



## ORIGINAL RESEARCH CONTRIBUTION

# Implementation of Adapted PECARN Decision Rule for Children With Minor Head Injury in the Pediatric Emergency Department

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## Abstract

**Objectives:** Of the currently published clinical decision rules for the management of minor head injury (MHI) in children, the Pediatric Emergency Care Applied Research Network (PECARN) rule, derived and validated in a large multicenter prospective study cohort, with high methodologic standards, appears to be the best clinical decision rule to accurately identify children at very low risk of clinically important traumatic brain injuries (ciTBI) in the pediatric emergency department (PED). This study describes the implementation of an adapted version of the PECARN rule in a tertiary care academic PED in Italy and evaluates implementation success, in terms of medical staff adherence and satisfaction, as well as its effects on clinical practice.

**Methods:** The adapted PECARN decision rule algorithms for children (one for those younger than 2 years and one for those older than 2 years) were actively implemented in the PED of Padova, Italy, for a 6-month testing period. Adherence and satisfaction of medical staff to the new rule were calculated. Data from 356 visits for MHI during PECARN rule implementation and those of 288 patients attending the PED for MHI in the previous 6 months were compared for changes in computed tomography (CT) scan rate, ciTBI rate (defined as death, neurosurgery, intubation for longer than 24 hours, or hospital admission at least for two nights associated with TBI) and return visits for symptoms or signs potentially related to MHI. The safety and efficacy of the adapted PECARN rule in clinical practice were also calculated.

**Results:** Adherence to the adapted PECARN rule was 93.5%. The percentage of medical staff satisfied with the new rule, in terms of usefulness and ease of use for rapid decision-making, was significantly higher (96% vs. 51%,  $p < 0.0001$ ) compared to the previous, more complex, internal guideline. CT scan was performed in 30 patients (8.4%, 95% confidence interval [CI] = 6% to 11.8%) in the implementation period versus 21 patients (7.3%, 95% CI = 4.8% to 10.9%) before implementation. A ciTBI occurred in three children (0.8%, 95% CI = 0.3 to 2.5) during the implementation period and in two children (0.7%, 95% CI = 0.2 to 2.5) in the prior 6 months. There were five return visits (1.4%) postimplementation and seven (2.4%) before implementation ( $p = 0.506$ ). The safety of use of the adapted PECARN rule in clinical practice was 100% (95% CI = 36.8 to 100; three of three patients with ciTBI who received CT scan at first evaluation), while efficacy was 92.3% (95% CI = 89 to 95; 326 of 353 patients without ciTBI who did not receive a CT scan).

**Conclusions:** The adapted PECARN rule was successfully implemented in an Italian tertiary care academic PED, achieving high adherence and satisfaction of medical staff. Its use determined a low CT scan rate that was unchanged compared to previous clinical practice and showed an optimal safety and high efficacy profile. Strict monitoring is mandatory to evaluate the long-lasting benefit in patient care and/or resource utilization.

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Minor head injuries (MHIs) continue to be a major problem in pediatrics, representing one of the most common reasons for visits in the pediatric emergency department (PED). The management of these children has long presented a common dilemma for emergency physicians due to the challenging task of balancing the need of head computed tomography (CT) scan for intracranial injury (ICI) identification on one hand, and of limiting the radiation- and sedation-associated risks,<sup>1-3</sup> as well as resource utilization, on the other. To optimize this balance, availability of effective and validated clinical decision rules in the ED is pivotal. Of the published decision rules for minor head injuries in children,<sup>4,5</sup> the recent Pediatric Emergency Care Applied Research Network (PECARN) rule,<sup>6</sup> derived and validated in the largest multicenter prospective study cohort with high methodologic standards, appears to be the best to accurately identify children at very low risk of clinically important traumatic brain injuries (ciTBIs) in the PED,<sup>5,7</sup> providing differentiated algorithms for children younger and older than 2 years of age.

These features, along with their simple and easy-to-remember structure, offer the potential for broad use in the ED. The implementation of evidence-based tools for clinical decision-making in the acute care setting has shown to improve quality of care as well as patients' outcomes.<sup>8-10</sup> Physician adherence to new decision rules and protocols, and their satisfaction with the innovation, are key points to achieve a significant change in clinical practice, which results in a long-lasting benefit in patient care and resource utilization.

