The Kids Are Alright

Pediatric Trauma Pearls

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KEYWORDS

• Pediatric trauma • Pediatric primary survey • Pediatric airway • Pediatric C-spine
• Pediatric head trauma • Pediatric trauma diagnostic imaging
• Transport of the pediatric patients with trauma • Pediatric trauma simulation

KEY POINTS

- Initial resuscitation and stabilization of pediatric patients with trauma is of critical importance.
- There are special differences to consider in the ABCs (airway, breathing, circulation) of pediatric trauma care.
- Clinicians should know the goals of pediatric trauma resuscitation.
- Common injury patterns, physiologic differences, and treatment approaches used in pediatric trauma centers may differ from those in adult trauma practices.

INTRODUCTION

Pediatric patients with trauma pose unique challenges, both practical and cognitive, to front-line care providers. Emergency physicians are already skilled at resuscitating and stabilizing patients with trauma. The initial resuscitation of a traumatized child should follow the same Advanced Trauma Life Support (ATLS) principles used with adult trauma resuscitations. Therefore, trained emergency physicians have all the skills and competencies required to manage acutely injured children. What is sometimes lacking is the confidence and experience required to understand the common injury patterns, physiologic differences, and treatment approaches used in pediatric trauma centers, which may differ from adult trauma practices.

Children have anatomic, physiologic, and metabolic differences that are well described in textbooks and the medical literature.[1,2] It is the combination of these factors that leads to unique injury patterns with different approaches and responses to

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treatment compared with adults. A similar traumatic mechanism can lead to slightly different internal injuries with unique management and treatment strategies between the two groups.

This article is intended for community, nonpediatric trauma center, emergency physicians who are frequently called on to assess, resuscitate, and stabilize injured children before they can be safely transferred to a pediatric trauma center for ongoing definitive care and rehabilitation.

This article focuses on the most common and practical pointers regarding pediatric patients with trauma with a blunt mechanism of injury. It does not focus on penetrating traumatic injuries. Most pediatric patients with blunt trauma are not rushed to the operating room (OR) for emergency surgery. Most pediatric patients with trauma with a blunt mechanism of injury respond and stabilize with an appropriate initial medical resuscitation. Well-resuscitated and stabilized patients are then able to be transported safely to a pediatric trauma center for ongoing definitive care and rehabilitation.

Typical Emergency Medical Services Patch Call

A 5-year-old boy, injured while crossing the street when he was struck by a vehicle at city speeds (~50 km/h). He is crying and pale, with a hematoma to the left forehead; bruising to the left side of the upper abdomen; and an obvious, closed, deformity of his left tibia and fibula. His vital signs are heart rate (HR), 135 beats/min, respiration rate (RR), 30 breaths/min; blood pressure (BP), 95/65 mm Hg; and O_2 saturations of 91% on room air, which improve to 97% with supplemental O_2.

Key issues to focus on:

- Based on their anatomy, children respond to external forces like bobble-head figurines. They have a large cranium on a short, weak, neck. There is usually some component of head injury (mild, moderate or severe) that needs to be managed. Supportive therapy for traumatic brain injury (TBI) is the mainstay of treatment. Ongoing, active assessment for signs and symptoms of increased intracranial pressure (ICP) is required. Clinical signs of increased ICP necessitate active treatments focused on reducing ICP.
- Cervical spine (C-spine) injuries are rare but C-spine protection and assessment are important. Be concerned about young, nonverbal children who do not move their necks. Be reassured but cautious with young, nonverbal children who freely turn their heads while crying.
- Pulmonary contusions are the most common intrathoracic injuries. Pneumothorax and hemothorax occur less frequently than in adults because of the flexibility of the bones in the rib cage and the transmission of blunt force to the organs and tissues underneath.
- Intra-abdominal injuries most commonly involve bleeding of the large solid organs (ie, spleen and liver).
- Orthopedic injuries and pain management are also common considerations in pediatric patients with multitrauma. Be concerned when children are lying still and not freely moving an extremity. Be reassured when children are spontaneously moving their arms and legs, because they are less likely to have a significant fracture in that limb. Pain and hypovolemia are both common causes of tachycardia, so they need to be addressed in the initial approach to the patient.

PRIMARY SURVEY

ATLS principles for initial assessment are the same in pediatric patients as in adult patients with trauma. The ABCDE (airway, breathing, circulation, disability, expose) cognitive model is organized to identify and treat life-threatening issues as soon as possible.[3] A Broselow tape and color-coded pediatric resuscitation equipment system (eg, cart, bags) should be readily available so that unnecessary challenges and delays in locating the proper-sized equipment can be minimized. Continuous monitoring of vital signs is essential for ongoing assessment of response to interventions. A vigilant algorithm of assess, reassess, and reassess again must be maintained to accurately follow a patient's positive trajectory toward improvement and stabilization, or to quickly recognize and respond to a patient's deterioration, which would require more aggressive resuscitation and treatment. Call for assistance as early as necessary. Mobilize transport teams and obtain clinical support and advice from pediatric experts as early as possible. There is no shame in calling for advice. Pediatric experts are always willing to assist, advise, and accept patients in transfer. Pediatric trauma centers do not put up obstacles to patient transfer and should always be there to assist their community partners.

Pediatric Primary Survey: Airway, Breathing, Circulation, Disability, Exposure

A talking or crying child has a patent airway, is breathing spontaneously, and has sufficient BP to maintain cerebral perfusion and could be considered stable initially.[4] In contrast, a quiet, nonvocalizing child with an altered level of consciousness (LOC) likely has severe, multisystem injuries.[4] Emergency departments (EDs) should be equipped with a quick and accessible reference for age-specific vital signs as well as tips for key numbers to remember or cutoffs to keep in mind. Check vital signs, temperature, and glucose level immediately. On initiating assessment of the ABCDEs, make sure to oxygenate, start intravenous lines, and begin fluid resuscitation.

