Thoracic and abdominal trauma in children

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ABSTRACT
Thoracic and abdominal trauma is relatively uncommon in children experiencing polytrauma. Survival depends on early recognition and timely management. Recent review is to review literature about the thoracic and abdominal trauma in children and to appraise available evidence regarding newer modalities of trauma imaging in Emergency department(ED). Recent literature shows us that extended FAST (Focused assessment by sonography in trauma) is as effective as Computerized Tomography (CT) imaging in unstable children with abdominal and thoracic trauma. Methodical examination by primary and secondary survey along with simultaneous intervention once life threatening injury is identified improves the survival in these children. CT imaging should be performed in the ED only in hemodynamically stable children. Extended FAST examination using ultrasonography (USG) helps in early identification of life threatening injuries as well as avoiding CT imaging till the child gets stabilized in the ED.

Key words: trauma, abdominal, thoracic, FAST, extended FAST.

Introduction:
Serious thoracic and abdominal injuries in children often are reported as isolated instances of trauma of an unusual or dramatic type. Failure to recognize these injuries or inaccurate appraisal of damage may result in inadequate or tardy treatment.

- Dr. John L. Keeley in 1962.

Amongst children experiencing major or minor trauma, thoracic trauma is relatively uncommon. Around 4-8% of poly-trauma victims sustained thoracic injury. Survival, as in all other serious injuries, depends on early recognition and timely management.

THORACIC TRAUMA

Etiology
Although, 60-80% of chest injuries in children occur due to blunt trauma, around 50% are attributed to impact by motor vehicles. High velocity impact during pedestrian crossing or motor vehicle crashes account for this type of injury. On the contrary, penetrating thoracic trauma occurs following stab or gunshot, accidental fall over sharp objects or being gored by animals.

Mortality rate for children with thoracic trauma is high, ranging between 15 and 26%. In addition, risk of death, increases with associated injuries. Indeed, around 82% of children with thoracic trauma had head injury. On the contrary, cause of death in penetrating trauma, is predominantly due to the thoracic injury.

Anatomic and physiologic considerations:
Injury patterns in children are different from adults due to the following reasons:
1. Children have greater pliability of the ribs than adults. Hence, more kinetic injury is transmitted to the underlying organs. Blunt trauma, manifests with apparently minimal injury, such as abrasion, laceration, ecchymosis, in addition to respiratory symptoms. It is not uncommon to have lung contusion without fracture ribs in children.
2. The chest wall is more compliant, due to primarily immature bone structure. The bones are cartilaginous (less ossified). A protective feature, considerable force is needed to cause rib fracture.
3. As a result, intra-thoracic injuries such as traumatic asphyxia and commotion-cordis can occur without obvious chest wall injuries.
4. Mediastinum is more mobile, resulting in displacement of the heart and trachea secondary...
to pneumothorax, hemothorax or diaphragmatic rupture. The latter, leads to reduced venous return, predisposing to hypotension.

5. Cardiac and pulmonary reserves are minimal, while their metabolic demands are high. This physiological feature characteristic for children predisposes to rapid deterioration.

Emergency department evaluation: Stabilization and assessment is performed concurrently. History, is obtained as stabilization is being performed. The nature of injury is probed. Fall from significant height, speeding vehicles, aids in anticipating thoracic injury.

Physical examination: Often, significant injuries may not be immediately recognizable. Pulmonary contusion or blunt cardiac injury on initial presentation may be difficult to identify on arrival in to the ED.

Primary survey

• Airway examination:
  • If un-responsive, airway is opened using the jaw-thrust maneuver.
  • Additionally, it may be obstructed due to bleed, secretions or foreign body.
  • Laryngeal injury is potentially life threatening

• Examination of breathing:
  • Assessment for respiratory rate effort and pattern can guide diagnosis.
  • Bag valve mask ventilation is initiated if respiratory effort is inadequate. If spontaneously breathing, air-entry is checked.
  • Additional examination includes, checking for neck veins in older children and adolescents. Distension of neck vein is suggestive of pneumothorax. However, neck vein distension may not be always being noted in children with pneumothorax.
  • Life threatening injuries to be recognized:
    ▪ Tension pneumothorax
    ▪ Open pneumothorax
    ▪ Flail chest
    ▪ Pulmonary contusion
    ▪ Massive Hemothorax
  • Pulmonary injuries may be manifested as respiratory distress due to lung function compromise by contusion or pneumothorax.

