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# The Effect of Observation on Cranial Computed Tomography Utilization for Children After Blunt Head Trauma

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## KEY WORDS

traumatic brain injury, computed tomography, clinical observation

## ABBREVIATIONS

TBI—traumatic brain injury  
CT—computed tomography  
PECARN—Pediatric Emergency Care Applied Research Network  
GCS—Glasgow Coma Scale  
CI—confidence interval

Drs Nathan Kuppermann and Lise E. Nigrovic conceived and designed the study. Dr Nathan Kuppermann obtained grant funding. Drs Nathan Kuppermann, James F. Holmes, Peter S. Dayan, Jeff E. Schunk, Arthur Cooper, Shireen M. Atabaki, John Hoyle, Ms Adele Foerster and the other site principal investigators listed in the acknowledgement section acquired data and provided supervision for the study. Drs Lise E. Nigrovic and Nathan Kuppermann and Ms Michelle Miskin conducted the data analysis and interpreted the data. Drs Lise E. Nigrovic and Nathan Kuppermann drafted the manuscript. All authors critically revised the manuscript.

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**WHAT'S KNOWN ON THIS SUBJECT:** Emergency-department observation of children with minor blunt head trauma for symptom progression before making a decision regarding computed tomography may decrease computed tomography use. The actual impact of this strategy on computed tomography use and clinical outcomes, however, is unknown.



**WHAT THIS STUDY ADDS:** Clinicians currently observe some children with head trauma before deciding whether to obtain a cranial computed tomography scan. Patients who were observed had a significantly lower rate of overall cranial computed tomography use after adjusting for markers of head injury severity.

## abstract

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**OBJECTIVE:** Children with minor blunt head trauma often are observed in the emergency department before a decision is made regarding computed tomography use. We studied the impact of this clinical strategy on computed tomography use and outcomes.

**METHODS:** We performed a subanalysis of a prospective multicenter observational study of children with minor blunt head trauma. Clinicians completed case report forms indicating whether the child was observed before making a decision regarding computed tomography. We defined clinically important traumatic brain injury as an intracranial injury resulting in death, neurosurgical intervention, intubation for longer than 24 hours, or hospital admission for 2 nights or longer. To compare computed tomography rates between children observed and those not observed before a decision was made regarding computed tomography use, we used a generalized estimating equation model to control for hospital clustering and patient characteristics.

**RESULTS:** Of 42 412 children enrolled in the study, clinicians noted if the patient was observed before making a decision on computed tomography in 40 113 (95%). Of these, 5433 (14%) children were observed. The computed tomography use rate was lower in those observed than in those not observed (31.1% vs 35.0%; difference:  $-3.9%$  [95% confidence interval:  $-5.3$  to  $-2.6$ ]), but the rate of clinically important traumatic brain injury was similar (0.75% vs 0.87%; difference:  $-0.1%$  [95% confidence interval:  $-0.4$  to  $0.1$ ]). After adjustment for hospital and patient characteristics, the difference in the computed tomography use rate remained significant (adjusted odds ratio for obtaining a computed tomography in the observed group: 0.53 [95% confidence interval: 0.43–0.66]).

**CONCLUSIONS:** Clinical observation was associated with reduced computed tomography use among children with minor blunt head trauma and may be an effective strategy to reduce computed tomography use. *Pediatrics* 2011;127:1067–1073

Minor blunt head trauma is a common reason for children to present to the emergency department,<sup>1</sup> although the prevalence of traumatic brain injury (TBI) is low.<sup>2-5</sup> Cranial computed tomography (CT) is the reference standard for emergently diagnosing TBI in children. Clinicians frequently include an emergent CT in the diagnostic evaluation of children with nontrivial blunt head trauma who present to the emergency department. Furthermore, emergency-department utilization of cranial CT has increased substantially over the last decade.<sup>6,7</sup>

Cranial CT is not without risks. Most important are the long-term risks of lethal malignancy induced from the ionizing radiation exposure associated with CT scans.<sup>8-11</sup> Although estimates of the magnitude of this risk vary, children are at greater risk than adults both because their tissues are more radiosensitive (because of a larger proportion of dividing cells) and because they have longer life expectancies during which a radiation-induced malignancy could develop.<sup>12</sup> Strategies to reduce this risk include minimizing the radiation dose in CT scans<sup>13-15</sup> and avoiding unnecessary CTs, while at the same time minimizing the risk of missing clinically important TBIs.<sup>4,16</sup>

