Pediatric Trauma: How is it Different?

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Objectives:
- Summarize overview of ATLS principles for pediatrics
- Describe current trends for the care of the injured pediatric patient
- Identify resources for participants to care for the pediatric trauma population
Pediatric Trauma
How is it Different?

Lisa Runyon, CPNP
Primary Children’s Hospital
Acute Care Surgery/Trauma Service
Objectives

Review significant differences – Anatomical, Radiologic, Lab value, and Psych-Social differences

Summarize overview of ATLS principles for pediatrics

Describe current trends for the care of the injured pediatric patient

Identify resources for participants to care for the pediatric trauma population
Anatomical Differences

*Vital signs and GCS*

*Skull and Facial bone development*
  - Dental development

*Brain development*
  - Anatomy
  - Cognitive development
    - Decision making and cognitive recovery

*Spinal injury patterns*

*Abdominal Injury patterns*

*Extremity injuries*
  - Fractures vs. strains/sprains (overuse)
## Infant Milestones

<table>
<thead>
<tr>
<th>Age</th>
<th>Typical Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 month</td>
<td>Lifts head when supine. Responds to sounds. Stares at faces</td>
</tr>
<tr>
<td>2 months</td>
<td>Vocalizes. Follows objects across fields of vision. Holds head up for short periods.</td>
</tr>
<tr>
<td>3 months</td>
<td>Recognizes familiar faces. Holds head steady. Visually tracks moving objects.</td>
</tr>
<tr>
<td>4 months</td>
<td>Smiles. Laughs. Can bear weight on legs. Vocalizes when spoken to.</td>
</tr>
<tr>
<td>5 months</td>
<td>Distinguishes between bold colors. Plays with hands and feet.</td>
</tr>
<tr>
<td>6 months</td>
<td>Turns toward sounds and voices. Imitates sounds. Rolls over in both directions.</td>
</tr>
<tr>
<td>7 months</td>
<td>Sits without support. Drags objects towards self.</td>
</tr>
<tr>
<td>8 months</td>
<td>Says “Mama” or “Dada” to parents. Passes objects from hand to hand.</td>
</tr>
<tr>
<td>9 months</td>
<td>Stands while holding onto things.</td>
</tr>
<tr>
<td>10 months</td>
<td>Picks things up with “pincer” grasp. Crawls well with belly off the ground.</td>
</tr>
<tr>
<td>11 months</td>
<td>Plays games (patty cake &amp; peek-a-boo). Stands without support for a few seconds.</td>
</tr>
<tr>
<td>12 months</td>
<td>Imitates the actions of others. Indicates wants with gestures.</td>
</tr>
</tbody>
</table>
## Glasgow Coma Scale

<table>
<thead>
<tr>
<th>Activity</th>
<th>Score</th>
<th>Infant Response</th>
<th>Adult Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eye Opening</strong></td>
<td>4</td>
<td>Spontaneous</td>
<td>Spontaneous</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>To speech or sound</td>
<td>To speech</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>To painful stimuli</td>
<td>To pain</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>Verbal</strong></td>
<td>5</td>
<td>Appropriate words, sounds or social smile</td>
<td>Oriented to person, place, month and year</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Cries but consolable</td>
<td>Confused</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Persistently irritable</td>
<td>Inappropriate words</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Restless/agitated</td>
<td>Incomprehensible</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>Motor</strong></td>
<td>6</td>
<td>Spontaneous movement</td>
<td>Obeys commands</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Localizes pain</td>
<td>Localizes pain</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Withdraws to pain</td>
<td>Withdraws to pain</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Abnormal extremity flexion</td>
<td>Abnormal extremity flexion</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Abnormal extremity extension</td>
<td>Abnormal extremity extension</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
First several years: High skull to face ratio
Cranium, orbits, forehead prominent
Lack of paranasal sinus and dental development
Frontal and upper orbital regions exposed to trauma
Lower face relatively protected
Use of Cuffed Endotracheal Tubes

- Previous concerns about cuffed ETT causing tracheal necrosis are no longer relevant due to improvements in the design of the cuffs.
- Ideally, cuff pressure should be measured as soon as it is feasible
- 30 mmHg is considered safe
ATLS Principles for Pediatrics
- Airway and C-spine

Proper positioning with ½-1 inch of padding to accommodate the large occiput (up to age 8 years) and provide proper airway alignment.

