Computed Tomography for Minor Head Injury: Variation and Trends in Major United States Pediatric Emergency Departments

Rebekah Mannix, MD, MPH[1], William P. Meehan, MD[1,2], Michael C. Monuteaux, ScD[1], and Richard G. Bachur, MD[1]

Objectives To investigate the variation and trends in neuroimaging in children examined for minor head injury at major US pediatric emergency departments.

Study design We conducted a retrospective study of children <19 years of age with mild head injury who were examined and discharged home from the emergency department at 40 pediatric hospitals from 2005 to 2009 by using the Pediatric Health Information Systems database. Variation in computed tomography (CT) rates between hospitals was assessed for correlation with hospital-specific rates of intracranial hemorrhage, admission, and return visits. Age-adjusted trends in CT use were calculated for the 5 years.

Results In the 5 years, the median rate of imaging for minor head injured patients was 36% (IQR, 29%-42%; range, 19%-58%). There was no correlation between institution-specific rates of CT imaging and intracranial hemorrhage, admission, or return-visit rates. Age-adjusted rates of CT use decreased in the 5-year period (OR, 0.94; 95% CI, 0.92-0.97; $P < .001$).

Conclusions In this study, we found significant practice variation in CT use at pediatric hospitals examining children with minor head injury. These data may help guide national benchmarks for the appropriate use of CT imaging in pediatric patients with minor head injury. *(J Pediatr 2012;160:136-9)*.

Pediatric head trauma results in >650 000 emergency department (ED) visits and 64 000 hospitalizations in the United States every year.[1] However, although pediatric head injury is relatively common, pediatric traumatic brain injury (TBI) requiring neurosurgical intervention is far less frequent.[2,3] Although pediatric TBI can be readily diagnosed with computed tomography (CT), such evaluations carry a heavy public health burden of cost and radiation exposure.[4,5] Recently, efforts have been made to develop reliable clinical decision rules for mild TBI,[2,6,7] but it remains uncertain how these rules will affect clinical practice. Earlier studies have described significant practice variation in the use of imaging after pediatric head injury, with rates ranging from 5% to 70%.[6,8,9] There is some evidence to suggest that pediatric EDs have lower rates of diagnostic imaging than general EDs.[10] The goal of this study was to investigate CT use in children with minor head injury discharged home after examination at pediatric hospitals.

Methods

We used the Pediatric Health Information System (PHIS) database, an administrative database maintained by Child Health Corporation of America (Shawnee Mission, Kansas). The PHIS database (data from the National Association of Children's Hospitals and Related Institutions, Alexandria, Virginia) includes patient-level data from 40 hospitals that are located in 17 of the 20 major metropolitan areas in the United States and that account for >70% of all freestanding children's hospitals in the United States. Participating hospitals electronically submit detailed patient data, including demographics (age, sex, race/ethnicity), payer source, episode of care information (admission date, disposition, repeat hospitalization), as many as 21 *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) diagnosis codes, and resource use information, including imaging procedure codes, to the database. Maintaining and validating the quality of the PHIS data is a joint effort among Child Health Corporation of America, the participating hospitals, and Thomson Reuters (the data warehouse vendor for PHIS). Validity and reliability checks of the data are performed. Data are included in the database only when classified errors occur in <2% of a hospital's quarterly data.

The study was approved by the institutional review board and the administrators of the PHIS database. In accordance with PHIS policies, the identity of the institutions will not be reported.

CT	Computed tomography
ED	Emergency department
ICD-9-CM	*International Classification of Diseases, Ninth Revision, Clinical Modification*
PHIS	Pediatric Health Information System
TBI	Traumatic brain injury

From the [1]Division of Emergency Medicine, Department of Medicine, and [2]Division of Sports Medicine, Department of Orthopedics, Children's Hospital Boston, Boston, MA

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Study Population

In a 5-year study period (2005-2009), we identified patient visits for minor head injury in children <19 years old discharged home from the ED with the ICD-9-CM codes for skull fracture (800.xx to 804.xx), concussion (850.xx), other brain injury (854.xx), and head injury not otherwise specified (959.01). Because the database does not include any clinical data, discharge from the ED was used as a proxy for our definition of "minor" head injury. For comparison purposes, we ascertained rates of intracranial hemorrhage (851.xx to 853.xx) for all patients (discharged and admitted) treated at the pediatric hospitals in the 5-year period. These patients were classified as having "significant" head injury.

