Emergency Department Practice Variation in Computed Tomography Use for Children with Minor Blunt Head Trauma

Rachel M. Stanley, MD, MHSA[1], John D. Hoyle, Jr., MD[2], Peter S. Dayan, MD, MSc[3], Shireen Atabaki, MD, MPH[4], Lois Lee, MD, MPH[5], Kathy Lillis, MD[6], Marc H. Gorelick, MD, MSCE[7], Richard Holubkov, PhD[8], Michelle Miskin, MS[8], James F. Holmes, MD, MPH[9], J. Michael Dean, MD, MBA[8], and Nathan Kuppermann, MD, MPH[9], and the Pediatric Emergency Care Applied Research Network (PECARN)*

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)*.

Traumatic brain injury (TBI) is a major cause of death and disability in children, resulting in more than 7000 deaths, 60 000 hospitalizations, and more than 600 000 visits to the emergency department (ED) annually in the US.[1,2] Cranial computed tomography (CT) is the imaging modality of choice to identify TBI acutely, and many children (5%-70%)[3-5] seen in EDs with blunt head trauma are evaluated with CT scans. The use of CT, however, is variable between clinicians and hospitals[4,6] and appears unrelated to the frequency of clinically important TBIs (ciTBIs).[3,4,7-9] The reasons to use CT scanning judiciously include the risks of pharmacologic sedation,[10,11] the risk of radiation-induced malignancies, and cost.[12-17] Several studies have addressed variation in CT use after pediatric head trauma but are limited by their retrospective designs, performance in mostly children's hospitals, and lack of adjustment for risk of TBI.[3,4,6,8,18]

In 2009, two clinical prediction rules to identify children at very low risk of ciTBI after head trauma for whom CT scans typically are not indicated were derived and validated in the Pediatric Emergency Care Applied Research Network (PECARN).[7] Prospectively collected data from that study also enable the investigation of practice variation in CT use across a variety of providers and hospitals. Furthermore, the PECARN data enable stratification by risk of ciTBI, thus greatly mitigating methodological limitations of previous studies,[19] and provide evidence to empower clinicians (and families) with their clinical decision-making.

The purpose of this study was to evaluate variation in ED cranial CT use for children with minor blunt head trauma. We aimed to assess the degree of

ciTBI	Clinically important traumatic brain injury
CT	Computed tomography
ED	Emergency department
EM	Emergency Medicine
GCS	Glasgow Coma Scale
PECARN	Pediatric Emergency Care Applied Research Network
PEM	Pediatric Emergency Medicine
TBI	Traumatic brain injury

From the [1]Department of Emergency Medicine and Pediatrics, University of Michigan, Ann Arbor, MI; [2]Division of Emergency Medicine, Michigan State University College of Human Medicine, Helen DeVos Children's Hospital, Grand Rapids, MI; [3]Department of Pediatrics, Columbia University College of Physicians and Surgeons, New York, NY; [4]Department of Emergency Medicine, Children's National Medical Center, George Washington School of Medicine, Washington, DC; [5]Department of Pediatrics, Harvard Medical School, Boston, MA; [6]Department of Pediatrics, State University of New York at Buffalo and Women and Children's Hospital of Buffalo, Buffalo, NY; [7]Department of Pediatrics, Medical College of Wisconsin, Milwaukee, WI; [8]Department of Pediatrics, University of Utah and PECARN Data Coordinating Center, Salt Lake City, UT; and [9]Department of Emergency Medicine, University of California Davis School of Medicine, Davis, CA

*List of members of PECARN is available at www.jpeds.com (**Appendix**).

Supported in part by the Health Resources and Services Administration (HRSA), Maternal and Child Health Bureau (MCHB; R40MC02461), the Emergency Medical Services of Children (EMSC) Program through the PECARN. PECARN is supported by the following cooperative agreements: U03MC00001, U03MC00003, U03MC00006, U03MC00007, U03MC00008, U03MC22684, and U03MC22685. The authors declare no conflicts of interest.

