Variation in Pediatric Head CT Protocols in Washington State

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Disclosures

None
Clinical Issues

- Traumatic brain injury (TBI) leading cause of injury related deaths
- Computed tomography (CT) of head is the most frequent imaging tool used to diagnose and treat acute TBI
- CT scans of head are associated with radiation exposure
Nationwide Pediatric CT utilization

Brenner et al AJR 2001
Radiation and Pediatric Patients

• At increased lifetime risk simply because of life expectancy

• Higher sensitivity at the same effective dose (more proliferating tissues)

• Use of inappropriate protocols (i.e. adult) can lead to unnecessary exposure
Organ dose is Higher for Younger Patients

Brenner et al. AJR 2001
Lifetime Risk of Cancer

Brenner et al AJR 2001; based on BEIR V (solid line) and ICRP 60 (dashed line) data
Head CT Radiation Exposure: Media Attention

“CT scans for children raise alarm”
Seattle Times; Jan 22 2001

“CT scans may harm children’s brains”
The Guardian; Jan 2 2004
Case # 1: 2008

• Parents sue California hospital over pediatric CT radiation overdose
  – Rural California hospital sued by parents of a child who underwent a CT exam during an emergency department visit for a neck injury.
  – The parents allege… 23-month-old boy received radiation burns and has permanent chromosomal damage due to excessive radiation exposure from the CT scan, which took over an hour to perform.
Case # 2: 2009

- California DOH...determined that excessive radiation exposure to a **two-year-old boy** who was allegedly subjected to **151 CT scans** while in the machine for **65 minutes**...had radiation burns on **his face and head**...due to “operator error” by the radiologic technologist.

- JR...taken to ...a small town hospital on the Northern California coast, to **check for possible head injuries** after he fell out of bed the night before.

- The boy's parents, filed the suit against the hospital and radiologic technologist claiming **medical malpractice and battery**.
As Low As Reasonably Achievable (ALARA)

• Performing only necessary examinations
• Limiting the region of coverage
• Adjusting CT settings based on clinical indication and size of child

Frush et al. Pediatrics 2003
Results – Repeated CTs at HMC

Wang, Hollingworth, Vavilala, Jarvik PCCM 2005
## Relationship between CT Changes and Neurosurgery

<table>
<thead>
<tr>
<th>CT changes</th>
<th>Neurosurgery after 2\textsuperscript{nd} CT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Improvement / No change</td>
<td>4 (1%)</td>
</tr>
<tr>
<td>Worsening / New lesion</td>
<td>14 (9%)</td>
</tr>
</tbody>
</table>

\[\text{Chi-Square} = 19.8; \ p<0.001\]

Wang, Hollingworth, Vavilala, Jarvik PCCM 2005
Definitions: Effective Dose

- **Effective dose (ED)** – single dose parameter reflects risk of non-uniform exposure in terms of equivalent whole-body exposure
- Unit is mSv
- ED takes into account the biological effect of radiation dose received
- **ED for a typical head CT is 1-2 mSv**
  - 1 person in 1000 expected to develop cancer with exposure to 10 mSv
- **Weighted EDw** – takes account of child age and organ sensitivity
Dose Varies by Age and Institution

Smaller age group (0-3) had highest dose

3 Aims of Present Study

1. To understand where injured children receive head CT scans in WA state
2. To document variation in head CT protocols
3. To examine by trauma center designation
   – scan protocols
   – protection strategies
   – cancer risk
Hypotheses

1. Large within and between Trauma Designation variation in scan protocols
2. Pediatric friendly protocols at higher level (Levels 1-2) trauma centers
3. Lower level (3-5) trauma centers associated with
   – Higher Dose
   – Higher cancer risk
   – Less protection strategies
Study Design

• Survey of WA state
  – DOH Trauma Centers (1-5)
  – Radiology administrator/Lead CT technician name from internet, contacts
  – Initial contact by letter
  – Follow up email with instructions to complete on-line UW Catalyst survey
  – Two failed e-mail responses to the administrator
    • Phone call
    • Fax, Email
• Analysis: Unit of analysis was hospital, Descriptive, BEIR VII

*Not aware of central repository
## Survey Administered to Trauma Centers in WA State

