Pediatric Trauma

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Objectives

- Discuss the epidemiology of pediatric trauma
- Discuss unique anatomic and physiologic characteristics of children
- Review early management and transport
- Review of individual organ systems with regards to trauma management
Pediatric Trauma

- Trauma: forceful disruption of bodily homeostasis
- A serious injury or shock to the body
- Injury to living tissues caused by an extrinsic force
- Bodily injury posing a treat to human life without immediate medical intervention
Epidemiology

- Leading cause of death in children and young adults (49%)
- Boys > girls: ratio 2:1
- CNS injury causes most of morbidity
- Increased morbidity with multisystem injury
- Blunt trauma more common than penetrating
  - Later more lethal
  - Most blunt trauma accidental
  - MVA responsible for 75% childhood deaths
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</table>

*WISQARS™ Produced By: Office of Statistics and Programming, National Center for Injury Prevention and Control, Centers for Disease Control and Prevention
Data Source: National Center for Health Statistics (NCHS), National Vital Statistics System*
### Incidence and mortality of pediatric trauma

<table>
<thead>
<tr>
<th>Injury mechanism</th>
<th>Incidence (%)</th>
<th>Mortality (%)</th>
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<tbody>
<tr>
<td>Blunt</td>
<td>92</td>
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<tr>
<td>Fall</td>
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<tr>
<td>Motor vehicle injury—occupant</td>
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<td>4</td>
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<tr>
<td>Motor vehicle injury—pedestrian</td>
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<tr>
<td>Bicycle</td>
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<tr>
<td>Crush</td>
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</table>

Epidemiology

- Cost: estimated to be > 12 billion/yr
  - Immediate and long term care
  - Lost income

- Mortality
  - 50% at the scene: airway compromise, hypovolemic shock, CNS injury
  - 30% within first few hours of injury: golden hour
  - 20% within days/weeks: resulting complications, brain death
Early Management

- **Pre-hospital trauma care**
  - Emergency medical dispatcher instruction to lay rescuers
  - First responders/ emergency medical technicians
  - “platinum half hour”--- “golden hour”
  - “scoop and run” or “stay and play”

- **Where to take the child?**
  - Closest facility vs. Pediatric Trauma Center
  - Resuscitation focuses on airway management, ventilatory support, restoration of intravascular volume
Trauma Center

- Neurosurgeon
- Trauma Surgeon

Resuscitation Team

Surgical Specialties

Medical Specialties

- Nursing
- ICU

Orthopedic Surgeon

Anesthesia

OR

ALWAYS OPEN

TRAUMA CENTER
Rainbow Babies and Children’s Hospital

- Level I Trauma Center
- Designated by the American College of Surgeons Committee on Trauma (ACS-COT)
- Meets criteria for multi-disciplinary care
<table>
<thead>
<tr>
<th>Pediatric Surgical and Trauma Services - Rehabilitation - Injury Prevention</th>
<th>Pediatric Emergency Medicine and dedicated Pediatric Emergency Room</th>
<th>Dedicated Pediatric Operating Room and PACU</th>
<th>Pediatric Neurological Surgery</th>
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<tr>
<td>Pediatric Intensive Care Unit</td>
<td>Pediatric Dental Services &amp; Oral Surgery</td>
<td>Pediatric Anesthesiology</td>
<td>Pediatric Orthopedics</td>
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<tr>
<td>Pediatric Ground and Air Transport Services</td>
<td>Child Life Department</td>
<td>Pediatric Social Work Department</td>
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<td>Pediatric Allergy and Immunology</td>
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<td>Pediatric Cystic Fibrosis Center</td>
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<td>Pediatric GI Services</td>
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<td>Pediatric Cardiology</td>
<td>Pediatric Cardiothoracic Surgery</td>
<td>Pediatric Behavioral Psychology</td>
<td>Pediatric Endocrinology</td>
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</tbody>
</table>
Rainbow Babies and Children’s Hospital

- Founded over 120 years ago
- 244-beds
- >1,300 pediatric specialists
- 500,000 outpatient visits
- ~180 hospitalized children daily
- ~10,000 newborns, infants, children, and adolescents are hospitalized yearly
- >26,000 emergency room patients yearly
- 5,700 children trauma patients yearly
Rainbow Babies and Children’s Hospital

