Imaging Guidelines in Pediatric Trauma

Jon Ryckman, MD, FACS
Medical Director, Pediatric Trauma
Sanford Children’s Hospital
I have no financial conflicts of interest to disclose
Pediatric Trauma Considerations

• Mortality from trauma surpasses deaths from all other illnesses combined

• Typical mechanisms of injury based on age and stage of development

• Multisystem injury is the rule rather than the exception
Pediatric Trauma
Considerations

• Ionizing radiation does pose a real risk of malignancy in children
Objectives

• Identify the risk of ionizing radiation in children
• Discuss the utility of advanced imaging in pediatric trauma
• Propose guidelines for imaging in pediatric trauma patients
• Identify resources for imaging guidelines
Trauma in Children
Leading cause of death and disability
Pediatric Trauma Data

• On average, 9000-13000 children die each year from unintentional injury

• Death rates highest from motor vehicle crashes, particularly in the upper Plains

• Native American death rate highest among all races

• Over 9 million children present to ER each year for injury

• More than 16% of admissions for unintentional injury result in permanent disability
Impact of Pediatric Trauma

1 Child
Every hour, one child dies from an injury.

1 in 5
About 1 in 5 child deaths is due to injury.

4 Seconds
Every 4 seconds, a child is treated for an injury in an emergency department.

For every 1 child that dies there are...
- 25 hospitalizations
- 925 treated in ER
- Many more treated in doctors’ offices

INJURY
The #1 killer of children in the US

In 2005, injuries that resulted in death, hospitalization or an ER visit cost nearly $11.5 billion in medical expenses.

National Health Interview Survey, 2009 data release, CDC, National Center for Health Statistics.

Child (0-19 years) injury death rates vary by state

In 2009, more than 5,700 children’s lives would have been saved if the lowest state death rate was achieved nationally.

Child (0-19 years) injury death rates vary by state

In 2009, more than 5,700 children’s lives would have been saved if the lowest state death rate was achieved nationally.

Rate per 100,000 population
- 4.0 – 10.9
- 11.0 – 17.9
- 18.0 – 25.1
- Not applicable

US rate is 11.0

Injury Prevention

**Booster Seat**

Age 5 up until seat belts fit properly.

Once children outgrow their forward-facing seat, they should be buckled in a booster seat until seat belts fit properly. The recommended height for proper seat belt fit is 57 inches tall.
Mechanism of Injury

- Automobile occupant
- Pedestrian struck
- Bicycle
- Fall from height
- ATV accidents
- Non-Accidental trauma
Mechanism of Injury

- Pedestrian vs. Auto
  - Slow speed
    - Soft tissue contusions
    - Lower extremity fractures
  - Fast speed
    - Polytrauma
    - Head, chest, abdomen, lower extremity fractures
Mechanism of Injury

• Automobile Accident
  • Unrestrained
    • Multiple organ systems
    • Head, neck, abdomen
  • Restrained
    • Seatbelt complex
Mechanism of Injury

- Bicycle
- Without Helmet
  - Head, face, spine, upper extremity fractures
- Handle bar
  - Liver, spleen, pancreas, duodenum
Mechanism of Injury

- Fall from Height
  - Low level
    - Soft tissue contusions, upper extremity fracture
  - High level
    - Polytrauma
    - Head, face, spine, abdomen, long-bone fracture
Assessment of the Pediatric Trauma Patient
ABC’s

• Airway
• Breathing
• Circulation
• Disability
• Exposure/Environment
Adjuncts

- Lab tests
  - “Trauma panel” may be excessive
  - Needles hurt!
- Xrays
  - CXR
  - Pelvis
Additional Imaging

- Based on clinical suspicion
- FAST
- CT scans
- C-spine series
- Extremity x-rays
The Trouble with Radiation

• CT scanning carries a necessary exposure to ionizing radiation
  • Head CT = 200 plain films
  • Chest CT = 150 chest x-rays
  • Abdominal CT = 250 flat plates
  • Full body CT = same dose of radiation as received by survivors 1.5 miles away from Hiroshima atomic explosion
Is there really a risk?
Risk of Malignancy

- Risk of developing fatal malignancy secondary to CT scan is 1:1000
- Risk inversely proportional to age
- Risk may be site specific as well
  - Neck CT exposes thyroid gland, lymph nodes, salivary glands to high dose of radiation
Risk of Malignancy

• 2001 Study on risk of FATAL malignancy due to CT scan
• 0.18% Abdominal CT
• 0.07% Head CT
• 600,000 CTs performed yearly, 500 of those patients may die from the CT
Risk of Malignancy

- Multiple studies on risk from CT scan
- 3x Increased risk of leukemia and brain tumors (2012)
- Highest risk in younger patients and girls, Abd/Pelvis and Spine CT (2013)
  - In girls, one solid cancer may result:
    - 300-390 Abd/Pelvis
    - 330-480 Chest
    - 270-800 Spine
What do we do?
Imaging Guidelines

- ATLS: Do not delay transfer to center of definitive care by performing imaging
- 66% of patients meeting transfer criteria receive scans
- At least 25% of those scans are repeated
Is physical exam enough?

