CT SCANNING IN PEDIATRIC TRAUMA: OPPORTUNITIES FOR PERFORMANCE IMPROVEMENT AND RADIATION SAFETY

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Running title: CT scanning in pediatric trauma

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Abstract

Background: Recently, pediatric CT scanning protocols have reduced radiation exposure in children. Because evaluation with CT scan after trauma contributes to significant radiation exposure, we reviewed the CT scans in children at both initial presentation at a non-pediatric facility and subsequent transfer to a level I pediatric trauma center (PTC) to determine the number of scans, body area scanned, radiation dosage, and proportion of scans at each facility.

Methods: The trauma database was retrospectively reviewed for children aged 0 to 17 years old initially evaluated for trauma at another facility and then transferred to our PTC for pediatric specialty care between Jan 2000 and Dec 2010.

Results: 1562 patients with 1335 CT scans were reviewed over an 11-year period. The majority of CT scans occur at the referring facility compared to the PTC in a ratio of 7:3. CT of the head was the most frequent scan obtained (52%), and 17.9% of CT scans were repeated at the PTC. Less than 1% of CT scans performed at the non-pediatric centers contained radiation dosage information, precluding analysis of radiation exposure.

Conclusions: The majority of CT scans for trauma occur at non-pediatric facilities, which demonstrates the need for referring facilities to perform optimal CT scans with the least amount of radiation exposure to the child. We believe this provides an opportunity for PTC performance improvement by facilitating the transfer of images and educating referring facilities about indications for CT scans, dosage amounts, and radiation reduction protocols.

Keywords (10): Computed tomography; trauma systems; Radiation; Pediatric Trauma; radiology; Patient safety; repeat imaging; radiation exposure; transfers
Introduction

Traumatic injury accounts for more deaths in children than all other causes combined [1]. Because of the regionalization of pediatric specialty care in the United States, injured children are often initially evaluated at a non-pediatric facility and subsequently transferred to a pediatric trauma center (PTC) for definitive care [2]. Computed tomography (CT) has become more frequently used to evaluate injured children [2,3]. Prior studies have demonstrated an increase in repeated CT scans in both adults and children when initial evaluation occurs at a non-trauma center followed by a subsequent transfer to a trauma center [2,4]. In addition, some have noted that CT scanning for trauma is occurring more frequently at the referring facility [2]. This trend is worrisome if facilities use improper scanning indications, produce poor quality images, or use too much radiation per scan.

Increase in CT scanning has come under public scrutiny as fears of malignant risk from radiation receives mainstream media coverage [5,6]. Children are especially susceptible because they receive a larger “effective dose” than adults when adjusted for smaller, cross-sectional area and larger organ size [7,8]. Organ tissues of children are up to 10 times more radiosensitive than adults, and radiation damage is additive over the longer lifespan of a child [2,9,10]. In response, the As Low as Reasonably Achievable (ALARA) concept was introduced in 2001 to minimize radiation exposure in children by adjusting acquisition parameters to reflect pediatric patient size [7]. This was followed by the “Image Gently” initiative in 2007, which outlined specific strategies to reduce radiation and raise awareness of radiation [8]. In 2008, formulas and co-factors were published which allow calculation of the pediatric effective dose based on the size of the child. However, they require that the facility performing the CT scan have software to calculate and report the tube radiation [11].
Specific pediatric CT scanning protocols have previously demonstrated a reduction in radiation dosages and are likely employed at most pediatric facilities [12, 13]. However, some referring (adult) facilities have yet to develop their own pediatric scanning protocols placing children at risk for excessive radiation exposure [14]. We hypothesize that children receive the majority of CT scans at the referring facility prior to transfer to a PTC. The PTC must then review and interpret the images obtained and provided by the referring facility; therefore, it is important to assure that these images are properly obtained and are of the highest quality in order to avoid repeated scans. Because of the “dual” workup, as suggested by prior studies [2-4], we believe children who are evaluated for trauma at two facilities (a referring facility and then a PTC) are at risk for the highest number of CT scans.

