Paediatric trauma

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Key points

Anatomical and physiological differences in children require special consideration.

Most seriously injured children have multiple injuries.

Traumatic brain injury is responsible for >85% of deaths in paediatric trauma victims.

The dimensions of the child's torso lead to increased vulnerability of the intra-abdominal organs to injury.

Hypotension is a late sign of hypovolaemia. A child can lose >40% of blood volume before arterial pressure decreases.

Trauma is the leading cause of death and disability in children <1 yr of age. In the UK, >80% of injuries are caused by blunt trauma. Most seriously injured children have multiple injuries.[1] Head injury is present in the majority of cases and accounts for 75% of deaths. Injury mechanisms vary with age.[2] In infants, non-accidental injury (NAI) is most common, whereas, for toddlers, falls are the predominant injury mechanism. In older children and adolescents, road traffic accidents (RTAs) and sports injuries predominate. More than 50% of RTA's involve the child as a pedestrian and a further 20% as cyclists.[3]

Paediatric trauma deaths have a trimodal distribution with 50% dying at the scene from either severe head injury or major haemorrhage. A further 30% die within the first few hours from head injury, haemorrhage, or airway emergencies. Late deaths due to organ failure and sepsis are often due to inadequate initial resuscitation. Up to 30% of deaths are preventable by rapid identification of problems and early aggressive treatment.

Systematic approach to the paediatric trauma victim

The survival of children who sustain major life-threatening trauma depends upon good prehospital care, appropriate triage, and effective resuscitation. Many cases will initially be managed in the A&E department of a DGH. Paediatric trauma management requires a team approach and the co-ordinated efforts of multiple specialists. The team should consist of a paediatrician or paediatric A&E consultant, an anaesthetist or intensivist, and a nurse working in concert with A&E or ward staff. Other staff may be required, for example, a general surgeon, an ENT surgeon, and additional support including ODPs, theatre nurses, recovery nurses, and radiographers. Access to support services such as radiology, pathology, and laboratory services may also be needed.

After the initial stages of resuscitation, stabilization and further management should not be left solely to the anaesthetist.

The initial management of paediatric trauma is covered in APLS, EPLS, and ATLS courses and all use the common structured approach:[4]

- Primary survey
- Initial resuscitation
- Secondary survey
- Emergency treatment
- Definitive care

Primary survey and resuscitation

The primary survey follows the 'ABCDE' sequence and involves a rapid physiological assessment to identify immediate threats to life in a structured order.

Airway

The first priority in managing a child with acute trauma is to ensure a patent airway. Special airway considerations include the possibility of cervical spinal injuries, head injury, and the presence of a full stomach. The larger head and relatively smaller mid-face make airway obstruction more common in children than in adults. This together with increased respiratory rate and increased oxygen consumption makes establishing and maintaining the airway in children more urgent. Cervical spine injury is uncommon in children (<2% of trauma cases) compared with the large number (75%) with traumatic brain injury (TBI). The need to avoid a further hypoxic insult to the child with TBI while protecting the C-spine remains particularly challenging. In many cases, simple jaw thrust or insertion of an oral airway may relieve airway obstruction. In the trauma setting, orotracheal intubation is preferred to the nasal route. Indications for intubation are similar to adults.

Criteria for intubation/ventilation

- Respiratory inadequacy
- Glasgow Coma Scale (GCS) <8

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- Suspected raised intracranial pressure (ICP)
- Need for prolonged ventilation
- Need for transport to tertiary centre

Orotracheal intubation with manual in-line immobilization after rapid sequence induction should be used to secure the airway in blunt trauma with an uncleared C-spine. The circulatory state and the conscious level must be taken into account when choosing the induction agents and their dose. The goal of drug usage is to produce unconsciousness, improve intubating conditions, and blunt haemodynamic responses in children with head injury and possible raised ICP. Suitable induction agents include thiopental 2–5 mg kg^{-1}, etomidate 0.3 mg kg^{-1}, or ketamine 1–2 mg kg^{-1} combined with fentanyl 0.5–1.0 μg kg^{-1}.