Existing clinical prediction rules for the management of minor head trauma in children provide evidence-based tools to determine the risk of TBI after blunt head trauma and empower clinician decision making.<sup>4,16,17</sup> Implementation of prediction rules may decrease unnecessary CT scans by identifying children who are at very low risk for clinically important TBI for whom CT scans could be obviated. Another potential method to decrease unnecessary CT scans is observation of children with minor blunt head trauma in the emergency department for a period of time before making a decision regarding CT use. This would

potentially allow time for the child's symptoms and/or signs to improve or evolve, which may enhance the accuracy of CT decision making. However, this clinical strategy has not been rigorously evaluated.

We performed a secondary analysis of a large prospective cohort study conducted by the Pediatric Emergency Care Applied Research Network (PECARN) of children presenting to any of 25 participating emergency departments for minor blunt head trauma.<sup>4</sup> We sought to (1) determine how frequently the clinical strategy of observation before the decision to obtain a CT is used in current practice; and (2) assess the impact of clinical observation before CT decision making on CT rates.

## METHODS

### Study Design

We performed a planned subanalysis of a large, prospective cohort study of children younger than 18 years of age with nontrivial head trauma who presented to any of 25 participating PECARN emergency departments between June 2004 and September 2006. The study was approved by the institutional review board at each participating institution, with a waiver of consent at some sites and verbal consent for telephone follow-up at others. Study methods have been previously described in detail.<sup>4</sup> Specific methods pertinent to this subanalysis are provided below.

### Inclusion and Exclusion Criteria

We enrolled patients with Glasgow Coma Scale (GCS) scores of 14 to 15 after blunt head trauma who presented to the emergency department within 24 hours of the traumatic event. Patients with trivial injury mechanisms (eg, ground-level falls or running into stationary objects) without signs of TBI, or with penetrating trauma, comorbidities (ventricular

shunts, bleeding disorders), or previous neuroimaging were excluded.<sup>4</sup>

### Data Collection

After standardized training at each study site, including the definition of observation, treating faculty or fellow physicians completed a structured case report form for all enrolled patients. The case report form included patient demographics, injury mechanisms, clinical history, and physical examination findings. Clinicians indicated whether they observed the child for a period of time before deciding whether to obtain a cranial CT scan ("Was the patient observed in the ED after your initial ED evaluation to determine if to obtain head CT? yes/no"). If the clinician answered affirmatively to this question, the child was assigned to the "observation" group for analysis. If, however, the clinician responded negatively to this question, the patient was placed into the "no-observation" group for purposes of analysis. If this question was not answered, then the patient was excluded from this substudy. For children who were observed before a CT decision was made, clinicians also were asked to document whether headache (limited to verbal children  $\geq 2$  years of age), vomiting, or GCS scores worsened, stayed the same, or improved during the period of observation.

### Outcome Measures

After patient enrollment, study staff reviewed patient medical records to determine 2 outcomes: (1) rate of CT scan use and (2) frequency of clinically important TBI. Study staff who performed the medical record reviews were unaware of the clinical data from the emergency department. Clinically important TBI was defined as follows: intracranial injury resulting in death, neurosurgical intervention, intubation for longer than 24 hours, or hospital admission for 2 or more nights because of the head

trauma. For children discharged from the emergency department, clinical follow-up was performed (details described previously).<sup>4</sup>

### Statistical Analyses

We initially compared our 2 outcomes between children in the observation and no-observation groups. Subsequently, we compared CT rates on the basis of whether initial headache, vomiting, and GCS scores improved, stayed the same, or worsened for those patients who were observed in the emergency department before the decision to obtain CT scans. The Pearson  $\chi^2$  test of independence was used to compare groups.