The purpose of this study is to determine the incidence of CT scanning in referred pediatric trauma at the initial facility and a PTC over the last decade. In addition, the amount of duplicate (repeated) images will be determined and the pediatric effective dosage compared between the facilities. By studying the incidence of CT scans in trauma as part of performance improvement, we hope to educate referring facilities in pediatric radiation safety.

Methods

After obtaining Institutional Review Board approval, a retrospective review was conducted using the Women & Children’s Hospital of Buffalo pediatric trauma center (PTC) registry database. Patients included were aged 0 to 17 years evaluated for trauma at another facility in the Western New York region and then transferred to a PTC for pediatric specialty care and trauma service evaluation between January 2000 and December 2010. Basic demographic data and imaging studies were recorded. CT images at both the referring facility
and the PTC were reviewed to determine the number of CT scans obtained before and after transfer, body area scanned, and duplicated images upon transfer. In addition, CT images since the 2008 publication of pediatric effective dosage calculation were reviewed and examined to determine if this information was provided on CT scans from referring facilities (Fig. 1). No patients were excluded from the study.

The PTC in this study is designated by New York State as a Level I Regional Pediatric Trauma Center. It is the only state PTC outside of New York City and provides care for eight counties of Western New York, Northwestern Pennsylvania, and Southern Ontario. The Emergency Department receives more than 45,000 patients annually, with approximately 30 percent due to trauma. Over half of the pediatric trauma patients are referred from another facility. Trauma service activation occurs by a set of standard criteria or at emergency department staff discretion.

Results

Over the 11-year period, a total of 1,562 injured children requiring trauma service activation and evaluation were transferred to the PTC. A total of 874 patients received some type of CT imaging (56%). Among these patients, a total of 1,335 CT scans were performed, including those at the referring hospitals and the PTC. Table 1 demonstrates the database characteristics stratified by year. Patients were transferred from a total of 41 referring facilities with an average of 38 miles and ranging from 1 to 127 driving miles from the PTC. Table 2 demonstrates the percent of referrals and distance from the PTC.

As illustrated by Figure 2, CT scan of the head was the most common scan (53%) followed by CT of the abdomen and pelvis (28%) at both the referring facility and the PTC.
Figure 3 demonstrates trends over the study period with respect to the number of CT scans per patient that occur at both the referring facility and PTC, the number of duplicate CT scans, and the total scans per patient evaluated. On average, 0.60 CT scans per patient were obtained at the referring facility during the study period compared to 0.26 CT scans per patient at the PTC.

Table 3 demonstrates the total number and body area scanned at referring facilities and the duplication required upon transfer to the PTC. On average, 17.9% of all CT scans were repeated. When comparing the radiation dosage at the referring facility versus the PTC for duplicate CT scans it was determined that less than 1% of CT scans performed at the referring (non-pediatric) centers contained dosage information, which precluded analysis of radiation exposure.

Discussion

Over the 11-year study period, the number of CT scans peaked in 2007 with an average of one CT scan for every patient. Since then, there is a decreasing trend, though there have been no specific interventions to reduce imaging in the last several years. Transferred patients had over twice as many CT scans during workup at the referring facility as compared to the PTC after transfer. CT of the head was the most common followed by abdominal and pelvis, consistent with a prior pediatric study [3]. The total percent of patients receiving CT scans in this study (56%) is similar to prior studies ranging from 50 to 61% [2-4]. The proportion of these scans at the referring facility versus the PTC (7:3) in our study was greater than prior adult reports of 1:1 [3,4]. This highlights the importance efficient image sharing between the facilities. The number of duplicate scans was also less in our study (17.9%) compared to up to
half of CT scans requiring duplication in adult prior reports [4,15] and 91% in a pediatric report [2].

