Pediatric Trauma for the Adult Trauma Center: The New and/or Different in Pediatric Trauma

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Johns Hopkins Children’s Center
Pediatric Emergency Medicine
By the end of this lecture, participants will be able to...

• Describe physiologic differences relevant to pediatric trauma
• Describe common pediatric traumatic injury patterns
• Plan resuscitation care for pediatric trauma patients
• Anticipate needs for definitive care of pediatric injuries
• Support children and families in the trauma bay
Trauma is the single most important disease of children
### Epidemiology

#### 10 Leading Causes of Death by Age Group, United States – 2016

<table>
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<th>Rank</th>
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Epidemiology

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Data Source: NEISS All Injury Program operated by the Consumer Product Safety Commission (CPSC).
Produced by: National Center for Injury Prevention and Control, CDC using WISQARS™.
# 10 Leading Causes of Injury Deaths by Age Group Highlighting Unintentional Injury Deaths, United States – 2016

<table>
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<tr>
<th>Rank</th>
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<th>1-4</th>
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</tbody>
</table>

Data Source: National Center for Health Statistics (NCHS), National Vital Statistics System.
Produced by: National Center for Injury Prevention and Control, CDC using WISQARS™.
Children are not Little Adults
Children are Small
# Normal Pediatric Vital Signs

<table>
<thead>
<tr>
<th>Sign</th>
<th>0 – 2 years</th>
<th>3 – 5 years</th>
<th>6 – 12 years</th>
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<td>Heart Rate</td>
<td>&lt; 150 - 160</td>
<td>&lt; 140</td>
<td>&lt; 100 - 120</td>
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<tr>
<td>Blood Pressure</td>
<td>&gt; 60 - 70</td>
<td>&gt; 75</td>
<td>&gt; 80 - 90</td>
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<tr>
<td>Respiratory Rate</td>
<td>&lt; 40 - 60</td>
<td>&lt; 35</td>
<td>&lt; 30</td>
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</table>
Children have Better Reserves

**HEMODYNAMIC CHANGES WITH BLOOD LOSS IN CHILDREN**

- Heart Rate
- Blood Pressure
- Cardiac Output

Percent Blood Loss:
- 0
- 15
- 25
- 35
- 45
Children are Different Shapes
Hypothermia

• Evaporative heat loss
• Radiant heat loss
• Convective heat loss
• Conductive heat loss

• More body surface area (relative)
• More rapid respiration
“Unhappy Triad”

- Acidosis
- Hypothermia
- Coagulopathy
Children are Growing

• Skeletal Plasticity
  • Blunt trauma
  • Incomplete ossification
    • Cervical Spine
    • Growth plates in long bones
    • Open fontanelles / sutures
Children are Immature

- Kicking and screaming
- Refusal to talk to you
- Falling asleep after crying
Differences into Action in the Pediatric Trauma Bay

Adapting the Trauma ABCDE’s and F for kids
ABC's of Pediatric Trauma
Airway

- Hypoxia/hypoventilation is the most common cause of cardiac arrest in children

- Look, listen, and feel
  - Is the child crying/talking?

- Open airway

- Suction as needed
Airway

Flexion of the head + Loss of Consciousness = Airway obstruction
Airway

Indications for Intubation

• Respiratory Failure
• Inability to BVM
• Loss of Airway Reflexes
• GCS <9
• Decompensated Shock
Airway

How do you choose an ETT?
Breathing

• Assess breath sounds and chest rise and rate

• Give $O_2$

• Address thoracic injuries
  • Tension Pneumothorax
  • Open Pneumothorax (Sucking Chest Wound)
  • Flail Chest
  • Massive Hemothorax
  • Cardiac Tamponade

• Address gastric distension
Circulation

• Be wary of tachycardia

• Child’s Blood Volume approximately 80 cc/kg

• Shock occurs when > 25% volume loss

• 25% of 80 cc/kg = ????
## Disability

### Pediatric Glasgow Coma Score

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<tr>
<th>EYE OPENING</th>
<th>VERBAL</th>
<th>MOTOR</th>
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<tr>
<td>6</td>
<td></td>
<td>Spontaneous, purposeful</td>
</tr>
<tr>
<td>5</td>
<td>Interacts, smiles</td>
<td>Responds to touch</td>
</tr>
<tr>
<td>4</td>
<td>Spontaneous</td>
<td>Crying, inappropriate</td>
</tr>
<tr>
<td>3</td>
<td>With voice/touch</td>
<td>Moaning, inconsolable</td>
</tr>
<tr>
<td>2</td>
<td>With pain</td>
<td>Inconsolable, Agitated</td>
</tr>
<tr>
<td>1</td>
<td>No eye opening</td>
<td>No response</td>
</tr>
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</table>
Disability

