Does implementation of the PECARN rules for minor head trauma improve patient-centered outcomes in a lower resource emergency department: A retrospective cohort study

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Abstract
Background Managing children with minor head trauma remains challenging for physicians who evaluate for the need for computed tomography (CT) imaging for clinically important traumatic brain injury (cTBI) identification. The Pediatric Emergency Care Applied Research Network (PECARN) prediction rules were adopted in our pediatric emergency department (PED) in December 2013 to identify children at low risk for cTBI. This study aimed to evaluate this implementation's impact on CT rates and clinical outcomes. Methods Retrospective cohort study on pediatric patients with head trauma presenting to the PED of the American University of Beirut Medical Center in Lebanon. Participants were divided into pre- (December 2012 to 2013) and post-PECARN (January 2014 to December 2016) groups. Patients were further divided into <2 and ≥2 years and stratified into groups of low, intermediate and high risk for cTBI. Bivariate analysis was conducted to determine differences between both groups. Results We included 1362 children of which 425 (31.2%) presented pre- and 937 (68.8%) presented post-PECARN rules implementation with 1090 (80.0%) of low, 214 (15.7%) of intermediate and 58 (4.3%) of high risk for cTBI. CTs were ordered on 92 (21.6%) pre- versus 174 (18.6%) patients post-PECARN (p=0.18). Among patients <2 years, CT rates significantly decreased from 25.2% to 16.5% post-PECARN (p=0.03), and dropped in all risk groups but only significantly for low risk patients from 20.7% to 11.4% (p=0.02). There was no significant decrease in CT rates in patients ≥2 years. There was no increase in bounce-backs numbers, nor in admission rates or positive CT findings among bounce-backs. Conclusions PECARN rules implementation reduced CT rates, most significantly among patients <2 years at low risk for cTBI. The implementation did not increase the number of missed cTBI.

Background
Head trauma commonly occurs in childhood and accounts for a large percentage of pediatric emergency department (PED) visits worldwide (1, 2). In the United States (US), traumatic brain injury (TBI) results in more than 50,000 deaths and over 200,000 hospital admissions every year (1), about 125,000 of which end up with disability (3). Among pediatric patients, however, most head trauma cases are minor and only few require further interventions (4, 5). Nevertheless, given the acute (6)
and long-term (7, 8) sequelae associated with TBI, rapid identification of children who may require acute interventions for clinically-important traumatic brain injury (ciTBI) is of crucial importance in the PED. The group which poses the most clinical equipose and that has been extensively studied are the children who present with minor TBI.

Computed Tomography (CT) imaging is highly sensitive for the identification of ciTBI and remains the gold standard diagnostic tool for the evaluation of head trauma patients (9). However, the use of diagnostic radiation has been associated with an increased risk of cancer in children, whose tissues are more susceptible to radiation-related cancer than adults (10, 11). Moreover, the overuse (12-14) and variability (15, 16) in CT imaging of children with head trauma between clinicians and hospitals appear to be unrelated to the frequency of positive CT scans and ciTBI (4, 16-19). As such, for the management of these children, PED physicians should better evaluate the need for CT imaging for ciTBI identification in order to limit radiation exposure and optimize resource utilization (20).

In pediatric patients with head trauma, particularly young children, individual ciTBI predictors lack specificity, which makes it difficult for PED physicians to identify and predict the severity of TBI. The Pediatric Emergency Care Applied Research Network (PECARN) developed clinical prediction rules for ciTBI in pediatric patients with minor head trauma, hereafter referred to as the PECARN rules, which were derived and validated to identify children at very low risk of ciTBI (4). They include 6 different predictors for pediatric patients that are either less than or more than or equal to 2 years of age.

Upon several validations in various settings, these rules were shown to have 100% negative predictive value for ciTBI with a sensitivity of 100% (4, 5, 21, 22). Because of their good discrimination for ciTBI among children with head trauma, they were adopted in many EDs in an attempt to reduce head CT rates without affecting patient outcomes (23-25). As shown by Dayan et al. in their large prospective multicenter study, the implementation of the PECARN rules results in safe, but variable decreases in the use of CT, depending on the setting and method of implementation (23-25). In some EDs, however, despite successful implementation with high adherence and medical staff satisfaction, CT scan rates remained unchanged (20, 26). In settings with highly accurate clinician judgment, implementation of the PECARN rules may have limited impact on improving
In our institution, a Middle Eastern tertiary care academic center, the attending physicians who typically evaluate cases of pediatric trauma have a variety of training backgrounds, which is the case in most EDs in Lebanon (28). All pediatric patients with minor trauma are generally seen in our ED’s “low-acuity” section along with minor adult cases, where 24-hour attending physicians are mostly specialized in Family Medicine or Surgery and only occasionally in Emergency Medicine. In order to standardize the care provided by the different specialists, we implemented the PECARN rules in December 2013.

