Multiple Trauma Part VI:

Paediatric Trauma

Table of Contents

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Intended Learning Outcomes

Multiple Trauma Part VI: Paediatric Trauma

1. Describe similarities and differences between adult and children with major trauma
2. List and describe basic principles of acute pre- and in-hospital management of major pediatric trauma
3. Describe basic principles of intensive care for major pediatric trauma

eModule Information

Relevant Competencies from CoBaTrICE

Multiple Trauma Part VI: Paediatric Trauma

- **9.6** Describes the recognition of the acutely ill child and initial management of paediatric emergencies

1. Introduction

Major trauma is a leading cause of paediatric death and disability worldwide (Li et al. 2024). Paediatric trauma mortality is predominantly due to the presence of traumatic brain injury (TBI) or development of haemorrhagic shock and typically occurs at an early phase following the injury. During recent decades, the incidence and mortality of paediatric major trauma have decreased. This is due to improvement in traffic safety and, possibly, to development of early trauma response protocols, such as establishment of trauma centres and teams, and better imaging strategies.

As in all paediatric critical illnesses, as compared to adults, there is a lack of high-quality scientific evidence in the paediatric population. Most adult data can likely be extrapolated to adolescents, but as compared to adults, small children have different trauma mechanisms, mechanical properties in high-energy trauma, and different prognostic factors. However, a relative paucity of evidence should not lead to clinicians waiting for more studies before developing paediatric trauma guidelines. On the contrary, along with best evidence that is available, clinical judgement and continuous training locally should be used to develop best possible institutional paediatric trauma response protocols and teams.

The care of paediatric trauma patients, particularly in cases of non-accidental injury, can lead to significant psychological stress among healthcare providers. Structured post-event debriefings should be systematically implemented to support staff well-being and reduce the risk of secondary traumatic stress and burnout.

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- Li C, Jiao J, Hua G, Yundendorj G, Liu S, Yu H, Zhang L, Yang X, Liu L., Global burden of all cause-specific injuries among children and adolescents from 1990 to 2019: a prospective cohort study., 2024, PMID:38348839

2. Multiple Trauma Part VI: Definitions and epidemiology

2. 1. Definitions

There is no universal definition for major paediatric trauma. However, generally major trauma is defined as an injury or a combination of injuries severe enough to cause or potentially cause death or major disability. Typically, a patient with major trauma will be admitted to an intensive care unit and/or for major emergency surgery.

Similarly to the adult population, the Injury Severity Score is widely used in the paediatric patient population, although complex to use on scene (Champion, Sacco and Copes. 1995). More recently, other definitions of severe trauma have been reported, based on the need for one or more urgent interventions during initial management (Roden-Foreman et al. 2019), such as:

- the need for transfusion of packed red blood cells within the first six hours;
- the need for urgent specialized surgery (laparotomy, thoracotomy, vascular, urological, maxillofacial, embolization, craniectomy, intracranial pressure placement, spinal surgery, chest drainage, orthopaedic surgery AIS >3) within the first 24 hours;
- the need for mechanical ventilation other than for surgery within the first 72 hours;
- the need for vasopressors or inotropes;
- the need for critical care hospitalization for at least 72 hours.

Major bleeding also lacks a definition in children. The adult definition (Wong et al. 2020) can be used for children of adult size. In smaller children, major bleeding can be defined as rapid blood loss with shock or with no likelihood of control, anticipated or actual blood loss of 80 ml/kg in 24 hours or 40 ml/kg in 3 hours.

Several scoring systems for major paediatric trauma exist. Paediatric trauma score is one of them, originally developed for predicting mortality and has since extended to classify severity of injuries. The score considers the weight of the patient, the patency of the airway, systolic blood pressure, the level of consciousness, the presence of skeletal injury and the presence of penetrating wounds to form a score between -6 (worst outcome) to 12 (best outcome).

For this learning material, we will define a child as an individual under 18 years of age, and major trauma as any injury causing death or compromising basic vital functions so that there is need for major emergency surgery and/ or

treatment in an intensive care unit. As adolescents can in most circumstances be regarded as adults for their physiology in acute situations, this material will concentrate on infants and small children, where the differences for the adult practitioner are most pronounced.

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- Wong HS, Curry NS, Davenport RA, Yu LM, Stanworth SJ., A Delphi study to establish consensus on a definition of major bleeding in adult trauma., 2020, PMID:32984985

2. 2. Epidemiology

Paediatric major trauma is a leading cause of paediatric deaths worldwide (Li et al. 2024). The incidence of childhood injuries has declined since the 1990's and the mortality has halved, but injuries still cause significant morbidity and mortality in children and adolescents. Their incidence is higher in countries with higher socioeconomic status, but the mortality is higher in countries with lower development level. Injury patterns are dependent on the age and development of the child. It is worth noting that paediatric trauma is a relatively rare occurrence even in a large paediatric trauma centre. While most injuries are classified as unintentional, traffic and interpersonal violence also play a major role. Importantly, non-accidental injury is the leading cause of trauma-related fatalities in children younger than four years old but recognizing physical abuse in paediatric patients can be difficult.