0022-3476/$ - see front matter.
http://dx.doi.org/10.1016/j.jpeds.2014.08.008

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.[7] 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.[20] 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.[7] Using these risk factors, we categorized patients as low, middle, or high risk for ciTBI.[7] We classified patients with none of the PECARN risk factors in the age-specific prediction rules[7] 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.[7] 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

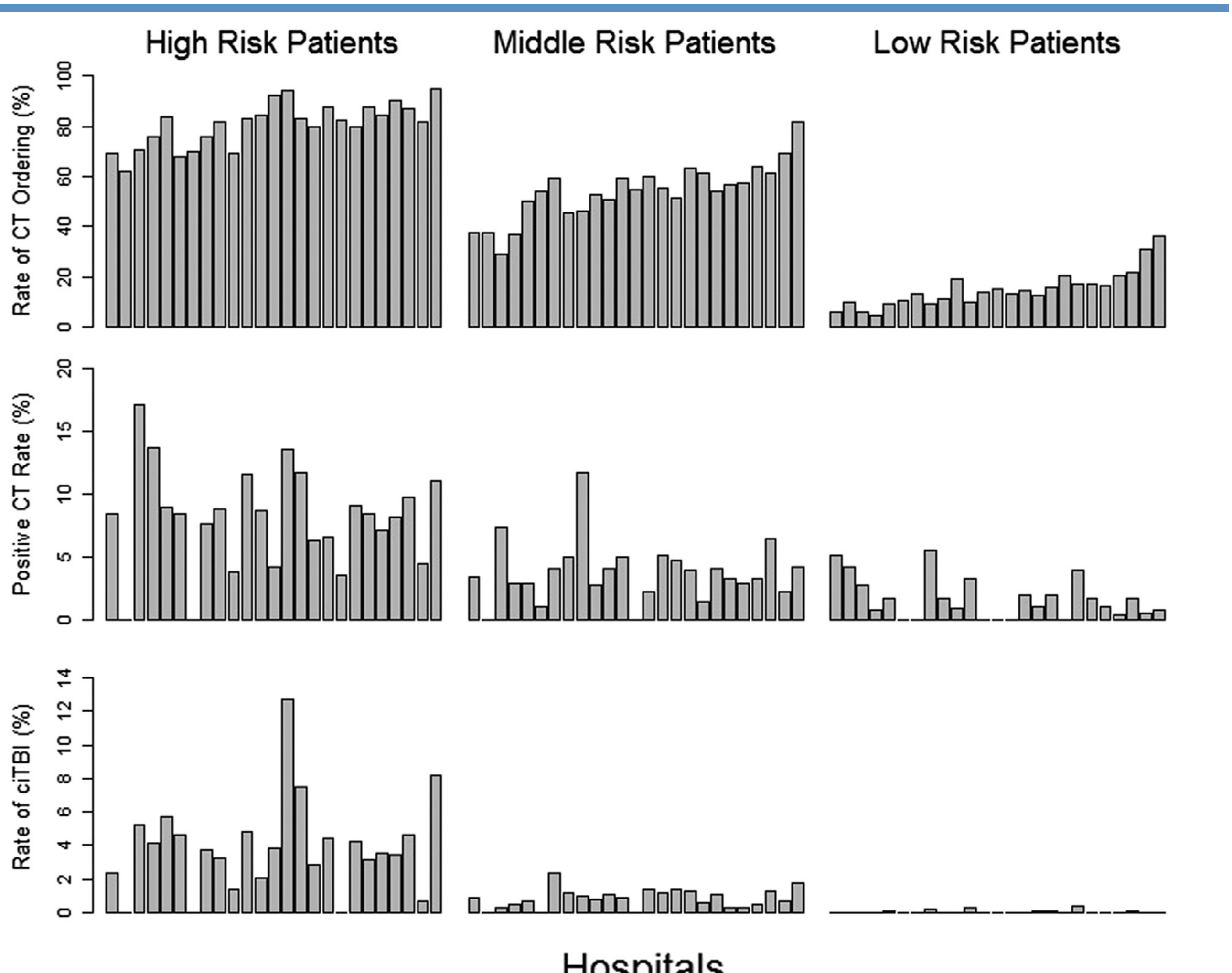

Figure 1. Rate of cranial CT scan ordering (*upper row*), rate of positive CT scans (*middle row*), and rate of ciTBIs (*bottom row*), stratified by risk of ciTBIs using the PECARN prediction rules.[7]

Table I. Rates of cranial CT use classified by hospital characteristics and risk for ciTBI

Hospital characteristics (N = 42 412)	Total N	CT rate	CT rate by risk for ciTBI: Low risk	Middle risk	High risk
Urban location	35 584	33.8%*	12.0%*	52.9%*	82.5%
Suburban location	6828	41.5%	20.4%	58.2%	82.6%
Total	42 412	35.0%	13.3%	53.8%	82.5%
Teaching hospital	39 607	34.9%†	12.8%‡	53.6%	82.7%
Nonteaching hospital	2805	36.8%	19.1%	57.2%	80.0%
Total	42 412	35.0%	13.3%	53.8%	82.5%
Freestanding children's hospital	24 543	31.0%§	10.8%§	49.2%§	81.4%¶
Nonfreestanding children's hospital	17 869	40.6%	17.0%	59.5%	83.8%
Total	42 412	35.0%	13.3%	53.8%	82.5%

*,‡,§$P < .001$ when comparing CT rates by hospital characteristics.
†,¶$P < .05$ when comparing CT rates by hospital characteristics.

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

Table II. Rates of cranial CT scanning in PECARN prediction rule low-risk patients (N = 23 477), classified by physician training/certification

Training/certification	Patients <2 y: Patients, n	Patients <2 y: CT, n (%)	Patients 2 to <18 y: Patients, n	Patients 2 to <18 y: CT, n (%)
PEM group	3560	562 (15.8%)	11 149	1508 (13.5%)
Pediatrics alone group	1516	155 (10.2%)	4861	460 (9.5%)
EM alone group	520	95 (18.3%)	1871	352 (18.8%)
Total	5596	812 (14.5%)	17 881	2320 (13.0%)

Within each age group, all pairwise comparisons of CT rates between physicians with different certifications are statistically significant ($P < .001$) except for the difference in CT rates in the younger age group between the PEM group and EM residency alone–trained group ($P = .15$). We did not adjust the P values for multiple comparisons; however, the significant comparisons were at the $P < .001$ level, so would remain significant after we adjusted for multiple comparisons.

(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.[3,4,8,18] 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.[4] 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] 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.

