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Computed Tomography-Related Radiation Exposure in Children Transferred to a Level 1 Pediatric Trauma Center

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Abstract

Purpose—Pediatric trauma patients presenting to Referring Facilities (RF) often undergo computed tomography scans (CT) to identify injuries before transfer to a Level 1 Pediatric Trauma Center (PTC). The purpose of our study was to evaluate RF compliance with the American College of Radiology (ACR) guidelines to minimize ionizing radiation exposure in pediatric trauma patients and to determine the frequency of additional or repeat CT imaging after transfer to a PTC.

Methods—After IRB approval, a retrospective review of all pediatric trauma admissions from January 2010–December 2011 at our American College of Surgeons (ACS) Level 1 PTC was performed. Patient demographics, means of arrival, injury severity score and disposition were analyzed. Patients who underwent CT were grouped by means of arrival: those that were transferred from a RF versus those that presented primarily to the PTC. Compliance with ACR guidelines and need for additional or repeat CT scans were assessed for both groups.

Results—697 children (<18yo) were identified with a mean age of 10.6 years. 321 (46%) patients presented primarily to the PTC. 376 (54%) were transferred from a RF, of which 90 (24%) patients underwent CT imaging prior to transfer. CT radiation dosing information was available for 79/90 patients (88%). After transfer, 8/90 (9%) of children imaged at a RF required additional CT scans. In comparison, 314/321 (98%) of patients who presented primarily to the PTC and underwent CT received appropriate pediatric radiation dosing. Mean radiation dose at PTC was approximately half of that at RF for CT scans of the head, chest and abdomen/pelvis ($p<0.01$).

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ASB – Conception and design, data collection, data analysis, writing the article, revision of article

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CML – Data analysis, revision of article

AG – Conception and design, data analysis, revision of article, obtaining funding

Conclusions—Pediatric trauma patients transferred from RF often undergo CT scanning with higher than recommended radiation doses, potentially placing them at increased carcinogenic risk. Fortunately, few RF patients required additional CT scans after PTC transfer. Finally, compliance with ACR radiation dose limit guidelines is better achieved at a PTC.

Keywords

Pediatric; Trauma; Radiation Exposure; Computed Tomography

Introduction

Trauma remains a leading cause of morbidity and mortality in children and adolescents, however with improved injury recognition, advances in resuscitation and post-injury care, the majority of children have excellent outcomes. The use of cross sectional computed tomography (CT) has significantly increased in the United States with children receiving 4-7 million CT scans each year¹. While protocols and guidelines exist to lessen potentially harmful ionizing radiation in children, many children are still imaged without adherence to these guidelines, thus placing them at higher risk for malignancy due to their smaller body size and more radiosensitive tissue²⁻⁸. Many of the protocols in existence at pediatric institutions follow the “as low as reasonably achievable” (ALARA) principle that attempts to limit the number of CT scans obtained and to make size- and weight-based adjustments prior to imaging^{8,9}.

Trauma remains a facet of pediatric surgery that relies on CT imaging to help with early injury identification and thus improve outcomes. While physical examination, laboratory testing and non-invasive, non-radiating imaging are integral components of the diagnosis and management of traumatically injured children, CT scan remains the most sensitive and specific radiologic test to identify injury and is thus included in the work-up in most emergency rooms^{5,9-13}. Prior studies have investigated the risk of radiation exposure risk and strategies for managing this risk as well as the need for repeat imaging once transferred to a pediatric trauma center^{3,5,9,12,14-17}. Few studies have investigated the adherence to low ionization protocols in the setting of pediatric trauma and compared those CT studies obtained at a referring facility (RF) to those at an American College of Surgeons-Verified Level 1 Pediatric Trauma Center (PTC). The purpose of our study was to evaluate RF compliance with the American College of Radiology (ACR) guidelines to minimize ionizing radiation exposure in pediatric trauma patients and to determine the frequency of additional or repeat CT imaging after transfer.

Methods

After institutional review board approval, a retrospective review of all blunt pediatric trauma admissions at an American College of Surgeons-Verified Level 1 Pediatric Trauma Center in Madison, WI was conducted. Patient demographics, means of arrival, injury severity score and disposition were obtained via chart review during the study period of January 1, 2010 through December 31, 2011. CT images including radiation doses for patients transferred from a RF and at the PTC were collected as well as the need for repeat imaging

at the PTC. Ionizing radiation doses for CT scans of the head, chest and abdomen/pelvis were then compared between the RF and PTC. Radiation dose is estimated by using the dose length product (DLP), which is calculated by multiplying the radiation dose of a single slice by the number of slices in a given study. This is an approximation of the total amount of radiation a patient receives during a scan and is directly related to patient risk². This number is calculated by the scanner and provided in the image set for CT examinations. Data was analyzed by a *t*-test, Fisher's exact test or Mann-Whitney test as appropriate and results were considered statistically significant if *p*-value was <0.05.