The aims of this study were to describe the implementation of an adapted version of the PECARN rules for the management of children with MHI in a tertiary care academic PED in Italy and to evaluate implementation success, in terms of medical staff adherence and satisfaction, as well as the effects on clinical practice.

## METHODS

### Study Design

This was an observational before-after study. The study was approved by the hospital ethics committee with waiver of written consent, and verbal consent was given for telephone follow-up in the postimplementation period.

### Study Setting and Population

The study was carried out in the PED of Padova Children's Hospital, an academic hospital providing primary and secondary care for a metropolitan area of 350,000 people (45,000 younger than 15 years) and tertiary care for a regional and extraregional population, with approximately 25,000 PED visits per year. Its four-bed short-stay observation unit allows for management of patients whose expected length of stay is 4 to 24 hours. Both attending physicians and residents in pediatrics provide patient care in the PED. The residency program in pediatrics at the University of Padova is a 5-year training program. Residents on duty in the PED primarily see approximately 95% of the children and discuss their diagnostic and therapeutic management with the attending physician, according to their

level of training. First- and second-year residents are fully supervised. Decisions on CT scan ordering have always to be taken in accordance with the PED consultant, independently of the level of training of the residents.

The adapted PECARN rule was applied to children presenting to the PED within 24 hours of blunt head trauma and Glasgow Coma Scale (GCS)  $\geq 14$ , between June and November 2010. Children with trivial injury mechanisms defined by ground-level falls or running into stationary objects, and no signs or symptoms of head trauma other than scalp abrasions and lacerations, were excluded. Children with penetrating trauma, preexisting neurologic disorders, known bleeding disorders, or neuroimaging at an outside hospital before transfer were also excluded.

Data were compared with those of children evaluated in the PED for MHI 6 months prior to the implementation of the adapted PECARN rule, between November 2009 and April 2010.

### Study Protocol

**Local Adaptation and Dissemination.** In our PED, patients with head trauma had been managed according to an internal protocol in use since 2003, based on the prediction rule published by Da Dalt et al. in 2006<sup>11</sup> (a summary of the protocol is reported in Appendix 1).

The use of this protocol allowed for a low cranial CT rate (between 5 and 10%) with no missed ICI requiring neurosurgery since its introduction, but its complex structure made it impractical for rapid consultation and decision-making in the ED. Furthermore, the protocol did not provide a separate rule for younger children. Therefore, after discussion with local experts on MHI, implementation of the adapted PECARN rules for a 6-month testing period was decided upon, and some minor modifications were made to the original algorithms. The PECARN rule categories "CT recommended," "Observation versus CT on the basis of other clinical factors," and "CT not recommended" were named, respectively, "high risk," "moderate risk," and "low risk" for ease of use.

Local adaptations to the PECARN rules, related to the moderate-risk group, were the following:

- For children younger than 2 years of age:
  - Amnesia was introduced alongside the other original predictors.<sup>11-13</sup>
  - In the presence of isolated vomiting, CT was highly suggested if there was repetitive vomiting (more than 5 episodes) or persistent vomiting for more than 6 hours after head trauma and a negative personal history for recurrent vomiting or motion sickness.<sup>14</sup>
- For all children:
  - The recommended duration of observation in the PED for children who did not undergo a CT scan was set to be of at least 6 hours for trauma and at least 12 hours for infants <6 months.

Dissemination of the adapted PECARN rules to physicians working in the PED was carried out in May 2010 and included: 1) dedicated teaching sessions; 2) e-mailing of teaching material, as well as the adapted

PECARN rules; 3) posters explaining the algorithms in the PED; 4) availability of the new protocol for the management of MHI, for online consultation in the intranet website; and 5) ample supply of pocket cards, including the pediatric GCS to the physicians working in the PED. Periodic reminders to on-call physicians were also performed by the study investigators during the implementation period.

### Data Sources

During implementation of the adapted PECARN rule, examining physicians were required to report clinical data in a standardized manner before any decision-making on the most appropriate management option. Prospective data collection was monitored weekly by study investigators.

Patients assessed for MHI during the preimplementation period were identified through the electronic PED database. Medical charts were then reviewed for inclusion/exclusion criteria and data abstraction.

