Objective To describe factors associated with computed tomography (CT) use for children with minor blunt head trauma that are evaluated in emergency departments.

Study design Planned secondary analysis of a prospective observational study of children <18 years with minor blunt head trauma between 2004 and 2006 at 25 emergency departments. CT scans were obtained at the discretion of treating clinicians. We risk-adjusted patients for clinically important traumatic brain injuries and performed multivariable regression analyses. Outcome measures were rates of CT use by hospital and by clinician training type.

Results CT rates varied between 19.2% and 69.2% across hospitals. Risk adjustment had little effect on the differential rate of CT use. In low- and middle-risk patients, clinicians obtained CTs more frequently at suburban and nonfreestanding children’s hospitals. Physicians with emergency medicine (EM) residency training obtained CTs at greater rates than physicians with pediatric residency or pediatric EM training. In multivariable analyses, compared with pediatric EM–trained physicians, the OR for CT use among EM-trained physicians in children <2 years was 1.24 (95% CI 1.04-1.46), and for children ≥2 years was 1.68 (95% CI 1.50-1.89). Physicians of all training backgrounds, however, overused CT scans in low-risk children.

Conclusions Substantial variation exists in the use of CT for children with minor blunt head trauma not explained by patient severity or rates of positive CT scans or clinically important traumatic brain injuries. (J Pediatr 2014;165:1201-6).
variation, and identify hospital, physician, and patient factors associated with variation. Understanding variation in CT use should help to implement strategies to reduce unwarranted CT use.

Methods

This was a planned secondary analysis of data from a prospective observational multicenter study of children with minor blunt head trauma conducted in PECARN. Pertinent methods for this analysis are summarized herein; the full details of the parent study have been published previously. This study was approved by the institutional review boards of all participating sites.

The parent study enrolled children from 25 EDs from June 2004 through September 2006. Eligible patients were seen within 24 hours of blunt head trauma and did not have neuroimaging obtained at outside hospitals before enrollment. We excluded patients with penetrating trauma, ventricular shunts, coagulopathies, brain tumors, or neurologic disorders that complicated clinical assessments. We defined patients with minor head trauma as those with Glasgow Coma Scale (GCS) scores of 14 or 15 on the initial ED evaluation.

ED physicians (faculty or fellows) completed standardized case report forms before obtaining CT results. Cranial CT scans were obtained at the discretion of the treating physicians after a complete history and physical examination. Hospital admission and subsequent management was also at the discretion of the treating physicians.

For hospitalized patients, site investigators reviewed medical records to obtain CT results and assess for ciTBIs. Standardized telephone interviews of guardians of patients discharged from the ED were completed 7-90 days after the ED visits, and, if the interview suggested a missed TBI, medical records and imaging results were reviewed to identify ciTBIs. If unable to contact the guardian, we reviewed medical records, trauma registries, and county morgue records to ensure no missed ciTBIs.

We defined a positive CT scan as any of the following: intracranial hemorrhage or contusion; cerebral edema; traumatic infarction; diffuse axonal injury; shearing injury; sigmoid sinus thrombosis; midline shift of intracranial contents or signs of brain herniation; diastasis of the skull; pneumocephalus; or skull fracture depressed by at least the width of the skull table.

We defined ciTBI as death from TBI, neurosurgery, endotracheal intubation for more than 24 hours for TBI, or hospital admission of 2 nights or longer duration associated with a positive CT. This definition was intended to exclude brief intubations to complete imaging or overnight admissions for minor CT findings.

PECARN hospital characteristics were obtained from a separately published network survey. We categorized sites as teaching or nonteaching (based on presence of residents in the ED >50% of the time), urban or suburban, and as freestanding or not-freestanding children’s hospitals. We categorized emergency faculty and fellows by their residency training or certification as Emergency Medicine (EM) residency alone, Pediatric residency alone (Pediatrics), Pediatric EM (PEM), Internal Medicine, Family Medicine, or Other. For the analysis, we considered clinicians with dual training or certification in EM and Pediatrics as part of the PEM group, and we combined Internal Medicine and Family Medicine physicians into the “other” category. If a resident, nurse practitioner, or physician’s assistant primarily evaluated the patient, we used the training or certification of the supervising physician.

Risk Stratification

We stratified each patient’s risk of ciTBI by using the clinical factors in the 2 age-specific PECARN prediction rules (one for children <2 years of age and the second for those 2-18 years old) derived and validated in the parent study. Using these risk factors, we categorized patients as low, middle, or high risk for ciTBI.

We classified patients with none of the PECARN risk factors in the age-specific prediction rules as low risk. We considered patients with GCS scores of 14, other signs of altered mental status, palpable skull fractures (for children <2 years of age), or signs of basilar skull fracture (for children 2 years or older) to be high risk. We classified all other patients as middle risk. Of note, the prediction rules were intended to identify low-risk patients for whom cranial CT scans can be obviated, not to identify patients for whom CT scans should be obtained. For purposes of the current study, however, we created high-, middle-, and low-risk strata to adjust for differences in severity case-mix of patients seen in different hospitals by different provider types.