Most of pediatric trauma mortality is related to the presence of TBI and/or massive bleeding. Due to lower physiological reserves to counteract respiratory or circulatory failure following chest injury or significant bleeding, children with trauma more often die on the scene of incident, during transport or in the emergency room compared adults (McLaughlin et al. 2018). Most of the mortality occurs in the acute or hyperacute phase (Theodorou et al. 2021), which poses challenges for the management of these patients in the prehospital and in-hospital setting. Triage must be accurate, transport has to occur to a competent centre without delay, and a prepared trauma team must be on place. In addition, measures aiming at preventing paediatric trauma are crucial.

References

- Li C, Jiao J, Hua G, Yundendorj G, Liu S, Yu H, Zhang L, Yang X, Liu L., Global burden of all cause-specific injuries among children and adolescents from 1990 to 2019: a prospective cohort study., 2024, PMID:38348839
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- Theodorou CM, Galganski LA, Jurkovich GJ, Farmer DL, Hirose S, Stephenson JT, Trappey AF., Causes of early mortality in pediatric trauma patients., 2021, PMID:33492107

3. Paediatric specificities (anatomical, physiological, clinical)

3. 1. General considerations

The most obvious challenge in children with severe injuries is their varying size, necessitating more preparations for the equipment and the team. Airway, breathing and infusion equipment must be compatible for all body sizes between 2 and 200 kg, drug and fluid doses need to be calculated beforehand, preferably even pre-drawn to appropriate sized syringes. Age-appropriate reference values must be easily available for the whole team (Table 1) (Van de Voorde et al. 2021). The team should trained to be reasonably comfortable with different equipment, dosing protocols and reference values.

Table 1: Normal values for age

	1 month	**1 year**	**5 years**	**10 years**
Respiratory rate	30-60/min	25-40/min	20-30/min	14-25/min
Heart rate	100-180/min	100-160/min	80-140/min	60-120/min
Mean arterial pressure (5th and 50th percentiles)	40-55 mmHg	50-70 mmHg	55-75 mmHg	55-75 mmHg

If not treating children regularly, visual aids and other memory systems are recommended instead of memorizing drug doses and equipment sizes. Using age- or size-based trolleys or other tools prepared for use is recommended. Training to use such equipment is crucial.

Some memory aids can be learned by all the team. For example, a **“rule of tens”** for emergency situations can be proposed:

- Adrenaline 1:10.000 solution **10** mcg/kg for cardiac arrest
- Fluid bolus **10** ml/kg, repeat if needed
- An infant's heart rate should be at least **10 x 10** = 100
- Blood volume is always less than **10 %** of body weight (7 % in children, 9-10 % in infants)
- Bleeding possibly needing attention= more than **10%** of blood volume

References

- Van de Voorde P, Turner NM, Djakow J, de Lucas N, Martinez-Mejias A, Biarent D, Bingham R, Brissaud O, Hoffmann F, Johannesdottir GB, Lauritsen T, Maconochie I., European Resuscitation Council Guidelines 2021: Paediatric Life Support., 2021, PMID:33773830

3. 2. Physiological differences and their implications on clinical management

In young children the bones of the limbs, the thoracic cage, the skull and the spine are more elastic. In high-energy trauma, it is not uncommon for small children to have significant injuries in soft tissues (brain, lungs, abdomen, spinal cord) without the presence of fractures in the surrounding bones.

The basic anatomic and physiologic differences between adults and children with trauma are presented in Table 2.

Table 2: Pediatric specificities, and implication for management

Steps		

A	The airway is narrow and easily obstructed by mucus or bleeding. In infants, the larynx is also relatively anterior and the epiglottis funnel shaped, with the narrowest part only after the chords.	• Secure the airway when a competent team is available, use bag and mask ventilation until that, remember naso- and oropharyngeal airway devices • Consider videolaryngoscopy for intubating infants as the first tool 8 • Use cuffed tubes for all children • Endotracheal tube size is calculated based on a formula: (Age in tears/4)+4 and 0.5 size less if cuffed • Correct orotracheal insertion depth for an appropriate size cuffed intubation tube is three times its size (9 cm for 3.0, 15 cm for 5.0, 21 cm for 7.0, etc)
B	Small children have high oxygen demands and low reserves (low functional residual capacity); desaturation occurs within less than a minute in preoxygenated and healthy infants, and within 10-20 seconds in case of compromised breathing or circulation.	• Train to use FAST ultrasound to detect pneumo-/haemothorax • Drain pneumo-/haemothorax and support breathing early • Always preoxygenate before any measures compromising breathing

