Pediatric Trauma

EVALUATION, STABILIZATION, and INITIAL MANAGEMENT AFTER MULTIPLE TRAUMA
Pediatric trauma remains one of the major cause of morbidity and death in children with injury accounting for most deaths among children older than 1 year.

About 20,000 children and teenagers die as a result of injury each year.

United States: >20 million children require medical attention for traumatic injury.
Leading causes of death among children
Ages 1-4, USA 2004
(Deaths per 100,000 children ages 1–4)

- Unintentional injuries: 49.8%
- Birth defects: 17.4%
- Cancer: 12.1%
- Homicide: 11.6%
- Heart disease: 5.8%
- Pneumonia/influenza: 3.4%
Pediatric Trauma Stats

- In children (1-19 yrs) injuries cause more deaths than all diseases combined.
- 80% of all trauma deaths occur either at the accident scene or in the hospital ED.
- Head Trauma the most common single injury associated with death; responsible for 80% of trauma deaths
- Multiple system injury more common.
- Mortality rate for children hospitalized after an accident is low.
Most pediatric trauma involves blunt injury; accounts for about 85% of all trauma

Penetrating injuries accounting for about 10% of all trauma

Compared with adults, children are predisposed to multiple organ injury because children are:

- More vulnerable to major abdominal injuries resulting from relatively minor forces
- Having a more immature musculoskeletal system, affording them less protection from external forces
- Having intraabdominal organs that are proportionally larger and closer together
The physiologic differences between a child and an adult lead to different injury patterns because of:

- Different biomechanics of a child’s body → lead to a greater inertia, movement, and transfer of energy to the head and brain leading to a higher percentage of head injuries in children.

- A child’s center of gravity is much higher than an adult’s → an infant has a center of gravity slightly above the umbilicus; at age 1 year, it is at umbilicus;

  example: if a child is restrained in a two-point lap belt in a car, the center of gravity is still above the point of restraint → causing a jackknife effect during a forward collision and often leading to intestinal and spinal cord injury.
In children who die soon, the primary mechanisms that cause death are airway compromise, hypovolemic shock, and CNS damage.

Rapid evaluation and management of these children will decrease the chance of death and morbidity.

In the trauma center a rapid sequences of events occurs to rapidly assess, resuscitate, and definitely manage the patient → TEAM WORK !!!
Special considerations in assessment and management of injured child

- Size and shape
- Skeleton
- Surface area
- Physiologic status
- Long-term effects
## Steps In A Trauma Evaluation

<table>
<thead>
<tr>
<th>Primary Survey</th>
<th>A, B, C, D, E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjuncts to primary survey</td>
<td>ECG, SaO2, blood pressure, blood work and baseline radiographs (chest, lateral cervical spine, and pelvis), adequate venous access and supplemental oxygen</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Secondary Survey</th>
<th>Assessment of complete history and physical examination (head to toe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjuncts to secondary survey (investigations)</td>
<td>Initial plain radiology Ultrasound CT scan Echocardiography, etc</td>
</tr>
</tbody>
</table>

### Definitive Management

Operative or non-operative treatment
Pediatric Assessment Triangle

**Appearance**
- posture, movement, muscle tone, mental state (unresponsive, confused, agitated, anxious, pain)
- skin color (pallor, mottled, cyanotic, flushed), injury, active bleeding (minor, moderate, profuse)

**Work of breathing**
- airway sounds (stridor, wheezing, coughing), apnea, tachypnea, retractions, nasal flaring, odors

**Circulation to skin**
<table>
<thead>
<tr>
<th>A=</th>
<th>Airway</th>
<th>Control C-Spine</th>
</tr>
</thead>
<tbody>
<tr>
<td>B=</td>
<td>Breathing</td>
<td>Blue Bad - Oxygen Good</td>
</tr>
<tr>
<td>C=</td>
<td>Circulation</td>
<td>Peripheral vs Central Pulse, Color, Temperature, Texture of Skin, Capillary refill</td>
</tr>
<tr>
<td>D=</td>
<td>Disability</td>
<td>Neuro evaluation AVPU, Pediatric Glasgow Coma Scale</td>
</tr>
<tr>
<td>E=</td>
<td>Exposure</td>
<td>Lose heat quickly- covered up</td>
</tr>
</tbody>
</table>
AVPU scale