Patient data included demographic features, data on out-of-hospital care when appropriate, time of injury, detailed mechanism of injury, site of trauma, features and onset of posttraumatic symptoms, at arrival, physical examination findings (including other sites of trauma), CT scan results when performed, duration of symptoms and observation in the PED, need for neurosurgery, and final disposition.

Data abstractors received formal training in medical records review using a standardized data collection form tested on a set of 20 charts of patients evaluated for MHI in May 2010 (dissemination period). Clear variable definitions (as reported in Kuppermann et al.<sup>6</sup>) and abstraction guidelines were also provided prior to the start of data collection. Data abstractors were not blinded to the study outcomes. Periodic meetings with the senior study coordinator were held to discuss conflicting, ambiguous, or missing data, as well as review of inclusion and exclusion criteria. CT scans were independently interpreted by site faculty radiologists unaware of this study.

Return visits within 2 weeks from discharge were monitored for each patient in both study periods, to identify possible cases of missed TBI. Telephone follow-up was also carried out for the same purpose, between 10 and 90 days from PED discharge for patients in the postimplementation period.

### Outcomes

The primary outcome of this study was evaluation of medical staff adherence to adapted PECARN rules, defined as the proportion of children managed according to the new rules, in relation to risk group stratification.

Satisfaction of medical staff with the implementation of the adapted PECARN rules was also assessed comparing the results of a survey asking to grade (from 1 to 4) the usefulness and ease of use for rapid decision-making of the protocol in use for MHI, prior to dissemination of adapted PECARN rules, and 6 months after their implementation. The questionnaire used was developed based on consensus by local experts on MHI.

The clinical and patient outcomes were: 1) CT scan rate in the pre- and postimplementation periods; 2) ciTBI

rates in the pre- and postimplementation periods (ciTBI was a priori defined, according to Kuppermann et al.,<sup>6</sup> as death from TBI, neurosurgery, intubation for more than 24 hours due to TBI or hospital admission of two nights or more associated with brain injury on CT); 3) return visits for symptoms and/or signs potentially related to MHI; 4) the safety of adapted PECARN rules application to clinical practice, defined according to Reilly and Evans<sup>15</sup> as the proportion of all patients experiencing a ciTBI who received head CT scan; and 5) the efficacy of adapted PECARN rules application to clinical practice, defined according to Reilly and Evans<sup>15</sup> as the proportion of all patients not experiencing a ciTBI who did not receive head CT scan.

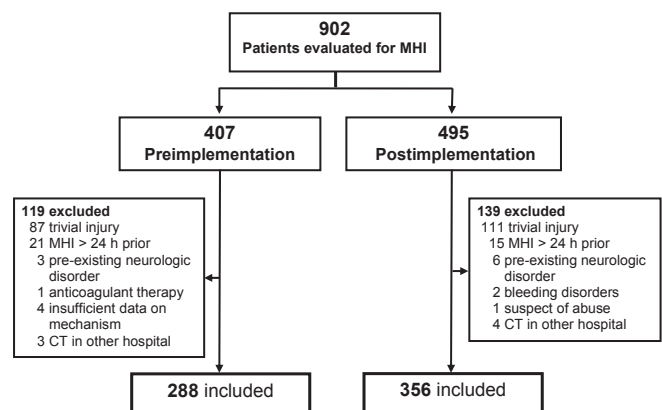
### Data Analysis

Continuous variables were expressed as median and interquartile range (IQR), because of nonnormal distribution. Categorical variables were expressed as percentages and 95% confidence intervals (CIs) were reported for main results. Comparison of categorical variables was performed by means of chi-square tests. Parameters displaying  $p \leq 0.05$  were considered statistically significant, with no adjustment for multiple comparisons. Statistical analyses were conducted using the statistical program MedCalc 11.1 (MedCalc Software, Mariakerke, Belgium).

## RESULTS

A total of 902 patients were evaluated for MHI in the two study periods. Of these, 644 met the inclusion criteria (356 after and 288 before implementation of adapted PECARN rule) and were ultimately included in the study (Figure 1).