Outcome

The primary outcome was CT imaging of the head in patients with minor head injury. The secondary outcome was a repeat ED visit within 1 week.

Analysis

We used simple statistics to describe the hospital-specific rates of minor head injury, significant head injury, and the use of diagnostic studies in patients with minor head injury. Because the decision to obtain a head CT might be balanced against admission for observation, we tested the correlation between hospital-specific rate of imaging for patients with minor head injury and hospital-specific admission rates for the same patient population. To test for trends of age-adjusted imaging use with time, we estimated logistic regression models with imaging rate as the dependent variable and year (2005-2009, inclusive) and categorical age as the independent variables.

Also, for each hospital, we calculated the rate of return visits for head injury diagnoses, including significant head injury within 1 week of an index visit, in which an initial diagnosis consistent with our definition of minor head injury was made (ie, "bounce" rate). We estimated a linear regression model with hospital-specific bounce rate as the dependent variable and rate of imaging as the independent variable, weighted by the hospital-specific number of patients with minor head injury. In this model, each hospital served as an observation (n = 40), and each observation was weighted by the hospital's total number of discharged patients. All statistical tests were two-tailed, and the alpha was set at 0.05.

Results

Of the 8 976 378 pediatric ED visits from 2005 to 2009, 161 319 patients (1.8%) were discharged home with minor head injury, and 6494 patients (0.07%) received a diagnosis of significant head injury. Hospital-specific rates of minor head injury and significant head injury ranged from 0% to 3.1% and 0.02% to 1.03%, respectively (**Table I**; available at www.jpeds.com). In the 5 years, the median rate of imaging for patients with minor head injury was 36% (IQR, 29%-42%; range, 19%-58%; **Figure 1**). The hospital-specific rate of imaging for patients with minor head injury was not associated with hospital-specific admission rates for the same patient population ($r = -0.06$; $P = .71$). There was no significant association between institution-specific rates of patients with significant head injury and the rate of CT use in patients with minor head injury ($r = 0.13$; $P = .44$, weighted by total ED volume per hospital; **Figure 2**) nor was there an association between institution-specific CT rates in patients with a minor head injury and return visits within 1 week after initial assessment ($r = 0.10$; $P = .55$, weighted by total ED volume per hospital; **Figure 3**).

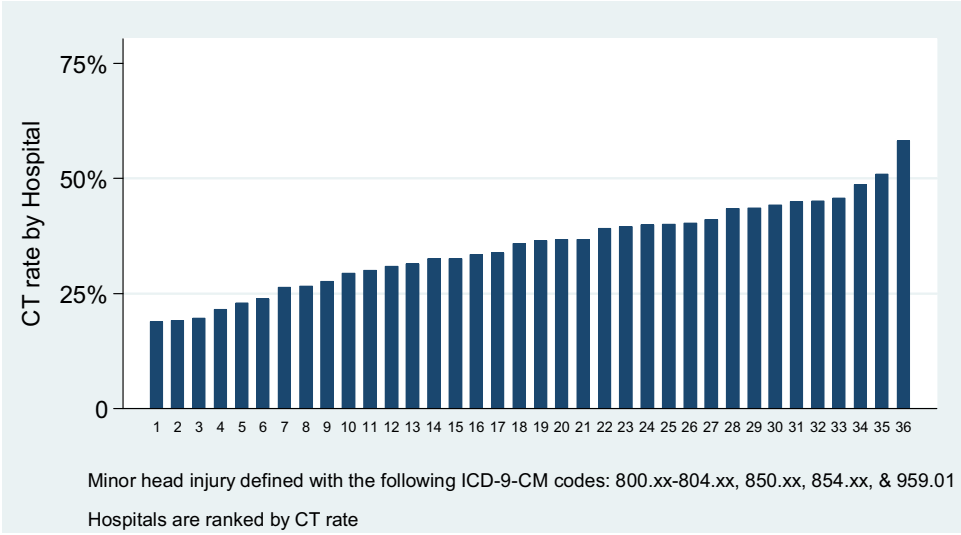

Figure 1. Rates of CT in pediatric patients with minor head injury discharged from the ED (n = 161 319) across a sample of pediatric hospitals in the US from 2005 to 2009.

