Isolated Loss of Consciousness in Children With Minor Blunt Head Trauma

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IMPORTANCE A history of loss of consciousness (LOC) is frequently a driving factor for computed tomography use in the emergency department evaluation of children with blunt head trauma. Computed tomography carries a nonnegligible risk for lethal radiation-induced malignancy. The Pediatric Emergency Care Applied Research Network (PECARN) derived 2 age-specific prediction rules with 6 variables for clinically important traumatic brain injury (ciTBI), which included LOC as one of the risk factors.

OBJECTIVE To determine the risk for ciTBIs in children with isolated LOC.

DESIGN, SETTING, AND PARTICIPANTS This was a planned secondary analysis of a large prospective multicenter cohort study. The study included 42 412 children aged 0 to 18 years with blunt head trauma and Glasgow Coma Scale scores of 14 and 15 evaluated in 25 emergency departments from 2004-2006.

EXPOSURE A history of LOC after minor blunt head trauma.

MAIN OUTCOMES AND MEASURES The main outcome measures were ciTBIs (resulting in death, neurosurgery, intubation for >24 hours, or hospitalization for ≥2 nights) and a comparison of the rates of ciTBIs in children with no LOC, any LOC, and isolated LOC (ie, with no other PECARN ciTBI predictors).

RESULTS A total of 42 412 children were enrolled in the parent study, with 40 693 remaining in the current analysis after exclusions. Of these, LOC occurred in 15.4% (6286 children). The prevalence of ciTBI with any history of LOC was 2.5% and for no history of LOC was 0.5% (difference, 2.0%; 95% CI, 1.7-2.5). The ciTBI rate in children with isolated LOC, with no other PECARN predictors, was 0.5% (95% CI, 0.2-0.8; 13 of 2780). When comparing children who have isolated LOC with those who have LOC and other PECARN predictors, the risk ratio for ciTBI in children younger than 2 years was 0.13 (95% CI, 0.005-0.72) and for children 2 years or older was 0.10 (95% CI, 0.06-0.19).

CONCLUSIONS AND RELEVANCE Children with minor blunt head trauma presenting to the emergency department with isolated LOC are at very low risk for ciTBI and do not routinely require computed tomographic evaluation.
HEAD traumas in children is common and accounts for more than a half million emergency department (ED) visits annually in the United States.1 The overall risk for traumatic brain injury (TBI) in children after blunt head trauma is low, with the estimated prevalence for TBI requiring neurosurgical intervention ranging from 0.6% to 8.3%.2-6 In children with minor blunt head trauma (defined by Glasgow Coma Scale [GCS] scores of 13-15), the risks are substantially lower.7-14 Nevertheless, failing to detect a clinically significant TBI can have devastating consequences,2,15,16 and fear of missing these rare injuries has been the main factor driving an increase in the use of computed tomography (CT) imaging over the past 2 decades.17-19 With the growing awareness of the malignancy risks associated with ionizing radiation exposure from CT,20-23 the use of emergent CT in head-injured children has been scrutinized.22

Of the clinical factors that strongly influence the use of CT after blunt head trauma, a history of loss of consciousness (LOC) is among the most frequent.11,16,24-30 Clinicians’ concerns about LOC increase with longer LOC duration; however, there is little evidence to support this concern when LOC occurs in isolation.2,16,31 Although LOC after blunt head trauma has been identified as a predictor for TBI in several previous multivariable analyses,2,14,26,30 the importance of a history of isolated LOC (without other symptoms or signs of TBI) as a predictor for clinically important TBIs (ciTBIs) is unclear. Clinical prediction rules derived from large multicenter studies aid the clinician in real-time evidence-based decision making regarding the use of cranial CTs in children with blunt head trauma.2,12,13

We previously derived and validated 2 age-specific clinical prediction rules for identifying children at very low risk for ciTBIs in 42 412 children with minor blunt head trauma in the Pediatric Emergency Care Applied Research Network (PECARN).12 Although a history of LOC was identified as a predictor of ciTBI in the prediction rules, the importance of isolated LOC and its association with ciTBI was not previously investigated. The objective of this study was to determine the risk for ciTBI in children with isolated LOC.