To address the possibility that children in the observation group might represent a group with different clinical characteristics (ie, with either more or fewer signs of TBI) than those in the no-observation group, we performed several analyses. We performed bivariable analysis to compare the children in the observation group with those in the no-observation group, with regard to the following factors: age (<2 years vs  $\geq 2$  years); altered mental status (GCS score of 14, agitation, sleepiness, slow responses, or repetitive questioning); a history of loss of consciousness (any duration of unconsciousness after injury); nonfrontal scalp hematoma (swelling of the scalp in the temporal-parietal or occipital areas); seizure (any posttraumatic tonic, clonic, or jerking activity); severe injury mechanism (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 age and >5 feet for children >2 years of age; or head struck by high-impact object); palpable or visible signs of skull fracture (probable or possible skull fracture on the basis of swelling or distortion of

**TABLE 1** Proportion of Children With Each Clinical Feature Between Children Who Were Observed Versus Those Who Were Not Observed Prior to the Decision of Whether to Obtain a Cranial CT

	Observation, %, n = 5433	No Observation, %, n = 34 680	Difference in Rates, %	95% CI
Vomiting	21.0	11.9	9.1	8.0–10.3
Aged <2 years	30.7	24.5	6.2	4.9–7.5
Altered mental status <sup>a</sup>	16.7	12.2	4.5	3.4–5.6
Severe injury mechanism <sup>b</sup>	17.4	13.4	4.0	3.0–5.2
Loss of consciousness	17.3	15.1	2.2	1.1–3.3
Seizure	1.3	1.2	0.1	–0.2–0.5
Clinical evidence of skull fracture <sup>c</sup>	3.1	3.0	0.1	–0.4–0.5
Nonfrontal scalp hematoma	18.4	18.5	–0.1	–1.2–1.0

<sup>a</sup> GCS of 14: agitation, sleepiness, slow responses, or repetitive questioning.

<sup>b</sup> Motor vehicle crash with patient ejection, death of another passenger, or rollover; pedestrian or bicyclist without helmet struck by motorized vehicle; falls of higher than 3 feet for children younger than 2 years of age and higher than 5 feet for children older than 2 years of age; or head struck by high-impact object.

<sup>c</sup> Probable or possible skull fracture based on swelling or distortion of the scalp on digital examination or signs of basilar skull fracture.

the scalp on digital examination or signs of basilar skull fracture); and vomiting (presence of any vomiting after the time of injury). For the bivariable analysis, we calculated the overall prevalence rate, differences in prevalence rates, and the 95% confidence intervals (CIs) for the rate difference for the prevalence of each of the clinical factors in the observation and in the no-observation groups. For all the analyses, we used SAS/STAT software (version 9.2; SAS Institute, Cary, NC).

### RESULTS

A total of 42 412 children with GCS scores of 14 to 15 were enrolled in the main study (77% of eligible patients). Clinicians documented whether the patient was observed before a decision was made to obtain or not to obtain a CT in 40 113 patients (95% of eligible, enrolled patients). All subsequent analyses are limited to the 40 113 children who had their observation status recorded. The median age of the children in this substudy was 5.6 years (interquartile range: 2.0–12.0) and 62% were boys.

Of 40 113 patients in this subanalysis, 5433 (14%) were observed in the emergency department before the decision of whether to obtain a CT was made, and 34 680 (86%) were not observed before the decision whether to obtain a CT was

made. The rate of clinician use of the strategy of observation before CT decision making varied between participating centers, ranging from 7% to 29%.

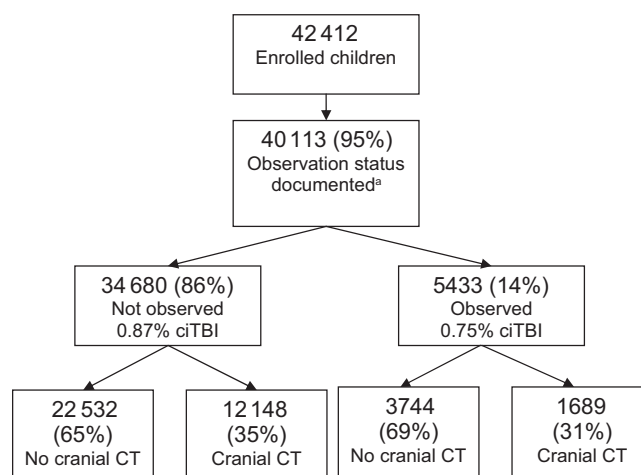
The median time from injury to emergency-department clinician evaluation was slightly shorter for the children in the observation group (1.5 hours [interquartile range: 0.9–2.7]) compared with the no-observation group (1.8 hours [interquartile range: 1.0–3.5]; difference: 0.3 hours [95% CI: 0.2–0.3]). Although statistically different, the 0.3-hour (18-minute) difference was minimal and is unlikely to be clinically important.

