ORIGINAL RESEARCH

DOI: 10.4274/globecc.galenos.2023.69885
Glob Emerg Crit Care 2023;2(2):33-40

Evaluation of Three Clinical Decision Rules in Pediatric Patients with Minor Head Injury: PECARN, CHALICE and CHATCH

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Abstract

Objective: In this study, we aimed to evaluate the diagnostic accuracy of the Pediatric Emergency Care Applied Research Network (PECARN), Canadian Assessment of Tomography for Childhood Head Injury (CATCH), and children's head injury algorithm for the prediction of important clinical events guidelines in identifying clinically important traumatic brain injury (ciTBI) in pediatric patients with minor head injury.

Materials and Methods: This single-center, prospectively designed study was performed in the emergency department (ED) of a tertiary hospital. The study included patients under 18 years old who presented to the ED with head trauma and a GCS of 14-15. The primary outcome of the study was the relationship between the decision rules and ciTBI.

Results: The study was completed with 502 patients. It was found that the PECARN algorithm was 80% sensitive in detecting ciTBI in patients younger than 2 years of age, and 84.55% in patients aged 2 years or older. While this rate decreased (50.0%) in CATCH, it was higher (89.54%) in CHALICE. In the detection of patients without a risk (specificity), all 3 algorithms found good detections, and the specificity rates were between 82% and 90%.

Conclusion: ciTBI risk prediction models will assist in clinical decision making and establish an accurate neuroimaging strategy. According to the results of our study, all three clinical decision rules can be safely used in the management of pediatric minor head trauma patients.

Keywords: Pediatrics, emergency department, clinically important traumatic brain injury

Introduction

Head injuries are common in children and are one of the leading causes of morbidity and mortality among pediatric patients. Head injuries mostly occur due to mechanisms such as falls, impact with a hard object, or striking a hard surface. Children with head injuries present to emergency departments (EDs) with complaints such as headache, nausea-vomiting, and bleeding [1].

The diagnosis of traumatic intracranial injuries is important and cranial computed tomography (CT) is the gold standard for their diagnosis [2]. Most patients with minor head injuries can be discharged after a period of observation, but a small proportion of their condition deteriorates and brain surgery intervention is required for intracranial hematoma. The use of CT in EDs is important for early diagnosis of these intracranial hematomas [3]. The lack of evidence to assist in identifying children with significant injuries and the concern of clinicians missing such an injury has led to uncertainty as to which patients require investigation. The increased availability and decrease in the time required for cranial CT has led to an increase in CT usage rates [4]. As a result, CT usage has become increasingly widespread while diagnostic yield remains low. The increased use of CT significantly increases health care costs and exposes a large number of children to the potentially harmful effects of ionizing radiation every year [3]. The lifetime cancer death risk attributed to the ionizing radiation dose from a single cranial CT is approximately 1 in 1.500 per year and 1 in 5.000 at age 10. Exposure of a child's brain to ionizing radiation can affect cognitive abilities in adulthood.

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Received: 08.02.2023 **Accepted:** 10.04.2023

Children with head injuries may be uncooperative due to fear or agitation and may require sedation that carries the risk of airway and hemodynamic compromise [4]. Three clinical decision rules have been developed to assist clinicians in reducing CT scans while determining all relevant injuries, to identify children with high risk of intracranial injury: Canadian Assessment of Tomography for Childhood Head Injury (CATCH), Pediatric Emergency Care Applied Research Network (PECARN), and children's head injury algorithm for the prediction of important clinical events (CHALICE) [5]. The PECARN rule is recommended for patients under 18 years of age, presenting within 24 hours, with blunt head trauma and a Glasgow Coma scale (GCS) score of 14-15. It helps in decision making for CT scans, observation, and discharge. The CATCH rule is used for patients presenting within the first 24 hours with a GCS score of 13-15, including those with blunt head trauma. CT scans are recommended if at least one of the criteria is present. The CHALICE rule can be used for all children with head trauma. It assists in decision making based on the history, physical examination, and mechanism of injury. If there is one of the criteria, a CT scan is recommended. If none of them are present, the patient has a low risk of intracranial injury. In this study, the aim was to evaluate the diagnostic accuracy of PECARN, CATCH, and CHALICE rules in determining clinically important traumatic brain injuries (ciTBI) in children with minor head trauma.