Methods

Study Design
We performed a planned subanalysis of a large prospective observational cohort study of children younger than 18 years of age with blunt head trauma enrolled in the 25 participating PECARN EDs between 2004 and 2006. Institutional review board approval was obtained for the study protocol at each participating institution. Waiver of consent or verbal consent for telephone follow-up was obtained, depending on the institution. The detailed methods from the parent study have been previously published.12 Methods for the current substudy are summarized here.

Inclusion and Exclusion Criteria
Children with blunt head trauma evaluated within 24 hours of injury and presenting with GCS scores of 14 and 15 were eligible for enrollment. We excluded children with histories of trivial injury mechanisms, defined as ground-level falls or running into stationary objects, and with no signs or symptoms of head injury except for scalp abrasions or lacerations. We also excluded children with penetrating trauma, significant comorbidities (eg, bleeding disorders and ventricular shunts), pre-existing neurologic disorders complicating assessment, or neuroimaging obtained at a transferring hospital.

LOC Definitions
We considered a history of LOC to be present if there was any period of unconsciousness reported after the traumatic event. The treating staff physician completed a structured data collection form for all enrolled patients, including whether there was a history of LOC, with options to answer yes, no, suspected, or unknown. For purposes of analysis, a response of suspected LOC was considered to be LOC. The duration of LOC was marked as either less than 5 seconds, 5 seconds to less than 1 minute, 1 to 5 minutes, more than 5 minutes, or unknown. On the case report form, clinicians were also asked to indicate the most important indications influencing their decisions to obtain cranial CT scans from a list of options.

Table 1. Definitions of Isolated LOC and the PECARN ciTBI Prediction Rules

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Isolated LOC Defined by the PECARN Rules (PECARN-Isolated LOC)</th>
<th>Expanded Definition of Isolated LOC (Expanded-Isolated LOC)</th>
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<tbody>
<tr>
<td>Children &lt;2 y</td>
<td>LOC&gt;5 s; none of the other age-specific PECARN predictors, altered mental status, nonfrontal scalp hematoma, severe mechanism of injury, palpable skull fracture, and acting abnormally according to parent</td>
<td>Any duration LOC; none of the other age-specific PECARN clinical predictors (from PECARN-isolated LOC) excluding mechanism of injury, none of the following: seizure, neurologic deficit, signs of basilar skull fracture, any scalp hematoma, any traumatic scalp finding (eg, abrasion, ecchymosis, and laceration), any headache, amnesia, and acting abnormally according to parent</td>
</tr>
<tr>
<td>Children ≥2 y</td>
<td>Any LOC; none of the other age-specific PECARN predictors, altered mental status, history of vomiting, signs of basilar skull fracture, severe mechanism of injury, and severe headache</td>
<td>Any LOC; none of the other age-specific PECARN clinical predictors (from PECARN-isolated LOC) excluding mechanism of injury, none of the following: seizure, neurologic deficit, palpable skull fracture, any scalp hematoma, any traumatic scalp finding (eg, abrasion, ecchymosis, and laceration), any headache, amnesia, and acting abnormally according to parent</td>
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Abbreviations: ciTBI, clinically important traumatic brain injury; LOC, loss of consciousness; PECARN, Pediatric Emergency Care Applied Research Network.

1. Altered mental status was defined as follows: Glasgow Coma Scale score ≤ 14, agitation, somnolence, repetitive questioning, or slow response to verbal communication.12

2. Severe mechanism of injury was defined as follows: motor vehicle crash with patient ejection, death of another passenger, or rollover; pedestrian or bicyclist without helmet struck by a motorized vehicle; falls of greater than 3 feet (for <2 years old) or falls of greater than 5 ft (for ≥2 years old); or struck by a high-impact object.12

3. Severe mechanism of injury was not included in this definition because it is not a sign or symptom of TBI.
We previously found the interrater reliability for the LOC variable to be substantial. The interrater reliability was moderate for children younger than 2 years (κ = 0.54) and nearly perfect for children 2 years and older (κ = 0.93). The interrater reliability for LOC duration for children younger than 2 years was κ = 0.48 and for children 2 years and older was κ = 0.87. Furthermore, in the parent study, we found that LOC (in addition to 5 other factors) was included as a significant predictor of cTBI for both age-specific clinical prediction rules, with different parameters by age group (Table 1).

