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Utilization of CT imaging in minor pediatric head, thoracic, and abdominal trauma in the United States

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ABSTRACT

Background: Liberal use of CT scanning in children with blunt trauma risks unnecessary radiation exposure and cost. Recent literature questions the utility of whole-body CT in stable children without clinical evidence of significant injury, but this is often done based on injury mechanism. The purpose of this study is to quantify the utilization of CT scans of the head, chest, abdomen, and pelvis based on injury severity in these body regions and to assess the impact of American College of Surgeons (ACS) pediatric trauma center designation on CT utilization in children with minor or no injuries.

Methods: We queried the National Trauma Databank for 2014, 2015, and 2016 to identify all patients 14 years and younger. Using Abbreviated Injury Scale (AIS) score as a proxy for injury severity, we analyzed the number of head, thoracic, and abdominal CT scans done for patients at low levels of injury severity (AIS 0–2) in each of these body regions and according to trauma center level designation (ACS I, II, III, standalone pediatric I or II, and non ACS accredited).

Results: Of 257,661 children who were entered into the database for any reason, overall CT utilization was 20% for head, 5% for the chest and 9% for the abdomen and pelvis. Children with no injuries or minimal injury to the head were scanned 7% and 46% of the time, respectively, for the chest 3% and 13% and for the abdomen 6% and 30%. For all body regions and all levels of injury severity, level 1 stand-alone pediatric centers displayed significantly lower CT utilization rates than others.

Conclusion: CT scan rates for children with minimal or no injuries to the head, chest, abdomen and pelvis are significant. Level 1 stand-alone pediatric trauma centers are least likely to perform these studies. Widespread education and acceptance of clinical guidelines for imaging in stable patients throughout trauma systems could alleviate this disparity.

Level of evidence: Level III retrospective comparative study

Trauma is the most common cause of morbidity and mortality in children, with more than 10 million children in the United States presenting to the emergency department each year for treatment of traumatic injuries [1]. Computed tomography (CT) scan is a widely used diagnostic modality in the evaluation of trauma patients. The speed, accessibility, and level of anatomic detail provided by computed tomography (CT) scans have made them an attractive diagnostic and screening tool since the 1970s [2]. Over the past two decades, concern has been raised about risk of future malignancy as a result of exposure to ionizing radiation in children, given the vulnerability of developing organs and the many remaining years of life in which cancer may develop [2,3]. Prior studies have documented disparities in overall doses of radiation to which pediatric trauma patients are exposed in different practice settings, with a specific eye toward variability in the use of pediatric-specific parameters when scanning children [3–5]. Clinical prediction rules and guidelines have been derived utilizing retrospective and prospective data to assist clinicians regarding appropriate utilization of CT in blunt trauma of the head, chest, abdomen and pelvis [6–8]. While studies demonstrate that implementation of evidence-based imaging guidelines has the ability to decrease CT utilization for trauma, acceptance at individual centers is variable, even among pediatric trauma centers where some these guidelines have been developed [9,10].

What is not clearly understood is to what degree modern trauma centers are over imaging children, as prior studies have not quantified imaging rates among children presenting without injuries or with minimal injuries. The purpose of this study is to quantify the utilization of CT scans of the head, thorax, and abdomen in children presenting to trauma centers who, in retrospect, were found to have no injury, or only minor to moderate injuries where the need for intervention is highly unlikely. We also sought to compare these imaging rates

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Table 1
Injury examples by AIS code.

AIS Score	Head	Chest	Abdomen
0	No injury	No injury	No injury
1	Subgaleal hematoma; Superficial scalp laceration; mild concussion, no loss of consciousness	Superficial muscle tear or contusion; minor soft tissue laceration, single rib fracture without flail; sternal contusion	Minor abdominal wall laceration/contusion; contusions of penis, testis, adrenal gland, vagina and perineum
2	Scalp laceration with >20% blood loss; cranial nerve contusion; simple, closed, nondisplaced skull fracture; mild concussion with brief of no loss of consciousness	Small (<50%) pneumothorax without hemothorax, minor (< 1 lobe) pulmonary contusion; major chest wall soft tissue laceration; esophageal hematoma or contusion	Grade 1 and 2 solid organ injuries; partial thickness intestinal injuries without perforation; mesenteric contusions (minor);

among various levels of trauma center accreditation. We hypothesized that many children without significant injuries are exposed to CT scanning at all trauma centers, but that unnecessary CT utilization is likely lower in stand-alone pediatric centers.

