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ORIGINAL ARTICLE

Comparison of CATCH, PECARN, and CHALICE clinical decision rules in pediatric patients with mild head trauma

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Abstract

Purpose The present study compares the most frequently used the CATCH, PECARN, and CHALICE clinical decision protocols with an aim to evaluate their effectiveness from the population perspective.

Methods This study included all patients under 18 years of age presenting with blunt head trauma and a Glasgow Coma Scale score of 13 and higher for whom the attending physician decided to order head computed tomography scans, and the legal representative provided an informed consent for inclusion in the study. The PECARN, CATCH, and CHALICE clinical decision rules were applied to the participating patients, and the data for each of the three international clinical decision rules were recorded. These data were then compared to head CT results.

Results Based on the head CT positivity, the sensitivity and specificity values for the PECARN were 82.76 and 45.03%; the sensitivity and specificity values for CATCH were 89.29 and 47.44%, showing statistical significance in predicting CT positivity; the CHALICE did not show statistical significance in detecting a pathological CT result. In terms of evaluating the need for hospitalization, the PECARN had a sensitivity of 83.87% and a specificity of 45.12%; the CATCH had a sensitivity of 90% and a specificity of 47.54%, showing statistical significance while the CHALICE did not significantly detect the need for hospitalization.

Conclusions The present study found that the PECARN and CATCH rules in children with minor head injury were significantly sensitive in detecting CT positivity and the need for hospitalization.

Keywords Brain · Clinical decision rules · Pediatrics

Background

Traumatic brain injury (TBI) is a significant cause of mortality and morbidity in the pediatric population [1]. The World Health Organization (WHO) estimates that TBI will be the major cause of death and disabilities by 2030 [2]. Of the patients hospitalized due to traumatic brain injury, 75% have sustained head trauma, and central nervous system injury is the most common cause of traumatic deaths in the pediatric population [3]. Head injuries are often divided into three classes according to the clinical assessment upon initial presentation as follows: minor head injury with a Glasgow Coma Scale (GCS) score of 13–15, moderate head injury with a GCS of 9–12, and severe head injury with a GCS of 3–8 [1]. Most head injuries are mild and patients do not require neurosurgical intervention; however, patients with loss of consciousness, amnesia, history of disorientation, and those deemed to be in a high-risk group may require neurosurgical intervention. Computed tomography (CT) scans of the head detect a pathological finding in 4–7% of the patients in this patient population [4]. Head CT results are essential in diagnosing TBI, allowing for fast and accurate diagnosis; however, disadvantages include patient exposure to ionizing radiation, difficulty of use in children, and increased hospital costs [5].

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The advantages and disadvantages must be carefully evaluated when predicting the need for brain imaging in children. Several protocols have been developed to help determine the need for performing head CT in children presenting with minor head injuries. The present study compares the most frequently used CATCH (Canadian Assessment of Tomography for Childhood Head Injury), PECARN (Pediatric Emergency Care Applied Research Network), and CHALICE (Children's Head Injury Algorithm for The Prediction of Important Clinical Events) clinical decision protocols with an aim to evaluate their effectiveness from mild head injury children perspective. All three clinical decision-making protocols in Appendix 1.

Materials and methods

Study design

The present study was designed as a prospective and observational study and was conducted in the Emergency Neurosurgery Outpatient Clinic at Health Sciences University Okmeydani Training and Research Hospital between October 1, 2019 and March 8, 2020. The Emergency Neurosurgery Outpatient Clinic is a part of the Emergency Department. In this clinic, there is a Neurosurgeon who deals with cases related to neurosurgery accepted by ambulatory or ambulance. The study was granted approval by the ethics committee of the same hospital (48670771-514.10). Before inclusion in the study, the patients or their legal representatives consented to participate in the study, and they signed a written informed consent form.

The study included all patients under 18 years of age presenting to the Emergency Neurosurgery Outpatient Clinic with blunt head trauma and a Glasgow Coma Scale score of 13 or higher for whom the attending physician decided to order computed tomography scans of the head and the legal representative provided informed consent for inclusion in the study.