In cases of circulatory inadequacy, the dose of thiopental should be reduced. Succinylcholine is widely used in children and is not contraindicated in the initial resuscitation phase, unless there has been a major crush injury. Once successful intubation has been performed, a naso/orogastric tube should be passed to prevent gastric dilation which can seriously compromise oxygenation and ventilation in the child. It is important to provide ongoing sedation, analgesia, and muscle relaxation to prevent coughing on the tube and alterations in ICP in children with significant head injury.

Breathing

Breathing and ventilation need to be rapidly assessed. Children have greater oxygen consumption, smaller functional residual volume, and increased chest wall compliance, predisposing to airway collapse and hypoxia. The diaphragm is both easily fatigued and easily displaced. Urgent intervention may be needed to treat tension pneumothorax, open pneumothorax, haemothorax, or flail chest.

Circulation

Circulation should be assessed by evaluating heart rate, capillary refill time, skin colour, arterial pressure (AP), and mental status. Particular attention should be paid to peripheral perfusion. Children compensate well after major haemorrhage as vasculature readily constricts and increases systemic vascular resistance to maintain perfusion pressure.

AP is well maintained until hypovolaemia is quite severe, >25–40% of blood volume loss.[5] Hypotension in a child is a sign of decompensated shock and may be abruptly followed by bradycardia. Tachycardia is a more useful sign of hypovolaemia, but may also reflect pain and fear. In small children, i.v. access is often easier in the hands and feet than in the antecubital fossae. If no i.v. access is achieved within 90 s in a severely injured child <6 yr of age, intraosseous access is appropriate. Initial fluid resuscitation should consist of warm isotonic crystalloid solution (Ringer's lactate or isotonic saline) and should be administered in 20 ml kg^{-1} boluses guided by heart rate, peripheral perfusion, AP, and mental status. If failure to improve with >40 ml kg^{-1} of crystalloid, then blood 10 ml kg^{-1} boluses should be given followed by frequent reassessments. In the face of ongoing haemorrhage, fresh frozen plasma and platelets will be required.

The trend in adult trauma resuscitation is to give smaller boluses of fluid 10 ml kg^{-1} followed by reassessment and further 10 ml kg^{-1} boluses as required.[6] A recent Cochrane systematic review concluded that there is no evidence from randomized clinical trials for or against early or larger volumes of fluids in uncontrolled haemorrhage.[7] Fluid loading may be harmful in the face of uncontrolled haemorrhage particularly after penetrating trauma. It can exacerbate bleeding and contribute to coagulopathy and hypothermia. Permissive hypotension (systolic AP=80 mm Hg) may be appropriate in this situation, providing that it is combined with immediate surgical intervention to control the bleeding. In children without a TBI, a systolic AP of 80 mm Hg is more than adequate to maintain organ perfusion. 'Best' fluid remains controversial in the initial treatment of the bleeding trauma patient. Both crystalloids and colloids are effective in correcting hypovolaemia. Large volumes of normal saline can lead to hyperchloraemic acidosis (Table 1).

Disability

The assessment of disability during the primary survey consists of a brief neurological examination to determine conscious level, and assessment of pupil size and reactivity. Conscious level is rapidly assessed using the AVPU score:

- A: Alert
- V: Responds to voice
- P: Responds to pain
- U: Unresponsive

The aim of the neurological assessment is to identify severe head injury which may require urgent neurosurgical intervention and neuroprotective intensive care strategies. Analgesia should be considered at this stage if not already given before intubation. Morphine is the drug of choice and should be given in a dose of 0.1–0.2 mg kg^{-1}.

Investigations

X-rays: CXR, pelvis, C-spine.

Investigations: ABG, FBC, cross-match, glucose, U&Es. Urinary catheter if required.

Detailed history of accident and medical history

Allergies
Medications
Past medical history
Last oral intake
Environment in which the injury occurred

Secondary survey and emergency treatment

The secondary survey is started as soon as the child is stabilized. This consists of a detailed head to toe examination of the child. C-spine protection is important especially during this phase as is avoidance of hypothermia. The use of warming blankets and overhead radiant heaters can help minimize heat loss. During the secondary survey, there is continued reassessment of ABCs.

Head and neck

The child should be assessed for injuries: bruising, lacerations, compound or depressed fractures, and cerebrospinal fluid leak. A neurological assessment should be performed consisting of a GCS, neurological examination, pupillary reflexes, and examination of fundi. The presence of retinal haemorrhages suggests NAI. A modified verbal and motor version of the GCS has been developed to aid in the evaluation of conscious level in infants and young children.[8] The GCS score and its modified version (with scores 3–15) are based on a child's best response in three areas, eye opening, verbal response, and motor response. TBI is classified as mild (GCS 13–15), moderate (GCS 9–12), or severe (GCS 3–8) (Table 2).