1. Methods

Following approval of this study by the Albany Medical Center Institutional Review Board as exempt, the American College of Surgeons' National Trauma Data Bank was queried for children ages 14 years and younger presenting to reporting trauma centers from 1 January 2014 to 31 December 2016. ICD 9 and ICD 10 codes were used to determine which children underwent any form of CT scan imaging of the head, thorax, and abdomen during their hospitalization. Abbreviated injury score (AIS) was used to determine injury severity in each body region: Head (Body Region 1), Chest (Body Region 3), Abdomen (Body Region 4). Facial injuries, extremity injuries and external soft tissue injuries/burns were not analyzed.

The AIS score is a well-established injury severity scoring system that is the basis for calculation of the injury severity score (ISS), which has been validated over several decades as a predictor of injury severity and clinical outcomes [11]. A score is applied to each body region retrospectively by a professional coder following discharge. The score is based on clinical exam and history, imaging results, operative findings and autopsy reports [12]. An AIS of zero signifies no injury was sustained in that body region. AIS of 1 describes a minor injury and AIS of 2 is a moderate injury. For the body regions analyzed in this study, the list of AIS 1 (minor) and 2 (moderate) injuries is limited, and often these injuries can be determined on history and exam alone. A list of examples is provided in Table 1 for clarity. This list encompasses the majority of such injuries, but for brevity is not exhaustive.

Analysis of rates of CT scans performed of the head, thorax, and abdomen was performed based on AIS by body region, and according to trauma center level designation. Multiple CT scans done on the same patient in the same body region were counted only once. Stand-alone adult or combined pediatric/adult trauma centers were treated similarly in this study and designated based on their highest overall adult level of accreditation. Only stand-alone pediatric trauma centers were analyzed separately as pediatric trauma centers.

Statistical significance for relationships was determined utilizing Pearson Chi^2 test and Modified Poisson Regression was used to compare CT scan rates by injury type and trauma center level designation and risk ratios and 95% Confidence intervals were reported with statistical significance assessed at 0.05 level.

Given that coding of the AIS score is somewhat reliant on imaging, it is possible that centers effective in limiting imaging will underdiagnose injuries not apparent on history and exam alone, and "miscode" these as an AIS of zero. In order to determine the impact of this potential confounder, patients were dichotomized to AIS of zero and all others for body regions 1, 3 and 4, and logistic regression was done to determine if there were significant differences in the incidence of AIS of zero across various trauma center accreditation levels.

2. Results

In the designated three-year period, 257,661 children ages 14 years and younger presented to all trauma centers reporting to the NTDB. Of these, 20% received a CT scan of the head, 5% received a CT scan of the thorax, and 9% received a CT scan of the abdomen. Children sustaining no injury overall to the head, chest, or abdomen were scanned 7%, 3%, and 6% of the time respectively. Children with mild injuries (AIS1) [12] were scanned in the head, chest or abdomen 46%, 13%, and 30% of the time, respectively. Children with moderate injury (AIS 2) [11] were scanned 50%, 22%, and 40%, respectively, for the head, chest, and abdomen. Raw numbers of CT utilization by AIS score and trauma center designation are listed in Tables 1, 2, and 3 and percentages are displayed in Figs. 1–3. In all body regions, and at all levels of certification, AIS correlated significantly with increased utilization of CT scan.