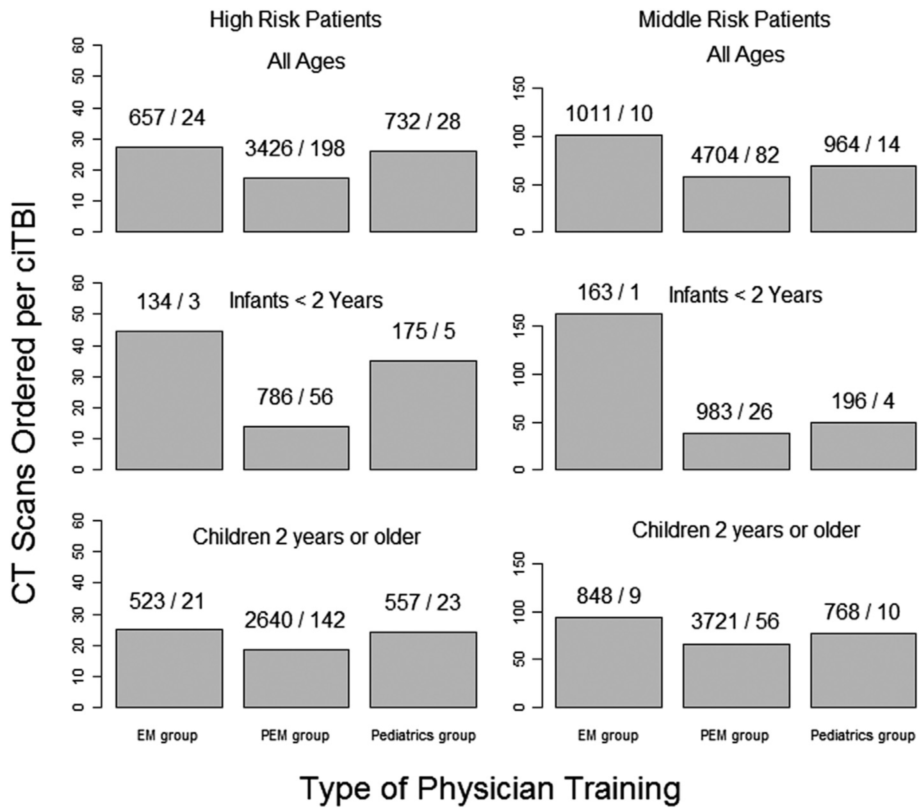

Figure 2. Ratio of CT ordering per ciTBI stratified by patient age and physician training. Risk of ciTBI was stratified using the PECARN prediction rules.[7] Note that the vertical axis scale differs between the high- and middle-risk strata. Numbers atop the columns indicate number of CT scans ordered/number of ciTBIs. The Fisher exact test was used to perform pairwise comparisons between the different physician training groups.

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 ciTBIs. Physicians from all training backgrounds overuse CT scans in low risk children with minor blunt TBI. ■

Submitted for publication Mar 21, 2014; last revision received Jun 19, 2014; accepted Aug 7, 2014.

Reprint requests: Rachel M. Stanley, MD, MHSA, Department of Emergency Medicine, University of Michigan, 1500 E Medical Center Dr, TC B1 354 / SPC 5303, Ann Arbor, MI 48109. E-mail: stanleyr@umich.edu