Patients aged 18 years and older, patients with a GCS score of less than 13, patients presenting with penetrating head trauma or trauma to the other body systems, patients with isolated mild facial trauma were excluded.

Data collection

The PECARN, CATCH, and CHALICE clinical decision rules were applied to the study patients, and the data for each of the three international clinical decision rules were recorded. These clinical decision rules aim to reduce the number of unnecessary imaging studies based on clinical decision and to ensure imaging studies are only run in patients who genuinely require them. Parameters of all three clinical decision rules such as demographic variables, mechanisms of injury, signs and symptoms were recorded (all parameters are available in Appendix 1). After recording these data, a comparison was made with head CT results (the absence or presence of a pathological finding requiring treatment or follow-up). Linear fracture, burst fracture, comminuted fracture, epidural hematoma, subdural hematoma, traumatic subarachnoid hemorrhage, and the presence of contusion were considered to be positive findings on head CT scans. Pediatric GCS score was used in the patient group aged 5 years and younger.

The endpoints of the study were head CT positivity and/or the need for hospitalization. Hospitalization decision was made by the clinical decision of the neurosurgeon at the Emergency Neurosurgery Outpatient Clinic.

Statistical analysis

Descriptive statistics were used to summarize the study data, and categorical variables were expressed as numbers and percentages.

In the comparison between the categorical variables according to CT results and hospitalization status, Pearson's chi-squared test was used in 2×2 contingency tables if the expected value in each cell was 5 or greater, and Fisher's exact test was used if the expected value in each cell was less than 5. Fisher–Freeman–Halton test was used if the expected value in each cell was less than 5 in the RXC contingency table.

Univariate and multivariate logistic regression model was used to explore the factors that might have affected CT positivity.

The patients were divided as CT-positive and CT-negative, and the individual effectiveness of PECARN, CATCH, and CHALICE criteria were evaluated according to the CT result. Sensitivity, specificity, positive predictive value, and negative predictive value were calculated for each of the three criteria for CT positivity.

The statistical analyses were performed using Jamovi (Version 1.0.1), JASP (Version 0.10.0), and MedCalc Statistical Software Trial version (MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org; 2015), and the level of statistical significance was set at a p value of 0.05.

Results

During the study period, 5220 patients under the age of 18 were admitted. 1512 were associated with trauma. Fifty-two patients were excluded because they did not want to participate in the study, 141 had a GCS below 13, and 315 were excluded because of isolated mild facial trauma. A total of 1004 patients were included in the study.

PECARN rules were applied to all patients. CATCH and CHALICE rules were applied to 966 patients included in the study. The age and gender distribution of the cases are presented in Table 1. According to our data, 290 patients (28.9%) were under 2 years of age, 676 (67.3%) were in the 2–14 years age group, and 38 (3.8%) were in the 15–18 years age group. Of the participating patients, 657 (65.4%) were male, and 347 (34.6%) were female. The same table also shows the Glasgow Coma Scale scores of the patients, the presence of scalp hematoma, and other clinical parameters. Accordingly, the GCS score was 15 in 99.5% of the patients, and 230 patients (22.9%) had frontal, 112 patients (11.2%) had occipital, 73 patients (7.3%) had parietal, and 43 patients (4.3%) had temporal scalp hematoma.

It was found that the PECARN criteria successfully predicted the presence of a pathology in head CT scans ($p = 0.005$). The PECARN criteria yielded a sensitivity of 82.76% and a specificity of 45.03%. The CATCH criteria