• Examination of circulation:
  • Assessment of heart rate and quality of heart sounds follows next. Heart sounds, are often muffled in pneumothorax or cardiac tamponade.
  • Evaluation of pulses, core-peripheral temperature gap, CRT, color is essential in the evaluation of shock.
  • The cardiac monitor, aids in identifying arrhythmias.
  • BP assessment helps to recognize hypotension. Hypertension may be noted if the child has severe traumatic brain injury with raised intra-cranial pressure.
  • Circulatory collapse occurs as a complication of severe thoracic injury. Massive hemothorax, obstructive shock due to cardiac tamponade, tension pneumothorax, or cardiogenic due to commotio cordis or arrhythmias are some of the life threatening causes.

Specific injuries

Bony Injuries:

Rib fracture: the rib cage is pliable; fractures are less common than adults. As ossification, progresses, bone fractures and flail chest become more common. Non-accidental injury is suspected if rib fractures are noted in children, less than 3 years. Radiological investigations are essential to rule out internal organ injury. Management priorities include supportive measures and to prevent atelectasis and pneumonia.

Flail chest: Although, uncommon in children, flail chest can lead to severe respiratory failure. Management includes pain relief, positive pressure ventilation and in more severe case operative fixation.

Spine injuries: Commonly associated with sports, this requires extensive radiological and neurological evaluation. Spinal cord injury without radiological abnormalities should be anticipated in all critically injured children. MRI is essential to rule out this condition and most useful in this context.

Pulmonary injuries:

Pulmonary contusion: This is the most common thoracic injury in children. Radiologically, the injured areas appear as consolidation with or without rib fractures. It can occur without external evidence of
lung trauma. The extreme pliability of young bones is considered the cause for this mismatch of lung contusion in the absence of rib fracture\(^1\). The ventilation perfusion mismatch, results in profound hypoxia leading to ventilation requirements. Computerized tomography is more sensitive in identifying abnormalities than the chest radiograph\(^2\). Management is conservative in children with less severe injuries. Recently, the ultrasound chest appears to play an important role in identification of lung contusion\(^3\).

**Pneumothorax**: A complication of both blunt and penetrating trauma to the chest, it can manifest as chest pain, difficulty in breathing and diminished breath sounds on auscultation. This may be missed on chest radiographs. Tension pneumothorax may present classically with hypotension, unilateral absence of breath sounds, muffled heart sounds, mediastinal shift. Management calls for emergency needle thoracocentesis and ICD placement.

**Hemothorax**: More commonly seen in penetrating injury, severe parenchymal injury or injury to the great vessels. It usually does not occur in isolation. Hemothorax can additionally reduce the circulatory volume. Management includes, prompt drainage of blood in the thorax along with fluid resuscitation. Organized blood could lead to scarring and acts as nidus for infection predisposing to empyema. Introduction of wide bore thoracostomy tube is therapeutic. Antibiotic use is controversial. Selective prophylactic antibiotics may be used in penetrating trauma such as bull gøre injuries, in the Indian context.

**Airway injuries**: Airway injury most frequently leads to distal tracheal or proximal bronchial rupture leading onto pneumo-mediastinum or pneumothorax. Airway disruptions are most frequently lethal within 1 hour of injury in 1/3 of children\(^7\). These injuries can be rapidly diagnosed by CT chest and surgical repair becomes imperative.

**Blunt cardiac injury**: The blunt chest trauma can lead to cardiac contusion, cardiac rupture and commotio cordis. Most of cardiac injury occurs a part of polytrauma. In an autopsy study by Scorpio et al, blunt cardiac trauma represented 15% of the blunt trauma fatalities, 54% of whom had walked into the ED. This tells us that rapid diagnosis and treatment can help in preventing fatalities in these children. Children with normal sinus rhythm and normal BP can be safely ruled out of cardiac trauma\(^4\). Children with significant cardiac trauma present with hypotension or arrhythmia. Urgent Echocardiography detects cardiac tamponade, wall or rupture, wall motion function and ejection fraction. Cardiac tamponade is diagnosed based on clinical evidence of Beck's triad: muffled heart sounds, engorged upper neck veins and low BP. This condition warrants immediate pericardiocentesis even prior to E-FAST