- The Pediatric Intensive Care Unit (PICU)
  - Cares for the most complex patients
  - Has among the best survival rates in the country
  - Leads the country in drug therapy & research
  - 23-bed unit
  - More than 1,800 critically ill children every year.
Ohio Pediatric Trauma

- Patients under 16 years of age, with at least one of the following:
  - Physiologic conditions
    - Depressed or deteriorating neurologic status
    - Respiratory distress or failure
    - Endotracheal intubation and/or vent support
    - Shock
    - Injuries requiring blood product transfusions
    - Requiring invasive monitoring, ICP monitoring, vasoactive medications
Patients under 16 years of age, with at least one of the following:

- **Anatomic conditions**
  - Fractures and deep penetrating wounds to extremities-neurovascular or compartment injury
  - Fractures of 2 or more long bones
  - Fracture of axial skeleton
  - Spinal cord or column injuries
  - Traumatic amputation with potential for re-implantation
  - Head Injury- CSF leak, open skull/ depressed skull fracture, LOC
  - Significant penetrating wounds to head, neck, trunk
  - Significant blunt injury to chest or abdomen
ACS Transfer Recommendations

- Carotid or vertebral artery injury
- Torn thoracic aorta or great vessels
- Cardiac rupture
- Bilateral pulmonary contusions
- Major abdominal vascular injury
- Grade IV or V liver injuries
- Unstable pelvic fractures
ACS Transfer Recommendations

- Fracture or dislocation with loss of distal pulses
- Penetrating injury or open fracture of skull
- GCS < 14 or lateralizing neurologic signs
- Spinal fracture or spinal cord deficits
- Significant torso injury with advance co-morbid disease
- Open long bone fractures
- >2 unilateral rib fractures or bilateral rib fractures with pulmonary contusion
Children Not Small Adults

- **Anatomical Difference**
  - Shape and Size
    - Variable weight and length: one size does not fit all
    - Broselow tape
  - Smaller body mass
    - Affect kinetic energy transfer - multiorgan trauma
  - Head proportionately larger
  - Skeletal growth
    - Incomplete calcifications, active growth centers, elasticity
    - Higher frequency of incomplete fractures/disturbances to growth
  - Surface area
    - Ratio body surface to volume diminished: thermal loss
    - Temperature regulation matures by age 10 yrs
Determination of size/ weight

- **BROSELOW PEDIATRIC RESUSCITATION MEASURING TAPES** provide approximate weight, vital signs and drug doses based on a child’s height.

![Image of BROSELOW Tapes]

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Weight Estimates

- If weight unknown and Broselow tape not available- can estimate from age
  - Age \leq 8 \text{ years}: (\text{Age} \times 2) + 8 = \text{weight (kg)}
  - Age > 8 \text{ years}: \text{Age} \times 3 = \text{weight (kg)}
Children Not Small Adults

- **Airway**
  - More anterior placed
  - Smaller overall diameter with larger tongues
  - Shorter trachea - risk mainstem intubation / dislodged tube
  - Smaller, narrower funneled shaped
    - Epiglottis changes from U shaped to thinner adult structure; drops from level of C1 to C3
Children Not Small Adults

- **Breathing:** Poor compensation for associated respiratory derangements
  - Larger oxygen consumption
  - Smaller functional residual capacity
  - Less pulmonary compliance/ greater chest wall compliance
  - Horizontally aligned ribs - diaphragm breathers

- **Abdominal organs larger**
  - More anterior and less subcutaneous fat - higher risk injury
  - Attain adult structure and function by time wt 35kg

- **Physiologic differences**
  - Variable heart rate, RR, BP
  - Infants dependent on HR for compensation/ cardiac output
  - Compensatory vasoconstriction: normal BP with early shock
  - Shock: late identification
  - Differences organ system function more pronounced < 2yrs age

- **Key to remember:**
  - Kids die from hypoxia and respiratory arrest
## VITAL SIGNS BY AGE

<table>
<thead>
<tr>
<th>AGE</th>
<th>WT kg</th>
<th>HR</th>
<th>BP</th>
<th>RR</th>
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<tr>
<td>0-6 m</td>
<td>3-6</td>
<td>130-180</td>
<td>60-80/40</td>
<td>40-60</td>
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<td>1-2 y</td>
<td>10-12</td>
<td>120-160</td>
<td>80/40</td>
<td>40</td>
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<td>2-5 y</td>
<td>12-18</td>
<td>100-120</td>
<td>90-100/60</td>
<td>30</td>
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<td>5-10 y</td>
<td>18-30</td>
<td>80-100</td>
<td>100-120/80</td>
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</table>
Management