Materials and Methods

This study, which was designed as a single-center and prospective study, was conducted at the Emergency Medicine Clinic of University of Health Sciences Turkey, Kartal Dr. Lütfi Kırdar City Hospital between July 1, 2022 and November 1, 2022. The Clinical Research Ethics Committee of the University of Health Sciences Turkey, Kartal Dr. Lütfi Kırdar City Hospital approved this study (approval number: 2022/514/228/2, date: 30.06.2022). Relatives of all participants were informed in detail before starting the study and approval was obtained via written informed consent forms.

The study included patients under 18 years old who presented to the ED with head trauma and a GCS of 14-15. Patients over 18 years old, patients with a GCS of 13 or below, patients with multiple trauma, patients taking anticoagulant drugs, and patients who could not be followed up were not included in the study.

A form was created by the researchers involved in the study to record the study data. The effectiveness of PECARN, CHALICE, and CATCH scores was compared. Variables in CATCH, CHALICE, and PECARN are provided in Table 1. All the variables for these scores were included in the study form. The forms were filled out only on days when the researchers were working. The data of patients who presented to the ED with minor head trauma was recorded in the form by the researchers in the

Table 1. Variables of CATCH, CHALICE, and PECARN

CHALICE	CATCH	PECARN	
		Children younger than 2 years	**Children 2 years and older**
History **1.** Witnessed LOC >5 minutes **2.** History of amnesia >5 minutes **3.** Abnormal drowsiness **4.** Over 3 discrete vomits **5.** Physician suspicion of non-accidental injury **6.** First ever seizure after injury **Examination** **7.** GCS <14 or <15 if under 1 year **8.** Suspicion of penetrating or depressed skull injury or tense fontanelle **9.** Signs of basil skull fracture **10.** Positive focal neurological finding **11.** Presence of bruise, swelling, or laceration >5 cm if <1 year old **Mechanism** **12**. Dangerous mechanism (MVA >40 mph, fall >3 meters, high speed projectile injury	CT head is required only for children with minor head injury (injury within the past 24 hours associated with witnessed LOC, definite amnesia, witnessed disorientation, persistent vomiting, or persistent irritability) plus any one of the following **High risk** **1.** GCS<15 two hours post injury **2.** Suspected open or depressed skull fracture **3.** History of worsening headache **4.** Irritability on examination **Medium risk** **5.** Any sign of basal skull fracture **6.** Large boggy hematoma of the scalp **7.** Dangerous mechanism (MVA, fall >3 ft/0.9 m, or from 5 stairs, fall from bicycle with no helmet)	**1.** GCS ≤14 **2.** Signs of altered mental status (agitation, somnolence, repetitive questioning, slow to respond to questions) **3.** Palpable skull fracture **4.**Occipital, parietal, or temporal scalp hematoma **5.** History of LOC ≥5 s **6.** Dangerous mechanism (MVA with ejection or death of other occupant or rollover, pedestrian or cyclist struck without helmet, falls over 3 ft/0.9 m, or struck by high-impact object) **7.** Parental concern	**1.** GCS ≤14 **2.** Signs of altered mental status (agitation, somnolence, repetitive questioning, slow to respond to questions) **3.** Signs of basilar skull fracture **4.** History of LOC **5.** History of vomiting **6.** Dangerous mechanism (MVA with ejection or death of other occupant or rollover, pedestrian or cyclist struck without helmet, falls over 5 ft/1.5 m, or struck by high-impact object) **7.** Severe headache

CATCH: Canadian Assessment of Tomography for Childhood Head Injury, CHALICE: Children's head injury algorithm for the prediction of important clinical events, PECARN: Pediatric Emergency Care Applied Research Network, GCS: Glasgow Coma scale, LOC: Level of consciousness, MVA: Motor vehicle accident triage section of the ED. The patients were then redirected to the trauma section of the ED, where their management was performed by another physician who was not involved in the research. Finally, the outcomes of the patients were obtained from digital medical records and/or by contacting the patients' relatives by telephone.

