Prehospital paediatric emergency care

▶ **Citation:** Kaufmann J, Laschat M, Wappler F: Prehospital paediatric emergency care. Anästh Intensivmed 2020;61:026–037. DOI: 10.19224/ai2020.026

Summary

Because prehospital paediatric emergency care is commonly rendered by non-specialist teams, always operating in a suboptimal environment, simple and feasible treatment recommendations are required. First and foremost, these are provided by the resuscitation guidelines, which provide recommendations consistent with the above premise not only for cardiac arrest but for most other important situations. The laryngeal mask airway and the intraosseous needle are essential technical adjuncts for airway management and venous access respectively. Equipment must be provisioned for each and every age bracket. Simple basic principles and support provided by references and aids can increase the safety of drug administration. Sound individual and institutional preparations for paediatric emergencies ensure safe initial care of the child prior to ongoing treatment provided by specialists.

Introduction

When considering prehospital paediatric emergency care, it is imperative to develop strategies based on a realistic analysis of circumstances and available resources, aiming to provide care at as close to optimum level as possible. Because the circumstances under which prehospital care is provided – consider for example the location, e.g. at the roadside – can per se be suboptimal, compromise is indispensable. Furthermore, competency and technical resources are not identical to those found in a specialised environment, e.g. a paediatric emergency department. In a prehospital environment, paediatric emergencies and – for example – endotracheal intubation are so uncommon that practice solely in this environment cannot provide for advanced experience [1].

More than 80% of emergency physicians are afraid of being overwhelmed by paediatric emergencies or have experienced overwhelming in such a situation [2].

Complex deficits have been described in the context of simulated scenarios [3] and prehospital emergencies [4]; for example, difficulties with endotracheal intubation arose in 2/3 of children with head injuries, whilst the same was only true of 1/5 of adults in the same health care setting. At the same time, intravenous access was successfully established in 86% of adults investigated, whilst the same could only be said of 66% of children [5]. The European Resuscitation Council (ERC) Guidelines note that due to real-life limitations, the recommendations must be "simple and feasible" [6]. Even though it may seem remarkable to read this in the preamble of a guideline, it is precisely this basic nature, seeking compromise, avoiding excessive burdens on the user and providing a clear, easily remembered

1 Abteilung für Kinderanästhesie, Kinderkrankenhaus der Kliniken der Stadt Köln gGmbH (Direktor: Prof. Dr. F. Wappler)

2 Fakultät für Gesundheit, Universität Witten/Herdecke (Dekan: Prof. Dr. S. Wirth)

Keywords
Prehospital emergency care – Children – Drug safety – Treatment recommendations

and practicable course of action which is its greatest quality. It is as such that these guidelines offer an essential contribution to safe paediatric emergency care.

Based on the aforementioned prerequisites, this review takes into account the feasibility and effectivity of recommended measures and adjuvants. Those measures which are either indispensable (e.g. intraosseous access) or which – whilst requiring only a small effort – would be expected to significantly enhance the safety of paediatric emergency care (e.g. the laryngeal mask airway) are emphasised. A potential desire for paediatric emergency care to be rendered solely by designated experts in the field is surely an example of the opposite – a measure requiring insurmountable effort, especially considering that the required number of experts couldn't even be provided. Good preparation in a "protected environment" (e.g. simulated scenarios), knowledge of current, simple, structured guidelines and the use of adjuvants enable non-specialised emergency physicians to provide safe care [7].

Typical challenges

Oxygenation

Significance of ventilation for paediatric emergencies

In contrast to adult resuscitation, in which cardiac arrest mostly arises from a cardiac incident, in children and especially in a prehospital environment, **respiratory causes** are usually foremost [8]. Here, cardiac arrest is typically the result of a respiratory incident leading to myocardial hypoxia. Whilst in an ideal scenario, adults whose cardiocirculatory arrest due to ventricular fibrillation is rapidly terminated by defibrillation won't necessarily suffer tissue hypoxia, the respiratory cause of cardiac arrest in children means that serious organ damage has already ensued. This is a major factor in the lower rate of survival in infants following cardiac arrest when compared with youths or adults [9]. A more favourable rate of survival in those few children presenting a cardiac rhythm amenable to defibrillation (approx. 5% of cases) underscores this mechanism.

Due to the typical pathophysiology of cardiac arrest, oxygenation and ventilation are the most important measures in paediatric resuscitation.

- As demonstrated by clear evidence and ascertained by all international guidelines, resuscitation of a newborn **is not possible without successful ventilation**, and chest compressions without ventilation are actually neither helpful nor indicated [10,11].
- Whilst, at least for lay persons providing telephone-guided aid, resuscitation of adults may be performed forgoing ventilation and providing chest compressions only [12], the resuscitation of children has been shown to be associated with a significantly higher rate of survival with good neurological outcome when lay persons provide chest compressions **and rescue breaths** [13].
- A further observational study involving prehospital paediatric resuscitation also showed conventional resuscitation incorporating ventilation to be superior. A relatively small group of children who received only ventilations without chest compressions showed even better "good neurological" outcomes [14]. This group was too small to deliver a statistically definitive result, but the finding underscores the **importance of ventilation** for the survival of children even **outside the neonatal period.**
- In addition, clinical experience shows very clearly that **infants and toddlers cannot be resuscitated without ventilation.** As such, measures and adjuncts which enable safe ventilation of children are indispensable and, whilst requiring only a small effort, have a significant effect on patient survival.

Even outside of resuscitation, providing oxygenation and ventilation to children takes on a central role. This is because – due to their relatively **high oxygen consumption and small pulmonary residual volume** relative to body weight – the reserve in children is small and they will suffer a decrease in oxygen saturation within seconds following respiratory arrest. On the other hand, the anatomy is advantageous when compared with that of the adult, with the larynx situated relatively higher and a factually difficult airway being rather less common. It has been shown that experience and clear strategies can significantly increase safety when managing the paediatric airway.

Airway management

Only approximately 5% of prehospital emergencies in Germany involve children, and of those only approximately 5% require endotracheal intubation. Therefore, statistically speaking, emergency physicians will perform prehospital endotracheal intubation of a child once every 3 years, and of an infant once every 13 years [1].

Airway management routine cannot be established only by experience as an emergency physician.