C	The infant myocardium is stiff, and cardiac output depends on heart rate. The capacity for vasoconstriction is significant and may mask circulatory failure.	• Increased heart rate is the best and earliest predictor of circulatory failure; capillary refill time may be more specific; do not rely on blood pressure • Low blood pressure is a very late sign of circulatory failure and/or hypovolemia; prepare for imminent cardiac arrest if a child with trauma has low blood pressure • Control bleeding, bolus vasoactive medications and fluids • Train to use FAST ultrasound to detect cardiac tamponade
D	Any child > 2 weeks old should make eye contact at some point and react meaningfully to being comforted. Otherwise, the level of consciousness is likely not normal. An infant's brain has high oxygen demands and in case of increased intracranial pressure and/or circulatory failure, secondary brain injury occurs quickly. As opposed to adults, children with TBI may also have massive haemorrhage, as the head is big and can accommodate a larger proportion of blood volume.	• Use AVPU (alert/responds to verbal stimuli/responds to pain/unresponsive) • The smaller the child, the more active one should be about reaching "brain-saving" treatment goals • Use age-appropriate intracranial pressure/cerebral perfusion pressure/mean arterial pressure targets • Treat increased ICP with the same principles that in adults (hyperosmolar treatment, normoventilation (pCO_2 targets 4.5-5.3 kPa or 30-40 mmHg, sufficient cerebral perfusion pressure • Use paediatric Glasgow coma score for < 2 years-old

E/F	Small children with extensive trauma and/ or bleeding lose heat quickly, and hypothermia will worsen the coagulopathy. Inexperience with paediatric fluid and drug doses may lead to underestimation of bleeding and slow its treatment by blood products.	• Avoid hypothermia, actively warm infants and small children • Treat bleeding with blood products as soon as possible • Give tranexamic acid, calcium and fibrinogen early • Calculate drug doses and fluids beforehand • Use cognitive aids • If using electronic health record systems, include paediatric dosages for emergency situations

4. Pre- hospital and initial management

4. 1. Organisational aspects

Whether in the pre-hospital setting or on admission to the intensive care or emergency department, to be effective in the management of trauma patients, interprofessional collaboration and communication are crucial. Clear allocation of roles and responsibilities is important given the rarity of major paediatric trauma. Regular simulation training remains the best way to collectively train and prepare for the management of severe trauma patients.

Healthcare units and emergency departments managing severely injured children should establish and implement locally standardized protocols to guide initial resuscitation and stabilization. These protocols should include critical components such as weight-based medication dosing, vascular access, and appropriate physiological monitoring (e.g., continuous ECG, pulse oximetry, and end-tidal CO_2 in intubated patients).

A pre-briefing with allocation of the various roles and respective tasks is a guarantee of the quality of the care provided. Physically, the positioning of each actor around the patient must also be structured. The use of cognitive aids with specific tasks for each position is strongly recommended, especially for children.
To ensure that the entire trauma team is strongly involved in the patient care, it is essential to consider a time-out (“10 seconds for 10 minutes”) to transmit all relevant patient information. As well, a status report on the patient's arrival and a progress report every 10-15 minutes is also helpful.

4. 2. Primary survey

According to the healthcare system and setting, a first quick initial triage is useful to assess:

- whether or not the patient is alive
- whether or not the patient is awake (AVPU, crying, moving etc)
- whether or not there is any breathing difficulties (respiratory rate and effort, SpO_2)
- whether or not the circulation is adequate (radial pulse, CRT)

4. 3. Management c-ABCDE

A paediatric trauma patient is evaluated using the cABCDE approach, similar to adult trauma patients (Table 3).

Table 3: cABCDE approach

c: Catastrophic Bleeding	Externalized bleeding can be controlled with tourniquets, staples, haemostatic dressings or simple manual compression.
A: Airway	Assessing and securing the airway: • Clear the upper airway by stretching the chin and jaw and opening the patient's mouth. • Mucus and vomit should be quickly decontaminated from the airways but the routine use of suction is discouraged since this can also provoke laryngospasm or bronchoconstriction. • Use of an oropharyngeal airway if consciousness is impaired. • Cervical extension should be avoided since excessive manoeuvre can damage the spinal cord. Immobilise the cervical spine manually as early as possible. Then use a correctly fitted c-spine collar, blocks and tape when tolerated and common sense to reach effective spinal immobilisation. Avoid hard collars if possible. • Uncuffed laryngeal mask airway is easy to apply and well-suited for prehospital use since prehospital endotracheal intubation may be a challenging procedure. The routine use of videolaryngoscopy and bougie or stylet may be useful in this setting.

B: Breathing	**Evaluation**
	• Ventilation initial assessment includes: respiratory rate, increased work of breathing and oxygenation. In the context of trauma, attention should be paid to looking for signs suggestive of pneumo- or haemothorax.
	