Results

During the study period six hundred ninety-seven children (<18 years old) were identified with a mean age of 10.6 ± 1.5 years. Three hundred twenty-one (46%) patients presented primarily to the PTC while 376 (54%) were transferred from a RF. Patient demographics including age, gender, means of arrival, injury severity score and disposition were collected (Table 1). There were no statistically significant differences in demographic variables between the patients presenting from a RF and those transported directly to a PTC. Ninety patients from the RF (24%) underwent CT imaging of the head, chest and/or abdomen/pelvis prior to transfer to the PTC (Figure 1). CT radiation dosing information was available for 79/90 patients (88%) transferred from RF. CT imaging of the head was obtained prior to transfer in 26/376 (7%) of children with an average dose length product (DLP) of 864 ± 79 mGy-cm, while 28/321 (8%) of children presented to the PTC underwent CT imaging of the head with an average DLP of 588 ± 78 mGy-cm ($p < 0.05$).

With respect to CT imaging of the chest prior to transfer from a RF, 23/376 (6%) children received an average DLP of 1980 ± 287 mGy-cm while 21/321 (7%) of children directly taken to a PTC received an average DLP of 768 ± 147 mGy-cm ($p < 0.05$). CT imaging of the abdomen/pelvis was obtained in 51/376 (14%) prior to transfer from a RF with an average DLP of 911 ± 189 mGy-cm, however 67/321 (21%) children that presented directly to a PTC who underwent CT received an average DLP of 260 ± 41 mGy-cm ($p < 0.05$). The average DLP for CT imaging of the head, chest and abdomen/pelvis were significantly less at the PTC vs. RF ($p < 0.05$) during the study period (Table 2). After transfer, 9% (8/90) of children imaged at a RF required additional/repeat CT scans (6 head CT, 2 abdomen/pelvis CT). For the children who received repeat head CT scans ($n=6$) the average cumulative dose was 2424 ± 790 mGycm while those that underwent repeat CT imaging of the abdomen/pelvis ($n=2$) was 2741 ± 69 mGy-cm.

Discussion

Pediatric trauma patients that sustain blunt head, chest and abdominal/pelvis trauma pose a diagnostic challenge to practitioners as the initial physical examination is often unreliable and can be associated with occult injury⁵. CT scanning has become an integral part of initial diagnosis and management of pediatric trauma however many pediatric trauma patients are often "over scanned" or when scanned, are done so with doses of ionizing radiation that place these children at greater risk for malignancy development in sensitive tissue^{9,12-14,18}. Recent data indicate significant growth in CT scan utilization in pediatric trauma patients,

primarily consisting of increased head and/or chest CT scans⁴. In addition, some authors have indicated that CT scanning at referring facilities often require duplicate scans of the same anatomic field after transfer and thus place them at increased potential clinical risk and cost¹. Scanning children prior to transfer is associated with a time delay, increase risk of clinical deterioration, radiation exposure, nephrotoxicity related to additional intravenous contrast administration and added cost of duplicate studies¹⁻⁵. Additionally, it has been suggested that CT imaging should not be used as a triage tool to determine if transfer is necessary, but rather should be performed at a Level 1 Pediatric Trauma Center¹. However, these concerns need to be balanced by the potential to unnecessarily over-triage by transferring all injured children to PTC.

In addition to increased cost and need for repeat imaging once at the PTC, children that undergo CT imaging at RF often are done with doses of ionizing radiation exceeding that which is required for clinical decision making^{2,3,7,15,18-20}. The American College of Radiology (ACR), National Cancer Institute and American Society of Radiologic Technologists have published practice standards, clinical guidelines and protocols for CT imaging of children. The Alliance for Radiation Safety in Pediatric Imaging was developed to improve the safety and effectiveness of imaging care of children worldwide and have developed the concept of as low as reasonably achievable (ALARA)⁸. They provide educational materials to clinicians and hospitals caring for children. Prior studies have investigated compliance with the ALARA principles and analyzed ordering practices and radiation exposure among pediatric trauma patients at national trauma centers. Given the variability among hospitals caring for pediatric trauma patients, imaging protocols, and inherent difficulties of calculating the actual ionizing radiation, determining the radiation dose delivered to children can often be a challenge. The purpose of our study was to evaluate RF compliance with the ACR guidelines to minimize ionizing radiation exposure in pediatric trauma patients and to determine the frequency of additional or repeat CT imaging after transfer.

Both groups of patients, those transferred from a RF and those that presented primarily to the PTC underwent CT imaging of the head and chest with nearly identical frequency, suggesting appropriate use of imaging by RF. There was an increased use of CT scanning of the abdomen/pelvis in those children that presented to the PTC directly as opposed to those that transferred from a RF. This increased utilization seen at the PTC may be secondary to the unknown true incidence of abdomen/pelvis CT scans performed at RF of children that are not transferred to a PTC for care. Additionally, this may reflect a higher incidence of concern for abdominal/pelvic trauma in those patients that are transferred versus those managed at RF.

