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Prediction of Clinically Important Traumatic Brain Injury in Pediatric Minor Head Trauma; proposing Pediatric Traumatic Brain Injury (PTBI) Prognostic Rule

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Abstract

Background: The present study assesses independent predictors of clinically important traumatic brain injury (ciTBI) in order to design a prognostic rule for identification of high risk children with mild head injury. ***Materials and Methods:*** In a retrospective cross-sectional study, 3,199 children with mild traumatic brain injury (TBI) brought to emergency ward of three hospitals in Tehran, Iran were gathered, from April 2014 to April 2016. The associations between probable predictors of ciTBI in children with mild TBI were assessed and a prediction rule for identification of high risk children in need of computed tomography (CT) scan was designed based on a stepwise multivariate logistic regression. ***Results:*** 592 (18.5%) children had ciTBI. History of loss of conciseness (odds ratio [OR]=3.0; p<0.0001), underlying disease (OR=3.6; p=0.002), Glasgow coma scale (GCS) score equal to 14 (OR=40.6; p<0.0001), altered mental status (OR=19.1; p<0.0001), need for intubation (OR=27.4; p<0.0001), presence of vomiting (OR=7.3; p=0.001), and sign of basilar skull fracture (OR=25.9; p=0.007), were the most important prognostic factors of ciTBI in children. Pediatric traumatic brain injury prognostic rule (PTBI prognostic rule) was designed based on these predictors. PTBI prognostic rule had an area under the curve of 0.93, a sensitivity of 100.0%, a specificity of 73.0% and a proper calibration (slope=0.97 and intercept=0.006) in identification of ciTBI. ***Conclusion:*** The present study showed that a few of children with mild TBI have ciTBI. Therefore, CT scans are not necessary in all of these children. Using PTBI prognostic rule can reduce the number of unnecessary CT scans.

Key Words: Decision support systems, Emergency service, Sensitivity and Specificity, Pediatrics.

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1- INTRODUCTION

Identification of high risk children with mild traumatic brain injury (TBI), is one of the most important challenging tasks in emergency wards. Many physicians use different imaging modalities for children, especially computed tomography scans (CT scan) to avoid medical malpractice (1, 2). However, studies report a relatively low prevalence of clinically important traumatic brain injury (ciTBI) in children with mild TBI and this renders many previously done CT scans unnecessary (3-5). In addition, younger children do not usually cooperate in these imaging procedures. Therefore, sedation is needed in some situations although sedating a child with minimum side effects is a challenging task (6, 7). Due to these limitations, researchers are looking forward to reduce the number of unnecessary CT scans in emergency wards, especially in children.

Researchers believe in prognostic models as a tool for classification of children for many years. There are many different scoring systems in the field of traumatic brain injury with most of them being designed based on data gathered from developed countries (8, 9). Although their value is assessed in other studies, their validation studies are conducted in similar societies (3, 10, 11). These models may lack an appropriate value in developing countries as the mechanism of trauma and management are different in children with mild TBI between developing and developed countries (12, 13). It is an important issue the incidence of traumatic brain injury in children is much more common in developing countries and therefore designation of a model based on data of children from these countries seems necessary. However, there are no studies focusing on this population. The present study aimed to design a prognostic rule for identification of high risk children with mild TBI based on independent predictors of ciTBI.

2- MATERIALS AND METHODS

2-1. Study design and setting

In a retrospective cross sectional study, data of children with mild TBI brought to emergency ward of three educational hospitals in Tehran, Iran were assessed, from April 2014 to April 2016. Data was gathered by a researcher familiar with assessing medical data. Before beginning the study, a pilot study (50 cases), was performed after a two-hour educational class about data gathering and checklist filling in order to control the accuracy of data gathering. In addition, some data were chosen randomly for assessment at the end of every week to assure the accuracy of data gathering. The study protocol was approved by the ethics committee of Tehran University of Medical Sciences and during the study period, all researchers adhered to the principles of the Helsinki declaration.

2-2. Patients

All data from children with mild TBI who had a consciousness level of 14 or 15 based on Glasgow coma scale (GCS), were entered in the present study. Incomplete file data, referring to the hospital after 24 hours from the accident were considered exclusion criteria. In this study data from all files were assessed.