**Commotio cordis**: A lethal ventricular arrhythmia which occurs due to blunt injury to the chest most frequently seen as a result of sports injuries in young athletes. More rapid reversal of this fatal arrhythmia by AEDs helps in improving the survival rate of these young persons

**Investigations**: 
*Imaging is mandatory to rule out internal thoracic injury.*
A chest radiograph is mandatory in the acute setting. To diagnose, a large number of life threatening complications of lung trauma, it is essential to identify pneumothorax, pneumo-mediastinum, air-space shadowing (resulting from pulmonary contusion), fracture ribs, flail chest, aortic dissection, subcutaneous emphysema, hemo-thorax and the diaphragmatic injuries. Pneumothorax is difficult to identify in the supine position. To enable recognition of pneumothorax, a cross table lateral view may be ordered. Air noted below the anterior chest wall aids in diagnosis of pneumothorax in supine patients.

**EFAST – Extended Focussed Assessment with Sonography for Trauma.**
An extension of FAST, it helps to diagnose, hemothorax, pneumothorax and intravascular filling status (IVC). This diagnostic modality is especially useful in patients who cannot be shifted for x-ray or CT chest imaging. In addition, it also helps in providing appropriate interventions in life threatening conditions for patient stabilisation (Fig 1a, 1b).

**Contrast enhanced CT chest (CCT)**
Penetrating trauma is an indication for contrast-
enhanced chest CT. The latter, is essential to look for occult vascular injury.

CCT is needed for more detailed evaluation of blunt chest trauma based on the nature of trauma, the clinical condition and the initial radiographic findings. If chest film is normal, patient is hemodynamically stable and alert, CT may not be indicated.

CT with contrast is needed following interventions such as thoracocentesis or inter-costal drainage. It aids to complete the survey and identify evolving conditions, such as traumatic pneumatocele, increasing hemo/pneumothorax, completion of drainage, vascular injuries, pericardial fluid status etc.

**BLUNT INJURY ABDOMEN**

Blunt trauma accounts for approximately 90% of all pediatric injuries; with falls and motor vehicle collisions accounting for most frequent mechanisms. Abdominal injury occurs in up to 8% of the children with and is responsible for 9% of all trauma deaths, as it is the leading cause of unrecognized fatal injury in children.

In about 25% of children sustaining multisystem trauma significant abdominal injuries were found. Mechanism of abdominal injury in children are motor vehicle accidents, falls, and sports injuries, stab injuries by animal horns, in the decreasing order of frequency.

**Anatomical peculiarities in children:**

- Intra-abdominal organs in children are proportionally larger and are in relative proximity to each other.
- Small size of a child results in greater degree of force per BSA, which can lead to significant intra abdominal injury.
- Abdominal wall is less muscular and has little fat to cushion the intra abdominal organs providing little protection to the intra abdominal contents.
- Fetal lobulation in pediatric kidneys paves way for easy separation and fracture. Being an abdominal organ in younger children, bladder can be easily injured from trauma due to blunt abdominal forces.

**Mechanisms:**

**Motor vehicle accidents:** Blunt injury from motor vehicle accidents are the most frequent cause of abdominal injury. Detailed history regarding speed and direction of the vehicles, location of the occupants and location and type of restraints should be obtained after initial resuscitation and stabilization of the child. Restraint use by children has shown to reduce mortality in children as they are less frequently and less severely injured. Unrestrained children are more likely to have head and neck injuries as well as injuries to face, thorax and extremities.

Children with blunt abdominal trauma having seat belt sign also have an increased incidence of abdominal injury. Seat belt syndrome described by Garrett and Braunstein includes injuries along the plane of the lap belt and includes large and small bowel injuries with their mesentery, stomach, liver, spleen, pancreas kidneys lumbar vertebrae, spinal cord injuries, pelvic fractures, and rib fracture. The lap belt type of restraint is designed to be worn at or below the level of anterior superior iliac spines. With rapid deceleration the belt rides above the iliac crest and over the abdomen which allows concentration of most force at the upper lumbar spine level with intra-abdominal injuries.

In children who were pedestrians struck by motor vehicle, age of the child is very important as run over injuries by vehicles are more common in younger children leading to crush injuries of abdomen and limbs whereas older children sustain impact injuries while crossing a street.