CT of the head was the most common body region requiring repeated imaging (109 of 527) followed closely by CT scans of the abdomen and pelvis (46 of 241). In some cases, it is difficult to retrospectively assess the indication for repeated CT scans. However, it appears that most of the repeated head CT scans (80%) were done in a continuum of care to monitor progression of a lesion or due to a change in patient’s condition. The remainder of the CT head images were repeated because images obtained at the referring facility were not immediately available for review. Of the CT abdomen and pelvis scans, approximately 50% were repeated because there was a concern about solid organ injury and the initial scans were done without intravenous (IV) contrast, 25% were poor quality images or had severe motion artifact, and 25% were not available for review. The one repeated CT neck scan was due to a lack of IV contrast at the initial scan in a child with seatbelt sign across the neck and concern for vascular injury. All of the 9 repeated CT C-spine and the 2 repeated face CT scans were due to inaccessibility. CT scans for trauma of the neck and abdomen and pelvis done without contrast severely limits their usefulness in detecting injury (solid organ or vascular). This may be due to lack of a state-licensed personnel to administer contrast at these facilities "after hours," the lack of the ordering physician to request intravenous contrast, fear of contrast-related complications, or lack of specific pediatric scanning protocols for trauma. Nephrotoxicity and allergic reactions due to intravenous contrast are rare in children, but do occasionally occur, and may occur more frequently than in the adult population [16,17].

We did not correlate the transferring facility or mode of transport to the numbers of CT scans per patient performed. Facilities farthest from a PTC may feel more pressure to screen patients with
CT scanning before making a longer distance transfer when initial work-up could suggest no injuries. Facilities farther away may also fear a longer distance transfer without a full work-up in case of missing a potentially life-threatening injury such as a bleeding solid organ that their local general surgeon must address prior to transfer. This may result in using CT scans more as a screening tool than an indicated diagnostic study. The majority of the 1,335 CT scans from the transferring facility did not have a formal, official associated radiologist report, which precluded analysis of actual CT scan findings. This highlights the fact that surgeons are often called upon to evaluate CT scans (sometimes poor quality) and make a decision to re-image the patient, admit for observation, or alter management strategies in the absence of an official radiologist report.

Our study did not have access to the number of injured children each facility evaluates with CT scans that do not need transfer to a PTC and did not categorize results by mechanism. This study also did not access the appropriateness (indication), quality, or results of each CT scan performed over the 11 year period. A prospective study gathering data on the indication for CT in transferred patients, compared to patients directly admitted to the PTC would help to refine the need for CT while tracking outcomes based on mechanism of injury.

Advanced Trauma Life Support (ATLS) teaches that referring facilities should not obtain diagnostic studies that the facility does not have the capability to treat, which delays transfer to a trauma center [18]. For example, if the decision to transfer a small child has already been made based on a head or orthopedic injury, it is unnecessary to obtain multiple body area CT scans (i.e. CT C-spine) when a treating specialist is not available. This unnecessary CT scanning at referring facilities contributes to costs and delays in definitive treatment, which likely translates to increased morbidity and mortality [4]. Malignancy risk from CT scanning should also be
considered as some have estimated 1 cancer caused per 1000 pediatric CT scans [14]. More precise measurements of this excess in needless radiation exposure provide an opportunity for quality improvement in all trauma systems.

One concerning finding of our study is the lack of retrievable radiation dosage information in the CT scans performed at referring facilities (less than 1%). If facilities are not using software that can calculate or report the radiation emitted by their CT scanner, they are not likely following ALARA guidelines to limit radiation exposure since they are unaware of their “baseline” radiation dosage. Some suggest that facilities be legally mandated to measure and report radiation exposure during CT scanning [19]. Meanwhile, it is expected that pediatric facilities have the most experience in limiting radiation for children [14]. Other reports have suggested slow “upgrades” in community imaging centers to CT scanning software that can re-calculate and lower the dose based on pediatric sized body mass [3,14].

