Effect of the Duration of Emergency Department Observation on Computed Tomography Use in Children With Minor Blunt Head Trauma

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Study objective: We determine the effect of the duration of emergency department (ED) observation on computed tomography (CT) rate for children with minor blunt head trauma.

Methods: We performed a prospective cohort study of children with blunt head trauma and a Glasgow Coma Scale score greater than 14. We defined time from injury as the time from head injury to initial physician (emergency attending physician or fellow) assessment. For children who were observed in the ED before CT decisionmaking, we defined ED observation time as time from initial physician assessment to the decision whether to obtain a CT. After adjusting for time from injury, patient age, sex, physician type, and study month, we measured the effect of ED observation time on CT rate in each of the 3 Pediatric Emergency Care Applied Research Network Traumatic Brain Injury risk groups.

Results: Of the 1,605 eligible patients, we enrolled 1,381 (86%). Of the enrolled patients, 676 (49%) were observed in the ED and 272 (20%) had a CT performed. After adjustment, every hour of ED observation time was associated with a decrease in CT rate for children in all 3 traumatic brain injury risk groups: high risk (adjusted odds ratio [OR] 0.11; 95% confidence interval [CI] 0.05 to 0.24), intermediate risk (adjusted OR 0.28; 95% CI 0.21 to 0.36), and low risk (adjusted OR 0.47; 95% CI 0.31 to 0.73). All 8 children with a significant traumatic brain injury had an immediate CT.

Conclusion: For children with minor blunt head trauma, ED observation time was associated with a time-dependent reduction in cranial CT rate, with no delay in the diagnosis of a significant traumatic brain injury. [Ann Emerg Med. 2013;62:597-603.]

Please see page 598 for the Editor's Capsule Summary of this article.

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INTRODUCTION

Background

Every year, more than half a million children present to the emergency department (ED) for evaluation of blunt head trauma,[1] but few children will have a significant traumatic brain injury.[2-5] Cranial computed tomography (CT) is the criterion standard for the diagnosis a of traumatic brain injury, but exposes children to ionizing radiation that increases the lifetime risk for radiation-associated malignancies.[6-9]

Importance

Clinical observation before the decision to obtain a CT allows clinicians to selectively image only children whose symptoms evolve or fail to improve. The American Academy of Pediatrics has long recognized the role of an observation period in the management of children with minor blunt head trauma,[10-12] and children with a significant traumatic brain injury rarely have a delayed diagnosis.[13] Furthermore, a recent study showed that observation before the decision to obtain a CT scan was associated with a significantly lower rate of overall CT use, with no increase in the rate of significant injuries.[14] However, these studies have not investigated the relationship between duration of ED observation before CT decisionmaking and CT rate.

Goals of This Investigation

To this end, we performed a prospective observational study of children with minor blunt head trauma presenting to a single pediatric ED for evaluation. Our goal was to determine how the duration of ED observation before CT decisionmaking affects CT usage for children with minor head injuries (Glasgow Coma Scale score of >14). We hypothesized that ED observation will be associated with a time-dependent decrease in CT use for children without a delay in diagnosis of a clinically important traumatic brain injury.

Editor's Capsule Summary

What is already known on this topic

Emergency department (ED) observation has been suggested as a strategy to decrease computed tomography (CT) scanning in children with minor blunt head trauma.

What question this study addressed

Are longer periods of observation associated with fewer CT scans?

What this study adds to our knowledge

In this prospective analysis of 1,381 children with minor blunt head trauma, emergency physicians elected to observe approximately half. Those observed received fewer CT scans, with increasingly longer observation associated with progressive decreases in imaging rate.

How this is relevant to clinical practice

Multihour periods of ED observation appear to reduce CT scanning in children with minor blunt head trauma.

MATERIALS AND METHODS

Study Design and Setting

We performed a prospective observational cohort study of all children who presented to a single pediatric ED for evaluation of minor blunt head trauma during an approximately 20-month study period (April 27, 2011, through December 31, 2012). Throughout the study period, a guideline for the care of children with minor blunt head trauma was available as a clinical reference and suggested management based on risk classification (low-risk patients should be discharged, intermediate-risk patients should be observed, and high-risk patients should have an immediate CT).