• Seat belt sign
• Abdominal bruising
• Abdominal wound
• Abdominal tenderness
FAST

- Data concerning FAST exam in children not conclusive
- When combined with physical exam, may be equivalent to CT for predicting intra-abdominal injury
- User-dependent
Blunt Abdominal Trauma

- Failure of non-operative therapy for solid organ injury in children is 3%
- Those that fail, usually fail within the first 6 hours after injury
Abdominal CT scans

- Not always necessary
- Should be done at definitive care center
- **Must** be done with IV contrast
Traumatic Brain Injury

- Greater than 50% of all deaths resulting from blunt trauma are due to brain injury
Brain Injury

• Goal of therapy is to prevent secondary injury
  • Ischemia
  • Hypoxemia
  • Hypotension
  • Cerebral edema
  • Increased intracranial pressure
Head Injury

- Over 85% of brain injuries are mild and not life threatening.
- Less than 50% of patients with TBI on head CT present with GCS 14-15.
- Among children presenting with GCS 15 after blunt head injury, prevalence of TBI is 0-7%, surgical intervention in <1%.
- Isolated loss of consciousness has almost no risk of significant traumatic brain injury.
Head Injury

- PECARN criteria
Imaging for Blunt Head Injury

**Figure 3**: Suggested CT algorithm for children younger than 2 years (A) and for those aged 2 years and older (B) with GCS scores of 14–15 after head trauma.
Child Abuse

• Highest morbidity and mortality for head injury seen in setting of abuse
  • 40% mortality
  • Nonfatal outcomes worse for abused child than for similar injuries in non-abused
Risk of C-spine injuries

• Very rare: 1-3% of all pediatric trauma patients

• Only half with vertebral injuries have neurological deficits

• SCIWORA may occur in 2/3 with spinal injury
Cervical Spine Imaging

• Altered Mental Status
• Focal deficits
• Neck pain
• Torticollis
• Substantial torso injury
• Predisposing condition (connective tissue disorders, etc)
• High risk MVC (rollover, ejection, etc.)
• Diving

• Absence of any of these variables = less than 2% chance of injury

• Application of this rule could potentially reduce ionizing radiation and/or immobilization by 25%
**PEDIATRIC TRAUMA IMAGING GUIDELINES**

**CONSIDER HEAD CT**

**AGE LESS THAN 2:**
- Altered mental status
- Scalp hematoma other than forehead
- Loss of consciousness greater than 5 seconds
- Severe injury mechanism
- Palpable skull fracture
- Not acting normal according to family

**AGE 2 OR OLDER:**
- Altered mental status
- Loss of consciousness
- Vomiting
- Severe injury mechanism
- Signs of basilar skull fracture
- Severe headache

**CHEST CT/ANGIOGRAM IS INDICATED:**

**AGE LESS THAN 13:**
- Abnormal CXR in blunt trauma (widened mediastinum)

**AGE 13 OR OLDER:**
- CT as clinically indicated

In penetrating trauma if concern for major vascular injury, then consider chest CT/CTA.

**IF UNABLE TO CLINICALLY CLEAR THE CERVICAL SPINE CONSIDER:**

**AGE LESS THAN 7:**
- AP/lateral X-rays (Odomos and if cooperative)
- If obtaining a head CT, a limited CT of C1/C2 is appropriate.

**AGE 7 OR OLDER:**
- CT c-spine

If the patient meets Modified Memphis Criteria for obtaining a CTA of the neck, then reconstitution of the cervical spine is appropriate; however, still cannot clear the spine based on CT alone.

**MODIFIED MEMPHIS CRITERIA FOR BLUNT CEREBROVASCULAR INJURY**

The modified Memphis criteria are a set of screening criteria for blunt cerebrovascular injury (BCVI) in trauma. The presence of one or more of these criteria makes necessary a complementary CTA or DSA study to exclude a BCVI.

The screening protocol criteria for BCVI are:
- base of skull fracture with involvement of the carotid canal
- base of skull fracture with involvement of petrous temporal bone
- cervical spine fracture
- neurological exam findings not explained by neuroimaging
- Horner syndrome
- Le Fort II or III fracture pattern
- neck soft tissue injury (e.g., seatbelt sign, hanging, hematoma)

**ABDOMEN/PELVIS CT WITH CONTRAST IS INDICATED:**

- Positive FAST
- Abdominal wall bruising/seat belt sign
- GCS<14
- Abdominal tenderness
- Thoracic wall trauma
- Complaints of abdominal pain
- Decreased breath sounds
- Vomiting

---

**PEDIATRIC TRAUMA SOCIETY GUIDELINES**

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal wall or lower chest bruising</td>
<td>CT scan</td>
</tr>
<tr>
<td>Abdominal pain or tenderness</td>
<td>1 Positive ultrasound</td>
</tr>
<tr>
<td>Low blood pressure = not shock</td>
<td>2 Increase AST/ALT &gt; 200/125</td>
</tr>
<tr>
<td></td>
<td>3 Hematuria &gt; SRBC/hpf</td>
</tr>
<tr>
<td></td>
<td>Observe</td>
</tr>
</tbody>
</table>