AVPU

• A = Normal, alert
• V = Responds to Verbal Stimulation
• P = Responds to Painful Stimulation
• U = Unresponsive
Exposure

Fully expose for secondary survey

Keep covered to avoid hypothermia
Family Presence in Trauma Bay

• Family presence is a positive

  • Assign someone on the trauma team
    • get information FROM family
    • provide information TO family
Family Presence During Pediatric Trauma Team Activation: An Assessment of a Structured Program

Karen J. O'Connell, MD, Mirna M. Farah, MD, Philip Spandorfer, MD, MSCE, Joseph J. Zorc, MD

ABSTRACT

OBJECTIVE. When a child presents to a trauma center with a serious injury, family members are often excluded from the initial trauma team evaluation. The objective of this study was to evaluate the outcomes of a structured program of family presence during pediatric trauma team activations by measuring (1) the need for termination of family presence, (2) times to completion of key parts of the trauma evaluation, and (3) the opinions of staff surveyed immediately after conclusion of family presence.

METHODS. This was a cross-sectional study that combined prospectively obtained data and surveys from trauma team evaluations in which family presence occurred, with retrospective chart review of all trauma activations
ONE VOICE concepts

• One voice should be heard
• Need parental involvement
• Educate the patient before the procedure

• Validate the child with words
• Offer a non threatening position
• Individualize the game plan
• Choose appropriate distractions
• Eliminate unnecessary people
Child Friendly Interactions

• Allow parent to help you calm the child
• Observe as much “exam” as you can
• Minimize number of people speaking to the child
• Minimize number of people in the room
• Use vocabulary appropriate to child
Trauma is No Accident

Recognizable Patterns Exist and Injury Prevention Matters
Patterns of Injury

Infants... Injury in the home
• Falls
• Choking
• Strangulation
• Child abuse

Toddlers...Exploring, Curious
• Falls
• Poisoning
• Pedestrian Injuries

School Age...New Independence
• Pedestrian Injuries
• Bicycles

Adolescents...Risk Takers, Peer pressure
• MVC
• Sports related injury
Falls
Bicycle Injury Pattern
Child Struck Injury Pattern
Child Passenger in MVC Injury Pattern
Lap Belt Injury
Lap Belt Injury Pattern
Proper Safety Belt Fit/Booster Seat Use

What does good belt fit vs poor belt fit look like in a booster?

Shoulder belt is centered over collarbone, and not on neck or off the shoulder

Lap belt is low and flat on tops of thighs/hips, and not riding up on the belly
Head Injury

• #1 cause of death in peds trauma (80%)
  • But most (>90%) head injuries are “minor”
• falls > MVA > MPA > bicycle > assault
• Rarely require surgery: 0.4 -1.5%
# Head Injury: Anatomic differences

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<tr>
<th>Protective</th>
<th>Susceptible</th>
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<tr>
<td>• fontanelles</td>
<td>• big head $\rightarrow$ torque</td>
</tr>
<tr>
<td>• open sutures</td>
<td>• soft cranium $\rightarrow$ injury w/o fracture</td>
</tr>
<tr>
<td>• plasticity</td>
<td>• less myelin $\rightarrow$ more shearing forces</td>
</tr>
<tr>
<td></td>
<td>• prone to reactive hyperemia</td>
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PECARN Head CT Rule < 2 yr

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

- **Yes**
  - 13.9% of population
  - 4.4% risk of ciTBI
  - 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**
  - 32.6% of population
  - 0.9% risk of ciTBI
  - 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

- **No**
  - 53.5% of population
  - <0.02% risk of ciTBI
  - CT not recommended¶
PECARN Head CT Rule > 2y

B

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

Yes

14.0% of population
4.3% risk of ciTBI

CT recommended

No

History of LOC, or history of vomiting, or severe mechanism of injury‡, or severe headache

Yes

27.7% of population
0.9% risk of ciTBI

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

58.3% of population
<0.05% risk of ciTBI

CT not recommended¶
Pediatric C-Spine Injury

- Lower incidence than adults
- Higher fatality rate than adults
  - Younger children higher level
- Usually associated with multi-trauma
Pediatric C-spine