Selection of Participants

We obtained written informed consent for study participation from physicians working in the ED. We included physicians trained in pediatric emergency medicine (attending physicians and fellows), as well as general pediatricians. We classified the single ED nurse practitioner working clinically during the study period as a general pediatrician. The institutional review board approved the study protocol.

We included children younger than 18 years and with a Glasgow Coma Scale score of 14 or 15, presenting to the ED for evaluation of blunt head trauma sustained within 24 hours of presentation. We excluded patients with trivial injury mechanisms (eg, ground-level falls or running into stationary objects, without signs of traumatic brain injury), neurologic comorbidities (eg, brain tumors, ventricular shunts), or bleeding disorders. Children who had neuroimaging performed before study form completion (either at an outside facility or at the study site ED) were excluded. Children presenting to the ED more than once for evaluation of different blunt head trauma injuries during the study period were eligible for enrollment at each visit. ED research coordinators and treating physicians were responsible for identifying all eligible patients during the study period.

Table 1. PECARN traumatic brain injury risk groups for children with minor head trauma (Glasgow Coma Scale score >14).[2]

PECARN TBI Risk Group	Predictors: Children Aged <2 Years	Predictors: Children Aged ≥2 Years
High	Altered mental status*	Altered mental status*
	Palpable skull fracture	Signs of basilar skull fracture†
Intermediate	Severe injury mechanism‡	Severe injury mechanism‡
	Loss of consciousness ≥5 s	Any loss of consciousness
	Nonfrontal hematoma	Vomiting
	Not acting right per parents	Severe headache
Very low	None	None

TBI, traumatic brain injury.
*Glasgow Coma Scale score 14, agitation, sleepiness, slow response, or repetitive questioning.
†Retroauricular bruising (battle sign), periorbital bruising (raccoon eyes), cerebrospinal fluid otorrhea or hemotympanum.
‡Motor vehicle crash with patient ejection, death of another passenger, or rollover; pedestrian or bicyclist without helmet struck by motorized vehicle; falls (of >3 feet for children <2 years or >5 feet for children ≥2 years); or head struck by high-impact object.

Methods of Measurement

After initial patient assessment, the treating physician completed a standardized study form, on which he or she indicated the date and time of patient head injury. We collected the age-based (aged <2 versus ≥2 years) Pediatric Emergency Care Applied Research Network (PECARN) traumatic brain injury clinical predictors (Table 1) on study data forms.[2] Physicians also indicated whether they planned to observe the child in the ED before deciding whether to obtain a cranial CT scan. "Nonobserved" patients were those for whom physicians made immediate decisions about CT use (ie, children either underwent immediate CT or were discharged without neuro imaging after initial physician evaluation). "Observed" patients were those whom physicians chose to observe before the decision whether to obtain a CT scan. For children who were observed, clinicians were asked to indicate how symptoms changed during the observation period. For children who ultimately had a CT or magnetic resonance imaging (MRI) performed, we asked the clinician the indications for obtaining neuroimaging.

The times of ED arrival, physician evaluation, ED CT order placement (if a CT was ordered), and ED disposition (discharge or hospital admission) were abstracted from the ED electronic tracking system. Patient race, ethnicity, and insurance status were obtained from patient registration data. We also reviewed the electronic medical records from the initial ED visit and for the 7 days after the initial injury to determine whether the child had neuroimaging or other interventions performed for the management of the head injury.