Even in paediatric emergency departments, emergency intubation performed by paediatric medical staff was associated with a serious drop in oxygen saturation in almost half of the cases. 2 out of 116 children even **suffered hypoxic cardiac arrest** [15]. **Prehospital intubation** associated with a lower rate of complications and higher rate of success can only be achieved by physicians who intubate children on an everyday basis. It is for these reasons that the ERC guidelines note that only those who have safe command of drugs required for intubation and are proficient in preoxygenation and intubation should consider prehospital intubation [6]. In all other cases **supraglottic airways** should be the airway adjuncts of choice. Under no circumstances may repeated intubation attempts be made, as these may lead to prolonged apnoea and can cause swelling and bleeding, leading to a total loss of the airway.

A prehospital trial involving more than 800 children suffering grave conditions (cardiac arrest, multiple trauma, head injuries) failed to show any difference in the survival rate or neurological outcome between those primarily successfully intubated and those who were mask ventilated [16]. Seeing then that even successful intubation cannot positively influence the outcome, the rationale behind intubation needs to be questioned. However, mask ventilation by itself is certainly also not an ideal ventilation strategy in a prehospital setting; it binds at least one person continuously and can be difficult to perform. At that point at the latest, the use of a supraglottic airway is required.

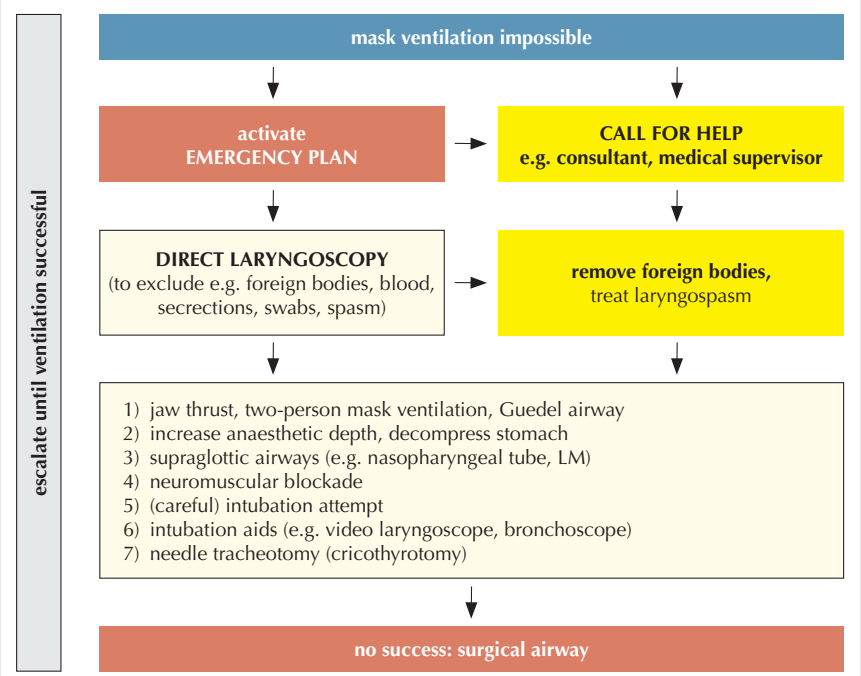
For situations when mask ventilation is not successful, a clear and simple strategy needs to be available for immediate recall and easy implementation (Fig. 1). The measures set out should be escalated step by step until ventilation of the child is successful. To a significant extent, the algorithm equates to the recommendations of the Scientific Working Group for Paediatric Anaesthesia (WAKKA) of the German Society of Anaesthesiology and Intensive Care (DGAI) [17]. However, the authors are of the opinion that laryngoscopy should be performed at an early stage of management, especially in a prehospital setting. This way airway obstruction by a foreign body or secretions can be detected at an early phase. It is not necessary to force the laryngoscope into a deep position as for intubation; instead it can be sufficient simply to open and light up the mouth, making it possible to detect the aforementioned complications, suction the airway or remove a foreign body using Magill forceps.

It is extremely unlikely that, following immediate and complete implementation of the measures set out, ventilation should remain impossible by the point at which a laryngeal mask airway is used.

Based on their own experience however, the authors do not share the WAKKA recommendation that invasive techniques (cricothyrotomy, tracheotomy, surgical airway) are never required. Needle cricothyrotomy cannot realistically be performed on infants and toddlers as the location coincides with the narrowest section of the paediatric airway and the short neck forces the operator to adopt a very steep approach [18, 19]. If anything, needle tracheotomy, which likewise is difficult, should be attempted; the procedure is possible with a less steep approach, and the tracheal lumen is wider at this location [20]. If at all possible, however, surgical tracheotomy – a procedure which can be performed by an experienced surgeon (including paediatric surgeons) within a small number of minutes – should be preferred [21].

The laryngeal mask airway (LM) is the airway adjunct which has been most thoroughly examined in good clinical trials for both elective and emergency use, is most commonly used, and as such is the supraglottic airway adjunct which can best be recommended for use in children from 1.5 kg body weight (BW) upwards [22]. Evidence for the use of the laryngeal tube (LT) is not comparable and consists solely of a small number of studies demonstrating successful use in children from 10 kg body weight upwards. Despite this fact, the LT is used surprisingly often in prehospital settings. However, according to current consensus reached by numerous professional bodies, provisioning the LT only whilst forgoing the LM as the clearly "better" airway adjunct, cannot be recommended. At the same time, provisioning both devices (LM and LT) and thereby promoting confusion, increasing costs and taking up additional space would seem less than ideal [22]. For a brief period at least, during intubation or when neither an LM nor an LT are available, sufficient ventilation can almost always be provided using a nasopharyngeal tube (pharyngeal tube; a nasally inserted tube in the "Wendl position") whilst manually providing closure of the mouth and contralateral nostril. It is imperative that all the aforementioned adjuncts and techniques

Figure 1



Algorithm for the management of difficult mask ventilation in a child.

should be trained in the context of job shadowing or through participation in simulated scenarios before they are used in paediatric care.

Cardiocirculatory support

Blood pressure by age

There is good evidence that age adapted normal blood pressure values (Tab. 1) are a sufficient therapeutic goal even in emergency situations with increased cerebral pressure [23] and as such should be achieved, but not overstepped [24]. It is also clear that failing to reach these values can cause serious damage.

Rational infusion therapy

Adequate fluid therapy is the basis of sufficient circulatory support. To avoid hyponatraemia and cerebral oedema only balanced electrolyte solutions may be used. When treating infants (<1 year of age), the use of solutions containing **additional glucose (1%)** is expedient, if available in the prehospital setting. Patient safety considerations, however, mean that individual blending of such solutions cannot be recommended. Instead, **intravenous boli of 0.1–0.2 g/kg BW glucose** can be used to treat low blood glucose levels, which should be determined for every infant and when confronted with altered consciousness.