- ATLS approach but need to incorporate principles of pediatric assessment

- Keep in mind neuroventilatory derangements 5x more common than hemodynamic derangements but later twice as lethal

- Primary survey
  - ABC’s
  - Continuous cycle of assessment, intervention, reassessment
Management- Airway /Cervical Spine Stabilization

- All else futile if airway control ineffective
  - Goal relieve anatomical obstruction, prevent aspiration, promote adequate gas exchange

- Proper immobilization essential
  - Avoid passive flexion
  - Keep plane of face parallel / sniffing position
  - Maintain neutral alignment: padding
  - Inline traction/stability
Management - Airway / Cervical Spine Stabilization

- Supplemental O2 – FIO$_2$ of 1 (100%)
- Clear airway
- Artificial airway
  - Oral airway
    - Only unconscious patient: elicit gag
    - May assist bag/mask ventilation
  - Endotracheal intubation
    - Oral not nasal
    - Aspiration risk: full stomach
    - Hemodynamic compromise
    - Less tolerant hypoxia: preoxygenation/denitrogenation
    - LMA
  - Surgical airway
Pediatric Airway Guidelines

- Endotracheal Tube Size: $16 + AGE_{4}$

- Diameter of the child’s 5$^{th}$ digit

- Size of child’s nares
Rapid Sequence

- **Preoxygenation**: Atropine sulfate 0.1-0.5 mg
- **Sedation**
  - **Hypovolemic**: Midazolam HCL 0.1 mg/Kg; 5 mg maximum
  - **Normovolemic**: Thiopental sodium 4-5 mg/Kg
- **Cricoid Pressure**
- **Paralysis***
  - **Short Paralysis**: Succinylcholine chloride <10 Kg: 2 mg/Kg; >10 Kg: 1 mg/Kg
  - **Longer Paralysis**: Vecuronium bro. 0.2 mg/Kg
- **Intubate, Check Tube Position, Release Cricoid Pressure**
Management – Breathing

- **Inadequate ventilation**
  - Abnormal respiratory pattern
  - Cyanosis
  - Clinical evidence hypercapnia ie increased sympathetic tone

- **Avoid hypercarbia/hypoxia**

- **Persistent desaturations**
  - Re-evaluate for asymmetry: pneumothorax
  - Tube position if indicated

- **Consider open chest wounds**
Management - Circulation

- **Shock major concern: often missed in early stages**
  - Mobile mediastinum: compensate for obstructive lesion
  - Vasculature better able to constrict
  - Maintain SVR, thus afterload and systemic BP longer
  - Frank hypotension late sign

- **Normal blood volume: 70-80ml/kg**
  - May not see hypotension until loss of 30% blood volume
  - 10-15%: mild tachycardia
  - 30%: tachycardia, diminished peripheral pulses
  - 30-45%: decreased urine output, thready central pulses, narrow pulse pressure
  - >45%: coma
### Table 3—Systemic Responses to Blood Loss in the Pediatric Patient

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>MILD BLOOD VOLUME LOSS (&lt;30%)</th>
<th>MODERATE BLOOD VOLUME LOSS (30%-45%)</th>
<th>SEVERE BLOOD VOLUME LOSS (&gt;45%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular</td>
<td>↑ Heart rate; weak, thready peripheral pulses</td>
<td>Low normal blood pressure, narrowed pulse pressure, markedly ↑ heart rate; absent peripheral pulses with weak, thready central pulses</td>
<td>Hypotension; tachycardia then bradycardia</td>
</tr>
<tr>
<td>Central Nervous System</td>
<td>Anxious, irritable, confused</td>
<td>Lethargic, dulled response to pain¹</td>
<td>Comatose</td>
</tr>
<tr>
<td>Skin</td>
<td>Cool, mottled; prolonged capillary refill</td>
<td>Cyanotic; markedly prolonged capillary refill</td>
<td>Pale, cold</td>
</tr>
<tr>
<td>Urinary Output</td>
<td>Minimal ↓</td>
<td>Minimal</td>
<td>None</td>
</tr>
</tbody>
</table>