	Management of respiratory failure
	• In case of respiratory arrest, ventilate with a manual insufflator at 100% FiO_2, then perform endotracheal intubation by the most experienced person, maintaining alignment/stabilization of the cervical spine. Large tidal volumes (>8 ml/kg) should be avoided since the air easily gets pushed inside the stomach which can lead to aspiration or high airway pressure.
	• In the event of respiratory distress, the underlying cause must be rapidly identified and corrected as quickly as possible, before considering invasive or non-invasive support, which could aggravate a pneumothorax.
	• Several factors need to be taken into account before considering endotracheal intubation:
	  ◦ Hemodynamic status: hemodynamic failure, generally linked to haemorrhagic or obstructive shock (pneumothorax), is likely to worsen during anaesthetic induction and mechanical ventilation;
	  ◦ Neurological status: disturbances of consciousness (Glasgow Coma Score ≤ 8) or agitation are indications for intubation;
	  ◦ The need for heavy sedation-analgesia.
	• It is recommended to have an assistant providing manual in-line stabilization during intubation. In the event of trauma, orotracheal intubation is always preferable to nasotracheal intubation. A rapid induction sequence is recommended (paralysing agent, hypnotics +/- analgesics). Prehospital intubation protocols should involve a checklist, standardized pre- and apnoeic oxygenation strategies, standardized drug dosages and videolaryngoscopy.
	
	Haemothorax

	• Haemothorax can cause hypovolemic shock and respiratory failure. A large-calibre drain with an external diameter usually corresponding to that of a child's little finger should be chosen. The management of a haemothorax also relies on the correction of haemorrhagic shock (see below).

C: Circulation	**Evaluation** • Circulation is evaluated using blood pressure, heart rate and central capillary refill time. Tachycardia is often more sensitive indicator of significant hypovolemia than blood pressure, but it is susceptible confounding factors such as pain, discomfort and fear. • Emergency ultrasound can be used to identify the site of bleeding and guide an interventional radiology procedure. In other cases, definitive haemostasis is usually achieved by surgery. **Management of hemodynamic failure** • Hemodynamic failure in the context of trauma should raise the suspicion of haemorrhagic shock. Management principles are based on damage control, transfusion and prevention of hypothermia. • The principles of damage control are equivalent in children and adults **(apart from the fact that permissive hypotension is contraindicated in children)**. Consideration should be given to compression of bleeding, use of staples, tourniquets or pelvic belts. Importantly, a scalp laceration in a young child may be sufficient to cause haemorrhagic shock. • In this context, two large-calibre for child size intravenous accesses are necessary. Intraosseous route must be considered rapidly. Secondly, transfusion of packed red blood cells should be rapidly considered. • Depending on the intensity of the bleeding, the massive transfusion protocol should be activated, based on the patient's weight (blood/PFC/platelets ratio between 1:1:1 and 2:1:1). If transfusion is not possible, and hypotension is present, 10 ml/kg of crystalloids may be considered. • Tranexamic acid should also be administered as soon as possible in haemorrhagic shock (e.g. 10 mg/kg fast bolus over at least ten minutes +/- 2 mg/kg/h thereafter). Fibrinogen and calcium administration can be also required. **Cardiac tamponade**

	• Cardiac tamponade is rare in paediatric patients. Its occurrence depends more on the speed with which the effusion builds up than on its volume. According to POCUS assessment, treatment is based on pericardial puncture and/or drainage and/or surgical removal of clot, and control of injury site through a (mini-) thoracotomy or sternotomy.
D: Disabilities	**Evaluation** • The level of consciousness evaluation should be based on the on-going age period. AVPU (Alert, Verbal, Pain, Unresponsive) and Glasgow Coma Score (with modifications) are commonly used. In children, a loud cry combined with spontaneous movement and good muscle tension is often related to well-being while a quiet, stationery and limp child raises significant concern. Pupils should be examined from unconscious patients. Pupils should always be examined, and imperatively from unconscious patients and before administering opioids or anaesthesia. **Management of reduced level of consciousness** • In the event of neurological failure, the patient must be intubated and sedated to protect the upper airway and to protect against secondary brain injury. If signs of intracranial hypertension or deterioration in neurology are detected, ventilation, oxygenation and MAP should be optimized, and osmotherapy should be rapidly initiated (see Brain Trauma section). In the context of severe trauma, particular attention must be paid to: • maintaining a certain mean arterial pressure; • temperature control; • appropriate sedative and analgesic treatment.