Table 1 Demographic characteristics, and signs and symptoms of the patients

Variables and their levels	Subgroup *n* (%)	*n* (%)
Age		
< 2		290 (28.9)
2–14		676 (67.3)
15–18		38 (3.8)
Gender		
Male		657 (65.4)
Female		347 (34.6)
Glasgow Coma Scale (GCS) score		
13		2 (0.2)
14		3 (0.3)
15		999 (99.5)
Scalp hematoma		
Absent		546 (54.4)
Frontal	230 (22.9)	
Occipital	112 (11.2)	
Parietal	73 (7.3)	
Temporal	43 (4.3)	
> 5 cm skin laceration, present		26 (2.6)
Palpable fracture, present		1 (0.1)
Presence of or suspected open fracture, present		2 (0.2)
Signs of basilar skull fracture, present		3 (0.3)
Abnormal behavior per parents, present		30 (3.0)
History of seizure after trauma, present		1 (0.1)
Loss of consciousness, present		31 (3.1)
Duration of the loss of consciousness		
5 s–5 min	2 (6.5)	
More than 5 min	29 (93.5)	
Amnesia		14 (1.4)
Duration of amnesia		
Less than 5 min	9 (64.3)	
More than 5 min	5 (35.7)	
Vomiting after trauma, present		83 (8.3)
Number of vomits if present		
Less than 3	71 (85.5)	
3 or greater	12 (14.5)	
Headache, present		109 (10.9)
Irritability, present		7 (0.7)
Neurological deficit, present		2 (0.2)
Tense fontanelle, present		29 (2.9)

Descriptive statistics are presented as number (%)

successfully predicted the presence of a pathology in head CT scans ($p < 0.001$), yielding a sensitivity of 89.29% and a specificity of 47.44%. However, the CHALICE criteria did not significantly predict the presence of a pathology in head CT scans (Table 2).

As shown in Table 3, the PECARN criteria significantly predicted the need for hospitalization ($p = 0.003$). The PECARN criteria yielded a sensitivity of 83.87% and a specificity of 45.12%. The CATCH criteria significantly predicted the need for hospitalization ($p < 0.001$). CATCH criteria yielded a sensitivity of 90.00% and a specificity of 47.54% while the CHALICE criteria did not significantly predict the need for hospitalization ($p = 0.740$).

Table 4 shows a comparison of patients' CT results in terms of age, gender, and several clinical characteristics. As seen in this table, the rate of CT positivity was higher in the patients under 2 years of age whereas the rate of CT positivity was lower in the 2–14 years age group; the difference was statistically significant ($p < 0.001$). When the types of scalp hematoma were examined according to CT results, the difference between the rates was statistically significant ($p < 0.001$). The CT positivity rate was higher in the presence of abnormal behavior per parents, vomiting after trauma, and irritability ($p = 0.009$, $p = 0.027$, and $p = 0.001$, respectively). The examination of other parameters did not show statistical significance ($p > 0.05$ for each, Table 4).

Table 5 shows univariate and multivariate logistic regression models created to explore the factors that might pose a risk for CT positivity. In the univariate logistic regression model, abnormal behavior per parent, vomiting after trauma, and the presence of occipital, parietal, and temporal scalp hematoma (non-frontal scalp hematoma) better predicted CT positivity in the 2–14 years age group compared to patients under 2 years of age ($p < 0.05$ for each). In the examination of Model 1 in multivariate logistic regression analysis, age being 2–14 years compared to under 2 years and abnormal behavior per parents significantly predicted CT positivity ($p < 0.001$ and $p = 0.011$, respectively). In the examination of Model 2, age being 2–14 years compared to under 2 years and the presence of non-frontal scalp hematoma compared to the absence of scalp hematoma significantly predicted CT positivity ($p < 0.001$).

Table 2 The statistics showing individual performances of PECARN, CATCH, and CHALICE criteria in predicting the presence of a pathology in head CT scans

	CT result		
	Positive	Negative	*p* value
PECARN (%)			
Positive	24 (82.8%)	536 (55.0%)	**0.005***
Negative	5 (17.2%)	439 (45.0%)	
Sensitivity (CI)	82.76%	64.23–94.15%	
Specificity (CI)	45.03%	41.87–48.21%	
CATCH (%)			
Positive	25 (89.3%)	493 (52.6%)	**< 0.001***
Negative	3 (10.7%)	445 (47.4%)	
Sensitivity (CI)	89.29%	71.77–97.73%	
Specificity (CI)	47.44%	44.20–50.69%	
CHALICE (%)			
Positive	2 (7.1%)	82 (8.7%)	0.999
Negative	26 (92.9%)	856 (91.3%)	
Sensitivity (CI)	7.14%	0.88–23.50%	
Specificity (CI)	91.26%	89.26–92.99%	