Overall, 292 patients (45.3%) were younger than 2 years, and the median age was 2.4 years (IQR = 0.9 to 5.2 years). A total of 332 patients (51.6%) were male, 591 (91.8%) were brought to the PED within 6 hours of trauma, and 258 (40.1%) had a frontal site of impact. Injury mechanisms were: fall from height ( $n = 397$ , 61.6%), fall from ground level or ran into stationary object ( $n = 91$ , 14.1%), bicycle collision or fall ( $n = 33$ , 5.1%), fall down the stairs ( $n = 32$ , 5%), head struck by



**Figure 1.** Flow chart of patient selection. MHI = minor head injury.

an object ( $n = 29$ , 4.5%), occupant in motor vehicle crash ( $n = 16$ , 2.5%), sports-related ( $n = 15$ , 2.3%), bicyclist struck by a motorized vehicle ( $n = 6$ , 0.9%), assault ( $n = 3$ , 0.5%), pedestrian struck by vehicle ( $n = 2$ , 0.3%), and other ( $n = 20$ , 3.1%).

Isolated head trauma occurred in 92% of patients and 637 (99%) had GCS scores of 15. Patient characteristics and outcomes were similar between the two periods (Table 1).

#### Adherence to and Satisfaction With Adapted PECARN Rules

Adherence to the adapted PECARN rule was observed for 330 of 353 patients (93.5%). Three patients were excluded from calculation because they left the PED earlier than recommended, due to parents' decisions. All of them were classified as moderate risk, they did not receive CT scans, and they did well at home as ascertained by telephone follow-up. Details on medical

staff adherence to the new rule, according to risk and age group, are reported in Table 2.

As for satisfaction of medical staff working in the PED (11 either full-time or part-time attending physicians and 46 residents during the study period) with the implementation of the new rules, the answer rates to the pre- and postimplementation surveys were 90 and 84%, respectively. The usefulness and ease of use for rapid decision-making at the bedside was scored  $\geq 3$  in 51% of cases for previous protocol and 96% for adapted PECARN rules ( $p < 0.0001$ ).

#### Clinical and Patient Outcomes

**CT Scan Rate.** The CT scan rate observed after adapted PECARN rule implementation was 8.4% (95% CI = 6% to 11.8%), not significantly different from that of the preimplementation period at 7.3% (95% CI = 4.8% to 10.9%). When the CT scan rate was analyzed by age group and study period, there were no

Table 1  
Distribution of Patient Characteristics and Outcomes According to Age Group and Study Period

Characteristic	Preimplementation (N = 288)		Postimplementation (N = 356)	
	Age < 2 years (n = 130)	Age > 2 years (n = 158)	Age < 2 years (n = 162)	Age > 2 years (n = 194)
Sex (M/F)	62/68	83/75	79/83	108/86
Site of impact				
Frontal only	55 (42.3)	64 (40.5)	71 (43.8)	68 (35)
Other than frontal only	56 (43.1)	91 (57.6)	70 (43.2)	118 (60.8)
Unknown*	19 (14.6)	3 (1.9)	21 (13)	8 (4.2)
Severe mechanism of injury	19 (14.6)	28 (17.7)	20 (12.3)	35 (18)
History of LOC (known or suspected)	3 (2.3)	8 (5)	5 (3)	12 (6.2)
LOC duration				
<5 seconds	1 (0.8)	2 (1.2)	2 (1.2)	7 (3.6)
>5 seconds	2 (1.5)	6 (3.8)	3 (1.8)	5 (2.5)
Amnesia		5 (3.2)		10 (5.2)
Headache		51 (32.3)		54 (27.8)
Severity of headache				
Mild		8 (5)		17 (8.7)
Moderate		24 (15.2)		24 (12.3)
Severe		10 (6.3)		8 (4.1)
Not reported		9 (5.7)		5 (2.5)
History of vomiting	11 (8.5)	38 (24)	14 (8.6)	58 (29.8)
Number of vomiting episodes				
<5 episodes	8 (6.2)	38 (24)	13 (8)	53 (27.3)
>5 episodes	3 (2.3)	0 (0)	1 (0.6)	5 (2.5)
Acting abnormally according to parent	6 (4.6)	14 (8.9)	9 (5.5)	21 (10.8)
GCS score (14/15)	1/129	2/156	0/162	4/190
Altered mental status	0 (0)	0 (0)	1 (0.6)	5 (2.5)
Signs of basilar skull fracture	0 (0)	0 (0)	0 (0)	1 (0.5)
Palpable skull fracture (or unclear exam)	3 (2.3)	1 (0.6)	0 (0)	7 (3.6)
Scalp hematoma	58 (44.6)	80 (50.6)	72 (44.4)	85 (43.8)
Location of scalp hematoma				
Frontal	30 (23.1)	38 (24.1)	45 (27.8)	39 (20.1)
Nonfrontal	28 (21.5)	42 (26.6)	27 (16.7)	46 (23.7)
CT scan rate	10 (7.7)	11 (7)	6 (3.7)	24 (12.4)
Patient outcomes				
ICI on CT	2 (1.5)	0 (0)	1 (0.6)	4 (2.1)
ciTBI				
Death	0 (0)	0 (0)	0 (0)	0 (0)
Neurosurgery	0 (0)	0 (0)	0 (0)	0 (0)
Intubation >24 hours	0 (0)	0 (0)	0 (0)	0 (0)
Hospital admission >2 nights	2 (1.5)	0 (0)	1 (0.6)	2 (1)