- Big Head
- Weak neck muscles
- Horizontal Facets
- Flat articular surfaces
- Anterior wedging
- Synchondroses
- Ligamentous laxity

Fig 2. The white line represents the more horizontal orientation of the facet joint in a young child (A) compared with an older adolescent and (B) as seen on the lateral radiograph.
C-Spine X-rays

• Pseudosubluxation
  • C2-C3 or C3-C4
  • Up to 50% overriding

• Swischuck’s Line

Fig 4. Lateral cervical spine radiograph shows pseudosubluxation of C2 on C3. The spinolaminar lines of Swischuck (second from left) and facet joints are intact.
SCIWORA

- Spinal Cord Injury Without Radiographic Abnormality
  - Paresthesias
  - Paralysis
- Previously up to half of cord injury in children
- Rate is declining with MRI but not going away
SCIWORA

• Plasticity of Spinal Column but NOT Cord
• Risk declines with age
• With MRI findings...
  • Complete transection – poor outcome
  • Hemorrhage – if minor, 40% recover
  • Edema – 75% recover
• 3 months in collar if MRI or SSEP abnl, or perisistant neuro deficit

Pang, Neurosurgery, 2004
Intra-abdominal Injury

- Thin abdominal wall
- Ribs and diaphragm are horizontal
- Compliant chest wall
- Less intra-abdominal fat
- Larger liver and spleen
- Kidneys, bladder sit high
Non-operative management of solid organ injury

• The spleen in children provides important cellular and humoral immunity
  • post-splenectomy sepsis
• At time of laparotomy, most splenic/liver lacerations not actively bleeding
Solid Organ Injury Protocol

Hemodynamically stable

- Grade I-II
  - Normal VS
    - Admit to ward
    - VS Q2 hrs x 4 (if unstable check Hct)
    - NPO
    - Bathroom privileges
    - VS stable x 12 hrs
      - Check Hct
    - Stable Hct
      - Regular diet
      - Ambulate
      - DC home after another 8 hrs
    - Unstable Hct
      - Recheck Q6 hrs
      - Consider ICU transfer if VS change
  
- Tachycardia due to low Hct
  - Consider transfusing 10-15 ml/kg (max 40 ml/kg total)
  - Check Hct post-transfusion
  - Admit ICU
  - VS Q1 hrs x 4 then Q4hrs
  - NPO
  - Bathroom privileges
  - Check Hct Q6 hrs until stable x 2

- Grade III-V
  - Normal VS
    - Admit/transfer to ward
    - VS Q2 hrs x 2 then Q4 hrs (if unstable check Hct)
    - NPO
    - Bathroom privileges
    - VS stable x 18 hrs
      - Check Hct
  
- Stable Hct
  - Regular diet
  - Ambulate
  - DC home after another 24 hrs

- Unstable Hct
  - Recheck Q6 hrs
  - Consider ICU transfer if VS change
Management of Pediatric Solid Organ Injury

• Non-operative management should be the standard in hemodynamically stable children with solid organ injury of ANY grade.

• What is the risk/benefit of imaging?
FAST for Pediatrics

- No consensus
- High specificity but low sensitivity

Test Characteristics of Focused Assessment of Sonography for Trauma for Clinically Significant Abdominal Free Fluid in Pediatric Blunt Abdominal Trauma

J. Christian Fox, MD, RDMS, Megan Boysen, MD, Laleh Gharabaghian, MD, Seric Cusick, MD, RDMS, Suleman S. Ahmed, Craig L. Anderson, MPH, PhD, Michael Lekawa, MD, and Mark L. Langdorf, MD, MHPE, RDMS

Abstract

Objectives: Focused assessment of sonography in trauma (FAST) has been shown useful to detect clinically significant hemoperitoneum in adults, but not in children. The objectives were to determine test characteristics for clinically important intraperitoneal free fluid (FF) in pediatric blunt abdominal trauma (BAT) using computed tomography (CT) or surgery as criterion reference and, second, to determine the test characteristics of FAST to detect any amount of intraperitoneal FF as detected by CT.

Methods: This was a prospective observational study of consecutive children (0–17 years) who required trauma team activation for BAT and received either CT or laparotomy between 2004 and 2007. Experienced physicians performed and interpreted FAST. Clinically important FF was defined as moderate or greater amount of intraperitoneal FF per the radiologist CT report or surgery.