References

1. Coronado VG, Xu L, Basavaraju SV, McGuire LC, Wald MM, Faul MD, et al. Surveillance for traumatic brain injury-related deaths—United States, 1997-2007. MMWR Surveill Summ 2011;60:1-32.
2. Faul M, Xu L, Wald M, Coronado V. Traumatic brain injury in the United States: emergency department visits, hospitalizations and deaths 2002-2006. Atlanta (GA): Centers for Disease Control and Prevention, National Center for Injury Prevention and Control; 2010.
3. Blackwell CD, Gorelick M, Holmes JF, Bandyopadhyay S, Kuppermann N. Pediatric head trauma: changes in use of computed tomography in emergency departments in the United States over time. Ann Emerg Med 2007;49:320-4.
4. Klassen TP, Reed MH, Stiell IG, Nijssen-Jordan C, Tenenbein M, Joubert G, et al. Variation in utilization of computed tomography scanning for the investigation of minor head trauma in children: a Canadian experience. Acad Emerg Med 2000;7:739-44.
5. Maguire JL, Boutis K, Uleryk EM, Laupacis A, Parkin PC. Should a head-injured child receive a head CT scan? A systematic review of clinical prediction rules. Pediatrics 2009;124:e145-54.
6. Mannix R, Meehan WP, Monuteaux MC, Bachur RG. Computed tomography for minor head injury: variation and trends in major United States pediatric emergency departments. J Pediatr 2012;160:136-9.e1.
7. Kuppermann N, Holmes JF, Dayan PS, Hoyle JD, Atabaki SM, Holubkov R, et al. Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. Lancet 2009;374:1160-70.
8. Mannix R, Bourgeois FT, Schutzman SA, Bernstein A, Lee LK. Neuroimaging for pediatric head trauma: do patient and hospital characteristics influence who gets imaged? Acad Emerg Med 2010;17:694-700.
9. Palchak MJ, Holmes JF, Vance CW, Gelber RE, Schauer BA, Harrison MJ, et al. A decision rule for identifying children at low risk for brain injuries after blunt head trauma. Ann Emerg Med 2003;42:492-506.
10. Sanborn PA, Michna E, Zurakowski D, Burrows PE, Fontaine PJ, Connor L, et al. Adverse cardiovascular and respiratory events during sedation of pediatric patients for imaging examinations. Radiology 2005;237:288-94.
11. Malviya S, Voepel-Lewis T, Prochaska G, Tait AR. Prolonged recovery and delayed side effects of sedation for diagnostic imaging studies in children. Pediatrics 2000;105:E42.
12. Pearce MS, Salotti JA, Little MP, McHugh K, Lee C, Kim KP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. Lancet 2012;380:499-505.
13. Brenner D, Elliston C, Hall E, Berdon W. Estimated risks of radiation-induced fatal cancer from pediatric CT. AJR Am J Roentgenol 2001;176:289-96.
14. Brenner DJ. Estimating cancer risks from pediatric CT: going from the qualitative to the quantitative. Pediatr Radiol 2002;32:228-31.
15. Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. N Engl J Med 2007;357:2277-84.
16. Faulkner K, Moores BM. Radiation dose and somatic risk from computed tomography. Acta Radiol 1987;28:483-8.
17. Miglioretti DL, Johnson E, Williams A, Greenlee RT, Weinmann S, Solberg LI, et al. The use of computed tomography in pediatrics and the associated radiation exposure and estimated cancer risk. JAMA Pediatr 2013;167:700-7.
18. Levine MB, Moore AB, Franck C, Li J, Kuehl DR. Variation in use of all types of computed tomography by emergency physicians. Am J Emerg Med 2013;31:1437-42.
19. Parkin PC, Maguire JL. Clinically important head injuries after head trauma in children. Lancet 2009;374:1127-9.
20. Alpern E, Stanley R, Gorelick M, Donaldson A, Knight S, Teach S, et al. Epidemiology of a pediatric emergency medicine research network: the PECARN Core Data Project. Pediatr Emerg Care 2006;22:689-99.

Appendix

Participating PECARN centers and site investigators include (in alphabetical order):