CI confidence interval

*Pearson's chi-squared test was used. Descriptive statistics are presented as number (%)

P values marked in bold are considered to indicate statistical significance ($p < 0.05$)

Table 3 The statistics showing individual performances of PECARN, CATCH, and CHALICE criteria in predicting the need for hospitalization

	Hospitalization		
	Yes	No	*p* value
PECARN (%)			
Positive	26 (83.9%)	534 (54.9%)	**0.003**
Negative	5 (16.1%)	439 (45.1)	
Sensitivity (CI)	83.87%	66.27–94.55%	
Specificity (CI)	45.12%	41.96–48.31%	
CATCH (%)			
Positive	27 (90.0%)	491 (52.5%)	**< 0.001**
Negative	3 (10.0%)	445 (47.5%)	
Sensitivity (CI)	90.00%	73.47–97.89%	
Specificity (CI)	47.54%	44.30–50.80%	
CHALICE (%)			
Positive	3 (10.0%)	81 (8.7%)	0.740
Negative	27 (90.0%)	855 (91.3%)	
Sensitivity (CI)	10.00%	2.11–25.53%	
Specificity (CI)	91.35%	89.36–93.07%	

CI confidence interval

*Pearson's chi-squared test was used. Descriptive statistics are presented as number (%)

P values marked in bold are considered to indicate statistical significance ($p < 0.05$)

Discussion

Of the patients included in the present study, the PECARN rules were applied to 1,004 patients, and the CATCH and CHALICE rules were applied to 966 patients. The study

Table 4 Comparison of age, gender, and several clinical characteristics according to CT results

	CT result		
	Negative ($n = 975$)	Positive ($n = 29$)	p value
Age			
< 2	270 (27.7%)	20 (69.0%)	**< 0.001****
2–14	668 (68.5%)	8 (27.6%)	
15–18	37 (3.8%)	1 (3.4%)	
Gender			
Male	638 (65.4%)	19 (65.5%)	0.999*
Female	337 (34.6%)	10 (34.5%)	
GCS score			
13	1 (0.1%)	1 (3.4%)	0.059**
14	3 (0.3%)	0 (0.0%)	
15	971 (99.6%)	28 (96.6%)	
Scalp hematoma			
Absent	543 (55.7%)	3 (10.3%)	**< 0.001****
Frontal	229 (23.5%)	1 (3.4%)	
Occipital	106 (10.9%)	6 (20.7%)	
Parietal	62 (6.4%)	11 (37.9%)	
Temporal	35 (3.6%)	8 (27.6%)	
Loss of consciousness, present	29 (3.0%)	2 (6.9%)	0.224***
Duration of the loss of consciousness			
5 s–5 min	1 (3.4%)	1 (50.0%)	0.127***
More than 5 min	28 (96.6%)	1 (50.0%)	
Amnesia, present	13 (1.3%)	1 (3.4%)	0.338***
Duration of amnesia			
Less than 5 min	8 (61.5%)	1 (100.0%)	0.999***
More than 5 min	5 (38.5%)	0 (0.0%)	
Abnormal behavior per parents, present	26 (2.7%)	4 (13.8%)	**0.009*****
Vomiting after trauma, present	77 (7.9%)	6 (20.7%)	**0.027***
Number of vomits if present			
Less than 3	65 (84.4%)	6 (100.0%)	0.586***
3 or greater	12 (15.6%)	0 (0.0%)	
History of seizure after trauma, present	1 (0.1%)	0 (0.0%)	0.999***
Headache, present	103 (10.6%)	6 (20.7%)	0.119*
Irritability, present	4 (0.4%)	3 (10.3%)	**0.001*****
Neurological deficit, present	1 (0.1%)	1 (3.4%)	0.057***

*Pearson's chi-squared test was used

**Fisher–Freeman–Halton test was used

***Fisher's exact test was used. Descriptive statistics are presented as number (%)

P values marked in bold are considered to indicate statistical significance ($p < 0.05$)

found that the PECARN and CATCH rules significantly predicted CT positivity and the need for hospitalization while the CHALICE rules did not significantly predict CT positivity and the need for hospitalization.