Specific to head imaging (Table 2), overall imaging rates in patients without head injury were < 10% at all centers, with level 1 and level 2 stand-alone pediatric centers displaying lower imaging rates than adult, unaccredited and combined centers. When comparing all centers, significantly fewer unnecessary scans were performed at level 1 stand-alone pediatric trauma centers (4.5%). Minor head injuries had much higher imaging rates (40%–56%) overall, however again significantly fewer scans were done at stand-alone level 1 pediatric trauma centers. Not surprisingly, moderate head injuries had even higher imaging rates (42%–62%). At this level of injury, pediatric stand-alone level 1 trauma centers continued to display significantly lower scanning rates than others (42%), with adult/combined level 1 centers close behind at 49%.

Thoracic imaging rates (Table 3) revealed significant disparities between stand-alone pediatric centers and adult/combined centers.

Table 2
Head CT utilization (number of patients imaged/total *n*).

Total	Level 1	Level II	Level III	Stand-Alone Pediatric Level 1	Stand-Alone Pediatric Level II	Other[a]
No Injury (AIS0) 12,148/181,297(6.7%)	3208/38,887 (8.3%)	1630/17,246 (9.5%)	394/4518 (8.7%)	1902/42,565 (4.5%)	439/9479 (4.6%)	4575/68,602 (6.7%)
Mild Injury (AIS1) 6092/13,298 (46%)	1461/2960 (49%)	903/1627 (56%)	188/405 (46%)	1125/2815 (40%)	276/543 (51%)	2139/4948 (43%)
Moderate Injury (AIS2) 14,731/29,735 (50%)	3446/7099 (49%)	2134/3632 (59%)	420/675 (62%)	2431/5736 (42%)	636/1292 (49%)	5664/11,301 (50%)

[a] Non ACS accreditation or unknown.

Table 3
Chest CT Utilization (number of patients imaged/total *n*).

Total	Level 1	Level II	Level III	Stand-Alone Pediatric Level 1	Stand-Alone Pediatric Level II	Other[a]
No Injury (AIS0) 7180/236,125 (3%)	2539/51,426 (4.9%)	1321/23,734 (5.6%)	253/5820 (4.4%)	326/54,352 (0.6%)	107/11,643 (0.92%)	2634/89,150 (3%)
Minor Injury (AIS1) 998/7433 (13.4%)	304/1642 (19%)	193/801 (24%)	37/161 (23%)	82/1970 (4%)	9/331 (3%)	373/2528 (15%)
Moderate Injury (AIS2) 578/2649 (22%)	174/706 (25%)	115/315 (36.5%)	17/52 (33%)	66/544 (12%)	9/74 (12%)	197/958 (21%)

[a] Non ACS accreditation or unknown.

Thoracic CT rates for patients without injury varied from 0.6 %to 5%, with significantly fewer scans done at both Level 1 and Level 2 Pediatric centers. Minor thoracic injures were scanned 19%–24% of the time at adult or combined centers vs 4% and 3% of the time at Level 1 and 2 pediatric centers, respectively. Finally, moderate injuries were scanned 25%–37% of the time at adult and combined centers, and only 12% of the time at stand-alone pediatric level 1 and 2 centers (Table 2). All these differences were statistically significant.

Abdominal CT (Table 4) rates were relatively low (<10%) in patients without injury but remained significantly lower in stand-alone Level 1 pediatric trauma centers (3.5%) and pediatric Level II (3.9%) centers vs. adult and combined centers (6%–8.8%). Minor injuries carried much higher CT rates (25%–36%) at all centers. However, level 1 stand-alone pediatric trauma centers had a significantly lower rate than all others at 25%. Moderate injuries carried a higher rate of imaging (36%–52%) at all centers, with level 1 adult/combined trauma centers displaying the lowest rates of imaging at 36%, a finding which also reached statistical significance.

When looking at summative CT scanning rates across all body regions for various injury severity scores by trauma center designation (Figs. 4–6), stand-alone Pediatric Level 1 trauma centers displayed significantly overall lower rates of unnecessary imaging across all centers. Pediatric Level 2 centers tended to perform better than adult or combined centers, with the exception of moderate level injuries. Level 1 adult or combined centers tended to perform better than Level 2 or 3. The majority of the differences between overall imaging rates between pediatric and adult centers were because of differences in thoracic imaging rates.