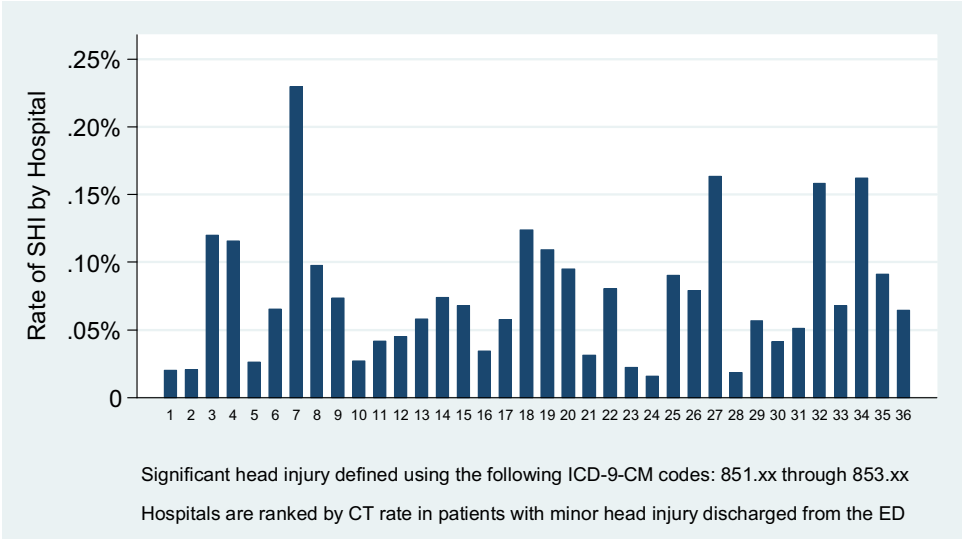

Figure 2. Significant head injury as a proportion of all ED visits across a sample of pediatric hospitals in the US from 2005 to 2009.

Rates of imaging were greatest in teenagers (48% for teenagers compared with 35% in infants, 28% in preschool-age children, and 37% in school-age children; **Table II**). Age-adjusted rates of CT decreased in the study period (adjusted OR, 0.94; 95% CI, 0.92-0.97; test of linear trend $P < .001$), but there was no evidence that the association between rates of CT and year differed by age ($P = .401$).

Discussion

Our study demonstrates that there is significant variation in rates of CT after minor head injury in children, even in major pediatric EDs. Although mild head injury is frequent in children, there is still controversy and variability in the use of neuroimaging for head injury. This is the first large-scale study to demonstrate variability and recent trends in CT use for minor head injury at major US pediatric EDs.

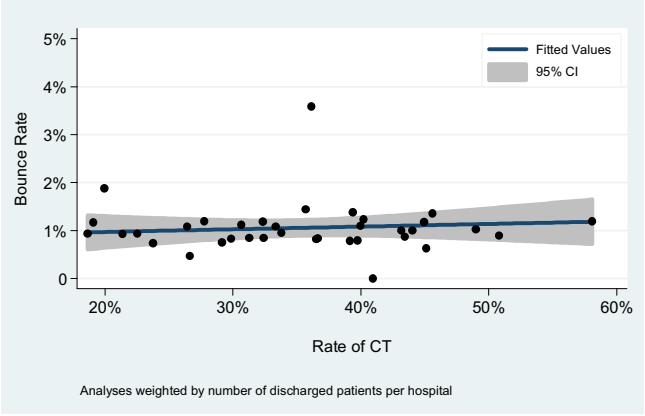

Figure 3. Association between rates of imaging of pediatric patients discharged from the ED with minor head injury (n = 159 322) and rates of subsequent ED visits across a sample of pediatric hospitals in the US from 2005 to 2009.

Unlike earlier studies looking at overall rates of CT use, we found a trend to decreased age-adjusted head CT use in the 5 years of our study.[8,11] Although not studied, possible explanations for this encouraging trend may be heightened awareness of the potential long-term consequences of radiation exposure and the adoption of more judicious recommendations supported by recent decision rules.[2,3,7] In this regard, our findings are similar to those of earlier studies, which demonstrate lower rates of imaging at pediatric EDs versus general EDs.[8,10] The rates found in our study are similar to those reported by Kuppermann et al, who found in a large prospective cohort that 35.3% of pediatric patients with mild TBI undergo head imaging.[2] The data in our study may be useful for national benchmarking of CT use for minor head injury.

However, our study shows that there is still significant improvement to be made, even at pediatric institutions. We found that despite relatively low rates of identified intracranial hemorrhage, CT rates for patients with minor head injury at pediatric hospitals ranged from 19% to 58%. This type of variation in management has been described in pediatric EDs compared with general EDs. Until now, however, such variation has not been described in pediatric EDs themselves. It is unclear how hospital-specific factors, such as case mix, relate to this variability. The rates of intracranial hemorrhage do not appear to correlate with the rates of imaging across institutions.

