by changing the person performing chest compressions at the end of every 2 minute cycle. Do not interrupt CPR more than 5 seconds for any action.*

ACTIONS IF A NON-SHOCKABLE RHYTHM IS IDENTIFIED (SEE ALSO THE VLE FOR A VISUAL ALGORITHM):

- Continue high-quality CPR at 15:2 ratio with BMV and supplemental oxygen. Minimise interruptions. Avoid hyperventilation.
- Establish circulatory access by peripheral IV or IO. In cases where it is likely to be difficult to obtain IV access, immediately go for IO access.
- Administer adrenaline IV/IO at 10 mcg/kg (0.1 ml/kg of a 1:10000 solution with a maximum of 1 mg or 10 ml) followed by a 2-10 ml flush of normal saline. Once given, repeat IV/IO adrenaline every 3-5 minutes of CPR.
- After 2 minutes of CPR: reassess rhythm, preferably during the 2 ventilations or in case of continuous compressions, a very brief pause in chest compressions. If no rhythm is present (asystole) or there is no change in the ECG appearance, resume CPR immediately. If an organised electrical activity (which is a potentially perfusing rhythm) is seen on the monitor, check for signs of life (and optionally a central pulse). If signs of life are present, post-resuscitation care should be commenced. If not, continue CPR (minimising interruptions).

ACTIONS IF A SHOCKABLE RHYTHM IS IDENTIFIED (SEE ALSO THE VLE FOR A VISUAL ALGORITHM):

The most important determinant of survival in these rhythms is prompt defibrillation. Defibrillation should be performed as soon as a defibrillator becomes available. Ventilation, oxygenation, chest compression, and vascular access should be quickly instituted but without delaying defibrillation.

! Minimise interruptions in chest compressions by planning actions before they are performed. If possible, minimise rescuer fatigue by changing the person performing chest compressions at the end of every 2 minute cycle. Do not interrupt CPR more than 5 seconds for any action.

Sequence of actions when using self-adhesive pads (first choice):

1. Confirm cardiac arrest and then start or recommence CPR.
2. Place appropriate self-adhesive pads on the child's chest: one below the right clavicle and one in the left midaxillary line, ensuring they do not touch one another. Avoid interrupting chest compressions whilst doing so.
3. Switch the defibrillator on, ensure it is in the non-synchronised mode; *select 'pads' as monitor lead and confirm shockable rhythm during a brief pause in chest compressions,* for instance during the 2 given ventilations.
4. Select appropriate energy: **4 J/kg** (rounding up to closest energy level) and *charge the defibrillator without interrupting compressions.*
5. Say: "STAND CLEAR, SHOCKING" in a loud voice; confirm the person performing chest compression has now taken his hands off the child's chest, nobody is touching the child, and high flow oxygen has been removed.
6. Deliver the shock.
7. Request *immediate resumption of CPR (starting with chest compressions) without reassessment of rhythm or pulse check*. In case of paddles, place them back in the defibrillator (this will not always be possible with infant paddles).
8. Continue CPR for **2 minutes** then briefly pause to check the ECG. If the rhythm is still a shockable, repeat previous steps and deliver a second shock. Then continue CPR for 2 minutes after which, if VT/VF persists, a third shock is indicated.

As soon as possible, and concurrent with the above sequence, obtain relevant history and investigations to identify reversible causes (4H's and 4 T's) and treat them appropriately.

After the third shock:

After the third shock, once CPR has been resumed, administer **adrenaline** 10 mcg/kg IV/IO (max 1 mg) and **amiodarone** 5 mg/kg IV/IO (max 300 mg). Give adrenaline every 3-5 minutes during CPR. If the child remains in VF/pVT, continue to alternate shocks

of 4 J/kg with 2 minutes of CPR. Give a second (final) dose of amiodarone 5 mg/kg (max 150 mg) after the 5th shock if VF/pVT persists. At that stage, consider escalating defibrillation doses stepwise up to 8 J/Kg (max. 360 J).

In the CoSy VLE we further describe how this sequence is slightly different when still using paddles and gel pads. We also explain the potential use of a 'three stacked shocks' strategy in certain specific indications.

If a potentially perfusing rhythm (PEA, pVT) is seen at the end of a 2-minute cycle of CPR the following actions should be taken:

- **If signs of return of spontaneous circulation (ROSC) are present, either clinically (eye opening, movement, normal breathing) and/or by monitoring ($ETCO_2$, SpO_2, blood pressure, ultrasound), post-resuscitation care should be commenced.**
- **If there are no signs of life, resume CPR and if PEA, switch to the non-shockable side of the paediatric ALS algorithm.**

If the rhythm changes to asystole at the end of a 2-minute cycle of CPR:

- **Resume CPR and switch to the non-shockable side of the paediatric ALS algorithm.**
- **When switching from shockable to non-shockable algorithm (or from non-shockable to shockable) 3-5 minute intervals between adrenaline administration should be maintained.**

Do not interrupt CPR during the two minutes CPR after a shock, even if an organised rhythm is observed, unless the patient shows evident signs of life suggesting ROSC. Chest compressions are resumed immediately after a shock without reassessing the rhythm or feeling for a pulse because, even if the defibrillation attempt is successful in restoring a rhythm, it is unlikely that the heart will immediately pump effectively. Even if a perfusing rhythm has been restored, giving chest compressions does not harm the heart.

AIRWAY AND VENTILATION DURING CPR

Hypoxia is one of the most frequent causes of cardiorespiratory arrest in children. Effective ventilation with the highest possible oxygen concentration (FiO_2 100 %) should be used to reduce the risk of persistence or occurrence of hypoxia during resuscitation. The vast majority of children can be adequately ventilated with BMV at the initial stages of resuscitation. It is better to continue with this until experienced help is available. However, if performed by someone experienced, especially when CPR during transport or prolonged resuscitation is anticipated, tracheal intubation might be considered. Where it is impossible to ventilate by BMV, consider the early use of an advanced airway (TT, SGA) or rescue technique. Use $ETCO_2$ monitoring when

an advanced airway is in place. $ETCO_2$ values can help to rapidly detect ROSC but should not be used as quality indicator or target.

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 case of cardiac arrest, tracheal intubation does not require any pre-medication. It is important that chest compressions are not or only minimally interrupted during intubation. Following intubation and confirmation of the correct tube position, chest compressions can be delivered continuously without pausing for ventilation. In this case, ventilations should approximate to the lower limit of normal rate for age e.g. breaths/min: 25 (infants), 20 (>1y), 15 (>8y), 10 (>12y). Once there is return of spontaneous circulation [ROSC], ventilate at a normal rate for age to achieve, as far as possible, a normal arterial carbon dioxide tension ($PaCO_2$).

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.

REVERSIBLE CAUSES (4H'S AND 4T'S)

As soon as possible obtain relevant history (e.g. antecedents, medications, trauma..) to identify reversible causes (4H's and 4T's) and treat them appropriately. Some of the reversible causes (hypovolaemia, tension pneumothorax, and cardiac tamponade) may temporarily improve with the administration of a fluid bolus. Tension pneumothorax and cardiac tamponade will also require definitive therapy. The child's temperature should be checked, and immediate (ideally bedside) testing of glucose, electrolytes and acid- base status should be performed. Peri-arrest ultrasound may help in identifying some of these causes, provided the examination does not interfere with CPR.

Accidental or deliberate poisoning may be diagnosed either by history or by laboratory analysis. When available and indicated, appropriate antidotes should be administered. Thrombosis (both coronary or pulmonary) is uncommon in children but may be found in children with special diseases e.g. nephrotic syndrome, sickle cell anaemia or when a central catheter is in place. If thrombosis is considered to be the cause of cardiorespiratory arrest, thrombolysis must be considered.

For certain life-threatening conditions (cardiac surgery, neurosurgery, trauma, drowning, sepsis, pulmonary hypertension) 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).

Table 6.1

4Hs	**H**ypoxia	**4Ts**	**T**ension Pneumothorax
	Hypovolaemia		**T**amponade (cardiac)
	Hypo-/hyperkalaemia / -calcaemia/ -magnesemia & hypoglycaemia		**T**hrombosis (cardiac - pulmonary)
	Hypo- /hyperthermia		**T**oxic agents

TRAUMATIC CARDIAC ARREST

Start standard CPR while searching for and treating any of the reversible causes:

- airway opening and ventilation with oxygen
- external haemorrhage control including the use of tourniquets in exsanguinating injury
- 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 thoracotomy in paediatric 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).

CHAPTER 6.3
ADVANCED LIFE SUPPORT: WORKING AS A TEAM

Paediatric resuscitation is stressful and sometimes highly time-critical. Traditionally courses have focused on the skills and knowledge required to deliver optimal care, but they have not considered the important role of teams, effective communication and leadership. Critical decision-making in a tense environment however depends largely on many **non-technical skills** comprising *team leadership, situational awareness, team membership, task distribution and above all communication amongst team members.*

Deficiencies in the requisite non-technical skills are one of the most common causes of adverse incidents. Promoting these non-technical skills is imperative and for this we refer e.g. to the Anaesthetists' Non-Technical Skills (ANTS) System that includes the components of:

- situational awareness
- timely decision-making
- team working, including team leadership
- task management

Figure 6.9 Team performance

A video on non-technical skills and some additional materials is provided in the CoSy VLE, please check them. We also provide some additional info on the role of the team leader and of the team members.

SITUATIONAL AWARENESS

This can be described as an individual's awareness of the environment at any one moment in a crisis and their ability to respond. This is particularly important when many events are happening simultaneously. Overload of information input with poor situational awareness may result in poor decision-making with serious consequences. At a cardiorespiratory arrest, all those participating will have varying degrees of situational awareness. *In a well-functioning team, all members will have a common understanding of current events, or shared situational awareness. It is important that* ***only the relevant information is shared*** *otherwise there is too much distraction or background 'noise' which may be irrelevant to the patient's immediate requirements.*

Important situational awareness factors include:

- consideration of the location of the arrest, which can give clues to the cause
- obtaining information from staff or witnesses about the events leading up to the arrest
- confirmation of the diagnosis
- noting actions already initiated e.g. chest compressions
- checking that a monitor has been attached and interpreting what it shows
- communicating with the team, gathering information
- implementing any immediate necessary action
- consideration of the likely impact of interventions
- determining the immediate needs

DECISION MAKING

This is the process of choosing a specific course of action from several alternatives. At a cardiorespiratory arrest decision-making usually falls to the most senior clinician present, which could equally be a consultant, a junior doctor or a ward nurse. This person will need to take on a leadership role before the resuscitation team arrives. The leader will assimilate information from those present and from personal observation and will use this to determine appropriate interventions. Typical decisions made include:

- confirmation of cardiorespiratory arrest
- calling the resuscitation team

- starting CPR
- attaching a defibrillator and delivering a shock

Once a decision has been made, clear unambiguous communication is essential to ensure that it is implemented. For example when a nurse finding a patient asks her colleague to call the resuscitation team – "John, this child is in cardiorespiratory arrest, please can you dial xxxx and call the resuscitation team and come back when you have done this."

TEAM WORKING, INCLUDING TEAM LEADERSHIP

Team membership and team leadership *(see below)* can be taught and improved by rehearsal, reflection and direct coaching. Cross-role training -the fact that trainees take up any role within a training session, regardless of their function in real-life circumstances- helps to understand the place and role of each member within a team.

TASK MANAGEMENT

The many decisions to be made usually fall to the team leader. The leader will assimilate information from the team members and from personal observation, and will use this to determine appropriate interventions. Typical decisions made during CPR include:

- diagnosis of the cardiorespiratory arrest rhythm
- choice of shock energy to be used for defibrillation
- likely reversible causes of the cardiorespiratory arrest
- how long to continue resuscitation

Once a decision has been made, clear unambiguous communication with the team members is essential to ensure that it is implemented.

During the resuscitation, there are numerous tasks to be carried out by the team members, either sequentially or simultaneously. The coordination and control, or management of these tasks is the responsibility of the team leader. They include:

- planning and briefing the team, prior to the arrival of the patient
- being inclusive of team members
- being prepared for both the expected and the unexpected
- identification of resources required – ensure that equipment is checked and specifics organised and delegated
- prioritising actions of the team
- watching out for fatigue, stress and distress amongst the team

- managing conflict
- communicating with relatives
- communicating with experts for safe handover both by telephone and in person
- debriefing the team
- reporting untoward incidents, particularly equipment or system failures
- participation in audit

Communication problems are a factor in up to 80 % of adverse incidents or near miss reports in hospitals. Communication is vital in every stage of managing a sick child, in summoning help, in preparing for the resuscitation, during the resuscitation and in organizing the post resuscitation care. The use of handover tools such as RSVP [Reason, Story, Vital signs, Plan] or SBAR [Situation, Background, Assessment, Recommendation] enables effective, timely communication between individuals from different clinical backgrounds and hierarchies (see separate lesson on Handover).

PERFORMING CPR AS A TEAM

Preparation/Anticipation

The team leader should know people's names and abilities, this helps create the initial team. Good communication with the team members results in the *appropriate task allocation and identifies if further senior help is required.* If there are sufficient members, one person may be delegated to managing the airway, another the breathing, and another the circulation. The team leader can explain that he will ask in turn how the airway, breathing and circulation are, in order to ensure that this order of priority of treatment is followed should any problems be found. The team leader should explain that he will ask for reassessment of the ABCDE, to see the effects of any interventions that have been carried out.

Preparation can be made if there is time by writing up predicted requirements, if the age or weight of the child is known. Frequently, a pre-alert for a child arriving by ambulance of his age allows for estimation of equipment, fluid and drugs prior to the patient's arrival. Checklists might be used to support decision making. In addition, anticipation of potential problems to encounter ("what if such and such happens") will likely improve team performance.

Resuscitation

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. Clear commands addressed directly to individuals keeps a team focused and a team leader should use **closed loop** techniques to ensure a task has been performed e.g. "Did you take blood samples, including gases and cross-matched 4 units packed cells. Yes. OK, thanks." It may be helpful to ask in turn the findings of the person dealing with the Airway, then Breathing and then the Circulation, addressing any problems that are found as they are identified.

Use 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.

Post Resuscitation Care

Resuscitation does not stop with ROSC. Handing the patient over to another colleague, or department or to a different hospital requires good *communication and handover* tools can provide a framework for information sharing at this stage. Eventually, the team leader will decide when to stop resuscitation efforts.

CHAPTER 7
ETHICS IN PAEDIATRIC LIFE SUPPORT

For more details, we refer to the Chapter on 'Ethics in Resuscitation' within the 2021 ERC guidelines, a link to which is provided in the CoSy VLE. The ethics of resuscitation in the context of a pandemic are described in a separate article.

MAJOR POINTS TO CONSIDER

- All patients must be considered equally. Medical practice must conform to civilian and criminal law. The ethical considerations regarding end-of-life decisions include achieving the best results for the individual patient, for relatives and for society as a whole by appropriate allocation of available resources. Clinicians should not use categorical or blanket criteria to determine the eligibility of a patient to receive treatment.
- All medical acts must be guided by the goal of achieving good for the patient. The actions of healthcare providers must not cause harm (or no further harm). The balance between the risks and the benefits of a proposed treatment must be evaluated carefully, considering the potential advantage for the patient.
- A patient has a right to confidentiality.
- Any person, if competent, has a right to accept or refuse treatment and to change their decision at any time. The opinion of children with decisional capacity (e.g. above a certain age) should always be taken into account during the process of shared decision making. In some cases, there may be a conflict of interest with parents, or parents may refuse appropriate treatment because of their beliefs. If this occurs the health staff must make decisions that protect the best interests of the child requesting only if needed, legal advice and support.
- Advance directives (decisions about treatment provided prospectively by an individual in case they are unable to participate directly in medical decision-making at some point in the future) also might exist in children. They should be clearly recorded and periodically reviewed.
- Physicians must not delay resuscitation interventions while trying to establish if an advance directive prohibiting CPR exists. Neither must CPR be attempted if it is considered more harmful than helpful, even if contrary to a valid and applicable advance decision. There may also be occasions where a clinician decides to override a prior decision to withhold CPR.
- Performing so-called 'slow code' (some 'symbolic' resuscitation measures but unhurriedly or omitting the most aggressive ones) to spare physician and

family the helpless feeling of doing nothing and avoiding potential conflict or the need to communicate bad news, is considered ethically unsound. A valuable alternative may be a 'tailored code', where high quality resuscitation is performed but clear limits are defined. Family members are informed in a transparent way what will be done and what not.

- Parents/family have the right and should be offered the opportunity to be present during invasive procedures including resuscitation, if this can be done safely. A dedicated member of the resuscitation team should be devoted to support them and explain the life support process in an empathic manner.

Table 7.1

Withholding or withdrawing CPR should be considered when:
Unequivocal criteria:
• When the safety of the provider cannot be adequately assured • When there is obvious mortal injury or irreversible death • When a valid and relevant advance directive becomes available that recommends against the provision of CPR
Further criteria to inform decision making:
• Persistent asystole despite 20 minutes of advanced life support (ALS) in the absence of any reversible cause • Unwitnessed cardiac arrest with an initial non-shockable rhythm where the risk of harm to the patient from ongoing CPR likely outweighs any benefit e.g. absence of return of spontaneous circulation (ROSC), severe chronic co-morbidity, very poor quality of life prior to cardiac arrest. • Other strong evidence that further CPR would not be consistent with the patient's values and preferences, or in their best interests.

Clinicians should clearly document reasons for the withholding or termination of CPR, and systems should audit this documentation.

Criteria that should not alone inform decision-making are e.g. pupil size, CPR duration, end-tidal CO_2 values, co-morbid state, initial lactate value, Suicide attempt...

Systems should implement criteria for early transport to hospital in cases of OHCA, taking into account the local context, if there are no criteria for withholding / terminating CPR. Transfer should be considered early in the CPR attempt and incorporate patient, event (e.g. distance to hospital, risk of high-priority transport for those involved), and treatment (e.g. risk of suboptimal CPR) factors. *Patients who may particularly benefit from early transport include emergency medical services (EMS) witnessed arrest [or by bystander performing high quality basic life support (BLS)] with either ROSC at any moment or ventricular fibrillation/tachycardia (VT/VF) as presenting rhythm and a presumed reversible cause (e.g. cardiac, toxic, hypothermia).*

In the CoSy VLE we further advice about how to communicate bad news (for instance in case of bereavement)

CHAPTER 8
POST-RESUSCITATION CARE, HANDOVER & TRANSPORT

A significant percentage of resuscitated children ultimately die or survive with serious neurological sequelae so good post resuscitation care is required to maintain organ perfusion and prevent secondary organ injury whenever possible.

More background information is provided in the CoSy VLE.

POST-ROSC STABILISATION

As post-ROSC stabilisation can involve the entire spectrum of intensive care techniques, this chapter will concentrate on treatments required immediately after resuscitation and interventions needed for safe transfer to the paediatric intensive care unit (PICU). The ABCDE approach can be followed in the post-resuscitation phase as it helps focus management priorities whilst providing ongoing assessment of the child.