Any of the following definitions are considered ciTBI; death from traumatic brain injury (TBI), neurosurgical intervention for TBI (intracranial pressure monitoring, elevation of depressed skull fracture ventriculostomy, hematoma evacuation, lobectomy, tissue debridement, dura repair), intubation of more than 24 hours for TBI, hospital admission of 2 nights or more for the TBI in association with TBI on CT.

Any of the following definitions were considered TBI on CT; intracranial hemorrhage or contusion, cerebral edema, traumatic infarction, diffuse axonal injury, shearing injury, sigmoid sinus thrombosis, midline shift of intracranial contents or signs of brain herniation, diastasis of the skull, pneumocephalus, and skull fracture depressed by at least the width of the table of the skull.

Statistical Analysis

To perform statistical analysis, SPSS v. 25.0 software package (SPSS Inc., Chicago, IL, USA) and MedCalc ver. 12.5 (MedCalc Software Ltd, Ostend, Belgium) were used. While evaluating the study data, the data were summarized by using descriptive statistical methods (frequency, percentage). Receiver operating characteristic analysis was applied for PECARN, CHALICE, and CATCH effectiveness in clinical decisions. Sensitivity and specificity calculated from the analysis were reported with their 95% confidence intervals. Area under the curve, pulse pressure variation and negative predictive value were also given to distinguish diagnostic efficiencies of PECARN, CHALICE, and CATCH.

The Fisher's exact test was applied for the independency of 2x2 crosstabs two categorical variables to determine relationships of PECARN, CHALICE, CATCH and the present of TBI on CT.

Results

After excluding 23 patients who did not meet the inclusion criteria of the study, the study was completed with 502 patients. Of these patients, 155 were under the age of 2, and 347 were 2 years old or older. Tables 2-4 show the distribution of variables in PECARN, CHALICE, and CATCH clinical decision-making algorithms among the included patients. The PECARN algorithm showed that the highest changes in consciousness and scalp hematoma were found in patients under 2 years of age. In patients over 2 years old, a history of vomiting and changes in consciousness were found more frequently compared to others. In the CATCH algorithm, larger and swollen scalp hematomas and high energy trauma classification were found to be more frequent than others. In the CHALICE algorithm, it appears that the presence of ecchymosis, swelling, laceration and abnormal sleepiness in patients is more commonly encountered compared to other conditions in younger patients.

Table 5 shows the sensitivity and specificity rates and 95% confidence intervals found for the PECARN, CHALICE, and CATCH clinical decision-making algorithms in order to measure their effectiveness in making the correct decision in the study. It was found that the PECARN algorithm was 80% sensitive in detecting ciTBI in patients under 2 years of age, and 84.55% sensitive in patients 2 years old or older. The rate decreased in CATCH (50.0%), while it was higher in CHALICE (89.54%). In detecting patients without risk (specificity), all three algorithms performed well, with specificity rates ranging from approximately 82% to 90%.

In terms of detecting TBI with CT, PECARN has the best sensitivity with a range of 80-82.26%, while the sensitivity of CATCH and CHALICE decreases. All algorithms have high specificity rates in this detection. In conclusion, the PECARN algorithm has more stable detections in terms of sensitivity compared to CATCH and CHALICE and that all three algorithms have roughly equal and high specificity rates in the range of 80-90%. Diagnostic accuracy of PECARN, CATCH, and CHALICE clinical decision rules were found to be statistically significant (p values respectively; 0.0046-0.0133, 0.0085 and 0.0001) (Table 5).

Discussion

In this study, analyses were performed regarding the risk classification of head injuries in children under the age of 18 using the PECARN, CATCH and CHALICE algorithms. According to the analyses, the PECARN, CATCH and CHALICE algorithms were successful in detecting high-risk head injuries.