- Airway with C-spine protection:
  - Clear secretions, and assess patency and need for immediate tracheal intubation
    - Indications for early intubation include[5,6]:
    - Airway obstruction, unrelieved by simple maneuvers.
    - Apnea.
    - Cardiac arrest.
    - Decreasing LOC (airway protection and control of CO_2).
    - Severe maxillofacial trauma.
    - Inhalation injury.
  - Focus on oxygenation. Always be prepared to support pediatric patients with good quality bag-valve-mask (BVM) ventilation. BVM maintains oxygenation and compensates for poor respiratory effort while providing time to smoothly and properly prepare for a pediatric intubation in the adult ED (**Fig. 1**).
  - Most pediatric patients can be oxygenated using O_2 or BVM initially until the primary survey can be completed and intubation equipment and drugs can be prepared. BVM is the key airway skill for non–pediatric emergency medicine physicians. The ability to properly maintain a mask fit, provide continuous positive airway pressure (CPAP), and bag-mask ventilate is a more valuable skill than being able to intubate the trachea.[5]
  - For successful BVM, ensure a tight seal and use high-flow oxygen. Be sure to apply CPAP as well as a jaw thrust and chin lift. If tolerated, an oral airway may assist by lifting an obtunded child's large tongue off the posterior pharyngeal wall. Use a 2-handed mask support technique if having difficulties in achieving an adequate seal and fit.[5]

Intubation checklist

Roles and duties

- ✔ Backup personnel called (RT, extra MD)
- ✔ Roles assigned
- ✔ Assess for difficult airway
- ✔ Airway management plan verbalized (A, B and C)

Equipment

- ✔ Personal Protective Equipment
- ✔ Suction-assembled, checked, working
- ✔ Oxygen-assembled, checked, working
- ✔ Bag mask (PEEP valve) + OPA / NPA
- ✔ Laryngoscope, alternate blade, lights working
- ✔ ETT (+size below)
- ✔ Stylet
- ✔ Backup airway (LMA)
- ✔ Bougie considered
- ✔ Monitors attached
- ✔ Vitals checked and optimized (incl. preoxygenate)
- ✔ Nasal prongs-with 2nd O2 source functioning
- ✔ Capnography ready
- ✔ Patient position optimized for ideal view
- ✔ IV access working (euvolemic)
- ✔ ETT tape/securing mechanism

Medications

- ✔ Atropine (20 mcg/kg)
- ✔ Ketamine (1–2 mg/kg)*2doses
- ✔ Succinylcholine (2 mg/kg)*2doses

Rescue (*2doses)

- ✔ Epinephrine 0.01 mg/kg 0.1 mL/kg 1:10000 IV/IO

Personnel

- ✔ Caregivers present or notified

Post intubation

- ✔ Depth checked (3*tube diameter)
- ✔ Placement checked*2 (capnography)
- ✔ Tube secured
- ✔ Sats improving? (DOPE)
- ✔ Insert NG / CXR called
- ✔ Midazolam/ other sedative
- ✔ Disposition

Age	Wgt kg	Uncuff ETT	Cuffed ETT	Blade (MAC)	Straight Blade	Depth cm	LMA	AirQ LMA	OPA	NPA
Prem	<3	2.5 – 3		0	0 or 1	7–8	0 to 1		Pink	12F
Term	>3	3 – 3.5	2.5 – 3	0	0 or 1	8–9	0 to 1	1.0	Blue	14F
6 – 12mo	6	3.5 – 4	3 – 3.5	1	1	10	1 to 1.5			14–16F
1	11	4	3.5	1 or 2	1 or 2	11	1.5	1.5	Black	18F
2	13	4.5	4	2	2	12	2			20F
3	15			2	2					22F
4	17	5	4.5	2	2	13		1.5 – 2		22F
5	19			2	2				White	24F
6	21	5.5	5	2	2	14	2.5	2		
7	23			2	3					
8		6	5.5	3	3	16			Green	26F
9				3	3					
10		6.5	6	3	3	18	3	2.5		

All sizes to be confirmed clinically before use. Drs. Michelle McTimoney, Dominique Eustace and Martin Gauthier. Last updated March 2015

Fig. 1. Intubation checklist (front and back). *, times; ETT, endotracheal tube; LMA, laryngeal mask airway; MD, doctor of medicine; NPA, nasopharyngeal airway; OPA, oropharyngeal airway; PEEP, positive end-expiratory pressure; RT, respiratory therapist.

- ○ Ensure adequate C-spine protection, particularly when moving the patient. A collar should be on all school-aged and adolescent children. Rolls and tape should be used for infants and toddlers.

- Breathing:
  - Assess for adequacy of respirations (spontaneous effort, breath sounds, and oxygen saturation levels).
  - Apply supplemental oxygen to all pediatric patients with trauma. Children desaturate quickly. It is important to prevent hypoxia.
    - O_2 by face mask in older patients. O_2 flow rate of 6 to 10 L/min.
    - O_2 by nasal prongs or mask in infants. O_2 flow rate of 2 L/min in infants/children less than 2 years of age. Flow rate of 4 L/min for children more than 2 years of age.
  - If the patient is intubated in the field, always reassess respirations bilaterally and confirm endotracheal tube (ETT) position after arriving in the ED.
    - Because of the short length of the trachea, right mainstem intubations are common in children. Always consider this if there are decreased breath sounds from the right chest.
    - Monitor the patient's end-tidal CO_2 continuously.
  - Insert a nasogastric (NG) tube to decompress the stomach; this is especially important if the child is difficult to ventilate or the child's stomach is becoming distended from BVM. A distended stomach interferes with ventilation.
- Circulation with control of external hemorrhage:
  - The accurate assessment of circulation and the adequate resuscitation of shock are ongoing challenges for those health care providers who do not treat pediatric trauma on a regular basis.
  - The most common cause of shock in pediatric patients with trauma is hypovolemia caused by bleeding.
  - Some of the most common bleeding sites are spleen, liver, pelvis, scalp, long bone fractures, and hemothorax.
  - The circulating blood volume in a child is only 80 mL/kg. Therefore, in smaller children, even a small amount of blood loss can have a significant impact on hemodynamics and perfusion.
  - Start 1 to 2 intravenous (IV) lines and draw trauma blood work while the ABCDEs are being assessed.
    - Order crossmatch or type and screen.
  - If unable to establish rapid intravenous access in an unstable patient, then insert an intraosseous (IO) line to begin the resuscitation.
  - When first intravenous/intraosseous access is established, give 20 mL/kg normal saline (NS) crystalloid bolus to start treatment while completing the assessment. Monitor HR (tachycardia), check capillary refill, and assess for sites of bleeding (abdomen, pelvis, long bone fractures). Hypotension is a late sign of decompensated shock.
  - Use warmed solutions if the patient is already cold. Prevent hypothermia.
  - Use a rapid infuser if a patient is unstable or decompensating and it is necessary to deliver volume support more quickly. Young children may require the push-pull method of fluid delivery by a syringe. Regular intravenous infusion pumps are too slow and should not be used in the initial stabilization of patients with trauma.
  - Be wary of tachycardia and signs of peripheral vasoconstriction (delayed capillary refill, cool extremities, weak peripheral pulses). Do not wait for BP to decrease. Compensated shock can quickly lead to rapid decompensation and arrest.
  - If the patient has not stabilized after the second 20-mL/kg bolus of NS crystalloid, then prepare to give 10 to 20 mL/kg of blood (uncrossmatched or type specific).