The studies about the PECARN criteria, the sensitivity of predicted CT positivity was found to be between 72.4 and 100%, and the specificity was between 52 and 70% [6–10]. In our study, the PECARN criteria predicted a positive result in 560 out of 1,004 patients to whom the criteria were applied. Similar to the literature, the PECARN performed significantly well in detecting a pathological finding in CT scans ($p = 0.005$). The PECARN criteria yielded a sensitivity of 82.76% and a specificity of 45.03%. The PECARN criteria were also successful in determining the need for hospitalization ($p = 0.003$), yielding a sensitivity of 83.87% and a specificity of 45.12%.

A study by Osmond et al. calculated a sensitivity of 98.1% and a specificity of 50.1% for the CATCH criteria

Table 5 The examination of factors affecting CT positivity using univariate and multivariate logistic regression analyses

	Univariate LR		Multivariate LR		Multivariate LR	
	Model		Model 1		Model 2	
	OR [95% CI]	*P* value	OR [95% CI]	*P* value	OR [95% CI]	*P* value
Age, reference: < 2						
2–14	0.16 [0.07–0.37]	**< 0.001**	0.17 [0.07–0.38]	< 0.001	0.12 [0.05–0.29]	**< 0.001**
15–18	0.36 [0.05–2.80]	0.332	0.45 [0.06–3.51]	0.448	0.33 [0.04–2.85]	0.312
Abnormal behavior per parents: present vs absent	5.84 [1.90–17.99]	**0.002**	5.17 [1.47–18.17]	0.011	2.85 [0.66–12.31]	0.161
Vomiting after trauma: present vs absent	3.04 [1.20–7.70]	**0.019**	1.94 [0.69–5.4]	0.207	0.93 [0.29–3.00]	0.909
Scalp hematoma, reference: absent						
Frontal	0.79 [0.08–7.64]	0.839	–	–	0.79 [0.08–7.68]	0.839
Occipital	10.25 [2.52–41.61]	**0.001**	–	–	13.3 [3.17–55.86]	**< 0.001**
Parietal	32.11 [8.72–118.23]	**< 0.001**	–	–	30.57 [7.96–117.41]	**< 0.001**
Temporal	41.37 [10.51–162.85]	**< 0.001**	–	–	61.07 [13.94–267.63]	**< 0.001**

LR logistic regression, *OR* odds ratio, *CI* confidence interval

Dependent variable: CT positivity

P values marked in bold are considered to indicate statistical significance

[11]. The study by Bozan et al. calculated a sensitivity of 48% and a specificity of 83% for the CATCH criteria [9].

In the present study, the CATCH criteria predicted a positive result in 518 out of 966 patients to whom the criteria were applied. The CATCH criteria anticipated the presence of a pathology in head CT scans ($p < 0.001$). The CATCH criteria yielded a sensitivity of 89.29% and a specificity of 47.44%, as well as performing significantly well in predicting the need for hospitalization ($p < 0.001$). In this regard, the CATCH criteria yielded a sensitivity of 90.00% and a specificity of 47.54%.

The study by Dunning et al. reported a sensitivity of 98% and a specificity of 87% for the CHALICE criteria [12]. In a study by Crowe et al., CHALICE criteria were found to have increased the number of unnecessary CT scans. Although these criteria provided a small gain in picking up additional cases with abnormal CT appearances, the authors reported that such usage resulted in unneeded CT scans in their clinical practice leading to unnecessary exposure to radiation and sedation. The same study emphasized that the CHALICE criteria were valuable, but the value of expectant observation and the role of an experienced clinician must also be defined [13].