Various risk algorithms are used for early diagnosis and rapid intervention in patients admitted to ED [6-8]. The risk algorithms should have high sensitivity and high negative predictive value in detecting the injury, meaning that if a patient is scored as having low risk, they should not actually have a serious head injury. Results of the study showed that PECARN has high sensitivity in both age groups (under 2 and over 2), and similar results were seen in other studies [9,10]. Sensitivity of CATCH and CHALICE algorithms was found to be slightly lower compared to results reported in other studies (86-100% for CATCH and 91-100% for CHALICE in the mentioned studies) [11,12]. Additionally, the negative predictive values of these 3 risk scales were found to be 82-90% in the analysis.

Clinically, severe traumatic head injuries have a significant place in the healthcare system. According to our results regarding PECARN, patients who came with serious head injury in the under-2 age group were generally present with

Table 2. Distribution of variables found in the PECARN clinical decision algorithm among patients in the study

PECARN	Frequency	Percentage	TBI detected on CT		
			Absent n (%)	Present n (%)	p values
<2 years patients; Glasgow Coma scale <15					
Absent	154	99.4	138 (89.6)	16 (10.4)	0.897
Present	1	0.6	1 (100)	0 (0)	
<2 years patients; signs of altered mental status					
Absent	146	94.8	130 (89)	16 (11)	0.407
Present	8	5.20	8 (100)	0 (0)	
<2 years patients; palpable skull fracture					
Absent	152	98.7	138 (90.2)	14 (9.2)	0.010
Present	2	1.30	0 (0)	2 (100)	
<2 years patients; occipital, parietal, or temporal scalp hematoma					
Absent	146	94.8	134 (91.8)	12 (8.2)	0.004
Present	8	5.20	4 (50)	4 (50)	
<2 years patients; history of loss of consciousness ≥5 s					
Absent	153	99.4	137 (89.5)	16 (10.5)	0.896
Present	1	0.6	1 (100)	0 (0)	
<2 years patients; dangerous mechanism					
Absent	148	96.1	133 (89.9)	15 (10.1)	0.488
Present	6	3.9	5 (83.3)	1 (16.7)	
<2 years patients; parental concern					
Absent	148	96.1	132 (89.2)	16 (10.8)	0.512
Present	6	3.9	6 (100)	0 (0)	
>2 years patients; GCS <15					
Absent	349	99.7	328 (94)	21 (6)	0.940
Present	1	0.3	1 (100)	0 (0)	
>2 years patients; signs of altered mental status					
Absent	334	95.2	315 (94.3)	19 (5.7)	0.270
Present	17	4.80	15 (88.2)	2 (11.8)	
>2 years patients; signs of basilar skull fracture					
Absent	349	100.0	328 (94)	21 (6)	-
>2 years patients; history of loss of consciousness					
Absent	348	99.1	328 (94.3)	20 (5.7)	0.169
Present	3	0.9	2 (66.7)	1 (33.3)	
>2 years patients; history of vomiting					
Absent	327	93.7	312 (95.4)	15 (4.6)	0.001
Present	22	6.30	16 (72.7)	6 (27.3)	
>2 years patients; dangerous mechanism					
Absent	342	98.0	322 (94.2)	20 (5.8)	0.355
Present	7	2.0	6 (85.7)	1 (14.3)	
>2 years patients; severe headache					
Absent	346	98.6	325 (93.9)	21 (6.1)	0.733
Present	5	1.40	5 (100)	0 (0)	

PECARN: Pediatric Emergency Care Applied Research Network, GCS: Glasgow Coma scale, CT: Computed tomography, TBI: Traumatic brain injury

Table 3. Distribution of variables found in the CATCH clinical decision algorithm among patients in the study

CATCH	Frequency	Percentage	TBI detected on CT		
			Absent n (%)	Present n (%)	p values
Glasgow Coma scale <15 two hours post injury					
Absent	501	99.8	466 (93)	35 (87)	0.072
Present	1	0.2	0 (0)	1 (100)	
Suspected open or depressed skull fracture					
Absent	502	100.0	466 (92.8)	36 (7.2)	-
History of worsening headache					
Absent	501	99.8	465 (92.8)	36 (7.2)	0.928
Present	1	0.2	1 (100)	0 (0)	
Irritability on examination					
Absent	501	99.8	464 (92.8)	36 (7.2)	0.928
Present	1	0.2	1 (100)	0 (0)	
Any sign of basal skull fracture					
Absent	502	100.0	466 (92.8)	36 (7.2)	-
Large boggy hematoma of the scalp					
Absent	463	92.2	443 (95.7)	20 (4.3)	0.000
Present	39	7.8	23 (59)	16 (41)	
Dangerous mechanism*					
Absent	489	97.4	455 (93)	34 (7)	0.238
Present	13	2.6	11 (84.6)	2 (15.4)	