A = awake and Alert
V = responds to Voice
P = responds to Pain, e.g. pinching or pulling frontal hair
U = Unconscious
# Modified Glasgow Coma Scale (James and Trauner, 1985)

<table>
<thead>
<tr>
<th>Activity</th>
<th>&gt;5 years</th>
<th>&lt;5 years</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eye-opening</strong></td>
<td>Spontaneous</td>
<td>Spontaneous</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>To voice</td>
<td>To voice</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>To pain</td>
<td>To pain</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td><strong>Verbal</strong></td>
<td>Orientated</td>
<td>Alert, babbles, coos</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Confused</td>
<td>Irritable</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Inappropriate words</td>
<td>Cries to pain</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Incomprehensible sounds</td>
<td>Moans to pain</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>No response to pain</td>
<td>No response to pain</td>
<td>1</td>
</tr>
<tr>
<td><strong>Motor</strong></td>
<td>Obeys commands</td>
<td>Spontaneous movements</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Localises to supraocular pain</td>
<td>Localises to supraocular pain</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Withdraws nailbed pressure</td>
<td>Withdraws nailbed pressure</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Flexion to supraocular pain</td>
<td>Flexion to supraocular pain</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Extension to supraocular pain</td>
<td>Extension to supraocular pain</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>No response</td>
<td>1</td>
</tr>
</tbody>
</table>

Score ≤ 8 = Comatose; Score ≥ 9 = Non Comatose
Secondary Survey

- History:
  - S = Signs and Symptoms
  - A = Allergies
  - M = Medications currently taken
  - P = Pertinent Past/ Present Illnesses
  - L = Last Meal
  - E = Events/environment related to the injury
- Complete physical examination
- Radiographs
- Laboratory tests
Head Trauma

- Major cause of death
  - Large heads
  - Thin skulls
  - Poor muscle control
- Diffuse edema more common than intracranial hematomas
- Monitor for signs of increased ICP
  - AVPU
  - Pupils
  - Vomiting
  - Cushing’s triad
- Hyperventilate
- Resuscitate hypovolemic shock aggressively
Mechanism of brain injury

Brain is thrown against bony irregularities or membranous slings or compressed against these surfaces by...

- Contact injury (head strikes or is struck by an object)
- Acceleration/deceleration injury (violent head motion causes compressive, tensile, and shear strain in brain tissue)
Coup - Contrecoup injury
### Types of primary injuries

| **Focal injuries**                        | Skull fracture                           |
|                                        | Parenchymal contusion                    |
|                                        | Parenchymal laceration                   |
|                                        | Vascular injury resulting in hematoma (subdural, extradural, or parenchymal) |
| **Diffuse injuries**                    | Diffuse axonal injury                    |
|                                        | Diffuse vascular injury                  |
Skull fractures

- Most are uncomplicated
- Basilar skull fractures
  - Battles sign, “raccoon eyes”
  - CSF rhinorrhea, CSF otorrhea possible
  - Cranial nerve injury possible
- Depressed skull fractures represent more severe injury
  - 1/3 are associated with dural laceration
  - 1/3 are associated with cortical laceration
  - May require surgical elevation
- Fracture crossing path of major vascular structure increases risk for significant bleeding
  - Middle meningeal artery
  - Large dural sinus
## Diffuse brain injury

| Diffuse axonal injury | - Usually from rapid acceleration/deceleration  
|                       | - Shear forces disrupt small axonal pathways (After disruption, axons degenerate, fragment, then disappear; the neurons then undergo Wallerian degeneration)  
|                       | - Spectrum from mild to severe |  
| Diffuse vascular injury | - Microvasculature more resistant to shear than axons  
|                       | - Results in multiple small hemorrhages throughout brain  
|                       | - Usually seen in fatal head injuries |
Severe head injury
With basilar skull fracture, right temporal hematoma, cerebral edema, hydrocephalus, and pneumocephalus
Intracerebral hemorrhage