Shireen Atabaki, MD (Children's National Medical Center, Washington, DC), Lynn Babcock-Cimpello, MD (University of Rochester, Rochester, NY), Michael Bachman, MD (St Barnabas Health Care System, West Orange, NJ), Mohamed Badawy, MD (University of Rochester, Rochester, NY), Subhankar Bandyopadhyay, MB, BS (Medical College of Wisconsin/Children's Hospital of Wisconsin, Milwaukee, WI), Dominic Borgialli, DO, MPH (Hurley Medical Center, Flint, MI), Kathleen M. Brown, MD (Children's National Medical Center, Washington, DC), James Callahan, MD (SUNY-Upstate Medical University, Syracuse, NY), Arthur Cooper, MD (Harlem Hospital Center, New York, NY), Peter S. Dayan, MD (Children's Hospital of New York Presbyterian, New York, NY), Michael J. Gerardi, MD, FAAP, FACEP (Atlantic Health System/Morristown Memorial Hospital, Morristown, NJ), Todd Glass, MD (Cincinnati Children's Hospital Medical Center, Cincinnati, OH), Mark S. Gorelick, MD (Medical College of Wisconsin/Children's Hospital of Wisconsin, Milwaukee, WI), James Holmes, MD (University of California Davis Medical Center, Davis, CA), John D. Hoyle, Jr, MD (Helen DeVos Children's Hospital, Grand Rapids, MI), E. Jacobs, MD (Holy Cross Hospital, Silver Spring, MD), David Jaffe, MD (Washington University/St. Louis Children's Hospital, St. Louis, MO), Nathan Kuppermann, MD, MPH (University of California Davis Medical Center, Davis, CA), Lois Lee, MD, MPH (Boston Children's Hospital, Boston, MA), Richard Lichenstein, MD (University of Maryland, Baltimore, MD), Kathleen Lillis, MD (Women and Children's Hospital of Buffalo, Buffalo, NY), Prashant Mahajan, MD, MPH, MBA (Children's Hospital of Michigan, Detroit, MI), Kraig Melville, MD (Calvert Memorial Hospital, Prince Frederick, MD), David Monroe, MD (Howard County Medical Center, Columbia, MD), Frances M. Nadel, MD, MSCE (Children's Hospital of Philadelphia, Philadelphia, PA), Elizabeth Powell, MD (Children's Memorial Hospital, Chicago, IL), Kimberly S. Quayle, MD (Washington University/St. Louis Children's Hospital, St. Louis, MO), Rachel M. Stanley, MD, MHSA (University of Michigan, Ann Arbor, MI), Neil Schamban, MD (Barnabas Health Care System, West Orange, NJ), Jeff Schunk, MD (University of Utah/Primary Children's Medical Center, Salt Lake City, UT), James Tsung, MD (Bellevue Hospital Center, New York, NY), and Michael Tunik, MD (Bellevue Hospital Center, New York, NY).

PECARN Steering Committee: Nathan Kuppermann, MD, MPH, Chair (University of California Davis Medical Center, Davis, CA), Elizabeth Alpern, MD (Children's Hospital of Philadelphia, Philadelphia, PA), James Chamberlain, MD (Children's National Medical Center, Washington, DC), J Michael Dean, MD, MBA (University of Utah, Salt Lake City, UT), Michael J. Gerardi, MD, FAAP, FACEP (Atlantic Health System/Morristown Memorial Hospital, Morristown, NJ), Julius Goepp, MD (University of Rochester, Rochester, NY), Mark S. Gorelick, MD (Medical College of Wisconsin/Children's Hospital of Wisconsin, Milwaukee, WI), John D. Hoyle, Jr, MD (Helen DeVos Children's Hospital, Grand Rapids, MI), David Jaffe, MD (Washington University/St. Louis Children's Hospital, St. Louis, MO), C. Johns, Nadine Levick, MD, MPH (Johns Hopkins University, Baltimore, MD), Prashant Mahajan, MD, MPH, MBA (Children's Hospital of Michigan, Detroit, MI), Ronald Maio, DO (University of Michigan, Ann Arbor, MI), Kraig Melville, MD (Calvert Memorial Hospital, Prince Frederick, MD), Steven Miller*, MD (Children's Hospital of New York Presbyterian, New York, NY), David Monroe, MD (Howard County Medical Center, Columbia, MD), Richard Ruddy, MD (Cincinnati Children's Hospital, Cincinnati, OH), Rachel M. Stanley, MD, MHSA (University of Michigan, Ann Arbor, MI), David Treloar, MD (University of Michigan, Ann Arbor, MI), and Allen Walker, MD (Johns Hopkins University, Baltimore, MD).

MCHB/EMSC liaisons: Daniel Kavanaugh, MSW, LCSW-C; Hae Young Park, MPH

Central Data Management and Coordinating Center (CDMCC), University of Utah, Salt Lake City, UT: J Michael Dean, MD, MBA; Richard Holubkov, Ph.D; Stacey Knight, MStat; Amy Donaldson, MS.