Values are reported as  $n$  (%) unless otherwise noted.

ciTBI = clinically important traumatic brain injury; GCS = Glasgow Coma Scale; ICI = intracranial injury; LOC = loss of consciousness.

\*Not directly witnessed fall with no evident signs of head trauma on physical examination.

Table 2  
Medical Staff Adherence to Adapted PECARN Rules According to Age and Risk Group

Group	Age < 2 years (Total N = 162)			Age > 2 years (Total N = 194)		
	n (%)	CT Performed	Adherence	n (%)	CT Performed	Adherence
High-risk group (n = 13)	0	0	0/0	13 (6.7)	12 (92.3)	12/13 (92.3%)
Moderate-risk group (n = 139)*	52 (32)	5 (9.6)	45/50 (90)†	87 (44.8)	11 (12.3)	71/86 (82.5%)†
Low-risk group (n = 204)	110 (68)	1 (0.9)‡	109/110 (99)	94 (48.5)	1 (1.1)‡	93/94 (99%)

PECARN = Pediatric Emergency Care Applied Research Network; PED = pediatric ED.  
 \*Three patients (two younger than 2 years and one older than 2 years) were excluded from adherence calculation because of the parents' decision to leave the PED earlier than recommended.  
 †Five patients younger than 2 years were observed in the PED for less than 6 hours from trauma: four had isolated risk factors (two mechanisms of trauma interpreted as severe, both falls, one initially not acting normally according to parents, one with an isolated episode of vomiting), while one presented an isolated episode of vomiting after a fall from borderline height. Fifteen patients older than 2 years were observed in the PED for less than 6 hours from trauma: 73% of these patients presented as isolated risk factors a history of vomiting of three or fewer episodes.  
 ‡The patient younger than 2 years underwent CT because of a scheduled flight back home with his family the same day; the patient older than 2 years underwent CT because of borderline features: 26 months of age, fall from approximately 120 cm, and enlarging occipital hematoma during observation. Both CT scans results were normal.

differences between the pre- and postimplementation periods for children younger than 2 years (7.7% vs. 3.7%,  $p = 0.219$ ) or for children older than 2 years (7% vs. 12.4%,  $p = 0.132$ ).

Intracranial injuries were detected by CT in 1.4% (95% CI = 0.4% to 2.8%) of children or 16.7% of performed CTs in the postimplementation period, compared to 0.7% (95% CI = 0.2% to 2.5%) or 9.5% of performed CTs in the preimplementation period. The ICIs identified on CT scan in the postimplementation period were one epidural hematoma, one subarachnoid bleed, one cerebral contusion, and two subdural hematomas (all cases but one subdural hematoma associated with skull fracture). In the preimplementation period, a case of subdural hematoma and one subdural hematoma and cerebral contusion with associated skull fracture were detected on CT. An isolated skull fracture was found in four patients (three in the post- and one in the preimplementation period).

#### Clinically Important Traumatic Brain Injury Rate.

Three patients (0.8%, 95% CI = 0.3 to 2.5) in the postimplementation period and two children (0.7%, 95% CI = 0.2% to 2.5%) in the preimplementation period met the definition of cTBI, all of them because of hospital admission of two nights or more due to TBI. No patient died, needed neurosurgery, or was intubated for longer than 24 hours. Initially missed cTBIs were also excluded by telephone follow-up, which was accomplished for 78% of patients presenting to the PED after adapted PECARN rule implementation.

