Comparison of Diagnostic Imaging Patterns Between Pediatric and Adult Trained Physicians in Adolescent Trauma Activations

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Objectives: The aim of this study was to investigate differences in utilization of diagnostic imaging between the adult and pediatric trauma teams when caring for adolescent trauma patients.

Methods: This was a retrospective observational study from 2015 to 2019 comparing pediatric trauma team activations for patients ages 12 to 14 and adult trauma team activations for patients ages 15 to 17 at a single institution verified as both a level I adult and a level I pediatric trauma center. Data were collected from a prospective trauma registry and manual chart review of the electronic medical records. The primary outcome was the frequency of whole body computed tomography (WBCT) and computed tomography (CT) imaging of individual body regions.

Results: We identified 191 adult and 100 pediatric trauma team cases, with similar proportions transferred from outside hospitals (40% vs. 43%). Among patients presenting directly from the scene, WBCT use was significantly higher in the adult trauma team group (64% vs. 12%; RR: 5.21; 95% CI: 2.57-10.58), as was CT of all individual body regions. For transferred patients, the adult trauma team more often performed WBCT and individual CT scans, excluding head CT. CT imaging rates before transfer did not differ between groups. No significant differences were observed in injury severity scores, altered mental status, length of stay, or missed injuries.

Conclusions: Among adolescents with similar injury severity, the adult trauma team more frequently utilizes WBCT and regional CT than the pediatric team. However, CT use before transfer from outside hospitals without dedicated pediatric trauma teams was similar across age groups.

Key Words: pediatric trauma, adolescent trauma, computed tomography, diagnostic imaging, trauma care utilization

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Worldwide, trauma is the leading cause of death in children and young adults ages 15 to 24 and the second most common cause of death for children ages 10 to 14.[1] Computed tomography (CT) scans are commonly utilized as the primary diagnostic strategy to identify or rule out serious injuries in trauma patients. Observational studies have shown an association between the use of whole body CT imaging (WBCT) and decreased mortality when compared with selective CT scanning in adult trauma patients[2–5] but have failed to show a decrease in mortality in children.[6,7] A more recent randomized control trial, the REACT-2 by Sierink et al[8] did not demonstrate a decrease in mortality from immediate WBCT scanning compared with selective imaging in adult trauma patients. Prior studies have shown less frequent utilization of WBCT in adolescent patients seen at pediatric trauma centers compared with adult trauma centers.[9,10] A recent single-center study reported that pediatric emergency medicine physicians ordered fewer CT scans on trauma patients compared with emergency medicine physicians.[11] Another study noted that staffing a community emergency department with pediatric emergency physicians lead to decreased frequency of head CTs for pediatric trauma patients.[12]

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Importance

It is widely believed that radiation from medical imaging may lead to a small but significant increase in risk of cancer over the lifetime of a patient. This risk is presumed greater in children.[13] Unnecessary CT scans increase radiation exposure, increase cost, and have the potential to cause delays for other patients in need for urgent CT imaging, while underutilization can result in missed or delayed diagnosis of important injuries. No prior studies have investigated differences in utilization of diagnostic imaging between adolescents managed by the adult and pediatric trauma teams, respectively, within one institution.

Goals of This Investigation

In the present study, we investigate differences in utilization of diagnostic imaging between the adult and pediatric trauma teams at the same institution when caring for adolescent trauma patients and the impact on length of stay, rates of missed injuries and unplanned readmissions. We hypothesized that a difference exists in the utilization of imaging in adolescent trauma patients between the adult and pediatric trauma teams, regardless of injury severity.

METHODS

Study Design and Setting

This was a retrospective observational study comparing pediatric trauma team activations for patients ages 12 to 14 and adult trauma team activations for patients ages 15 to 17 at a single hospital in the United States, verified as both a level I adult trauma center and a level I pediatric trauma center. The trauma team is activated if a case meets specific predetermined criteria. The response is a tiered system where the highest acuity cases are activated as "level red" and intermediate acuity cases as "level yellow." Low acuity trauma patients that do not meet the predetermined criteria are assigned "level green" and the trauma team is not activated. Trauma patients younger than 15 years of age are managed by the pediatric trauma team, while patients age 15 and older exclusively receive care from the adult trauma team. The pediatric trauma team is led by a pediatric surgeon and, most of the time, a pediatric emergency medicine physician, while the adult trauma team is led by a trauma surgeon and an emergency physician. A trauma surgeon may respond to level red pediatric activations to ensure a 15-minute response time window. Pediatric surgeons have a 30-minute response time. Response time can be up to 6 hours for trauma surgeons and pediatric surgeons for level yellow trauma patients.