Airway & breathing

If the child has been resuscitated using a BMV or a supraglottic device a decision needs to be made as to whether the child requires intubation and ventilation for ongoing care. This will be more likely if:

- There is a decreased level of consciousness and loss of protective airway reflexes.
- Airway pathology requires a secure airway.
- Lung pathology dictates need for ongoing positive pressure ventilation.
- A secure airway is required for safe transfer to a PICU.
- There is a high risk of child's clinical condition deteriorating.

Intubation requires training and expertise *(see above)*. Analgesia, sedation and muscle relaxant will be necessary in the majority of cases for intubation.

$ETCO_2$ monitoring is essential to confirm tracheal tube placement and for continuous ongoing monitoring. To avoid hypo- and hyperventilation, correlation with true arterial $PaCO_2$ is necessary as soon as possible as there may be a significant gap between $PaCO_2$ and $ETCO_2$. 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.

The position of the tracheal tube should be confirmed on a chest X-ray. If the tracheal tube is too long it may cause lobar collapse impeding ventilation. If the tube is too high it may accidentally dislodge into the oesophagus. Both BMV and ongoing positive pressure ventilation via a tracheal tube can cause gastric distention which may hinder ventilation. A gastric tube should be passed to deflate the stomach and reduce the risk of aspiration and vomiting; the position of the gastric tube can be confirmed on CXR. A nasogastric tube is most commonly placed but must be orogastric in children with head injury in case there is a basal skull fracture. Children who remain ventilated will need ongoing sedation and analgesia. Following intubation the most common complications causing failure of oxygenation or ventilation can be remembered using the acronym DOPES.

Although 100% oxygen is used during resuscitation, prolonged administration of high oxygen concentrations might result in pulmonary and cerebral toxicity. Therefore, once the child is stable with good perfusion restored, the inspired oxygen should be reduced to target normoxaemia (normal PaO_2; or likewise a SpO_2 between 94-98 %). Exceptions include: patients who have suffered smoke inhalation (CO or cyanide poisoning) or have severe anaemia when a high FiO_2 should be maintained as dissolved O_2 helps in oxygen transport in these circumstances. The ventilation goal after cardiopulmonary arrest should be to maintain adequate oxygenation and ventilation. Try to avoid both hypocarbia and hypercarbia. Suggested ventilatory parameters may need to be adjusted depending on the pathology of the child's condition and the oxygen and carbon dioxide levels in the blood. Mechanical ventilation demands specific knowledge and skills and is therefore best only used by healthcare providers with sufficient expertise.

Standard initial 'rescue' settings for a mechanical ventilator (pressure or volume controlled) for children after ROSC. To be adjusted in view of **oxygenation** (function of FiO_2 and PEEP) and **ventilation** (function of Respiratory rate and Tidal volume). The use of a mechanical ventilator demands specific expertise. We provide some possible initial ventilator settings in the CoSy VLE.

After ROSC, an intubated child should only be extubated after admission to a PICU and after a thorough assessment of hypoxic damage to the vital organs and the brain. A period of stability and further neuroprotective measures *(see below)* may be warranted before attempting extubation. Extubation prior to transfer is unwise even if the child is making some respiratory efforts, as this child can rapidly deteriorate. It is therefore better to provide adequate sedation and analgesia to allow ongoing ventilation. The child can be ventilated manually using a bag device attached to the tracheal tube (this can be safely achieved with $ETCO_2$ monitoring but is personnel intensive) or mechanically using a ventilator.

Circulation

Once central pulses have been restored, the circulation must be thoroughly evaluated and values maintained within age-appropriate limits. Continuous ECG monitoring is mandatory due to the high incidence of post-resuscitation arrhythmias. Systemic blood pressure (preferably mean arterial pressure) is an indirect measure of organ perfusion, and can be obtained non-invasively by manometer every few minutes or continuously if an arterial line is inserted. After fluid resuscitation palpation of the liver edge and listening to the lungs for basal crackles may give an indication of fluid status versus cardiac function. Central venous oxygen saturation and echocardiography may help with the treatment of circulatory and cardiac dysfunction. Reduction in blood lactate levels may also be useful in monitoring the child's response to circulatory resuscitation (normal levels < 2 mmol/l or 18 mg/dl).

The aim of circulatory management during post resuscitation care is to **ensure adequate perfusion and tissue oxygenation**. Myocardial dysfunction is common after CPR but is generally reversible and responsive to parental fluids and inotropes. Isotonic crystalloids are commonly used to optimise preload. Blood products should be used when specifically indicated. Inotropes and vasopressors should be considered if hemodynamic goals are not achieved despite optimised preload. If the child is not already intubated and ventilated at this point, this should be considered.

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.

Neurological stabilisation

After resuscitation there should be a simple neurological assessment to document level of consciousness, pupil reactivity, any posturing and focal signs. This assessment should be regularly repeated. The presence of focal signs should prompt the need for further neurological investigations such as brain-imaging once the child is stable.

Neuroprotective care post ROSC aims to avoid secondary brain injury by preventing hypo- and hypertension, hyperthermia, maintaining normal ventilation and oxygenation, avoiding abnormal blood glucose levels, hypo- or hypercapnia and seizures. It should start from the first minutes after ROSC. Underneath we highlight the most important steps to take and refer to the **CoSy VLE** for more information.

- **Cerebral perfusion:** preventing hypotension is crucial to prevent reduced cerebral blood flow and further brain injury. Any episode of hypotension will have an impact on subsequent outcome. The child's (mean) blood pressure should always be maintained at the upper level of the normal range.
- **Ventilation:** no data exist to support the targeting of a specific $PaCO_2$ after resuscitation from cardiac arrest; however, extrapolation of data from other studies suggests ventilation to normocapnia is appropriate.

- **Oxygenation:** Oxygen titration (utilizing PaO_2 or SpO_2) should be balanced against the risk of inadvertent hypoxaemia, so only started after initial stabilization.
- **Seizure control:** Blood glucose and electrolytes should be checked and any abnormalities corrected and the seizures treated. There is no evidence for the prophylactic use of any of these medications.
- **Temperature control:** After ROSC a strict control of temperature to avoid hyperthermia (> 37.5°) and severe hypothermia (< 32°) is mandatory. On the other hand, a resuscitated child with hypothermia and ROSC should not be actively rewarmed unless the core temperature is below 32° C.
- **Blood glucose:** Hypoglycaemia (< 50 (severe) -70 (mild) mg/dl (2.8 – 3.9 mmol/l)) and hyperglycaemia are associated with worse neurological outcome.
- **Analgesia and Sedation:** If patients do not show adequate signs of awakening within the first 10 minutes after ROSC, mechanical ventilation and ongoing analgo-sedation will be required. Some medications induce sleep but do not eliminate pain. It is important also to administer appropriate analgesia. Although some of these drugs are used as continuous infusions in the PICU, outside the PICU bolus administration may be easier. Repeated reassessment is then required to ensure that the effect of any bolus dose has not worn off. Never administer a neuromuscular relaxant without ensuring that the child is deeply sedated and will remain so.

Transportation

After initial resuscitation at the scene (out-of-hospital or in-hospital) the patient must be transported to an **appropriate PICU** (paediatric intensive care unit) for definitive care. The transfer must be carefully organised after communication between all the teams: PICU, Medical Emergency Team or Cardiac Arrest Team and local staff.

Prior to and during the transport, certain considerations should be kept in mind:

- **HELP:** if appropriate, expert help should be sought to further stabilise the child prior to transport.
- **AB:** continuously evaluate oxygenation and ventilation and adjust treatment accordingly. Secure all materials in place. Aspirate secretions before transport and en route; ensure a gastric tube has been placed. Ensure adequate analgo-sedation and consider neuromuscular blockade to reduce risk of accidental extubation. Do not tolerate agitation in an intubated child.
- **C:** continuously evaluate circulation and adjust treatment accordingly. Secure vascular access and take blood samples for analysis, if not already. Consider bladder catheterization to follow urinary output.
- **DE:** stabilise fractures and wounds. Control pain and anxiety. Prevent movement during transport (in-line stabilisation in case of trauma). Neuroprotective care should be instituted as soon as possible. Avoid both hyperthermia and

hypothermia, actively rewarm if core temperature is below 32° C. Inadvertent cooling may occur if environmental temperature is low during transfer. Deliberate mild hypothermia should only be instituted by experienced PICU teams.

- **CONTACT:** contact the receiving team/PICU and inform them about the child's condition, clinical course and treatment. Ensure that the parents are fully informed and that transportation can be arranged for them as well. Prepare full records of the events and interventions. All measures performed during stabilisation and transport should be registered according to the Utstein style for a later evaluation.

  Pre-transport diagnostic work-up in view of aetiology might be needed. The need to do certain tests and imaging should however be balanced against the time 'lost' before actual transport takes place. This is best discussed with the accepting team. Time-critical problems might warrant 'immediate' transfer.

  If the child has a condition requiring urgent e.g. (neuro)surgical intervention the local team may need to transport the child immediately; stabilization may not be possible until surgery is undertaken so time should not be lost attempting stabilization. The most experienced personnel should undertake the transfer and each hospital with an emergency department should have guidelines in anticipation of this scenario.

- **TRANSPORT:** check and secure equipment [resuscitation equipment, monitors, infusion pumps, ventilator, electric outlet, batteries, incubators, ambulance heating system, oxygen supplies] and medications for transport. Choose the optimal vehicle for the transportation, which may depend on the child's age and condition, the distance and time it will take to arrive at the receiving PICU, and the weather conditions. Experienced staff should be selected for the transportation. After resuscitation, the risks of further complications are high, hence the need for competent health care providers. The minimum team is one driver (who is familiar with the journey to the PICU and knows his location), and one doctor and one nurse both of whom are competent and confident in paediatric and/or newborn advanced life support and possess a good working knowledge of their equipment and the facilities within the transport vehicle. Clinical surveillance and monitoring must be continued during transport.

Handover

Good handover does not happen by chance but is a structured timely process demanding skills, technology and leadership. Good handover includes both information exchange and giving further direction. It is essentially a two-way communication where the accepting team actively participates, so to 'understand' the information given and the plan proposed. The use of some basic rules of communication [adequate preparation, closed-loop communication, avoidance of jargon or abbreviations…] and general training in communication can improve this process of handover.

A proposed structure for handover is given with the acronym RSVP [Reason – Story – Vital Signs– Plan]:

Table 8.1

Reason:	you – the patient – your main concern - why you call
Story:	short history of the patient – reason of admission
Vital Signs:	Vital Signs – relevant symptoms or test results
Plan:	what you want from the receiving end and what you suggest (you or they to do in the meantime); including concerns and uncompleted tasks…

Another widely used system for structured handover is SBAR [Situation, Background, Assessment, Recommendation].

An interesting article describing this tool and its value can be found on the CoSy VLE.

The ability to interpret a blood gas can give important information about the patient helping to guide further management in many different situations and settings. Knowing how to interpret a blood gas is not a goal of the EPALS course as such but for your interest, we provide a short and simple guide to basic blood gas analysis as background on the CoSy VLE.

CHAPTER 9
INITIAL MANAGEMENT OF SPECIFIC PAEDIATRIC EMERGENCIES

In childhood, cardiorespiratory arrest is mainly secondary to injury or illness and its outcome is poor; therefore strategies are needed to recognise and manage diseases which may prevent progression to organ failure and cardiorespiratory arrest. Initially, recognition of respiratory or/and circulatory failure are more important than making a precise diagnosis of the disease. However, in certain circumstances, knowledge of specific disease processes may help to appropriately manage the disease and improve the outcome.

We provide in this manual the key knowledge for each of these diseases and refer to the CoSy VLE for more details and background information.

LARYNGOTRACHEITIS (CROUP)

Croup is relatively frequent and defined as an acute clinical syndrome of inspiratory stridor, barking cough, hoarseness, and variable degrees of respiratory distress. Acute viral laryngotracheobronchitis is the most common form of croup.

Airway: the airway is at risk due to the marked swelling of the larynx and trachea which can lead to partial or complete obstruction of the airway if the oedema progresses; upper airway obstruction results in stridor, with stridor at rest indicating more severe compromise. If the child is conscious and breathing let him/her adopt the preferred position, as manipulation or agitation will increase respiratory effort and obstruction. However if the child is decompensating, open the airway, give 100% oxygen and start BMV if required. Advanced airway management is needed only in a few severe cases. It may be a challenge and inexperienced interference may worsen the situation. Help should be called in the form of an experienced team.

Breathing: respiratory rate and work of breathing increase with progressive airway obstruction but may start to fall when the obstruction is more severe and decompensated respiratory insufficiency occurs. Respiratory monitoring should be established and 100 % oxygen given. Nebulised adrenaline can be given to reduce airway oedema for children with severe respiratory distress (0.1-0.5 mg/kg, max. 5mg). Improvement is seen in minutes but wears off after 1-2 hours after which there may be rebound oedema so the patient must be carefully observed for at least 2-4 hours.

Steroids may be used to reduce laryngeal oedema. An oral steroid, dexamethasone, shows clear benefit even in mild cases with improvement in symptoms in 2-3 hours. One to two doses (0.15mg/kg) may be given.

In the differential diagnosis of croup, epiglottitis should be considered in some countries, or in unvaccinated children (Haemophilus Influenza b.)

RESPIRATORY FAILURE IN CASE OF TRACHEOSTOMY

In any child with an artificial airway that develops respiratory distress think DOPES. Difficulty in breathing may be caused by obstruction or displacement of the tracheostomy tube leading to ineffective ventilation. First pass a suction catheter through the tracheostomy tube and suction any secretions that may be present. If a suction catheter cannot be passed or suctioning is unsuccessful, the tracheostomy tube should be removed immediately and replaced. If a clean tube is not available, ventilation should be given at the tracheostomy stoma site until the tube is cleaned and replaced. If the child's upper airway is patent, it may be possible to provide BMV via the mouth and nose using a conventional bag and mask whilst the tracheal stoma site is occluded. In an emergency situation, tracheal intubation via the tracheostomy with a classical endotracheal tube may be needed. Attention should be given to correct positioning (not endobronchial).

BRONCHIOLITIS

Bronchiolitis is a common, potentially serious respiratory infection of infancy caused by certain viruses (of which about 75 % comprise respiratory syncytial virus [RSV]).

In addition, especially in young infants, regardless of the degree of respiratory failure, sudden life-threatening apnea may occur. The threshold for hospital admission of these children should therefore be low.

Airway: the airway is normally open but nasal obstruction from secretions can occur. Gentle suction of the nose to remove secretions and nasal decongestants may be needed if nasal obstruction impairs air entry.

Breathing: respiratory monitoring should be established and supplemental oxygen administered as required. In infants with compensated respiratory failure attention should be paid to avoid distressing the child and oxygen administration should be tailored to this aim. Non- invasive ventilation, usually continuous positive airway pressure (CPAP) delivered via a well- fitted interface (nasal prongs or nasal or facial masks) is the first choice for respiratory failure in infants with bronchiolitis in many centres. 'High-flow nasal cannula' oxygen might be an alternative.

Circulation: the circulation is often normal up to the end-stage of respiratory failure, but dehydration can be seen if an infant was unable to drink during the past days.

Disability: Tiredness, irritability and agitation reflect increasing respiratory decompensation.

Decreasing responsiveness is an ominous sign of impending respiratory or cardiorespiratory arrest.

ANAPHYLAXIS

Anaphylaxis is a severe, life threatening, generalized or systemic hypersensitivity reaction. Early diagnosis of anaphylaxis is crucial and will guide further treatment. It can be defined as:

- Acute onset of an illness (minutes to hours) with involvement of the skin, mucosal tissue, or both and at least one of the following findings, which may have a life-threatening character:
    - Compromised airway (risk of obstruction by swelling of the lips or tongue; or of the oral, pharyngeal or laryngeal mucosae). Stridor and/or hoarseness may be present.
    - Respiratory compromise e.g. dyspnoea, wheeze-bronchospasm, stridor, reduced PEF, hypoxemia
    - Reduced blood pressure or associated symptoms of end-organ dysfunction e.g. collapse, syncope
    - 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 (10-20 % of patients have no skin manifestations).

Remove the allergen immediately. In case of a bee sting, remove the sting as soon as possible.

The mainstay for treatment is adrenaline IM (in the anterolateral mid-thigh, NOT subcutaneous). This should be given immediately to all patients who have any respiratory or circulatory symptoms. IM adrenaline can be repeated if symptoms do not improve after 5-10 minutes.

Table 9.1

Dosage of adrenaline (pure 1:1000 solution = 1mg/ml) Intramuscular 10 mcg/kg or
Up to 6 years: 150 mcg IM (0.15 ml)
> 6 - 12 years: 300 mcg IM (0.3 ml)
> 12 years and adults: 500 mcg IM (0.5 ml)

In certain settings you might only have access to auto-injectable adrenaline. Knowing how to use this device is crucial both for the patient at risk as for healthcare providers.

A link to an educational video can be found in the CoSy VLE.

Airway: establish respiratory monitoring and give 100 % oxygen. If the child is still conscious and breathing let him/her adopt their preferred position, as manipulation or agitation will increase respiratory effort and airway obstruction. Advanced airway management may be necessary, anticipate for a difficult procedure.

Breathing: there may be shortness of breath, wheeze and hypoxia. Respiratory failure may be due to bronchospasm. Rarely respiratory support with BMV in preparation for an advanced airway will be required (a two person-technique will then be needed).

Circulation: Vasodilation is often profound and gives rise to early hypotension. The skin may be flushed and the capillary refill < 1". There is a relative hypovolaemia and increased capillary permeability with extravasation of intravascular fluids. Flushing, pallor, sweating, erythema, urticaria or angioedema may all occur. Gastrointestinal symptoms of vomiting, abdominal pain and diarrhoea can be present. The mainstay for treatment, as described, is adrenaline IM and this should be repeated if shock does not improve after about 5 minutes. The relative hypovolemia must be treated with 10-20 ml/kg crystalloid bolus(es) with re-assessment after each bolus. IV adrenaline might be considered by advanced resuscitation teams if shock persists. Infrequently, continuous vasoactive medication might be needed to sustain adequate blood pressure.

ASTHMA

Expiratory wheezing is found as a sign of airway obstruction. There is no correlation between the severity of wheezing and the degree of obstruction. There are other causes of wheezing that present alternative diagnoses which should be excluded: e.g. anaphylaxis, foreign body aspiration, subglottic mass, pneumonia, bronchiolitis, etc. The absence of wheezing may indicate a critical obstruction, whereas increased wheezing may indicate a positive response to bronchodilation.

Airway: the airway is normally open but can become obstructed when consciousness decreases. Allow the conscious child to adopt their own position.

Breathing: respiratory monitoring should be established and supplemental oxygen administered, titrating for SpO_2 94-98% (awaiting SpO_2 measurement, 100% FiO_2 can be given). As long as there is compensated respiratory failure, avoid distressing the child. However, be aware that agitation can also be a sign of ongoing hypoxia. The severity of the asthma attack can be evaluated by monitoring oxygen saturations, the child's clinical status (respiratory rate, ability to speak, level of responsiveness) and response to treatment. Clinical signs of decompensation or exhaustion may

indicate the necessity of an arterial blood gas; raised $PaCO_2$ levels signpost respiratory decompensation (>48 mmHg (6.5kPa) indicates life threatening asthma).