**Return Visits.** Return visits for symptoms potentially related to head trauma occurred in five (1.4%) and seven (2.4%) patients in the post- and preimplementation periods, respectively ( $p = 0.506$ ). None of these patients subsequently satisfied the definition of cTBI.

**Safety and Efficacy of Adapted PECARN Rules.** The safety of the adapted PECARN rules in our PED clinical practice was 100% (95% CI = 36.8% to 100%); three of three patients with cTBI who received CT scan at first

evaluation), while efficacy was 92.3% (95% CI = 89% to 95%) (326 of 353 patients without cTBI who did not receive a CT scan).

## DISCUSSION

Many clinical decision rules have been derived to identify the best diagnostic management of children with MHI, but only a few have been validated,<sup>5,16</sup> and no data are currently available on the effects of implementing any of these rules in daily clinical practice. Availability of high-quality evidence-based tools for clinical decision-making is especially useful in the acute care setting to optimize the approach to common presentations for which only a small minority of patients are at risk of a bad outcome. Our results showed that the new rules were successfully implemented, achieving high adherence and satisfaction of medical staff working in the PED. These findings are likely related to the easy structure of the rules, their flexibility, being assistive rather than directive for the moderate risk group, and the availability of risk estimates for cTBI for each risk group. Nonadherence was mostly registered for the moderate-risk group in children older than 2 years, in terms of earlier discharge than recommended, especially for patients who presented with isolated vomiting ( $\leq 3$  episodes) as the only risk factor and who were classified as low risk in the previous protocol. Compared to the United States, our clinical setting is characterized by a lower overall CT scan rate for MHI (~8% vs. 35%),<sup>6</sup> which may be attributed to differences in the population, the local management of MHI, the availability of observation beds in the PED, and different legal implications.

Patients included in our study satisfied the same inclusion and exclusion criteria as the PECARN rule, except for the upper age limit of 15 years for our population, compared to 18 years in the American study. This difference likely explains the higher percentage of children younger than 2 years found in our study (45% vs. 25% in the PECARN study) and the larger proportion of falls as trauma mechanism (80% vs. 51%), which

is more common in younger children and is generally responsible for less severe trauma. The lower percentages of children with GCS = 14 (1% vs. 3%), signs of altered mental status (1% vs. 12%), and signs of basilar or skull fractures (2% vs. 3.5%), all high-risk predictors for *ciTBI*, reflect the overall lower severity of trauma in our PED compared to the North American setting. Street accidents, generally responsible for the most severe trauma mechanisms, were four times more frequent in the United States, compared to our population (15% vs. ~4%). Even though *ciTBI* occurred in a similar proportion of patients (0.9% vs. 0.8%) in the two studies, none of our patients underwent neurosurgery or intubation for longer than 24 hours because of TBI, compared to 68 patients (0.16%) who needed either intervention in the PECARN study, while no cases of death from TBI were registered in either study. Nevertheless, the limited sample size of our study may also account for this finding.

Despite the differences in population and local context with the original setting, adapted PECARN rule implementation in our PED maintained unchanged the previous low CT scan rate, showing an optimal safety and high-efficacy profile. These results are noticeable because the PECARN rule was developed to reduce unnecessary head CT scans in a setting with a four-times-higher CT rate compared to ours, so that implementation of the rule in our setting might have brought an increase in the CT scan rate. The flexibility in decision-making provided by the rule for moderate-risk patients might have contributed to this potential effect, despite the recommended discretion for scanning this group, citing observation as the alternative course of action. The weight of other clinical factors influencing the decision-making process for moderate-risk patients, such as physician's experience and parental preference, is *a priori* unpredictable.

The unchanged CT scan rate in the postimplementation period may be explained by several factors: 1) the traditional conservative watchful waiting approach in the diagnostic management of head trauma in our center, 2) the availability of a short-stay observation unit within the PED that favors this approach,<sup>17</sup> and/or 3) the flexibility of the rule itself, which allowed physicians to prefer a conservative approach, choosing observation instead of CT scan for the great majority of moderate-risk patients.