Another area for improvement is in the imaging of teenagers. It is unclear why neuroimaging is increased in this age group, even after controlling for injury severity by

Table II. Rates of imaging studies in pediatric patients with minor head injury discharged from the ED (n = 161 319) across a sample of pediatric hospitals in the US from 2005 to 2009, stratified by age

	Rate (95% CI) of CT					
	2005	2006	2007	2008	2009	Total
<1 year	35.4% (33.9-36.9)	37.9% (36.5-39.3)	35.8% (34.5-37.1)	35.1% (33.8-36.3)	32.2% (31.1-33.4)	35.0% (34.4-35.6)
1-5 years	28.5% (27.6-29.4)	30.3% (29.4-31.2)	29.4% (28.6-30.2)	27.1% (26.4-27.9)	24.7% (24.1-25.4)	27.6% (27.3-28.0)
6-11 years	39.6% (38.3-41.0)	39.9% (38.6-41.2)	39.5% (38.4-40.7)	37.2% (36.1-38.4)	33.3% (32.4-34.3)	37.4% (36.9-37.9)
≥12 years	49.2% (47.8-50.6)	49.8% (48.5-51.0)	50.0% (48.8-51.2)	47.4% (46.2-48.6)	44.7% (43.7-45.7)	47.9% (47.3-48.4)
Total*	36.5% (35.9-37.1)	38.0% (37.4-38.6)	37.2% (36.6-37.7)	35.0% (34.5-35.5)	32.1% (31.7-32.5)	35.4% (35.1-35.6)

Minor head injury defined with these *ICD-9-CM* codes: 800.xx-804.xx, 850.xx, 854.xx, and 959.01.
*Test for linear trend of time on CT rates, adjusting for age: OR (95% CI) = 0.94 (0.92-0.97), $P < .001$.

analyzing only patients who were discharged with presumed minor head injury. We hypothesize that ease of imaging in the teenage population (ie, lack of need for sedation or restraint) may explain part of this phenomenon. The mechanisms of injury in this age group may be more concerning, which may also influence the decision to obtain a head CT.

Our study has several limitations. First, data are limited to tertiary-care, freestanding children's hospitals that are part of the PHIS system. Thus, our conclusions may not be generalizable to other academic or community hospitals. However, because of the variability described in earlier studies of head CT use in pediatric head injury, this small subset of hospitals likely provides important data for national benchmarks. Second, there may be important confounders that influence the variability of imaging rates in the PHIS hospitals, although we can only speculate on the nature of these confounders. Third, our diagnosis classifications rely on the ICD-9-CM coding system, which has the potential for inaccuracy. Fourth, our definition of minor head injury (on the basis of discharge from ED) should not be equated with other clinical studies that use mechanisms of injury or neurologic findings or scores to classify the head injury as minor. However, we believe this definition of mild is more conservative than those used in recent studies clinical studies that also include admitted patients. Although our definition of TBI may significantly underestimate the proportion of patients with mild TBI who both undergo CT evaluation and who have findings on CT, in the absence of clinical measures we feel our approach is most conservative and avoids misclassifying patients as having mild TBI when they had more significant injuries. Fifth, although we looked at return visit rates to the PHIS hospitals, we do not have data on whether patients went to other hospitals for a second visit. However, the PHIS hospitals represent the major pediatric centers for many regions and therefore are more likely the referral centers for neurosurgical emergencies, even when the child was initially seen at a different local hospital. Finally, the database does not include clinical outcome. Therefore, we were unable to demonstrate the impact of imaging on head injury outcomes. However, by limiting our analysis to patients who were discharged, we suspect that outcomes were not fundamentally altered by the use of advanced imaging in this subset of pediatric patients with head injury. ■

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Reprint requests: Rebekah Mannix, MD, MPH, Children's Hospital Boston, 300 Longwood Ave, Boston, MA 02115. E-mail: Rebekah.Mannix@childrens.harvard.edu

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Table I. Imaging studies of patients presenting to the ED with head injury across a sample of pediatric hospitals in the US, 2005 to 2009