A brain computed tomographic (CT) scan is indicated if the GCS <12, loss of consciousness at time of injury, skull fracture, retrograde amnesia, neurological symptoms/signs, or severe injury. The CT scan should also include C-spine and may include the chest or abdomen if indicated. The child should be referred to a neurosurgical unit if any of the following are present:

- Focal neurology
- Deteriorating neurological signs
- Evidence of increased ICP
- Abnormal CT
- Penetrating injury or depressed skull fracture

Emergency osmolar therapy is indicated for patients with signs of mass lesions or impending cerebral herniation. Mannitol 1 g kg^{-1} or hypertonic saline 5 ml kg^{-1} may be used. Hypertonic saline is not associated with an osmotic diuresis.

TBI is a major cause of morbidity and mortality in paediatric trauma victims. The primary goal of management of any child with severe TBI is the prevention of secondary insults, control of ICP, maintenance of adequate cerebral perfusion pressure (CPP), and identification of mass lesions requiring emergency surgical evacuation.[9] Secondary insults include hypoxia and hypotension.

Avoidance of hypotension cannot be overemphasized as just one episode of hypotension can double the risk of death. Systolic AP should be maintained at the recommended normal level for age. Over enthusiastic hyperventilation to P_{CO_2} <30 mm Hg may lead to cerebral ischaemia.

The current guidelines[10] recommend that children with a GCS 3–8 should have ICP monitoring and will require treatment if ICP >20 mm Hg. It is also recommended that the CPP should be maintained at >40 mm Hg. Although avoiding CPP <40 mm Hg is the only current recommendation for children with severe TBI, age-specific thresholds 40–60 mm Hg are likely important. Adult guidelines recommend CPP 50–70 mm Hg. The CPP is calculated by subtracting the ICP from the mean AP. It is important to note that impaired autoregulation is present in up to 50% of paediatric TBI patients. The role of therapeutic hypothermia in paediatric TBI is unclear.[11] A number of multicentre randomized trials are ongoing. The routine use of therapeutic hypothermia cannot be recommended at present.

Spinal injuries

Spinal cord injuries are rare in children, <2% of trauma victims. The cartilaginous vertebral bodies are less lightly to fracture and the elastic ligaments and horizontal facet joints contribute to increased spinal mobility in children. This tends to protect the spine from injury by dispersing energy over several segments.

Because of the underdeveloped neck musculature and disproportionately large head, young children are more likely to suffer high spinal injuries (C_1–C_3). The fulcrum of spinal flexion is C_{2-3} in the child and C_{5-6} in the older child. Subluxations and dislocations are common. In all cases of major trauma, spinal injury must be presumed until spinal clearance is possible. It can be difficult to rule out spinal cord injury in children radiologically

Table 1 Normal physiological parameters in children

Age (yr)	Respiratory rate	Systolic AP	Heart rate
<1	30–40	70–90	110–160
1–2	25–35	80–90	100–150
2–5	25–30	80–105	95–140
5–12	20–25	90–110	80–120
>12	15–20	100–120	60–100

Table 2 The Glasgow Coma Scale

Standard	Score	Paediatric
Eye opening		
Spontaneous	4	Spontaneous
To speech	3	To speech
To pain	2	To pain
None	1	None
Verbal response		
Orientated	5	Age appropriate
Confused	4	Irritable, cries
Inappropriate words	3	Cries to pain
Incomprehensible	2	Moans to pain
None	1	None
Motor response		
Obeys commands	6	Spontaneous movement
Localizes to pain	5	Withdraws to touch
Withdraws to pain	4	Withdraws to pain
Abnormal flexion	3	Abnormal flexion
Extensor response	2	Extensor response
None	1	None

as up to 50% of spinal cord injuries may exist without radiological evidence (SCIWORA).[12] CT scans are useful for upper spinal injuries. If clearance is not clinically possible at 72 h, then a magnetic resonance imaging scan is indicated.