This study aimed to evaluate the impact of this implementation on the medical care provided in our PED despite the resource constraints, by measuring the changes in head CT scan rates before and after implementation as well as PED length of stays, missed ciTBIs and patient bounce-backs.

Methods
Study Design and Setting
This was a retrospective cohort study conducted on pediatric patients presenting with minor head trauma to the ED of the American University of Beirut Medical Center (AUBMC), a large tertiary care center in Lebanon. Ethical approval was obtained from the Institutional Review Board at AUBMC under the protocol number [BIO-2017-0452].

Study Population
We included all patients aged 0 to 18 years presenting to the PED with head trauma between the 1st of December 2012 and 30th of December 2016. We excluded patients with trivial injury mechanisms, which included ground-level falls or running into stationary objects, and those with no signs or symptoms of head trauma other than lacerations or abrasions. We also excluded patients with penetrating trauma, a Glasgow Coma Scale (GCS) score < 14, neurologic or bleeding disorders, known brain tumors, ventricular shunts, and those presenting after evaluation and imaging for head trauma at another hospital (20). As our ED adopted the evidence-based PECARN clinical prediction rules for minor head trauma in December 2013, hereafter referred to as the PECARN rules, participants were divided into pre- (1st December 2012 to 31st December 2013) and post-PECARN (1st January 2014 to 30th December 2016) groups. Based on the risk stratification algorithm from the PECARN study (4),
patients were further stratified by age into < 2 and ≥ 2 years of age as well as by risk into low, intermediate and high risk for ciTBI (see Additional file 1).

Implementation of PECARN rules
At implementation, in December 2013, all emergency providers were educated about the rules, including those based in the ED and rotating trainees. The rules were also presented in monthly meetings with the medical ED staff and taught to ED residents annually. Educational references consisted of posters in the PED. As opposed to previous studies (24), the implementation of the PECARN rules in our study took place in a setting with no pediatric Emergency Medicine trained physicians, no quality improvement (QI) team in place and less experience in specialized QI intervention efforts.

Data Collection
Collected variables included patient demographics, mechanisms of injury, symptoms and physical exam findings, as well as management and clinical outcomes. The primary outcome of this study consisted of the rates of head CT ordered pre- and post-implementation of the PECARN prediction rules. Secondary outcomes consisted of balancing measures such as PED length of stays, neurology and neurosurgery consults, admission rates, rates of missed ciTBIs and 2 week bounce-backs for symptoms and/or signs potentially related to minor head trauma.

Data Analysis
Patients in both groups were compared, and their baseline characteristics described and presented as mean ± SD for continuous variables and frequency (%) for categorical variables. On bivariate analysis, Student’s t-test was used for continuous data while Chi-square and Fisher’s exact tests were used for categorical data. All statistical analyses were performed using SPSS 24 (Statistical Package for Social Sciences). Statistical significance was set at a bilateral p-value of 0.05.

Results
Patient Characteristics
A total of 1897 pediatric patients presenting with head trauma were screened and 1362 were included in this study, of which 425 (31.2%) presented pre- and 937 (68.8%) presented post-PECARN rules implementation (Fig. 1). Our study population consisted of 1090 (80.0%) patients of low risk, 214 (15.7%) of intermediate risk and 58 (4.3%) of high risk for ciTBI, with no significant difference in
risk between pre- and post-PECARN groups \((p = 0.94)\) (Fig. 1). More than two thirds of our population was \(\geq 2\) years of age with no significant difference between pre- (68.2%) and post-PECARN (67.0%) groups \((p = 0.66)\). In general, there were no significant differences in patient characteristics and injury presentations between pre- and post-PECARN groups except for slightly less vertigo \((0.5% \text{ vs } 0.0%, p = 0.04)\) and altered level of consciousness \((8.0 \text{ vs } 4.2%, p = 0.004)\) in the post-PECARN group (Table 1).