Acetate-based balanced electrolyte solutions are the most suitable fluids for maintenance and fluid replenishment.

Basal requirements can be calculated using the **4-2-1 rule:**

- 4 ml/kg/h for every kg for the first 10 kg BW,
- 2 ml/kg/h for every kg for the next 10 kg BW,
- 1 ml/kg/h for every additional kg BW.

To balance deficits caused e.g. by preoperative fasting, in keeping with the above recommendation for basal requirements, the basal requirement for the first hour can be assumed to be a blanket 10 ml/kg/h [26]. Children suffering exsiccosis in the context of vomiting and diarrhoea or inadequate fluid intake due to poor health require larger fluid volumes. The fluid deficit can be categorised by weighing the child or by clinical assessment (Tab. 2, taken from [27]). In addition, respiratory variation of the pulse oximeter plethysmograph can point to serious hypovolaemia.

Deficits resulting in haemodynamic disruption and any other situation in which blood pressure is insufficient with-

Table 1

Age adapted blood pressure range (min – max) considered safe [25].

Age group	Age adapted blood pressure	
Preterms (approximation)	Mean arterial pressure = gestational age in weeks	
	systolic pressure	**mean arterial pressure**
Preterms	55–75	35–45
0–3 months	65–85	45–55
3–6 months	70–90	50–65
6–12 months	80–100	55–65
1–3 years	90–105	55–70
3–6 years	95–110	60–75
6–12 years	100–120	60–75
>12 years	110–135	65–85

Table 2

Estimating fluid loss (dehydration) based on clinical signs [27].

Signs and Symptoms	minimal/no dehydration	slight/medium dehydration	severe dehydration
Weight loss	<3%	3–8%	≥9%
Consciousness, health	normal	agitated, irritable or tired	apathetic, lethargic, unconscious
Drinking	normal	thirsty, drinks greedily	drinks poorly or is unable to drink
Heart rate	normal	normal to increased	tachycardia; severen cases: bradycardia
Pulse quality (comparison of central vs. peripheral pulses)	normal	normal to decreased	weak or not palpable
Respirations	normal	normal to deep; increased resp. rate	deep breathing (acidosis!)
Eyes	normal	sunken	deeply sunken
Tears	present	reduced	none
Mucosa	moist	dry	desiccated
Skin folds	smooth immediately	delayed smoothing, but ≤2 s	standing >2 s
Capillary refill	normal	prolonged (<3 s)	severely prolonged (>3 s)
Urine production	normal	reduced	oliguria or anuria
Fluid loss (ml/kg BW)*	<30	mild 30–50 medium 50–100	>100

Resp.: Respiratory; **BW:** Body weight;
* for children <6 years of age; school children and adults require smaller fluid volumes due to their smaller extracellular space relative to body weight.

out clear cause should be treated by administration of a 20 ml/kg BW fluid bolus with subsequent re-evaluation [6]. Current knowledge suggests that for children with fever and serious infectious disease (e.g. pneumonia, sepsis) fluid should, when possible, only be administered in this fashion once [28] and catecholamines introduced early. Repeated administration may be necessary, especially when treating exsiccosis and hypovolaemia; however, an (additional) drop in haemoglobin levels through haemodilution should be kept in mind. Whilst the use of colloids is typically not necessary and their value unclear, attempted treatment of an otherwise unstable circulatory situation by administration of 5–10 ml/kg BW, taking the manufacturer's recommendations regarding contraindications and maximum doses into account (e.g. 6% HES 130/0,42: 30 ml/kg), can be justified [27].

Rational use of catecholamines

The aim of treatment with catecholamines is to re-establish adequate perfusion and oxygenation of the organs. A significant intraindividual variability in pharmacokinetics and -dynamics [29] and the effect of catecholamines can be observed in infants and toddlers (due, amongst other things, to individual receptor density and intracellular response [30,31]). When there is no response to treatment, increasing the dose by one order of magnitude is recommended, titrating down once an effect ensues [32]. Another peculiarity when compared to the treatment of adults is the use of dopamine which, on the basis of available data, is still the most commonly used catecholamine in newborns, infants and toddlers [32,33]. Table 3 summarises the catecholamine of choice for treatment of different types of shock in children based on current guidelines [34–42] and provides "rules of thumb" for preparation of and dosing with syringe drivers.

Even for septic shock, noradrenaline is not the catecholamine of choice in children because the increase in afterload rapidly leads to a decrease in contractility [32]. As such, noradrenaline should be carefully titrated and used only in conjunction with an inotropic catecholamine.

In prehospital situations, safe and rapid treatment with catecholamines can be difficult to implement, particularly because drug choice and dose are often unfamiliar, and dopamine and in some cases syringe drivers, are not routinely provisioned by emergency services. As such, it is necessary to stabilise the cardio-circulatory situation during transfer to a paediatric intensive care or emergency facility using a simple and safe concept. Cafedrine/Theodrenaline (Akrinor®) is an example of a suitable drug. The manufacturer's summary of product characteristics recommends the following doses [43]: "…Children: depending on the severity of the condition, in the 1st and 2nd years of life 0.2–0.4 ml, in the 3rd to 6th years of life 0.4–0.6 ml, from the 7th year of life on 0.5 to 1.0 ml administered intramuscularly or intravenously as a single dose…" Experience suggests that a quarter of this dose should be given initially and the drug then titrated according to effect. It is also possible to bolus 0.5 (-1) µg/kg adrenaline, whereby the effect is short lived and repeat doses may be required.

Injecting the contents of a 1 ml = 1 mg ampoule of adrenaline into a bottle containing 100 ml of isotonic saline (NaCl 0.9%) results in a concentration of 10 µg/ml, which can then be dosed highly accurately using 1 ml syringes with a 0.01 ml scale.

Gaining access for drug administration and fluid therapy

Placement of an intravenous catheter can often be difficult in paediatric emer-

Table 3
Prehospital treatment of children with haemodynamic shock using catecholamines.