  - Assess for and control obvious sources of bleeding (eg, blood-soaked clothing).
    - Internal bleeding (bulging abdomen, hemothorax) requires aggressive resuscitation toward definitive management.
    - If there is a suspicion of an obvious open-book pelvic fracture, wrap or splint the pelvis to decrease blood loss.
  - Most pediatric patients with trauma do not require an urgent trauma laparotomy or thoracotomy in the OR and stabilize when resuscitated properly.
- Disability:
  - Conduct a brief neurologic examination and check neurologic responses.
  - Spontaneous movement.
  - Sensation or complaints of pain.
  - Responsiveness to voice.
  - Assess Glasgow Coma Scale (GCS) score (Pediatric GCS). The AVPU (alert, voice, pain, unresponsive) test can be a useful surrogate for GCS. In general, patients who are either P or U have a GCS less than 8 and cannot protect their own airways.
- Expose patient:
  - Assess all surface areas (including diaper) while preventing risk of hypothermia by keeping the trauma room warm and covering the patient with warm blankets after the assessment.
  - Quickly conduct a musculoskeletal assessment for obvious limb deformities (**Box 1**).

Recently Published Innovations That May Affect the Primary Survey

Acker and colleagues[7] recently attempted to improve on shock recognition and treatment. A novel look at the shock index, pediatric age adjusted (SIPA) may be able to predict severity more accurately than BP alone. Hypotension alone (systolic BP [SBP] <90 mm Hg for ages 4–6 years; SBP <100 mm Hg for ages 7–16 years) predicted need for the OR (13%), ETT (17%), and transfusion (22%). SIPA score (defined as HR divided by systolic BP) predicts the need for OR (30%), ETT (40%), and transfusion (53%).[7] Because tachycardia is an early but nonspecific indicator of hypovolemia and SBP is a specific but late marker of hypovolemia, it makes sense that combining the two measures into the SIPA may improve the ability to predict the need for important interventions such as OR, intubation, or blood transfusion.

Golden and colleagues[8] studied whether or not admission hematocrit could predict the need for transfusion secondary to hemorrhage in pediatric patients with blunt trauma. They found a significant decrease in admission hematocrit for patients requiring a transfusion. Cutoff admission hematocrit of 35% or less had a sensitivity of 94% and negative predictive value of 99.9% in identifying children who needed a transfusion after blunt trauma.[8]

Obtaining trauma laboratory tests in pediatric patients can be a challenge. The future may involve noninvasive methods of assessment. Ryan and colleagues[9] studied a novel, noninvasive hemoglobin measurement device. The pulse co-oximeter (Pronto device) was studied in 114 patients. There was good correlation between hemoglobin levels across various methods of measurement, including noninvasive strategies.[9]

Diagnostic Imaging for Blunt Pediatric Trauma at Referring Center Before Transport

The ninth edition of ATLS recommends only chest and pelvic radiographs for patients with blunt trauma at the referring center before transport.[3] For children whose C-spines cannot be clinically cleared, a lateral neck radiograph may be used as a screening tool

Box 1
Back to the case: summary of airway, breathing, circulation, disability, exposure survey and initial actions

Airway

- Patent; no obvious injury or obstruction

Breathing

- Good, spontaneous effort, mildly tachypneic at 30 breaths/min
- O_2 saturation is good at 97% on 10 L/min by face mask
- Decreased breath sounds to LLL with bruising
- Trachea midline

Circulation

- Tachycardic at 135 beats/min
- Abdomen tender in LUQ with bruising
- Pelvis stable and nontender
- Capillary refill 3 seconds centrally and 4 seconds peripherally

Disability

- Eyes closed, opens to speech, confused, obeys commands
- Patient is verbal (V in AVPU score); GCS = 13

Exposure

- Closed deformity of left tibia/fibula, good pulses
- No other obvious injuries

Actions

- Maintain O_2 saturation with supplemental oxygen
- Start intravenous line and give 20 mL/kg of NS
- Draw trauma laboratory tests
- Maintain C-spine precautions

Abbreviations: LLL, left lower lobe; LUQ, left upper quadrant.

but is not mandatory as long as the C-spine remains immobilized and protected. Pelvic radiographs on pediatric patients may be omitted in children at low risk for fracture with a normal GCS and normal hemodynamic status without any signs of abdominal trauma, abnormalities on pelvic examination, or an associated femur fracture or hematuria.[10]

- C-spine radiograph: may be done if unable to clinically clear or may be deferred if child is left in cervical collar for transport
- Chest radiograph: yes
- Pelvic radiograph: yes, if suspicion of pelvic fracture or hemodynamic instability
- Computed tomography (CT) imaging: should not delay transport; usually best decision is to allow the pediatric trauma center to perform CT imaging

Puckett and colleagues[11] recently studied advanced imaging at referral centers before transfer to designated pediatric trauma centers and concluded that advanced imaging at referral centers exposes children to excess radiation. Overall, the mean radiation dosing was 54% lower at pediatric trauma centers (51% lower for CT abdomen and pelvis and 62% lower for CT head). These findings support the ATLS recommendation for prompt transfer without delay for advanced imaging.[11] Therefore, do not delay transfer to definitive treatment with investigations that are likely to need to be repeated and will not aid the immediate clinical management (**Box 2**).