Results: The study enrolled 431 patients, excluded 74, and analyzed data on 357. For the first objective, 23 patients had significant hemoperitoneum (22 on CT and one at surgery). Twelve of the 23 had true-positive FAST (sensitivity = 52%; 95% confidence interval [CI] = 31% to 73%). FAST was true negative in 321 of 334 (specificity = 96%; 95% CI = 95% to 98%). Twelve of 25 patients with positive FAST had significant FF on CT (positive predictive value [PPV] = 48%; 95% CI = 28% to 69%). Of 332 patients with negative FAST, 321 had no significant fluid on CT (negative predictive value [NPV] = 97%; 95% CI = 94% to 98%). Positive likelihood ratio (LR) for FF was 13.4 (95% CI = 6.9 to 20.8) while the negative LR was 0.50 (95% CI = 0.32 to 0.70). Accuracy was 93% (333 of 357, 95% CI = 90% to 96%). For the second objective, test characteristics were as follows: sensitivity = 20% (95% CI = 13% to 30%), specificity = 98% (95% CI = 95% to 99%), PPV = 76% (95% CI = 54% to 90%), NPV = 78% (95% CI = 73% to 82%), positive LR = 0.05 (95% CI = 0.0 to 0.2), and negative LR = 21.8, negative LR = 0.05 (95% CI = 0.7 to 0.9), and accuracy = 78% (277 of 357, 95% CI = 73% to 82%).

Conclusion: In this population of children with BAT, FAST has a low sensitivity for clinically important FF but has high specificity. A positive FAST suggests hemoperitoneum and abdominal injury, while a negative FAST aids little in decision-making.

ACADEMIC EMERGENCY MEDICINE 2011; 18:477-482 © 2011 by the Society for Academic Emergency Medicine
JAMA | Original Investigation

Effect of Abdominal Ultrasound on Clinical Care, Outcomes, and Resource Use Among Children With Blunt Torso Trauma: A Randomized Clinical Trial

James F. Holmes, MD, MPH; Kenneth M. Kelley, MD; Sandra L. Wootton-Gorges, MD; Garth H. Utter, MD, MSc; Lisa P. Abramson, MD; John S. Rose, MD; Daniel J. Tancredi, PhD; Nathan Kuppermann, MD, MPH

**IMPORTANCE** The utility of the focused assessment with sonography for trauma (FAST) examination in children is unknown.

**OBJECTIVE** To determine if the FAST examination during initial evaluation of injured children improves clinical care.
Figure 2. Clinician Suspicion of Intra-abdominal in the FAST Group Before and After the FAST Examination

<table>
<thead>
<tr>
<th>Clinical suspicion of intra-abdominal injury after FAST examination, %</th>
<th>&lt;1</th>
<th>1-5</th>
<th>6-10</th>
<th>11-50</th>
<th>&gt;50</th>
<th>Total No. of Patients</th>
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<tbody>
<tr>
<td>&lt;1</td>
<td>101 (97%)</td>
<td>3 (3%)</td>
<td>0</td>
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<td>104</td>
</tr>
<tr>
<td>1-5</td>
<td>68 (34%)</td>
<td>120 (60%)</td>
<td>7 (4%)</td>
<td>3 (2%)</td>
<td>1 (1%)</td>
<td>199</td>
</tr>
<tr>
<td>6-10</td>
<td>4 (4%)</td>
<td>25 (27%)</td>
<td>55 (59%)</td>
<td>7 (7%)</td>
<td>3 (3%)</td>
<td>94</td>
</tr>
<tr>
<td>11-50</td>
<td>0</td>
<td>2 (4%)</td>
<td>9 (19%)</td>
<td>33 (70%)</td>
<td>8 (8%)</td>
<td>47</td>
</tr>
<tr>
<td>&gt;50</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1 (11%)</td>
<td>8 (89%)</td>
<td>9</td>
</tr>
<tr>
<td>Total No. of Patients</td>
<td>173 (38%)</td>
<td>150 (33%)</td>
<td>71 (16%)</td>
<td>44 (10%)</td>
<td>15 (3%)</td>
<td>453</td>
</tr>
</tbody>
</table>
Radiation Risk for Children

• 1 CA / 5,000 scans

Lancet, Aug 2012

Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study

Mark S Peacock, Jane A Sabatti, Mark P Little, Kieran McHugh, Choonsik Lee, Kwang Pyo Kim, Nicola L Howe, Cecile M Ronckers, Preetha Rajaraman, Sir Alan W Craft, Louise Parker, Amy Berrington de Gonzalez

Summary

Background Although CT scans are very useful clinically, potential cancer risks exist from associated ionising radiation, in particular for children who are more radiosensitive than adults. We aimed to assess the excess risk of leukaemia and brain tumours after CT scans in a cohort of children and young adults.