Logistic regression was done to further analyze the potential impact of limited imaging on factitiously depressing the AIS score to zero. The results of this are listed in Table 5. Children presenting to pediatric trauma centers were significantly more likely to have no identifiable injury to the head than those presenting to adult centers. As the only AIS 1 or 2 injury to the head completely reliant on imaging is a simple, nondisplaced skull fracture, it is possible that pediatric centers may have underdiagnosed this injury. For thoracic and abdominal injuries, there was no significant difference between level 1 pediatric and adult/combined centers, however both the lower level adult and pediatric centers had significantly increased proportions of patients that presented without identifiable injuries in these body regions.

3. Discussion

Each year, millions of children throughout the United States present to hospitals as a result of a traumatic injury [1]. Many of these children suffer minimal injury to the head, chest, and abdomen, but are still highly likely to undergo CT scanning, with overall 20% receiving a CT of the head, 5% undergoing CT of the chest, and 9% undergoing CT of the abdomen. Children without any documented injury to the head were scanned 6% of the time, to the chest 3% of the time, and to the abdomen 6% of the time. Children with minor injuries unlikely to require medical, surgical or percutaneous intervention (Table 1) [12] underwent head CT 46% of the time, CT of the Chest 13% of the time, and Abdominal CT 30% of the time. At both levels of injury and in all body regions, stand-alone Level 1 pediatric trauma centers demonstrated significantly less excessive use of CT imaging compared to all other centers, with the exception of minor injuries to the chest, where level 2 pediatric centers outperformed all others.

Given the increasing scrutiny regarding long term effects of ionizing radiation in children, many centers have implemented strategies to decrease the use of CT scanning when possible. These include the use of alternative imaging modalities, the development of validated assessment

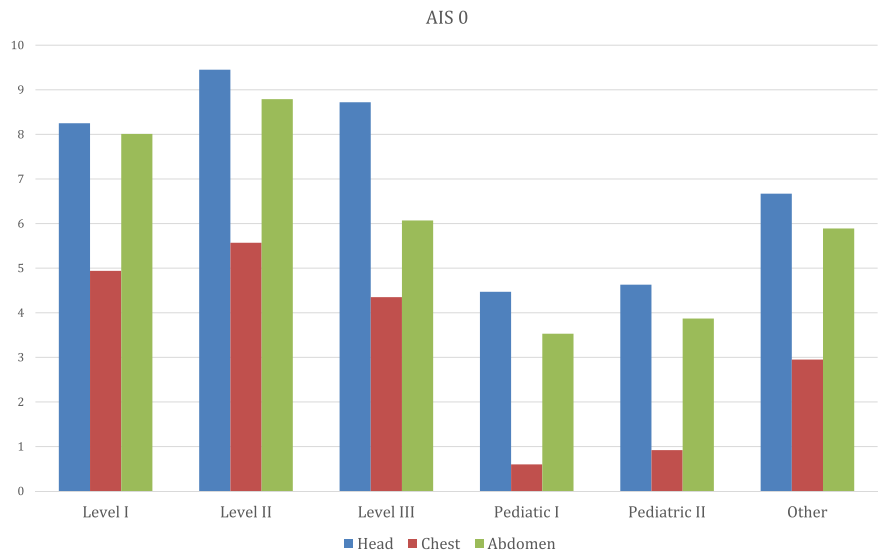

Fig. 1. CT rates (%) for patients without injuries by trauma center designation.