In cases of decompensated respiratory failure it might become necessary to support ventilation. BMV will be difficult because of increased airway resistance with added risk of gastric inflation. Intubation of an asthmatic is a risky procedure and can precipitate worsening of the bronchospasm so should be performed by an expert team. Indications for intubation include: cardiac or respiratory arrest, severe or progressive hypoxia and rapid deterioration in conscious level. Acidosis and hypercapnia may indicate impending exhaustion but should alone not prompt intubation. Mechanical ventilation of a child with status asthmaticus is extremely challenging, expert help should be sought early on. Attempts should be made to avoid hyperinflation by limiting tidal volume (sufficient for chest rise) and respiratory rate (allowing for increased expiratory time).

Non-Invasive Ventilation delivers both oxygenation and positive airway pressure/ PEEP, and its use might prevent further decompensation, provided the child still has sufficient respiratory drive.

Circulation: This might be normal, but equally dehydration or obstructive shock (caused by pneumothorax or dynamic hyperinflation) can occur. If dehydration is suspected, a fluid bolus should be given, as hypovolaemia will further compromise circulation in patients with dynamic hyperinflation.

! In case of cardiac arrest, early consideration of the 4H/4T's is mandatory.

Disease-specific treatments should be timely, aggressive and protocolised:

- **Nebulised/Inhaled beta-2 agonists:** are first line agents for an acute asthma attack and should be administered as early as possible. Doses can be repeated at regular intervals. Severe attacks may even necessitate continuous nebulised short-acting beta-2 agonists (SABA e.g. salbutamol) in the first hour. Salbutamol can be given by a metered dose inhaler with a large volume spacer (and face mask) (2-10 puffs) or by nebuliser (2.5 – 5 mg or 0.15 mg/kg) with high flow oxygen. In near-fatal asthma hypoventilation may prevent effective delivery of nebulized drugs.
- **Steroids:** asthma is an inflammatory disorder and steroids are mandatory for treatment. Give steroids early, either oral or intravenous, as they take a few hours to take effect. Use the steroid you're most familiar with (e.g. prednisolone 1-2 mg/kg with a maximum of 60 mg/day).
- **Nebulised anticholinergics:** provide additional bronchodilatation and may be added to nebulised beta agonists for moderate and severe cases.

- **Magnesium:** a single dose of intravenous magnesium sulphate can be given in acute severe asthma not responding to inhaled bronchodilator therapy. Give as a slow IV bolus (50 mg/kg) over 20 minutes to diminish the risk of hypotension, or as a nebulised solution (150 mg).

Antibiotics are not recommended unless there is evidence of bacterial infection.

Intramuscular [IM] adrenaline should be considered in patients with acute severe symptoms and no pre-existing disease. In these patients it might be difficult to distinguish from anaphylaxis and the use of IM adrenaline, as per anaphylaxis guideline, is then considered appropriate.

DEHYDRATION - HYPOVOLEMIC SHOCK

Dehydration arises from increased fluid loss and/or decreased intake, which cannot be compensated by the kidneys. Hypovolaemic shock occurs when central circulatory homeostatic mechanisms can no longer compensate for the relative lack of circulating volume and hypotension ensues. Major causes of dehydration and hypovolemic shock in children are burns, trauma, gastrointestinal disorders, and diabetic ketoacidosis. Signs of dehydration often, but not always, precede those of shock.

Airway: the airway is most often patent and safe as long as consciousness is not compromised.

Breathing: many present with tachypnoea to compensate for reduction in circulating volume (and hence oxygen delivery) to the tissues and/or in response to the accompanying metabolic acidosis. In children with clear signs of circulatory failure, even if still compensated, support should initially be given with oxygen 100% (and then tailored in view of SpO_2). Ventilatory support by BMV or mechanical ventilation might become necessary if the level of consciousness deteriorates or pulmonary oedema develops.

Circulation: capillary refill time, pulse volume, heart rate, blood pressure, urine output and level of consciousness should be assessed to determine degree of circulatory failure/shock and to guide management. Vascular access should be sited, bloods taken and the need for volume expansion in any sick child should be balanced with the degree of presumed hypoperfusion; the immediate aim is to treat hypotension with fluid bolus therapy and then more slowly correct any remaining fluid deficits. Moderate to severe dehydration will require accurate replacement of the estimated fluid deficit (and ongoing loss) with monitoring of plasma electrolyte and glucose levels. The rate of fluid replacement will depend on the degree of electrolyte disorders and the time elapsed from the onset of dehydration (the more chronic the dehydration, the slower the correction).

In children with clear signs of hypovolemic shock several fluid boluses (rapid boluses of 10 ml/kg ; up to 40-60 ml/kg) may be required during the first hour of resuscitation;

the child should be reassessed after each bolus to avoid fluid overload. Use balanced crystalloids plasmalyte or e.g. Ringer's Lactate as a first choice; 0.9% saline is an acceptable alternative. In resource poor settings a more gradual fluid resuscitation (up to e.g. 100 ml/kg over 8 h) can be done.

The need for greater volume replacement indicates fluid-refractory shock and a source of on going bleeding or fluid loss should be sought and treated immediately (and sepsis considered as an alternative diagnosis). In cases of haemorrhagic shock crystalloid boluses should be kept to a minimum; blood products should be used as soon as practically feasible. Surgical assistance is required to locate and manage ongoing blood loss.

Consider 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 traumatic brain injury. 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.

SEPTIC SHOCK

Sepsis is a major cause of morbidity and mortality in children. It is the result of a whole-body inflammatory response to an infection. Early recognition and intervention is crucial. *Shock in sepsis can be distributive and cardiogenic in nature. It can be accompanied by both vasoconstriction (as a compensatory mechanism) or vasodilation (vasoplegic syndrome) and by increased or decreased cardiac output.*

Airway: the airway is most often patent and safe as long as consciousness is not compromised.

Breathing: many of these children will present with tachypnoea to compensate for suboptimal circulation and/or metabolic acidosis. In children with clear signs of shock, even if still compensated, support should initially be given with oxygen 100 % (and then tailored to SpO_2). Ventilatory support might become necessary once consciousness drops or pulmonary oedema develops.

Circulation: the assessment of signs of shock, both clinically (including urinary output), biochemically (including blood gas, lactate and coagulation) and by cardiovascular monitoring are essential to guide further management. Urgent vascular access is mandatory if shock is established. In children with clear signs of shock, even if still compensated, several fluid boluses (up to 60-100 ml/kg) may be required during the first hour of resuscitation. Reassess after each bolus and avoid repeated boluses in children who no longer have signs of poor perfusion or those who show signs of fluid overload (bilateral basal lung crackles, hepatomegaly, jugular distention).

Initial fluid boluses are given as balanced crystalloids (or normal saline if these are not available); boluses of human Albumin solution 4-5% are an alternative. Care should

be taken to include sufficient blood products when infusing larger volumes of fluid – exceeding the child's own circulating volume (80 ml/kg). Sepsis already induces coagulopathy, anaemia and thrombocytopenia and this might be exacerbated by dilution.

- Early tracheal intubation and mechanical ventilation should be considered in children who need more than 40-60 mL/kg fluid boluses. Experienced help should be sought early.
- In severe septic shock cardiac failure may be present early on, because of a direct cardiotoxic effect. Early addition of inotropic and/or vasopressor medication is often required to obtain sufficient organ perfusion. International guidelines suggest doing this in all children with septic shock who need more than 40 ml/kg fluid bolus.
- In children with febrile illness but not showing signs of circulatory failure, a more cautious approach to fluid therapy should be used, with frequent reassessment of the child.

Disease-specific treatment: blood cultures should be taken as soon as feasible and broad- spectrum antimicrobial therapy should be given within the first hour (e.g. ceftriaxone).

CARDIOGENIC SHOCK

Cardiogenic shock arises from pump failure of the heart. It can be acute (e.g. myocarditis) but is equally often the end result of a chronic cardiac problem, including congenital heart diseases and cardiomyopathies. Typically, parents consult with indirect alarm signs such as feeding problems, failure to thrive, lethargy, sweating, poor weight gain… The most common paediatric presentation is a 6 week old infant with a VSD (ventriculoseptal defect) in heart failure.

Detailed 'C' evaluation shows alarming signs of shock. The presence of basal lung crepitations, dilated jugular veins (seen in older children) and increasing liver edge are signs of impending heart failure; chest radiography shows a distended cardiac shadow, occasionally prominent vascular markings often with pulmonary oedema (in the case of fixed pulmonary hypertension lungs can be translucent). ECG monitoring can show mild to severe sinus tachycardia, low voltage in cases of pericardial effusion and any kind of arrhythmia. Urgent echocardiography is required.

Airway: the airway is most often patent and safe as long as consciousness is not compromised.

Breathing: many of these children will have a degree of pulmonary oedema with tachypnoea and fine crepitations heard over the lungs. In general, support should initially be given with oxygen 100 %. Ventilatory support might become necessary once the conscious level drops and/or pulmonary oedema worsens. Non-invasive

ventilation can be useful in infants but early tracheal intubation and mechanical ventilation should be considered, if expert help is available, as this decreases oxygen consumption and directly supports the failing heart.

Circulation: the assessment of signs of shock, both clinically (including urinary output), biochemically (including blood gas, lactate and coagulation) and by cardiovascular monitoring are essential to guide further management. Urgent vascular access is mandatory if shock is established. In general one initial bolus of fluid (5-10 ml/kg) might be beneficial but if this results in increasing tachycardia, liver edge and crepitations then diuretics may be indicated. The response to a fluid bolus should be carefully monitored (clinical assessment of preload, lung auscultation, ultrasound).

In the absence of arrhythmia, with increasing signs of heart failure consider a continuous infusion of intravenous inotropes early (e.g. dobutamine). It is also vital to seek the early attention of a paediatric cardiologist and referral to a PICU is mandatory.

ARRHYTHMIA

Life-threatening cardiac rhythm disturbances in children are more frequently the result, rather than the cause of acute illness. Respiratory and/or circulatory failure leading to hypoxia, acidosis and/or hypotension are the most common causes of rhythm disturbances, rather than primary heart disease as in adults.

Children with cardiomyopathy, myocarditis, or following heart surgery for a congenital heart defect or children born in families where congenital arrhythmias are present, are at increased risk for sudden arrhythmias. Electrolyte disturbances or drugs, used in therapeutic or toxic amounts, may also cause arrhythmias.

Evaluation

The electrocardiogram (ECG) expresses the progress of the electric impulse through the heart. It does not represent the effectiveness of myocardial contraction, tissue perfusion or the child's general clinical state. Therefore therapeutic decisions must only be made after careful clinical assessment of the child's circulation.

The interpretation of a normal ECG is described on the CoSy VLE.

Always treat the patient, not the monitor! During evaluation of the ECG it is important to recognise possible artefacts. Detachment of the electrodes can simulate asystole and vibrations transmitted to the leads (e.g. during transportation) may mimic ventricular fibrillation. Chest compressions may generate ECG tracings that resemble ventricular complexes. The numerical heart rate displayed on the monitor may be misleading. It is good to record the pulse manually or by auscultation of the heart if in doubt.

Without needing to become an ECG expert, every ALS provider should be able to distinguish all major arrhythmias in view of the different related treatment options. The following questions are helpful:

Table 9.2

1. Are there still signs of life?
If not, this should be considered an arrest rhythm and CPR should be initiated.
2. Are there signs of progressive or decompensated cardiogenic shock?
The more severe the shock, the more time-critical the intervention. Arrhythmias without any signs of circulatory failure can often wait for a paediatric cardiologist to evaluate and guide treatment.
3. Is the heart rate fast (>140-180/min in view of age) or slow (< 60/min; < 80/min in infants)?
4. Are the QRS complexes narrow (< 0.08 sec) or wide (> 0.08 sec)?
If QRS complexes are narrow, tachycardia is of supraventricular origin. If QRS complexes are wide, although it is still likely in children that the origin is supraventricular, the arrhythmia is considered ventricular until proven otherwise. In abnormal rhythms, the ECG may be helpful in discriminating between narrow and wide complex tachycardia but clinical evidence of poor perfusion will indicate the urgency of treatment for both these types of tachycardia.
5. Regular or Irregular?
Irregular rhythms can be caused by atrial fibrillation, extra beats with compensatory pause, heart block etc. If seen in children, this is often related to a history of cardiac surgery or specific medications intoxications.

Bradycardia

Symptomatic bradycardia in children is often caused by respiratory or circulatory failure and may be a sign of imminent cardiac arrest. Hypoxia, acidosis, hypotension, hypothermia and hypoglycaemia all depress normal cardiac activity and slow conduction through cardiac tissues. *All slow rhythms that cause haemodynamic*

instability should be treated immediately, even when the blood pressure is still normal, because they may progress to cardiopulmonary arrest. Initial treatment should, as always, start with securing the airway and ensuring optimal oxygenation with 100 % oxygen and BMV if required.

If the presenting bradycardia is presumed to be secondary to hypoxia and/or ischemia and the heart rate does not improve above 60/min or is rapidly dropping with impaired or absent circulation, the situation should be considered impending arrest and chest compression and adrenaline should be started. This is particularly important in infants in whom cardiac output is more dependent on the heart rate than on stroke volume.

Figure 9.1 Bradycardia

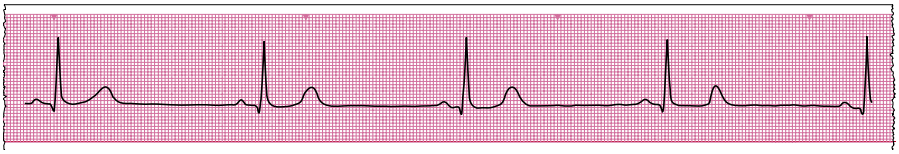
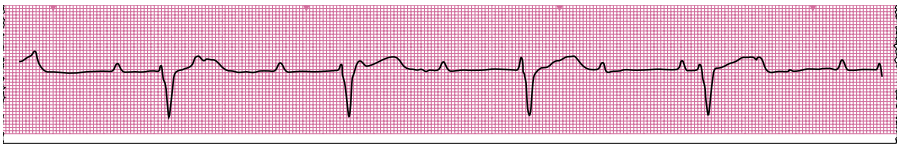


Figure 9.2 3th degree AV block



Occasionally excessive vagal stimulation (e.g. induced by suctioning or during tracheal intubation) or central nervous system insults may produce bradycardia. When vagal tone is the suspected cause of bradycardia or in primary AV conduction block, atropine (20mcg/kg, max 0.5mg/dose) is indicated. Adrenaline should be given if immediate improvement does not occur after atropine.

Occasionally, bradycardia can be caused by complete heart block or sick sinus syndrome unresponsive to oxygenation, ventilation, chest compressions and other medications, and emergency pacing (external or intravenous) may be lifesaving. Early expert help is mandatory.

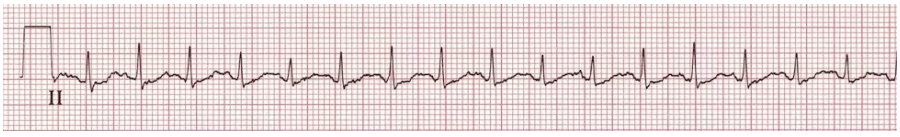
! **Pacing is not helpful in children with bradycardia secondary to hypoxic/ischaemic myocardial insult or respiratory failure and it has been shown to be ineffective in the treatment of asystole.**

Sinus tachycardia

In children with a fast rhythm it is important to first establish whether it is a sinus or abnormal rhythm.

Sinus tachycardia [ST] is the most common tachycardia in children. It represents the body's physiological response to a pathological situation, such as respiratory failure, hypovolaemia, sepsis or anaemia.

Figure 9.3 Sinus tachycardia



Only measures to treat the underlying condition should be instituted. Other measures (e.g. anti- arrhythmic drugs) that slow the rhythm are dangerous.

Supraventricular tachycardia

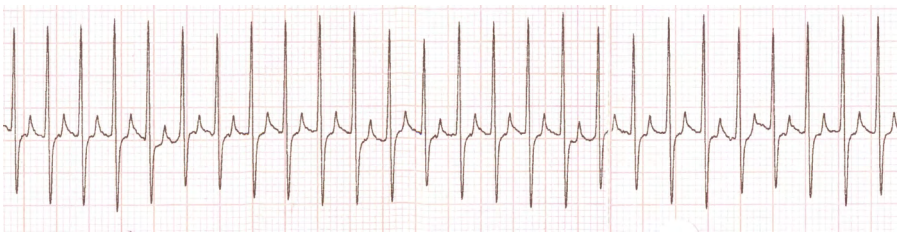
Supraventricular tachycardia **[SVT]** is the most frequent primary cardiac arrhythmia in children. It is a *paroxysmal, regular rhythm with narrow QRS complexes* (usually caused by a re-entry mechanism through an accessory pathway or through the atrioventricular conduction system). The raised heart rate causes irritability, crying, fatigue, loss of appetite, pallor, sweating and in older children palpitations, chest pain, near-fainting and anxiety. It can lead to cardiovascular collapse and shock, especially in infants.

Airway and Breathing should be assessed and maintained; high flow oxygen should be provided and BMV as required. 100 % FiO_2 is given when signs of shock are recognised.

- For children and infants in compensated circulatory failure, vagal manoeuvres may be tried to slow atrioventricular conduction and allow a return to sinus rhythm. This can be achieved in young infants by placing an ice bag transiently over the face. In older children, unilateral carotid sinus massage or Valsalva manoeuvres (e.g. blowing through the outlet of a syringe to expel the plunger) may be used. Eyeball pressure should not be used as this can result in retinal damage. Vagal manoeuvres should never delay definitive treatment, especially if signs of shock are apparent.
- **Adenosine** can be tried first, in children and infants who are not yet decompensated, as long as there is an appropriate intravenous access and sufficient blood circulation. Give a rapid bolus of 0.1-0.2 mg/kg (max 6 mg) followed by an immediate saline flush via a large vein (as close to the heart as

possible); ensure a rhythm strip is running during administration for later expert evaluation. Especially in younger children, higher initial doses seem more effective. In case of persistent SVT, repeat adenosine after at least 1 minute at a higher dose (0.3 mg/kg, max 12-18 mg).

Figure 9.4 Supraventricular tachycardia



In children with decompensated circulatory failure due to supraventricular (SVT), the first choice for treatment is immediate electrical cardioversion (synchronised with the R wave) 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.

The sequence of actions for **cardioversion** is very similar to the one for defibrillation *(see lesson about ALS in detail)*. However the defibrillator must actively be placed into the synchronised mode. Some defibrillators will need to have ECG electrodes connected to detect the R waves. After selecting the correct energy level and charging, it will be necessary to keep the discharge button pressed until the R wave is identified by the device and the shock delivered. This might take several seconds. *An evaluation of signs of life (or a pulse check) should be performed after every cardioversion attempt (to avoid missing a subsequent PEA or pVT).*

Differentiating ST from SVT may be difficult. A history consistent with hypovolaemia, infection, etc. is usually present with ST, whereas the history is often vague in SVT. P waves are absent or abnormal in SVT, however, they may be difficult to identify in both SVT and ST once the rate exceeds 200/min. SVT generally is faster (> 220/min in infants, > 180/min in children > 1y). There is no beat-to-beat variability in SVT (R-R interval stable). The onset and termination of SVT is abrupt.