Usually frontal or temporal lobe; Can be bilateral (contracoup injury)
Can act as mass lesions and cause intracranial hypertension
Contusion

Usually frontal or temporal lobe; Small cortical vessels and neural tissue damaged; Damaged vessels may thrombose, leading to ischemia
Epidural hematoma

- Usually arterial in origin
- Between skull and dura, limited by suture lines
- Often from tear in middle meningeal artery
- Initial injury may seem minor, followed by “lucid interval,” then neurologic deterioration
- May expand rapidly and require emergency craniotomy
Subdural/Subarachnoid Hemorrhage

The bridging veins travel from the surface of the cerebral cortex through the arachnoid and subdural spaces under the skull (left). When violent shaking or impact injury causes shearing of the bridging veins (right), the subdural space fills quickly with blood. Bleeding into the subarachnoid space also can occur.
Subdural hematoma

- Usually venous bleeding (bridging veins)
- On surface of cortex, beneath dura and outside arachnoid, not limited by suture lines.
- Typically requires greater force to produce than epidural hematoma
- Usually associated with severe parenchymal injury
Secondary ischemic brain injury

- Compounds the potential for adverse neurologic outcome
- Caused by
  - Post injury hypotension
  - Hypoxemia
  - Intracranial hypertension which impairs cerebral blood flow
**Intracranial Hypertension**

- Reduced cerebral perfusion pressure (CPP = MAP-ICP)
- Brain herniation:
  - uncal herniation;
  - diencephalic and midbrain/upper pontine herniation;
  - temporal lobes herniation
  - lower pontine and medullary herniation

**Note:**
Central or uncal herniation through the tentorium is compatible with intact survival; Foramen magnum hernation is not compatible with intact survival.
Brain Herniations

1. Temporal lobes herniation
2. Uncal herniation
3. Diencephalic and midbrain/upper pontine herniation
4. Lower pontine and medullary herniation
## Normal Intra Cranial Pressure

<table>
<thead>
<tr>
<th>Age group</th>
<th>mmHg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn</td>
<td>0.7-1.5</td>
</tr>
<tr>
<td>Infant</td>
<td>1.5-6.0</td>
</tr>
<tr>
<td>Children</td>
<td>3.0-7.5</td>
</tr>
</tbody>
</table>

Note: ICP in hydrocephalic infant = 7.5-30 mmHg
Monitoring of intracranial pressure

- Ventriculostomy
- Fiberoptic-Tipped Intraparenchymal Cath
- Subdural bolt
- Subdural/Epidural Catheter
- Electroencephalography
- Sensory-Evoked Potentials