Strict monitoring of the adapted PECARN rules use in our PED following the 6-month active implementation period is mandatory to evaluate the long-lasting benefit in patient care and/or resource utilization. Larger well-designed studies and rigorous impact analysis, as well as cost-effectiveness analysis, are advocated to provide evidence-based data to support the use of PECARN rules in daily clinical practice.

## LIMITATIONS

Several limitations of our study should be noted. First are the limitations inherent to the study design. Without a randomized controlled trial, it is difficult to assess the possible influence of clinical advances or other system changes on the effects observed in this study.

However, a single-site randomized controlled trial would have been difficult to carry out because of the high risk for contaminating the intervention and control groups, while a multi-institutional randomized study, the preferred trial design, implies relevant logistic and economic challenges that are difficult to overcome, especially without previous evidence of impact.

As far as data collection is concerned, all medical charts were reviewed by chart abstractors who were not blinded to the study hypothesis. This is the most common limitation in medical record review studies in emergency medicine and could have introduced bias to the study results. CT scan evaluation, however, was performed in a blinded manner by consultant radiologists unaware of this study. Furthermore, recommended strategies for medical chart data abstraction<sup>18</sup> (i.e., standard chart abstraction form with clear *a priori* variable definitions and abstraction form guidelines) were provided to study investigators. Collection of prospective data by on-call residents during the postimplementation period might have affected quality of clinical data. However, specific instructions provided to the medical staff working in the PED during the teaching sessions, as well as supervision by attending physicians and monitoring by the study investigators, limited the possibility of incorrect data gathering and reporting.

With regard to medical staff satisfaction, the use of a nonvalidated assessment tool might have influenced our results. Nevertheless, the large difference in medical staff satisfaction between the previous protocol and the adapted PECARN rules, along with the high adherence to the new rules, make a false-positive result very unlikely.

The limited sample size of our study should also be considered. In our PED, implementation of the adapted PECARN rules for an initial 6-month testing period was decided upon due to the need to closely monitor the effects of its use in a different setting from the one of original derivation and validation, taking into account that the flexibility of the rule itself did not allow for accurate estimation of its actual effect in clinical practice. In addition, this time frame best suited the need for a reliable evaluation of medical staff satisfaction in a setting where residents rotate on a yearly basis.

Finally, telephone follow-up in the postimplementation period was not possible for 22% of patients. However, the monitoring of all patients records for any return visit in our PED and the written instructions given to parents on the need to reassess the child in our center for symptoms or signs potentially related to head trauma limit the possibility of unrecognized *ciTBIs*. Our hospital is a referral center for a large metropolitan area, being a tertiary care pediatric facility provided with both pediatric neurosurgery and a pediatric intensive care unit. Nevertheless, the small possibility that discharged children, for whom telephone follow-up was not possible, were subsequently examined at other hospitals cannot be completely excluded.

## CONCLUSIONS

An adapted version of the Pediatric Emergency Care Applied Research Network minor head injury rules was

successfully implemented in an Italian tertiary-care academic pediatric ED, achieving high adherence and satisfaction of medical staff. Its use resulted in a low CT scan rate that was unchanged compared to previous clinical practice, and showed excellent safety and efficacy profiles. Strict monitoring is mandatory to evaluate the long-lasting benefit in patient care and resource utilization.

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## APPENDIX 1

### Summary of Previous Protocol for Management of Children With MHI in Our PED

Patients who sustained a blunt head trauma were classified into three groups:

1. A high-risk group of children for whom CT was recommended. Patients were defined as high-risk if they met at least one of the following criteria: GCS score  $\leq 12$  or drop of 2 points since arrival, focal neurologic signs, loss of consciousness  $> 5$  minutes, signs of basal or complicated skull fracture.
2. A moderate-risk group of children, who did not present any of the above reported features, and whose risk of ICI and subsequent management (CT, skull x-rays, or observation alone) was differentiated according to a three-subgroup classification, based on the presence of specific clinical predictors or the combination given by the severity of trauma mechanism with the presence and site of large scalp hematoma (the last feature considered only for children  $< 2$  years).
3. A low-risk group of children for whom no diagnostic imaging was recommended. Patients were defined as low-risk in the absence of any of the features of the high- and moderate-risk groups and the possible presence of up to four episodes of vomiting immediately after trauma, mild headache confined to site of trauma, or loss of consciousness of only a few seconds.