E: Environment	- Temperature control and prevention of hypothermia is crucial as patients can cool down significantly despite all preventive measures being taken. Patient exposure to freezing temperatures and prolonged extrication can cause significant challenges. When operating in tropical climates, using a vacuum mat and/or heating blankets particularly in small children, the risk of hyperthermia should also be considered. Repeated or continuous temperature monitoring is recommended particularly if the transfer time is long. - Effective pain management with opioids decreases oxygen consumption and helps to alleviate negative circulatory effects and improve cooperation. Conscious patients often require medication for the prevention and management of nausea and vomiting. - In addition, the team should focus on the parents and caregivers of the paediatric patients regarding: - mechanism of injury, detailed past medical history of the child - informed consent for treatment and procedures - comfort and psychological aspects - Despite there are different approaches to this issue, parents would often like to accompany the child to the hospital and be present during initial management.

4. 4. Haemorrhagic shock

Key messages for haemorrhagic shock management are presented in Table 4.

Table 4: Haemorrhagic shock guideline overview, modified from Russel 2022

Preparation and learning	Prepare and train your team for a massive transfusion protocol in your institution

Prehospital or initial measures	• In exsanguinating haemorrhage, use (commercially available) tourniquets
	• Consider prehospital blood transfusion if available
	• Remember the "lethal diamond" of acidosis, coagulopathy, hypocalcaemia, and hypothermia
	  ◦ Start temperature control measures immediately (warming blankets, fluid warmer or warmed fluids)
	  ◦ Minimize crystalloids
	  ◦ Give calcium gluconate early

Use of blood products	• Give blood products rather than crystalloids to maintain adequate MAP in a bleeding patient • If available, give whole blood rather than blood components (low titter O blood if available) • When using components, as soon as available, target 1:1:1 (red cells:plasma:platelets)
Use of adjunct agents	• Consider empiric tranexamic acid; give 10 mg/kg within 3h of trauma • No evidence for or against empiric prothrombin concentrate/fibrinogen/ other specific products; can be considered after. 80ml/kg PRBC

Treatment goals	• Correct hypothermia, acidosis, hypocalcaemia, and coagulopathy
	• Do not use a permissive hypotension strategy
	• Target physiologic / near-physiologic resuscitation goals that would optimize tissue perfusion and oxygen delivery
	• Start goal-directed therapy when available/ possible
	  ◦ Viscoelastometry to direct transfusion and use of adjunct agents
	  ◦ Give fibrinogen if deficit (either cryoprecipitate or fibrinogen concentrate)
	  ◦ Maintain ionized calcium > 1 mmol/l
	  ◦ Give other products if deficit

In Text References

(Russell, Leeper and Spinella. 2023)

References

- Russell RT, Leeper CM, Spinella PC., Damage-control resuscitation in pediatric trauma: What you need to know., 2023, PMID:37314396

4. 5. Emergency medications

A list of emergency medications and dosages is presented in Table 5.

Table 5: Medications and dosage in trauma emergency settings (subject to variability according to commercial presentation)

Fluids	
Fluid expansion (balanced/non-balanced crystalloids)	10 ml/kg
*Packed red cells and other blood components	*10-20 ml/kg
Inotropes/vasopressors	
Adrenaline	1: 10.000 solution 10 µg/kg in cardiac arrest, titrate 1-2 µg/kg bolus otherwise
Norepinephrine	0.1-1 µg/kg/min infusion
Osmotherapy	
Mannitol 20%	0.25-15 g/kg
Hypertonic Saline 3%	3 ml/kg
Sequence rapid induction	
Ketamine / S-Ketamine	1-4 mg/kg / 1-2 mg/kg
Etomidate	0.3 mg/kg
Rocuronium	0.6-1.2 mg/kg for rapid sequence induction (up to 100 mg)
Suxamethonium	1-2 mg/kg for rapid sequence induction
Analgesics/hypnotics	
Morphine	0.1-0.4 mg/kg titration
Fentanyl	1-2 µg/kg titration
Sufentanyl	0.2-1 µg/kg/hr

Midazolam	0.1-0.3 mg/kg/hr, 0.05 - 0.1 mg/kg bolus
Propofol	In hemodynamic stable patients. Titrate bolus 1-5 mg/kg, infusion 4-10 mg/kg/h for short term
Other	
Tranexamic Acid	10-15 mg/kg during 10 min max 1g
Fibrinogen	50 mg/kg max 4g
Calcium gluconate 10 %	0.5 ml/kg, max 10 ml, slow IV bolus

4. 6. Cardiac arrest in paediatric trauma

Injury to the cervical spinal cord should be suspected in all traumatized patients, particularly in cases of severe head trauma or sudden cardiac arrest. Aside from that, resuscitation in a of a paediatric trauma patient in cardiac arrest is similar as in other circumstances, following up-to-date guidelines current recommendations (Van de Voorde et al. 2021; Russell, Leeper and Spinella. 2023):

- identify and treat reversible trauma-related causes, including externalized or non-externalized bleeding (e.g. thoracostomy, tourniquet, pelvic stabilizer, etc.);
- identify and treat reversible trauma-related causes such as pneumothorax, hypovolemia, and hypoxia
- perform cardiopulmonary resuscitation, trying to minimize spinal column movements as much as possible;
- do not systematically use a defibrillator at the scene of an accident, unless there is a high probability of shocking the underlying rhythm, for example after electrocution.