Selection of Participants

Patients were selected for inclusion if they were 12 to 17 years old and triggered trauma team activation during the study period from January 1, 2015 to December 31, 2019. The 5-year study period was chosen with the aim of having enough patients to detect a 20% difference in rates of the primary outcome with 80% power. Patients arriving directly from the scene and transfers from outside hospitals were analyzed separately. Patients with burns or in cardiac arrest upon arrival were excluded.

Measurements

Demographic data, injury severity scores (ISS), Glasgow Coma Scale (GCS) score, trauma mechanism and length of stay (LOS) were obtained from the trauma center's prospectively maintained data registry.

Data on CT imaging studies that were performed were obtained by chart review of the medical imaging section of the electronic medical record (EMR). In addition, the ED note and the initial trauma service notes were manually reviewed for patients transferred from outside hospitals to identify CT imaging studies performed at referring hospitals before transfer. CT imaging of each body region (head, cervical spine, chest, abdomen, and pelvis) for patients transferred from outside hospitals was categorized into 4 categories: not performed, performed before transfer, performed at trauma center, and performed both before transfer and at trauma center. For patients arriving from the scene, only 2 categories were used: performed or not performed.

Missed injuries were also identified by manual chart review of the EMR. For admitted patients, both the tertiary trauma survey and the discharge summary were reviewed to identify injuries missed in the ED but later diagnosed during hospitalization. All notes in the EMR system from discharge until one month after the injury were reviewed manually for diagnosis of injuries that had been missed during the initial encounter.

The chart review process was performed by a single reviewer, a post-graduate year (PGY) 2 emergency medicine resident. The data were abstracted using an electronic data collection form (provided as Supplemental Document, Supplemental Digital Content 1, http://links.lww.com/PEC/B551). Missed injuries were classified as either injury to an extremity or injury to the head, neck, and torso. The head, neck, and torso injuries were further categorized as whether they had CT imaging of the involved body region during the initial trauma evaluation or not.

Outcomes

The primary outcome was the frequency of WBCT and CT imaging of individual body regions. WBCT was defined as CT of the head, cervical spine, chest, abdomen, and pelvis. Secondary outcomes were ISS, rates of altered mental status, proportion of patients admitted to the hospital, emergency department (ED) LOS, hospital LOS, intensive care unit (ICU) LOS, missed injuries and unplanned readmissions. Altered mental status was defined as having a GCS of <15. Missed injuries were defined as injuries that required treatment, repeat imaging, observation or referral and were first identified after admission to the hospital or after discharge from the ED.

Analysis

Continuous features were summarized with medians and interquartile ranges. Categorical features were summarized with frequency counts and percentages. Clinical features were compared between patient age groups using Wilcoxon rank-sum tests for continuous features and χ^2 tests or Fisher's exact tests for categorical features. For CT imaging performed, the relative risk with 95% confidence intervals was also provided. The relative risk was constructed for the older age group relative to the younger. SPSS version 23 software package (IBM Corporation, Armonk, NY) was used for statistical calculations.

The study was deemed exempt by the hospital's Institutional Review Board.

RESULTS

Characteristics of Study Subjects

The trauma registry database included 297 trauma team activations for patients ages 12 to 17 during the study period. After excluding patients with burns and those in cardiac arrest upon arrival, 291 patients were included in the study. There were almost twice as many adult trauma team activations (patients ages 15 to 17) compared with pediatric trauma team activations (patient ages 12 to 14).

Table 1 summarizes patient demographics, rates of transfers from outside hospitals, mode of transport and mechanism of injury. In all, 120 patients were transferred from outside hospitals and the proportion of transfers were similar in both adult and pediatric trauma team activations (40% vs. 43%). Five percent of pediatric trauma team activations and 10% of adult trauma team activations were from penetrating injuries. Car crashes were the most common mechanism of injury for the adult trauma team activations, while crashes from using uncaged motorized vehicles [all-terrain vehicles (ATVs), motorcycles, dirt bikes, and snowmobiles] were the most common mechanism in pediatric trauma team activations.