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Table 9.3 Differentiating ST from SVT

	Sinus Tachycardia (ST)	Supraventricular Tachycardia (SVT)
History	Clues e.g. fever, fluid or blood loss	Non-specific No clear aetiology
Heart Rate (beats/min)	< 220/min Infant < 180/min Child	> 220/min Infant > 180/min Child
P Wave	present/normal – not clearly seen at HR > 200	P wave absent/abnormal
Beat-to-beat variability (R-R)	Yes Responds to stimulation	No
Onset and end	Gradual	Abrupt

Ventricular tachycardia

In children, wide QRS tachycardia is uncommon and more likely to be supraventricular than ventricular in origin. However, *until proven otherwise, wide QRS complex tachycardia should be considered to be ventricular tachycardia [VT] in haemodynamically unstable children.*

VT is a potentially perfusing rhythm meaning that *it can also be associated with an absence of circulation, becoming then a cardiac arrest 'shockable rhythm' (pulseless VT).*

- Airway and Breathing should be assessed and maintained. High flow oxygen and BMV should be provided as required. 100 % FiO_2 is given if signs of shock are recognised.
- If the patient has a pulse and clinical signs of shock then **cardioversion** is the treatment of choice with the same energy as in SVT: 1 J/kg as first dose and the second, if required, 2 J/kg (up to a max. of 4J/kg for subsequent doses). Analgesia and sedation will be required if the child is still conscious.
- If the second cardioversion is unsuccessful or if VT recurs, amiodarone or lidocaine should be considered after consultation with of a paediatric cardiologist.
- As for defibrillation, cardioversion is more likely to be successful if hypoxia, acidosis, hypothermia, and hypoglycemia have been corrected (check 4 H's and 4 T's).

Polymorphic VT (Torsade de pointes) *(figure 8.8)* is a very rare wide QRS polymorphic ventricular tachycardia in children, which typically deteriorates rapidly to VF or pulseless VT. It has a specific treatment: Magnesium sulphate 50 mg/kg IV/IO, over 10 to 20 minutes (maximum dose 2 g).

Figure 9.5 Ventricular Tachycardia

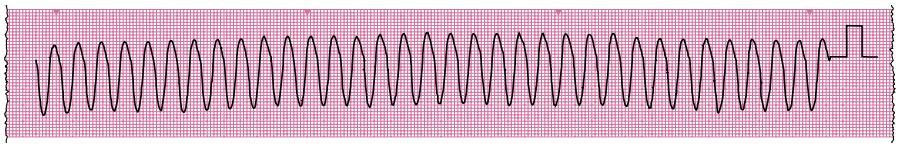
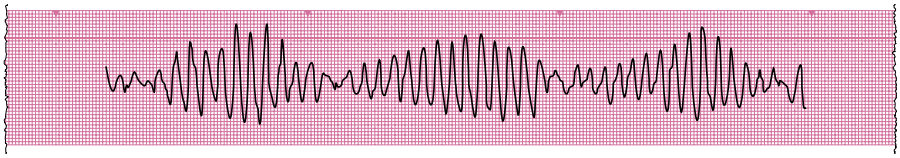


Figure 9.6 Polymorphic VT (Torsade de pointes)



COMA

Conscious level may be altered by disease, injury, or intoxication. Coma or unconsciousness is defined as only responding to pain (P) or less in the AVPU scale, a Glasgow Coma Motor Score of 4 or below, or a total Glasgow coma score of 8 or below.

- **Airway and Breathing:** respiratory monitoring should be established and 100 % oxygen given (titrated).The airway must be considered to be at risk of obstruction when any alteration of consciousness occurs. As coma deepens, the airway is likely to obstruct. When the child becomes deeply unresponsive, or there is no protective cough or gag reflex, aspiration may occur. In addition, coma may lead to a slow respiratory rate and/or inadequate respiratory effort. This is even more likely if the child is receiving drugs with respiratory depressant side effects (e.g. benzodiazepines).

  The airway should be opened and patency maintained by appropriated means. If breathing is inadequate and hypoxia is present after airway opening, BMV with oxygen should be performed. If protection against aspiration is required, intubation must be performed avoiding increases in intracranial pressure.

- **Circulation:** the aetiology of the coma may affect the circulation and shock (e.g. hypovolemic shock, septic shock, trauma…), if present, should be managed appropriately.

- **Disability:** the level of consciousness should be assessed. Signs of raised intracranial pressure should be identified [posturing, falling GCS, rising BP with bradycardia, pupil abnormalities] and if present senior help informed (consultant neurosurgeon, paediatric intensivist). Seizures (also subclinical) should be identified and controlled.

Disease-specific treatment: during management of a comatose child, hypoglycemia and electrolyte disturbances should be ruled out and treated with minimal delay. Early neuroprotective care to limit further brain injury is crucial *(see also the lesson on trauma or post-resuscitation care)*.

- A constellation of febrile illness with altered behaviour or consciousness, or new onset seizures or new focal neurological signs should raise the possibility of (meningo-)encephalitis and should trigger appropriate investigations and rapid 'empiric' treatment (e.g. acyclovir). Encephalitis can be challenging to identify in very young infants as features are often non-specific such as lethargy, excessive irritability, and poor feeding.
- *Lumbar puncture is only recommended after initial stabilisation and as far as there are no contraindications such as impaired consciousness, focal neurological signs, signs of intracranial hypertension, signs of shock or coagulation abnormalities. It should never delay necessary treatments.*
- Common presenting features of stroke in children include hemiparesis, (sudden) headache, altered mental state, speech disturbance, and seizures. Seizures, altered mental state and non-focal signs are more likely in infants. Children presenting with sudden onset of unexplained neurological symptoms, particularly those that persist after resuscitation should be considered for urgent neuroimaging.

HYPOGLYCAEMIA

Hypoglycaemia is defined as a plasma glucose level < 50 (severe) -70 (mild) mg/dl (2.8 – 3.9 mmol/l). Signs of hypoglycemia include irritability, lethargy, tachypnea, tachycardia, sweating, weakness, tremor, confusion, seizures and coma. Hypoglycemia must be identified and treated early to avoid irreversible brain damage.

- Children with mild hypoglycemia may be treated with standard glucose administration, either by maintenance glucose infusion (6-8 mg/kg/min) or by oral rapid acting glucose (0.3 g/kg tablets or equivalent), followed by additional carbohydrate intake.
- Children with severe hypoglycemia with altered level of consciousness should be treated immediately with **IV dextrose 10 % solution 3 ml/kg (0.3 g/kg)** in bolus. Plasma glucose level should be monitored after 5- 10 minutes and treatment repeated if the reponse is inadequate.

In the absence of IV glucose, a child with a low blood glucose and reduced level of consciousness can also be treated temporarily with glucagon (either IM or SC 1 mg > 25 kg and 0.5 mg < 25 kg, or 0.03 mg/kg) or intranasally (3 mg; 4-16y).

A subsequent glucose maintenance infusion (6-8 mg/kg/min) should be started to reverse catabolism and maintain adequate glycemia.

INTOXICATION

The general approach to a child with presumed intoxication is an ABCDE approach. The personal safety of the rescuer should always be considered. Airway obstruction and respiratory failure due to decreased consciousness is the most likely cause of morbidity and mortality. Vomiting can lead to aspiration. If the child is unconsciousness (but breathing normally), he or she can be put into a (left lateral) recovery position with close monitoring of airway and breathing (every minute). Related hypotension usually responds to fluid boluses, although sometimes there is a need for vasoactive drugs. Temperature, ECG, electrolytes, blood glucose and blood gases should be monitored and abnormal values treated.

! **In the case of cardiac arrest, prolonged resuscitation and extracorporeal life support should be considered.**

SEIZURES

Seizures are the most common paediatric emergency. The neurological status should be assessed and treated only after airway, breathing, and circulation have been assessed and managed, as these are the initial priority in seizures. However in many cases ABC's may only improve once the seizures have been treated.

Most seizures are brief and terminate without intervention. Those lasting more than 5' are unlikely to terminate without active management. **Convulsive status epilepticus** is defined as a convulsive seizure that continues for a prolonged period of time (longer than 5'), or convulsive seizures that occur one after the other with no recovery in between. Refractory CSE is present if second line agents fail to stop seizures or, if the child has been seizing for longer than 30'.

Non-convulsive status epilepticus is defined as a change in mental status or behavior from baseline, associated with continuous activity on EEG, which is also seen to be a change from baseline. Non-convulsive status epilepticus can follow convulsive status epilepticus.

Prolonged seizures may cause serious complications including permanent neuronal injury, apnoea, hyperkalaemia, cerebral oedema, rhabdomyolysis.

- **Airway and Breathing:** respiratory failure is due to airway obstruction (caused by tongue hypotonia or secretions) or decreased level of consciousness slowing the respiratory rate. Respiratory arrest can occur due to central nervous system depression; this is more likely if the child is receiving e.g. benzodiazepine for the emergency treatment of a seizure. Open airway and maintain patency by appropriated means. Respiratory monitoring should be established and oxygen given (titrated). If the child remains hypoxic, BMV with oxygen should be performed. Tracheal intubation and ventilation may sometimes be necessary to protect the airway and to prevent aspiration of the stomach contents.

- **Circulation:** this is generally normal up to the end-stage of respiratory failure. However if the aetiology of the seizures is associated with other diseases, such as meningococcal septicaemia, circulatory failure may present earlier.
- **Disability/Disease-specific treatment:** seizures should be controlled by anti-epileptic drugs according to local or national protocols. Underlying mechanisms and diagnoses, as mentioned above, should be identified and treated. Always ask what medications the child is on regularly and what medications have been administered so far (e.g., rectal diazepam). Vascular access should be obtained early to assist further treatment and to check blood glucose and electrolytes (and eventually other tests).

  If convulsions persist for more than 5 minutes, the first-line therapy is a benzodiazepine (e.g. midazolam, lorazepam). Which benzodiazepine via which route to give depends on availability, context, social preference and expertise of the providers. Dose suggestions are given in the **CoSy VLE**.

  If convulsions persist another 5 minutes, administer a second dose of benzodiazepines and prepare for a long-acting second-line agent. Seek expert advice.

DIABETIC KETOACIDOSIS

The clinical history of diabetic ketoacidosis (DKA) may include polyuria, increased thirst, weight loss, abdominal pain (mimicking appendicitis) and confusion. The patient may already have had symptoms for several weeks. Clinical features at presentation therefore often include dehydration, abnormal deep sighing respirations (secondary to metabolic acidosis), vomiting and decreased consciousness. *Fever is not a feature of DKA* and might point to a concomitant infection.

DKA can cause cerebral oedema in some children and this is still a risk of significant morbidity in these children. Other causes of morbidity in DKA include aspiration pneumonia and hypokalaemia. It is imperative to get senior help early.

- **Airway and Breathing:** Ensure the airway is patent and if the child has a reduced level of consciousness they may require an airway adjunct. The child may also require a nasogastric tube if vomiting; this should be aspirated and left on free drainage. Titrated oxygen should be given in view of the SpO_2. Patients are often severely tachypnoeic to try and compensate for the metabolic acidosis.
- **Circulation:** the patient should be assessed for signs of circulatory failure and a cardiac monitor attached. Vascular access should be obtained and blood gases, blood sugar, blood ketone levels, urea and electrolytes (serum potassium and sodium levels very important) all checked (if blood ketones not available check urine). Shock is not frequent in DKA but if present requires adequate fluid volume resuscitation. Senior assistance should be requested and a paediatric intensivist informed if shock is present. The use of IV bicarbonate should be avoided (except

when hyperkalaemia or severe acidosis with impaired myocardial contractility are present and after senior advice) as its use is associated with an increased risk of cerebral oedema.

- **Disability:** the level of consciousness must be assessed and reassessed frequently searching for signs of raised intracranial pressure [posturing, falling GCS, rising BP with bradycardia, pupil abnormalities] and if these signs become apparent senior help should be summoned immediately.
- **Disease-specific treatment:** the aim is to correct dehydration, as per local protocol. As there is potassium depletion early IV potassium, even with normal serum values, is mandatory. Insulin infusion should commence after the initial fluid bolus(es) have been given.

HYPERKALAEMIA

Hyperkalaemia should be considered as a continuum with worsening signs and symptoms as levels increase. Severe hyperkalaemia (in general $K^+ > 6.5$ mmol/l) is characterised by muscular weakness, paralytic ileus, respiratory arrest, and heart conduction disturbances leading to arrhythmias and eventually to cardiac arrest.

The treatment of hyperkalaemia is dependent on the speed of occurrence of the symptoms and the clinical state of the child. If the child is in cardiorespiratory arrest or shows toxic ECG changes, treatment includes stabilisation of the cardiac membrane and shift of potassium into cells by means of:

1. An intravenous bolus of calcium gluconate 10 % (0.5 ml/kg max 20ml; over 2-5 minutes if the child is not in arrest). The calcium antagonizes the toxic effects of hyperkalaemia, stabilising the myocardial cell membrane. The effect of calcium gluconate is rapid in onset but short-lived (30- 60') and administration can be repeated.
2. An insulin – glucose IV bolus: initially as a bolus (for instance 2 ml/kg glucose 20 % solution, with 3U fast-acting insulin per 50 ml glucose 20% or equivalent), followed by an infusion of IV glucose (to avoid hypoglycemia afterwards - not needed if the initial glycaemia is > 250 mg/dl), with careful monitoring of the blood glucose. The 'insulin – glucose' bolus can be repeated if hyperkalaemia persists. The effect occurs already after 15'.
3. Salbutamol administration via nebulizer at high dose (e.g. 5 times the bronchodilation dose). Effective at 20-30', although this can vary between patients.
4. Intravenous Sodium Bicarbonate (1mEq/kg), if there is acidosis or renal failure, or for a child in cardiac arrest due to hyperkalaemia.
5. Haemodialysis/haemofiltration for severe life-threatening high levels of potassium

HYPOKALAEMIA

Hypokalaemia (K^+ < 3.5 mmol/l) is characterized by muscular weakness, constipation, paresthesias, and tetany. ECG can show T-wave changes. Severe hypokalaemia (< 2.5 mmol/l) can cause cardiorespiratory arrest, life-threatening arrhythmias, paralysis, rhabdomyolysis, paralytic ileus, and metabolic alkalosis. Hypokalaemia is more dangerous in children with pre-existing heart disease.

Treatment of severe hypokalaemia (< 2.5 mmol/l) or hypokalaemia associated with arrhythmias consists of a careful infusion of potassium under ECG monitoring (in an intensive care environment). An infusion of 0.5-1 mmol/kg/hour of potassium chloride is given until any hypokalaemic cardiac arrhythmia resolves and/or the potassium level is > 3.5 mmol/l. For severe hypokalaemia in a pre-arrest state, give IV boluses of 1 mmol/kg (max 30 mmol) over at least 20 minutes to a monitored child and repeat until the serum potassium is above 2.5 mmol/L avoiding inadvertent hyperkalaemia. Also give IV magnesium 30- 50 mg/kg.

HYPO- AND HYPERCALCAEMIA

The treatment of severe hypocalcaemia includes intravenous or intraosseous administration of calcium chloride 10 % (0.2 ml/kg, max 10ml). If hypocalcaemia is associated with hypomagnesaemia, magnesium replacement will also be necessary.

Treatment of hypercalcaemia is mandatory when symptoms appear. Initial treatment consists of fluid resuscitation with normal saline (e.g. twice the calculated basic requirement). Levels of both serum potassium and magnesium must be monitored. Furosemide can be useful in patients with fluid overload; however in children with renal insufficiency and oliguria, dialysis is necessary.

HYPERTHERMIA

HEAT STROKE is defined by a central body temperature of >40-40.5 °C associated with central nervous system dysfunction, and is potentially life-threatening.

Early recognition is crucial and correct measurement of core temperature mandatory (rectal, oesophageal, bladder, intravascular). Apart from standard ABCDE actions, removal from the heat source and active cooling are crucial steps. This can be achieved by undressing, fanning with cold air and mist, or application of ice packs (neck, armpit and groin or alternatively on the skin surfaces of cheeks, soles and palms). Cautious cold-water immersion can be considered for adolescents and young adults. Cooling blankets can be used. IV crystalloids at room temperature can be administered. Cooling efforts can be stopped once the core temperature has dropped below 38°C. Benzodiazepines are suggested to avoid shivering or seizures during the cooling process, antipyretic treatment is ineffective. As heat stroke can be accompanied by organ dysfunction, victims need to be admitted to a pediatric intensive care unit.

Heat stroke should not be confounded with fever, which is generally a benign physiologic mechanism resulting from immune activation in infections, or with malignant hyperthermia, which involves development of a hypermetabolic crisis (with amongst other signs also variable hyperthermia) when susceptible patients are exposed to volatile anesthetics.

HYPOTHERMIA

Persistent hypothermia is a 'reversible cause' for refractory cardiac arrest (see 4H/4T). As such, active rewarming may be necessary and the general rule 'no child can be declared dead if not warm' holds. Standard CPR should be started for all children in CA, however delayed or intermittent CPR may be considered when the child is deeply hypothermic (< 28°C) and if continuous CPR is not possible. If the temperature is below 30°C, limit the number of shocks to 3 and do not give adrenaline. Adrenaline can be given when temperatures are above 30°C but then still with an interval of 6-10' (as long as there is hypothermia).

A child who is considered to have a chance of a favourable outcome should ideally be transported as soon as possible to a centre with extracorporeal life support (ECLS) (or if not, cardiopulmonary bypass) availability.

COVID-19 IN CHILDREN

At the present time, there is sufficient evidence that SARS-CoV-2 infection is less frequent in the pediatric population than in adults, and that it occurs in most cases with mild symptoms in the form of upper respiratory tract infections or in mild lower respiratory tract infections (other unspecific gastrointestinal symptoms or skin signs can occur).

However, some children, especially those with previous comorbidities, may present with severe infections of the lower respiratory tract.

There is currently no evidence to recommend a specific treatment in children with suspected or confirmed COVID-19. However, with current knowledge, in the case of moderate respiratory infections with hypoxemia and infiltrates on radiography, the use of corticosteroids (dexamethasone) and antiviral treatment (remdesivir) are suggested.

PIMS-TS / MIS-C: Some children can develop a multisystem inflammatory syndrome (MIS-C) which can present with severe symptoms and that this is related to active or recent infection by SARS-CoV-2. This condition has been named, among other proposals, "Pediatric inflammatory multisystem syndrome temporally associated with SARS-CoV-2 (PIM-TS)".

For more details on diagnosis and management we refer to the CoSy VLE.

- **AIRWAY & BREATHING:** The airway is normally open but nasal obstruction from secretions can occur in small infants. If this happens, secretions should be suctioned, ideally with closed suction systems and adopting the appropriate safety measures, since it is an aerosol-generating procedure. Respiratory monitoring should be established and in cases of hypoxemia supplemental oxygen must be administered, titrating for SpO_2 94-98%. The generation of aerosols should be avoided as far as possible.

  As part of PIMs-TS, if there are signs of respiratory distress or pathological auscultation, it is important to suspect, identify and treat cardiogenic pulmonary oedema.