References

- Van de Voorde P, Turner NM, Djakow J, de Lucas N, Martinez-Mejias A, Biarent D, Bingham R, Brissaud O, Hoffmann F, Johannesdottir GB, Lauritsen T, Maconochie I., European Resuscitation Council Guidelines 2021: Paediatric Life Support., 2021, PMID:33773830
- Russell RT, Leeper CM, Spinella PC., Damage-control resuscitation in pediatric trauma: What you need to know., 2023, PMID:37314396

5. Triage and orientation

Triage accuracy is essential for delivering effective trauma care, especially in the paediatric population where unique challenges exist. It is very important that the prehospital team gives a pre-notification of severely injured child to the accepting hospital. There should be clear criteria for the trauma team activation and the necessary notifications to theatres, blood bank, radiology etc.

In children, triage scoring tools relying on physiologic parameters rather than mechanism of injury have been shown to be more precise in predicting severity of injury while intervention-based systems such as Need for Surgeon Presence and Need For Trauma team Intervention have been show to more accurately reflect the needs of the patient in real-time (Roden-Foreman et al. 2019; McGaha P et al. 2020; Morris et al. 2020).

Several physiological criteria have been reported in the literature to assess paediatric patient severity: 1/the age-adjusted shock-index (heart rate to systolic blood pressure ratio) (Acker et al. 2015), whose pathological value is > 1.2 in 4-6 year olds, > 1 in 6-12 year olds, and > 0.9 in those over 12; 2/the motor component of the Glasgow Coma Score (GCS) (Acker et al. 2014); 3/a combination of the reverse Shock Index and the GCS (Reppucci et al. 2022) whose pathological value is < 16.

Under-triage of patients can be catastrophic if the patient is transported to a centre without appropriate capability or capacity while over-triage leads to alarm fatigue and unnecessary costs to the system. Importantly, under triage increased the risk of early death after paediatric major trauma (Ageron et al. 2025; Ageron et al. 2021).

Depending on the health care system, the organization of care for severely traumatized paediatric patients is more or less well structured. Theoretically, patient orientation should be based on the qualification/certification of facilities and on patient severity. An efficient and well-structured trauma network including paediatrics is crucial.

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6. Intensive care management

Depending on patient stability and previous management, the c-ABCDE algorithm may need to be repeated.

Once the admission phase is over, management will depend on the types of injuries and any organ failure. The degree of monitoring (clinical, biological and radiological) will depend on the lesions and the patient's stability.

Particular attention should be paid to psychological support for patients and their families, especially in the event of post-traumatic stress disorder, a frequent complication in severe trauma patients and their families (Meneses et al. 2021).

References

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7. Imaging strategy

Overall, imaging strategy in the paediatric trauma patient does not differ from the adult population and will highly depend on the patient's clinical stability. If unstable, emergency imaging includes a chest X-ray, pelvic X-ray and FAST (Focused Assessment with Sonography for Trauma) ultrasound (Bouzat et al. 2020; Bouzat et al. 2017). POCUS is particularly relevant in the assessment of thoracic and abdominal blunt trauma, but the negative predictive value is limited (Long et al. 2022). As in adults, Transcranial Doppler may be performed in cases of neurological failure to guide therapy, depending on local expertise (O'Brien, Maa and Reuter-Rice. 2015). The aim of these examinations is to guide the first emergency procedures in order to stabilize vital functions (Piccolo et al. 2017). In the context of a massive influx of victims, and given the expected limited availability of CT scans, the role of FAST-type ultrasound is even more important.

A precise and exhaustive assessment is obtained with a whole-body computed tomography (CT) scan, which is the reference examination for severe trauma patients (Huber-Wagner et al. 2009). Ideally, it should be performed within one hour of the trauma, which is why it is important to limit the time spent on scene. The CT scan should include a brain scan without contrast, a full spine scan and a thoraco-abdomino-pelvic scan with contrast.

In-hospital paediatric trauma teams should regularly rehearse CT transport procedures. In suspected traumatic brain injury, team should be prepared to actively manage elevated intracranial pressure during imaging, as this phase carries a considerable risk for secondary cerebral insults if not appropriately addressed. Following imaging, the head should be rapidly elevated to a 30-degree angle to facilitate venous drainage and help reduce intracranial pressure.

In the case of facial trauma, bone reconstructions will enable precise fracture analysis.
Importantly, the available evidence suggests that both abdominal and cranial CT scans are overused in the evaluation of injured children globally. Furthermore, as CT-related ionising radiation can cause malignancies, CT use should be avoided when not indicated. The intra-abdominal injury and traumatic brain injury prediction rules derived by the Pediatric Emergency Care Applied Research Network (PECARN) were designed to reduce inappropriate use of CT in children with abdominal and head trauma, respectively. It also has to be noted that CT scans should not delay surgical interventions when they are clearly indicated.

