Pediatric Trauma

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The University of Michigan
Sheep health classes
Objectives

1. To examine the epidemiology of pediatric trauma
2. To review the initial assessment and resuscitation of pediatric trauma patients
3. To identify specific injuries
4. To describe the anesthetic management of pediatric trauma cases
Incidence

- 25% of all trauma
- 2006; 6 million children treated in ED
- Leading cause of death ages 1-18
- 4738 trauma deaths in 2006 in US
- 60% pediatric deaths due to trauma

U.S. Department of Health and Human Services 2009
Death

- 70% due to TBI
- 20% thoracic injuries
- 10% abdominal injuries

Ten leading causes of child and adolescent death, 2016

Motor vehicle crash
Firearm-related injury
Malignant neoplasm
Suffocation
Drowning
Drug overdose or poisoning
Congenital anomalies
Heart disease
Fire or burns
Chronic lower respiratory disease

Rate per 100,000 individuals aged 1-19 years

Note: Based on data from the Centers for Disease Control and Prevention’s Wide-ranging Online Data for Epidemiologic Research system.

Pediatric Trauma

- size means less margin for error
- vital signs
- greater chance of dying at scene & ED
- difficult IV access
- hypothermia develops rapidly
- multi-system injury is common
- high incidence of blunt trauma
- greater force over smaller area
- immature skeleton results in internal injury
Death

- Within seconds of the trauma
- Within minutes to hours “Golden Hour”
- Days to weeks

Rotondo, M. F., Cribari, C., Smith, R.S., (2014). Resources for the Optimal Care of the Injured Patient
Trauma Centers

- Lessons from Korea and Vietnam
- 3 tiered trauma system
- Pediatric trauma centers

American College of Surgeons Committee on Trauma 1997
Classification

Level I
Comprehensive trauma care, regional resource, leadership in education, research, and system planning.
Immediate availability of trauma surgeons, anesthesiologists, physician specialists, nurses, and resuscitation equipment.
1200 admissions a year or 240 major trauma patients per year or an average of 35 major trauma patients per surgeon

Level II
Comprehensive trauma care either as a supplement to a level I trauma center in a large urban area or as the lead hospital in a less population-dense area.
Meet essentially the same criteria as level I but volume performance standards are not required and may depend on the geographic area served.
Not expected to provide leadership in teaching and research.

Level III
Provides prompt assessment, resuscitation, emergency surgery, and stabilization with transfer to a level I or II as indicated.

Rotondo, M. F., Cribari, C., Smith, R.S., (2014). Resources for the Optimal Care of the Injured Patient
Pediatric Trauma Centers

- Improved outcomes
- Increased overall survival

Society of Black Academic Surgeons

Treatment outcomes of injured children at adult level 1 trauma centers: are there benefits from added specialized care?


a Department of Surgery, Howard University College of Medicine, Washington, DC, USA; b Department of Surgery and Division of Pediatric Surgery, Johns Hopkins University School of Medicine, Baltimore, MD, USA; c Department of Surgery, University of California, San Diego School of Medicine, San Diego, CA, USA
Advanced Trauma Life support (ATLS)

- Systematic protocol for initial resuscitation and evaluation
- Primary survey
- Secondary survey
- Continual reassessment
Primary survey and resuscitation

- **Airway:** assure a patent airway
- **Breathing:** assess and provide adequate respiration
- **Circulation:** assess and assist circulation, CPR
- **Disability:** neurologic injury or
- **Diagnosis:** diagnostic measures
- **Exposure:** remove clothing, evaluate for further injury, prevent hypothermia
Airway: Anatomical Differences

- Obligate nasal breathers
- Larger tongue which rests against palate
- Narrow nares
- Larger head with protuberant occiput
- Shorter neck

Airway: Anatomical Differences

- Larynx more cephalad
- Floppy epiglottis, angled toward airway
- Anterior commissure more caudad
- Cricoid is smallest diameter

Airway: Inline Axial stabilization

From Pediatric Trauma, Reynolds, PI et.al. Smiths Pediatric Anesthesiology, 9th Ed., 2016
Airway

• Pre-Hospital Intubations
  o 57% success rate
  o 44% with hypoxia, hypercarbia, or other major airway complication
  o BE WARY and CONFIRM correct placement

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Emergency Endotracheal Intubation in Pediatric Trauma

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DON K. NAKAYAMA, M.D., MARY J. GARDNER, R.N., and MARC I. ROWE, M.D.
Breathing
Circulation: Pediatric Shock