Methods In our retrospective cohort study, we included patients without previous cancer diagnoses who were first examined with CT in National Health Service (NHS) centres in England, Wales, or Scotland (Great Britain) between 1985 and 2002, when they were younger than 22 years of age. We obtained data for cancer incidence, mortality, and loss to follow-up from the NHS Central Registry from Jan 1, 1985, to Dec 31, 2008. We estimated absorbed brain and red bone marrow doses per CT scan in mGy and assessed excess incidence of leukaemia and brain tumours cancer with Poisson relative risk models. To avoid inclusion of CT scans related to cancer diagnosis, follow-up for leukaemia began 2 years after the first CT and for brain tumours 5 years after the first CT.

Findings During follow-up, 74 of 178 604 patients were diagnosed with leukaemia and 135 of 176 587 patients were diagnosed with brain tumours. We noted a positive association between radiation dose from CT scans and leukaemia (excess relative risk [ERR] per mGy 0.036, 95% CI 0.005–0.120; p=0.0097) and brain tumours (0.023, 0.010–0.049; p<0.0001). Compared with patients who received a dose of less than 5 mGy, the relative risk of leukaemia for patients who received a cumulative dose of at least 30 mGy (mean dose 51–13 mGy) was 3.18 (95% CI 1.46–6.94) and the relative risk of brain cancer for patients who received a cumulative dose of 50–74 mGy (mean dose 60–42 mGy) was 2.82 (1.33–6.03).

Interpretation Use of CT scans in children to deliver cumulative doses of about 50 mGy might almost triple the risk of leukaemia and doses of about 60 mGy might triple the risk of brain cancer. Because these cancers are relatively rare, the cumulative absolute risks are small: in the 10 years after the first scan for patients younger than 10 years, one excess case of leukaemia and one excess case of brain tumour per 10 000 head CT scans is estimated to occur. Nevertheless, although clinical benefits should outweigh the small absolute risks, radiation doses from CT scans ought to be kept as low as possible and alternative procedures, which do not involve ionising radiation, should be considered if appropriate.

Funding US National Cancer Institute and UK Department of Health.
So which kids need a CT?

• High clinical suspicion

• Hemodynamically unstable

• Concerning Mechanism of Injury

• Clinical signs/symptoms
  • Bruising
  • Tenderness

• Laboratory findings
  • AST/ALT, lipase
  • Unexplained bleeding (hematuria, low HCT)
Image Gently Campaign

Image Gently Impact
The image gently campaign launched 1/22/08. This is a snapshot of what has happened since:
19,180 medical professionals have taken the pledge
This website has been visited 391,142 times
The CT protocol has been downloaded over 26,425 times

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Protocols  Radiologic Technologist
Resources  Medical Physicist

Safety Reports Series
No. 71

IAEA: Radiation Protection in Paediatric Radiology
The International Atomic Energy Agency (IAEA) has released a new document on pediatric radiation protection. CLICK HERE TO DOWNLOAD A PDF OF THIS DOCUMENT.

Recent News
NCRP Report 172 Available
The NCRP Report No. 172, Reference Levels and Achievable Doses in Medical and Dental Imaging: Recommendations for the United States is now available. This Report represents an important continuation of NCRP reports on radiation safety and health protection in medicine and lays the foundation for the development and application of DRLs and achievable doses for diagnostic x-ray examinations. Please click here to read the NCRP press release and for

News from Image Wisely
The Minnesota Department of Health is the first state health agency in the country... Thanks to everyone who has pledged to image wisely, including many this week at...
Attention RSNA attendees! Learn more about new Image Wisely nuclear medicine initiatives...
Nuclear medicine exams help save and extend lives every day. Our new initiative...
Summary

• Pediatric trauma is ubiquitous and preventable
• Consider what is normal for age
• Careful physical exam and imaging
• Practice child and family centered medicine