2-3. Data gathering

Probable predictors of ciTBI in children with mild TBI were identified by a literature review. These variables included age, gender, mechanism of trauma, underlying disease (diabetes, hypertension, asthma, seizure and epilepsy), GCS, injury in other organs, history of loss of conciseness between injury and hospital admission, need for intubation, presence of nausea and vomiting, altered mental status, sign of basilar skull fracture (retro-auricular bruising, periorbital bruising, hemotympanum, cerebrospinal fluid otorrhea, cerebral spinal fluid rhinorrhea) and scalp hematomas. The ciTBI was defined as death, TBI related hospitalization (more than two nights) and need for neurosurgery. As CT scans were not done for all patients (due to ethical concerns), individuals without CT scan were followed by phone for two weeks after discharge.

2-4. Ethical approval

The study protocol was approved by the ethics committee of Tehran University of Medical Sciences. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

2-5. Statistical analysis

Sample size was calculated with the help of Hajian-Tilaki's suggested method (14). Based on table.1 in the mentioned study, a sample size of 1,825 patients was calculated considering a sensitivity of 95%, a ciTBI prevalence of 5% (15), a confidence interval of 95% and a marginal error of 0.01. At the end, data of 3,199 children were assessed.

Data were analyzed by STATA statistical program version 11.0. Quantitative and qualitative data were present and mean ± standard deviation (SD) and frequency (%), respectively. In the first step, the association between ciTBI and probable predictors were assessed using a Chi-squared test. In the next step, independent predictors of ciTBI were identified using a stepwise multivariate logistic regression, reporting odds ratio (OR), and regression coefficients with 95% confidence interval (95% CI). At the end, all independent predictors were given a weight based on their regression coefficients and a prediction rule was designed for identification of high risk children in need of a CT scan. Finally, area under the receiver operating characteristics (ROC) curve (AUC), calibration of the model, sensitivity, specificity, positive predictive value, negative predictive value, positive and negative likelihood ratio of this model were assessed.

3- RESULTS

During the study period, 4,051 children between the ages of 1 to 18 years old with mild TBI were brought to the studied emergency wards. Among them 218 (5.4%) children were discharged against medical advice and files of 268 (6.6%) had missing data. Additionally, 366 (9.0%) children were lost to follow up. Therefore, data of 3,199 (79.0%) children were entered in the present study (**Figure.1**).

Children under study had an average age of 9.3±5.1 years and 2,582 (80.8%) of children were boys. The most common mechanisms of trauma were accident of two motorcycles (41.9%), and accident between pedestrian and motor vehicles (35.4%). A CT scan was performed for 2,248 (70.3%) children of which 619 (19.3%) had positive findings. The most common findings were skull fracture (24.9%) and epidural hematoma (16.0%). In addition, 592 (18.5%) cases of ciTBI were identified and 96 (3.0%) children died at the end. The association (based on univariate analysis) between ciTBI and demographic and basal characteristics of children is reported in **Table.1**.

History of loss of conciseness (OR=3.0; p<0.0001), underlying disease (OR=3.6; p=0.002), GCS score equal to 14 (OR=40.6; p<0.0001), altered mental status (OR=19.1; p<0.0001), need for intubation (OR=27.4; p<0.0001), presence of vomiting (OR=7.3; p=0.001) and sign of basilar skull fracture (OR=25.9; p=0.007) were the most important prognostic factors of the presence of ciTBI in children based on a multivariate logistic regression analysis (**Table.2**). In the next step, a scoring system was designed for identification of patients in need of CT scan. Therefore, a weight was given to each variable based on its regression coefficient in prediction of the presence of ciTBI and finally pediatric traumatic brain injury prognostic rule (PTBI prognostic rule) was designed. Prognostic factors in this model are history of loss of conciseness, presence of underlying disease; GCS score equal to 14, altered mental status, need for intubation, the presence of vomiting and sign of basilar skull fracture. PTBI prognostic rule had an area under the curve of 0.93 (95% CI: 0.92 to 0.94) and had a proper calibration in prediction of TBI in children (slope=0.97 and intercept=0.006). Brier score and scaled reliability of PTBI were 0.08 and 0.004, respectively (**Figure.2**).