- **CIRCULATION:** A high proportion of sick patients will present with shock and require acute resuscitation. In patients with suspicion or evidence of ventricular dysfunction, careful reassessment for signs of fluid overload and early consideration of inotropic / vasopressor treatment is needed. An echocardiogram is important in the detection of ventricular dysfunction and coronary artery aneurysms. Extracorporeal membrane oxygenation should be considered if medical support fails. Possible arrhythmias should be treated according to the type and clinical deterioration they produce.

Given the limited current experience and the absence if high certainty evidence, it can be assumed that the recommendations described here will be modified as new scientific evidence appears, making it the responsibility of each healthcare provider to keep themselves up to date.

CHAPTER 10
SEVERE PAEDIATRIC TRAUMA

Trauma is the leading cause of death and disability worldwide in children over 1 year of age. Blunt trauma is seen in 80 % of paediatric cases; of these, two thirds are associated with brain injury. This type of injury accounts for 75 % of traumatic deaths. Injury patterns in children vary from those seen in adults, owing to the different physiological and anatomical responses to trauma. Children have a relatively bigger head compared to adults and thus a higher incidence of brain injury. Further, there is a relatively smaller muscle mass, less subcutaneous tissue and increased elasticity of the ribs and other bones. This means that, in the child, more of the impacting energy is transmitted to underlying organs such as the lungs (often without rib fractures) or the abdomen (with damage to visceral organs). Internal injury must therefore always be suspected as there may have been considerable force involved without external signs being present. The history of the mechanism of injury must always be sought and clinical consequences of how the impacting energy has been dispersed through the child's body must be considered.

When dealing with an injured child, possibly having multiple more or less severe injuries, it is vital that priorities are identified and appropriate resuscitative measures carried out as soon as problems are encountered. These measures must be applied in a structured manner to ensure maximal benefit. Importantly, these actions are part of **a structured TEAM approach**.

Overall, this structured approach consists of the same sequential steps of any emergency assessment, but specifics are added in view of the 'traumatic' aetiology:

1. *First Observational Assessment or Quick Look ('5 second round').*
2. *Primary Physiological Assessment by using an adapted ABCDE approach.*
3. *Secondary Clinical Assessment with a focused medical history and detailed physical examination.*
4. *Tertiary Complementary Assessment with laboratory, imaging and other ancillary studies.*

In trauma, part of this tertiary assessment may have already been performed in the primary assessment during the active search for internal life-threatening injuries (pneumothorax, bleeding, brain injury…) and the institution of necessary treatments (cross-match, surgery…).

Although the importance of an ABCDE approach is still emphasised – treat first what kills first-, the care for a polytrauma child demands a team to work in parallel with different team members having dedicated tasks. Given the time-critical context of severe trauma, for each individual case, proper preparation and anticipation is very important. Moreover, each service that might receive children after severe trauma should have policies in place regarding the specific organisation of acute paediatric trauma care within their institution.

More details about this trauma team approach and a demonstration video are provided in the CoSy VLE.

The general ABCDE principles of resuscitation for the injured child are similar to those of the critically ill child but a few important differences are described in the subsequent chapter. Overall this ABCDE serves as a 'common language' between team members, so that priorities remain visible – even during parallel care.

A STRUCTURED TEAM APPROACH

1. Quick look (5 second round)

Upon the child's arrival, the team leader takes a short time-out (quick look) before any hand- over or further evaluation to assess life-threatening conditions that need immediate intervention. Specific attention should be given to the patency of the airway, signs and symptoms of tension pneumothorax, important (external) bleeding, and threatening cardiorespiratory arrest.

2. Primary survey

Airway compromise, respiratory and circulatory failure and brain injury can co-exist following trauma. A systematic rapid evaluation ('the primary survey') identifies life-threatening problems and can be remembered by ABCDE. Monitoring (at least pulse oximetry and ECG) should be attached as soon as available.

Specific points of attention are related to the traumatic origin and deserve proper and timely attention:

- A + in-line cervical stabilisation
- B + ? tension pneumothorax
- C + ? bleeding
- D + ? intracranial hypertension
- E + ? AMPLE, temperature and pain

Resuscitation occurs throughout the primary survey, with problems being treated as soon as they are found following the rule: 'treat first what kills first'.

It is essential that the process of ABCDE is adhered to. 'Distracting' injuries must not interrupt this or life-threatening injuries may be missed. In pre-hospital trauma care, time is an important issue and therefore part of the initial resuscitation can be done 'en route'.

Despite the fact that the sensitivity and specificity of point-of-care ultrasound in children is limited and highly operator dependent, the place of ultrasound as rapid bedside tool to assist in early identification of life-threatening problems is becoming more and more established as part of the primary survey.

3. Focussed assessment & treatment (secondary- tertiary survey)

The secondary survey consists of a full examination to detect all injuries. The child's entire body must be examined, from head to toe including the back and perineum. Further details should be sought regarding the mechanism of injury and the direction and magnitude of the impacting forces in order to guide the management of the child (environment). This secondary survey should only start when all immediate life-threatening injuries have been treated and the child has been stabilised. The vital signs relating to ABCD should be regularly re-assessed during and after the secondary survey; if the child's clinical signs deteriorate the primary survey should be repeated. In the pre-hospital setting, examination and treatment should be limited to the primary survey to detect and manage life-threatening injuries before and during transportation to the hospital.

> **!** **In trauma, part of the tertiary assessment has already been started in the primary assessment; however, active search for internal life-threatening injuries (pneumothorax, bleeding, brain injury) and the institution of necessary treatment (cross-match, surgery..) should be on-going.**

Blood Sampling and Imaging

As soon as possible blood samples should be taken for blood typing and cross-matching, baseline biochemistry, coagulation and cell count, and for blood gas analysis and lactate.

Routine radiological investigations in the resuscitation room include:

- Thorax, antero-posterior view
- Pelvis, antero-posterior view
- Cervical spine, lateral view

However, despite the acknowledged risk of radiation injury, children at risk for major injury (suspected from mechanism of trauma or presenting symptoms) should preferably receive a full body 'trauma' CT scan. Pelvis and/or spinal X-ray can then be omitted and included in the CT evaluation.

X-ray of any limb injury can wait until the child is stable and the secondary survey has been completed. These X-rays should have an antero-posterior view as well as lateral view to avoid missing fractures. If not already performed as part of the primary survey, point-of-care ultrasound might provide rapid bedside information and in certain children even avoid the need for further radiology or CT.

4. Emergency treatment & the need for secondary transfers

Emergency treatments are not as time-critical as resuscitation measures needing to be carried out to save life or organs during the initial management. Nonetheless, they are important and must be managed in the first hours, or potentially life-threatening conditions may develop and limb-threatening problems may become irreversible. If further emergency treatment is to be undertaken in a specialist centre a secondary transfer will be necessary.

Secondary Transfer

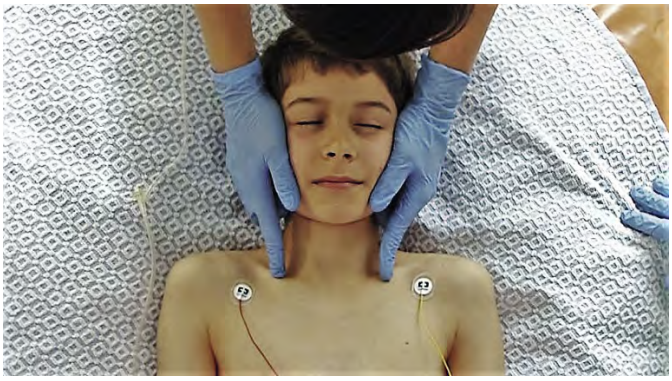
Ideally, severely injured children are transported directly from pre-hospital scene to a centre with expertise in pediatric trauma. If not, a secondary transfer should be arranged as soon as possible. Sometimes children sustain injuries that need immediate surgical intervention (epidural hematoma, uncontrolled bleeding) and this surgery should be done at the initial hospital or if it is impossible, immediate transfer should be arranged by the local team. The initial team should contact the receiving hospital regarding the clinical state of the child, giving details of suspected injuries, the AMPLE history and any procedures or treatments which have been carried out.

Ideally the competencies of the transfer team should be the same as the receiving hospital. The transfer team must be able to deal with any problem arising during transfer, such as a deteriorating airway, inadequate ventilation or circulatory problems. External haemorrhage must be controlled before and during transport and there must be secure intravenous or intraosseous access. The ABCDE parameters must be evaluated and monitored throughout. When possible, the transfer should be instigated without delay and unnecessary examinations and treatments avoided, provided the child can be safely transported without deteriorating en route. The expected time of arrival and the need for additional specialists must be communicated early and clearly to the receiving team, in order that the necessary expertise is available on arrival.

THE AIRWAY IN TRAUMA

If **cervical spine injury** is suspected, airway opening should be attempted using a jaw-thrust manoeuvre while preserving manual in-line immobilisation of the cervical spine. The oropharynx should be cleared of debris, blood, vomit, and other secretions by gentle suction under direct vision. The neck is inspected for distended veins, tracheal deviation, wounds, or subcutaneous emphysema.

Figure 10.1 Manual in-line immobilisation of the cervical spine



Sometimes, in order to open the airway, a slight head tilt, applied gradually until airway is open, may be needed. It may also be necessary to support the airway by using airway adjuncts, remembering that these will not protect the patient from aspiration in the event of vomiting.

In severe trauma, a tracheal tube might be necessary to secure the airway and optimise ventilation. Intubation is a skilled technique and should be carried out by an experienced practitioner. Supraglottic airway devices may be good alternatives if intubation cannot be accomplished safely. Cervical spine [C-spine] in-line immobilisation should be maintained throughout the procedure.

Spinal Immobilization is indicated whenever there is a high-energy trauma and/or there are signs or symptoms of potential spinal injury and/or there is decreased consciousness. However, if a patient is fighting immobilisation and is un-cooperative, the decision will have to be made to sedate them or not to immobilise. Fighting with the patient should be avoided. Immobilising the head whilst allowing the rest of the body to rotate is worse than doing nothing.

see the CoSy VLE for a descriptive video

Figure 10.2 Head blocks for C-spine immobilisation

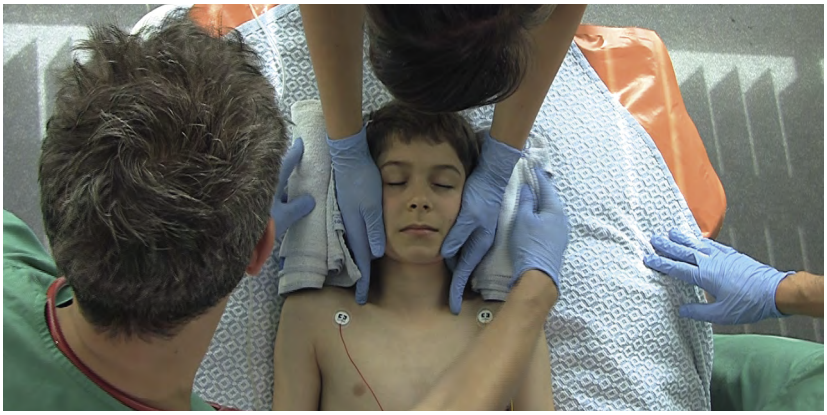
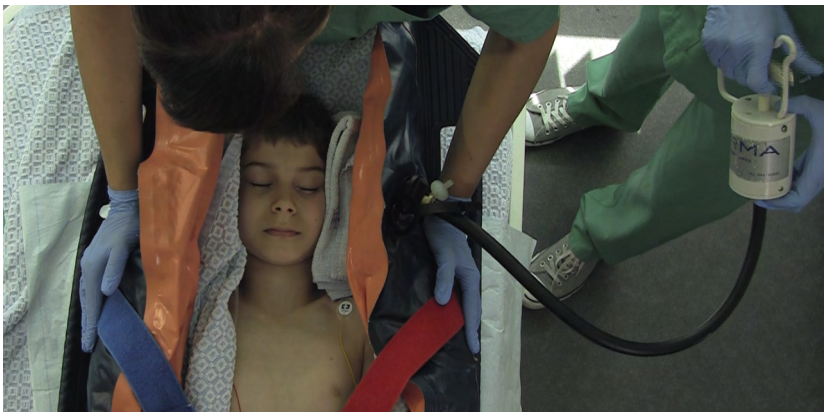


Figure 10.3 Positioning into a vacuum mattress



ABC always has priority, so if needed one should never be afraid of careful manipulation in terms of ABC stabilization.

Walking patients can position themselves on a stretcher, for non-ambulant patients a scoop stretcher is preferred to a spinal long board. If possible, a spinal longboard should only be used for pre-hospital extraction but not for further immobilisation. A quick dorsal inspection can be done whilst applying the scoop, thus avoiding the need for any further log-roll. Ideally each immobilized patient is scooped into a vacuum mattress, which remains in place throughout the remaining transfer. Each service should have a specific protocol about immobilisation in order to avoid unnecessary handling and transfers, which are dangerous for the critically injured patient. In case of a pre-hospital time-critical situation the decision can be taken to keep the patient on the scoop stretcher until in the hospital.

Regardless of being on a scoop stretcher or in a vacuum mattress, specific further attention to in- line C-spine immobilization is mandatory. A child, compared to an adult has a relatively large head, immature vertebral bodies (with less tensile strength) through which the spinal cord travels, strong elastic intervertebral ligaments, flexile joints capsules and easily compressible soft tissue in the neck. As these structures are pliable, injury to the cervical spinal cord, although uncommon, may occur even without radiographic abnormality [SCIWORA] being seen on either X- ray or CT scan.

In-line immobilization of the C-spine can be maintained manually by a single rescuer throughout the on-going resuscitation, although this incapacitates one rescuer from doing other things and sometimes obstructs further proper care. As an alternative, to further immobilize the C-spine, the use of head blocks (or equivalent) is advocated. These head blocks can be either positioned within the vacuum mattress or strapped upon the scoop stretcher.

There is much controversy concerning the use of cervical collars, especially in children. Cervical collars might induce problems in airway management or cerebral perfusion. Importantly there is no proof of their added value in terms of preventing further C-spine injury, especially if the collar does not fit well. This is often the case in children. Therefore the standard use of collars is no longer advised. Collars might still have a place during the extraction of a severely injured child or later on in the definitive care of a child with a proven C-spine injury (for instance during surgery). If a collar is used it should be a good fit (size, adequate positioning).

! **A normal cervical spine X-ray (or even CT-scan) does not guarantee the absence of neurological damage. In-line immobilisation can only be removed when there has been a normal neurological examination in an alert patient, an absence of intoxication, no focal deficit (motor/sensor; priapism…), no local pain or swelling, and no distracting injuries. In all other situations the possibility of an undetected spinal lesion should be considered, as certain lesions will only be visible on MRI.**

BREATHING IN TRAUMA

The effectiveness of breathing and ventilation must be evaluated after the airway has been opened and oxygen administered as appropriate. Do not give pre-emptive oxygen therapy in children without signs of or immediate risk for hypoxaemia or shock.

If breathing is ineffective, ventilation should be assisted by BMV, starting with 100 % oxygen. Tracheal intubation should be considered when breathing is ineffective. Management of the airway may be difficult, airway adjuncts and intubation aids should be used as appropriate. Video- laryngoscopy may be specifically helpful in this scenario but needs trained personnel to be effective. Very rarely, a surgical airway may be necessary.

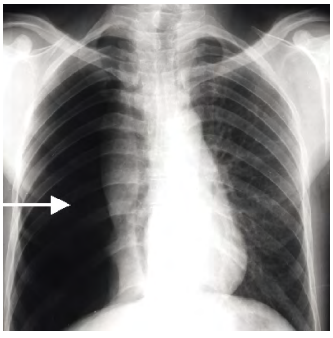
Controlled rapid sequence intubation should (only) be performed by an experienced practitioner. Cervical spine in-line immobilisation without any (or minimal) extension of the neck during intubation is important but in case of difficulties, airway management remains the first priority. A second designated person may be required to control the cervical spine during the intubation manoeuvre. Only the oral route is used for tracheal intubation as the nasotracheal route procedure can lead to: neck extension (worsening cervical spine injury), damage to adenoid tissue (with associated haemorrhage) and in case of a basilar skull fracture, direct damage to the brain. Correct positioning of the tracheal tube should be confirmed clinically, by capnography ($ETCO_2$) and by chest X-ray. Ultrasound may also be used to confirm lung ventilation and rule out pneumothorax or haemothorax.

Hyperventilation should be avoided in all (head-injured) patients, unless there are signs of imminent herniation, as cerebral vasoconstriction induced by hypocapnia aggravates brain ischaemic injuries. The arterial PCO_2 should be maintained in the normal range (35-45 mmHg or 4.6-6 kPa).

Significant gastric distension can occur with swallowed air or BMV. It impairs diaphragmatic movements, affects ventilation and increases the risk of vomiting and aspiration of the stomach contents. Therefore, a gastric tube should be placed as soon as possible if the patient has been ventilated by bag and mask and then intubated. The oral route is mandatory in case of suspected or actual craniofacial trauma (owing to the risk of maxillofacial or basilar skull fractures). The position of the gastric tube must be checked after insertion.

Pneumothorax is defined as air within the pleural space with collapse of the lung, which progressively impedes ventilation and later circulation. Pneumothorax can often be diagnosed clinically but chest X-ray and ultrasound are sometimes necessary to confirm the diagnosis. Subcutaneous emphysema might be detected as a sign of associated pneumomediastinum. There are three main types: simple, open, and tension pneumothorax. Respiratory failure can be caused by all three.

Figure 10.4 Tension Pneumothorax is in fact primarily a clinical diagnosis. This X-ray should not need to exist as diagnosis and emergency treatment should have happened before imaging.



Signs of pneumothorax should actively be searched for as part of the B evaluation.

Simple pneumothorax represents a limited air leak, which causes the lung to collapse but without significant haemodynamic signs. It may only be identified after chest imaging and may be managed conservatively provided there is continuous monitoring on the child's physiological parameters. A chest drain is mandatory only if the child requires positive pressure ventilation because a simple pneumothorax can, in this case, be converted into tension pneumothorax.

A Tension Pneumothorax is rather uncommon in spontaneously breathing children but becomes more likely when a child is ventilated with positive pressure. When air is forced into the pleural cavity without means of escape, the pressure in the cavity will rise. Raising pleural pressure will displace the mediastinum to the opposite side of the chest and obstruct the great vessels superior or inferior vena cava, interfering with venous return and causing obstructive shock with a concomitant fall in systemic blood pressure. The jugular venous pressure is raised if there is no associated hypovolaemia. Further signs of tension pneumothorax include: hypoxemia, absent/decreased breath sounds on affected side and tracheal deviation away from the side of the tension pneumothorax. If competent, use ultrasound to confirm the diagnosis if this does not delay treatment. Treatment consists of proper airway opening and oxygen (100 %) by face mask, BMV or mechanical ventilation and immediate decompression of the pneumothorax.

Needle thoracentesis: A large bore cannula several cm in length is inserted into either the 4th or 5th intercostal space (ICS) slightly anterior to the midaxillary line or alternatively, the second intercostal space in the mid-clavicular line on the side of the tension pneumothorax. The needle of the cannula is removed and a hiss of escaping air may be heard as the pressure within the pleural space is released. The cannula is left open to air. A definitive chest drain should be inserted as soon as the primary survey has been completed.