HEAD INJURY

Many pediatric patients with trauma present with a component of TBI, which can be mild, moderate, or severe. Resuscitative efforts must preserve cerebral perfusion pressure (CPP) without increasing ICP. Remember that the CPP is the difference between the mean arterial pressure and the ICP (CPP = MAP − ICP). Initial principles of TBI management are the same in adult and pediatric patients with similar goals of therapy. First, do no harm. Provide the necessary supportive therapies of the primary survey and initial resuscitation. Avoid secondary neuronal injury by preventing hypoxia and hypotension. Further ICP spikes are preventable with appropriate administration of analgesics and anxiolytic agents before noxious stimuli.[12]

In children, most TBI involves closed, intracranial injury without signs of increased ICP and should be managed supportively. Protect the airway if there is a low GCS, oxygenate, ventilate to normal P_{CO_2} (35–40 mm Hg), and resuscitate with fluid and/or blood as needed to prevent hypotension and maintain CPP.[3]

Less frequently, children have closed, intracranial injuries with signs of increased ICP (depressed LOC plus asymmetric pupils or bradycardia, hypertension, and/or irregular respirations). This situation requires recognition and aggressive medical treatment by raising the head of the bed, moderate hyperventilation (P_{CO_2} 30–35 mm Hg) and medical treatment with 3% hypertonic saline (5 mL/kg), which is preferred by pediatric centers, or mannitol (1 g/kg) if hypertonic saline is not readily available. Transfer as soon as possible for definitive neurosurgical assessment and care.[3]

A statewide study by Gross and colleagues[13] assessed patients 15 to 17 years old with severe TBI and found no significant difference in mortality (adjusted odds ratio [AOR], 0.82; *P* = .754), functional status at discharge (*P* = .136), or total complication rate (AOR, 1.21; *P* = .714) between adult and pediatric trauma centers. Clearly, the principles and goals of TBI management are similar for adults and children. Adolescents with TBI receive similar care and may have comparable outcomes. The challenges for front-line emergency care providers is the resuscitation and stabilization of young infants and children with TBI (**Box 3**).

CERVICAL SPINE

Children can be a challenge to treat, especially based on their age and developmental level. Restraining them can be problematic and those with C-spine injuries are no exception. It can also be difficult for children to communicate where their pain or neurologic symptoms are coming from. A key adage is to protect the cord and investigate later. Trauma teams must always have a high suspicion index for spinal cord

Box 2
Back to the case: next steps in management

Actions

- Call for lateral C-spine and chest radiograph
- Obtain focused abdominal sonography in trauma (FAST) when able

Box 3
Back to the case

Assess

- GCS remains 13
- No signs of increased ICP
- No signs of skull fracture or hemotympanum

Actions

- Patient has closed head injury without signs of increased ICP
- Supportive therapy
- Prevent hypoxia and hypotension
- GCS adequate, does not require intubation for airway protection

injuries, especially when there are multiple injuries. This high suspicion-index is maintained by ensuring proper resuscitation, protecting the spinal column, and avoiding excessive spinal manipulation. Most children do not require sedation to remain properly immobilized. Sometimes pain control, removal of the uncomfortable backboard, a parent's presence, or distraction techniques may be all that are required to immobilize the child.[14] If a patient is unstable but immobilized, spinal column evaluation can be deferred until stabilization. It is estimated that spinal cord injury occurs in 1% to 2% of pediatric patients with trauma.[15,16] The most common location of the injury (60%–80%) is in the C-spine.[17]

Note that investigating cord injuries in children requires knowing the distinct differences between the adult and pediatric spine with respect to injury patterns, anatomic variances, and radiographic characteristics.[14]

By 8 years of age, children's spines are anatomically similar to those of adults, with the important difference being that children's spines do not take on adult-type fracture patterns until early adolescence.[14,15,17] Children less than 14 years old tend to have higher C-spine injuries (C1–C4) because the immature spine's fulcrum is at the C2 to C3 level. Patients more than 14 year old tend to have lower C-spine injures (C5–C7)[17,18] because the adolescent/adult fulcrum is lower at the C5 to C6 level.[14,19,20]

The patterns of C-spine injury in children less than 10 years old tend to be dislocations and spinal cord injuries without radiographic abnormalities (SCIWORA).[17,18]

Clinically, patients with SCIWORA injuries have obvious neurologic deficits consistent with spinal cord injury on physical examination, but their routine radiographs do not show a fracture. Higher levels of imaging, such as MRI, are needed to define the exact injury.

The main reason why children are prone to dislocation and SCIWORA injuries is because of the pediatric spine's increased mobility.[17,19] The injury patterns in children more than 10 years of age tend to be fractures and are more easily identifiable on routine radiographs or CT scans.[14,17]

The trauma literature reveals conflicting recommendations on optimal C-spine imaging and questions persist as to whether radiographs or CT is a better approach. In adults, there is literature and local practice patterns that support early and aggressive CT use for patients with trauma. Pediatrics is different. The rate of C-spine injury is low. There are also potential long-term side effects of increasing doses of radiation to the entire body and the thyroid gland in C-spine imaging specifically. In light of that, pediatric algorithms are generally less aggressive. The available evidence for pediatric

C-spine clearance is limited and some is extrapolated from adult studies. The authors advocate an organized, stepwise approach to investigation and CT radiation minimization.[21] In the absence of conclusive evidence, the Trauma Association of Canada (TAC) Pediatric Subcommittee National Pediatric Cervical Spine Evaluation Pathway: Consensus Guidelines provide a logical and safe approach to the pediatric C-spine in traumatized patients (Figs. 2 and 3).[21]