We compared the clinical characteristics between the patients observed and those who were not observed to assess whether CT rates might differ between groups on the basis of clinical findings (Table 1). Children who were observed before the decision of whether to obtain a CT were younger and were more likely to have had severe mechanisms of injury. Children who were observed also were more likely to present with vomiting, altered mental status, or a history of loss of consciousness. There was no difference between groups in the rates of posttraumatic seizures, clinical evidence of skull fractures, or scalp hematomas on examination.

The CT use rate was significantly lower

in children who were observed before the decision regarding CT use was made (1689 of 5433 [31.1%]) compared with those not observed before a decision regarding CT use was made (12 148 of 34 680 [35.0%]; difference:  $-3.9\%$  [95% CI:  $-5.3$  to  $-2.6\%$ ]) (Fig 1). In the unadjusted analysis, the 3.9% absolute decrease translates to the elimination of 39 cranial CT scans per 1000 children who presented to the emergency department with blunt head trauma or a 11% relative reduction from the baseline 35% CT use rate. However, the rate of clinically important TBI was similar between the 2 groups (41 of 5433 [0.75%] in the observation group versus 301 of 34 680 [0.87%] in the no-observation group; difference:  $-0.1\%$  [95% CI:  $-0.4$  to  $0.1\%$ ]). Table 2 lists the types of clinically important TBIs in patients observed and not observed before CT decision making. Of 5433 children in the observation group, 3744 (69%) were discharged home from the emergency department without a CT scan during the initial emergency-department visit and 26 (0.7%) returned to a health care facility later for a CT scan. Of these, 4 children had traumatic findings on the CT scan, but only 1 had a clinically important TBI (the child was hospitalized for 2 nights for head-injury management and required no additional acute intervention). Of the 34 680 children in the no-observation group, 22 532 (65%) were discharged from the hospital from the emergency department without a CT scan during the initial emergency-department visit, and 81 (0.4%) returned later for a CT scan. Of these, 3 had traumatic findings on CT scan and none had a clinically important TBI.

After adjusting for all clinical covariates included in the bivariable analysis, as well as for hospital center, the odds of obtaining a CT scan remained significantly different between groups (adjusted odds ratio for obtaining a CT scan



**FIGURE 1**

Patient flowchart. ciTBI indicates clinically important traumatic brain injury. <sup>a</sup>Observation was defined as a period of time spent in the emergency department before clinician decision of whether to obtain a CT scan was made.

**TABLE 2** Distribution of Types of Clinically Important TBI (ciTBI) for Patients Who Were Observed Versus Those Who Were Not Observed Prior to the Decision of Whether to Obtain a Cranial CT

Type of ciTBI	ciTBI in Observation Group, <i>n</i> = 41 of 5433 (0.75%)	ciTBI in the No-Observation Group, <i>n</i> = 301 of 34 680 (0.87%)
Death from head injury	0	0
Emergent neurosurgical intervention <sup>a</sup>	6 (15%)	50 (17%)
Intubation for >24 hours <sup>a</sup>	0	8 (3%)
Hospital admission for >2 days <sup>a</sup>	41 (100%)	297 (99%)

<sup>a</sup> For management of head injury.

when comparing the observed and not-observed patient groups: 0.53 [95% CI: 0.43–0.66]). However, the odds of having a clinically important TBI remained similar between groups after these adjustments (adjusted odds ratio for clinically important TBI when comparing observed and not-observed patient groups: 0.81 [95% CI: 0.57–1.17]).

In those patients observed before a decision regarding CT was made, changes in symptoms and signs over time affected the likelihood of CT use (Table 3). For patients with initial headaches (who were  $\geq 2$  years of age), vomiting, or a GCS score of 14, the rate of CT use was lower for those patients whose symptoms improved compared with those whose symptoms either remained the same or worsened during the period of observation. For patients with no initial headaches (who were  $> 2$  years of age), no vomiting, or with an initial GCS scores of 15, the cranial

CT rate was lower if the symptoms stayed the same compared with those whose symptoms worsened. For patients who, after a period of emergency-department observation, had either no initial headache or improved headache, no vomiting or improved vomiting, as well as those with GCS scores of 15, the CT rate was 976 of 4010 (24.3%) compared with 13 837 of 40 113 (34.5%) for the whole population of patients in this substudy.