Main Results

In patients presenting to the trauma center directly from the scene, WBCT was more frequently utilized by the adult trauma team compared with the pediatric trauma team (64% vs. 12%; RR: 5.21; 95% CI: 2.57-10.58). All individual body regions were more frequently imaged by the adult trauma team with the greatest difference was seen in the use of chest CT (73% vs. 12%; RR 5.93; 95% CI 2.94-11.97). Overall, 84% of patients managed by the adult

TABLE 1. Characteristics of the Study Subjects

	Adult Trauma Team Age 15-17 (N = 191)	Pediatric Trauma Team Age 12-14 (N = 100)
Age, y		
Median (Q1, Q3)	16 (15, 17)	13 (12, 14)
Range	15-17	12-14
Sex, n (%)		
Male	136 (71)	79 (79)
Female	55 (29)	21 (21)
Race, n (%)		
White	160 (84)	90 (90)
Non-White	31 (16)	10 (10)
Hospital transfer, n (%)	77 (40)	43 (43)
Mode of transport, n (%)		
Air EMS	70 (37)	32 (32)
Ground EMS	87 (46)	43 (43)
Private vehicle	34 (18)	25 (25)
Injury mechanism, n (%)		
Car crashes	73 (38)	10 (10)
Car crashes with restraint	38 (52)	4 (40)
Uncaged motorized vehicles*	64 (34)	46 (46)
Sport injuries	12 (6)	12 (12)
Fall from heights	3 (2)	10 (10)
Bicycle	6 (3)	7 (7)
Pedestrian hit by a vehicle	5 (3)	3 (3)
Gunshot wound	4 (2)	3 (3)
Stab wound	9 (5)	1 (1)
Other	15 (8)	8 (8)
Injury type, n (%)		
Penetrating	19 (10)	5 (5)
Blunt	172 (90)	95 (95)

*Uncaged motorized vehicles include all-terrain vehicles (ATVs), motorcycles, dirt bikes and snowmobiles.

trauma team underwent CT imaging compared with 47% of pediatric trauma team patients (RR: 1.78; 95% CI: 1.34-2.36) (Table 2).

In patients transferred from outside hospitals, WBCT and CT of all individual body regions were more frequently performed at the trauma center in patients managed by the adult trauma team compared with patients managed by the pediatric trauma team. For head CT, the difference did not reach statistical significance. Rates of WBCT imaging and CT of individual body regions at outside hospitals before transfer were similar between the two age groups (Table 3).

Injury severity scores were similar between the age groups, both for patients arriving directly from the scene and transferred from outside hospitals (Fig. 1 and Table 4). No significant difference was found between the two groups with regard to rates of altered mental status (GCS < 15), pulse rate, systolic blood pressure, ED LOS, hospital LOS, ICU LOS, and proportion of patients admitted to the hospital (Table 4).

Six patients managed by the adult trauma team presented with SBP ≤ 90 mm Hg, of whom 5 (83%) underwent WBCT. In comparison, 4 patients managed by the pediatric trauma team had SBP ≤ 90 mm Hg, with one (25%) undergoing WBCT. Rates of WBCT did not vary with activation level (yellow vs. red).

For the pediatric trauma team activations, a pediatric surgeon was present at some point during the trauma resuscitation in 78% of cases and was present before the patient's arrival in 33% of the cases. Sixty percent of pediatric trauma team activations were staffed by pediatric-trained emergency physicians, while the remaining 40% were staffed by emergency physicians without pediatric subspecialty training. Excluding patients with WBCT performed at outside hospitals, pediatric emergency physicians performed WBCT in 4 of 53 cases (8%) compared with 5 of 35 cases (14%) for emergency physicians ($P = 0.51$). A pediatric surgeon was present at the time the scan was ordered in 6 of 9 WBCT cases (67%) and present at some point during the trauma resuscitation in all 9 cases.

The median time from patient arrival to CT order was 7 minutes (IQR: 2.5 to 13 min) in adult trauma team activations and 11 minutes (IQR: 8 to 16 min) for pediatric trauma team activations ($P < 0.001$). One pediatric and six adult trauma team activations had CT orders placed more than 1 hour after patient arrival.

There were 21 transfer patients who had repeat CT imaging at the receiving trauma center. Reasons for repeat imaging were intracranial hemorrhage with need for interval imaging (8 cases), lack of thoracic and lumbar spinal reconstructions (6 cases), need for oral contrast to evaluate for bowel injury (1 case), images from the outside hospital not available (3 cases) or of inadequate quality (2 cases). In one case, there was a repeat CT of the cervical spine for no apparent reason.