Type of shock	Catecholamine	Dose	Rules of thumb a) Preparation b) Dosing c) Escalating treatment
hypodynamic/ cardiogenic, preterms and newborns	dopamine	5–20 µg/kg/min	a) 1 ampoule dopamine 5 ml = 50 mg; 1 ml = 10 mg + 29 ml NaCl 0.9% → 0.33 mg/ml b) rate (ml/h)) = body weight equating to 6 µg/kg/min c) dobutamine, hydrocortisone, adrenaline
hypodynamic/ cardiogenic, all other age brackets	dobutamine	5–20 µg/kg/min	a) 1 ampoule dobutamine 50 ml = 250 mg; draw up undiluted → 5 mg/ml b) rate (ml/h) = 1/10th body weight age brackets equating to 8 µg/kg/min
hypovolaemic	adrenaline	0.05–2.5 µg/kg/min	a) 1 ampoule adrenaline 1 ml = 1 mg; 6 ml = 6 mg + 44 ml NaCl 0.9% → 0.12 mg/ml b) rate (ml/h) = 1/10th body weight equating to 0.2 µg/kg/min
septic	adrenaline	0.05–2.5 µg/kg/min	a) 1 ampoule adrenaline 1 ml = 1 mg; 6 ml = 6 mg + 44 ml NaCl 0.9% → 0.12 mg/ml b) rate (ml/h) = 1/10th body weight equating to 0.2 µg/kg/min c) noradrenaline carefully titrated, only if extremities warm
additionally, as required:	noradrenaline	0.05–2.5 µg/kg/min	a) 1 ampoule Noradrenalin 1 ml = 1 mg; 6 ml = 6 mg + 44 ml NaCl 0.9% → 0.12 mg/ml b) rate (ml/h) = 1/10th body weight equating to 0.2 µg/kg/min

gencies and may be impossible in some circumstances, e.g. exsiccosis or cardiac arrest. In prehospital emergencies of this kind, placement of **a central venous line is inarguably not a suitable alternative.**

The intraosseous (IO) needle is a quick, easy and safe adjunct for access to the vascular system.

Complications are rare and are only to be expected when the needle remains in situ for prolonged periods of time. The current ERC Guidelines recommend the use of an IO needle in all **critically ill children in whom venous access has not been able to be established within one minute** [6]. The most suitable and typical location in children is the proximal anterior tibia. Use of IO needles can be trained using chicken bones, which provide for very realistic conditions. It is essential that training should take place before taking on work in emergency care. Intraosseous drills (EZ-IO®, Teleflex), which are widely available in Germany, are not suitable for newborns and small infants weighing less than 3 kg. The tibial spongiosa is so shallow in these children that there is a risk the posterior cortex could be pierced, leading to serious damage or even requiring amputation of the lower leg [44]. Instead, suitable manual needles need to be provisioned. The authors have had very good experience using **18 g butterfly needles** in these situations, as is also recommended elsewhere [45]. They can easily be gripped by the wings, are very sharp and have a tube attached, simplifying the use.

For on-off administration of sedatives and analgesics, the **intranasal route** using an atomiser ("mucosal atomization device" – MAD) is an option. The intense vascularisation of the nasal mucosa and the close proximity to the brain lead to a **rapid onset of action comparable** with that following intravenous administration.

Owing to venous drainage avoiding liver passage, first-pass metabolism does not occur following nasal administration of drugs, and most drugs achieve bioavailability similar to that following intravenous administration.

Doses **similar to those used for intravenous administration** can often be used for intranasal administration. The total should always be split across both nostrils so as to utilise the maximum possible mucosal surface. Administered volumes should preferably be 0.2–0.3 ml per nostril and should not exceed 1 ml. Copious quantities of secretions or blood can inhibit adequate resorption from the nose, making cleansing or selection of an alternative method necessary. Published experience is available especially for

- midazolam
- fentanyl
- sufentanil
- ketamine and
- dexmedetomidine

Drug safety in paediatric emergency care

Grave errors occur regularly during paediatric emergency care, even in specialised facilities such as paediatric emergency departments.

Because **suitable doses** have to be **calculated on an individual basis**, mistakes such as misplacing the decimal point can lead to results which are off by an order of magnitude. Whilst typical doses feel familiar when treating adults, the wide range of paediatric patients – ranging from infants to youths – precludes familiarity with correct doses. Even doses off by an order of magnitude can be serviced from a single ampoule, making recognition of the error less likely. Because prehospital care is neither rendered in a specialised environment, nor by specialised personnel [6], significantly increased error rates are incurred. A study in the USA showed that adrenaline was administered incorrectly 60% of the time, and that the average overdose was 808% of the recommended 10 µg/kg BW dose [46]. Whilst it is not known from which point on overdosing adrenaline is potentially fatal, there is no doubt that overdosing by an order of magnitude (1,000% of the recommended dose; 100 µg/kg BW) is not compatible with survival [47]. All international guidelines warn explicitly of overdosing adrenaline during resuscitation of paediatric patients of any age. **Vigilance** derived simply from awareness of the danger and recognition of personal fallibility is pivotal for drug safety [48].

Using simple measures can help achieve a significant increase in drug safety when caring for children [49,59].

It can safely be assumed that any measure which reduces the cognitive load of the prescribing physician will increase drug safety in children.

In a test of written orders for adrenaline administration for resuscitation, for example, **use of a simple table** was shown to avoid nine out of ten single order of magnitude errors, and the same fraction of errors by two orders of magnitude [51]. A similar effect was also seen when the Paediatric Emergency Ruler ("PädNFL"; "Pädiatrisches Notfalllineal"; www.notfalllineal.de) was used during treatment of "real" prehospital paediatric emergencies: nine out of ten severe dosing errors (> 300% of the recommended dose) of all drugs studied were avoided [52]. With regard to adrenaline, which was overdosed by more than 300% of the recommended dose in all cases where the PädNFL was not used, no mistakes were made when using the PädNFL.

Body weight is a deciding factor for drug administration and must, as such, be taken into meticulous consideration. In a prehospital analysis in Germany only 0.5% of emergency physicians' records specified the weight of the child [52]. If the parents can give the weight of the child, that weight should be used. When the weight is unknown however, estimates based on age are unhelpful and **weight should be estimated based on length.**

Team communication is pivotal. Regardless of any hierarchy, all those involved must check every order in its entirety (weight of the child, desired dose per kg BW, calculated dose and quantity to be administered) and acknowledge it by repeating the entire order before a drug is administered [53]. When 1 ml syringes with a 0.01 ml scale are used, dilution can be avoided for most drugs so long as administration is followed by flushing with NaCl 0.9%. Every emergency physician should have paediatric pharmacologic information (e.g. age-specific contraindications and doses) at their disposal on scene, e.g. in the shape of a tabular compilation or pocketbook.

Common paediatric disorders

Preliminary remarks

The three most common prehospital paediatric disorders, each accounting for approximately a third of cases, are injuries, respiratory disorders and seizures.

In addition to these three, intussusception (which does not occur in adults), abdominal pain caused by systemic lymphadenopathy in the context of infection, and unexplained events are described below.