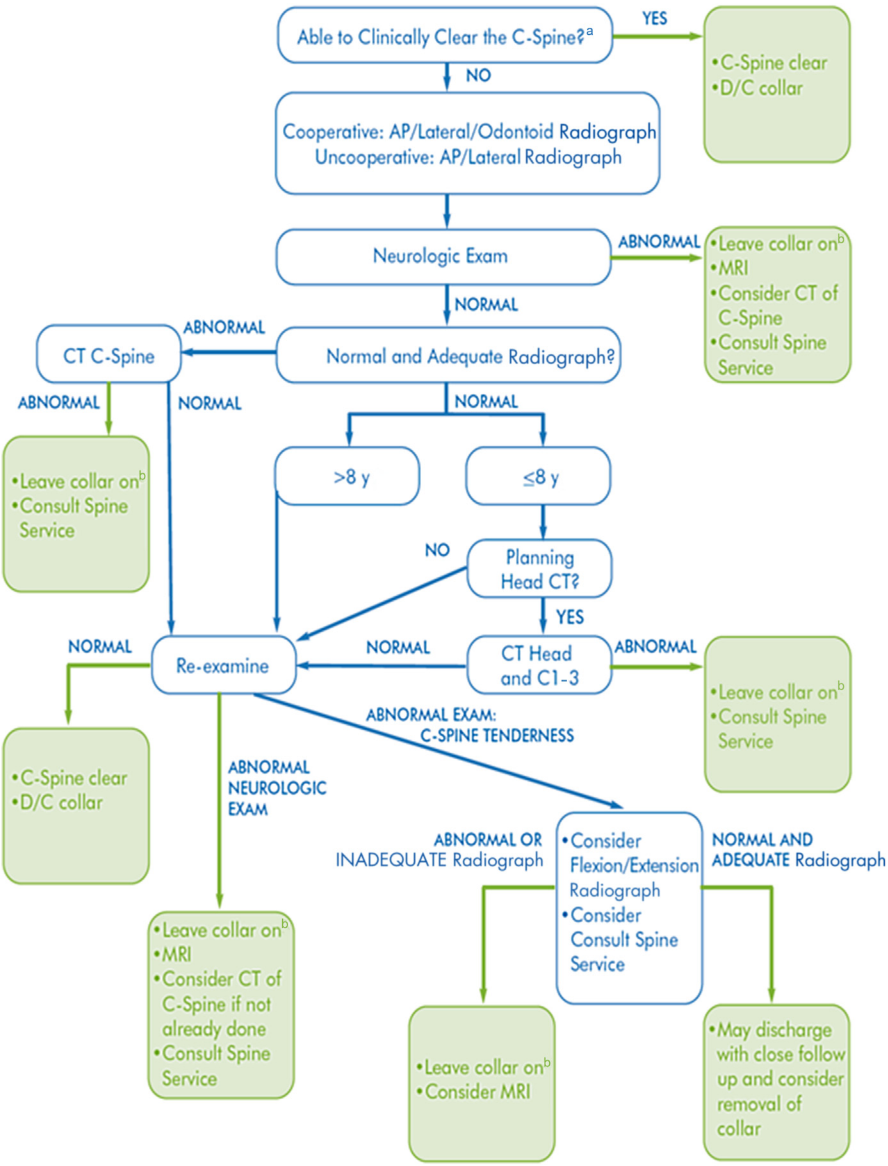

Fig. 2. TAC national pediatric C-spine evaluation pathway: reliable (Awake and alert with GCS = 15) clinical examination. [a] Meets NEXUS (National Emergency X-Radiography Utilization Study) criteria and moves head in flexion/extension and 45° to both sides with no pain. [b] Change to long-term C-spine collar as soon as appropriate.