Data Analysis and Management Subcommittee (DAMS): James Chamberlain, MD, Chair (Children's National Medical Center, Washington, DC), M. Brown, Howard Corneli, MD (University of Utah, Salt Lake City, UT), Julius Goepp, MD (University of Rochester, Rochester, NY), Richard Holubkov, PhD (University of Utah, Salt Lake City, UT), Prashant Mahajan, MD, MPH, MBA (Children's Hospital of Michigan, Detroit, MI), Kraig Melville, MD, Calvert Memorial Hospital, Prince Frederick, MD), Ernest Stremski, MD (Children's Hospital of Wisconsin, Milwaukee, WI), and Michael Tunik, MD (Bellevue Hospital Center, New York, NY).

Grants and Publications Subcommittee (GAPS): Mark S. Gorelick, MD, Chair (Medical College of Wisconsin/Children's Hospital of Wisconsin, Milwaukee, WI), Elizabeth Alpern, MD (Children's Hospital of Philadelphia, Philadelphia, PA), J. Michael Dean, MD, MBA (University of Utah, Salt Lake City, UT), George Foltin, MD (Bellevue Hospital/New York University School of Medicine, New York, NY), Jill G. Joseph, MD, PhD, MPH (Children's National Medical Center, Washington, DC) Steven Miller*, MD (Children's Hospital of New York Presbyterian, New York, NY), Frank Moler, MD (University of Michigan, Ann Arbor, MI), Rachel M. Stanley, MD (University of Michigan, Ann Arbor, MI), and Steven Teach, MD, MPH (Children's National Medical Center, Washington, DC).

Protocol Concept Review and Development Subcommittee (PCRADS): David Jaffe, MD, Chair (Washington University/St. Louis Children's Hospital, St. Louis, MO), Kathleen Brown, MD (Children's National Medical Center, Washington, DC), Arthur Cooper, MD (Harlem Hospital/Columbia University, New York, NY), J. Michael Dean, MD, MBA (University of Utah, Salt Lake City, UT), C. Johns, Ronald

Maio, DO (University of Michigan, Ann Arbor, MI), Clay Mann, PhD, MS (University of Utah, Salt Lake City, UT), David Monroe, MD (Howard County Medical Center, Columbia, MD), Kathy Shaw MD, MSCE (Children's Hospital of Philadelphia, Philadelphia, PA), Daniel Teitelbaum, MD (University of Michigan, Ann Arbor, MI), and David Treloar, MD (University of Michigan, Ann Arbor, MI).

Quality Assurance Subcommittee (QAS): Rachel M. Stanley, MD, MPH, Chair (University of Michigan, Ann Arbor, MI), D. Alexander, J. Brown, Michael J. Gerardi, MD, FAAP, FACEP (Atlantic Health System/Morristown Memorial Hospital, Morristown, NJ), Maryann Gregor (University of Michigan, Ann Arbor, MI), Richard Holubkov, PhD (University of Utah, Salt Lake City, UT), Kathleen Lillis, MD (Women and Children's Hospital of Buffalo, Buffalo, NY), B. Nordberg, Richard Ruddy, MD (Cincinnati Children's Hospital, Cincinnati, OH), Michael Shults, MA (University of California at Davis, Davis, CA), and Allen Walker, MD (Johns Hopkins University, Baltimore, MD).

Safety and Regulatory Affairs Subcommittee (SRAS): Walt Schalick, MD, PhD, Chair (University of Wisconsin, Milwaukee, WI), J. Brennan, J. Brown, J. Michael Dean, MD, MBA (University of Utah, Salt Lake City, UT), John Hoyle, Jr, MD (Helen DeVos Children's Hospital, Grand Rapids, MI), Nadine Levick, MD, MPH (Johns Hopkins University, Baltimore, MD), Ronald Maio, DO (University of Michigan, Ann Arbor, MI), Richard Ruddy, MD (Cincinnati Children's Hospital, Cincinnati, OH), T. Singh-Weik, MPH, NREMT-P (Children's National Medical Center, Washington, DC), and Joseph Wright, MD (Children's National Medical Center, Washington, DC).

* Deceased