Trauma

Most injuries are isolated to a single extremity. The same basic principles used in adult trauma care should be applied, adequate analgesia provided, and the injury stabilised carefully. Using suppositories in an emergency situation is unlikely to provide a rapid and adequate effect. Instead, administering opioids such as fentanyl via a nasal atomiser [54] or using one of the alternatives set out in Table 4 [55] is well suited.

As a rule, care for children with multiple trauma follows the same basic principles which apply to adult care [56].

Owing to their proportions and skeletal development, however, up to 90% of children with serious injuries also have head injuries, while the chest and abdomen are less commonly affected when compared with adults. It is noteworthy that children may regularly suffer serious intracranial injury without showing external signs (such as bruising or neurological symptoms). For this reason, serious trauma requires neurocranial imaging, preferably in a paediatric radiology department. Prior to fusion of the fontanelles, ultrasound is a rapid, radiation-free imaging tool, while all other children with a score of <12 on the Paediatric Glasgow Coma Scale should undergo computed tomography (CT) or magnetic resonance imaging (MRI). Bony injuries are better seen on CT, whilst brainstem injuries and haemorrhage are better represented on MRI. Subgaleal haemorrhage represents a special type of head injury which does not occur in adults, and which involves haemorrhage between the scalp and the calvaria. As the haematoma may spread around the whole head, blood loss may become life-threatening and must be recognised as such, triggering blood transfusion if required. External compression is not helpful, and obsolete in the case of open fontanelles. Those providing prehospital care should be aware of subgaleal haemorrhage and include assessment for this injury in their trauma evaluation, which would otherwise be comparable with an appropriate adult routine. In contrast, pelvic fractures leading to significant blood loss do not occur in toddlers.

Table 4
Examples of suitable prehospital emergency analgesia.

Drug, mode of delivery	Dose, Dosing interval
Piritramide (e.g. Dipidolor)	
• IV	0.05–0.1 mg/kg BW initial bolus 0.025 mg/kg BW every 5 min until pain free
Morphine	
• IV	0.05–0.1 mg/kg BW initial bolus 0.025 mg/kg BW every 5 min until pain free
Fentanyl (ampoules containing 50 µg/ml)	
• IV	1–2 µg/kg BW initial bolus 0.25 µg/kg BW every 5 min until pain free
• intranasal using MAD	1.5 µg/kg BW (0.03 ml/kg BW)
Esketamine (e.g. Ketanest S, ampoules containing 5 mg/ml or 25 mg/ml)	
• rectal	10 mg/kg BW
• IV	0.5–1 mg/kg BW
• intranasal using MAD	2 mg/kg KG
Ketamine (e.g. Ketamin, ampoules containing 10 mg/ml or 50 mg/ml)	
• rectal	15–20 mg/kg BW
• IV	1–2 mg/kg BW
• intranasal using MAD	4 mg/kg BW

MAD: mucosal atomization device (nasal atomiser).

Respiratory emergencies

Asthma

Sudden occurrence of dyspnoea with an expiratory stridor and prolonged expiration should bring a diagnosis of asthma to mind. In addition to auscultation, the smaller the child, the more helpful laying hands on the chest can be – bronchospasm, secretions, consolidation and the breathing pattern can all be felt and localised. Therapeutic measures (Tab. 5) don't differ from those employed in adults [7], and inhaled therapies don't require age-based dose adjustment.

Croup syndrome (stenosing laryngotracheitis)

Sudden occurrence of an inspiratory stridor together with a barking cough is usually caused by Croup syndrome which generally arises in conjunction with viral infections, but which may

Table 5
Pharmacological treatment for asthma attacks (from [7]).

Nebulised treatment	
Epinephrine (e.g. Infectokrupp®)	up to 10 kg BW: 1 ml + 1 ml NaCl 0.9 % (= 4 mg) from 10 kg BW: 2 ml undiluted (= 8 mg)
Salbutamol nebuliser solution (e.g. Sultanol® sol.)	5 – 10 drops (= 1.25 – 2.5 mg) (1 drop per year or 3 kg BW, minimum 3, maximum 10 drops) in 2 ml NaCl 0.9%
Ipratropium bromide solution (z. B. Atrovent® sol.)	5 – 10 pumps (= 0.125 – 0.25 mg) Dose as for salbutamol, in 2 ml NaCl 0.9%
Inhalation using a spacer	
Salbutamol (e.g. Sultanol®)	1 – 2 puffs (0.1 – 0.2 mg)
Fenoterol (e.g. Berotec®)	1 – 2 puffs (0.1 – 0.2 mg)
Terbutaline (e.g. Bricanyl®)	1 – 2 puffs (0.25 – 0.5 mg)
Corticoids	
Methylprednisolone (e.g. Urbason®)	2 – 4 mg/kg BW IV
Prednisolone (e.g. Decortin H®, Solu Decortin®)	2 – 10 mg/kg BW IV
Prednisone (e.g. Decortin®, Rectodelt®)	5 – 10 mg/kg BW (usually 100 mg) per rectum
β_2 mimetics IM	
e.g. Epinephrine or Terbutaline	10 µg/kg BW (max. 300 µg)
Additional Options	
Magnesium, Ketamine, Theophylline	

occur spontaneously, and which in turn is caused by subglottic swelling of mucous membranes. Croup is seldom threatening and can be treated in an equivalent fashion to asthma. The differential diagnoses include **tracheitis** and **epiglottitis** (see below), both of which can be differentiated from Croup by a prolonged progressing course and high fever. In unvaccinated children especially, hoarseness, inspiratory stridor and a barking cough – which can typically be triggered by applying pressure on the tongue using a spatula – progressing over days may indicate **diphtheria**, a disease once referred to as "real Croup".

Epiglottitis, Tracheitis

Since the introduction of the Haemophilus influenza B vaccination, epiglottitis has become extremely rare, but does still occur because not all parents go through with recommended vaccinations – but also because other pathogens can be causative. The clinical picture seen in epiglottitis is similar to that seen in croup syndrome and is characterised by **inspiratory stridor** and **coughing**. However, unlike Croup syndrome, children with epiglottitis show signs of serious bacterial infection including high fever and notable poor general condition. **Preclinical intubation** should only be attempted in dire straits and can be extremely problematic in the presence of purulent swelling of the epiglottis. The receiving hospital should be informed of the suspected diagnosis as early as possible so as to be able to have an experienced team available for the patient on arrival. Tracheitis, which cannot be differentiated from epiglottis clinically, has become the most common form of life-threatening respiratory tract infection. The diagnosis can only be made by bronchoscopy. As a rule, these children can be intubated without difficulty; even so, intubation should be performed using a fibreoptic scope, taking samples and ensuring precise placement of the tube at the same time.