CPP = MAP - ICP
ICP Monitoring
# Management of increased ICP

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Head position</strong></td>
<td>Head elevated 30 degrees and midline</td>
</tr>
<tr>
<td><strong>Sedation and pain control</strong></td>
<td>Analgesic + anxiolytic: Fentanyl, morphine, or propofol plus a benzodiazepine</td>
</tr>
<tr>
<td><strong>Seizure prophylaxis</strong></td>
<td>Phenytoin or phenytoin</td>
</tr>
<tr>
<td><strong>Neuromuscular blockade</strong></td>
<td>Facilitates mechanical ventilation and control of pCO2; prevents shivering;</td>
</tr>
<tr>
<td><strong>Temperature control</strong></td>
<td>Maintain temp&lt;37.5 °C; scheduled acetaminophen, body exposure, cooling blanket</td>
</tr>
</tbody>
</table>
| **Osmotherapy with mannitol or NS 3%** | Scheduled if elevated ICP is persistent
Follow serum osmolality and Na; hold mannitol if serum osm > 320 mOsm/l |
| **Refractory intracranial hypertension** | Barbiturate “coma”; Induced hypertension; Decompressive craniotomy; Hypothermia          |
| **Drainage of CSF** | Possible if ventricular catheter is in place
Set at 20 cm H2O; CSF drains when ICP exceeds drainage pressure; |
<table>
<thead>
<tr>
<th>Clinical Characteristic &amp; Outcome</th>
<th>Mild Concussion</th>
<th>Cerebral Contusion</th>
<th>Diffuse Axonal Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of Consciousness</td>
<td>None</td>
<td>Immediate</td>
<td>Immediate</td>
</tr>
<tr>
<td>Length of Consciousness (hr)</td>
<td>None</td>
<td>&lt; 6</td>
<td>6 – 24</td>
</tr>
<tr>
<td>Decerebration</td>
<td>None</td>
<td>None</td>
<td>Rare</td>
</tr>
<tr>
<td>Post Traumatic Amnesia</td>
<td>Minutes</td>
<td>Minutes-Hours</td>
<td>Hours</td>
</tr>
<tr>
<td>Memory Deficits</td>
<td>None</td>
<td>Mild</td>
<td>Mild-Moderate</td>
</tr>
<tr>
<td>Motor Deficits</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Outcome at 3 Months (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>100</td>
<td>95</td>
<td>63</td>
</tr>
<tr>
<td>Moderate</td>
<td>0</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Severe</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Vegetative</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Death</td>
<td>0</td>
<td>0</td>
<td>15</td>
</tr>
</tbody>
</table>
Spinal Trauma

- Uncommon
  - Usually occur at C₁, C₂, C₃ (high C-spine)
  - Dislocations more common than fractures
- Suspect if trauma involves:
  - Sudden deceleration
  - Head injuries
  - Decreased LOC
- Resist temptation to pick child up and run!
- Spinal Cord Injury Without Radiographic Abnormality (SCIWORA)
Thoracic injuries in children are relatively uncommon but result in a predisproportionate percent of morbidity and mortality compared with other traumatic injuries.

Second only to head trauma as cause of trauma deaths.

Children with significant thoracic injuries require intensive monitoring and hemodynamic and respiratory support.

Most thoracic injuries in children result from blunt trauma.
Chest Trauma (2)

- Chest wall flexible:
  - Rib fracture uncommon
  - Extensive intrathoracic injury can occur without rib fracture
- Mobile mediastinum
  - Poor tension pneumothorax tolerance
- Limited respiratory reserve
  - Poor chest injury tolerance 90% blunt
- The most modifications of thoracic trauma in children are rib fractures, pneumothoraces, hemothoraces, and pulmonary contusion
**Diagnosis and Immediate management of Child with Chest Injuries**

<table>
<thead>
<tr>
<th>Airway</th>
<th>GCS $\leq 8$ warrants endotracheal intubation. Patients with suspected cervical injuries-cervical stabilization during intubation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breathing</td>
<td>Both hemithoraces are observed for symmetrical motion, and auscultation of breath sounds. Arterial PO2 analysis and pulse oxymetri for assessing oxygenation. Chest radiography</td>
</tr>
<tr>
<td>Circulation</td>
<td>Recording the pulse rate and blood pressure. Capillary refill. Cardiac tamponade?</td>
</tr>
</tbody>
</table>
Life Threatening Chest Injuries

- Tension Pneumothorax
- Tension Hemothorax
- Pulmonary Contusion
- Traumatic asphyxia
- Great Vessel Injury
- Cardiac Tamponade
- Flail Chest
- Ruptured Diaphragm
Abdominal Trauma

- Most common pediatric trauma form
- Usually blunt
- Liver, spleen injury more common than in adults
  - High, broad costal arch
  - Relatively larger organs
  - Weak abdominal wall
- Tenderness = Significant trauma until proven otherwise
- Distension = Significant trauma until proven otherwise
Blunt Abdominal Injuries

- 80% involve a single organ
- Liver 30%
- Spleen 30%
- Kidney 17%
- Small bowel 8%
- Pancreas 5%
- Bladder 2%
Extremity Trauma

- Never severe enough to warrant attention before head, chest, abdominal injury
- Priorities remain with ABC’s
- Pliant bones absorb/ dissipate significant force
  - Greenstick fractures common
  - Treat painful, tender, guarded extremities as fractures
## Pediatric Trauma Score