While CT scanning has become an invaluable diagnostic tool, it can also be overused and lead to excessive radiation exposure, delays in care, and increased cost to the health care system if not used appropriately [20,21]. As a PTC, we have an obligation to help educate community and adult centers in the proper implementation of pediatric imaging guidelines for trauma and ALARA principles [22,23]. As a trauma system, we are working with our pediatric radiologists to develop ways to provide feedback to referring facilities regarding images transferred with injured children. Feedback to referring facilities regarding indications and appropriateness of CT scanning may be very subjective and inaccurate. However, it could easily be made when a transfer lacks copies of images or if electronic images are in an inaccessible format. Queries could also be made on the radiation exposure for each scan, which would likely decrease excessive radiation exposure in the referring facility by exploiting the Hawthorne effect.
Knowing that radiation is being measured by pediatric standards, the Hawthorne effect may cause the referring facility to address excesses in radiation exposure at their facility if they are aware that the PTC is quantifying every transferred child’s total radiation exposure. A trauma network’s utilization of electronic image sharing via the internet (as in the lifeIMAGE™ system, Newton, MA) or so called “cloud-based” storage systems would eliminate system incompatibilities and forgotten or lost data discs during transfer. The key to success and implementation of any quality and performance improvement program is good communication among the trauma system with the goal of optimum utilization of resources for the best patient outcome.

In conclusion, our study indicates that over the last decade there has been an increase in CT scanning for trauma at referring facilities prior to transferring a patient to our institution. Since the majority of the radiologic evaluation occurs at a referring facility prior to transferring the patient to a PTC, a regional trauma system must ensure seamless transfer of imaging studies with the patient. A PTC should also provide feedback when necessary to protect children from excessive radiation exposure caused by unnecessary duplication of CT scans, scans done improperly or without legitimate indications, and from facilities using excessive radiation due to absence of specific pediatric protocols.

Acknowledgements: Kathy Duke for assistance with the trauma database and Amanda Hartin, MS for assistance with editing.
Legends

**Fig. 1** CT scanner output of numbers used to calculate pediatric effective radiation dosage.

**Fig. 2** Body area distribution of referred and PTC CT scans.

**Fig. 3** Number of CT scans per patient over the study period.

**Table 1** Patient demographics and CT scans totals per year.

**Table 2** Distance of PTC from referral center and percent of referrals from each distance.

**Table 3** Referred CT scans by area and year and duplicated scans upon arrival to the PTC.

**References**


43rd annual meeting of the Canadian Association of Pediatric Surgeons, Ottawa, ON, September 22-24, 2011.