We defined a positive CT result as either a skull fracture or a traumatic brain injury (eg, intracranial hemorrhage or contusion, cerebral edema, traumatic infarction, midline shift or signs of brain herniation, diffuse axonal injury, or pneumocephalus). We defined a clinically important traumatic brain injury as a head injury resulting in death, intubation for greater than 24 hours, neurosurgery, or a 2-day or longer hospitalization for management of head injury.[2]

We defined time from injury as the time from head injury to initial emergency physician evaluation (this included the time from ED arrival to physician evaluation). For observed patients, we defined ED observation time as time from physician evaluation to time of CT order placement for children who had a CT, or as the time from physician evaluation to the time of ED disposition for children who did not. We defined ED length of stay as the time from ED arrival to disposition (Figure 1).

We applied the age-based PECARN traumatic brain injury prediction rules to the study population. We stratified children into 3 risk groups (very low, intermediate, and high) according to published classifications (Table 1).[2] Children with no traumatic brain injury predictors were classified as very low risk. Children with 1 or more traumatic brain injury predictors were classified as intermediate or high risk, according to the specific traumatic brain injury predictors present. Children who were missing 1 or more traumatic brain injury predictors with no high-risk traumatic brain injury predictors could not be assigned a PECARN traumatic brain injury risk group.

Outcome Measures

Our primary outcome measure was the performance of a cranial CT scan (yes versus no). Children who had a cranial MRI performed were included in the CT group for the purposes of this study. Our secondary outcome measure was ED length of stay.

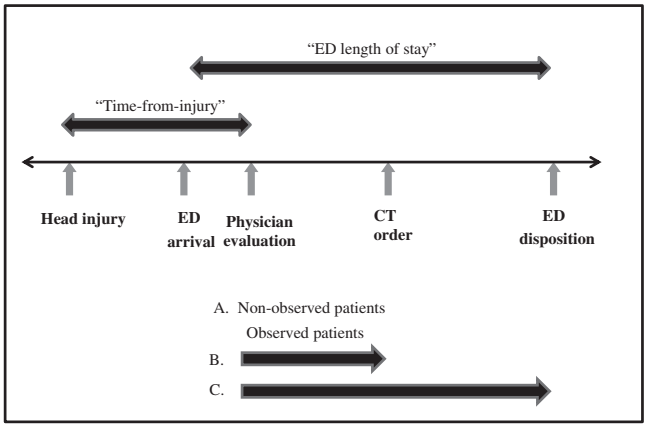
Primary Data Analysis

We described the data with descriptive statistics with 95% confidence intervals (CIs) or population proportions, as appropriate. We performed bivariable analysis comparing the clinical characteristics and management of children with minor head trauma who were observed versus not observed in the ED before CT decisionmaking. We compared categorical variables, using rate differences and median times with the Hodges-Lehmann method, which accounts for the possibility that the population distributions differ between groups.

Next, we investigated the relationship between the duration of ED observation time and CT rate. Using multivariable logistic regression, we measured the association between ED observation time and CT rate in each of the 3 PECARN traumatic brain injury risk groups after adjusting for time from injury, patient age, patient sex, physician type (pediatric emergency medicine attending physician or fellow versus general pediatrics), and study month. We also adjusted for study month to account for previously observed decreases in cranial CT rates.[15] For the secondary outcome measure, we compared the ED length of stay for observed versus not observed children with blunt head trauma.

We assumed a baseline CT rate for children with minor blunt head trauma of 25%, based on an institutional CT rate of 30% in 2005 and an assumed temporal decrease during the intervening period. We then powered our study to detect a 20% decrease in CT rate from baseline associated with clinical observation before CT decisionmaking with an α of .05 and a β of .10. With these assumptions, we estimated a need to enroll approximately 600 children within each management strategy (observation versus no observation before CT decisionmaking).

We used Stata (version 12.0; StataCorp, College Station, TX) to calculated the median differences between time intervals.[16] We used the SPSS package (version 21.0; SPSS, Inc., Chicago, IL) for all other analyses.[17]



A. Non-observed patients either had an immediate CT or were discharged without neuroimaging
B. Observed patients: ED observation time for children who undergo a CT scan
C. Observed patients: ED observation time for children who are discharged from the ED without a CT scan

Figure 1. Definitions of study intervals.