For the purposes of the current analysis, we defined isolated LOC in 2 ways to correspond with 2 possible clinician interpretations of isolated LOC: (1) isolated LOC defined by the PECARN rules (PECARN-isolated LOC): isolated LOC with no other PECARN cTBI age-specific predictors and (2) expanded definition of isolated LOC (expanded-isolated LOC): isolated LOC with no other PECARN age-specific clinical predictors and no other clinical factors identified in other pediatric studies of TBI (Table 1). The more extensive list of variables defining expanded-isolated LOC did not include mechanism of injury because it is not a clinical sign or symptom of head injury. Because the exact mechanism of injury is sometimes unclear in the history (eg, height of fall or speed of motor vehicle), this variable was excluded from the expanded-isolated LOC definition so that it would characterize only the clinical presentation of the child. Children were excluded from these analyses if data were missing on any of the age-specific PECARN predictors for PECARN-isolated LOC or any of the PECARN clinical predictors or more than 1 of the variables among the other factors for expanded-isolated LOC.

### Outcome Measures and Definitions

We analyzed 2 outcome measures: (1) cTBI and (2) TBI on CT. Clinically important TBI was defined as (1) death from intracranial injury, (2) any neurosurgical intervention, (3) intubation longer than 24 hours for the head injury, or (4) hospitalization for 2 nights or longer owing to the head injury in association with TBI on CT. Traumatic brain injury on CT included any traumatic intracranial injury and skull fractures depressed at least the width of the table of the skull.

### Data Analysis

For purposes of analysis, the study cohort was divided into children younger than 2 years and those 2 years and older, as per the PECARN cTBI rules. We first calculated the risk for TBI on CT and cTBI for all patients with histories of LOC, regardless of the presence of other risk factors. For the analysis of TBI on CT, we only included children who had CT scans performed; all of the children with cTBI had CT scans performed. We then conducted a bivariable analysis comparing the rates of TBI on CT and cTBI in children with PECARN-isolated LOC vs non-isolated LOC. We calculated frequencies and 95% CIs for categorical variables and the median and interquartile ranges for continuous variables. We then calculated the rates and 95% CIs for TBI on CT and cTBI for those with expanded-isolated LOC. Because of the relatively small sample sizes in the younger age group, we used exact methods to calculate the estimates of relative risk. We also calculated the risk for cTBI for PECARN-isolated LOC plus 1 additional age-specific PECARN predictor. Finally, we calculated the risk for TBI on CT and cTBI stratified by the duration of LOC. We used StatXact (version 8.0) to calculate the relative risk estimates in the younger age group. We used SAS/STAT software (version 9.2; SAS Institute Inc) for all other analyses.

### Results

#### Study Population

We enrolled 42,412 children in the parent study (74.4% of 57,030 eligible children). There were similar rates of TBI on CT between the enrolled and missed eligible patients. In the current analysis, we excluded 1719 children (4.1%) with missing information regarding the presence or absence of a history of LOC. Of the 40,693 remaining children (95.9%), the clinician indicated yes or suspected LOC after head injury for 6286 (15.4%). Among the 13,637 children with cranial CT performed, 5010 (36.7%) had histories of LOC. Of these 13,637 children imaged with cranial CT, 3797 (27.8%) had LOC recorded by the clinician as one of the most important indications influencing their decision to obtain a CT scan.

For the 6286 children with any history of LOC, the median age was 12.7 years (interquartile range, 7.2-15.4 years); 5745 (91.4%) were 2 years and older; 66.2% were boys; and 92.6% had GCS scores of 15. For children without histories of LOC, the median age was 4.7 years (interquartile range, 1.7-10.4 years), and 97.9% had GCS scores of 15. Clinically important TBI occurred in 159 children (2.5%) with any history of LOC and in 162 children (0.5%) with no history of LOC (rate difference, 2.0%; 95% CI, 1.7-2.5). Among children with any LOC and no CT performed, none had cTBI. There was no statistically significant difference in the rate of TBI on CT between the children with (5.1%) and without (4.9%) histories of LOC (rate difference, 0.2%; 95% CI, −0.6 to 1.0).