- Also prevents pseudosubluxation of the cervical spine
- 40% of children < 7 years old show anterior displacement of C2-C3

The practice of inserting the oral airway backward and rotating it 180° degrees is not recommended for children, as trauma with resultant hemorrhage in to soft tissue structures of the oropharynx may occur.
Current Trends in Pediatric Trauma Care

Airway

Kids: Not Just Little Adults
Pediatric Airway Anatomy

- Larynx higher
  - C4: cricoid ring at birth
  - C5: Age 6
  - C6: Adult

- Narrowest part of the airway: cricoid ring in kids vs glottis in adults

- Vocal cords not at 90° angle to trachea

- Floppy omega shaped epiglottis
Aligning Axes

**ADULT**

1. **Pharyngeal axis (PA)**
2. **Oral axis (OA)**
3. **Laryngeal axis (LA)**

**CHILD**

1. **Oral axis**
2. **Pharyngeal axis**
3. **Tracheal axis**
Anatomic Factors Associated with a Difficult Airway

- Small mouth, limited mouth opening or short interincisor distance
- Short neck, limited neck mobility
- Mandibular hypoplasia
- Poor mandibular translation
- Obesity
- Mucopolysacharridoses
- High arched narrow palate

Wheeler Pediatric Critical Care Medicine 2007
Pediatric vs. Adult Physiology

- Lower functional residual capacity (FRC), with closing volume closer to FRC >> atelectasis

- Higher CO₂ production
  - 100-150ml/kg/min vs adults 60ml/kg/min

- Higher metabolic rate (O₂ consumption)
  - 7-9ml/kg/min compared to 3ml/kg/min adults

- Tidal volume (ml/kg) is relatively consistent with adults, so kids need a higher RR to achieve a higher minute ventilation to eliminate CO₂
Now You Know...

- Lots of differences exist between kids’ and adults’ airways. Remember the shoulder roll to help align axes.

- Several common congenital syndromes are associated with difficult pediatric airways. Knowing is half the battle.

- LMAs are a great rescue airway tool and can be used/modified for intubation in the can’t intubate/can’t ventilate situation.
ATLS Principles for Pediatrics

Head Trauma

- Blood loss from scalp wounds can be more significant in pediatrics
- Children are particularly susceptible to the effects of secondary brain injury that may be produced by hypovolemia, with attendant reductions in cerebral perfusion, hypoxia, seizures, or hyperthermia.
- The effect of the combination of hypovolemia and hypoxia on the injured brain is devastating BUT hypotension from hypovolemia is the worst single factor.
Head

Head is proportionately larger mass

Softer, thinner skull

Prominent occipital region

Craniofacial disproportion

Bridging veins easily torn

Large subarachnoid space
Current Trends

Head Trauma

• PECARN Study (Pediatric Emergency Care Applied Research Network)

The PECARN Head Injury Study

Goal: to derive a clinical decision rule to accurately identify children at near zero risk of clinically important traumatic brain injury after blunt trauma with high accuracy and wide generalizability
Minor Head Trauma in Children

- ~97% of children with BHT evaluated in EDs, and 75% of those evaluated with CT, have “minor” BHT (GCS 14-15)
- ~50% of those with TBI on CT present with GCS 14-15
- Among children with GCS 15 after head trauma, prevalence of TBI is 0-7%, surgical intervention in <1%

Dietrich 1993; Schunk 1996; Quayle 1997; Greenes 1999; Palchak 2003; Oman 2006; Kuppermann 2009; Osmond 2010
PECARN (enrolled 42,414)

Isolated LOC

6,132 with any LOC

576 (9.4%) w/ isolated LOC

326 (56.6%) CT performed

3 TBI on CT (0.9%, 95% CI 0.2, 2.7)

1 Clinically-important TBI (ciTBI) (0.2%, 95% CI 0, 1.0)

Lee/Kuppermann 2014
Blunt Head Trauma in Children

historical factors

Other possible predictors: vomiting and headache

- Frequently seen with TBI, however, frequently not “statistically significant” in (small) studies...
- In multivariate analyses, patients with TBI “missed” by the models frequently have vomiting and/or headache
- Recent large studies using vomiting/headache as CT criteria missed no “important” TBIs (Palchak 2003, Haydel 2003, Oman 2006, Dunning 2006, Kuppermann 2009)
- Isolated vomiting and isolated headache and risk of cTBI:
  - Isolated vomiting – 2/815 (0.2%; 95% CI 0, 0.9%)
  - Isolated headache – 0/2,462 (0%; 95% CI 0, 0.1%)