RESULTS

Characteristics of Study Subjects

We enrolled 98 physicians in this observational study. Of these, 55 (56%) were emergency medicine attending physicians (53 pediatric emergency medicine and 2 emergency medicine), 22 (20%) were pediatric emergency medicine fellows, and 21 were general pediatricians. All clinicians approached agreed to study participation.

Of the 1,605 eligible patients who presented to the ED during the study period, we collected study forms for 1,381 (86% of eligible patients) (Figure 2). The majority of patients were missed during overnight hours when research coordinators were not available. Missed eligible patients had an age distribution, as well as CT rate, similar to that of patients enrolled (data not shown). Of the 1,381 enrolled children, 509 (37%) were younger than 2 years and 829 (60%) were boys. Only 12 children had more than 1 ED evaluation for separate head injuries.

Overall, 271 children (20% of study population) had a CT performed and 1 child had a cranial MRI (0.07%), for an overall neuroimaging rate of 20% (referred to going forward as CT rate). The proportion of patients who had a CT decreased each month during the study period (odds ratio [OR] 0.97; 95% CI 0.95 to

0.99). Clinicians indicated the following reasons for ordering CT scans for their head-injured patients (each patient could have more than 1 reason): clinical findings concerning for intracranial injury (73%), concerning injury mechanism (26%), young age of patient (16%), referring or consulting physician request (5%), parental request (4%), and other reasons (18%).

Of the 1,381 study patients, we successfully applied the PECARN traumatic brain injury rules to 1,369 (99%) of enrolled patients, using collected predictor data (12 patients had missing PECARN predictors). Of those classified, 724 (53%) were very low risk, 498 (36%) were intermediate risk, and 147 (11%) were high risk. CT rates varied by PECARN traumatic brain injury risk group: 4% of patients in the very low traumatic brain injury risk group, 26% in the intermediate-risk group, and 69% in the high-risk group (OR 7.2; 95% CI 5.6 to 9.2).

Overall, clinicians decided to observe 676 patients (49% of study patients) in the ED before CT decisionmaking (Table 2). The proportion of children who were observed before CT decisionmaking increased each month during the study period (OR 1.05; 95% CI 1.03 to 1.07). Of the 705 nonobserved patients, 240 (34%) underwent immediate CT and 465 (66%) were discharged without an ED observation period. Clinicians were more likely to observe older children and those in the intermediate traumatic brain injury risk group. The number of positive CT results was higher for the children who were not observed before CT decisionmaking. The most common type of positive CT result was a nondisplaced skull fracture (47% of children with a positive CT scan result). Only 8 patients in our study (0.6% of the study cohort) had a clinically important traumatic brain injury (1 required neurosurgical intervention and 7 spent 2 or more nights in the hospital for management of their head injuries). All 8 children were classified as high risk and none were observed before CT decisionmaking.

Clinical symptoms improved for most children during the period of observation. Thirty-one of 41 children with abnormal mental status initially (76%) normalized, 61 of 78 children older than 2 years who vomited initially (78%) had resolution, 27 of 41 children older than 2 years with severe headache initially (66%) improved or resolved, and 35 of 35 children younger than 2 years who were acting abnormally initially (100%) returned to baseline. During the observation period, 36 patients (5% of observed children) received antiemetics.

Main Results

Children whom clinicians chose to observe presented to the ED sooner after their head injury than those who were not observed (Table 3). For children who were observed before CT decisionmaking, the median duration of observation was similar across the 3 PECARN traumatic brain injury risk groups. Overall, children who were observed in the ED before CT decisionmaking had a longer ED length of stay.

The CT rate was lower for children who were observed (5% observed versus 34% nonobserved; OR 0.10; 95% CI 0.07 to 0.14). After adjusting for time from injury, patient age, sex, physician type, and study period, every hour of ED observation was associated with a time-dependent decrease in CT rate overall

Table 2. Comparison of characteristics between children who were observed versus those who were not before the decision whether to obtain a cranial CT.