#### PECARN-Isolated LOC and TBI

For the primary analysis, we focused on children with LOC but no other PECARN predictors (PECARN-isolated LOC). Of the 6286 children with histories of LOC, 436 (6.6%) were excluded because of missing data, most (n = 312) of these patients were missing the severity level of the headache, leaving 5850 children (93.1%) for analysis. Furthermore, PECARN-isolated LOC was present in 2780 (47.5%) of these 5850 patients, of whom 2623 (94.4%) were 2 years and older and 1993 (71.7%) had cranial CT scans performed. The rate of TBI on CT was 1.9% (95% CI, 1.4-2.6; 38 of 1993), and the rate of cTBI was 0.5% (95% CI, 0.2-0.8; 13 of 2780). With PECARN-isolated LOC, the risk for TBI on CT and cTBI was significantly lower than in patients with histories of nonisolated LOC (ie, those having other PECARN cTBI predictors; Table 2). The rates of cTBI in children with LOC >5 seconds for children <2 years and any
LOC for children ≥2 years) plus 1 additional age-specific PECARN ciTBI predictor are presented in Table 3. The eTable in the Supplement provides descriptions of the 13 children with PECARN-isolated LOC and ciTBIs. All had other clinical factors previously shown to be associated with TBI but no other PECARN clinical predictors.

**Expanded-Isolated LOC and TBI**

For the second analysis, we focused on children meeting the expanded-isolated LOC definition (LOC in the absence of any other clinical predictor identified in a pediatric TBI study) because many clinicians may consider a factor isolated only in the absence of any other studied and reported risk factors, independent of ciTBI prediction rules.35 For this analysis, of the 6286 children with histories of LOC, 154 (2.4%) were excluded because of missing data, most (n = 105) of these patients were missing the variable of whether or not they had a headache, leaving 6132 children (97.6%) for analysis. Expanded-isolated LOC was present in 576 (9.4%) of these patients, of whom 432 (75.0%) were 2 years and older and 326 (56.6%) had cranial CT scans performed. The rate of TBI on CT was 0.9% (95% CI, 0.2-2.7; 3 of 326) and that of ciTBI was 0.2% (95% CI, 0.0-1.0; 1 of 576). To explore the importance of the duration of LOC and TBI, we reported the rates of TBI on CT and ciTBI for children with any history of LOC, regardless of the presence or absence of other symptoms, and for children with expanded-isolated LOC, stratified by duration of LOC (Table 4). The duration of LOC did not significantly affect the risk for ciTBI in those with expanded-isolated LOC, although the numbers in each duration category of LOC were small.

**Discussion**

Loss of consciousness is common in children with blunt head trauma and is an important factor influencing CT use for these children.2,11,24-26,28,35 A history of LOC was reported in 15.4% of children enrolled in this large prospective cohort. Furthermore, a history of LOC was identified as one of the primary indications for obtaining cranial CT in nearly 30% of children who were imaged with CT. The overall risk for ciTBI for children with histories of LOC was higher than that for children without LOC but this included children with other signs and symptoms of TBI in addition to LOC. Children with PECARN-isolated LOC and no other PECARN ciTBI predictors had a very low rate of ciTBI (0.5%), and this rate was even lower in children with the expanded definition of isolated LOC (0.2%). There was incremental risk for ciTBI with the addition of 1 PECARN predictor in conjunction with a history of LOC. Given that a history of LOC has a very strong influence on imaging decisions,9,16,24-26,30,37,38 these findings highlight the need for clinicians to determine whether LOC occurred with or without other ciTBI risk factors when deciding on CT use.