Primary Outcome

The primary outcome measures for this study were as follows: (1) the rates of cranial CT scans obtained among the PECARN hospitals; and (2) the rates of obtaining CT scans by type of clinician training.

Statistical Analyses

We used descriptive statistics to summarize the data. We defined the CT rate as the number of CT scans divided by the number of patients evaluated. We defined the positive CT rate as the number of positive CT scans divided by the number of CT scans obtained and the rate of ciTBIs as the number of ciTBIs divided by the number of patients evaluated. For patients categorized as middle or high risk, we obtained a normalized rate of CT scans by dividing the number of CT scans obtained by the number of ciTBIs identified. In the low-risk stratum, there were very few ciTBIs, so this adjustment was not applicable. We sorted the hospitals based on their overall rate of CT scan use, with the same ordering of hospitals used in subsequent comparative analyses.

To compare CT use among clinician types, we performed two multivariable logistic regression analyses (one for patients <2 years of age and one for those ≥2 years of age). In these analyses, we adjusted for the PECARN rule risk strata...
in addition to the following specific variables: for children younger than 2 years of age, we adjusted for severity of mechanism of injury, history of loss of consciousness, history of vomiting, history of posttraumatic seizure, the presence of a scalp hematoma, signs of skull fracture, and any neurologic deficit. For children 2 years of age and older, in addition to the PECARN risk strata, we adjusted for severity of mechanism of injury, history of posttraumatic seizure, whether acting abnormally per parent, any headache, the presence of a scalp hematoma, signs of skull fracture, posttraumatic amnesia, and any neurologic deficit. We performed the analyses using SAS statistical software, version 9.2 (SAS Institute Inc, Cary, North Carolina).

**Results**

Of 43,399 patients in the parent study, 969 were excluded for GCS scores below 14, and 18 patients were missing the primary outcome of the parent study (ciTBI). This left 42,412 patients with GCS scores of 14-15 for the current hospital-level analysis. An additional 670 patients for whom the certification of the supervising clinician was unknown were removed from the physician-level analysis.

Of participating hospitals, 20 (80%) of 25 were urban, and 21 (84%) of 25 were teaching hospitals. The median annual volume of all participating hospitals was 26,502 (range, 10,000-89,122). The rate of CT scans at participating EDs ranged from 19.2% to 69.2%. The variations in ED CT scan use by hospital persisted when patients were stratified into high-, middle-, and low-risk groups by the PECARN rules (Figure 1). The rate of CT use across hospitals did not exhibit any apparent relationship with the rates of positive CT scans and of ciTBIs (Figure 1).

Across hospitals, there was substantial variation in the rate of CT scans obtained adjusted for the rate of ciTBI with a range of 14.5-111.7 CT scans per ciTBI. Table I demonstrates the rate of CT use based on hospital characteristics, both overall and

![Figure 1. Rate of cranial CT scan ordering (upper row), rate of positive CT scans (middle row), and rate of ciTBIs (bottom row), stratified by risk of ciTBIs using the PECARN prediction rules.](image)

Emergency Department Practice Variation in Computed Tomography Use for Children with Minor Blunt Head Trauma
stratified by the risk of ciTBI. In low- and middle-risk patients, clinicians obtained CTs more frequently at suburban hospitals and nonfreestanding children’s hospitals.

Table II shows the CT rate in low-risk patients based on age group and physician training/certification. Physicians with pediatric residency alone had the lowest overall rate of CT use (9.6%), and physicians with EM training alone had the greatest (18.7%). This pattern was similar for children of all ages.

Figure 2 illustrates the rate of CT use in patients at middle or high risk of ciTBI, based on physician training/certification, normalized for the rate of ciTBI. In both the younger and older patient age groups, physicians with EM residency training alone obtained CTs more frequently than physicians with pediatric residency training alone, when we adjusted for the rate of ciTBI. There were no statistically significant differences between any of the physician training categories in the middle-risk group regardless of grouping. For the high-risk patients, overall and for the high-risk young age group, there was a statistical difference between the PEM group and the Pediatrics group (Overall: P = .04; Young: P = .04); and the PEM group and EM group (Overall: P = .03; Young: P = .03). There were insufficient numbers of patients with ciTBI in the middle-risk patients younger than 2 years of age to make statistical comparisons.

In the multivariable logistic regression analyses comparing CT use by physician training for patients of all severities, after adjusting for risk of ciTBI, we found that EM physicians obtained CTs at a significantly greater frequency in both age groups. Compared with PEM physicians, the OR for CT-ordering among EM physicians for patients younger than 2 years of age was 1.24 (95% CI 1.04-1.46) and for patients 2 years of age and older was 1.68 (95% CI 1.50-1.89). In addition, physicians with pediatric residency training alone obtained CT scans significantly less often than those in the PEM group. Compared with the PEM group, the OR for CT ordering by physicians with pediatric residency training alone for patients younger than 2 years of age was 0.72 (95% CI 0.63-0.82) and the OR for children older than 2 years of age was 0.87 (95% CI 0.79-0.96).