| Variables                          | Pre-PECARN \((N = 425)\) | Post-PECARN \((N = 937)\) | p-value |
|-----------------------------------|--------------------------|--------------------------|---------|
| **Symptoms, n (%)**               |                          |                          |         |
| Dizziness                         | 26 (6.1)                 | 54 (5.8)                 | 0.8     |
| Vertigo                           | 2 (0.5)                  | 0 (0.0)                  | 0.04    |
| Amnesia                           | 11 (2.6)                 | 18 (1.9)                 | 0.43    |
| Nausea                            | 15 (3.5)                 | 27 (2.9)                 | 0.52    |
| Vomiting                          | 68 (16.0)                | 136 (14.5)               | 0.48    |
| Seizure                           | 4 (0.9)                  | 8 (0.9)                  | 0.87    |
| Vision changes                    | 3 (0.7)                  | 13 (1.4)                 | 0.3     |
| Altered level of consciousness    | 34 (8.0)                 | 39 (4.2)                 | 0.004   |
| Severe headache                   | 9 (2.1)                  | 19 (2.0)                 | 0.91    |
| LOC                               | 20 (4.7)                 | 39 (4.2)                 | 0.65    |
| LOC > 5sec                        | 17 (4.0)                 | 20 (2.1)                 | 0.05    |
| **Physical Exam findings, n (%)** |                          |                          |         |
| Scalp Occipital/Parietal/Temporal Hematoma | 19 (4.5)    | 44 (4.7)                 | 0.86    |
| Palpable skull fracture           | 0 (0.0)                  | 1 (0.1)                  | 0.5     |
| Signs of basilar skull fracture   | 1 (0.2)                  | 1 (0.1)                  | 0.57    |
| Not acting normally as per parent | 9 (2.1)                  | 36 (3.8)                 | 0.1     |
| Altered mental status             | 17 (4.0)                 | 38 (4.1)                 | 0.96    |
| GCS 14                            | 2 (0.5)                  | 2 (0.2)                  | 0.7     |
| GCS 15                            | 417 (98.1)               | 920 (98.2)               |         |
| **Risk Stratification, n (%)**    |                          |                          |         |
| Low Risk                          | 338 (79.5)               | 752 (80.3)               | 0.94    |
| \(\geq 2\)                        | 116 (34.3)               | 264 (35.1)               | 0.8     |
| Intermediate Risk                 | 222 (65.7)               | 488 (64.9)               |         |
| \(\geq 2\)                        | 69 (16.2)                | 145 (15.5)               | 0.94    |
| High Risk                         | 13 (18.8)                | 29 (20.0)                | 0.84    |
| \(\geq 2\)                        | 56 (81.2)                | 116 (80.0)               |         |
| High Risk                         | 18 (4.2)                 | 40 (4.2)                 | 0.94    |
| \(\geq 2\)                        | 6 (33.3)                 | 16 (40.0)                | 0.63    |
| **Management and clinical outcomes** |                          |                          |         |

Only 8 (1.9%) patients in the pre-PECARN group and 7 (0.7%) in the post-PECARN group were diagnosed with ciTBI \((p = 0.09)\). Among patients that had CT imaging, only 8 (8.7%) pre- and 13 (7.5%) post-PECARN had positive findings on CT \((p = 0.73)\). Nevertheless, significantly more discharge
instructions were given post-PECARN rules implementation (51.0% vs 44.0%, p = 002). There was no significant difference in the number of neurology and neurosurgery consults (6.6% vs 4.4%, p = 0.09), ED length of stay (75.2 ± 76.6 vs 69.3 ± 68.1 minutes, p = 0.18) nor in patient disposition (96.8% vs 92.4% discharged home, p = 0.66) between pre- and post-PECARN groups (Table 2).