- Children with multiple injuries often present in shock
- Normal blood pressure until 25-35% blood loss
- High sympathetic tone
- Tachycardia > hypotension

Circulation

• Rapidly assess pt for signs of shock

• Peripheral routes; Ultrasound

• Central access
  - femoral
  - internal jugular
  - subclavian

• C-spine immobilization
Circulation: Intraosseous access

Ellemunter: Arch Dis Child Fetal Neonatal Ed, Volume 80(1). January 1999.74F
Circulation: Intraosseous access

EZ-IO

Bone Injection Gun

EZ-IO., Bone Injection Gun. Courtesy Vidacare, San Antonio, Texas; Bone Injection Gun
Courtesy Waismed, Kansas City, Missouri
Diagnostic Evaluation

• Clinical evaluation supplemented by radiological examination

• Imaging techniques allow non-operative management in thoracic and abdominal injuries

• Replacing ex-laps and DPL

• POCUS
Disability

- Changes in mental status = reevaluate A, B, C’s
- Brain injury/CT/neurosurgeon
**Disability**

### AVPU Pediatric Response Scale

- **A** - The patient is awake.
- **V** - The patient responds to verbal stimulation.
- **P** - The patient responds to painful stimulation.
- **U** - The patient is completely unresponsive.

### Table II: Glasgow Coma Score or PGCS

<table>
<thead>
<tr>
<th></th>
<th>Infant &lt;1 yr</th>
<th>Child 1-4 yrs</th>
<th>Age 4–Adult</th>
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</thead>
<tbody>
<tr>
<td><strong>EYES</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>4 Open</td>
<td>Open</td>
<td>Open</td>
<td>Open</td>
</tr>
<tr>
<td>3 To voice</td>
<td>To voice</td>
<td>To voice</td>
<td>To voice</td>
</tr>
<tr>
<td>2 To pain</td>
<td>To pain</td>
<td>To pain</td>
<td>To pain</td>
</tr>
<tr>
<td>1 No response</td>
<td>No response</td>
<td>No response</td>
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<tr>
<td><strong>VERBAL</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5 Coos, babbles</td>
<td>Oriented, speaks, interacts, social</td>
<td>Oriented and alert</td>
<td></td>
</tr>
<tr>
<td>4 Irritable cry, consolable</td>
<td>Confused speech, disoriented, consolable</td>
<td>Disoriented</td>
<td></td>
</tr>
<tr>
<td>3 Cries persistently to pain</td>
<td>Inappropriate words, incomsolable</td>
<td>Nonsensical speech</td>
<td></td>
</tr>
<tr>
<td>2 Moans to pain</td>
<td>Incomprehensible, agitated</td>
<td>Moans, unintelligible</td>
<td></td>
</tr>
<tr>
<td>1 No response</td>
<td>No response</td>
<td>No response</td>
<td>No response</td>
</tr>
<tr>
<td><strong>MOTOR</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Normal, spontaneous movement</td>
<td>Normal, spontaneous movement</td>
<td>Follows commands</td>
<td></td>
</tr>
<tr>
<td>5 Withdraws to touch</td>
<td>Localizes pain</td>
<td>Localizes pain</td>
<td></td>
</tr>
<tr>
<td>4 Withdraws to pain</td>
<td>Withdraws to pain</td>
<td>Withdraws to pain</td>
<td></td>
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<tr>
<td>3 Decorticate flexion</td>
<td>Decorticate flexion</td>
<td>Decorticate flexion</td>
<td></td>
</tr>
<tr>
<td>2 Decerebrate extension</td>
<td>Decerebrate extension</td>
<td>Decerebrate extension</td>
<td></td>
</tr>
<tr>
<td>1 No response</td>
<td>No response</td>
<td>No response</td>
<td>No response</td>
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</tbody>
</table>
Exposure

• Remove garments, roll patient over

• Rapid, warm room, fluids, radiant warmer, convective warmers

• Children have larger surface area to weight ratio
Secondary Survey

• AMPLE Pneumonic
  o Allergies
  o Medications
  o Past medical history
  o Last meal
  o Events associated with injury
Broselow Tape

A Rapid Method for Estimating Weight and Resuscitation Drug Dosages From Length In the Pediatric Age Group
Traumatic Brain Injury (TBI)

- Leading cause of mortality in children (70%)
- MVA most common cause
- 30-50% under 4 years of age due to falls or abuse
- Risk factors: large head, weak neck muscles, high center of gravity, thinner cranial bones, less myelinated nerve tissue

Traumatic Brain Injury (TBI)