Foreign body aspiration

Foreign body aspiration typically occurs when a playing child inserts something into their mouth or eats something with a smooth surface in a restive situation. Initially, the foreign body enters the trachea, causing an impressive bout of coughing, expelling the foreign object. If instead the foreign body reaches the bronchial system, the child's condition will commonly improve [57]. However, in the course of things, the object may dislocate into the trachea causing a life-threatening situation. As such, following aspiration, children should always present to a competent hospital where any suspicion of aspiration should be investigated by bronchoscopy. Chest radiographs on the other hand do not provide any helpful information [57].

In the case of an unconscious child, the **oral cavity must be inspected and swept** without delay, followed immediately by measures as set out in the resuscitation guidelines. These describe in detail the measures to be taken in case of foreign body aspiration (including, amongst other things, the Heimlich manoeuvre and back blows) [6]. The oral cavity should be inspected using a laryngoscope as soon as possible, removing any visible foreign objects. If the condition does not improve, the child should be intubated. If ventilation is not possible via the correctly situated tube, attempts should be made to push the foreign body into one or the other main bronchus by intentional deep insertion of the tube, following which ventilation of the unrestricted lung should be performed after retracting the tube into the trachea. If the aforementioned measures are not successful, success is not to be expected and the child should be transferred to hospital undergoing ongoing resuscitation, where the foreign body can be removed from the trachea.

Seizures

Although seizures in children are usually febrile, other possible causes must be considered:

- hypoglycaemia
- intoxication
- head injury

Meningitis must be excluded in infants suffering a febrile seizure without an obvious focus of infection. Repeated application of rectal drugs, which are

difficult to control and have a delayed onset of action, can cause overdose and respiratory depression. As such, the use of drugs and routes of administration set out in Table 6, leading to a rapid onset of action, would seem better suited [7].

Abdominal lymphadenopathy and intussusception

Regardless of the focus of infection, toddlers regularly suffer swelling of the abdominal lymph nodes, causing abdominal pain. This can lead to an erroneous diagnosis of an abdominal disorder, which in turn can sometimes even culminate in unwarranted surgery.

Children complaining of abdominal pain must always be investigated for a focus of infection outside the abdomen, e.g. by auscultation of the lungs and inspection of the tympanic membranes.

The swollen abdominal lymph nodes may, however, actually cause a real abdominal emergency, namely **intussusception**. This usually occurs at the ileocecal junction and involves parts of the intestine folding into one another, typically triggering abrupt, severe spasmodic pain. Bloody diarrhoea may also occur. Spontaneous reduction of intussusception can occur, although delaying treatment whilst hoping for spontaneous resolution is not permissible as there is a risk of necrosis of the affected portions of the intestines when untreated. The diagnosis is made using sonography and treatment by reduction of intussusception by insufflation of air or fluid can be provided by the radiology department of any paediatric hospital.

Unexplained events

Emergency services are regularly confronted with reports of events perceived to be life-threatening, whilst the elicited history doesn't provide for clear-cut deductions and the child presents itself in good health. Formerly an **apparent life-threatening event (ALTE)**, this expression has been replaced by the term **brief resolved unexplained event (BRUE)**. This nomenclature was chosen so as to include events which had not been interpreted as life-threatening. Despite this, the term still defines a condition involving a change in

- muscle tone
- skin colour
- consciousness
- and/or breathing.

A working diagnosis of BRUE is only permissible if a detailed history and examination by a paediatrician shows no further irregularities. Colloquially, the term "unexplained event" is often used. Generally speaking, these events have a multitude of possible causes, including gastroesophageal reflux, seizures and upper respiratory tract infections. **Cardiopulmonary causes, however, are very rare.** Adherence to guideline-recommended treatment of BRUE requires the emergency services to present children for treatment by a consultant paediatrician at a children's hospital [58]. Following thorough examination by the paediatrician, immediate discharge from hospital may be justified.

Table 6
Pharmacological treatment for seizures.

Sublingual tablets	
Lorazepam (e.g. Tavor® Expidet®)	<0.05 mg/kg BW administered as a sublingual tablet
Intranasal administration	
Midazolam* (e.g. Buccolam®, Dormicum®)	0.2 mg/kg BW (maximum 10 mg)
Lorazepam (e.g. Tavor® pro injectione)	0.1 mg/kg BW (maximum 4 mg)
Intravenous drug administration	
Clonazepam (e.g. Rivotril®)	0.05–0.1 mg/kg BW IV (max. 2 mg)
Midazolam (e.g. Dormicum®)	0.1–0.2 mg/kg BW IV or intranasal
Diazepam (e.g. Valium®)	0.05–0.2 mg/kg BW IV
Thiopental (e.g. Trapanal®)	1 mg/kg BW IV

* midazolam solutions for IV administration cause smarting when administered intranasally.

The role of parents during emergency care

Presence of parents

Whenever possible, parents should have the opportunity to be present during treatment of their children.

On one hand, parents are generally well informed of the past medical history of their child, can tell the precise weight and offer the only possibility to elicit a history. On the other hand, it has been shown time and again that relevant psychopathologies are significantly less common in parents who were present for at least some of the treatment of their child, even when the child died. As such, the resuscitation guidelines recommend parents should be given the opportunity to be present during treatment of their child, so long as their presence does not impact on the quality of medical care [6].

Child abuse and neglect

It should not be overlooked, however, that parents may play a role in or be the cause of the illness or injury. Parents smoking at home, for example, may be the sole cause of asthma in their child. To an often underestimated degree, children may be the **victims of violence or neglect.** The most recent available figures show an incidence of 10–15% in Germany, although a significant dark figure has to be assumed. A review article looking at head injuries in children determined that a quarter of all injuries in children under 2 years of age were inflicted by others [59]. Recognising abuse gains particular importance with the knowledge that violence and abuse are commonly **not single occurrences** but rather not only repeat themselves

but escalate. This does not mean that the worst should always be assumed of parents or that forensic aspects should dictate treatment. Nevertheless, simple **attentive observation and recording of attendant circumstances** can offer a chance to free the child from a spiral of abuse through a process managed by a family court after completion of medical care (further reading regarding the legal framework and suitable course of action is provided by [60]).