*Motor vehicle accident, fall >3 ft/0.9 m, or from 5 stairs, fall from bicycle with no helmet, CT: Computed tomography, TBI: Traumatic brain injury, CATCH: Canadian Assessment of Tomography for Childhood Head Injury

scalp hematoma and changes in consciousness. In the over-2 age group, nausea and changes in consciousness were also identified as clinical presentations. In a study done by Runde and Beiner [13], it was mentioned that younger patients in the groups evaluated as high risk had more scalp hematomas or palpable fractures or confusion, while older children had admission due to changes in consciousness or GCS scores below 14. In a study done by Hennelly et al. [14], it was emphasized that when determining an appropriate imaging strategy for children with minor head trauma, one must consider the quality of life based on health status and radiation risk in their analysis of the management of these cases. In a similar study, it was stated that PECARN's algorithm can help in the clinical decision-making stage for children patients who are isolated with a GCS score of 14 or with consciousness disturbance and who are identified as high risk [15]. In a study done by Bressan et al. [16], information was provided about determining risk with different predictive combinations in the PECARN medium and high-risk groups in traumatic head injuries, supporting the study that we carried out. Studies have shown that the use of PECARN has resulted in a significant decrease in the rate of CT scans in places with high rates of CT scans, and has not caused any increase in places with low rates of CT scans [17]. When compared, a cost-effectiveness study conducted by Nishijima et al. [18] in the United States showed that PECARN was seen as the dominant and effective strategy compared to general clinical understanding (CT scan rate at 33.8%). In another similar analysis conducted by Holmes et al. [19] in England, both CHALICE and PECARN were emphasized and it was noted that both were effective approaches. As in the literature studies, it was concluded that all three decision rules were useful in this study.

Study Limitations

The results of our study should be evaluated taking into account the limitations. The numerical scarcity of the patient population that came with traumatic head injury, suitable for our age group, caused a wide confidence interval in the calculation of some predictive signs. As in other studies related to PECARN [9], we did not exclude children who were injured from our population due to small injury mechanisms, falling from the same level or running/walking injuries caused by stable objects. Although the rate of serious traumatic head injury is low in low-risk injury mechanisms, in our study, there were cases that resulted in intracranial injury even in such an injury. The results of our study should not be generalized to the general public due to factors such as the doctors at our center being more experienced in managing pediatric trauma patients.

Table 4. Distribution of variables found in the CHALICE clinical decision algorithm among patients in the study

CHALICE	Frequency	Percentage	TBI detected on CT		
			Absent n (%)	Present n (%)	p values
Witnessed LOC >5 minutes					
Absent	496	98.8	461 (92.9)	35 (7.1)	0.362
Present	6	1.2	5	1	
History of amnesia >5 minutes					
Absent	495	99.0	461 (92.9)	35 (7.1)	0.313
Present	5	1.0	4 (80)	1 (20)	
Abnormal drowsiness					
Absent	479	95.4	445 (92.9)	34 87.1)	0.503
Present	23	4.6	21 (91.3)	2 (8.7)	
Over 3 discrete vomits					
Absent	492	98.2	458 (93.1)	34 (6.9)	0.131
Present	9	1.8	7 (77.8)	2 (22.2)	
Physician suspicion of non-accidental injury					
Absent	499	100.0	463 (92.8)	36 (7.2)	-
First ever seizure after injury					
Absent	500	100.0	464 (92.8)	36 (7.2)	-
Glasgow Coma scale <14 or <15 if under 1 year					
Absent	501	100.0	465 (92.8)	36 (7.2)	-
Suspicion of penetrating or depressed skull injury or tense fontanelle					
Absent	500	100.0	464 (92.8)	36 (7.2)	-
Signs of basil skull fracture					
Absent	502	100.0	466 (92.8)	36 (7.2)	-
Positive focal neurological finding					
Absent	501	99.8	465 (92.8)	36 (7.2)	0.928
Present	1	0.2	1 (100)	0 (0)	
Presence of bruise, swelling, or laceration >5 cm if <1 year old					
Absent	126	81.3	443 (93.9)	29 (6.1)	0.003
Present	29	18.3	22 (75.9)	7 (24.1)	
Dangerous mechanism					
Absent	495	98.6	461 (93.1)	34 (6.9)	0.084
Present	7	1.4	5 (71.4)	2 (28.6)	
Fall >3 meters					
Absent	501	100.0	465 (92.8)	36 (7.2)	-
High speed projectile injury					
Absent	499	99.4	463 (92.8)	36 (7.2)	0.800
Present	3	0.6	3 (100)	0 (0)	