In the case of patients with vertebro-medullary lesions, Magnetic Resonance Imaging (MRI) may be discussed depending on patient stability and the availability of the examination, without delaying management (Roquilly et al. 2020).

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8. Specific trauma

8. 1. Abdominal trauma

Most abdominal injuries in children are related to a non-penetrating trauma, essentially due to a car accident, a sports accident or a fall (Naiditch et al. 2024). The type of injury found is similar in adults and children, with the exception of pancreatic or intestinal trauma, which may be more frequent in children.

Clinical examination of the abdomen is sometimes delicate in children, given their apprehension. Reassuring the child and ensuring adequate pain relief before the abdomen clinical examination are helpful. A seat belt syndrome is sometimes the only clinical feature, and its presence increases the likelihood of intra-abdominal lesions, as does a lumbar fracture. Since children often ingest large quantities of air when they cry, a nasogastric tube can help to relieve the patient and facilitate the examination.

In the initial phase, despite its low negative predictive value, FAST ultrasound is a useful tool for assessing abdominal injuries in children (Fornari and Lawson. 2021). However, management should not be dictated by the amount of intra-peritoneal blood, but by the patient's hemodynamic status and response to treatment. Abdominal CT scan with contrast remains the gold standard, but according to PECARN rules, abdominal ultrasound may be sufficient to detect basic abdominal lesions in the most stable patients (Holmes et al. 2017). When a CT scan is required, radiation dose should be kept as low as possible.

The therapeutic management of patients with abdominal trauma is essentially dictated by the patient's stability. Compared with the management of adults, the management of abdominal trauma in children is essentially based on a non-invasive approach (Gates et al. 2019). Selective, non-surgical management of solid organ injuries in children who are hemodynamically stable or rapidly stabilized during initial management is recommended in paediatrics. The presence of intraperitoneal blood on CT or FAST, the degree of injury and/or the presence of a vascular blush do not necessarily suggest laparotomy. Bleeding from a spleen, liver or kidney is generally self-limiting. For patients benefiting from this non-invasive approach, children should be managed in trauma centres with paediatric intensive care facilities supervised by a qualified surgeon.

For patients who are hemodynamically unstable or unresponsive to initial management, solid organ angio-embolization is a first-choice therapeutic option, but it should only be performed in centres with experience in paediatric procedures and operational access to the operating room. This decision must be multidisciplinary, including the paediatric surgeon, the intensive care or emergency physician and the interventional radiologist.

Finally, if the hemodynamic state cannot be normalized, and if the diagnostic procedure performed shows the presence of blood, then invasive management by laparotomy must be performed rapidly for damage control.

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8. 2. Thoracic trauma

Eight percent of childhood traumas involve the thorax. The thorax also serves as a marker for other injuries, since over 2/3 of children with thoracic trauma have another significant injury.
Like abdominal trauma, most thoracic injuries in children are blunt traumas, mainly resulting from traffic accidents or falls. The higher compliance of the chest wall means that pulmonary contusions are more frequent and rib fractures rarer in the paediatric population (Sweet et al. 2023). When these are present, they indicate the high energy level of the trauma.

The mobility of mediastinal structures means that children are particularly at risk of tension pneumothorax, the most common life-threatening injury in children. Pneumomediastinum is rare, and benign in the vast majority of cases. Diaphragmatic rupture, traumatic aortic dissection, tracheobronchial ruptures, costal flaps and cardiac contusions are rarely seen in children. When diagnosed, these lesions are treated in the same way as in adults.

The incidence of penetrating trauma increases in older children and management is similar as in adult population. Chest X-rays are usually sufficient to identify thoracic lesions, but CT scans remain the reference examination for the most severe patients.

Most thoracic injuries in children require symptomatic treatment and pleural drainage. Emergency thoracotomy is exceptionally necessary in children, and there are no specific recommendations in this population.

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8. 3. Brain trauma

Head injuries are more common in children with severe trauma than in adults (Wyen et al. 2010). Most head injuries in children result from motor vehicle accidents, abuse, sports accidents and falls.
Severe traumatic brain injuries (TBI) are associated with significant long-term morbidity, often impacting cognitive, motor, and psychosocial function. Prevention and early recognition of injury mechanisms are crucial. From an intensive care perspective, timely and effective intervention is essential to limit secondary brain injury and prevent further neuronal damage.

The child's brain is anatomically different from that of an adult. Small children are particularly susceptible to TBI due to distinct anatomical and physiological characteristics. The head is proportionally larger than the rest of the body, and the immature brain has a higher water content, reduced myelination of axonal fibers, and ongoing neurodevelopment, rendering it more vulnerable to shearing injuries and metabolic disturbances. Furthermore, the cranial bones are thinner and more compliant, and the scalp is delicate, offering less mechanical protection. Limited intracranial compliance in children also predisposes them to rapid increases in intracranial pressure following injury. As a result of reduced buoyancy, sudden movements of the head are more likely to induce parenchymal lesions, while extracerebral hematomas are less frequent than in adults. Contrary to certain beliefs, the fontanel does not protect against intracranial hypertension in young children.