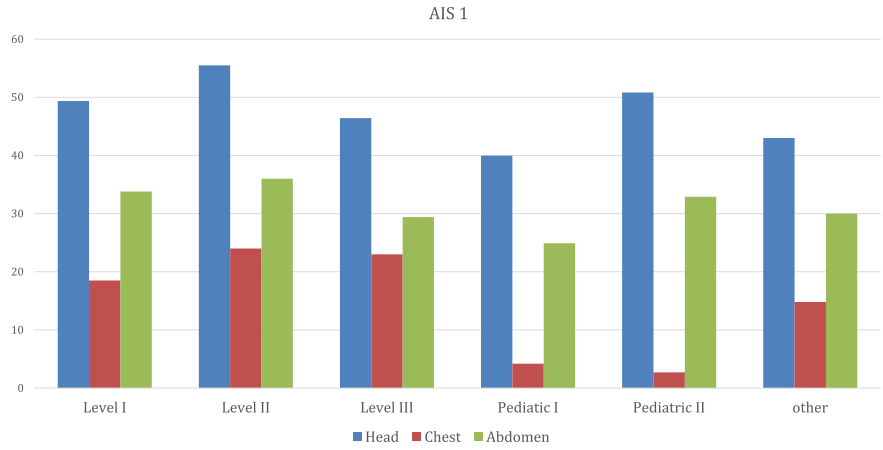

Fig. 2. CT rates (%) in patients with minor injuries by trauma center designation.

tools to guide clinical decision making, including with regard to imaging, and awareness campaigns targeting clinicians, technicians, and the lay-public about the risks and benefits of CT scans [13,14]. Numerous centers have demonstrated that the implementation of validated assessment tools, guidelines, and pathways has led to rapid and sustainable changes in practice patterns that decrease pediatric radiation exposure without increasing the rates of clinically significant missed injuries in children suffering from blunt trauma [6–10,15]. However, although clinical evidence does not justify liberal use of whole-body CT in the evaluation of stable children suffering from blunt trauma, it is still commonly practiced [16]. Prior to this study, the use of CT scanning in patients with minimal or no injuries was not well quantified. What this study adds to the literature is a gold standard regarding CT utilization. As these calculated over imaging rates are based on a retrospectively determined lack of injury, or minor to moderate injury designation, it is not realistic that any trauma center could meet an over imaging rate of zero, given that the need for imaging is based on clinical suspicion and not clinical certainly. But this does provide a benchmark for quality improvement moving forward.

The most established clinical decision rule for imaging in injured children is the Pediatric Emergency Care Applied Research Network (PECARN) guideline for imaging in minor head trauma [6]. Since publication in 2012 it has been validated in multiple countries [17] and the algorithm is now incorporated not only into the American College of Surgeons' Trauma Quality Improvement Program's Best Imaging Practices [18], but also in the 10th edition of ATLS [1]. Of note, most of the findings on the PECARN algorithm which would automatically place a child into the “clinically observe or scan” group would generate an AIS score of 1 or 2 (scalp hematoma, laceration, nondisplaced skull fracture, or mild concussion). The authors of the study state that, in these patients, the decision to image should be based not only on the parent's preference but also on the ability of the facility to safely observe the patient. It is very possible that low level combined centers, as well as many adult centers, are perceived as lacking the resources to safely observe a pediatric patient with a head injury. This could explain the larger disparities in imaging rates seen for mild and moderate imaging between pediatric level 1 centers and others.