Table 2
Management and clinical outcomes of patients presenting with head trauma pre- and post-PECARN rules implementation

| Variables                                      | Pre-PECARN (N = 425) | Post-PECARN (N = 937) | p-value |
|------------------------------------------------|----------------------|-----------------------|---------|
| Length of stay, mean in minutes (± SD)         | 75.2 (± 76.6)        | 69.3 (± 68.1)         | 0.18    |
| Diagnosed with ciTBI¹                           | 8 (1.9)              | 7 (0.7)               | 0.06    |
| Neurosurgical intervention                     | 1 (12.5)             | 0 (0.0)               | 0.33    |
| Admission > 2 nights                           | 4 (50.0)             | 5 (71.4)              | 0.4     |
| Admission for persistent neurologic symptoms and signs | 4 (50.0)         | 3 (42.9)              | 0.78    |
| Consult Neurology/Neurosurgery                 | 28 (6.6)             | 41 (4.4)              | 0.09    |
| CT imaging                                     | 92 (21.6)            | 174 (18.6)            | 0.18    |
| No acute post traumatic change                 | 77 (83.7)            | 146 (83.9)            | 0.96    |
| Disposition                                    |                      |                       |         |
| Home                                           | 402 (94.6)           | 885 (94.5)            | 0.2     |
| Inpatient/PICU                                  | 10 (2.4)             | 12 (1.3)              |         |
| Transfer/AMA                                    | 13 (3.1)             | 40 (4.3)              |         |
| Discharge instructions                          | 187 (44.0)           | 478 (51.0)            | 0.02    |
| Bounce backs                                    | 31 (7.3)             | 65 (6.9)              | 0.81    |
| CT imaging                                      | 2 (6.5)              | 8 (12.3)              | 0.38    |
| Positive CT findings²                          | 1 (3.2)              | 1 (1.5)               | 0.59    |
| Disposition                                    |                      |                       |         |
| Home                                           | 30 (96.8)            | 61 (92.4)             | 0.66    |
| Inpatient                                      | 1 (3.2)              | 4 (6.1)               |         |
| AMA                                            | 0 (0.0)              | 1 (1.5)               |         |

¹ ciTBI: Clinically important traumatic brain injury
² Positive findings: intracranial hemorrhage/contusion, cerebral edema, traumatic infarction, diffuse axonal/shearing injury, sigmoid sinus thrombosis, midline shift, skull diastasis, pneumocephalus, or depressed skull fracture.

Primary outcome - CT scanning rates

CT scans were ordered on 92 (21.6%) patients pre- versus 174 (18.6%) patients post-PECARN rules implementation (p = 0.18) (Table 2).

Among patients < 2 years of age, there was a significant decrease in CT scan rates from 25.2% pre-PECARN to 16.5% post-PECARN (p = 0.03). When stratified by risk, CT scanning rates were found to drop in all risk groups but only significantly for low risk patients from 20.7–11.4% (p = 0.02) (Fig. 2).

Among patients ≥ 2 years, there was no significant decrease in CT scan rates between pre and post groups (20.0% vs 19.6%, p = 0.88). When stratified by risk, a slight increase in CT scanning rates was observed among low risk patients (7.7% vs 9.8%, p = 0.35) and a decrease was observed in
intermediate (58.9% vs 51.7%, p = 0.37) and high risk (66.7% vs 62.5%, p = 0.81) patients (Fig. 3).

Secondary outcomes
There was no observed increase in the number of bounce backs between pre- and post-PECARN groups (7.3% vs 6.9%, p = 0.81). Among those who bounced back, CT scans were ordered on 6.5% of patients pre-PECARN and 12.3% of patients post-PECARN (p = 0.38) and no significant change in positive CT findings and patient disposition was noted (Table 2).

Discussion
In the Middle East, the epidemiology of ciTBI and CT imaging rates of children presenting to the PED with head trauma remain understudied (29, 30). This study evaluating the impact of PECARN rules implementation in the PED of the AUBMC in Lebanon provides a better understanding of the characteristics, clinical management and outcomes of pediatric patients presenting to our institution for minor head trauma. Moreover, this is the first study to evaluate the implementation of the PECARN rules in the region and specifically in a middle-income country, without administrative resources for QI work. The main findings of a significant decrease in CT scanning rates among low risk patients less than two years of age without any adverse effect on patient outcomes suggest that the PECARN rules reliably identify patients at low risk for ciTBI and their implementation can safely reduce the burden of CT imaging on children with head trauma, even in lower income settings with limited resources and implementation efforts.