**Discussion**

In this subanalysis of a large prospective cohort study of children with minor blunt head trauma, we discovered 4 major findings. First, there was substantial variation in use of CTs, and overuse of CTs in children with minor blunt head trauma across hospitals, which was not explained by the rate of positive CT scans, rate of ciTBIs, or the severity of patient clinical findings. Second, low- and middle-risk children were more likely to undergo CT scans in suburban or nonfreestanding children’s hospitals. Third, the type of physician training or certification contributed to the varying rates of CT use in all patient risk strata. Fourth, physicians from all training backgrounds in this study overused CTs in low-risk children with minor blunt head trauma.

To assess the impact of recent, large prediction rules for ciTBI and make before-and-after comparisons, we needed to establish a baseline of practice variation between hospital types and physician types. In fact, recent studies on variability not only agree with the variability that we found in our study but do not include a large population of patients studied prospectively and were not able to provide the degree of detail and analysis we provide in the current analysis.5,4,8,10 In a review of cranial CT use in 9 Canadian children’s hospitals, clinicians obtained CT scans in 6%–26% of patients without apparent relationship to the frequency of TBI.3 Two independent studies of National Hospital Ambulatory Medical Care Survey data also identified variable rates of CT scanning in children with blunt head trauma.3,8,10 Which doubled between 1995 and 2005.3 Finally, an analysis of the Pediatric Health Information System data noted that CT use for head trauma varied from 19% to 58% among 40 institutions, with no association between the rate of CT scanning and the proportion of children with significant TBIs.6 None of these database studies, however, could address CT use adjusted for individual patient risk of ciTBI or assess the actual CT findings, detailed patient outcomes, detailed hospital characteristics, or differences between types of providers.
Our study adds to these previous ones, noting that variation in CT use among hospitals exists across risk strata for ciTBIs and that all clinicians overuse CTs across all risk strata, which may reflect a desire not to miss clinically important injuries. However, clinicians obtained CT scans for a substantial proportion of patients, even when patients were at low or moderate risk for ciTBIs. Fortunately, variation in CT scan use between hospital types and physician training was less demonstrable in patients at high risk of ciTBIs.

Our data also showed that if a hospital had a greater overall CT scan rate, then the rate across all risk groups also was greater. This finding suggests that each hospital has a “culture” or normative practice that may contribute to CT scanning patterns. When we adjusted for the rates of ciTBI at each hospital, we found no relationship between CT scan rates and the underlying rate of ciTBIs. Our data also suggest that differences observed between different hospital types may relate to the training and certification of physicians staffing EDs in different hospitals, with pediatric EDs within general hospitals more likely to be staffed by general emergency physicians.

We noted that the EM residency alone group ordered CT scans at greater rates across all risk strata compared with the pediatric residency alone group or the PEM group, after adjusting for the severity of signs and symptoms. Interestingly, physicians with pediatric residency alone training ordered CT scans at the lowest rates in the lowest risk population. It is important to recognize, however, that the problem of CT scan overuse for those at low risk of ciTBIs is not limited to any particular physician group, because the data demonstrated rate of CT overuse in low-risk children by all physician types across all patient age groups.

Among high-risk patients, overall differences in the rate of CT scanning were much less apparent between hospitals and physicians with different training, particularly in those patients 2 years of age and older. These findings suggest similarity among physicians in their recognition of high risk of ciTBI and their risk aversion of missing TBI in high-risk children compared with those of lower risk.

The purpose of the PECARN prediction rules is to reduce unnecessary CT use in patients who are identified as very low risk of ciTBIs. Our results suggest that the PECARN prediction rules have the potential to reduce unnecessary CT scanning in most types of EDs, staffed by most types of physicians. Although educational efforts might be best focused on general emergency physicians, pediatric providers also order CT scans in very low-risk patients, and variation of CT scanning persisted across hospitals and physicians even after adjusting for rates of ciTBI.
Our study has several limitations. During the more than 2 years of the study, if an individual physician worked many shifts at one site, then he or she may have disproportionately influenced the results at that site. Because of the large number of sites and hundreds of physicians involved in this study, however, it is unlikely that this occurred sufficiently to affect the results. In addition, the sites involved in this study were largely urban and suburban, with few rural sites. Therefore, our findings may not be generalizable to rural EDs. Despite these limitations, there is substantial variation in cranial CT use in the management of children with minor blunt head trauma, which is not explained by the severity of symptoms and signs, rates of positive CT scans or rates of cTBIs. Physicians from all training backgrounds overuse CT scans in low risk children with minor blunt TBI.

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