Characteristic	Observed, N=676, n/N (%)	Nonobserved, N=705, n/N (%)	Rate Difference, n% (95% CI)
Sex (male)	394/676 (58)	439/705 (62)	−4 (−9 to 0)
Age ≥2 y	460/676 (68)	412/705 (58)	10 (5 to 15)
Race			
White	327/676 (48)	340/705 (48)	0 (−5 to 5)
Black	102/676 (15)	108/705 (15)	0 (−4 to 4)
Other	247/676 (37)	257/705 (37)	0 (−5 to 5)
Ethnicity			
Hispanic	124/623 (20)	146/659 (22)	−2 (−7 to 2)
Non-Hispanic	499/623 (80)	513/659 (78)	2 (−2 to 7)
Insurance			
Private	426/673 (63)	452/701 (65)	−2 (−6 to 4)
Public	233/673 (35)	234/701 (33)	2 (−4 to 6)
None	14/673 (2)	15/701 (2)	0 (−1 to 1)
PECARN TBI risk group			
Very low	327/669 (49)	397/700 (57)	−8 (−13 to −3)
Intermediate	301/669 (45)	197/700 (28)	17 (12 to 22)
High	41/669 (6)	106/700 (15)	−9 (−12 to 6)
Patient outcome			
CT performed	32/676 (5)	240/705 (34)	−28 (−32 to −24)
Positive CT findings*	4/676 (1)	49/705 (7)	−7 (−9 to −5)
Clinically important TBI†	0/676 (0)	8/705 (1)	−1 (−2 to 0)
Hospital admission Rate	21/676 (3)	76/705 (11)	−8 (−10 to −5)

*Skull fracture or traumatic brain injury defined as intracranial hemorrhage or contusion, cerebral edema, traumatic infarction, midline shift or signs of brain herniation, diffuse axonal injury, or pneumocephalus.

†Traumatic brain injury resulting in death, neurosurgical intervention, intubation for longer than 24 hours, or hospital admission for 2 nights or longer.

Table 3. Median intervals for children who were observed versus those who were not before the decision whether to obtain a cranial CT.

Intervals	Observed Median Time (IQR), Hours	Nonobserved Median Time (IQR), Hours	Median Time Difference (95% CI), Hours
Injury to ED arrival	0.9 (0.6 to 1.7)	1.8 (0.8 to 4.2)	−0.7 (−0.9 to −0.6)
ED arrival to physician evaluation	0.5 (0.3 to 0.9)	0.6 (0.3 to 1.0)	−0.1 (−0.1 to 0)
ED observation time*			
Overall	2.5 (1.8 to 3.3)	n/a	n/a
Very low-risk TBI group	2.4 (1.6 to 3.0)		
Intermediate-risk TBI group	2.6 (1.9 to 3.4)		
High-risk TBI group	3.0 (2.3 to 4.0)		
CT time (if performed)			
Physician evaluation to CT order placement	1.8 (1.2 to 2.8)	0.2 (0.1 to 0.5)	1.6 (1.2 to 2.1)
ED length of stay			
Overall use	3.2 (2.5 to 4.0)	2.3 (1.5 to 3.5)	1.0 (0.9 to 1.2)
CT obtained	5.1 (4.1 to 6.3)	3.5 (2.8 to 4.5)	1.5 (0.9 to 1.5)
CT not obtained	3.2 (2.5 to 3.8)	1.8 (1.4 to 2.5)	1.3 (1.1 to 1.4)

TBI, traumatic brain injury; *CT*, computed tomography.
*For children who were observed, ED observation time was the time of physician evaluation to CT order placement (for those who had a CT performed) or to ED disposition (either discharge or admission).

(adjusted OR 0.31; 95% CI 0.25 to 0.37). We observed a similar time-dependent decrease in cranial CT rate in each of the 3 PECARN traumatic brain injury risk groups (Table 4).