---

*Sanford Children’s*
**CONSIDER HEAD CT**

**AGE LESS THAN 2:**
- Altered mental status
- Scalp hematoma other than frontal
- Loss of consciousness greater than 5 seconds
- Severe injury mechanism
- Palpable skull fracture
- Not acting normal according to family

**AGE 2 OR OLDER:**
- Altered mental status
- Loss of consciousness
- Vomiting
- Severe injury mechanism
- Signs of basilar skull fracture
- Severe headache

**IF UNABLE TO CLINICALLY CLEAR THE CERVICAL SPINE CONSIDER:**

**AGE LESS THAN 7:**
- AP/lateral X-rays (Occiput and/or cooperative)
- Ultrasound head/CT if indicated

**AGE 7 OR OLDER:**
- CT c-spine
- Ultrasound head/CT if indicated
IF UNABLE TO CLINICALLY CLEAR THE CERVICAL SPINE CONSIDER:

AGE LESS THAN 7:
- Altered mental status
- Scalp hematoma (frontal)
- Loss of consciousness greater than 5 seconds
- Severe injury to the head
- Palpable skull fracture
- Not acting normal to family

AGE 7 OR OLDER:
- CT c-spine

If obtaining a head CT, a limited CT of C1C2 is appropriate.

If the patient meets Modified Memphis Criteria for obtaining a CTA of the neck, then reconstruction of the cervical spine is appropriate; however, still cannot clear the spine based on CT alone.

MODIFIED MEMPHIS CRITERIA FOR BLUNT CEREBROVASCULAR INJURY

The modified Memphis criteria are a set of screening criteria for blunt cerebrovascular injury (BCVI) in trauma. The presence of one or more of these criteria makes necessary a complementary CTA or DSA study to exclude a BCVI.

The screening protocol criteria for BCVI are:
- Base of skull fracture with involvement of the carotid canal
- Base of skull fracture with involvement of petrous temporal bone
- Cervical spine fracture
- Neurological exam findings not explained by neuroimaging
- Horner syndrome
- Le Fort II or III fracture pattern
- Neck soft tissue injury (e.g. seatbelt sign, hanging, hematoma)
**CHEST CT/ANGIOGRAM IS INDICATED:**

**AGE LESS THAN 13:**
- Abnormal CXR in blunt trauma (widened mediastinum)

In penetrating trauma if concern for major vascular injury, then consider chest CT/CTA.

**AGE 13 OR OLDER:**
- CT as clinically indicated

**IF UNABLE TO CLINICALLY CLEAR THE CERVICAL SPINE CONSIDER:**

**AGE LESS THAN 7:**
- AP/Oblique X-rays (Ovoid ossicles indicative of dysostosis cleidocranialis)
- If obtaining a head CT, a limited CT of C2 is appropriate.

**AGE 7 OR OLDER:**
- CT c-spine

If the patient meets Modified Memphis Criteria for obtaining a CTA of the neck, then reconstruction of the cervical spine is recommended. However, this cannot be determined based on CT alone.
ABDOMEN/PELVIS CT WITH CONTRAST IS INDICATED:

- Positive FAST
- Abdominal wall bruising/seat belt sign
- GCS<14
- Abdominal tenderness
- Thoracic wall trauma
- Complaints of abdominal pain
- Decreased breath sounds
- Vomiting
**PEDIATRIC TRAUMA IMAGING GUIDELINES**

**CONSIDER HEAD CT**
- **AGE LESS THAN 7**
  - Altered mental status

- **AGE 2 OR OLDER**
  - Altered mental status

**IF UNABLE TO CLINICALLY CLEAR THE CERVICAL SPINE CONSIDER:**
- **AGE LESS THAN 7**
  - AP/Lateral X-rays (Occiput to T1 if cooperative)
  - If obtaining a head CT, a limited CT of C1-C2 is appropriate.

- **AGE 7 OR OLDER**
  - CT c-spine

**PEDIATRIC TRAUMA SOCIETY GUIDELINES**

- Abdominal wall or lower chest bruising
- Abdominal pain or tenderness
- Low blood pressure - not shock

**Yes**

**CT scan**
- **Yes**
  - Positive ultrasound
  - Increase AST/ALT > 200/125
  - Hematuria > 5RBC/hpf

**No**

**Observe**

**1 Positive ultrasound**

**2 Increase AST/ALT > 200/125**

**3 Hematuria > 5RBC/hpf**
Conclusion

• Pediatric Trauma is a leading cause of morbidity and mortality

• Rapid, appropriate interventions are life-saving and can prevent morbidity

• Advanced imaging in pediatric trauma is not without risk and should only be used when the benefit outweighs the risk
• Imaging should never delay transfer to definitive care

• If advanced imaging is considered, please consult with definitive care center
• Head CT should be done WITHOUT contrast

• Chest or abdominal CT scans must be done WITH contrast
Our children are our only hope for the future, but we are their only hope for their present and their future.
Any Questions?