Missed Injuries or Unplanned Readmissions

We identified 8 patients with missed injuries diagnosed during the 1-month follow-up period. Five of these were extremity fractures. A case of tooth avulsion was missed

TABLE 2. CT Imaging Performed for Patients Presenting Directly From the Scene

	Adult Trauma Team Age 15-17 (N = 114)	Pediatric Trauma Team Age 12-14 (N = 57)	Relative Risk (95% CI)	*P*
Any CT performed, n (%)	96 (84)	27 (47)	1.78 (1.34-2.36)	< 0.001
Whole Body CT, n (%)	73 (64)	7 (12)	5.21 (2.57-10.58)	< 0.001
Head CT, n (%)	87 (76)	22 (39)	1.98 (1.40-2.79)	< 0.001
Cervical spine CT, n (%)	87 (76)	16 (28)	2.72 (1.77-4.17)	< 0.001
Chest CT, n (%)	83 (73)	7 (12)	5.93 (2.94-11.97)	< 0.001
Abdomen/pelvis CT, n (%)	82 (72)	10 (18)	4.10 (2.31-7.28)	< 0.001

CT indicates computed tomography; WBCT, whole body computed tomography.

TABLE 3. CT Imaging Performed for Patients Transferred to the Trauma Center From Outside Hospitals

		Adult Trauma Team Age 15-17 (N = 77)	Pediatric Trauma Team Age 12-14 (N = 43)	Relative Risk (95% CI)	P
Any CT performed, n (%)	Trauma center	52 (68)	19 (44)	1.53 (1.06-2.21)	0.02
	Transferring hospital	38 (49)	28 (65)	0.76 (0.55-1.04)	0.14
WBCT, n (%)	Trauma center	26 (34)	2 (5)	7.26 (1.81-29.12)	0.001
	Transferring hospital	18 (23)	11 (26)	0.91 (0.48-1.75)	0.96
	Combined*	9 (12)	1 (2)	5.03 (0.66-38.35)	0.09
Head CT, n (%)	Trauma center	40 (52)	15 (35)	1.49 (0.94-2.36)	0.11
	Transferring hospital	33 (43)	26 (60)	0.71 (0.50-1.01)	0.10
Cervical spine CT, n (%)	Trauma center	33 (43)	8 (19)	2.30 (1.17-4.53)	0.01
	Transferring hospital	32 (42)	21 (49)	0.85 (0.57-1.28)	0.56
Chest CT, n (%)	Trauma center	40 (52)	5 (12)	4.47 (1.91-10.47)	< 0.001
	Transferring hospital	19 (25)	10 (23)	1.06 (0.54-2.07)	1.00
Abdomen/pelvis CT, n (%)	Trauma center	41 (53)	10 (23)	2.29 (1.28-4.10)	0.003
	Transferring hospital	22 (29)	12 (28)	1.02 (0.56-1.86)	1.00

*CT scan of at least one body region was completed at an outside hospital; the rest of the scans were completed at the trauma center.
CT indicates computed tomography; WBCT, whole body computed tomography.

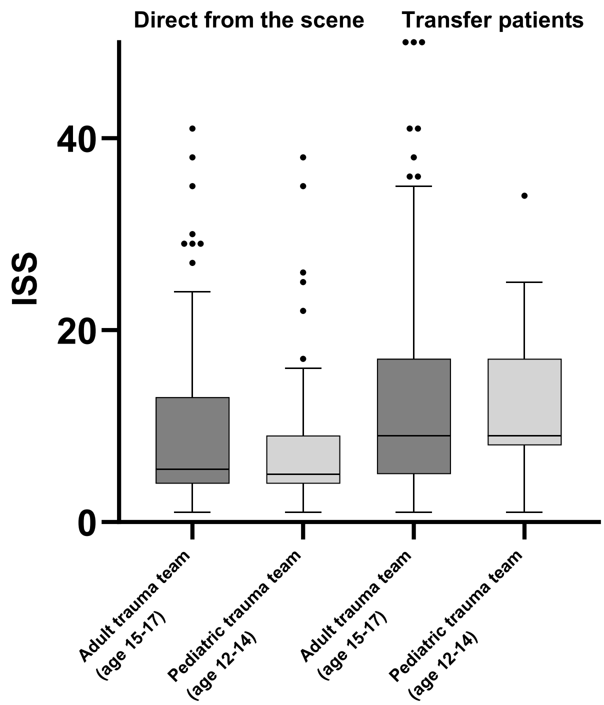

FIGURE 1. Injury severity scores (ISS) for patients arriving directly from the scene and for transfer patients.