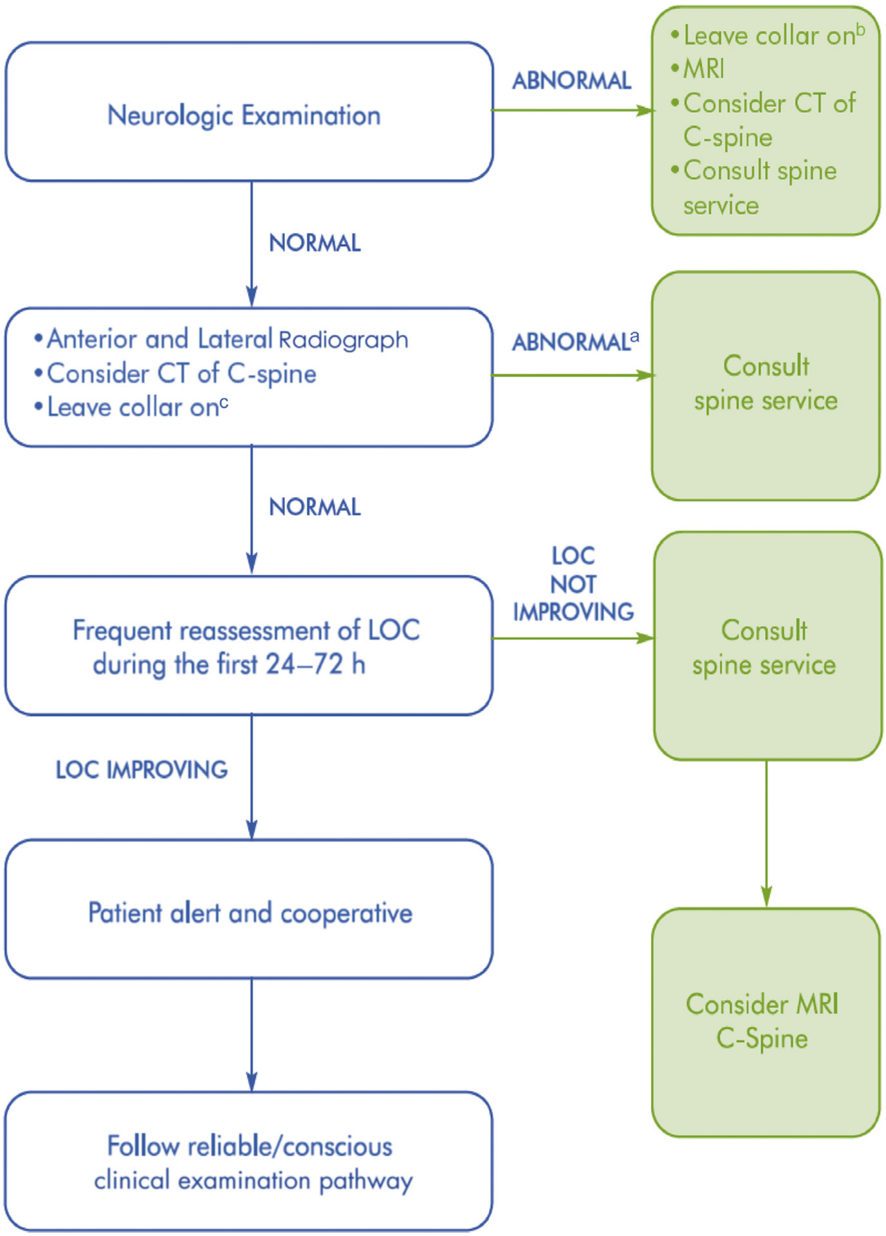

Fig. 3. TAC national pediatric C-spine evaluation pathway: unreliable (Unconscious or decreased LOC with GCS less than 15) clinical examination. [a] Consider thoracic/lumbar spine injury in patients with a documented C-spine injury. [b] Change to long-term C-spine collar as soon as appropriate.

Connelly and colleagues[22] studied limiting C-spine CT use in pediatric patients with trauma. Implementation of an institutional performance and patient safety program around C-spine imaging decreased CT rates 30% to 13% (*P*<.001), whereas radiographs increased 7% to 25% (*P*<.001). Based on these changes, they estimated a 22% (male) and 38% (female) decrease in lifetime attributable risk for any cancer (**Box 4**).[22]

Box 4
Back to the case

Assess

- Patient has some neck pain but no numbness or tingling
- Grossly normal peripheral neurologic examination

Actions

- Maintain C-spine protection
- Await lateral neck radiograph

THORACIC TRAUMA

Next to head injury, thoracic trauma is the second most common cause of mortality in pediatric trauma.[23] In multi-injured children, thoracic trauma increases mortality 20-fold. It accounts for between 4.5% and 8% of the patients cared for in pediatric trauma centers.[24,25]

Note that thoracic trauma patterns of injury differ between infants and teenagers.[24,25] Thoracic trauma injuries often result in abnormal ABCs (airway, breathing, circulation), which may require:

- Fluid and/or blood administration
- Chest tube insertion
- Intubation

Less than 10% need emergency surgery to control bleeding or air leak from the lung.[26]

A compliant and pliable chest wall results in more forces transmitted to internal organs, rather than rib fractures, meaning significant contusion and respiratory compromise in infants and children, but rarely rib fractures or externally visible chest wall signs.[23] Therefore, pulmonary contusions are the most common intrathoracic injury. Increased tissue elasticity results in increased mediastinal mobility, which seems to be protective because vascular injuries to the heart or great vessels are rare.[26,27]

Golden and colleagues[28] studied the role and influence of CT chest in the evaluation of pediatric thoracic trauma and advocate limiting its use. They studied 139 patients with chest radiograph (CXR) and CT for blunt thoracic trauma. Chest CT versus CXR increased diagnosis of contusion/atelectasis (30.3% vs 60.4%), pneumothorax (7.2% vs 18.7%), and fractures (4.3% vs 10.8%). Most importantly, chest CT only changed the management of 4 patients in their series (**Box 5**).[28]

ABDOMINAL TRAUMA

Approximately 8% to 12% of all patients with blunt trauma have intra-abdominal injuries. Although more common than thoracic injuries, abdominal injuries are 40% less fatal.[29] Mortality from solid organ injuries is typically determined by the degree of injury.[30–32]

Important anatomic differences between children and adults include[30]:

- Children are smaller, transferring kinetic energy over a smaller area.[33]
- Ribs are less calcified and more pliable, resulting in more force transmitted to thoracic and upper abdominal organs.[33]

Box 5
Back to the case

Assess

- Respiration rate, 28 breaths/min; O_2 saturation, 98% on face mask
- Trachea midline
- Respiratory effort not labored
- Review CXR
- No pneumothorax or hemothorax
- Pulmonary contusions in left lung

Actions

- Continue as doing
- Assess circulation with plan to reassess breathing

- Thinner abdominal wall and weaker musculature provide less protection to intra-abdominal organs.[33]
- Infants and young children are at higher risk for multiple organ injuries because of the close proximity of intra-abdominal organs.[33,34]

Be particularly suspicious of intra-abdominal injuries with high-risk mechanisms, including lap belts (hollow viscus injury), handle bars (pancreatic injury), snowboarding, and all-terrain vehicle incidents (liver and spleen lacerations).[30,33]

Front-line care providers must understand the most common injury patterns and use physical examination, laboratory investigations, and focused abdominal sonography in trauma (FAST) and CT to diagnose abdominal injuries in children. Most solid organ abdominal injuries are treated nonoperatively. Nonoperative treatment requires a high index of suspicion, appropriate fluid and blood resuscitation, as well as accurate diagnosis and evaluation of injuries. Contact and refer pediatric patients early for definitive care at a pediatric trauma center because most solid organ injuries in children can be managed through nonoperative treatment in experienced centers.[33] For example, nonoperative management of splenic injuries is successful in 97% of cases, with the highest success rates in pediatric trauma centers compared with adult centers. Effective nonoperative management depends on aggressive and adequate fluid and blood resuscitation. Larger volumes of blood loss may require activation of massive transfusion protocols (Fig. 4). Remember to insert an NG tube and indwelling urinary catheter in children with abdominal injury before transfer in order to increase the sensitivity of serial physical examinations. Although less common, hollow viscus injuries do not cause immediate hemodynamic instability and instead require performance of serial examinations to detect an evolving peritonitis.

Focused Abdominal Sonography in Trauma in Children

Intra-abdominal free fluid detected on FAST examination is not necessarily an indication for emergent laparotomy in children, as it might be in adult patients with trauma.[10] A positive FAST is useful in highlighting potential intra-abdominal bleeding and stressing the importance of appropriate and aggressive fluid and blood resuscitation. FAST examinations are not adequate to rule out intra-abdominal injuries.[10] Sola and colleagues[35] support FAST in combination with physical examination and laboratory markers to possibly forego the use of abdominal CT scans in low-risk children.