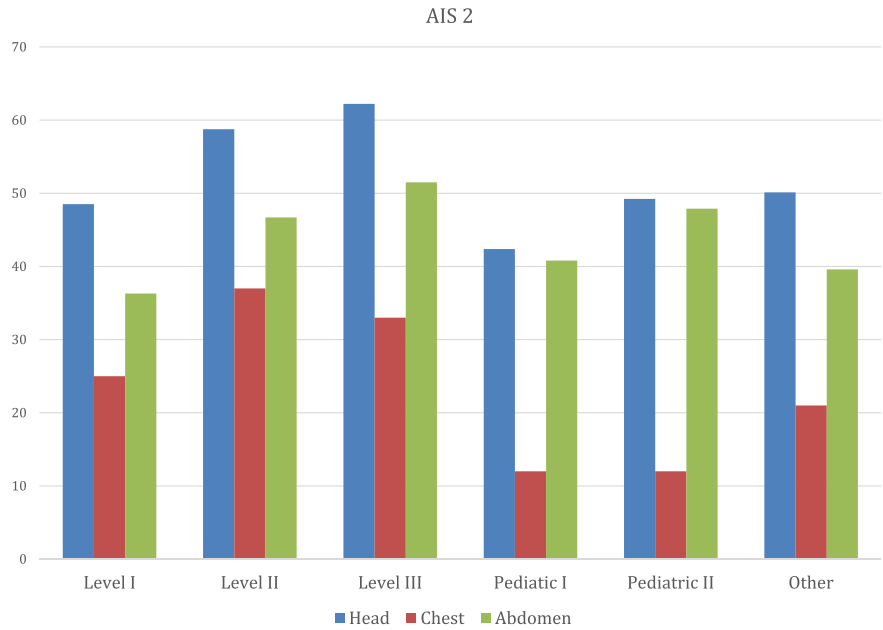

Fig. 3. CT rates (%) for patients with moderate injuries by trauma center designation.

Table 4
Abdominal CT Utilization (number of patients imaged/total *n*).

Total	Level 1	Level II	Level III	Stand-Alone Pediatric Level 1	Stand-Alone Pediatric Level II	Other[a]
No Injury (AIS0) 13,850/230,330 (6%)	4032/50,368 (8%)	2050/23,334 (8.8%)	346/5702 (6%)	1852/52,448 (3.5%)	439/11,341 (3.9%)	5131/87,137 (5.9%)
Minor Injury (AIS1) 3252/10,780 (30%)	833/2466 (34%)	371/1029 (36%)	58/197 (29%)	673/2707 (25%)	150/456 (33%)	1167/3925 (30%)
Moderate Injury (AIS2) 3001/7433 (40%)	644/1771 (36%)	400/857 (47%)	68/132 (52%)	642/1572 (41%)	114/238 (48%)	1133/2863 (40%)

[a] Non ACS accreditation or unknown.

Of greater significance are the profound differences in imaging rates for chest CT between pediatric and adult/combined centers. It is very well established in clinical studies that chest CT offers little benefit over chest X-ray in screening pediatric patients with blunt thoracic injury [8,19]. Regardless, CT imaging rates for no, mild, and moderate injury (small pneumothorax, pulmonary contusion, etc.) were significant, particularly at level 2 and 3 centers. This practice could likely be impacted by educational initiatives and the consistent use of clinical guidelines, in additional to regional trauma care quality improvement initiatives.

The least amount of disparity across centers was seen with abdominal CT. Although pediatric level 1 centers still significantly outperformed others in patients without injuries and with minor injuries. Since 2014, when the data collection period for this cohort opened, several large clinical studies have been published to help guide abdominal imaging practices in children with blunt trauma [7,20,21]. These may have subsequently impacted unnecessary imaging rates in abdominal trauma, as it is clear that local implementation of such guidelines at individual centers has had a significant impact on the incidence of unnecessary abdominal CT scans [10].

There are significant limitations to this analysis and the results need to be interpreted with caution. First, while the AIS score is a validated measure of injury severity, it is given retrospectively by a professional coder with access to operative, radiographic, and autopsy data. It is not intended for use as a prospectively applied guide to intervention. Therefore, while this study does offer insight into the degree of overimaging in the current practice of pediatric trauma, its results cannot provide guidance on imaging strategies based on clinical presentation. Second, while the ACS' National Trauma Data Bank is a robust and well-maintained repository of information with multiple internal quality assurance checks, it is still subject to problems with data capture and fidelity. Third, in this study there was no accounting for the impact of combined adult and pediatric centers verification vs adult verification alone. However, given that the ACS mandates that all adult centers seeing more than 100 pediatric trauma patients a year must obtain pediatric verification, it is unlikely that large number of patients in this cohort were seen at a stand-alone adult center. Fourth, the body regions designated in the AIS scoring system do not cleanly correlate with anatomic scanning protocols for the head, chest and abdomen. Specifically, cervical spine injuries also are included in body region 1 (head), and pelvic fractures are not included in body region 4 (abdomen). Therefore, it is possible that the AIS codes assigned to the head CT patients also reflect cervical spine injuries, and some abdominal CTs were obtained to evaluate for pelvic fracture which is not reflected in the AIS for body region 4. However, given the very low rates of isolated cervical spine and bony pelvic injury in pediatric trauma [22,23], this is unlikely to have had a significant impact on the results. In addition, this study does not account for imaging done at an outside facility prior to transfer to a referral center. Therefore, it is possible that some improved performance in unnecessary imaging rates by the higher-level centers may partially be owing to imaging already obtained at an outside center prior to a patient's transfer. Finally, there is the important impact of imaging itself on designation of the AIS score. Centers that are successful in minimizing overimaging are more likely to miss minor and clinically insignificant moderate injuries not apparent on clinical exam or history, potentially inflating the proportion of patients with a designation of AIS zero (no injury). Logistic regression analysis of this did find that stand-alone level 1 pediatric trauma centers were more likely to see children without an identifiable head injury, which may have been owing to underdiagnosis of simple skull fractures, which do not typically require treatment. As the majority of injuries designated minor or moderate in these body regions can be determined based on physical exam or history (Table 1),