despite the patient undergoing a head CT. Two other cases (diaphragm rupture with herniation of the stomach and traumatic ventricular septal defect) underwent CT imaging of the torso, but at the time of imaging, the injuries were not apparent on CT. We did not find any head, neck or torso injuries that were missed because a CT scan was not ordered during ED evaluation. No readmissions occurred due to injuries not identified during the initial trauma evaluation.

DISCUSSION

At our institution, WBCT is much less frequently used in adolescent trauma patients managed by the pediatric trauma team when compared with adolescent trauma patients managed by the adult trauma team, despite having similar injury severity scores. The results of this study are in line with the results of studies comparing rates of WBCT imaging of adolescent trauma patients between adult and pediatric trauma centers.[9,10] We demonstrate that this pattern can occur within an institution that is verified as both a level I adult and a level I pediatric trauma center.

Higher rates of CT imaging can increase the detection of small or clinically insignificant injuries, artificially raising the ISS. This can bias comparisons by making the group with more CT scans appear to have more severe trauma. In our study, however, ISS did not differ significantly between age groups, indicating that the higher CT utilization in older adolescents was not due to greater injury severity.

For patients transferred to the trauma center from outside hospitals, there was no difference in the rates of WBCT or CT imaging of individual body regions performed before transfer between the age groups. The referring hospitals do not have a dedicated pediatric trauma

TABLE 4. Secondary Outcomes

	Direct From the Scene			Transfer Patients		
	Adult Trauma Team Age 15-17 (N = 114)	Pediatric Trauma Team Age 12-14 (N = 57)	*P*	Adult Trauma Team Age 15-17 (N = 77)	Pediatric Trauma Team Age 12-14 (N = 43)	*P*
ISS, median (Q1, Q3)	5.5 (4, 13)	5 (4, 9)	0.14	9 (5, 17)	9 (8, 15.5)	0.63
Major trauma, n (%)*	22 (19)	7 (12)	0.35	20 (26)	11 (26)	1.00
GCS <15, n (%)	15 (13%)	4 (7%)	0.34	18 (23%)	6 (14)	0.32
ED LOS, min, median (Q1, Q3)	135.5 (93, 219)	168 (133, 194)	0.06	110 (67, 158)	90 (55, 134.5)	0.18
Hospital LOS, d, median (Q1, Q3)	1 (1, 3.5)	2 (1, 4)	0.82	2 (1, 4.5)	2 (1, 3)	0.35
ICU LOS, d, median (Q1, Q3)	2 (1, 2)	6 (1, 8.5)	0.29	1 (1, 4)	1 (1, 1.5)	0.14
Hospital admission, n (%)	82 (72)	33 (58)	0.10	68 (88)	41 (95)	0.32
Pulse rate, median (Q1, Q3)	94 (80, 110)	92 (81, 110)	0.79	93 (81, 108)	99 (86, 114)	0.13
SBP median (Q1, Q3)	130 (118, 140)	130 (120, 140)	0.63	128 (118, 138)	122 (118, 132)	0.21

*Major trauma defined as ISS >15.

ED indicates emergency department; GCS, Glasgow Coma Scale; ICU, intensive care unit; ISS, injury severity score; LOS, length of stay; SBP, systolic blood pressure.

team, but have the same team taking care of trauma patients regardless of their age. These findings suggest that the trauma team's composition, training background, and the guidelines it follows may influence decisions about advanced imaging more than patient age, injury extent, or nature.

Adult trauma teams care for patients spanning many decades, including geriatric patients that have greater mortality, higher rates of complications from injuries (eg, rib fractures) and less reliable vital sign changes compared with younger patients, thus justifying more liberal use of advanced diagnostic imaging.[14–16] We speculate that the increased utilization of CT imaging in the 15 to 17 year old cohort can be largely explained by "mis"classification of these patients as "adult" leading to activation of the adult trauma team, and a resultant default to the common practice of liberal CT imaging often employed in evaluation of older trauma patients.