Dayan/Kuppermann 2014
Blunt Head Trauma in Children

**physical examination**

**Decreased level of consciousness**

<table>
<thead>
<tr>
<th>Eye Opening</th>
<th>Verbal Response</th>
<th>Motor Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spontaneous</td>
<td>Oriented (coos/smiles) 5</td>
<td>Follows (spontaneous) 6</td>
</tr>
<tr>
<td>To voice</td>
<td>Confused (fussy/cries) 4</td>
<td>Localizes pain 5</td>
</tr>
<tr>
<td>To pain</td>
<td>Inappropriate (screams) 3</td>
<td>Withdraws to pain 4</td>
</tr>
<tr>
<td>None</td>
<td>Incomprehens. (grunts) 2</td>
<td>Decorticate posture 3</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>Decerebrate posture 2</td>
</tr>
</tbody>
</table>

- Definition of minor BHT varies (GCS $\geq 13$? $\geq 14$? $15$?)
Blunt Head Trauma in Children

physical examination

Decreased level of consciousness

- Risk of TBI if GCS = 15 is ~2-3%
- Risk of TBI if GCS = 14 is ~7-8%
- Risk of TBI if GCS = 13 is ~25%
- GCS an important predictor in multivariable analyses

Recommendations for children younger than 2

**A**

GCS=14 or other signs of altered mental status†, or palpable skull fracture

- Yes
  - 13.9% of population
  - 4.4% risk of cTBI
  - CT recommended

- No
  - Occipital or parietal or temporal scalp haematoma, or history of LOC ≥ 5 s, or severe mechanism of injury‡, or not acting normally per parent
    - Yes
      - 32.9% of population
      - 0.9% risk of cTBI
      - Observation versus CT on the basis of other clinical factors including:
        - Physician experience
        - Multiple versus isolated§ findings
        - Worsening symptoms or signs after emergency department observation
        - Age < 3 months
        - Parental preference
      - CT not recommended
    - No
      - 53.2% of population
      - < 0.02% risk of cTBI
      - CT not recommended

**The Rule**
Recommendations for children 2 years and older

- GCS-14 or other signs of altered mental status†, or signs of basilar skull fracture:
  - Yes: CT recommended (14.0% of population, 4.3% risk of ciTBI)
  - No: History of LOC, or history of vomiting, or severe mechanism of injury‡, or severe headache:
    - Yes: Observation versus CT on the basis of other clinical factors including:
      - Physician experience
      - Multiple versus isolated§ findings
      - Worsening symptoms or signs after emergency department observation
      - Parental preference
    - No: CT not recommended (57.2% of population, <0.05% risk of ciTBI)

†The Rule
Circulating Blood Volume

*Infant 80 ml/kg*

- Two month old
  - 5kg x 80 ml/kg = **400 ml**
- One year old
  - 10kg x 80 ml/kg = **800 ml**

*Can of soda = 12 ounces*

- 360 cc
ATLS Principles for Pediatrics

**Fluid Resuscitation**

- Failure to improve hemodynamic abnormalities following the first bolus of resuscitation fluid raises the suspicion of continuing hemorrhage, prompts the need for administration of a second and perhaps a third 20 ml/kg bolus of isotonic crystalloid fluid, and requires the prompt involvement of a surgeon.

- When starting an additional bolus of isotonic crystalloid fluid OR AT ANY POINT in the volume resuscitation the child’s condition deteriorates, consideration must be given to the early use of 10 ml/kg of type specific OR O-negative warmed pRBCs.
ATLS Principles for Pediatrics

Shock

Blood loss associated with long bone and pelvic fractures is proportionately less in children than adults.

Blood loss related to an isolated closed femur fracture treated appropriately is associated with an average fall in Hct of 4% points.

Hemodynamic instability in the presence of an isolated femur fracture should prompt evaluation for other sources of blood loss (most likely abdomen).
Pediatric Spine Anatomical Differences

**Entire spine is C shaped at infancy**

**Spinal Curves develop due to gravitational stresses**

**Natural increasing lumbar lordosis and thoracic kyphosis during adolescent growth spurt**

**Muscle, ligament and fascia all can lag behind bone growth during early puberty**

- May cause tight back extensors and hip flexors
Vertebral Anatomy

Two cylindrical pedicles emerge from the vertebral arch.