**Bicycle accidents/ handle bar injuries:** Two mechanisms of injury are explained with accidents involving bicycle. First are high-speed mechanisms, in which the rider is thrown from the bicycle or the bicycle collides with a car or stationary object. These mechanisms are often associated with severe multi-system trauma. The second mechanism of injury occurs following a relatively low speed crash, in which the bicycle handlebars strike the rider in the neck, abdomen, or pelvic region. The percentage of children with abdominal or pelvic injury after bicycle-
related trauma, who sustained direct impact from a handlebar, may be as high as 78%.

Emergency department evaluation: Initial assessment includes complete exposure during primary survey with management of life threatening injuries as and when identified. In children with abdominal trauma, circulation will be affected more frequently. Presence of hypotensive shock preceded by tachycardia is indicative of abdominal trauma as heart rate is the most sensitive indicator of intravascular volume. Overdistension of stomach due to ingested air can decrease the diaphragmatic expansion hence insertion of oro gastric tube and early decompression must be done. Similarly Foley's catheterization should be done to decompress bladder after establishing a stable pelvis and in those children with no risk for urethral trauma.

After ruling out other life threatening causes of hypotensive shock fluid resuscitation should be started. According to the American college of surgeons fluid resuscitation guidelines 20ml/kg of warm isotonic fluids should be started in hemodynamically unstable children, if after 40ml/kg child remains hemodynamically unstable administration of 20m/kg of whole blood should be strongly considered.

After completion of primary survey a careful and secondary head to toe survey is conducted the following findings suggestive of abdominal injury include abrasions and contusions on the abdominal wall (seat belt sign), abdominal distension, and tenderness. Abdominal distension may be a sign of hemoperitoneum, or due to significant aerophagia leading to massive gastric distension. Rectal examination is an important adjunct to the abdominal examination, as is evaluation of the pelvis.

Physical Examination
Abdominal examination in children sustaining blunt abdominal trauma is often unreliable and inaccurate, with a high rate of missed abdominal injuries. The initial abdominal examination may not show significant abdominal pathology (up to 45%), and sequential examinations are essential to exclude an evolving abdominal problem.

FAST (Focused assessment with sonography for trauma)

FAST is a rapid, four-view ultrasound examination carried out during the primary survey that assesses for hemothorax and hemo pericardium. The four views include – RUQ (right upper quadrant or perihepatic), LUQ (left upper quadrant or perisplenic), Sub-xiphoid (pericardial) & pelvic view to look for fluid / blood collection in the respective quadrants.

The minimum volume required to detect fluid on a FAST scan is in the range of 200–620 ml. free fluid typically appears as an anechoic collection, whereas clotted blood appear echogenic. If any view reveals an anechoic collection, the FAST examination is considered positive and injury is presumed. The examination is considered negative only if all the views are free of fluid or blood. The study is indeterminate if any one view cannot adequately be assessed (Fig2).

Injuries that are not usually associated with a large amount of free fluid include injuries to diaphragm, bowel and mesentery, pancreas, liver and spleen (contained by within their capsules) and retroperitoneal injuries including renal injuries. Detection and location of intra-peritoneal free fluid are dependent upon location of injury, time elapsed between injury and presentation, bowel gas patterns, Fluid volume, positioning of patient and quality of the FAST examination (observer expertise), and presence of subcutaneous emphysema.

Ultrasound should not be used exclusively for the assessment of blunt injury. It should be used in addition to the clinical assessment protocol. It is safe, repeatable every 6-8 hours and gives dynamic information about the ongoing loss of fluid / blood. It
helps to reduce the number of computed tomography (CT) scans and diagnostic peritoneal lavage examinations (DPLs). It is also associated with shorter hospitalisation, less complications and lower costs. Haemodynamically stable patients should undergo a CT scan when there is a moderate probability of intra-abdominal injury determined by the mechanism of injury.

Taylor et al\(^{10}\) in a retrospective study identified the following predictors of abdominal injuries in children after blunt trauma: mechanism of injury, revised trauma score (RTS) less than or equal to 12, abdominal tenderness, abdominal distension, absent bowel sounds, fractured pelvis, gross hematuria, chest trauma, and hematocrit less than 30% were all associated with abnormal CT scan. Prospective study by Holmes et al, showed that low blood pressure, abdominal tenderness, femur fracture, hematocrit less than 30%, alanine aminotransferase (ALT) greater than 125 U/L and/or aspartate aminotransferase (AST) greater than 200 U/L, and urinalysis with greater than 5 RBC/HPF (red blood cells per high power field) were significantly associated with abdominal injuries on CT scan\(^{11}\).