- CBF higher in infants 65 ml/100g/min
- CMRO$_2$ higher 5 ml/100g/min
- lower autoregulatory limits in infants
- immature response to hypocapnia in neonates
- open sutures accommodate slow increases in ICP

Traumatic Brain Injury (TBI)
Traumatic Brain Injury (TBI)
Traumatic Brain Injury (TBI)

- Phases:
  1. Primary injury
  2. Secondary injury due to cerebral response to trauma
  3. Secondary injury due to systemic response to trauma

**Traumatic Brain Injury (TBI)**

- Goals: minimize secondary effects
- Consider TBI in all children regardless of symptoms
- GCS
  - $< 14$ mild brain injury
  - 9-13 moderate
  - $< 8$ severe

Traumatic Brain Injury (TBI)

- GCS <13, decrease of 2 points or localizing signs: CT of head indicated
- GCS ≤ 8, indication for intubation and hyperventilation
- GCS ≤ 8 mortality rate as high as 32%
- Seizures not uncommon even after minor injury

Traumatic Brain Injury (TBI)

- Treatment Goals
  - Aggressively treat hypotension

Blood Pressure and Outcome after Severe Pediatric Traumatic Brain Injury

Monica S. Vavilala, MD, Anna Bowen, MD, MPH, Arthur M. Lam, MD, Joshua C. Uffman, MD, Jeffrey Powell, MD, H. Richard Winn, MD, and Frederick P. Rivara, MD, MPH

Early hypotension worsens neurological outcome in pediatric patients with moderately severe head trauma

Evan R Kokoska a, b, Gregory S Smith a, b, Thomas Pittman a, b, Thomas R Weber a, b
Traumatic Brain Injury (TBI)

• Treatment Goals
  o Avoid hyperglycemia

Relationship between hyperglycemia and outcome in children with severe traumatic brain injury

Rebecca L. Smith, MD; John C. Lin, MD; P. David Adelson, MD; Patrick M. Kochanek, MD, FCCM; Ericka L. Fink, MD; Stephen R. Wisniewski, PhD; Hülya Bayir, MD; Elizabeth C. Tyler-Kabara, MD, PhD; Robert S. B. Clark, MD; S. Danielle Brown, RN, MS; Michael J. Bell, MD
Spinal Injury

- C-spine fractures occur in 7-10% of children with TBI

- Fulcrum of cervical mobility in infant or young child C2-C3

- Fulcrum of cervical mobility in adult C5-C6 or C6-C7

- 60% of pediatrics fractures in C1 or C2 compare to 16% in adult

- C-spine fractures less common in pediatrics because of ligament flexibility

Spinal Injury

- Odontoid process fracture, most common in childhood

- Due to higher fulcrum and inherent weakness of the growth plate at the base of the dens
SCIWORA

- Spinal Cord Injury WithOut Radiologic Abnormality
- < 8 years of age
- Mechanism: stretching of elastic ligaments with stretching of spinal cord
Chest injuries

- Account for 20% of all pediatric deaths
- Immediately life threatening
- Tension pneumothorax, flail chest, tracheal/bronchial injury, aortic tears
- 78% can be managed with observation and chest tubes
- Chest wall more compliant, highly mobile mediastinum
Abdominal Trauma

• 3rd leading cause of trauma death
  - often occult fatal injury
• blunt: MVA, bikes, sports, assault

Abdominal Trauma: Anatomic issues

- larger solid organs, less musculature, compact torso, elastic ribcage, liver & spleen anterior
  - most solid organ
  - spleen > liver > kidney > pancreas > intestine
- bladder intra-abdominal
  - 10% have GU injury

Abdominal Trauma
Lawn Mower related Injuries

• More than 19,000 injuries and 75 deaths caused by riding lawn-mower accidents each year.

• Children under 15 represent 25% of injuries and 30% of deaths due to lawn-mower accidents (most deaths in those under age 5)

• Ride-on mowers 3x injury rate

Lawn Mower related Injuries

- 60% of riding lawn-mower accidents occur when the lawnmower being reversed
- Serious injury and death occurs when a child is allowed to ride on the mower
- 7% of children who incur mower related injuries require hospitalization, twice the rate of any other consumer product

Lawn Mower related Injuries

- Serious avulsion injuries to soft tissue and bone
- Gross contamination from soil and grass, leading to infection
- Injuries requiring multiple staged surgeries to cleanse wounds and provide soft tissue coverage
Lawn Mower related Injuries: AAP recommendations