A pair of flattened laminae complete the arch posteriorly.
Pediatric Spine Anatomical Differences

*Spine has less protection*

*Greater growth potential*

*Remodeling ability*

*Malleability*

- ability to sustain considerable energy before failure
- Concern for subluxation injuries (no fx but neurological exam deficits)
- Spinal cord is less elastic than young surrounding ligamentous tissue
Pediatric Spine Anatomical Differences

**Hypermobile**
- Physiologic range of motion is considerably greater due to differences in ligamentous restraints and orientation to the facet joint

**Weak growth plates**
- **THE WEAKEST LINK**, physeal injuries frequently accompany disc protrusions in children

**Changing spinal contours**

**No degenerative changes and the canal is usually larger**
ATLS Principles for Pediatrics  
C-spine

Skeletal growth centers can resemble fractures.

Basilar odontoid synchondrosis appears as a radiolucent area at the base of the dens ((especially in < 5 years of age))

Apical odontoid epiphysis appear as separations on the odontoid view (usually seen between 5-11 yrs)

The growth center of the spinous process can resemble fractures of the tip of the spinous process.
Bone Ossification

Development of the ring finger, row by row. The image top-left is from a baby, the image at the lower-right is from a nineteen year old. In the fifth image, the epiphysis appears, which becomes wider and in the final images fuses with the metaphysis. These images are taken from the Greulich and Pyle atlas.
Odontoid Image

Obtained in child age 5 yrs and older

Dens of axis (C2)

Lateral masses of atlas (C1)

Should include the entire odontoid process and the Right and Left C1, C2 articulations
Pediatric Injury Patterns

*Cervical ligament injury*
- Facets more horizontally aligned
- Cervical vertebrae wedge shaped
- Increased elasticity in cervical ligaments

*Seat belt complex*
- Lumbar fracture
- Bowel perforation, solid organ injury, pancreatic injury
- Abdominal contusion
Seatbelt sign
Small bowel perforation
Conclusion

- **Who fails:** Not many. Age and gender don’t matter, pancreas and grade do.
- **What predicts failure:** Bicycles, hypotension, non-responders, high ISS, low GCS
- **When do they fail:** Earlier than adults, typically 2 hours
- **Where?** Non-pediatric trauma centers, centers with non-pediatric surgeons
- **Why?** Continued bleeding, peritonitis, pancreatic injury, bowel injury; not delayed bleeding. Lack of a protocol
Bone Growth
Growing Bone

**Positives**

- Remodeling potential is extensive
- Accepts more angular deformity than adults
  - Especially in metaphysis (45-60 degrees)
- Healing is rapid
- Non-union is rare

**Negatives**

- Overgrowth is common, increased blood supply leads to overgrowth
- Progressive deformity can and does occur with physis injury
  - Angular deformity and shortening
  - Growth arrest
    - Femur 36%
    - Distal Tibia 26%
    - Proximal Tibia 20%
Ligamentous injuries

Ligaments in children have greater mechanical strength than epiphysis, physis or perichondrial ring (cuff-like extension and thickening of the periosteum of the growth plate).

Epiphyseal separation requires less force than ligament tear, so true sprains are unusual in children prior to adolescence.

When x-rays are normal think occult fracture (separation of unossified epiphysis) or Salter Harris I fracture without displacement.

If in doubt, immobilize and see in follow-up.
Other Common Pediatric Injuries

Medial Epicondylitis – Little Leaguer’s Elbow – repetitive stress on the apophysis of the medial humeral epicondyle ossification center

Osgood-Schlatter “disease” – microfracture through the apophyseal cartilage

Wrist pain in gymnasts – growth plate abnormalities (per MRI) in the skeletally immature patients

Soft tissue injuries in the forearm – return to sports only after pain is absent and joint motion is normal.
Lab Values

Physiologic Nader and Hct/Hgb values
Circulating Blood volume
## Normal Hemoglobin/Hematocrit Levels

<table>
<thead>
<tr>
<th>Age</th>
<th>HGB Mean</th>
<th>HGB Range</th>
<th>HCT Mean</th>
<th>HCT Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cord Blood</td>
<td>16.8</td>
<td>13.7-20.1</td>
<td>55</td>
<td>45-65</td>
</tr>
<tr>
<td>2 weeks</td>
<td>16.5</td>
<td>13-20</td>
<td>50</td>
<td>42-66</td>
</tr>
<tr>
<td>3 months</td>
<td>12</td>
<td>9.5-14.5</td>
<td>36</td>
<td>31-41</td>
</tr>
<tr>
<td>6 months – 6 years</td>
<td>12</td>
<td>10.5-14</td>
<td>37</td>
<td>33-42</td>
</tr>
<tr>
<td>7-12 years</td>
<td>13</td>
<td>11-16</td>
<td>38</td>
<td>34-40</td>
</tr>
<tr>
<td>Adult Female</td>
<td>14</td>
<td>12-16</td>
<td>42</td>
<td>37-47</td>
</tr>
<tr>
<td>Adult Male</td>
<td>16</td>
<td>14-18</td>
<td>47</td>
<td>42-52</td>
</tr>
</tbody>
</table>
Normal values for hematocrit and hemoglobin during the first year of life in healthy term infants