We defined isolated LOC in 2 ways but focused on those patients with LOC but no other PECARN ciTBI predictors (PECARN-isolated LOC). Although a history of LOC is one of the PECARN predictors, the presence of LOC alone does not place a child at high risk.32 With more widespread use of the age-specific PECARN ciTBI prediction rules in clinical practice,39-43 further defining the importance of each PECARN predictor in isolation, particularly LOC, is
important.4-4 Because ciTBI is very uncommon in children with isolated LOC, routine CT scanning is unlikely to be beneficial, and a period of observation prior to CT decision making may safely decrease CT use.39,45,46

Parents are often disturbed by witnessing LOC in their children, and clinicians frequently obtain cranial CT scans based on this history.9,16,24,26,30,37,38 A history of LOC has been suggested as an indication for CT in prior studies.9,16,26,30,37,38 Many of these previous studies were limited by small sample sizes, retrospective designs, nonstandard definitions of TBI, differing inclusion criteria and definitions of other signs and symptoms of TBI, and varying outcome definitions. However, to our knowledge, other studies have not demonstrated that LOC is associated with a substantially increased risk for TBI (in particular ciTBI), especially in those patients with normal cranial and neurologic examination findings.3,5,7,13,14,35

Furthermore, and more importantly, prior to the current study, there had been very limited data regarding the risk for ciTBI in the setting of isolated LOC. A few small studies have reported no TBIs in children with isolated LOC after blunt head trauma.8,35 Although LOC was a ciTBI predictor in the parent PECARN study, in the current subanalysis, we demonstrated that when LOC occurs in isolation, with no other clinical risk factors, the risk for ciTBI is remote.

Many studies attempting to derive clinical prediction rules for cranial CT evaluation after blunt head trauma, including several large prospective studies, have not identified LOC as an important factor.3,4,7,13,14 One large, prospective, multicenter study included LOC longer than 5 minutes in their 14-variable rule, which was developed to identify children at high risk for ciTBI who should undergo cranial CT evaluation. However, in that study, there was no description of children with TBIs who had LOC in isolation.2 In the current study, LOC longer than 5 minutes’ duration was very uncommon, and in the expanded-isolated group, there was only 1 child with ciTBI, whose duration of LOC was unknown.

This study had several potential limitations. First, not all children had cranial CT scans performed during their ED evaluations because this decision was at the discretion of treating clinicians. However, all children in the study had clinical follow-up, allowing for accurate assessment of ciTBI. In addition, the presence or absence of LOC was recorded for most (95.9%) of the study population; thus, even with complete data, the results would be unlikely to change. Because we would not be able to determine whether LOC was isolated owing to missing data, we were unable to analyze a small percentage of children in the 2 analyses as follows: 436 (6.9%) in the PECARN-isolated LOC group and 154 (2.4%) in the expanded-isolated LOC group. It is also possible that clinicians completing case report forms may have had different interpretations of a history of LOC. These differences are likely to be minimal because site investigators received training in data collection and had access to a study manual of operations providing the LOC definition. Also, a previous analysis of this study population determined good to excellent interrater reliability for the LOC variable.22 Finally, in spite of the large total number of patients enrolled in the study, the number of children younger than 2 years with PECARN-isolated or expanded-isolated LOC from which to determine risks for this age group was relatively small.

### Conclusions

Children with isolated LOC after blunt head trauma, with normal physical examination findings and no other signs or symptoms of ciTBI, are at very low risk for ciTBI and do not routinely require cranial CT evaluation. In these children, clinical observation for the development of other signs or symptoms of ciTBI prior to CT decision making may be an effective management strategy to avoid the radiation risks of CT. Emergent neuroimaging can be safely avoided in the absence of development of other clinical signs of ciTBI.
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Author Contributions: Ms Miskin and Dr Kuppermann had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Lee, Dayan, Holmes, Kuppermann. Acquisition, analysis, or interpretation of data: Lee, Monroe, Bachman, Glass, Mahajan, Cooper, Stanley, Miskin, Holmes, Kuppermann. Drafting of the manuscript: Lee, Kuppermann. Critical revision of the manuscript for important intellectual content: All authors. Statistical analysis: Lee, Miskin, Kuppermann. Obtained funding: Kuppermann. Administrative, technical, or material support: Kuppermann. Study supervision: Lee, Bachman, Glass, Mahajan, Cooper, Stanley, Dayan, Holmes, Kuppermann.

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