- Keep children out of yard and in house while mowing the lawn
- Never allow young children to mow the lawn (recommended age is >12 y.o. for a walk-behind mower and 16 y.o. for a riding lawn mower)
- Never allow passengers on the riding lawn-mower
- Wear long pants and sturdy shoes while mowing
- Clear lawn of trash, glass, large rocks, etc. prior to mowing
- Do not ride sideways on a sloped surface
- Do not remove safety devices, shields, or cut-off switches from your mower
- Mow during daylight hours

Facial Trauma

- 42% of pediatric injuries less than 5 years of age
- Mechanism of Injury
  - Falls
  - Dog bites
  - Risky behaviors
- “The falling zone”

Burns: differences between children and adults

- Children have thinner skin that is more easily damaged by burns.
- Young children are more likely to die from burns than adults.
- Children can be burned accidentally or intentionally.
- Child’s body proportions change over time so that estimating burn area differs.

Pediatric burn injuries, Vija Krishnamoorthy et al; International Journal of Critical Illness and Injury Science 2012 Sep-Dec
Burns: Rule of 9’s

From: Burns-Gordon L. Klein and David N. Herndon; Pediatrics in Review December 2004
Burns: types

- **Scalds**: 85% involve toddlers
- **Contact**: child touches hot object
- **Flame**: house fires, inhalational injuries
- **Electrical**: household current
- **Chemical**: swallowing caustic substances
- **Radiation**: over exposure to the sun
Burns: Scalds

Temperature/exposure time for a child to sustain a burn

Child Abuse

- 3.2 million referrals to CPS/25% indicative of abuse
- Non MVA: high index of suspicion
- 794,000 + cases
- 1,760 deaths

Risk Factors for Child Abuse

**Parental or caregiver characteristics**
- Poverty
- Unemployment
- Lack of or minimal education
- Social isolation
- Single parenting or unrelated caregivers

**Caregiver history**
- Substance abuse
- Domestic violence
- Mental illness
- Their own neglect or abuse as children

U.S. Department of Health and Human Services Administration on Children 2012-2013
Child Abuse: Clues

History
- story $\neq$ injuries
- history changing
- injury $\neq$ development
- delay seeking help
- inappropriate level of concern

Physical Exam
- multiple old and new bruises
- fractures of posterior rib, sternum, spiral long bone
- immersion burns, cigarette
Child Abuse: Management

- DOCUMENT
- Full P/E (rectal, genital)
- Photograph
- CBC, PT/PTT, LFTs, lipase, U/A
- Skeletal survey
- CT head, abd prn
- Child Protection
Perioperative Management:

- NPO status
- Patient monitoring
- Induction agents
- Maintenance
Perioperative Management: NPO

- Residual gastric volumes correlate to interval from oral intake to injury
- Bag mask at the scene, or crying can cause gastric distension
- Trauma patients have 5 times the risk for aspiration compared to elective surgery
- should be considered at risk for aspiration

Monitoring

- Monitoring
  - Based on extent of injuries
  - ROTEM, TEG

## Perioperative Management: Induction Agents

<table>
<thead>
<tr>
<th></th>
<th>Thiopental</th>
<th>Propofol</th>
<th>Etomidate</th>
<th>Ketamine</th>
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<tbody>
<tr>
<td>SVR</td>
<td>-</td>
<td>-</td>
<td>+/-</td>
<td>+</td>
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<tr>
<td>SV</td>
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<td>CPP</td>
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<td>ICP</td>
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<tr>
<td>CMRO₂</td>
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<td>+/-</td>
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From Pediatric Trauma, Reynolds, PI et al. Smiths Pediatric Anesthesiology, 9th Ed., 2016
Resuscitation

- Massive Transfusion Protocol
  - Defined as administration of one or more blood volume within 24 hours
  - 1:1:1 PRBCs to FFP to platelets
Perioperative Management: Maintenance

• Stable children, standard anesthetic acceptable
• Unstable children may require a balanced technique
• Uncertain injuries avoid N₂O
• Severe head trauma, Sevoflurane preferred
Thermoregulation

- Heat Loss
  - Large BSA:weight ratio
  - Less subcutaneous fat
  - Decreased ability to regulate core temperature
  - Exposure
Anesthesiologist’s Role

- Specific pediatric expertise in:
  - Airway management
  - Ventilation
  - Vascular access
  - Fluid therapy

- Facilitate rapid transition to the OR
- Consult for ER sedation
Summary

- Pediatric trauma accounts for 25% of all trauma
- ATLS is a continuum
- Careful evaluation, frequent reassessment, with good teamwork can contribute to a positive outcome
- Be aware of potential abuse
- Watch your toddler!