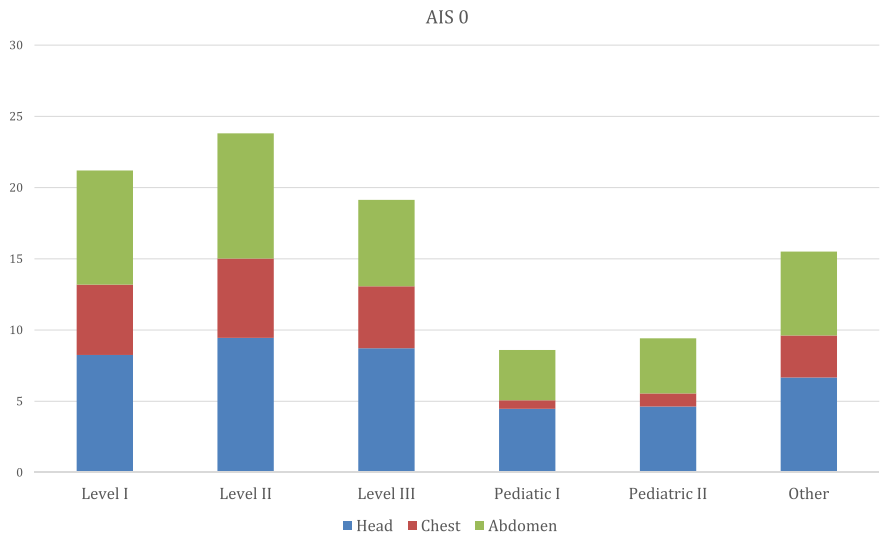

Fig. 4. Summative CT rates (%) for patients without injuries by trauma center designation:

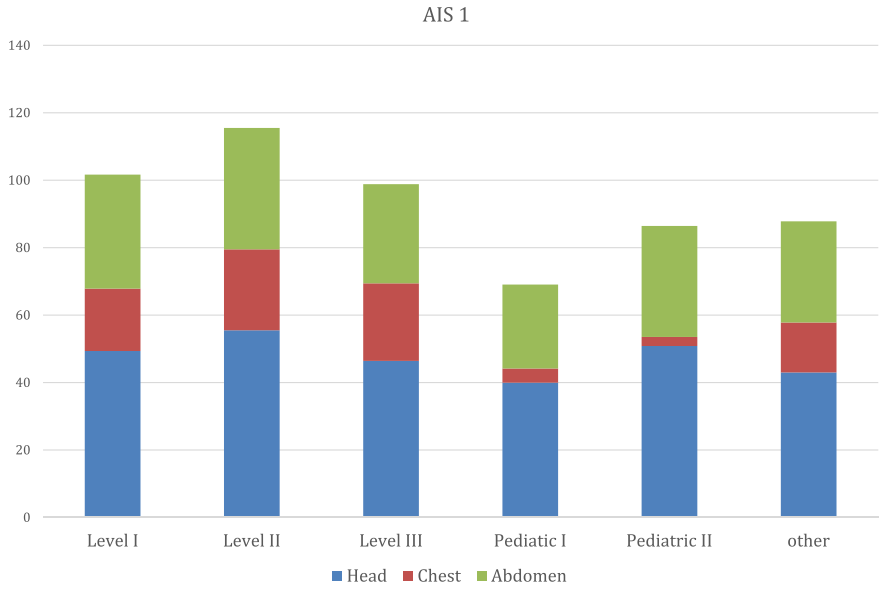

Fig. 5. Summative CT rates (%) in patients with minor injuries by trauma center designation:

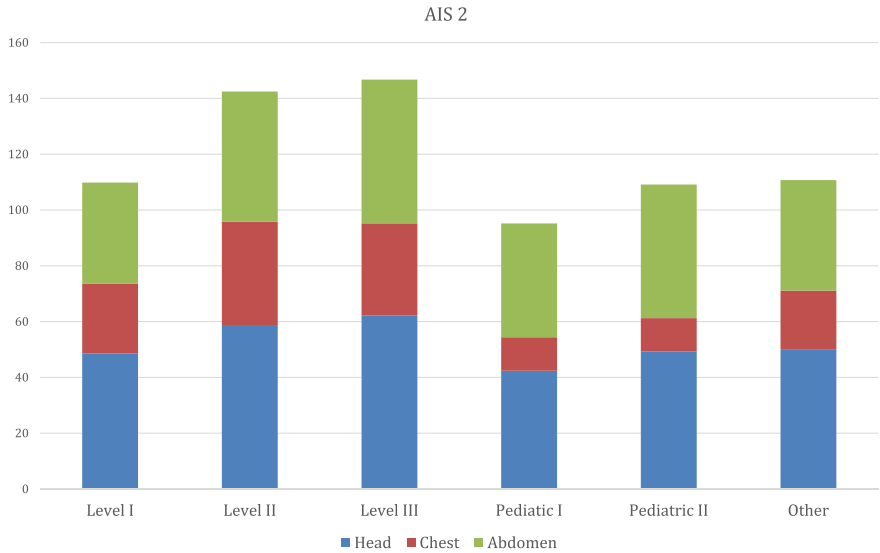

Fig. 6. Summative CT rates (%) for patients with moderate injuries by trauma center designation.

Table 5
Logistic regression: patients presenting without identifiable injury by trauma center designation.

Verification level	Relative Rate (standard error) AIS = 0		
	Head	Chest	Abdomen
Adult/Combined Level 1	1.0	1.0	1.0
Adult/Combined Level2	0.85(0.02)*	0.97(0.04)	1.04(0.3)
Level 3	1.08(0.04)	1.25(0.09)*	1.45(0.86)*
Unaccredited/Other	1.09(0.02)*	1.17(0.03)*	1.08(0.22)*
Pediatric Level 1	1.29(0.03)*	0.99(0.03)	1.03(0.02)
Pediatric Level 2	1.34(0.07)*	1.31(0.07)*	1.37(0.06)*

* $p < 0.05$.

we suspect the impact of this variable is low, however it is a potential confounder and difficult to quantify. Finally, we did not assess the impact of alternate forms of imaging such as plain films and MRI.

4. Conclusion

Children sustaining minor traumatic injuries are frequently imaged with CT scans which are unlikely to change therapy. This analysis of minor injuries, as defined by the retrospectively applied AIS score, reveals that many pediatric trauma patients are receiving more head, abdominal and thoracic CT scans than their injuries warrant. This is more common in adult and combined adult/pediatric trauma centers than stand-alone pediatric centers. The perceived inability of some centers to safely observe a pediatric patient may limit the ability to forego unnecessary imaging in these locations. However, these results also highlight the importance of establishing protocols to limit the amount of radiation to the minimum necessary exposure at all trauma centers participating in the care of children. Further, these data support the ongoing need to develop and inform all centers regarding evidence-based guidelines to direct imaging practices.

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