Especially in small children (under one year) intracranial bleeding alone can lead to haemorrhagic shock. This should be considered in cases of unexplained shock, particularly in infants presenting with decreased level of consciousness.

Cerebral CT remains the gold standard for patients with head trauma. Here again, there are PECARN rules for performing CT scans, which prevent overuse of this examination.
From a pathophysiological point of view, children are more susceptible to the consequences of secondary brain damage, which can be caused by hypovolemia, hypoxia, seizures and/or hyperthermia. It is therefore essential to prevent and treat secondary brain damage.
The management of patients with traumatic brain injury is highly codified and requires rapid and early assessment, according to the c-ABCDE sequence (Kochanek et al. 2019). The primary lesion must be controlled, with management of any haemorrhagic shock and neurosurgical intervention if necessary (early neurosurgical advice is systematic). Appropriate sequential assessment and management of head trauma to prevent secondary brain damage - such as hypoxia and hypoperfusion - is also essential.

Appropriate and timely management of head trauma is critical in paediatric patients. Even a single episode of hypoxia or hypotension increases mortality in paediatric TBI. Specifically, their combined presence was clearly associated with significantly increased mortality.
Specifically, their combined presence was associated with a mortality rate of 43.9%, highlighting the importance of preventing these secondary insults in children with traumatic brain injury.

Early endotracheal intubation with adequate oxygenation and ventilation can prevent the progressive onset of central nervous system damage. In parallel, strict control of secondary cerebral aggression and osmotherapy should be considered in cases of intracranial hypertension, preferably with hypertonic saline (Shein et al. 2016).

In the context of intubation for suspected or confirmed elevated intracranial pressure (ICP), pharmacologic induction must be carefully tailored to the patient’s neurologic and haemodynamic state. The choice and dosing of an analgesic, hypnotic agent, and neuromuscular blocker (avoid if possible) should minimize rises in ICP and avoid hemodynamic instability. Vasoactive agents and their dose must be prepared so that they are readily available prior to induction, as even transient hypotension or hypoventilation can exacerbate secondary brain injury and significantly worsen neurological outcomes. Pupillary size and reactivity should be meticulously assessed and documented immediately before and after intubation, as changes may indicate evolving intracranial pathology. Then, always maintain the head in a 30-degree elevated position to facilitate venous return and support intracranial pressure management.

If intracranial pressure monitoring is performed, ICP < 15 mmHg should probably be targeted (Woods et al. 2021) (Table 6).

Finally, because the outcome of head trauma patients is more dismal, the existence of severe head trauma must influence the overall surgical strategy and anaesthetic modalities. The risk-benefit ratio of any surgery must be measured and considered collegially.

Table 1: Clinical targets in TBI management

Parameters	
Cerebral Perfusion Pressure	• > 44 mmHg in children from 0 to 5 years-old • > 50 mmHg in children from 5 to 17 years-old
Intracranial Pressure	• < 15 mmHg in children under 2 years-old • < 20 mmHg for everyone else
Mean Arterial Pressure when intracranial pressure unknown	• >40 mmHg in children from 1 month to 1 year old • >50 mmHg in children 1 to 4 years old • > 60 mmHg in children from 5 to 8 years-old • > 70 mmHg in children more than 8 years old
Systolic Blood Pressure when intracranial pressure unknown	• > 90 mmHg in children under 1 year • > 95 mmHg in children from 1 to 5 years-old • > 100 mmHg in children from 5 to 11 years-old • > 110 mmHg in children over 12 years-old

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9. Key messages

The age-based variation in normal observations, varying size in the required equipment, variation in medication dosage as well as the different psychosocial requirements are challenging in children.

- Paediatric trauma patients must be admitted to a centre with resources and skills appropriate to the patient's severity.
- Organizational aspects are crucial in the management of trauma patients.
- Initial management is based on the c-ABCDE algorithm, including damage control management.
- Tachycardia is often a more sensitive indicator of significant hypovolemia than blood pressure, but it is susceptible to confounding factors such as pain, discomfort and fear.
- Temperature control and particularly prevention of hypothermia is very important in children
- Diagnostic strategy is based on emergency ultrasound and whole-body CT for most patients.
- In cases of trauma brain injury, prevention and treatment of secondary brain damage is essential. Maintain adequate blood pressure and oxygenation to ensure cerebral perfusion. Hypertonic saline should be administered based on clinical assessment when intracranial pressure is suspected or confirmed, to reduce cerebral edema and to support cerebral perfusion.