CHALICE: Children's head injury algorithm for the prediction of important clinical events, CT: Computed tomography, TBI: Traumatic brain injury, LOC: Level of consciousness

Table 5. Diagnostic accuracy of PECARN, CATCH, and CHALICE clinical decision rules

	PECARN		CATCH	CHALICE
	<2 years	≥2 years	All patients	All patients
	n=155	n=347	n=502	n=502
ciTBI				
Sensitivity (95% CI)	80.0 (68.4-90.5)	84.55 (76.9-90.4)	50.00 (24.7-75.3)	89.54 (61.2-97.3)
Specificity (95% CI)	82.26 (74.4-88.5)	88.48 (84.5-91.7)	89.54 (86.2-92.3)	86,13 (82.4-89.3)
TBI on CT				
Sensitivity (95% CI)	80.00 (55.3-85.3)	82.26 (74.4-88.5)	55.56 (38.5-75.5)	51.85 (31.9-71.3)
Specificity (95% CI)	80.95 (72.6-87.2)	89.06 (78.8-95.5)	90.51 (83.9-98.7)	91.06 (87.7-95.8)
AUC	0.721	0.836	0.672	0.743
p values	0.0046	0.0133	0.0085	0.0001
NPV	92.00	95.43	95.98	94.42
PPV	80.77	84.44	66.67	83.33

CI: Confidence interval, ciTBI: Clinically important traumatic brain injury, TBI on CT: Traumatic brain injury on computed tomography, PECARN: Pediatric Emergency Care Applied Research Network, AUC: Area under the curves, CHALICE: Children's head injury algorithm for the prediction of important clinical events, CATCH: Canadian Assessment of Tomography for Childhood Head Injury, PPV: Positive predictive value, NPV: Negative predictive value

Conclusion

ciTBI risk prediction models will assist in clinical decision making and in establishing an accurate neuroimaging strategy. According to the results of our study, all three clinical decision rules can be used safely in the management of pediatric minor head trauma patients. More studies are needed to demonstrate reliability and accuracy in hospitals with non-specialized doctors or healthcare professionals in pediatric patients.

Ethics

Ethics Committee Approval: The Clinical Research Ethics Committee of the University of Health Sciences Turkey, Kartal Dr. Lütfi Kırdar City Hospital approved this study (approval number: 2022/514/228/2, date: 30.06.2022).