In this study, only 8 (1.9%) patients before and 7 (0.7%) patients after implementation were diagnosed with ciTBI. These low incidence rates imply that the majority of head trauma cases encountered in our PED are minor and do not require any imaging. Our results are similar to those of a large US prospective study conducted by Nigrovic et al. where only 0.9% of 42,412 patients with minor blunt head trauma had a ciTBI (31). They are also comparable to those of a French prospective study by Lorton et al. where only 0.6% of 1499 patients with minor head trauma had a ciTBI (5). These low rates of ciTBI thus illustrate the worldwide and more specifically Lebanese population’s heightened awareness and concern for ciTBI and its consequences; which leads patients to seek evaluation in the ED even after a minor head trauma. As such, it is essential for ED physicians to
optimize their approach to this common presentation for which only a minority are at risk of a bad outcome, given the potential harm associated with CT imaging of children with head trauma (10, 11). In our institution, baseline overall CT scanning rates were 21.6% before any intervention. Interestingly, in the literature, the several studies investigating the impact of PECARN rules on CT scanning rates of pediatric patients with head trauma display different baseline rates of head CT scanning. Whereas our clinical setting is characterized by a lower overall baseline CT scan rate (21.6% vs. 35.3% in the PECARN study) when compared to the US (4, 31, 32), our CT scanning rates seem to be higher than those reported in Europe (5.1–8.4%) (5, 20). Compared to the large prospective US study validating the PECARN prediction rules, our study included a higher percentage of children younger than 2 years of age and a lower proportion of cases with severe mechanisms of injury or with high-risk predictor findings for ciTBI, such as signs of altered mental status or of basilar skull fractures (4). Moreover, the majority (80.0%) of the patients included in this study were at low risk of a ciTBI and only 4.3% of them had a high risk for ciTBI compared to 56% and 14% of the patients enrolled in the large prospective US study, respectively (4). Actually, in a previous Lebanese study, Habre observed that severe cases of TBI rarely reached hospitals and are thus underestimated in Lebanon (29). These differences reflect the overall lower severity of trauma cases presenting to our PED and further emphasizes the need for selective CT imaging of Lebanese children with minor head trauma. Moreover, the observed variability in baseline rates in different populations highlights the importance of this study in Lebanon as it provides a real-world understanding of how PECARN rules perform differently in different settings.

In our institution, the implementation of the PECARN rules led to a 3% decrease in CT scanning rates of children with head trauma, down to 18.6%. Despite our study’s decrease in the amount of head CTs performed on patients after PECARN rules implementation, it is quite surprising that no significant increase was seen in the frequency of positive CT findings. Among patients who were scanned, only 8.7% (pre) and 7.5% (post) had positive findings on CT. These rates of abnormal CTs are lower than previously reported rates (23), which shows that a high number of unnecessary CT scans are still being performed in our institution. In the literature, implementation studies conducted in different
settings achieved mixed results with regards to changing practice. Some studies report no change between implementation and control groups (20, 26, 27), while others report consistent and substantial decreases in CT imaging rates (23–25). The change in CT scanning rates appears to be influenced by the baseline CT rates (16, 19, 33), the preexisting clinician accuracy (27), the medico-legal climate, the inclination for shared decision making with families (25) and the availability of observation units for conservative watchful waiting on intermediate risk patients (20). As such, in settings such as the US and Canada with high baseline CT rates and variability between CT rates (16, 19), clinical decision rules may contribute to a safe reduction in CT rates (24, 25) but perhaps not in other settings with low CT rates or high clinician accuracy as has been shown in Italy (20) or Australia (33–35) and in our study.

Nevertheless, although our baseline rates are comparable to those of a recent QI study conducted in the US, the implementation of PECARN guidelines in our PED had less of an impact on CT use when compared to results reported by Nigrovic et al. consisting of a CT scan decrease from 21–15% after implementation and down to 9% through individual provider feedback (24). According to previous studies, a CT rate of less than 15% is achievable for all children with minor blunt head trauma (20, 24, 25). Knowing that there is substantial variability in adherence to PECARN rules between physicians worldwide (26); some of the physicians working in the pediatric ED section in our institution may have been reluctant to adhere to the rules as their adoption is usually influenced by local practice and culture (36). In addition, the pediatric patients included in this study were evaluated by physicians with a surgical, emergency or family medicine rather than pediatric or pediatric ED background, which have been reported to have higher CT imaging rates (25). As such, provider related factors might have weakened the impact of PECARN rules implementation on CT scanning rates in our institution.