Our institution does have guidelines on head imaging in trauma patients younger than 15 years of age based on the Pediatric Emergency Care Applied Research Network (PECARN) head injury algorithm. These guidelines have been studied and validated in patients younger than 18 years of age, but have not been formally implemented for the 15- to 17-year age group at our institution. Similarly, the pediatric trauma team follows a guideline for evaluation of potential cervical spinal injuries that is not used by the adult trauma team. The pediatric cervical spine protocol favors utilization of plain films over CT scans when clinical clearance is not possible for all but select patients. Developing unified imaging guidelines for trauma teams managing anatomically and physiologically similar patients could help reduce variation in imaging practices. A robust review and performance improvement process to assess the efficacy of these guidelines in reducing unnecessary imaging without sacrificing significant injury detection would also be an important part of the intervention.

One argument for the liberal use of cross-sectional imaging is to expedite the workup and eliminate the need for ED observation, thereby improving disposition decisions and decreasing ED LOS. In our study, admission rates, ED LOS and hospital LOS were not different between the two groups, suggesting that at our institution, CT imaging does not significantly influence the need for observation in the ED or in the hospital.

Missed injuries identified during the 1-month follow-up period were rare in our study. No injuries were missed as a result of not obtaining CT imaging at our trauma center. Most of the missed injuries were extremity fractures, which highlights the importance of careful clinical examination of the extremities and obtaining the appropriate radiographs before disposition of the trauma patient.

Limitations

The small sample size of the study limits the conclusions that can be made about missed injuries. The small sample size and mix of responders to the pediatric activations challenge the ability to separate out activations with pediatric trauma surgeons vs. general trauma surgeons and pediatric emergency physicians versus general emergency physicians.

Because this study was retrospective, key clinical details necessary to determine whether CT scans were clinically indicated or aligned with established guidelines and clinical decision tools were frequently incomplete or missing from the medical record. As a result, we were unable to assess the appropriateness of imaging or evaluate guideline adherence.

Demographic data, ISS, GCS score, trauma mechanism and length of stay (LOS) were obtained from the trauma center's data registry, which is prospectively coded by staff that were unaware of the study hypothesis, which limits the risk of bias. The data on CT imaging and missed injuries were abstracted by manual chart review of the EMR by a single reviewer. The data were abstracted using an electronic data collection form, but the form was not pilot-tested before being used. The data abstractor was a physician who used the EMR system on a daily basis but did not receive any special training before abstracting the data. There is a potential for abstractor bias as the data abstractor was one of the study investigators and was not blinded to the study hypothesis. However, the objectivity of the data on CT imaging (either performed or not performed) decreases the risk of bias.

The imaging section of the electronic medical record does always contain information on all imaging studies performed at the trauma center. Therefore, there should not be any missing data on imaging studies performed at the trauma center. It is possible that information on imaging performed at an outside hospital before transfer could have been missed. With regards to missed injuries, if patients presented with missed injuries to outside hospitals that do not share the EMR system, they would not have been identified by the chart review process.

Although we report rates of altered mental status as having GCS < 15, our data did not include clinical assessment of intoxication, which could influence the decision to obtain CT imaging. The mechanism of injury was different between patients managed by the adult trauma team and patients managed by the pediatric trauma team. In addition, details of the injury mechanisms, such as the speed of the vehicle involved in a collision or the height of a fall, were not included in our data. If patients managed by the adult trauma team had more dangerous mechanism of injuries that could account for at least part of the difference in rates of CT imaging observed between the two groups.

The study was limited to a single institution verified as both a level I adult and a level I pediatric trauma center that serves a large catchment area, which does not include a major metropolitan environment and therefore may not be generalizable to other trauma centers. Further studies are warranted to identify if the same results apply outside of this single institution. Future studies would ideally be prospective and multicenter and should try to further elucidate if the difference in practice is based on the trauma team training background, the guidelines that the teams follow or by difference in injury mechanism, clinical presentation and injury patterns between the groups.

CONCLUSIONS

Our study shows that, among adolescent trauma patients with similar ISS, the adult trauma team (ages 15 to 17) more frequently utilizes WBCT and CT imaging of individual body regions than the pediatric trauma team (ages 12 to 14) at the same institution. For patients transferred from outside hospitals without a dedicated pediatric trauma team, no difference exists in the use of CT imaging before transfer between the two age groups.

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