Informed Consent: Relatives of all participants were informed in detail before starting the study and approval was obtained via written informed consent forms.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: H.D.E., N.B.Ç., S.K., S.G., Concept: A.U.S., R.A., S.K., Design: R.A., H.D.E., A.Y.K., N.B.Ç., Data Collection or Processing: S.G., H.D.E., A.Y.K., S.K., Analysis or Interpretation: N.B.Ç., A.U.S., S.G., Literature Search: R.A., A.Y.K., H.D.E., S.G., Writing: R.A., A.Y.K., A.U.S., H.D.E.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Bressan S, Eapen N, Phillips N, Gilhotra Y, Kochar A, Dalton S, et al. PECARN algorithms for minor head trauma: Risk stratification estimates from a prospective PREDICT cohort study. Acad Emerg Med. 2021;28:1124-33.
2. Babl FE, Bressan S. Physician practice and PECARN rule outperform CATCH and CHALICE rules based on the detection of traumatic brain injury as defined by PECARN. Evid Based Med. 2015;20:33-4.
3. Caceres JA, Goldstein JN. Intracranial hemorrhage. Emerg Med Clin North Am. 2012;30:771-94.
4. Lyttle MD, Crowe L, Oakley E, Dunning J, Babl FE. Comparing CATCH, CHALICE and PECARN clinical decision rules for paediatric head injuries. Emerg Med J. 2012;29:785-94.
5. Babl FE, Borland ML, Phillips N, Kochar A, Dalton S, McCaskill M, et al. Accuracy of PECARN, CATCH, and CHALICE head injury decision rules in children: a prospective cohort study. Lancet. 2017;389:2393-402.
6. Kılıç M, Ak R, Dalkılınç Hökenek U, Alışkan H. Use of the AIMS65 and pre-endoscopy Rockall scores in the prediction of mortality in patients with the upper gastrointestinal bleeding. Ulus Travma Acil Cerrahi Derg. 2022;29:100-4.
7. Kılıç M, Ak R, Alışkan H. The utility of hemoglobin, albumin, lymphocyte and platelet (HALP) score in predicting mortality among COVID-19 patients: a preliminary study. Signa Vitae. 2023;19:143-7.
8. Ak R, Hökenek NM. Comparison of AIMS65 and Glasgow Blatchford scores in predicting mortality in patients with upper gastrointestinal bleeding. Rev Assoc Med Bras (1992). 2021;67:766-70.
9. Gambacorta A, Moro M, Curatola A, Brancato F, Covino M, Chiaretti A, et al. PECARN Rule in diagnostic process of pediatric patients with minor head trauma in emergency department. Eur J Pediatr. 2022;181:2147-54.
10. Kuppermann N, Holmes JF, Dayan PS, Hoyle JD Jr, Atabaki SM, Holubkov R, et al. Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. Lancet. 2009;374:1160-70.
11. Osmond MH, Klassen TP, Wells GA, Correll R, Jarvis A, Joubert G, et al. CATCH: a clinical decision rule for the use of computed tomography in children with minor head injury. CMAJ. 2010;182:341-8.

12. Nigrovic LE, Stack AM, Mannix RC, Lyons TW, Samnaliev M, Bachur RG, et al. Quality improvement effort to reduce cranial CTs for children with minor blunt head trauma. Pediatrics. 2015;136:227-33.

13. Runde D, Beiner J. Calculated decisions: PECARN pediatric head injury/trauma algorithm. Pediatr Emerg Med Pract. 2018;15(Suppl 6):CD3-CD4.

14. Hennelly KE, Mannix R, Nigrovic LE, Lee LK, Thompson KM, Monuteaux MC, et al. Pediatric traumatic brain injury and radiation risks: a clinical decision analysis. J Pediatr. 2013;162:392-7.

15. Dalziel K, Cheek JA, Fanning L, Borland ML, Phillips N, Kochar A, et al. A cost-effectiveness analysis comparing clinical decision rules PECARN, CATCH, and CHALICE with usual care for the management of pediatric head injury. Ann Emerg Med. 2019;73:429-39.

16. Bressan S, Eapen N, Phillips N, Gilhotra Y, Kochar A, Dalton S, et al. PECARN algorithms for minor head trauma: Risk stratification estimates from a prospective PREDICT cohort study. Acad Emerg Med. 2021;28:1124-33.

17. Yang K, Zhao M, Sun J, Nie X. Accuracy of PECARN decision rule in minor blunt head trauma in pediatric emergency department: a meta-analysis. Int J Clin Pract. 2021;75:e14586.

18. Nishijima DK, Yang Z, Urbich M, Holmes JF, Zwienenberg-Lee M, Melnikow J, et al. Cost-effectiveness of the PECARN rules in children with minor head trauma. Ann Emerg Med. 2015;65:72-80.

19. Holmes MW, Goodacre S, Stevenson MD, Pandor A, Pickering A. The cost-effectiveness of diagnostic management strategies for children with minor head injury. Arch Dis Child. 2013;98:939-44.