In our study, the CHALICE predicted a positive result in 84 out of 966 patients. CHALICE criteria did not significantly predict the presence of a pathology in CT scans ($p = 0.999$) and yielded a sensitivity of 7.14% and a specificity of 91.26%. Likewise, the CHALICE criteria did not significantly predict the need for hospitalization ($p = 0.740$). The number of patients found positive according to the CHALICE criteria was less than the other decision rules. This situation may be due to the fact that seizures, focal neurological deficits and amnesia etc., which are among the CHALICE criteria, are not included in the other rules and these criteria were seen less than the criteria included in the other decision rules. On the other hand, tense fontanelle and skin lacerations larger than 5 cm were detected more than the other CHALICE criteria but these criteria were not found to be significant in detecting the positivity of CT. All these reasons may be cause of statistically insignificant of CHALICE decision rules. In other studies, although it was not statistically insignificant, but it has been reported that CHALICE had the lowest sensitivity [5, 8].

When the factors affecting positive CT results in the present study were evaluated using univariate and multivariate logistic regression analyses, abnormal behavior in a child per parent, vomiting after trauma, and the presence of non-frontal scalp hematoma significantly predicted CT positivity in patients aged 2–14 years compared to patients under 2 years of age in univariate logistic regression analysis ($p < 0.05$ for each). In multivariate logistic regression analysis, abnormal behavior in a child per parent and the presence of non-frontal scalp hematoma predicted CT positivity in patients aged 2–14 years compared to patients under 2 years of age. Similar to the present study, the study by Burns et al. found the presence of scalp hematoma, particularly non-frontal scalp hematoma, to be associated with brain injury [14].

Some existed studies have reported that the use of the PECARN criteria does not reduce the number of CT scans or medical costs in centers with limited use of head CT in patients with head trauma, while other studies have reported that the use of the PECARN criteria substantially reduced the use of CT scans in healthcare facilities with a high volume of CT use [15, 16]. However, a study by Dalziel et al. comparing the cost-effectiveness of the PECARN, CATCH, and CHALICE criteria in their clinic reported a higher cost-effectiveness for the usual approach [17]. In the present study, when these three clinical decision rules were applied to the patients for whom the decision of CT scans had been made by a physician, the use of the PECARN and CATCH was considered to reduce the number of patients undergoing head CT, and thus reduce the costs. In addition, the PECARN and CATCH criteria are considered to predict the need for hospitalization.

Limitations

The single-center study design is the most important limitation of the present study. The clinical approach may vary across various centers. Another limitation in the study design is the inclusion of patients for whom the decision to perform CT scans was made by a physician. Therefore, the clinical decision of the physician could not be compared to the clinical decision rules. The authors consider that studies comparing clinical approaches of clinicians in a multicenter study setting together with clinical decision rules would provide more reliable data.

Conclusion

The present study found that the PECARN and CATCH criteria significantly predicted CT positivity and the need for hospitalization in children with minor head injuries. Among the PECARN criteria, abnormal behavior in a child per parent and the presence of non-frontal scalp hematoma significantly predicted CT positivity in the 2–14 years age group compared to patients under 2 years of age. The authors consider that the use of the PECARN and CATCH criteria safely reduced the number of unnecessary CT scans.

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Author contributions The authors confirm contribution to the paper as follows: study conception and design: TA, GMA; literature search: SEA, GMA; data collection: GMA; analysis and interpretation of results: GMA, SEA; draft manuscript preparation: TA; writing: GMA; critical revision; TA. All authors reviewed the results and approved the final version of the manuscript.

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Availability of data and material The datasets generated analyzed during the current study are not publicly available but are available from the corresponding author.

Code availability Not applicable.

Declarations

Conflict of interest Authors state that there is no conflict of interest.

Ethical approval Approval was obtained from the ethics committee of Prof. Dr. Cemil Tascioglu Training and Research Hospital (48670771–514.10). The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Consent to participate Written informed consent was obtained from the parents or legal guardians.

Consent for publication Not applicable.

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