References

1. Eich C, Roessler M, Nemeth M, Russo SG, Heuer JF, Timmermann A: Characteristics and outcome of prehospital paediatric tracheal intubation attended by anaesthesia-trained emergency physicians. Resuscitation 2009;80:1371–1377
2. Zink W, Bernhard M, Keul W, Martin E, Volkl A, Gries A: Invasive techniques in emergency medicine. I. Practice-oriented training concept to ensure adequately qualified emergency physicians. Anaesthesist 2004;53:1086–1092
3. Lammers R, Byrwa M, Fales W: Root causes of errors in a simulated prehospital pediatric emergency. Acad Emerg Med 2012;19:37–47
4. Heimberg E, Heinzel O, Hoffmann F: Typical problems in pediatric emergencies: Possible solutions. Med Klin Intensivmed Notfmed 2015;110:354–359
5. Bankole S, Asuncion A, Ross S, Aghai Z, Nollah L, Echols H, et al: First responder performance in pediatric trauma: a comparison with an adult cohort. Pediatr Crit Care Med 2011;12:e166–170
6. Maconochie IK, Bingham R, Eich C, López-Herce J, Rodríguez-Núñez A, Rajka T, et al: European Resuscitation Council Guidelines for Resuscitation 2015. Section 6. Paediatric life support. Resuscitation 2015;95 223–248
7. Kaufmann J, Laschat M, Wappler F: Die präklinische Versorgung von Notfällen im Kindesalter. Anästh Intensivmed 2012;53:254–267
8. Turner NM: Recent developments in neonatal and paediatric emergencies. Eur J Anaesthesiol 2011;28:471–477
9. Atkins DL, Everson-Stewart S, Sears GK, Daya M, Osmond MH, Warden CR, et al: Epidemiology and outcomes from out-of-hospital cardiac arrest in children: the Resuscitation Outcomes Consortium Epistry-Cardiac Arrest. Circulation 2009;119:1484–1491
10. Wyllie J, Bruinenberg J, Roehr CC, Rüdiger M, Trevisanuto D, Urlesberger B: European Resuscitation Council Guidelines for Resuscitation 2015. Section 7. Resuscitation and support of transition of babies at birth. Resuscitation 2015;95:249–263
11. Wyckoff MH, Aziz K, Escobedo MB, Kapadia VS, Kattwinkel J, Perlman JM, et al: Part 13: Neonatal Resuscitation: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation 2015;132:S543–560
12. Hupfl M, Selig HF, Nagele P: Chest-compression-only versus standard cardiopulmonary resuscitation: a meta-analysis. Lancet 2010;376:1552–1557
13. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Nadkarni VM, et al: Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: a prospective, nationwide, population-based cohort study. Lancet 2010;375:1347–1354
14. Goto Y, Maeda T, Goto Y: Impact of dispatcher-assisted bystander cardiopulmonary resuscitation on neurological outcomes in children with out-of-hospital cardiac arrests: a prospective, nationwide, population-based cohort study. J Am Heart Assoc 2014;3:e000499
15. Kerrey BT, Rinderknecht AS, Geis GL, Nigrovic LE, Mittiga MR: Rapid sequence intubation for pediatric emergency patients: higher frequency of failed attempts and adverse effects found by video review. Ann Emerg Med 2012;60: 251–259
16. Gausche M, Lewis RJ, Stratton SJ, Haynes BE, Gunter CS, Goodrich SM, et al: Effect of out-of-hospital pediatric endotracheal intubation on survival and neurological outcome: a controlled clinical trial. JAMA 2000;283:783–790
17. Weiss M, Schmidt J, Eich C, Stelzner J, Trieschmann U, Müller-Lobeck L et al: Handlungsempfehlung zur Prävention und Behandlung des unerwartet schwierigen Atemwegs in der Kinderanästhesie. Anästh Intensivmed 2011;52:S54–S63
18. Cote CJ, Hartnick CJ: Pediatric transtracheal and cricothyrotomy airway devices for emergency use: which are appropriate for infants and children? Paediatr Anästh 2009;19 Suppl 1:66–76
19. Navsa N, Tossel G, Boon JM: Dimensions of the neonatal cricothyroid membrane – how feasible is a surgical cricothyroidotomy? Paediatr Anaesth 2005;15:402–406
20. Johansen K, Holm-Knudsen RJ, Charabi B, Kristensen MS, Rasmussen LS: Cannot ventilate-cannot intubate an infant: surgical tracheotomy or transtracheal cannula? Paediatr Anaesth 2010;20:987–993
21. Holm-Knudsen RJ, Rasmussen LS, Charabi B, Bøttger M, Kristensen MS: Emergency airway access in children – transtracheal cannulas and tracheotomy assessed in a porcine model. Pediatric Anesthesia 2012;22:1159–1165
22. Hoffmann F, Keil J, Urban B, Jung P, Eich C, Schiele A, et al: Interdisziplinär konsentierte Stellungnahme: Atemwegsmanagement mit supraglottischen Atemwegs hilfen in der Kindernotfallmedizin. Larynxmaske ist State-of-the-art. Anästh Intensivmed 2016;57:377–386
23. Chambers IR, Jones PA, Lo TY, Forsyth RJ, Fulton B, Andrews PJ, et al: Critical thresholds of intracranial pressure and cerebral perfusion pressure related to age in paediatric head injury. J Neurol Neurosurg Psychiatry 2006;77:234–240
24. Catala-Temprano A, Claret Teruel G, Cambra Lasaosa FJ, Pons Odena M, Noguera Julian A, Palomeque Rico A: Intracranial pressure and cerebral perfusion pressure as risk factors in children with traumatic brain injuries. J Neurosurg 2007;106:463–466
25. Coté CJ, Lermann J, Todres ID: A practice of anesthesia for infants and children. 4th Edition. Philadelphia: Saunders 2009
26. Sümpelmann R, Becke K, Brenner S, Breschan C, Eich C, Höhne C et al: S1-Leitlinie: Perioperative Infusionstherapie bei Kindern. Anästh Intensivmed 2016;57:368–376
27. Osthaus W, Ankermann T, Sümpelmann R: Präklinische Flüssigkeitstherapie im Kindesalter. Pädiatrie up2date 2013;08:67–84
28. Duke T: New WHO guidelines on emergency triage assessment and treatment. Lancet 2016;387:721–724
29. Banner W, Jr., Vernon DD, Minton SD, Dean JM: Nonlinear dobutamine pharmacokinetics in a pediatric population. Crit Care Med 1991;19:871–873
30. Artman M, Kithas PA, Wike JS, Strada SJ: Inotropic responses change during postnatal maturation in rabbit. Am J Physiol 1988;255:H335–342
31. Papp JG: Autonomic responses and neurohumoral control in the human