¹The child's dulled response to pain with this degree of blood loss (30%-45%) is often indicated by the decreased response noted when an IV catheter is inserted.
Management - Circulation

- Assessment: signs of shock
  - Heart rate: tachycardic
  - Pulses: loss of peripheral pulses, narrow pulse pressure, loss of central pulse - you are too late
  - Blood pressure:
    - Lower limits systolic: 70+(2 x age in years)
    - Diastolic: 2/3 systolic
Basic steps to management

- Control active hemorrhage
  - Direct pressure

- Cognition of potential internal bleeding

- No tourniquet or MAST

- Correction of coagulopathies: dilutional / losses
  - Platelets, FFP: replace when greater than 2x blood volume, 80ml/kg in young child
  - Amicar
  - Factor VII
Basic steps to management (cont.)

- Vascular access: essential in all patients
  - Large bore peripheral catheter: ideally two sites of access
  - IO placement: do not delay
  - Central access
Basic steps to management (cont.)

- Volume Replacement
  - 20-40 ml/kg warmed isotonic fluids
  - 3:1 rule
  - Over resuscitation
    - Hemorrhage/edema vs. delayed resuscitation
- Crystalloid vs. colloid
  - Meta-analysis showing no difference
  - Crystalloid cheaper but more important: readily available
  - Albumin: lower levels inflammatory cytokines, apoptosis
  - No hypotonic solutions
  - Isotonic saline vs. Ringers Lactate
Basic steps to management (cont.)
- Other fluids to consider
  - Hypertonic saline
    - Redistribution of extracellular fluid
    - Less neutrophile activation
    - Hyperchloremic metabolic acidosis
  - Albumin
    - Provides approximately 80% intravascular colloid oncotic pressure
    - 5% for acute resuscitation
  - Hydroxyethyl starch
    - Platelet dysfunction
    - Plasma volume expansion 24-36hr
Basic steps to management (cont.)

- Blood products
  - 3:1 rule
  - PRBC: Hct depends on anticoagulant used
    - Citrate phosphate: 65%-75%
    - Adenine anticoagulants: 50%-60%
  - Type and cross ASAP: start with O negative trauma pack
  - Blood warmer
  - Platelet replacement: After 2x blood volume replacement
  - Blood replacement products
Management- Disability / Exposure

- Abbreviated neurologic exam
  - Cognitive
    - GCS
    - AVPU
  - Pupils
    - Early sign of developing intracranial hypertension
    - Asymmetry, sun setting
  - Motor
    - Early detection spinal cord injury
Glascow Coma Scale

**Eye Opening (4)**
1. NO EYE OPENING
2. TO PAIN
3. TO COMMAND
4. SPONTANEOUSLY

**Motor (6)**
1. NONE
2. EXTENTION*
3. FLEXION*
4. WITHDRAWL*
5. LOCALIZES*
6. OBEYS COMMANDS

* TO PAIN
Differences In GCS Verbal

**ADULT (5)**
1. NO RESPONSE
2. INCOMPRHENSIBLE
3. INAPPROPRIATE
4. CONFUSED
5. ORIENTATED

**PEDIATRIC (5)**
1. NO RESPONSE
2. INCONSOLABLE
3. CONSOLABLE
4. INAPPROPRIATE INTERACTIONS
5. SMILES, ORIENTATED
Hypothermia

- Children have a higher body to surface area to mass ratio
- Hypothermic infants are more difficult to resuscitate
- Loose heat easily
- Resuscitation area, ED, Radiology, OR should be warmed with high humidity
- Minimize exposure: keep covered as much as possible
- Warmed IV fluids
CNS Injury

- Leading cause of death in pediatric trauma
- 85-90% minor: GCS > 12
- Keep on alert: initial exam and scans do not always tell the truth----ICH occurs with time

Anatomical difference kids vs. adults
- Infants with fontanelles/open sutures: edema without ICH
- Felt to have more plasticity
- Larger heads----more torque
- Soft cranium: thus parenchymal injury without fractures
- Less myelin so increased risk affect from shearing forces
- Prone to reactive hyperemia
CNS Injury

- Variable Presentation
  - Altered mental status: LOC, irritability
  - Full fontanelle, split sutures, palpable deformities
  - Ecchymosis, hematomas
  - Asymmetrical, dilated or non-reactive pupils
  - Sun setting eyes, disconjugate gaze
  - Rapid deterioration vs. completely normal
    - GCS not good predictor in infants: trust overall exam
CNS Injury - Management