<table>
<thead>
<tr>
<th>Components</th>
<th>+2</th>
<th>+1</th>
<th>-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>&gt;20 kg (44 lbs)</td>
<td>10-20 kg (22-44 lbs)</td>
<td>&lt;10 kg (22 lbs)</td>
</tr>
<tr>
<td>Airway</td>
<td>Patent</td>
<td>Maintainable</td>
<td>Unmaintainable</td>
</tr>
<tr>
<td>Systolic BP Pulses</td>
<td>&gt;90</td>
<td>50 – 90</td>
<td>&lt;50</td>
</tr>
<tr>
<td>Radial</td>
<td>Carotid</td>
<td>Nonpalpable</td>
<td></td>
</tr>
<tr>
<td>CNS</td>
<td>Awake</td>
<td>+LOC (responsive)</td>
<td>Unresponsive</td>
</tr>
<tr>
<td>Fractures</td>
<td>None</td>
<td>Closed or suspected</td>
<td>Multiple closed or open</td>
</tr>
<tr>
<td>Wounds</td>
<td>None</td>
<td>Minor</td>
<td>Major, penetrating or Burns &gt; 10%</td>
</tr>
</tbody>
</table>

9 –12=Minor Trauma; 6 –8=Potentially Life Threatening; 0 –5=Life Threatening
Nonaccidental Trauma (Intentional injury)

- The caretaker is unable to explain the injuries/mechanism of injury
- The timing of injury doesn’t fit with the time of presentation
- The child’s developmental stage is not sync with the history
- The history of injury changes over time or from caretaker to caretaker
# Patterns of injury

<table>
<thead>
<tr>
<th>Accidental</th>
<th>Nonaccidental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral</td>
<td>Bilateral/symmetrical</td>
</tr>
<tr>
<td>Isolated injury</td>
<td>Multiple injuries</td>
</tr>
<tr>
<td>Amorphous shape</td>
<td>Well-defined shape</td>
</tr>
<tr>
<td>Prominent bone areas</td>
<td>Soft tissue areas</td>
</tr>
<tr>
<td>Posterior aspect of body</td>
<td>Anterior aspect of body</td>
</tr>
<tr>
<td>One age of injury</td>
<td>Multiple ages of injury</td>
</tr>
</tbody>
</table>
Shaken Baby Syndrome = SBS (Abusive Head Trauma)

- The clinical history is vague
- Symptoms unspecified (lethargy, poor feeding, and irritability or may have had a seizure like episode)
- The diagnosis is made in the presence of signs:
  - Subdural hemorrhage
  - Retinal hemorrhage
  - Skeletal injury
- Differential diagnosis: sepsis, meningitis, new onset seizure, metabolic disorder
Treatment

- Do immediate resuscitation
- Treatment in the PICU:
  - Decrease intracranial hypertension
  - Optimized cerebral blood perfusion
  - Maintained metabolic homeostasis
- Skeletal trauma → give adequate analgetic
**FIGURE 1**

Acceleration-deceleration injury

Violent shaking produces acceleration-deceleration forces that cause significant injury to the brain. Rotational forces exerted on the brain result in shear injury.

**FIGURE 3**

The magnifying force of an impact injury

The impact of the infant's head against a solid surface magnifies the forces suffered by the brain by 10 to 50 times compared to the forces caused by shaking alone.

**FIGURE 4**

Spinal cord injury

Violent shaking can cause trauma directly to the spinal cord resulting in apnea and cardiovascular collapse.

Pall or blue skin

Lethargic eyes
During violent shaking, the perpetrator’s hands wrap around the child’s thorax (left). Note that the fingers are located over the spinal column, where the vertebrae act as a fulcrum, resulting in posterior rib fractures (right). (Reproduced with permission from Lauridson J, Levin A, Parrish R: Animated Graphic Demonstration of Shaken Baby Syndrome (CD-ROM). Ogden, Utah: National Center on Shaken Baby Syndrome, 2000)