Chest trauma

Thoracic injuries occur in ~3% of children with blunt trauma and are a significant cause of mortality. Of the thoracic injuries identified during the secondary survey, pneumothorax, haemothorax, and pulmonary contusion are common whereas blunt cardiac, tracheobronchial tree, aortic, and diaphragmatic injuries are rare. The elasticity of children's ribs reduces the risk of rib fracture, but allows the transfer of energy to internal structures. Pulmonary contusion without rib fractures is common. The presence of rib fractures is a reliable marker of the severity of the trauma. If the nature and extent of the thoracic injuries is uncertain, a chest CT is indicated.

Abdominal trauma

Abdominal trauma accounts for about 10% of trauma in children but is the leading cause of initially unrecognized fatal injury. It is second only to airway problems as the most frequent cause of preventable death. The dimensions of the child's torso lead to increased vulnerability of intra-abdominal organs. Superiorly, the very pliable ribs allow solid organ injury to the liver and spleen, and inferiorly, the pelvis fails to protect the bladder. Splenic injury is the most common followed by hepatic, renal, intestine, and pancreatic.

A physical examination detects 97% of abdominal injuries. The presence of bruising, abrasions, guarding, tenderness, and abdominal distension is suggestive of injury. The presence of haematuria should alert one to the possibility of renal injury.

If still in doubt, a double contrast-enhanced CT scan of the abdomen is the diagnostic tool of choice. More than 90% of abdominal injuries in children are managed non-operatively. Indications for laparotomy include:

- A haemodynamically unstable child with a distended abdomen, despite adequate resuscitation
- Proven peritonitis
- Pneumoperitoneum
- Renal vascular injury

Limbs

Skeletal injury occurs in 10–15% of the paediatric trauma victims. It is uncommon for extremity trauma to be life-threatening and most can be managed without surgery. Pelvic fractures are rare in children. Single, closed, long bone fractures may cause significant blood loss and lead to hypovolaemic shock and therefore should be immobilized in splints as soon as possible. As a general rule, an open fracture causes twice as much blood loss as a closed fracture as there is no tamponade effect from surrounding tissues. Thus, a single, open, femoral shaft fracture may result in up to 40% loss of blood volume.

Non-accidental injury

NAI is the most common cause of head injury in the first year of life. Coma+retinal haemorrhage is NAI until proven otherwise. Subdural haemorrhages are the most common finding on CT scans. Other common associated injuries include fracture shaft of the femur in a child <3 yr, bruising in a finger mark pattern, bite marks, or cigarette burns. Other supporting evidence includes delay in seeking help, history incompatible with nature and severity of injuries, injuries of different ages, and abnormal demeanour in the child. Paediatric referral is essential in suspicious circumstances.[13]

Definitive care

Once the child has been stabilized, they should be transferred to a paediatric intensive care unit (PICU) for ongoing care. Early referral to the regional PICU allows transport to be organized by the receiving unit and enables advice and support to be given before the transfer. Children with significant head injuries should be referred early to the regional neurosurgical unit. It is currently recommended that surgical evacuation of a significant haematoma should occur within 4 h of presentation to an emergency department.[14] In such cases, it may not be appropriate to await the arrival of a retrieval team and a team from the referring hospital may have to undertake the transport.

Arrangements should be in place for situations where it is clinically inappropriate to await the retrieval team. Arrangements should include advice from the lead centre, a list of conditions that are time-critical for the hospital concerned, and contact details of relevant specialists where additional advice may be required, for example, neurosurgeons. The child should be escorted by a doctor and nurse with experience, training, or both in (i) care of the critically ill child, (ii) emergency transfer, and (iii) airway management. Appropriate drugs and equipment must be available for an emergency transfer. Drugs and equipment should be checked in accordance with local policy.

Parents

Appropriate information, encouragement, and support should be available to parents to enable them to participate fully in decisions about, and the delivery of, care to their child. They should be regularly updated on the progress of their child. At all stages of the care pathway, the need for information and support for the family should be borne in mind, including, if necessary, through bereavement. The organization of transfer and retrieval should include arrangements to minimize difficulties for families. If they cannot accompany the child in the ambulance, parents should be offered transport to the admitting hospital by taxi. Arrangements should be in place to ensure that financial support is available to cover the costs of transport and overnight accommodation if applicable.[15]

Declaration of interest

None declared.

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Please see multiple choice questions 37–40.