## DISCUSSION

In this study, we evaluated a clinical management strategy for the care of children with minor blunt head trauma. In our large, multicenter, prospective study of pediatric head trauma, we found that observation before making a decision regarding CT use was common (14% of patients) and was associated with approximately one-half the adjusted odds of

**TABLE 3** Comparison of Cranial CT Rates by Progression of Clinical Symptoms Among the Patients Observed in the Emergency Department Prior to the Decision of Whether to Obtain a Cranial CT,  $n = 5433$

Clinical Factor	Patients	Cranial CT
	<i>n</i>	Rate, <i>n</i> (%)
Initial headache <sup>a</sup>	1792	802 (45)
Improved	1159	405 (35) <sup>b</sup>
Same	397	282 (71)
Worse	49	42 (86)
Missing	187	73 (39)
Initial vomiting	1134	518 (46)
Improved	832	297 (36) <sup>b</sup>
Same	163	144 (88)
Worse	27	25 (93)
Missing	112	52 (46)
Initial GCS 14	192	140 (73)
Improved	115	73 (63) <sup>b</sup>
Same	49	45 (92)
Worse	5	5 (100)
Missing	23	17 (74)
No initial headache <sup>a</sup>	1410	354 (25)
Same	1269	306 (24) <sup>c</sup>
Worse	32	17 (53)
Missing	109	31 (28)
No initial vomiting	4266	1158 (27)
Same	4038	1090 (27) <sup>c</sup>
Worse	24	17 (71)
Missing	204	51 (25)
Initial GCS 15	5241	1549 (30)
Same	4556	1257 (28) <sup>c</sup>
Worse	390	193 (49)
Missing	295	99 (34)

<sup>a</sup> Initial headache was only assessed for verbal children 2 years of age and older.

<sup>b</sup>  $P < .001$  for comparison between improved, same, and worse groups.

<sup>c</sup>  $P < .001$  for comparison between same and worse groups.

obtaining a CT scan compared with non-observed patients. Not only did the patients who were observed have a significantly lower rate of overall CT use, but these patients also had a similar rate of clinically important TBI, even after adjusting for factors associated with TBI. Furthermore, the rate of CT use was lower for patients whose symptoms improved during the period of observation. The PECARN head trauma clinical decision rules accurately identify children at the lowest risk of clinically important TBI, for whom CT is typically not necessary.<sup>4,16</sup> In that study, abnormal mental status and signs of skull fracture were associated with a relatively high risk of clinically important TBI, such that CT would typically be recom-

mended for children with these clinical findings.<sup>4</sup> However, several other risk factors were neither associated with a high risk nor very low risk of clinically important TBI. The ideal candidates for emergency-department observation before CT decision making are likely those patients who are neither at high nor very low risk of clinically important TBI but who may have other risk factors that place them in an "intermediate"-risk group. In the original study in which the clinical prediction rules were derived,<sup>4</sup> children younger than 2 years of age were in such an intermediate-risk group if they did not have clinical evidence of an abnormal mental status or skull fractures but had at least 1 of the following risk factors present: nonfrontal scalp hematoma; loss of consciousness for longer than 5 seconds; severe mechanism of injury; or not acting normally per parent. Children 2 years of age or older were in a similar intermediate-risk group if they also did not have clinical evidence of an abnormal mental status or basilar skull fractures but had a history of loss of consciousness, history of vomiting, severe mechanism of injury, or severe headache.<sup>4</sup>

In the clinical prediction rule validation set, a substantial number of patients (~30%) fell into these intermediate-risk groups, in which the overall risk of clinically important TBI was 0.9%.<sup>4</sup> Interestingly, in the current substudy reported here, we found that children observed before the decision was made to have a CT scan were more likely to have clinical factors that would place them in this intermediate-risk group than children who were not observed (clinicians evaluated the patients and gathered the patient data before the creation of the prediction rules that resulted from the original study). For patients either in the very-low or the high-risk groups, clinicians made more immediate decisions about whether to obtain a cranial CT

scan. In addition, for those patients who were observed before the decision was made to obtain a CT scan, clinicians were less likely to obtain a CT for those whose symptoms (headache, vomiting, or GCS) improved during the period of observation, further suggesting the success of this strategy. Although the risk of clinically important TBI in this intermediate-risk group is nonnegligible, cranial CT itself presents radiation risks. The clinical strategy of observation allows CT to be used selectively for children who are not in a high-risk group for clinically important TBI and whose symptoms progress or do not resolve over a period of observation.