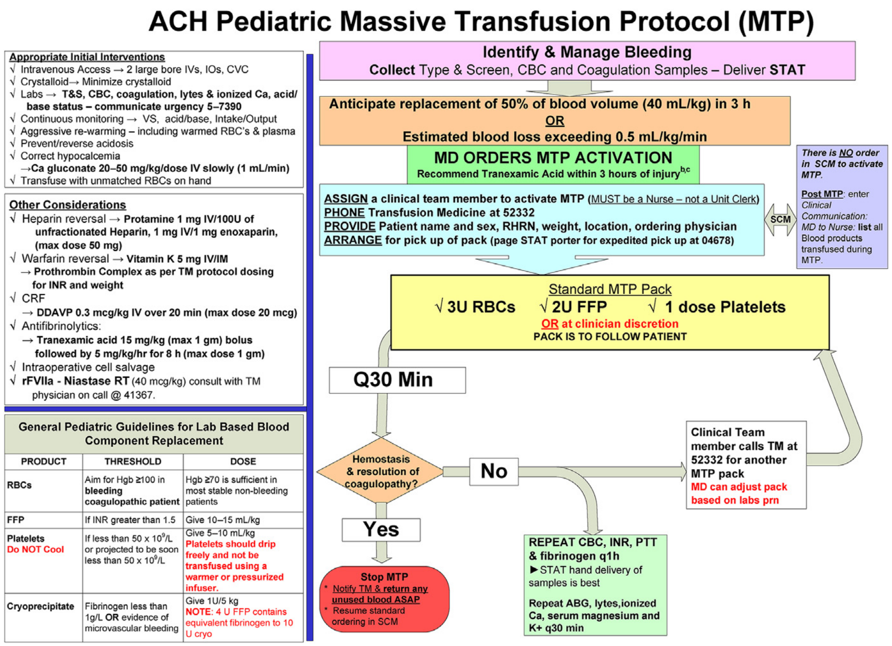

Fig. 4. Alberta Children's Hospital mass transfusion protocol. [a] Massive transfusion definitions: replacement of 50% of blood volume in 3 hours (40 mL/kg) or blood loss greater than 2 mL/kg/min or replacement of a blood volume (80 mL/kg) in 24 hours. [b] Royal College of Paediatrics and Child Health evidence statement: major trauma and the use of tranexamic acid in children, November 2012. [c] CRASH-2 trial collaborators. Effects of tranexamic acid on death, vascular occlusive events, and blood transfusion in trauma patients with significant haemorrhage (CRASH-2): a randomised, placebo-controlled trial. Lancet 2010;376:23.

FAST combined with aspartate transaminase or alanine transaminase levels greater than 100 IU/L is an effective screening tool for intra-abdominal injury in children following blunt abdominal trauma. Pediatric patients with negative FAST and liver transaminase levels less than 100 IU/L may be observed rather than subjected to the radiation risk of CT.[35]

The role and indications for point-of-care ultrasonography (POCUS) in pediatric trauma is a growing area of research. POCUS is being studied for its usefulness in detecting pneumothorax and as an adjunct to physical examination in assessment of volume status. A complete review of the current state of POCUS for pediatric trauma is beyond the scope of this article (**Boxes 6** and **7**).

Use of Angiography

Fenton and colleagues[36] studied angiography use in pediatric patients with blunt abdominal trauma. They studied 12,044 patients who were evaluated for blunt abdominal trauma. A total of 8% of all patients had abdominopelvic injuries. Only 3% (n = 26 patients) underwent angiography (29 procedures: 21 abdomen, 8 pelvic, 3 both). Eleven patients underwent embolization of the spleen. No hepatic, renal, or pelvic vessels were embolized. Median time to interventional radiology (IR) was 7.3 hours. These findings suggest that it may be unnecessary for pediatric trauma centers to have access to IR within 30 minutes.[36]

Box 6
Back to the case

Assess

- After first bolus of 20 mL/kg of NS patient remains HR 130 beats/min, capillary refill of 3.5 seconds
- Tenderness and bruising to LUQ with LLL pulmonary contusion
- Clinical suspicion for an acute splenic injury

Actions

- Start second bolus of 20 mL/kg of NS
- FAST study positive for free fluid in abdomen
- Call for packed red blood cells (PRBCs) or massive transfusion protocol (MTP)

Assess

- Patient remains tachycardic, pale, and poorly perfused after second NS bolus

Action

- Transfuse 10 mL/kg of PRBCs
- Call pediatric trauma center for advice, support, and transport

Box 7
Back to the case

Assess

- Repeat primary survey

A

- Patent, no concerns

B

- Stable, no change with good O_2 saturation on face mask

C

- HR, 100 beats/min; BP, 98/65 mm Hg; capillary refill, 2 seconds; warm extremities

Actions

- Continue intravenous hydration
- Have further PRBCs plus or minus MTP available and ready
- Splint left tibia/fibula
- Give 1 μg/kg of fentanyl if needed for pain
- Speak with pediatric trauma center
- Complete secondary survey
- Complete trauma transport checklist
- Continue to support hemodynamics as needed with fluids and blood
- Prepare patient for transport

A recent systematic review of pediatric blunt renal trauma management by LeeVan and colleagues[37] supports current conservative management protocols. Short-term and long-term outcomes are favorable in grade IV and V renal injuries. Interventions based on CT findings alone are not recommended. The review supports emergent operative management only for persistent hemodynamic instability, and minimally invasive interventions should be used when indicated (angioembolization, stenting, percutaneous drainage).[37]

Pelvic Fractures

Swaid and colleagues[38] conducted a comparison study of pelvic fractures and associated abdominal injuries between pediatric and adult patients with blunt trauma. They found a 0.8% incidence of pelvic fractures in pediatric patients compared with 4.3% in adults (P<.0001). Overall mortality was similar between the two groups (5.4% vs 5.2%). The only statistically significant difference in injury between pediatric patients and adults was rectal injury (1.2% pediatric vs 0.2% adult; P<.0001). In pediatric patients, they found no correlation between severity of pelvic fractures and severity of concomitant splenic/hepatic injuries.[38]

TRANSPORT

Pediatric patients with trauma are best cared for in centers that are prepared to treat sustained injuries.[39,40] Critically ill children have better clinical outcomes when they are treated in tertiary pediatric intensive care units (PICU).[40] The centralization of PICUs has increased the need for interhospital transport and therefore many countries have developed specialized pediatric retrieval teams that undertake the stabilization and safe transfer of critically ill children. There is good evidence that, when specialized transport teams are matched correctly, the incidence of complications is decreased.[41]

Preparing for Transport: Before Leaving the Sending Facility

Once a decision has been made to move the patient, as long as the patient is deemed safe for transport, then avoid undue delay,[39,40] especially if the patient requires definitive care or emergent surgery at a tertiary care hospital. A few details that must be taken into account are:

- Optimizing the patient's condition before transport.
- Ensuring that the patient has received a full primary and secondary survey before departure.
- Communicating with the receiving hospital before the patient's departure. Clinicians must be able to anticipate patient care needs during transport and be prepared to manage those needs (**Box 8**).