<table>
<thead>
<tr>
<th>Question 1</th>
<th>How many total trauma patients did you have in 2007?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 2.</td>
<td>How many children received head CT scans in your institution for head trauma in 2007?</td>
</tr>
<tr>
<td>Question 3.</td>
<td>What is the number of CT scanners that are on site at your hospital?</td>
</tr>
<tr>
<td>Question 4.</td>
<td>Are there one or more scanners dedicated for pediatric imaging?</td>
</tr>
</tbody>
</table>
| Question 5 | For the CT machine dedicated to pediatric imaging (or the CT machine most often used for pediatric head trauma CT scans), please provide the following information:  
  a. CT Manufacturer  
  b. CT Model  
  c. Single or Multidetector  
  d. If multi, specify number of detector rows |
<table>
<thead>
<tr>
<th>Question 6</th>
<th>Do you have a specific protocol for performing head CT scans on pediatric trauma patients?</th>
</tr>
</thead>
</table>
| Question 7 | Please provide the following information for your pediatric head CT protocol. If no pediatric protocols are in place, please provide what you use below.  
   a. Kilovolts (kVp)  
   b. Milliamperes (mA)  
   c. Rotation Time (sec)  
   d. Scan Mode (Axial or Helical)  
   e. Pitch  
   f. Beam Collimation (i.e. 5x4, 0.625x64, etc.)  
   g. Anatomy Scan Range |
| Question 8 | Have you implemented any dose-reduction strategy for pediatric head CT scans? (i.e. Automatic Tube Current Modulation, Patient Size-Specific Protocols, etc.) If yes, what year were they implemented?  
   a. yes or no  
   b. what year were they implemented? |
| Question 9 | Do you use shielding for patients having CT scans? If yes, please indicate which organs you shield for and the type of shielding used for each organ.  
   a. yes or no  
   b. What type of shielding? |
Results
Flow Chart of Trauma Centers Surveyed

77 Hospitals Screened and Approached

- 3 Excluded (no CT)
- 7 Refused

67 Included

- 15 Non-responders

51 Respondents

Overall 76% Response Rate
## Response Rate by Trauma Designation

<table>
<thead>
<tr>
<th>Level</th>
<th>Total # of hospitals</th>
<th>% of state</th>
<th>Response Rate (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1%</td>
<td>100% (1)</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>5%</td>
<td>100% (4)</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
<td>30%</td>
<td>70% (16)</td>
</tr>
<tr>
<td>4</td>
<td>33</td>
<td>43%</td>
<td>70% (23)</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>21%</td>
<td>44% (7)</td>
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Response Rate by Question

<table>
<thead>
<tr>
<th>Question</th>
<th>TC 1</th>
<th>TC 2</th>
<th>TC 3</th>
<th>TC 4</th>
<th>TC 5</th>
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<tr>
<td>Q1</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>70</td>
<td>40</td>
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<tr>
<td>Q2</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>91</td>
<td>60</td>
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<tr>
<td>Q3</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<td>Q5a</td>
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<td>Q5b</td>
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<td>100</td>
<td>100</td>
<td>60</td>
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<tr>
<td>Q5c</td>
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<tr>
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<td>100</td>
<td>100</td>
<td>65</td>
<td>100</td>
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</table>
Distribution of Trauma Centers Across WA State
Distribution of 3 Highest Pediatric Head CT Imaging Volume Centers in WA State by Trauma Designation
Average Number of Children Receiving Head CT Scans by Trauma Center Level

Average Number of Children Receiving CT Scans by Trauma Center Level

Average Number of Children Per TC Level

<table>
<thead>
<tr>
<th>Trauma Center Level</th>
<th>n=1 (695)</th>
<th>n=4 (267)</th>
<th>n=16 (436)</th>
<th>n=23 (805)</th>
<th>n=7 (12)</th>
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<tr>
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<td>20.0</td>
<td>40.0</td>
<td>60.0</td>
<td>80.0</td>
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</table>
Average mAs a Function of Trauma Center Level

Average mAs by Trauma Center Level

Trauma Center Level

Average mAs (mAs)

0 50 100 150 200 250 300 350 400

1 2 3 4 5

Milliamperes (mAs)
Percentage of Trauma Centers having Dose Reduction Strategies As a Function of Trauma Center Level
Mean Effective Dose as a Function of Trauma Center Level for Age 0 (newborn) Female Child

n = number responses with complete dose data

Age 0 (newborn) - most radiation sensitive group

Effective Dose (mSv)

n=1
n=2
n=2
n=3
n=11
Mean Organ Dose as a Function of Trauma Center Level for Age 0 (newborn) Female Children

n = number responses with complete dose data

Age 0 (newborn) - most radiation sensitive group
Technical Aspects of Head CT Scanning

• Higher dose
  – High KV: energy; we set this
  – High mAs (includes rotation time):
    • # x-rays; we set this
  – ? Single detectors

• Total dose depends on combination of these factors
Conclusions

• Response rates for Levels 3-5 were lower; larger N
• Volume and technical questions had lower response rates
• Most children receive head CT scans at Level 1,2 TC
• Imaging and protection protocols vary by trauma designation
• Levels 4 and 5 have higher KV and mAs
• Higher radiation dose in Level 4 (maybe Level 5)
• Large variability in dose and cancer risk between TC
• Large variability in dose within Level 4 TC (maybe others)
• Level 1 TC early adopter of protection strategies
• Levels 3-5 associated with
  – Lack of pediatric specific scanner availability
  – Lack of pediatric protocols
  – Less and late adoption of protection strategies
  – Higher dose variability and more cancer risk
Acknowledgements

• WA State Trauma Centers
• Colleagues
  – Colin Raelson, MS
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  – Brent Stewart, PhD
  – Fred Rivara, MD
  – Wendy Cohen, MD