The line of action in any thoracic/abdominal trauma can be divided in three categories:\(^9,19,20,21\):

1. **Unstable patients with thoracic /abdominal injury:**
   - Seriously ill children, who cannot be shifted for CXR or CT scan, should be subjected to bedside FAST to urgently check for hemo thorax / pneumothorax or hemopericardium. This helps rapid intervention such as thoraco-centesis or pericardiocentesis respectively. If FAST is positive for fluid or blood, patient can be shifted to the operation theatre for urgent laparotomy. If FAST is negative or equivocal FAST, a rapid search for other potential causes of hypotension is necessary. A repeat FAST may be performed. If uncertainty persists, a diagnostic peritoneal lavage (DPL) is indicated.

2. **Stable patients with high clinical suspicion of thoracic/abdominal injury:**
   - Significant history, abdominal pain, abdominal wall bruising, macroscopic haematuria, unexplained hypotension, equivocal clinical findings, other distracting injuries, or a Positive FAST can be transferred CT and surgical management.

3. **Stable patients with low clinical suspicion of thoracic/abdominal injury:**
   - Stable patients, who are negative for FAST, need admission for clinical monitoring with serial FAST examinations. If these, hemodynamically well patients, also have normal urinalysis and normal haemoglobin levels, they can be safely discharged with advice to report any further symptoms. Sensitivity and specificity for the FAST examination vary considerably in the literature. Sensitivity ranges from 42% to 98% and specificity from 95% to 100%. Several factors contribute to the large variation in sensitivity, and include inclusion criteria, equipment and techniques used, experience of the operators and reference standards\(^{19}\).

**CT imaging in abdominal injury:**

**Indications for abdominal CT scan in hemodynamically stable patients\(^{20}\):**
- Abdominal tenderness not caused by minor, superficial injury (eg, bruise, abrasion), persistent hypovolemia, bleeding from natural orifices, run over tyre marks and in patients with suspected pelvic fractures.
- Seat belt sign or syndrome
- Findings that suggest a significant risk for IAI in a patient with distracting injuries
- Initial serum aspartate aminotransferase (AST) \(>200\) IU/L or ALT \(>125\) international unit/L
- Gross hematuria (\(\geq 50\) RBCs per high-powered field) in otherwise asymptomatic patients
- Declining or unexplained hematocrit or hematocrit <30 percent
- Unclear aetiology for fluid or blood requirements
- Inability to perform adequate abdominal examination or serial abdominal examinations (eg, uncooperative children younger than two to three years or those with impaired mental status, or planned general anaesthesia) in a patient with findings indicating IAI
- Positive focused assessment with sonography for trauma (FAST) exam in a hemodynamically stable patient

If clinical symptoms such as abdominal distension or bowel injury suspected, an x-ray abdomen and diagnostic peritoneal lavage is mandated. Bile or faeces following DPL, necessitates laparotomy.
Abdominal CT with intravenous contrast is the preferred diagnostic imaging modality to detect intra-abdominal injury. It is highly sensitive for both intra-peritoneal hemorrhage and solid organ injuries. CT is sensitive and specific in diagnosing liver, spleen, and retroperitoneal injuries. These injuries may be managed nonoperatively.

Solid viscera (spleen / kidney / liver) injury is graded from 1-5. Five is characterised by complete avulsion of the hilar vessels (Fig 3).

Penetrating injury (even a stab wound) warrants surgical exploration.

Unstable patients / positive FAST patients – surgical exploration

Stable patients with FAST negative – serial FAST / observation

Stable patients with positive FAST – CECT imaging

Bowel injury with positive CECT /positive DPL – surgical exploration

Solid viscera injury –until grade 4 – self limiting / conservative management


**Summary of Treatment of Abdominal Trauma:**

* Penetrating injury (even a stab wound) warrants surgical exploration.
* Unstable patients / positive FAST patients – surgical exploration
* Stable patients with FAST negative – serial FAST / observation
* Stable patients with positive FAST – CECT imaging
* Bowel injury with positive CECT /positive DPL – surgical exploration
* Solid viscera injury –until grade 4 – self limiting / conservative management
* Solid viscera injury – grade v/ shattered (unstable) – exploration.

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**References**

19. Natarajan B, Gupta PK, Cemaj S, Sorensen M,


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