Rarely, children with apparently minor blunt head trauma will be initially asymptomatic but will clinically deteriorate after a period of time after the initial injury. Such a clinical deterioration is typically attributed to increased intracranial pressure from either an expanding intracranial hematoma or progressive cerebral edema. In 1 retrospective study of 967 children with blunt head trauma, 4% of children with intracranial injuries developed symptoms after a lucid interval of 2 hours.<sup>18</sup> In a second retrospective study of 53 children with epidural hematomas, 34% were diagnosed more than 6 hours after injury (mostly because of a delayed presentation for medical care).<sup>19</sup> However, the first study included patients whom most clinicians would consider symptomatic (children with a loss of consciousness of up to 5 minutes in duration), and the second study focused on a single infrequent type of intracranial injury known to be associated with delay in diagnosis on occasion. A recent population-based study<sup>20</sup> found that the incidence of delayed diagnosis of intracranial injury was very low (defined as a child with initial normal GCS and normal physical examination who had any type of intracranial injury diagnosed by neuroimaging >6 hours after injury). In this retrospective cohort

of 17 692 children with minor blunt head trauma presenting to any emergency department in the Calgary Health Region over an 8-year study period, no child had a delayed diagnosis of intracranial hemorrhage with deterioration in level of consciousness at the time of diagnosis (upper limit of 95% CI: 0.02%). Five children in that study had a delayed diagnosis of intracranial hemorrhage, although without a deterioration in level of consciousness at the time of diagnosis (upper limit of 95% CI: 0.07%).<sup>20</sup> These studies offer additional evidence that observation after minor head trauma provides an important management strategy for a subset of children with apparently minor blunt head trauma by allowing symptom progression or resolution in a monitored environment.

The strategy of observation for the management of head trauma has been only studied in a limited fashion. Investigators measured the impact of a clinical pathway for children with minor blunt head trauma that included observation at a single Canadian emergency department over a 2-year period.<sup>21</sup> Eleven (3%) of 417 study patients were observed in the emergency department for between 3 and 6 hours before the decision of whether to either admit to the hospital or obtain emergent neuroimaging was made. None of the observed patients had unexpected clinical deteriorations or had clinically important missed TBIs. Such algorithms require additional study with larger numbers of patients in diverse settings.

Our study has several limitations. First, only 73% of all eligible patients were enrolled in this substudy. However, patients enrolled in the original study did not differ significantly from those not enrolled either in patient age or prevalence of TBI identified by CT scan, suggesting that we included a nonbiased sample.<sup>4</sup> Second, because of the observational study design, patients who were observed before the decision

whether to obtain a CT scan differed in many regards from those for whom clinicians decided immediately whether to obtain a CT scan. Although we performed a multivariable analysis to adjust for important clinical factors associated with TBI to address potential differences between the study groups, there may have been some residual confounding. Third, we did not record the duration of observation before CT decision making, and its impact on emergency-department length of stay, and therefore cannot make specific recommendations regarding the period of observation. Finally, we were unable to determine whether observation caused any clinically important delays in neurosurgery for the patients in the observation group who required neurosurgical intervention.

## CONCLUSIONS

Clinical observation before making a decision regarding CT scan use seems to be a safe and potentially effective strategy to manage a subset of children with minor blunt head trauma. This clinical strategy may prove to reduce unnecessary exposure to the long-term risks of ionizing radiation, while minimizing the risk of missing clinically important TBIs. Subsequent studies are needed to determine the appropriate duration of clinical observation, to study the safety of the observation strategy, as well as to measure the impact on both CT use rates and overall emergency-department length of stay.

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†Deceased

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## The Effect of Observation on Cranial Computed Tomography Utilization for Children After Blunt Head Trauma

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