Of the CT images performed at the RF (head, chest and abdomen/pelvis), there was a statistically significant higher dose of ionizing radiation provided to the injured children as compared to the ionization radiation dose at the PTC. One might speculate that decreased awareness of the ALARA guidelines, practice standards and clinical guidelines might be responsible for the higher doses of ionizing radiation administered. Increased awareness and education at RF may help to decrease the administration of higher dose CT scans in pediatric trauma patients. Based on the findings of our study, we have initiated a combined Pediatric

Trauma/Pediatric Radiology quality improvement effort geared towards education and protocol development for our referring institutions.

This module includes suggested guidelines on when to obtain brain and/or abdominal imaging, as well as guidance on CT protocols to achieve ALARA.

Our investigation also clearly illustrated that with an electronic medical record and ease of CT image transfer programs, all additional CT imaging obtained for children transferred from a RF to the PTC was clinically justified rather than for poor image quality, incomplete studies or missing studies from the RF. Clearly this lessens the need for repeat CT imaging and thus greatly decreases the risk of additional ionizing radiation to pediatric trauma patients. Of the CT scans that were repeated after transfer from the RF (6 head CT and 2 abdomen/pelvis) these were performed to follow progression of known head trauma (subdural, subarachnoid hemorrhage) and to re-evaluate patients who had a change in their abdominal examination with concurrent lab abnormalities.

Our study has several limitations including the retrospective nature of data from analysis of a large institutional trauma registry. Retrospective analyses are inherently limited by missing or incorrectly entered data. In addition, dose reports for CT imaging obtained at RF were incomplete or absent for 12% of children. While this certainly could alter the statistics, it is unlikely given the marked differences observed for increased radiation doses at RF as compared to the PTC. Finally, the true incidence of CT imaging obtained for blunt pediatric trauma at RF is unknown since only a subset of children are transferred to a PTC for care. Furthermore, the CT imaging obtained at the PTC was only the imaging obtained while the child remained in the emergency room. We know that many pediatric trauma patients receive additional imaging (plain radiographs, CT scans) once admitted to the PTC however this data was not the focus of our study and is not included in our dataset. Finally there is limited literature available that best estimates the effective dose of ionization radiation obtained from CT scans however effective dose (as calculated from DLP) is a good measure of potential detriment to radiosensitive tissue of children².

Conclusions

In summary, CT imaging remains the gold standard in evaluating blunt trauma in pediatric patients. The results of the CT scans help with early injury identification and thus improve outcomes. While physical examination, laboratory testing and non-invasive, non-radiating imaging are crucial to the diagnosis and management of traumatically injured children, CT scan remains the most sensitive and specific radiographic test to identify injury and thus included in the work-up in most emergency rooms. Given the smaller body size, increased radiation sensitivity of tissue and unreliable physical examination, more and more children are receiving CT scans at non-pediatric facilities, or in the community with higher than necessary doses of ionizing radiation, thus placing them at higher risk for developing malignancy later in life. Guidelines have been established and published to limit the harmful effects of ionizing radiation, however, adherence to these guidelines can be a challenge at referring facilities or those hospitals unfamiliar with the dose attenuation needed for children. Our study will provide a stepping-stone for local and statewide education to

embrace the ALARA principles as it pertains to pediatric blunt trauma of lower radiation dosing, avoiding duplicate studies and imaging only when results will change clinical care. Radiation dose from pediatric CT examinations is minimized through proper patient positioning in the scanner as well as through adjusting exam parameters based on patient size, not just weight, and study indication. Additionally, pre-contrast images are avoided in pediatric patients and limited delayed scans are only performed when clinically indicated through the anatomic region of concern. Certainly this data can be further extrapolated to other areas of pediatric care that depend on CT imaging for exceptional clinical care.

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There were no statistically significant differences in demographic variables between the patients presenting from a RF and those transported directly to a PTC. Ninety patients from the RF (24%) underwent CT imaging of the head, chest and/or abdomen/pelvis prior to transfer to the PTC.

Figure 1.

There were no statistically significant differences in demographic variables between the patients presenting from a RF and those transported directly to a PTC. Ninety patients from the RF (24%) underwent CT imaging of the head, chest and/or abdomen/pelvis prior to transfer to the PTC.

Table 1

Demographics

Demographic	PTC N(%)	RF N(%)	p value
Age, mean $\pm$ SD (yr)	10.5 $\pm$ 1.2	10.9 $\pm$ 1.4	0.32
Sex % male	64%	64%	
Means of Arrival			
Ambulance	188 (59)	264 (70)	<0.01
Private Vehicle	94 (29)	33 (9)	<0.01
Helicopter	39(12)	79 (21)	<0.01
Disposition			
Floor	237 (74)	255 (68)	0.1
PICU	77 (24)	114 (30)	0.07
Discharge from ER	7 (2)	7 (2)	0.8
ISS median, (IQR)	4, (2-9)	5, (4-10)	0.42

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Table 2

	RF	PTC	p-value
Head CT	864±79 (26)	588±78 (28)	<0.01
Chest CT	1980±287 (23)	768±147 (21)	<0.01
Abdomen/Pelvis CT	911±189 (51)	260±41 (67)	<0.01