Pediatric Trauma Training Using Simulation-Based Education

Severe pediatric blunt trauma is a high-acuity, low-frequency situation that requires both clinical competence and team confidence. The authors highly support and advocate multi-disciplinary, simulation-based training in pediatric trauma resuscitation.

Two reports published by the Institute of Medicine report the importance of collaborative practice and interdisciplinary training in the coordination of health care.[42] Pediatric trauma resuscitation is a complex and time-sensitive procedure. Effective teamwork is essential to better outcomes.[43] Teamwork does not occur spontaneously, so, simulation-based practice is essential. Focus groups of various trauma team members (physicians, nurses, respiratory therapists). Four key areas of

Box 8
Pediatric trauma transport checklist

- Ensure the airway is patent and/or secure before transport
- If there is a risk of losing airway on the transport, then intubate before departure
- If intubated, mechanical ventilation is preferred to hand bagging
- Confirm ETT placement before departure with chest radiograph and end-tidal CO_2 detection
- Secure the ETT
- Consider a predeparture blood gas measurement to assess adequacy of ventilation and oxygenation
- Ensure suction is working and available
- Assess the need for chest tube before transport
- If there is the potential for free air, consider pressurizing the cabin or limiting altitude
- Adequately fluid resuscitate the patient before transport
- Control hemorrhage by direct pressure, staples, or suturing (if necessary)
- Consider ongoing fluid losses in fluid calculations
- Aim for at least 2 large-bore intravenous lines (or equivalent) for transport
- Secure and protect all intravenous lines; ensure there is no kinking or blockage
- Use intraosseous access if you are unable to obtain intravenous access
- Secure intraosseous needle with tape and gauze to prevent its dislodgement during transport
- For fluid-refractory shock, bring blood products on the transport if clinically indicated
- Assess the need for analgesia, sedation, and neuromuscular blockade before departure
- Ensure proper and sufficient medications are available and on board
- Consider continuous infusions of sedatives/analgesics, rather than intermittent boluses, especially for longer transports

Data from Cheng A. Transport of the pediatric trauma patient. In: Mikrogianakis A, Valani R, Cheng A, editors. The hospital for sick children manual of pediatric trauma. Philadelphia: LWW; 2008. p. 277–8.

improvement identified through participation in simulation are leadership, communication, cooperation/teamwork, and roles.[44] In situ trauma simulations are highly recommended so that teams are practicing in the authentic patient care environment with the same equipment that they will use during a real trauma care situation. Training in the in situ environment also allows the evaluation of space, systems, and equipment in an attempt to identify latent safety threats and maximize safe and high-quality care.[44]

SUMMARY

Caring for pediatric patients with trauma requires all elements of the health care system to work together by appreciating how best to assess children, understanding the most common injuries incurred, and knowing how to treat those injuries most efficiently and effectively. Front-line emergency physicians have the necessary knowledge and competencies through ATLS. Pediatric experts are keen to provide advice and to support front-line colleagues requiring assistance (**Box 9**).

Box 9
Top 10 pediatric trauma pearls

1. Follow general ATLS principles
   - A systematic approach avoids missing key findings in both the primary and secondary surveys
   - Almost all pediatric trauma cases result from a blunt mechanism and rely on an effective trauma resuscitation (ABCDEs) and very rarely on an emergent operation
2. Call for patient transport/advice/support as soon as possible
   - Helps to maintain situational awareness and avoid fixation errors
   - Obtain radiographs when they will be helpful
   - Do not delay transfer for advanced imaging (CT scanning) unless it will change management acutely or change decision to transport
3. Maintain oxygenation at all times
   - Most pediatric arrests are from prolonged hypoxemia
4. Beware of persistent tachycardia
   - Cardiac output completely HR dependent
   - Treat hypovolemia aggressively
   - Hypotension is a late sign of uncompensated shock
   - Goal of trauma resuscitation is to normalize vital signs
5. Be mindful of atypical spaces for significant hemorrhage in children
   - Difficult to diagnose because of compensation
   - Pelvis, long bones, subgaleal space
6. Do not be afraid of transfusion of blood components
   - Pediatric blood volume is estimated to be only 80 mL/kg, and 25% blood volume loss is predicted to cause hypotension
   - A 1-year-old patient weighing 10 kg would only have to lose 200 mL (<1 cup) of blood to reach this level
   - A 6 year old patient weighing 20 kg only has to lose 400 mL (<2 cups) of blood to reach this level
7. Avoid hypothermia if possible
   - Children prone to hypothermia with large surface area to volume ratio (especially the heads of infants and toddlers)
   - Remove all wet clothing
   - Use warm intravenous fluids and a warming blanket
   - Hypothermia significantly affects volume status and, along with acidosis, leads to coagulopathy
8. Be mindful of using analgesia to treat pain
   - Treatment of pain is often an afterthought
   - Splint all fractures
   - Ensure adequate volume resuscitation before giving medications that may compromise hemodynamics
9. Allow parents to be present whenever possible
   - The trauma room is an unfamiliar/fearful/anxiety-provoking environment
   - History taking and cooperation can be challenging
   - Children on a backboard with spine protection cannot see their parents in the trauma room (allow parents to make eye contact and touch their children whenever appropriate)
10. Be mindful of the possibility of nonaccidental trauma
    - Do the injuries match the mechanism?
    - Maintain an appropriate index of suspicion

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