early antenatal heart. Basic Res Cardiol 1988;83:2–9
32. Shukla A, Steven JM, McGowanJr. FX: Cardiac Physiology an Pharmacology. In: CJ Coté, J Lerman and ID Todres. A practice of anesthesia for infants and children. 4th. Saunders 2009
33. Hunt R, Osborn D: Dopamine for prevention of morbidity and mortality in term newborn infants with suspected perinatal asphyxia. Cochrane Database Syst Rev 2002;CD003484
34. Brissaud O, Botte A, Cambonie G, Dauger S, de Saint Blanquat L, Durand P, et al: Experts' recommendations for the management of cardiogenic shock in children. Ann Intensive Care 2016;6:14
35. Berner M, Rouge JC, Friedli B: The hemodynamic effect of phentolamine and dobutamine after open-heart operations in children: influence of the underlying heart defect. Ann Thorac Surg 1983;35:643–650
36. Dellinger RP, Levy MM, Rhodes A, Annane D, Gerlach H, Opal SM, et al: Surviving sepsis campaign: international guidelines for management of severe sepsis and septic shock: 2012. Crit Care Med 2013;41:580–637
37. Harada K, Tamura M, Ito T, Suzuki T, Takada G: Effects of low-dose dobutamine on left ventricular diastolic filling in children. Pediatr Cardiol 1996;17:220–225
38. Havel C, Arrich J, Losert H, Gamper G, Mullner M, Herkner H: Vasopressors for hypotensive shock. Cochrane Database Syst Rev 2011;CD003709
39. Lampard JG, Lang E: Vasopressors for hypotensive shock. Ann Emerg Med 2013;61:351–352
40. Sakr Y, Reinhart K, Vincent JL, Sprung CL, Moreno R, Ranieri VM, et al: Does dopamine administration in shock influence outcome? Results of the Sepsis Occurrence in Acutely Ill Patients (SOAP) Study. Crit Care Med 2006;34:589–597
41. Stopfkuchen H, Racke K, Schworer H, Queisser-Luft A, Vogel K: Effects of dopamine infusion on plasma catecholamines in preterm and term newborn infants. Eur J Pediatr 1991;150:503–506
42. Emmel M, Roesner D, Roth B: Hypovolämischer Schock – Besonderheiten des Kindesalters. Refresher Course der DAAF 2008;34:193–204
43. Fachinformation Akrinor, Firma AWD Pharma, Dresden. Stand Juli 2001
44. Oesterlie GE, Petersen KK, Knudsen L, Henriksen TB: Crural amputation of a newborn as a consequence of intraosseous needle insertion and calcium infusion. Pediatr Emerg Care 2014;30:413–414
45. Lake W, Emmerson AJ: Use of a butterfly as an intraosseous needle in an oedematous preterm infant. Arch Dis Child Fetal Neonatal Ed 2003;88:F409
46. Hoyle JD, Davis AT, Putman KK, Trytko JA, Fales WD: Medication dosing errors in pediatric patients treated by emergency medical services. Prehosp Emerg Care 2012;16:59–66
47. Perondi MB, Reis AG, Paiva EF, Nadkarni VM, Berg RA: A comparison of high-dose and standard-dose epinephrine in children with cardiac arrest. N Engl J Med 2004;350:1722–1730
48. Kaufmann J, Schieren M, Wappler F: Medication errors in paediatric anaesthesia-a cultural change is urgently needed! Br J Anaesth 2018;120:601–603
49. Kaufmann J, Wolf AR, Becke K, Laschat M, Wappler F, Engelhardt T: Drug safety in paediatric anaesthesia. Br J Anaesth 2017;118:670–679
50. Kaufmann J, Laschat M, Wappler F: Medikamentenfehler bei Kindernotfällen – eine systematische Analyse. Dtsch Arztebl Int 2012;109:609–616
51. Bernius M, Thibodeau B, Jones A, Clothier B, Witting M: Prevention of pediatric drug calculation errors by prehospital care providers. Prehosp Emerg Care 2008;12:486–494
52. Kaufmann J, Roth B, Engelhardt T, Lechleuthner A, Laschat M, Hadamitzky C, et al: Development and Prospective Federal State-Wide Evaluation of a Device for Height-Based Dose Recommendations in Prehospital Pediatric Emergencies: A Simple Tool to Prevent Most Severe Drug Errors. Prehosp Emerg Care 2018;22:252–259
53. Kaufmann J, Becke K, Höhne C, Eich C, Goeters C, Güß T et al: S2e-Leitlinie – Medikamentensicherheit in der Kinderanästhesie. Anästh Intensivmed 2017;58:105–118
54. Borland M, Jacobs I, King B, O'Brien D: A randomized controlled trial comparing intranasal fentanyl to intravenous morphine for managing acute pain in children in the emergency department. Ann Emerg Med 2007;49:335–340
55. Kaufmann J, Laschat M, Wappler F: Analgesie und Narkose im Kindesalter. Notfallmedizin up2date 2012;7:17–27
56. Kaufmann J: Versorgung des kindlichen Polytraumas. Anästh Intensivmed 2010;51:612–614
57. Kaufmann J, Laschat M, Frick U, Engelhardt T, Wappler F: Determining the probability of a foreign body aspiration from history, symptoms and clinical findings in children. BJA: British Journal of Anaesthesia 2017;118:626–627
58. Tieder JS, Bonkowsky JL, Etzel RA, Franklin WH, Gremse DA, Herman B, et al: Brief Resolved Unexplained Events (Formerly Apparent Life-Threatening Events) and Evaluation of Lower-Risk Infants. Pediatrics 2016;137:e1–e32
59. Duhaime AC, Christian CW, Rorke LB, Zimmerman RA: Nonaccidental head injury in infants – the „shaken-baby syndrome". N Engl J Med 1998;338: 1822–1829
60. Jacobi G, Dettmeyer R, Banaschak S, Brosig B, Herrmann B: Misshandlung und Vernachlässigung von Kindern – Diagnose und Vorgehen. Dtsch Arztebl Int 2010;107:231–239.

Correspondence address

Jost Kaufmann
MD, PhD

Kinderkrankenhaus der Kliniken der Stadt Köln gGmbH
Amsterdamer Straße 59
50735 Köln, Germany

Phone: +49 0221 8907 15199
Fax: +49 0221 8907 5264

Mail: jost.kaufmann@uni-wh.de

ORCID-ID: 0000-0002-5289-6465