If the child deteriorates at any stage following the needle thoracentesis, the tension pneumothorax may have recurred e.g. due to the cannula kinking. Needle thoracentesis should then be repeated and early chest drain insertion should be considered.

Immediate thoracostomy (making an incision at the 4th or 5th intercostal space slightly anterior to the midaxillary line with rapid dissection into the pleural space) might be a better alternative to needle thoracentesis but this procedure demands proper training. Convert to standard chest tube drainage as soon as practically feasible.

In the CoSy VLE we present a video showing how to perform needle thoracocentesis at the second intercostal space midclavicular. As stated above, the 4th or 5th intercostal space, slightly anterior to the midaxillary line is a good (if not better) alternative position for needle decompression.

Massive haemothorax develops due to blood accumulating in the thoracic cavity as a result of a pulmonary parenchymal injury (pulmonary vessels) or chest wall injuries (e.g. from intercostal arteries). A haemothorax may contain a significant proportion of a child's total circulatory blood volume. Clinical signs of a haemothorax include: hypoxemia, hypovolaemic shock, decreased chest wall movements, decreased breath sounds and dullness to percussion on the affected side. Neck veins may be flat, not full or distended.

Treatment consists of proper airway opening and oxygen (100 %) by face mask, BMV or mechanical ventilation. Two large bore intravenous cannula or intraosseous needles should be inserted and fluid bolus(es) of 10 ml/kg given. Blood products -as well as tranexamic acid- should be used as soon as possible and a chest drain needs to be inserted.

! As blood loss can be rapid through the chest drain, fluid replacement must be available and circulatory access secured before its insertion. Temporary clamping of the chest drain and urgent thoracotomy may be required if the initial blood drainage is > 20 ml/kg, with persisting loss requiring continuing blood transfusion.

For information about an open pneumothorax and about a flail chest, we refer to the CoSy VLE.

CIRCULATION IN TRAUMA

Restoring the normal circulating volume and haemostasis are key elements of the management of a child with haemorrhagic shock. Therefore, two routes of vascular access (peripheral short, wide-bore cannulas and/or intraosseous access) must be secured in children who have suffered severe trauma. At the same time, blood samples should be taken for blood cross-match, blood gas analysis and other laboratory studies. In the prehospital setting, a single secure IV/IO is most often sufficient to have before departure to hospital, where a second access is then done upon arrival in the trauma center.

Blood loss is the most common cause of shock in injured children. Blood loss can be visible (external) or hidden (internal). Less frequent causes of shock associated to trauma are cardiogenic (commotio cordis or cardiac contusion) or obstructive (pneumothorax, tamponade) in nature. Rarely hypotension with or without bradycardia is caused by spinal or neurogenic shock.

Traumatic haemorrhage

Life-threatening bleeding should be identified by the trauma team leader in the 5 second-round. Any obvious exsanguination from a vessel must be controlled by direct pressure using a thin layer of gauze even if the haemorrhage seems unimpressive due to the initial protective vasoconstriction. Protective gloves should always be worn. Rescuers should use a tourniquet (preferably manufactured but if needed improvised) in case of an uncontrollable, life-threatening external bleeding.

Open fractures can cause large quantities of blood to be lost; splinting of limb fractures, which realigns normal anatomy, reduces blood loss. Pelvic fractures or major long bone closed fractures may also be associated with soft tissue damage and the extravasation of blood. Such injuries when isolated, do not generally lead to hypovolaemic shock in children. Especially in adolescents, when a significant bleeding is suspected from a pelvic fracture with pelvic ring disruption, a compressive belt or bed-sheet may be applied. Head trauma is not associated with hypovolaemia (except in infants), therefore a search for another source of bleeding must take place if hypovolaemic shock is present.

If hypovolaemia persists, despite control of external haemorrhage, and the need for fluid resuscitation continues, internal haemorrhage must be actively sought and corrected or the child may die. Intra-abdominal, retroperitoneal and intrathoracic bleeding are the main causes of life-threatening internal haemorrhage in children. Intra-abdominal haemorrhage (rupture of an intra- abdominal organ such as the spleen or the liver or major blood vessels) can present with peritonism, abdominal distension (which does not decompress with a gastric tube) and signs of circulatory failure. Often initial signs are few and a high index of suspicion is required. An early ultrasound examination by a trained operator might detect free fluid in the thorax or abdomen of children with trauma to the torso, however a negative ultrasound examination does not rule out severe internal bleeding. Patients with significant free fluid and continuing haemodynamic instability might need immediate surgical intervention; therefore surgical involvement in the management of any trauma case is mandatory. The gold standard to detect internal bleeding remains contrast-enhanced CT scan (although this has to be balanced against the risk of radiation exposure).

Remember that the total circulating blood volume in children is around 80 ml/kg. The evaluation of blood loss and the degree of hypovolaemic shock depends on the assessment of heart rate, blood pressure, peripheral pulse, peripheral perfusion, preload, level of consciousness, oxygenation and respiratory rate. The volume of blood loss can be estimated according to the changes in these signs. The child should be reassessed repeatedly as there may be rapid alterations in the circulatory status. Response to treatment must also be assessed to see if further interventions are required.

! A decrease in blood pressure is a late sign (often > 50 % of total blood volume is already lost), and therefore not very useful to initiate or guide treatment.

TREATMENT: Although local protocols may differ e.g. with the blood product ratio, there is consensus to strictly limit the use of crystalloids in severe trauma (< 20 ml/kg) in favour of an early and balanced use of blood products in bolus (PRC, fresh-frozen plasma and platelets). In case of haemorrhagic shock, blood products are given as rapid boluses and should ideally be warmed. Monitoring of the clinical response to each fluid bolus is essential to guide therapy. Single haematocrit measurements should not be employed as marker for bleeding. Base deficit and lactate however are good measures for the degree of circulatory failure and bleeding.

Surgery may be indicated if shock persists despite more than 40 ml/kg of blood products, or repeated transfusion is needed to maintain normal physiological parameters. An experienced surgeon will be needed to decide whether immediate operative intervention is necessary to stop internal bleeding. Surgery should focus on bleeding control ('damage control surgery') and brain protection; other procedures should be postponed. Angiographic embolisation should always be considered in older children with on-going bleeding.

> **! It is vitally important to avoid hypotension at all cost in children with suspected brain injury because this is a major cause of secondary brain injury. Only in those children with massive haemorrhage due to a penetrating trauma where it is certain there is no concomitant brain injury, a strategy of permissive hypotension (mean arterial pressure at fifth percentile for age, see 'normal values') is acceptable.**

In view of this, for massive haemorrhage it is advocated to use the following ratio of blood products: for each 10 ml/kg PRC, also 10 ml/kg fresh-frozen plasma and 5 ml/kg of platelets. If type-specific or full cross-matched blood is not available, then Group O Rhesus-negative blood and AB fresh-frozen plasma should be used. It is important to be aware that the administration of more than 40ml/kg O-negative blood will complicate a later cross-match if not already obtained. Ionized calcium levels should be monitored and corrected when needed.

Coagulation monitoring (including fibrinogen levels) and possibly thrombo-elastometry might guide further haemostatic therapy. The aim for a platelet count is > 100,000 in case of active bleeding and for a Hb of 7g/dl (> 4.3 mmol/l). Fibrinogen therapy should be considered if fibrinogen level is < 1.5-2 g/l and/or if there are signs of fibrinogen deficit. Considering the current level of evidence and the relative safety of it, a bolus of tranexamic acid 20mg/kg (max 1g) is advised, followed by 2mg/kg/h during 8 hours (or until the bleeding stops; max. 1g) in all children with massive haemorrhage, provided it can be started within the first three hours after trauma.

Cardiac tamponade

Cardiac tamponade generally results from penetrating injuries rather than from blunt injuries and is therefore not often seen in paediatric trauma. The heart is pierced and blood fills the pericardial sac. This limits the space for cardiac filling,

causing obstructive shock. Cardiac tamponade requires emergency thoracotomy. Pericardiocentesis might be attempted if immediate thoracotomy is not available. The procedure should be guided by ultrasound and a pericardial drain should be left in situ after the procedure.

Great vessels injuries

These lesions are rapidly fatal, unless the leak is contained by a subadventitial haematoma. The patient may present with shock, and a high index of suspicion should be triggered by a widened mediastinum on the chest X-ray. Diagnosis is confirmed by CT-angiography, urgent surgical treatment is required.

Cardiorespiratory arrest in trauma has a dismal prognosis unless treated fast and aggressively. Pupil reactivity in itself is not a reliable sign to predict outcome. Survival is correlated with CPR duration, quality and overall pre-hospital time.

High-quality CPR should be initiated, and reversible causes should be evaluated immediately by clinical signs and ultrasound, as they represent the only chance for a good outcome. Hypoxemia and hypovolemia/haemorrhage should be treated aggressively. Suspected tension pneumothorax should be decompressed by needle decompression (or thoracostomy) with a low threshold for an attempt. Chest tube insertion can be carried out after ROSC. In case of traumatic cardiac tamponade, emergency pericardiocentesis can be attempted if an emergency thoracotomy is not possible within minutes of loss of vital signs. In an out-of- hospital setting, only essential life-saving interventions should be performed on- scene followed by rapid transfer to the nearest appropriate hospital.

Chest compressions are performed simultaneously with the above interventions depending on the available personnel and procedures. Try to minimise spinal movement as far as possible during CPR without hampering the process of resuscitation, which clearly has priority.

Based on the mechanism of injury, correction of reversible causes might precede adrenaline administration. 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.

Disability & exposure-environment in trauma

The goal in the primary survey is to diagnose severe head injury which may require urgent neurosurgical intervention, and/or may determine the need for specific intensive care techniques.

The child's vital signs and neurological status **(pupil, AVPU or GCS-M)** need to be recorded on a regular basis and the results interpreted in the context of the child's clinical state. Ideally, initial neurological assessment needs to be made before administration of sedative or paralysing drugs as these agents may mask clinical

findings. Specifically, the pupils must be examined for size, symmetry and response to light (consensual and direct). Abnormal or asymmetric pupils (miotic, mydriatic, fixed) in association with head injury may indicate an intracranial mass (most probably oedema or bleeding) on the same side and requires urgent neurosurgical referral and immediate treatment.

Severe intracranial hypertension and imminent herniation

Raised ICP can lead to herniation of the brain through for instance the tentorium or the foramen magnum, with subsequent (brain) death. Except for young infants, the skull has limited ability to expand ('closed box'). Therefore, if one of the three components within the skull (blood, cerebrospinal fluid or parenchyma) increases in volume this might lead to an increase in ICP. Initially there are compensatory mechanisms in place (cerebrospinal fluid, blood flow) but once these fail –often suddenly- there is a steep rise in ICP and brain herniation can occur. Clinical signs of severe intracranial hypertension and imminent herniation can then be detected namely: systemic hypertension, bradycardia, irregular respirations (Cushing's triad) and pupil abnormalities. Often signs and symptoms are far less clear in the compensatory phase. Depending on trauma mechanism and initial presentation clinicians should institute 'brain- protective treatment' very early to prevent intracranial hypertension and otherwise to identify and control it as soon as possible.

! Systemic hypertension associated with bradycardia and irregular respiration suggests raised ICP and imminent herniation. The hypertension should not be treated with antihypertensive agents but urgent therapy for raised ICP should be instituted.

Exposure and Environment in Trauma

The child's clothes should be removed or cut in an appropriate manner so that any injuries can be seen. Warming devices such as an overhead radiant heater, warming blankets and fluid warmers, should be used to keep the child warm as hypothermia can be deleterious especially in the presence of hypovolaemic shock. A search should be made for clues in the environment to better understand or determine the injuries. A short and focused history must be obtained and can be remembered by the acronym **AMPLE** (allergies - medications - past history - last meal - events).

Although not strictly part of the primary survey, the clinician should be alert to institute early pain management when needed. In general, trauma is associated with pain and this should be recognised and treated as early and effective as possible. Opioids (intravenous or sometimes mucosal) are often needed in cases of severe trauma.

! Hypoxia and hypovolemia can cause symptoms of agitation, grunting and altered consciousness, and should be excluded at all times. This should however not be a reason to give suboptimal pain treatment.

FOCUS ON BRAIN INJURY

Head injuries are responsible for 70 % of deaths in the first 48 hours following paediatric trauma. Clinicians should institute 'brain-protective treatment' *(see below)* very early in the patient care to prevent intracranial hypertension and to identify and control it as soon as possible. Primary brain damage occurs at the time of the trauma and is generally irreversible. However, aggressive treatment can prevent secondary brain damage, which may be due to hypoxia, ischemia (caused by hypotension, intracranial hypertension…) or direct cell injury (hypoglycemia, seizures…).

> **! Isolated head injuries usually do not cause hypovolaemia. In the presence of hypovolaemic shock, internal haemorrhage must be considered and intra-thoracic, retroperitoneal and/or intraabdominal trauma must be ruled out. In young infants however scalp lacerations and in certain cases acute epidural haematomas can lead to a significant blood loss (and hypovolaemic shock).**

Children with a history of loss of consciousness, headache, vomiting, amnesia, seizures and/or a severe (high-energy) injury mechanism have a higher risk for a more severe brain injury. Clinical warning signs include bruises and lacerations, fractures, and other lesions such as haemotympanum, rhinorrhea, or focal neurological pathology. The Glasgow Coma Scale or the Motor subscale must be scored as early as possible, along with a full neurological assessment before the administration of sedative or paralysing agents, as such agents might mask further clinical findings.

A cerebral CT scan should be performed in every injured child with diminished consciousness and/or after a high energy trauma mechanism, unless there is profound haemodynamic instability. Resuscitation equipment and a resuscitation team must always be at hand as the seemingly stabilised patient can suddenly deteriorate.

NEUROSURGERY: Early involvement of a neurosurgeon is mandatory to decide upon the need for surgical decompression, intra-cranial pressure monitoring or haematoma drainage. An epidural haematoma is a life-threatening emergency requiring immediate drainage. It can expand rapidly and cause very sudden herniation with unilateral mydriasis, and loss of consciousness followed by bilateral mydriasis and bradycardia.

NEUROPROTECTIVE CARE:

- The mean arterial pressure should be maintained above the 50th percentile of the normal value for age to preserve cerebral perfusion pressure. Cerebral hypoperfusion, even for short periods, will lead to secondary injury and should be avoided at all cost. Fluid boluses to treat hypovolaemic shock are essential even though there may already be brain injury. Often it will be necessary to add vasoactive drugs to sufficiently increase cerebral perfusion pressure. Once the shock is stabilised, fluids must be given more judiciously, as excessive fluids might worsen cerebral oedema.

- Normoxemia should be maintained. Hypoxia, especially when combined with hypoperfusion, will induce secondary brain damage. The impact of hyperoxemia is unclear. After the initial primary stabilization, it is advised to titrate oxygen (FiO_2) in line with PaO_2 or an SpO_2 between 94 and 98 %.
- Normocapnia ($PaCO_2$ 35-45 mmHg, 4.6-6.0 kPa) should be maintained as far as possible. Do not use $ETCO_2$ as a surrogate for $PaCO_2$ when aiming for normocapnia unless there is a proven correlation. Hypocapnia can induce focal ischaemia and therefore hyperventilation ($PaCO_2$ 30 mmHg) should only be carried out under careful supervision if there is imminent herniation. Hypercapnia induces vasodilation and thus potentially increases ICP. It is unclear in how far this affects prognosis.
- Sufficient analgo-sedation/general anaesthesia should be provided, whilst being careful to avoid hypotension. If signs of raised ICP occur, the level of sedation/ anaesthesia should be increased. Pain and stress markedly increase cerebral metabolic demands and can pathologically increase cerebral blood volume and ICP.
- Normothermia (36-37.5° C) is the aim and hyperthermia should be treated aggressively. There is insufficient evidence to advocate induced hypothermia outside specific research protocols.
- Venous drainage from the brain should be optimised as far as possible. The internal jugular veins should not be cannulated for central venous access, as this hinders venous drainage and may aggravate the progression of raised ICP. The head and chest can be slightly elevated (30°), provided there is no evidence of systemic hypotension, to aid venous drainage. Flexion of the body when achieving elevation should be avoided in order that the entire spine remains in-line. If the child becomes hypotensive, this elevation should be discontinued until this has been treated.
- Glycaemia and electrolytes should be maintained within the normal range. Hyper- and definitely hypoglycaemia should be avoided, as these aggravate ischaemic cerebral lesions. Administration of glucose-containing solutions must be avoided during resuscitation, unless they are used to treat documented hypoglycaemia. Monitoring of blood sugar levels is always mandatory. Hyponatremia and hypomagnesaemia should also be avoided.
- Seizures should be treated aggressively, using benzodiazepines and other antiepileptic medication as required. There is no evidence for the preventive use of antiepileptic medications.

! There is no place for steroid therapy in raised ICP due to trauma.

In cases where there is evidence of intracranial hypertension hypertonic saline (e.g. NaCl 3 % 3-5ml/kg bolus) may be used as a safe and effective way to lower ICP. It has the advantage of concomitantly raising the circulating volume. The effect is transient and probably requires an intact blood-brain

barrier. Monitoring of serum osmolarity and urine output is essential if hypertonic saline is used. Osmotic therapy in the case of unilateral brain injury/oedema (e.g. epidural hematoma) may increase midline shift. Ideally, a neurosurgeon should be consulted before administration of osmotic therapy.

Other bodily injuries

We only provide some highlights in this manual and refer to the CoSy VLE for more details.

- **Rib fractures:** Rib injuries are always significant and point to significant thoracic trauma in children and underlying chest and abdominal injuries must be suspected. Adequate analgesia and examination for underlying damage is mandatory.
- **Intra-abdominal (visceral) injury:** The majority of children with visceral injury may be managed conservatively (meaning nonoperatively) in a paediatric intensive care unit, provided there is an experienced (paediatric) surgeon with the necessary facilities available should the child deteriorate. Indications for operative intervention include penetrating injury, perforated bowel, and refractory hypovolaemic shock unresponsive to fluid resuscitation. Importantly, operative interventions in the first hours post trauma should be limited to life-saving or organ-saving procedures (damage control surgery). Further surgery should be postponed to the following days, once the patient has been sufficiently stabilised.
- **Skeletal injury:** Skeletal trauma is rarely life-threatening but may be impressive and its appearance must not distract from adherence to ABCDE steps of managing an injured child. The few life-threatening conditions in skeletal trauma which are treated in the primary and secondary survey include crush injury of the abdomen and pelvis; traumatic amputation of an extremity, either partial or complete, and massive long bone open fracture. In addition, neurovascular lesions and the emergence of a compartment syndrome should be identified early as they can be limb- threatening.

  The extremities should be inspected for bruising, swelling, deformity, laceration, and evidence of open fractures. Any open wound on top of a fracture is an open fracture unless proven otherwise. Gentle palpation should be undertaken to establish any areas of tenderness, and to evaluate the surface temperature and capillary refill time. It is essential that the perfusion, and the sensory and motor function of the limb, especially distal to injury, is recorded and acted upon (e.g., the absence of pulses distal to a supracondylar fracture can be limb-threatening unless managed urgently).