LIMITATIONS

Our study has several important limitations. First, because few children received a diagnosis of a clinically important traumatic brain injury, we had limited ability to determine whether ED observation before CT decisionmaking could be associated with a clinically important delay in head injury diagnosis. Although observation did not delay a clinically important diagnosis in any of our patients, a much larger multicenter study of children presenting to the ED with minor blunt head trauma would be needed to address this important clinical question.

Second, the study times we chose may only approximate the actual times at which various events occurred. For example, we selected the time of attending provider sign-up on the tracking board as the best approximation of the time of physician evaluation, although the actual patient evaluation may not have occurred precisely at this time. Similarly, time of injury was documented according to caregiver report and could not be independently verified. Additionally, for observed patients, we were unable to determine at what point during the observation period clinical symptoms improved or resolved.

Third, our clinical follow-up was limited to electronic medical record review for return visits. Because we did not perform additional clinical follow-up for children discharged from the ED without a CT, we may have missed identifying a child with a clinically important traumatic brain injury who returned to another medical center for management. This possibility however, seems very unlikely according to the extremely low prevalence of this event in the prospective PECARN traumatic brain injury cohort study (only 1 of 42,412 children with blunt head trauma was initially discharged from the ED and later returned to the ED and was found to have a clinically important traumatic brain injury; 0.002% of study cohort).[2] We would expect that most children requiring neurosurgery would have returned to the study institution because it is the major trauma referral center in the area.

Fourth, we cannot be certain that children who did not have a CT performed did not meet our positive CT result definition because many children with a positive CT result do not require any specific intervention for their injuries.

Fifth, clinicians decided to observe a head-injured child according to a number of factors, most important of which is the severity of the head injury. Although we stratified by severity with the PECARN traumatic brain injury risk classification and adjusted for a number of patient and clinician factors, including time from injury to physician evaluation, we cannot exclude the possibility of residual confounding in our analysis.

Sixth, this study was conducted at a single institution, which may limit its generalizability to other clinical settings. We did, however, include a large number of providers with a variety of training and experience levels, which at least partially reflects the breadth of providers providing ED care to children.

Table 4. The relationship between ED observation time in hours and cranial CT rate by PECARN TBI risk group.

PECARN TBI Risk Group	Adjusted OR* (95% CI)
Overall	0.31 (0.25–0.37)
Very low	0.47 (0.31–0.73)
Intermediate	0.28 (0.21–0.36)
High	0.11 (0.05–0.24)

*Adjusted for time from injury, patient age, sex, physician type (pediatric emergency medicine versus general pediatrics), and study month.

DISCUSSION

We performed a single-center prospective cohort study of children with minor blunt head trauma presenting to the ED. Observation was a common management strategy in our study cohort and was associated with a time-dependent decrease in CT rate for children in each of the PECARN traumatic brain injury

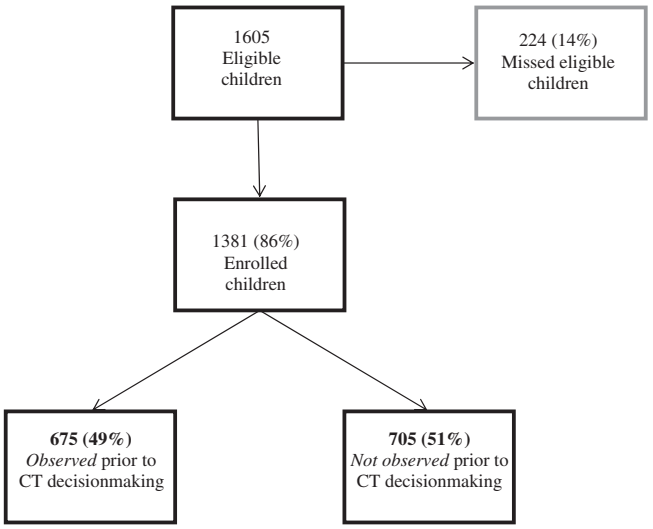


Figure 2. Patient flow diagram.

risk groups, even after taking into account the time from injury to physician evaluation. All of the children with a clinically significant traumatic brain injury had an immediate CT scan without undergoing a period of observation.