![Graph showing normal values for hematocrit and hemoglobin during the first year of life in healthy term infants.](image)

Data from:
You have more than one trauma patient

- Parents/Siblings/Friends/Care Providers

Child’s perception/understanding of the trauma and injuries

Parent’s perception/understanding of the trauma and injuries

School issues

Recovery process

- Not just returning to baseline but actually continuing to heal, cognitively grow and recover
- PTSD in pediatric Trauma
ATLS Principles for Pediatrics

Diagnostic Adjuncts

- CT scan – When CT evaluation is necessary, radiation must be kept As Low As Reasonably Achievable (ALARA).
- In order to achieve lowest doses possible, perform CT scans only:
  - When medically necessary
  - Scan only when results will change management
  - Scan only areas of interest
  - Use the lowest radiation dose possible
Trends in Pediatric Radiology

Ionizing Radiation

<table>
<thead>
<tr>
<th>TABLE 1 Estimated Medical Radiation Doses for a 5-Year Old Child</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedure</td>
</tr>
<tr>
<td>3-view ankle</td>
</tr>
<tr>
<td>2-view chest</td>
</tr>
<tr>
<td>Tx 99m radionuclide gastric emptying</td>
</tr>
<tr>
<td>Natural background (Denver)</td>
</tr>
<tr>
<td>Head CT</td>
</tr>
<tr>
<td>Chest CT</td>
</tr>
<tr>
<td>Abdomen CT</td>
</tr>
</tbody>
</table>

- Measurements of radiation exposure
  - Gray (Gy)—absorption of 1 joule radiation energy by 1 kg matter
  - Sievert (Sv)—accounts for the biologic effects of radiation
- Children more sensitive to radiation effects than adults
  - Growing organs
  - Long latent period of oncogenic effect (varies with type of cancer)
  - For CT, any given exposure results in a dose that is relatively higher since kid’s have a smaller cross-sectional area

Brody, Pediatrics, 2007
Rice, JPS, 2007
AAP Summary Statement

“There is wide agreement that the benefits of an indicated CT scan far outweigh the risks. It is the responsibility of...health care professionals...to ensure that each CT scan is indicated. It is the responsibility of radiology personnel to insure that radiation risk is minimized.”

Section on Radiology, 2007
Pediatric Radiology

PTSF Pediatric Committee Imaging Statement

- Avoid protocolized scanning (pan scans)
- Use dose minimization strategies
- Defer imaging if a child is to be transferred, unless the accepting institution requests it
- Pediatric trauma centers should avoid rescanning children unless absolutely necessary
Pediatric Radiology

Reduction of radiation exposure in pediatric patients with trauma: cephalic stabilization improves adequacy of lateral cervical spine radiographs
Afif N. Kulaylat a, Joshua G. Tice b, Moran Levin t, Allen R. Kunselman c, Sosamma T. Methratta d, Robert E. Cilley e, □

Downward traction on the arms and manual stabilization of the head significantly increases the ability to obtain adequate lateral c-spine images
Pediatric Radiology

Bottom line...

- Not all kids require imaging to clear their necks
- Plain films are a useful screening tool
- Mechanism of injury and altered GCS are important elements for decision making
Local Pediatric Trauma Care Resources

*Primary Children’s Hospital – Acute Care Surgery and Trauma Team office – 800-903-7262*
  - Program Medical Director – Eric Scaife, MD and Robert Bolte, MD
  - Program Manager – Kris Hansen, RN

*Car Seat Hotline – 801-662-CARS*

*ATLS Courses – Utah Medical Association office*

*Pediatric Concussion Clinic*
  - Primary Children’s Hospital (< 5 years Old) 801-662-4949
  - University of Utah Clinic (>5 years old) 801-581-9087

*Western Pediatric Trauma Conference – Deer Valley Resort, July 2015*
Questions?