Assessment of the vascular status of the limb relies on determining:

- the presence and quality of peripheral pulses distal to the injury
- capillary refill time, and skin temperature gradient
- sensation and motor function (neurological status of the limb); paraesthesia; pain

The emergency treatment of vascular limb injury includes fluid resuscitation after A and B with haemostasis of obvious bleeding; pain relief and alignment and immobilisation by splintage. If pain increases after immobilisation, then ischaemic injury and/or compartment syndrome must be excluded.

1. Crush injury of the pelvis

Crush injury of the pelvis can be associated with hypovolaemic shock which remains resistant to fluid resuscitation until the pelvic disruption is stabilised and injured vessels (venous and/or arterial) are occluded. This may be achieved by using a pelvis belt, an external pelvis fixator or by operative means (incl. radiographic embolisation). In either case, urgent surgical management is required. Avoid multiple examination of pelvic stability as this may increase bleeding. Evaluation for associated urogenital injury (urinanalysis, imaging) is necessary. Never insert a urinary catheter unless urethral injury has been ruled out.

2. Traumatic amputation

In complete amputation, blood loss is usually limited owing to the initial spasm of the transected blood vessels. In partial amputation there may be considerable blood loss, as vasospasm may not occur and urgent compression may be needed. The child may need to be treated for hypovolaemic shock. Tourniquets or vessel clamps should be used in those cases with life-threatening injury where direct pressure fails to control the bleeding. An amputated limb should be isolated in a sterile bag and then put on ice.

3. Massive open long bone fractures

This is usually obvious and needs immediate treatment if there is associated exsanguinating haemorrhage. The child may be in hypovolaemic shock and should be treated for this; direct pressure should be applied to the bleeding vessels with gauze. Splinting the limb in the correct anatomical position will help to reduce blood loss.

4. Compartment syndrome

This occurs when the interstitial pressure is higher than the capillary tissue pressure in a fascial compartment and local ischaemia results; for example, in a circumferential burn of the upper arm.

Presenting signs are pain, accentuated by passive muscle stretch; decreased sensation; local swelling and muscle weakness. It is important to have a high level of suspicion and to recognise compartment syndrome early as distal pulses only disappear when the intra-compartmental pressure rises above arterial pressure. Initial treatment is the releasing of any constricting bandage. Surgical intervention may be required to try to save the limb.

BURNS (THERMAL INJURY)

For details on the assessment of burns we refer to the CoSy VLE.

The upper airway may be compromised due to injury from burns or chemical irritants from noxious agents. The airway is at risk of early oedema and the situation may deteriorate rapidly and suspicion of potential airway compromise should prompt immediate consideration of tracheal intubation; delay may make intubation impossible. Difficult intubation should be anticipated and airway adjuncts or video-laryngoscopie should be considered.

In severe cases, there may be circumferential burns to the thorax which limits chest movement. Escharotomies (fasciotomy through burned tissue) may be required to reduce the constricting effect of the burns. Particles inhaled during a fire may contribute to respiratory distress and must be removed by suction/lavage after intubation and bronchoscopy. In case of fire in a confined space, for example a house fire, CO and/or cyanide intoxication should always be considered and treated if necessary with 100 % oxygen and consideration of hyperbaric O_2 therapy and/or cyanide antidotes.

Fluid resuscitation of 10 ml/kg boluses of isotonic fluid should be given if there are signs of shock. Hypovolemia after burns will take time to evolve and early shock in a patient with burns must lead to an active search for other reasons for shock (haemorrhagic in case of concomitant trauma; septic…).

Early use of opioids (intravenous/intraosseous or mucosal) should be considered in children with significant burns.

Importantly, initial care includes irrigation of limb wounds with lukewarm running water for at least 15-20 minutes. Afterwards the wounds should be kept dry with plastic film or gauze until proper care can be provided. Pressure on burned skin should be avoided. Wound care should be started as soon as possible to avoid infection. Care should be taken to avoid hypothermia due to irrigation and during transport. The tetanus vaccine status of the child should be determined to identify if a tetanus booster is required.

DROWNING

Drowning is a process resulting in respiratory impairment from immersion (at least the face and airway entrance must be covered with the fluid) or submersion (the complete body is under the fluid) in water or another fluid. The most common and detrimental consequence of drowning is asphyxia with hypoxia. The duration of hypoxia is the critical factor in determining the outcome.

Safety (S)

Personal safety is always a priority. Attempt to save the child should be made without entry into water. The child should be reached with a rescue aid (e.g. stick, clothing), or by throwing a rope, a buoyancy aid or using a boat. If entry into water is essential, a flotation device should be used. No rescuer should ever dive head first in the water when attempting a rescue.

The child should be removed from the water by the fastest and safest means available. If possible, the victim should be removed from the water in a horizontal position to avoid post- drowning hypotension and cardiovascular collapse, but extraction should not be delayed to achieve this.

Airway (A) and Breathing (B)

Cervical spine injury is rare and C-spine immobilisation is difficult to perform in the water. Cervical spine immobilisation is therefore not indicated unless severe injury is likely (e.g., diving, waterslide use). The airway should be opened. Attempts to clear the airway from water are not helpful and may delay resuscitation.

The drowning victim rescued from the water within minutes of submersion often exhibits agonal breathing. If there is no normal spontaneous breathing after opening the airway, rescue breathing should be started. In-water rescue breathing should be started only if the rescuer is trained to do so. Otherwise, rescue breathing must be started when out of water or in shallow water.

High-flow oxygen should be given during initial assessment of the spontaneous breathing child.

Circulation (C)

If there are no signs of life or no pulse, external chest compression should be started as soon as the victim is placed on a firm surface. If continuous CPR is not possible and the child is deeply hypothermic (<28° C), consider delayed or intermittent CPR. If the core body temperature is **below 30° C** and the child shows a shockable rhythm only three defibrillation attempts should be performed until the T° is above 30° C. In case of such deep hypothermia also IV drugs should be withheld until T° is > 30° C, after which adrenaline is given at twice the normal dose interval (6- 10 minutes) until the

temperature is above 34° C. Assessment for signs of life should be prolonged in case of deep hypothermia.

After prolonged immersion, most victims will have become hypovolaemic due to the cessation of hydrostatic pressure of water on the body and rapid IV fluid is needed.

Preventing further heat loss is undertaken by removing wet clothes, providing insulation and planning a rapid transfer to hospital). Rewarming, both passive and active is crucial. During rewarming patients will require large quantities of fluids, as vasodilation causes expansion of the intravascular space. Cooling decreases cellular oxygen consumption and thus exerts a protective effect on the heart and brain (cardiac arrest can be tolerated for up to 10 times longer) because deep hypothermia develops before asphyxia. No child can be proclaimed dead until his body temperature is above 34°. There are ample reports of good outcome after prolonged resuscitation (several hours) for cardiac arrest in hypothermic children including drowning victims. Resuscitation should only be withheld in hypothermic patients if the arrest is clearly attributable to a lethal injury, fatal illness, prolonged asphyxia or there is an incompressible chest. *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.*

CHILD ABUSE

Child abuse may present as various types of physical injury. Healthcare providers must **pay attention** to clues that may indicates such conditions particularly if:

- The history is incompatible with the clinical findings, frequently changing, inconsistent with the child's motor development or improbably complex.
- The interval between time of injury and presentation at the hospital is inexplicably long.
- The trauma is repetitive .
- The parental answers are inappropriate (unduly aggressive, apparently unconcerned, or over- anxious).
- Stories told by parents or the child's guardian are inconsistent.
- Certain characteristic injuries are present which may include: spiral fractures caused by twisting, bucket handle fractures, posterior rib fractures, cigarette burns etc.

Importantly, the child should be hospitalised and protected against possible repetition of injury. Parents should be seen by a senior professional, preferably one experienced in child abuse.

CHAPTER 11
NEWBORN LIFE SUPPORT

Newborn resuscitation is different in many respects from resuscitation at any other time of life, however the general **ABC** can be followed with certain specific changes.

Specific background information can be found again in the CoSy VLE.

For the rest of this chapter we will define a newborn as preterm if they are less than 35 weeks gestation at birth. Newborn Life support only applies to the resuscitation just after birth.

PREPARING FOR RESUSCITATION

Ideally babies should be born in a place which has been specially prepared, whether it is in a hospital delivery room or at home, and should be attended by healthcare professionals with experience in newborn resuscitation. However, unexpected births do occur and this chapter focuses on preparing providers for the resuscitation of the newborn in non-maternity settings. The principles of management are the same wherever a baby is born; however, the environmental conditions and the expertise of the personnel involved will be different.

Some healthcare professionals may have to deal with an unexpected delivery and may have to manage the newborn without normal neonatal facilities. Such professionals should be trained in neonatal resuscitation and maintain their skills in this area. It can be difficult to decide whether there is time to transport the mother to hospital or whether it is safer to remain in the pre- hospital setting. Appropriate triage of the mother in labour should also be part of the training of these healthcare providers.

Equipment

The required minimum set of equipment includes a device for safe ventilation of the newborn, warm dry towels, equipment for clamping and cutting the umbilical cord and clean gloves for the caregivers in any circumstances **(see also CoSy VLE)**.

Equipment of appropriate size (neonatal and premature) should always be used for resuscitating a newborn. Equipment must be checked that it is functioning properly before every delivery. Prewarmed towels should be prepared for drying and covering the baby.

Environment

Wherever the delivery occurs caregivers must provide both heating for the room and ways of keeping the baby warm. Ideally resuscitation should be on a warm, well-lit, draught- free, flat surface under a radiant warmer, where the equipment of resuscitation is immediately available.

The provision of the proper environmental temperature is essential in any circumstances. The temperature that is comfortable for adults is not warm enough for naked, wet newborns, especially for premature babies. If the newborn's condition allows, the best heat source for the baby is their mother when placed skin to skin on her and both mother and baby are then covered with dry and warm towels, especially in out-of-hospital settings.

Preventing Heat Loss

The thermoregulation of the newborn is inadequate. Heat production is limited (especially for premature, intrauterine growth restricted or asphyxiated newborns). The environment is much colder after birth, and this, combined with wet skin increases heat loss. Hypothermia lowers arterial oxygen tension, increases metabolic acidosis and complicates the resuscitation process. Core temperature should be kept at 36.5º-37.5º C at all times.

Particular attention should be paid to preventing heat loss by:

- pre-warming the environment, having warm towels available
- protecting the baby from draughts
- drying the term baby immediately after delivery, removing the wet towel and covering the head and body of the baby apart from the face with a new warm towel
- If the baby does not need resuscitation, placing the baby skin-to-skin on the mother and covering both of them with a warm towel.
- If the baby needs resuscitation, the baby should be placed on a warm surface under a pre- heated radiant heater if one is available.
- When covering a very preterm infant with a (food grade) plastic bag/ polyethylene wrapping (apart from face), the baby should not be dried first and should be kept under a radiant warmer.

EVALUATION OF THE NEWBORN

It is possible to assess the newborn's condition by checking tone (and colour), breathing adequacy and heart rate (typically performed in this order). Initial assessment may occur before the umbilical cord is clamped and cut. Take appropriate action to keep the baby warm during these initial steps. Re-assess frequently.

Initial handling is an opportunity to stimulate the infant during assessment by

- Drying the infant,
- Gently stimulate the infant as you dry them, for example by rubbing the soles of the feet or the back of the chest. Avoid more aggressive methods of stimulation.

TONE (& Colour)

The tone of the baby should be checked, the baby may be well flexed with good tone or floppy like a rag doll. A very floppy newborn is likely to be unconscious and in need of resuscitation. Colour is a poor means of judging oxygenation. Cyanosis can be difficult to recognise. Pallor might indicate shock or rarely hypovolaemia – consider blood loss and plan appropriate intervention.

BREATHING

The baby's breathing should be checked. If breathing, then the rate, depth and symmetry, and work/effort of respiration should be assessed. Most babies start breathing regularly within ninety seconds of birth. Good spontaneous respiratory activity soon after birth often manifests as vigorous crying. Apnoea, irregular or gasping breathing is abnormal. If abnormal breathing persists after drying and stimulating, intervention is required.

HEART RATE

The heart rate is best assessed with a stethoscope on the chest (apex) (or an electrocardiograph (ECG) or a saturation monitor may be used to assess it). Feeling for a pulse at the base of the umbilical cord might be misleading. Even in a healthy baby the cord does not always pulsate, nor does the rate of cord pulsation always reflect the true pulse rate.

The heart rate can be estimated by multiplying the number of beats in 6 seconds by 10. It is usually clear that the heart rate is either very slow (less than 60/minute), slow (60-100/minute) or fast (more than 100/minute). It is not necessary to count it with complete accuracy. A heart rate below 100/minute is abnormal.

! During resuscitation, the heart rate is the most sensitive indicator of a successful response to interventions.

PULSE OXIMETRY

Colour is a poor means of judging oxygenation, which is better assessed by pulse oximetry, if available. The oxygen saturation should be measured pre-ductally (right hand or wrist).

APGAR

The APGAR scoring system, with scores assigned at 1 and 5 minutes of life is often used to record the condition of the newborn, but should not be used to make decisions about resuscitation.

RESUSCITATION OF THE NEWBORN

Most term newborns do not require any resuscitative intervention at birth other than to be kept warm. Babies with poor tone, who do not cry or breathe spontaneously, may need some intervention; resuscitation is a matter of Airway, Breathing, Circulation and possibly Drugs: A B C D, in that order. Variations in the procedure may be needed when faced with significant prematurity.

A demonstration video is provided in the Cosy VLE.

Immediately after birth: The stop-clock should be started, or the time of birth noted in order to be able to accurately note the timing of interventions and of recovery of the baby.

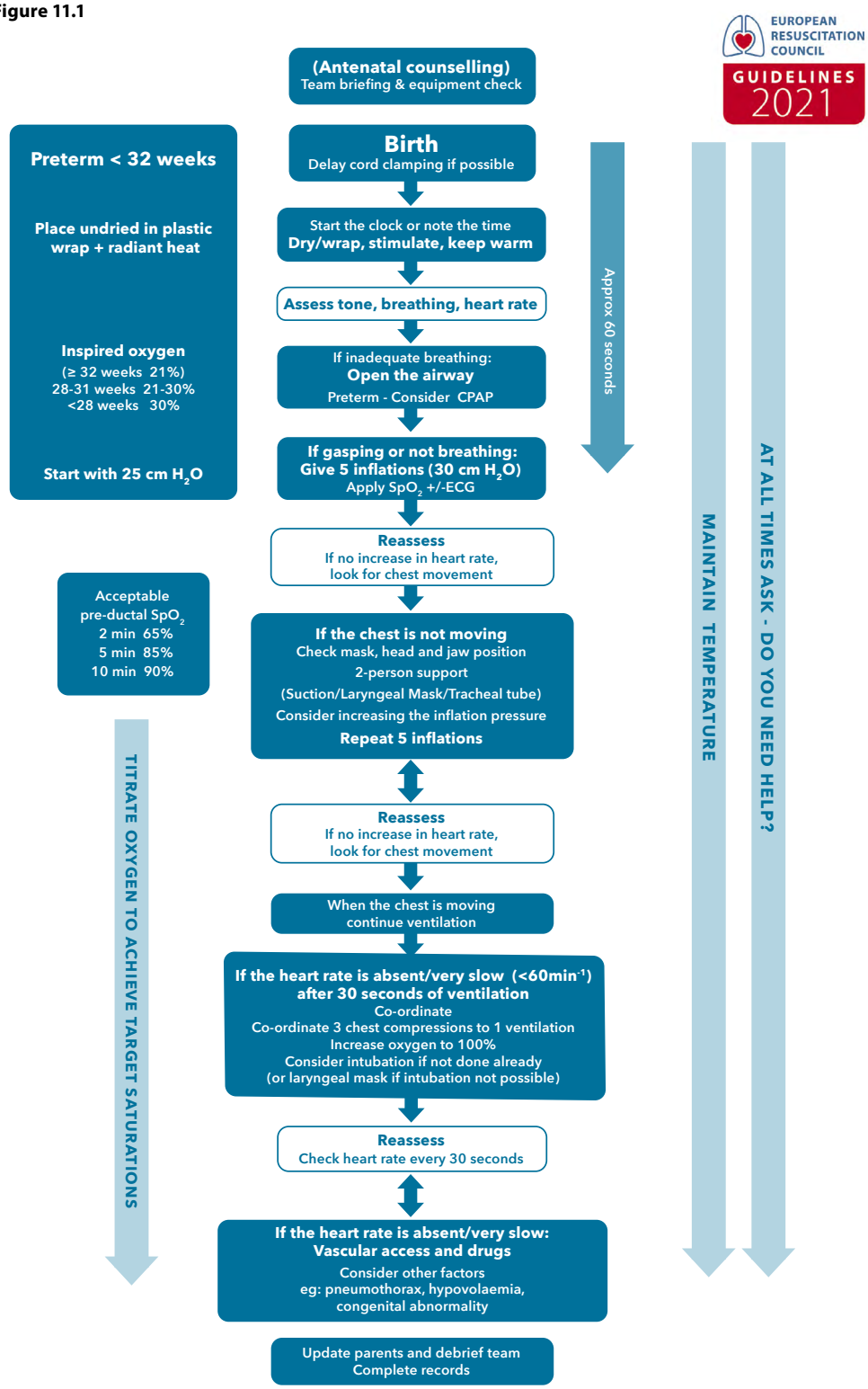
The baby should be wrapped in a warm, dry towel. The baby is then dried quickly and effectively. The wet towel should be removed and the baby wrapped in a clean dry warm towel, covering the baby's head with a hat. More vigorous methods of stimulation should be avoided. During this period it should be possible to assess the baby and decide whether any intervention is going to be needed.

Consider whether help is needed. The earlier the call for help is made, the quicker it will arrive.

The baby who is breathing regularly after drying, with a fast heart rate > 100/min and a good tone, needs no further intervention and may be handed to the mother. He can be placed on her chest and abdomen, skin-to-skin, with both covered by a blanket. Adequate warmth is provided by the mother. The upper airway may be cleared if necessary and this may be accomplished by wiping the baby's mouth and nose. Ongoing observation of breathing, activity, and colour is necessary to determine the need for additional intervention.

- For uncompromised newborns, regardless of gestational age, a delay in cord clamping of at least 1 min after complete delivery is now recommended (the baby must be maintained skin-to-skin with the mother or if that's not the case, 10 cm below the level of the placenta).

Figure 11.1



A baby who is not breathing adequately or has a heart rate < 100/min or has a poor muscle tone should be dried and covered and, if the situation allows, placed under a radiant heat source, so that further actions (ABCD) may then be taken. Immediate cord clamping will likely be needed to allow resuscitation efforts to commence promptly.

Airway

The airway should be positioned correctly and opened. The newborn's head is larger compared with the rest of his body and has a particularly prominent occiput which causes the neck to flex when the baby is lying on his back. The airway is opened by supporting the head in a neutral position. Extension or flexion of the head should be avoided, both of which can obstruct the airway. To maintain the head in a neutral position a towel folded in a thickness of 2-3 cm can be placed under the shoulders.

In floppy babies the jaw can drop back allowing the tongue to obstruct the oropharynx; the jaw-thrust manoeuvre will bring the tongue forward and open the airway. The insertion of an oropharyngeal airway may also be useful.