Hospital	Total ED visits	Minor head injury cases discharged from the ED	Percent of all ED visits (95% CI)		Significant head injury cases	Percent of all ED visits (95% CI)	
A	199 602	5011	2.5%	(2.4-2.6)	247	0.12%	(0.11-0.14)
B	284 008	7442	2.6%	(2.6-2.7)	329	0.12%	(0.10-0.13)
C	274 658	4603	1.7%	(1.6-1.7)	261	0.10%	(0.08-0.11)
D	322 018	4432	1.4%	(1.3-1.4)	219	0.07%	(0.06-0.08)
E	330 343	5652	1.7%	(1.7-1.8)	216	0.07%	(0.06-0.07)
F	313 778	9602	3.1%	(3.0-3.1)	283	0.09%	(0.08-0.10)
G	290 684	4350	1.5%	(1.5-1.5)	169	0.06%	(0.05-0.07)
H	297 695	8075	2.7%	(2.7-2.8)	171	0.06%	(0.05-0.07)
I	269 001	4656	1.7%	(1.7-1.8)	138	0.05%	(0.04-0.06)
J	218 177	3311	1.5%	(1.5-1.6)	75	0.03%	(0.03-0.04)
K	177 998	3517	2.0%	(1.9-2.0)	162	0.09%	(0.08-0.11)
L	202 541	3338	1.6%	(1.6-1.7)	221	0.11%	(0.09-0.12)
M	234 411	3314	1.4%	(1.4-1.5)	52	0.02%	(0.02-0.03)
N	186 536	1829	1.0%	(0.9-1.0)	77	0.04%	(0.03-0.05)
O	420 750	4699	1.1%	(1.1-1.1)	110	0.03%	(0.02-0.03)
P	388 803	6542	1.7%	(1.6-1.7)	176	0.05%	(0.04-0.05)
Q	377 602	6063	1.6%	(1.6-1.6)	244	0.06%	(0.06-0.07)
R	208 125	3085	1.5%	(1.4-1.5)	56	0.03%	(0.02-0.03)
S	238 032	5603	2.4%	(2.3-2.4)	135	0.06%	(0.05-0.07)
T	125 730	1534	1.2%	(1.2-1.3)	23	0.02%	(0.01-0.03)
U	298 005	4259	1.4%	(1.4-1.5)	239	0.08%	(0.07-0.09)
V	83 870	295	0.4%	(0.3-0.4)	137	0.16%	(0.14-0.19)
W	494 824	9159	1.9%	(1.8-1.9)	207	0.04%	(0.04-0.05)
X	263 864	3774	1.4%	(1.4-1.5)	195	0.07%	(0.06-0.08)
Y	23 144	0	0	NA	139	0.6%	(0.50-0.70)
Z	563 328	14 569	2.6%	(2.5-2.6)	382	0.07%	(0.06-0.07)
AA	169 992	3998	2.4%	(2.3-2.4)	35	0.02%	(0.01-0.03)
BB	76 584	216	0.3%	(0.2-0.3)	176	0.23%	(0.20-0.26)
CC	400 851	11 479	2.9%	(2.8-2.9)	125	0.03%	(0.03-0.04)
DD	65 788	270	0.4%	(0.4-0.5)	79	0.12%	(0.09-0.15)
EE	199 023	4974	2.5%	(2.4-2.6)	315	0.16%	(0.14-0.18)
FF	74 241	1087	1.5%	(1.4-1.6)	15	0.02%	(0.01-0.03)
GG	411 915	4446	1.1%	(1.0-1.1)	326	0.08%	(0.07-0.09)
HH	210 653	1783	0.8%	(0.8-0.9)	155	0.07%	(0.06-0.09)
II	43 180	298	0.7%	(0.6-0.8)	70	0.16%	(0.12-0.20)
JJ	155 434	3673	2.4%	(2.3-2.4)	152	0.10%	(0.08-0.11)
KK	27 691	0	0	NA	108	0.39%	(0.32-0.46)
LL	11 619	0	0	NA	34	0.29%	(0.19-0.39)
MM	23 065	0	0	NA	238	1.03%	(0.90-1.16)
NN	18 815	381	2.0%	(1.8-2.2)	3	0.02%	(0.00-0.03)
Summary*	8 976 378	161 319	1.8% (1.79-1.81)		6494	0.072% (0.071-0.074)	

Head injury defined with these ICD-9-CM codes: 800.xx-804.xx, 850.xx-854.xx, and 959.01.
Significant head injury defined with these ICD-9-CM codes: 851.xx-853.xx.
*Values represent the sum in all hospitals.