- Avoid hypoxic ischemic event
  - Maintain adequate oxygenation and ventilation
    - Do not hyperventilate/hypoventilate
  - Intravascular volume resuscitation
  - Maintain MAP:
    - >70 adolescent
    - >60 child
    - >50 infant
- Isotonic fluids
- Optimal ventilation
- Control glucose load
- ICP precautions
- Osm therapy
Spinal Injuries

- Uncommon, only 5% but can be deadly
- Anatomical differences
  - Interspinous ligaments and joint capsules more flexible
  - Vertebral bodies wedge anterior: tend to slide forward in flexion
  - Facet joints are flat
  - Larger head: angular forces applied to upper neck relatively greater
Spinal Injuries
Spinal Injuries- Management

- KEEP IMMOBILIZED
  - Collar that fits/ rolls for infants
  - Side rolls
  - Head straps as well as those to control trunk/extremities

- X-ray vs. CT
  - How high suspicion for injury
  - Limitations of clinical exam: distracting injuries

- Surgical fixation when indicated
- Steroids out of favor
Thoracic Injuries

- Occur in 6% pediatric trauma victims
- Major contributor to mortality
- 90% related to blunt trauma
- Marker for injury severity
Life-threatening Injuries

- Airway injury

- Tension pneumothorax / Massive hemothorax
  - Tension pneumo leads to hemodynamic instability
  - Tracheal deviation, acute respiratory distress, hemodynamic instability not explained by hemorrhage

- Cardiac injury and tamponade
  - Chest pain, dysrhythmias, myocardial dysfunction
  - Sudden death: Commotio Cordis
  - Cardiac tamponade- obstructs venous return and cardiac output
  - Beck’s Triad: pulsus paradoxus, quiet precordium, distended neck veins
  - Unexplained tachycardia in the younger child

- Rib fractures / Flail chest: lost continuity with thorax
  - Paradoxically movement- in inspiration, out expiration
  - Requires controlled mechanical ventilation; intubation in the field
Abdominal Injuries

- Blunt trauma cause in 83% with 9% mortality

- Pay attention to physical exam
  - Skin loss, ecchymosis, puncture wounds, distension, guarding, rebound tenderness

- Labs: may not see bump with initial labs
  - LFT’s, Amylase, Lipase, ABG- acid/base status, UA

- Diagnosis by radiographic studies
  - CT preferred method
  - Fast Exam- beside ultrasound
  - Peritoneal Lavage falling out of favor
Burns

- **Severity**
  - First degree: superficial involvement of epidermis
  - Second degree: epidermis and partial dermis
  - Third degree: full thickness, nerve damage, eschar

- **Infants**: inflicted, immersion, spills

- **Older kids**: flames, fire crackers

- **Assessment**
  - Rules of nine vs. 1% palm
  - Often underestimate
Burns

- Transfer directly to a verified burn center
  - Burns >10% total body surface area
  - Full thickness burns of the face, hands, feet, genitalia, perineum or major joints
  - Third degree burns in any age group
  - Electrical burns (including lightening injury)
  - Chemical burns and inhalation injury
Burns Combined with Traumatic Injuries

- Select destination based on which set of injuries create the greatest risk to life and limb

- Severe injuries with minor burns = Trauma Center

- Severe burns with minor injuries = Burn center
Child Abuse: Clues

**History**
- story ≠ injuries
- history changing
- injury ≠ development
- delay seeking help
- inappropriate level of concern

**Physical Exam**
- multiple old and new bruises
- posterior rib #, sternum #, spiral # < 3
- immersion burns, cigarette
Summary

- Trauma leading cause mortality in pediatrics requiring multidisciplinary approach to management
- Rapid organized assessment and intervention required to optimal outcome; dependent on constant reassessment
- Children are not small adults- need for understanding of anatomical and physiologic differences for optimal care
- Rapid aggressive management of the pediatric trauma patient can lead to positive outcomes, even with the most severe injuries
- What happens in the field and on transport sets the stage for things to come
We are just a phone call away! One call puts you in touch with the Transfer and Referral Center and an attending physician in the pediatric Emergency Department.

216-844-PEDS (7337)

If the injuries are particularly severe you will be placed in conference call with the pediatric trauma surgeon on duty as well.