Suction is only needed if the airway is obstructed. Obstruction may be caused by e.g. thick meconium or blood clots. If suction is performed, a 10 Fr suction catheter or a paediatric Yankauer (at a maximum depth of 5 cm) should be used and suction time limited, otherwise vagally mediated apnoea or bradycardia may occur. Negative pressure should not exceed 150 mmHg or soft tissue injury may occur. Aggressive suctioning can delay the onset of spontaneous breathing and cause laryngeal spasm. The specific situation of meconium is detailed in the text below.

Breathing (B) & stimulation:

Most newborns are stimulated to breathe by routine drying.

If the baby has adequate spontaneous breathing and the heart rate > 100/min but there is signs of increased work of breathing and/or persistent cyanosis then start pulse oximetry and consider supplemental oxygen and/or CPAP (continuous positive airway pressure). High-flow blended oxygen can be given by a face mask, flow-inflating bag, oxygen mask, oxygen from a tubing held inside a cupped hand. CPAP can be easily provided by a T-piece device.

> **!** **Free-flow oxygen cannot be given reliably with a self-inflating bag and mask device held over the face without compression of the bag to open the one-way-valve.**
>
> **Rarely babies remain hypoxaemic despite breathing and a good heart rate because of medical conditions which include: cyanotic heart disease, pneumothorax, congenital pneumonia, surfactant deficiency, congenital diaphragmatic hernia.**

If the baby does not breathe effectively (or is gasping or apnoeic) after drying, stimulating and opening the airway, or the heart rate remains less than 100 beats/min then INFLATION BREATHS, initially with room air, should be commenced to inflate the baby's lungs.

The primary measure of adequate lung inflation is a prompt improvement in heart rate.

60 seconds after birth...: The heart rate should be checked; Pulse oximetry and ECG should be attached, if this does not interfere with resuscitation attempts. If the heart rate increases to above 100/min and the baby does not breathe spontaneously then it is merely necessary to continue gently ventilating the baby at a rate of about thirty breaths per minute until the baby starts to breathe by himself. If the baby initially responds by gasping then ventilation should be continued until normal breathing continues.

Without adequate lung aeration, chest compressions will be ineffective; therefore, where the heart rate remains very slow, confirm effective ventilation through observed chest movement or other measures of respiratory function before progressing to chest compressions.

Check for chest movement:
Visible passive chest movement with inflations indicates a patent airway and delivered volume. Failure of the chest to move may indicate obstruction of the airway, or insufficient inflation pressure and delivered volume to aerate the lungs.

If passive chest movement is not seen:

1. The mask should be reapplied and the quality of the seal checked for a good fit.
2. The head should be repositioned.
3. The inflation pressure should be increased (or rarely the duration of inflation).
4. A jaw-thrust, either single-handed or with the aid of a second person should be applied.
5. An oropharyngeal (or nasopharyngeal) airway could be considered.
6. A laryngoscope can be used to inspect the oropharynx with a large bore suction catheter to remove any obstructions seen (under direct vision).
7. Alternative methods for ventilatory support (ETT or supraglottic airway) can be attempted.

When the chest is moving:
If passive chest movement is seen and there is still no increase in heart rate (above 60 beats/min) after 30" of adequate ventilations then chest compressions should be started. Effective lung aeration should be confirmed before progressing to circulatory support.

Chest compressions are always performed in conjunction with ventilation, coordinating compressions and ventilations in a 3 to 1 ratio. Use a synchronous technique, providing three compressions to one ventilation at about 15 cycles every 30 seconds. However, the quality of the compressions and breaths are more important than the rate. Simultaneous delivery of compressions and ventilation should be avoided.

! **Reassess heart rate and breathing at least every 30 seconds.**

ONCE CHEST COMPRESSIONS...

At this stage, the current advice is to increase supplementary **oxygen towards 100%.** The heart rate and breathing should be checked every 30 seconds.

Drugs and fluids might be indicated after 30 seconds of effective chest compressions (and good lung inflation).

Drugs are rarely used when resuscitating newborns, because bradycardia is usually caused by hypoxia, and adequate ventilation and/or chest compressions results in increasing heart rate. However, in a few babies there may be no clinical improvement despite good lung inflation and 30 seconds of effective chest compressions. In this situation, stimulation of the myocardium (with adrenaline) may be attempted.

! **In the absence of an adequate response... Consider other factors which may be impacting on the response to resuscitation and which require addressing such as the presence of pneumothorax, hypovolaemia, congenital abnormalities, equipment failure etc.**

IN DETAIL:

We provide some further core information on specific parts of newborn resuscitation in the text underneath and refer to the CoSy VLE for background information and for some demonstration videos.

- **CORD CLAMPING:** Where immediate resuscitation or stabilisation is not required, aim to delay clamping the cord for at least 60 seconds. A longer period may be more beneficial. Clamping should ideally take place after the lungs are aerated. Where adequate thermal care and initial resuscitation interventions

can be safely undertaken with the cord intact it may be possible to delay clamping whilst performing these interventions.

In case of poor/failed transition (need for resuscitation), clamp cord immediately and transfer to the resuscitation platform. Delay cord clamping only if you are able to appropriately support/resuscitate the infant.

Where delayed cord clamping is not possible consider cord milking in infants >28 weeks gestation.

- **OPENING THE AIRWAY:** Place the infant on their back with the head supported in a neutral position. In floppy infants, pulling the jaw forwards (jaw lift) may be essential in opening and/or maintaining the airway and reducing mask leak. When using a facemask, two person methods of airway support are superior and permit true jaw thrust to be applied.

  An oropharyngeal airway may be useful in term infants when having difficulty providing both jaw lift and ventilation, or where the upper airway is obstructed, for instance in those with micrognathia. However, oropharyngeal airways should be used with caution in infants ≤34 weeks gestation as they may increase airway obstruction. A nasopharyngeal airway may also be considered where there is difficulty maintaining an airway and mask support fails to achieve adequate aeration.

  Airway obstruction can be due to inappropriate positioning, decreased airway tone and/or laryngeal adduction, especially in preterm infants at birth.

  Suction is only required if airway obstruction due to mucus, meconium, blood clots, etc. is confirmed through inspection of the pharynx after failure to achieve aeration.

- **INFLATION BREATHS:** For the first few breaths it may be helpful to maintain the initial inflation pressure up to 2-3 seconds to help lung expansion. This is generally best achieved by T-piece techniques but standard BMV is also adequate. The mask should fit comfortably over the baby's nose and mouth without pressing into the eye sockets or overlapping the chin.

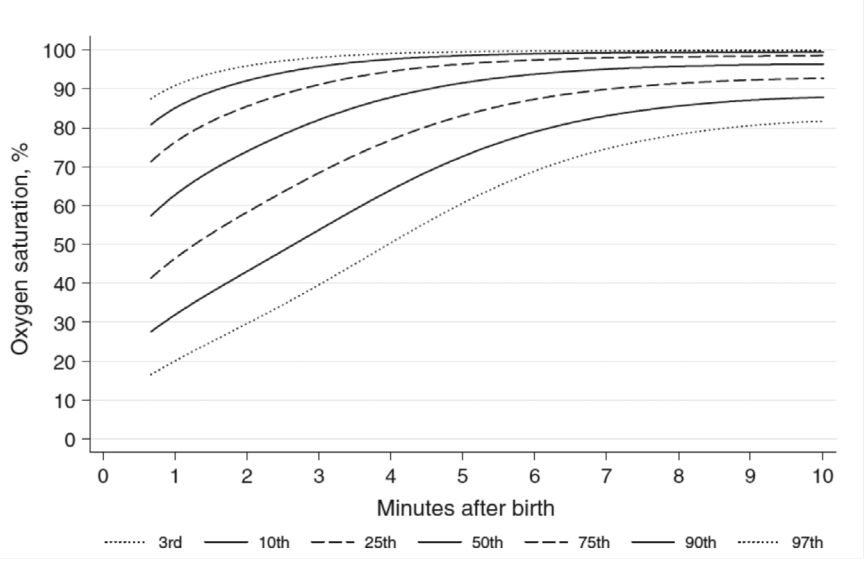
  The risk of lung volutrauma (damage to the lung caused by overdistention) should be considered because of prolonged inspiratory pressure. For term babies an inflation pressure of 30 cm, and for preterm babies 25 cm H_2O may be applied five times for up to 2-3 seconds each time.

- **OXYGENATION** At present, the standard approach to term newborns receiving resuscitation at birth with positive-pressure ventilation is to use room air instead of 100 % oxygen. If, despite effective ventilation, there is no increase in heart rate, or oxygenation (measured by pulse oximetry) remains unacceptable, higher concentrations of oxygen should be used. In preterm infants, resuscitation should be initiated in air or low concentration oxygen (21-30 %).

Thus: Resuscitation of the term baby should always start with room air. The use of supplemental oxygen should be guided by pulse oximetry or started when chest compressions are needed.

Guidance by pulse oximetry allows the possibility to apply appropriate concentration of oxygen using blenders, and thus to avoid hypoxia and hyperoxia in both, term and preterm newborns. Reliable readings can in general be obtained within 2 minutes of birth. Acceptable pre-ductal SpO_2 values are shown in the presented table. Infants born prematurely may take longer to reach 90 %. Avoid increasing the oxygen supply too rapidly (titrate to have a SpO_2 of 80% or above at 5 minutes).

Table 11.1 Acceptable SpO_2 values in newborns, related to minutes after birth



- **TRACHEAL INTUBATION:** Tracheal intubation requires training and experience. In virtually all cases it is possible to resuscitate a newborn baby using mask ventilation. Occasionally this is ineffective and tracheal intubation is required. On rare occasions, such as in resuscitating a child with a diaphragmatic hernia, use of tracheal intubation is clearly preferable. The timing of tracheal intubation will depend on the availability of someone with the appropriate skills.
- **CHEST COMPRESSIONS:** Two techniques are recommended for performing chest compressions in the newborn.
    - The two-thumb encircling hand technique is the preferred method, because it generates greater peak systolic and coronary artery pressures. One healthcare provider can manage the airway and breathing at the head end of the neonate, while another positioned toward the foot end, performs the compressions. The thumbs are placed over the lower third of

the sternum (above the xyphoid process), with the other fingers encircling the chest and supporting the back. Pressure must be briskly applied on the sternum and not over the adjacent ribs.

- If the resuscitator's hands are small and cannot encircle the chest, or encircling the chest interferes with other resuscitative efforts, such as umbilical vein catheterisation, the two-finger method may be used as an alternative. This entails placing two fingers over the sternum, at right angle to the chest, with the other hand supporting the back.

With either method, the chest should be briskly compressed to approximately one third of its anterior-posterior diameter; the compression depth should be adequate to generate a palpable pulse. Fingers or thumbs should not be lifted off the chest at any time, but chest wall should be allowed to return in its relaxed position between compressions.

Figure 11.2 Two-thumb encircling hand technique for chest compressions in a newborn

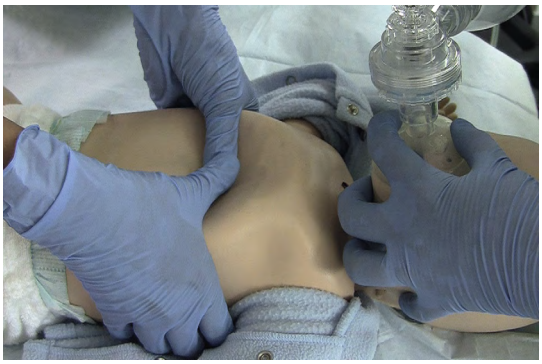
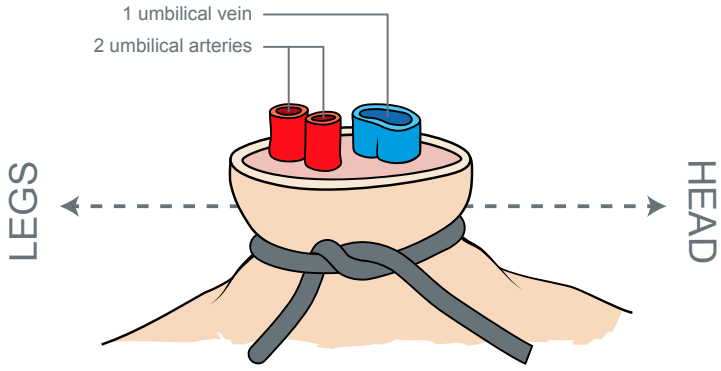


Figure 11.3 Two-finger method for chest compressions in a newborn

- **VASCULAR ACCESS:** A newborn may require a vascular access for administration of medications and fluids. Several methods of access can be used in the delivery room, but the umbilical vein is recommended for drug and fluid administration in resuscitation. The umbilical vein is easily located and cannulated (see also the video below for those interested). In the event that fluids and medications are required and attempts of gaining vascular access are unsuccessful, intraosseous access may be an effective alternative, although experience in newborns is still limited. The tracheal route is no longer recommended in the newborn, although the 2021 ERC guidelines still mention an intra-tracheal dose for adrenaline.

Figure 11.4 Umbilical vein cannulation



- **DRUGS AND FLUIDS:**

  Adrenaline: Adrenaline is indicated when the heart rate remains below 60 beats/min after 30 seconds of adequate ventilation and chest compressions. The recommended IV (or IO) first dose is 10 mcg/kg (0.1 ml/kg of a 1:10,000 solution) with subsequent IV doses of 10–30 mcg/kg (0.1-0.3 ml/kg of a 1:10,000 adrenaline) if required (every 3 to 5 minutes). If intubated and really no other access available, one could consider a dose of 50–100 micrograms/kg intra-tracheally. The concern that large doses of adrenaline may lead to prolonged systemic hypertension and subsequent intracranial haemorrhage, and the paucity of experimental data, mean that higher doses should not be used in newborns, especially in preterm infants.

  Fluid: Fluid resuscitation should be considered if there is a poor response to other resuscitative measures, and hypovolaemia is suspected or established (pale, poor perfusion, weak pulse). Hypovolaemia may be suspected even without obvious bleeding, particularly when signs of circulatory failure are present. Isotonic crystalloids are the fluids of choice. If significant haemorrhage is thought to have occurred, blood transfusion with O Rh negative red blood cells is the treatment of choice. If this is not immediately available, an isotonic

crystalloid should be used, rather than albumin-containing solutions. A bolus of 10 ml/kg is given IV (or IO) over 5 to 10 min. The exact amount and duration of administration depends on the degree of hypovolaemic shock. Ideally, correction of volume deficit should be gradual to decrease the risk of intracranial haemorrhage. The dose may be repeated after further clinical assessment and observing the changes in the vital signs.

Sodium Bicarbonate: There is no evidence to support the routine use of bicarbonate in the resuscitation of the newborn. Hyperosmolarity and carbon-dioxide production generated from sodium bicarbonate could lead to myocardial and cerebral impairments. It might be considered in a prolonged unresponsive resuscitation with adequate ventilation to reverse intracardiac acidosis.

Glucose: The heart cannot work without glucose and the glycogen stores present in the heart at birth diminish after delivery. Glycaemia should be checked if there is no response to adrenaline and hypoglycemia treated (glucose 10 % 2.5 ml/kg).

- **POST-RESUSCITATION CARE:** Newborns who required resuscitation may remain unstable or deteriorate. Once adequate ventilation and circulation are established, the infant should be admitted to a **specialised unit**, where further monitoring and treatment can be provided. Hypoglycaemia (and to a lesser degree maybe hyperglycemia) is associated with adverse neurological outcome, so blood glucose concentration should be maintained in the normal range. A continuous infusion of glucose 10% should be started at 2 ml/kg/hour. Aim to keep the temperature between 36.5 °C and 37.5 °C. Rewarm if the temperature falls below this level and there are no indications to consider therapeutic hypothermia.

  After resuscitation of the newborn, continuous monitoring and anticipation of possible complications must continue until the baby is safely **transported to a neonatal unit**.

MECONIUM

Non-vigorous newborn infants delivered through meconium-stained amniotic fluid are at significant risk for requiring advanced resuscitation and a neonatal team competent in advanced resuscitation may be required.

Routine suctioning of the airway of non-vigorous infants is likely to delay initiating ventilation and is not recommended. In the absence of evidence of benefit for suctioning, the emphasis must be on initiating ventilation as soon as possible in apnoeic or ineffectively breathing infants born through meconium-stained amniotic fluid. Should initial attempts at aeration and ventilation be unsuccessful then physical obstruction may be the cause. In this case inspection and suction under direct vision be considered. Rarely, an infant may require tracheal intubation and tracheal suctioning to relieve airway obstruction.

PREMATURITY

Prematurity greatly increases the likelihood that a baby will require some help at birth but this help is more likely to be support of a fragile infant rather than resuscitation of a nearly dead one. Preterm newborns get cold more quickly, have more fragile lungs, weaker muscles, fewer reserves and are less able to produce surfactant.

In **very preterm** infants (i.e. below 32 weeks of gestation), routine drying and wrapping may not be sufficient to maintain a good temperature. If a radiant warmer is available (and only then), these babies should be placed under that radiant warmer and then covered with food-grade plastic wrapping, apart from the face, without drying them beforehand. All resuscitation manoeuvres can be performed with the plastic cover in place. In prolonged resuscitation care should be taken to ensure that the baby is not overheated.

Delayed cord clamping or milking the umbilical cord is recommended for premature babies, who do not need immediate resuscitation.

ETHICS IN NEWBORN LIFE SUPPORT

In some circumstances, either not starting or stopping resuscitation of a newborn may be considered at or soon after birth (e.g. extremely premature infants and those with severe congenital abnormalities). International and local protocols should define the procedure to be followed in these difficult conditions. In many countries, non-initiation of resuscitation in the delivery room is appropriate for infants with confirmed gestation < 23 weeks or birth weight < 400 g, anencephaly, or confirmed trisomy 13 or 18. Conversely, resuscitation is nearly always indicated in babies with gestational age of 25 weeks or above, as well as in most of the children with congenital malformations.

The choice to provide or to withhold resuscitation may be more difficult in other settings, for instance in an emergency department, when antenatal information may be incomplete or unreliable. When the prognosis is uncertain or there is incomplete information about the pregnancy and the status of the newborn, resuscitation is recommended. This will allow time to gather more complete information and to offer counselling to the family. Ideally, in conditions associated with uncertain prognosis and high rate of severe morbidity in case of survival, parental opinions regarding resuscitation should be checked and supported, if appropriate. In fact, studies indicate that parents desire a larger role in decisions to resuscitate and continue life support in their severely compromised newborns.

When the heart rate has been undetectable for longer than 10 minutes after delivery review clinical factors (for example gestation of the infant, or presence/absence of dysmorphic features), effectiveness of resuscitation, and the views of other members of the clinical team about continuing resuscitation. If the heart rate of a newborn term infant remains undetectable for more than 20 minutes after birth despite the provision of all recommended steps of resuscitation and exclusion of reversible causes, consider stopping resuscitation. Where there is partial or incomplete heart rate improvement despite apparently adequate resuscitative efforts, the choice is much less clear. It may be appropriate to take the infant to the intensive care unit and consider withdrawing life sustaining treatment if they do not improve. Where life-sustaining treatment is withheld or withdrawn, infants should be provided with appropriate palliative (comfort focused) care.

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