Moreover, similar to a nonrandomized multicenter trial (25), the decrease in CT rates in this study was particularly significant among low risk children less than 2 years of age decreasing from 20.7–11.4% (p = 0.02). Our results are consistent with previous reported findings of an overall higher rate of correctly indicated head CT scans ordered on children less than 2 years of age after implementation of PECARN rules (20, 26). These findings are noteworthy as children younger than 2 years are the
most sensitive to radiation (4). Specifically, children younger than 2 years with none of the predictor variables for ciTBI have less than 0.02% risk of ciTBI, implying that CT scans are not indicated for most children in this low-risk groups (4). In our institution, however, before implementation, a substantial proportion (20.7%) of low risk children younger than 2 years were still scanned. Physicians’ certainty in evaluating very young patients is usually lower than for older patients due to the concern of being unable to reliably identify ciTBI. Indeed, the clinical assessment of children less than two years of age is challenging as their neurologic examination is difficult to obtain and interpret; they may be asymptomatic despite having a ciTBI, are at risk for abusive head trauma, and are more prone to skull fractures than older children. Additionally, despite being informed of the clinical inappropriateness and radiation risks of CT imaging, parents often prefer to be reassured with negative results for younger children (37). As this study results show, PECARN rules reduced uncertainty and improved accuracy in medical decision-making and thus provide support for ED physicians to predict which children can be safely managed without CT scanning (38).

All things considered, according to this study with a relatively large sample size in a limited resource setting, despite not having a QI team in place and an ability to monitor things closely, the PECARN rules seem to meet the objective of limiting the use of CT, yet this reduction could be greater by implementing more changes provided additional resources and administrative support are available. Because structural support has been shown to be effective at supporting reliable change (39), it may be beneficial to create a head trauma electronic order set to remind clinicians of the ciTBI predictors in children with minor head trauma. Future interventions may also include individual provider feedback on CT scanning rates (40, 41) and surveys for PED physicians about causes for failing to adhere to guidelines (42). Prospective well designed studies with detailed impact analysis would further support the use of PECARN rules in daily clinical practice. It would be then be ideal to implement these changes at a national level, especially given the prevalence of pediatric head trauma.

Limitations
This is a retrospective single center study, where missing or inaccurate data especially in this history
and physical exam findings may not have been accounted for. However, we kept the data collection simple, following the PECARN predictors. Additionally, bounce-backs to our center were captured from our Electronic Health Records, but patients who presented to outside facilities after evaluation and discharge from our center may have been missed. Moreover, no standard QI techniques were used to study the effects of implementation. As such, the decrease being a result of the implementation alone is uncertain, however, no other interventions related to care of minor head trauma were implemented at that time.

Conclusions
PECARN minor head trauma rules’ implementation reduced head CT use in our pediatric ED, with the greatest impact observed among patients less than 2 years of age at low risk for ciTBI. The intervention did not increase the number of missed ciTBI. As such, it is recommended that the PECARN head CT rules be implemented, even if in a simple fashion, in a lower resource setting, as a guide for ED physicians in their clinical decision-making regarding imaging of children with minor head trauma.

Abbreviations
AUBMC
American University of Beirut Medical Center
ciTBI
Clinically important traumatic brain injury
CT
Computed tomography
ED
Emergency Department
PECARN
Pediatric Emergency Care Applied Research Network
PED
Pediatric Emergency Department
GCS
Glasgow Coma Scale
TBI
Traumatic brain injury
Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the Institutional Review Board at AUBMC under the protocol number [BIO-2017-0452].

Consent for publication

The Institutional Review Board at AUBMC, under the protocol number [BIO-2017-0452], approved to waive the consent process for the participants in this study.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Not applicable.

Authors' contributions

RS, SS and HT contributed to the conception and design of the study, CW, IB, RS and MH participated in data collection, CW, AW and MM worked on cleaning and management of data, MM and HT took part in data analysis, RS, HT, AW and CW participated in the interpretation of the results and all authors contributed to the writing of the manuscript. All authors read and approved the final manuscript.

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Study flowchart of pediatric patients presenting to the PED with minor head trauma.
Figure 2

CT rates (%) in children <2 years pre- and post-PECARN stratified by risk for ciTBI.
Figure 3

CT rates (%) in children ≥2 years pre- and post-PECARN stratified by risk for ciTBI.

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