Observation has been previously associated with a reduction in cranial CT rate in a large multicenter study of children presenting to the ED for evaluation of head trauma.[14] Our findings add to these previous findings by demonstrating the time-dependent effect of ED observation time on the CT rate for all children at risk of traumatic brain injury. In fact, every hour of ED observation reduced rate of CT use by 70% on average after adjustment for other patient and provider factors. The proportion of the clinicians who chose to observe a child with blunt head trauma before CT decisionmaking increased significantly (15% in the PECARN study of observation conducted at 25 participating institutions[14] to approximately 50% in our current investigation), reflecting widespread clinician acceptance of this management strategy at the study institution.

Clinical observation before CT decisionmaking allows selective CT scanning for children whose symptoms evolve or do not improve during the period of observation. In principle, observation would be most useful for children at intermediate risk, for whom the need for cranial CT may not be entirely clear at the initial evaluation. Indeed, in our study population, 60% of children in the intermediate PECARN traumatic brain injury risk group were observed before CT decisionmaking. The majority of these patients had resolution of symptoms during the course of the observation period. We found that observation was also associated with a reduction in CT rates for children in both the very low- and high-risk PECARN traumatic brain injury groups. For children in the high-risk group, those with initially altered mental status that improves during observation may not require neuroimaging. Because one fifth of patients had a CT performed but only a few children had a clinically important traumatic brain injury (and even fewer required an acute intervention), further improvements in the ED care of children with minor blunt head trauma may still be possible.

As expected, we measured an increase in ED length of stay for patients who were observed before CT decisionmaking. In our study cohort, clinicians chose to observe children in all 3 PECARN traumatic brain injury risk groups. However, the risk of a clinically significant traumatic brain injury for children in the very low-risk group is low,[2] suggesting that many of these children might be safely discharged home without requiring ED observation. By reducing the observation rate for children in the very low-risk group, the effect of this management strategy on ED length of stay might be reduced. Longer ED lengths of stay have been associated with increased resource use and reduced throughput for other patients.[18,19] Further studies will be needed to evaluate the tradeoff in health care costs between a longer ED visit and a reduced CT rate.

Our study was not designed to determine the optimal period of observation before CT decisionmaking. We were unable to exclude the possibility that clinical observation beforehand would lead to a delay in the diagnosis of a clinically important traumatic brain injury. However, a previous investigation demonstrated that a delayed presentation (>6 hours after injury) of a significant traumatic brain injury was exceedingly rare.[13] In our study, the median time between head injury and CT decisionmaking was approximately 4 hours for observed patients (which includes 2.5 hours of ED observation), which we believe represents a reasonable observation period for a head-injured child. The decision to forgo imaging after an ED observation period will depend on physician risk tolerance and shared decisionmaking between physicians, patients, and their families.[20]

Pediatric cranial CT use has increased significantly during the last several decades,[21-23] although more recent work demonstrates modest decreases in cranial CT rates for children with blunt head injury.[15] Children, because of their rapid growth rates and longer life expectancies, are more radiosensitive than adults. A recent large retrospective study demonstrated an increase in the 10-year risk of both leukemia and brain cancer for children who underwent a CT scan in childhood and young adulthood.[8] Given the long-term risks of lethal malignancy,[6-9] both clinicians and parents of children remain appropriately concerned about exposing children to ionizing radiation. Recent surveys suggest that parents prefer observation in the ED over immediate CT in the management of their child's head injury.[24] Future work will need to elucidate the best method of risk communication to patients and their families in regard to ED decisions involving diagnostic imaging.

In summary, ED observation before CT decisionmaking for children with minor blunt head trauma was associated with reduced CT usage without a delay in the diagnosis of clinically important traumatic brain injury. Evidence-based guidelines for the care of children with minor blunt head trauma should include ED observation as a management strategy, particularly for those children at intermediate risk of traumatic brain injury. Further studies are needed to clarify the optimal period

of observation and to substantiate the safety of this management strategy.

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