<table>
<thead>
<tr>
<th>Year</th>
<th>Total patients scanned</th>
<th>Total CT scans</th>
<th>Referred CT scans</th>
<th>PTC CT scans</th>
<th>Age</th>
<th>ISS</th>
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<td>38</td>
<td>56</td>
<td>36</td>
<td>20</td>
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</tr>
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<td>2001</td>
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<td>62</td>
<td>95</td>
<td>59</td>
<td>36</td>
<td>7.57</td>
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<tr>
<td>2002</td>
<td>112</td>
<td>70</td>
<td>93</td>
<td>58</td>
<td>35</td>
<td>6.71</td>
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<tr>
<td>2003</td>
<td>165</td>
<td>97</td>
<td>130</td>
<td>84</td>
<td>46</td>
<td>7.78</td>
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<tr>
<td>2004</td>
<td>95</td>
<td>56</td>
<td>75</td>
<td>52</td>
<td>23</td>
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<td>144</td>
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<td>38</td>
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<td>42</td>
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</tr>
<tr>
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<td>167</td>
<td>120</td>
<td>47</td>
<td>7.45</td>
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<tr>
<td>2009</td>
<td>187</td>
<td>113</td>
<td>172</td>
<td>122</td>
<td>50</td>
<td>7.74</td>
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<td>2010</td>
<td>153</td>
<td>77</td>
<td>118</td>
<td>88</td>
<td>30</td>
<td>7.25</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1562</td>
<td>874</td>
<td>1335</td>
<td>933 (70%)</td>
<td>402 (30%)</td>
<td>7.56 (SD – 0.70)</td>
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Table 1: CT Scan totals and population demographics per year.
<table>
<thead>
<tr>
<th>Miles from PTC</th>
<th>Percent of patients</th>
<th>Number of Referring Facilities</th>
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<tr>
<td>0 - 24</td>
<td>29.6%</td>
<td>13</td>
</tr>
<tr>
<td>25 - 49</td>
<td>35.8%</td>
<td>10</td>
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<tr>
<td>50 - 74</td>
<td>22.5%</td>
<td>7</td>
</tr>
<tr>
<td>75 - 99</td>
<td>11.1%</td>
<td>7</td>
</tr>
<tr>
<td>&gt;= 100</td>
<td>1.0%</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>41</strong></td>
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</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Head</th>
<th>Abd</th>
<th>Chest</th>
<th>C-Spine</th>
<th>Face</th>
<th>Neck</th>
<th>Other</th>
<th>Total Scans</th>
<th>Repeated</th>
</tr>
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<td>2000</td>
<td>28 (6)</td>
<td>4 (2)</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>36</td>
<td>8 (22%)</td>
</tr>
<tr>
<td>2001</td>
<td>44 (14)</td>
<td>12 (3)</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>59</td>
<td>17 (29%)</td>
</tr>
<tr>
<td>2002</td>
<td>36 (7)</td>
<td>18 (3)</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>58</td>
<td>10 (17%)</td>
</tr>
<tr>
<td>2003</td>
<td>49 (12)</td>
<td>32 (8)</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>84</td>
<td>20 (24%)</td>
</tr>
<tr>
<td>2004</td>
<td>31 (6)</td>
<td>17 (5)</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>52</td>
<td>11 (21%)</td>
</tr>
<tr>
<td>2005</td>
<td>51 (10)</td>
<td>26 (4)</td>
<td>4</td>
<td>13 (2)</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>95</td>
<td>16 (17%)</td>
</tr>
<tr>
<td>2006</td>
<td>50 (11)</td>
<td>33 (2)</td>
<td>6</td>
<td>13 (1)</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>106</td>
<td>14 (13%)</td>
</tr>
<tr>
<td>2007</td>
<td>51 (10)</td>
<td>34 (8)</td>
<td>7</td>
<td>18 (2)</td>
<td>1</td>
<td>1 (1)</td>
<td>1</td>
<td>113</td>
<td>21 (19%)</td>
</tr>
<tr>
<td>2008</td>
<td>66 (12)</td>
<td>26 (3)</td>
<td>9</td>
<td>15 (3)</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>120</td>
<td>18 (15%)</td>
</tr>
<tr>
<td>2009</td>
<td>75 (17)</td>
<td>24 (4)</td>
<td>6</td>
<td>11</td>
<td>3 (1)</td>
<td>0</td>
<td>3</td>
<td>122</td>
<td>22 (18%)</td>
</tr>
<tr>
<td>2010</td>
<td>46 (4)</td>
<td>15 (4)</td>
<td>10</td>
<td>9 (1)</td>
<td>5 (1)</td>
<td>0</td>
<td>3</td>
<td>88</td>
<td>10 (11%)</td>
</tr>
</tbody>
</table>

**Total Scans:** 527 | **Repeated:** 109 (21%) 46 (19%) 0 (0%) 9 (11%) 2 (14%) 1 (50%) 0 (0%) (17.9%)
Distribution of referred CT scans

- Head: 56%
- Abd/Pelvis: 26%
- C spine: 9%
- Chest: 6%
- Face: 2%
- All other: 1%
Distribution of PTC scans

- Head: 44%
- Abd/Pelvis: 32%
- C spine: 11%
- Chest: 4%
- Face: 5%
- Neck: 2%
- All other: 2%
Figure 3

Ratio: (# of CT Scans per patient evaluated)

- Referred
- PTC
- Duplicate scans
- Total scans