Table.3 shows the discrimination performance of PTBI prognostic rule in prediction of ciTBI. This model had a sensitivity and specificity of 100% and 73.0%, respectively considering the presence of at least one prognostic factor in children. A decision tree for identification of children with mild TBI who need a CT scan is proposed based on PTBI. Therefore a CT scan is ought to be done if any of the predictors included in PTBI prognostic rule is present (**Figure. 3**).

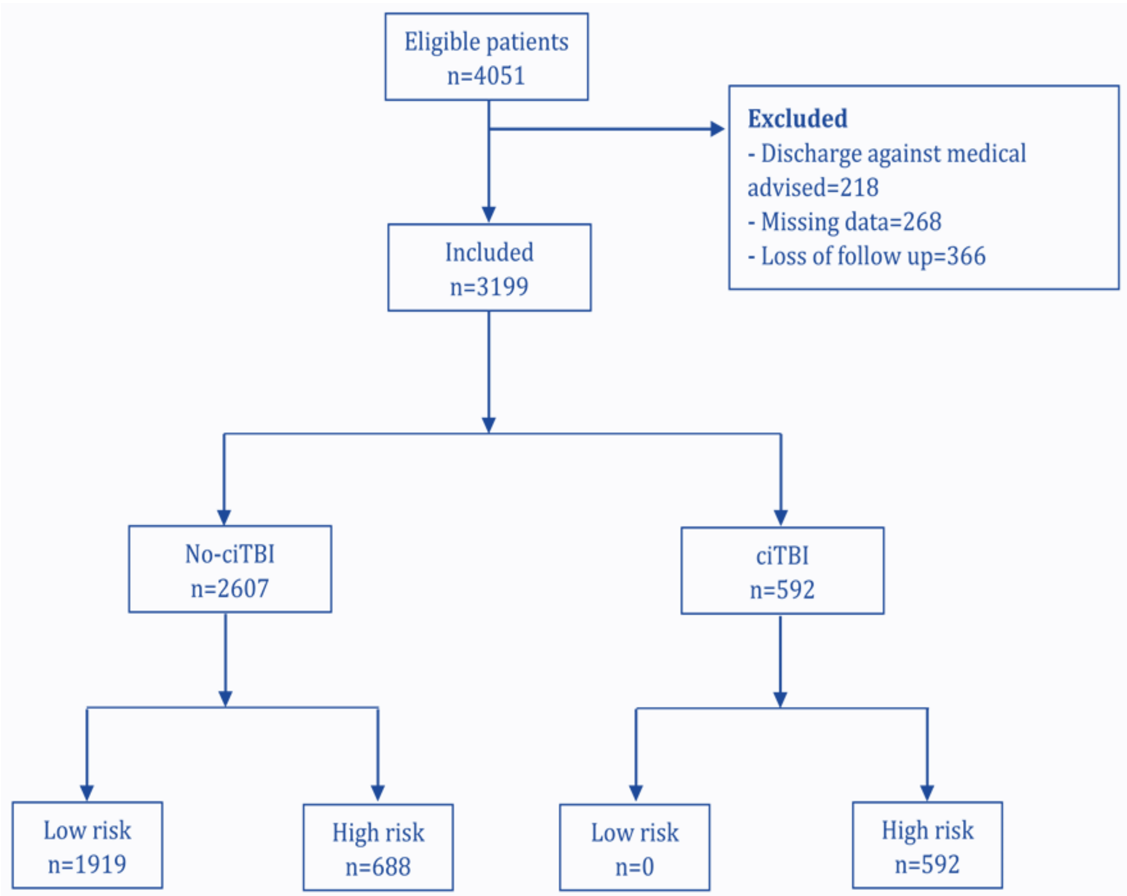

Fig.1: Flowchart of included patients. ciTBI: Clinically important traumatic brain injury

Table-1: Association of baseline and clinical characteristics and TBI related mortality

Variables	No-ciTBI (n=3103)	ciTBI (n=96)	Total (n=3199)	P-value
Age (year)				
1-3	385 (14.8)	85 (14.4)	470 (14.7)	0.32
4-6	556 (21.3)	147 (24.8)	703 (22.0)	
7-11	696 (26.7)	148 (25.0)	844 (26.4)	
12-18	970 (37.2)	212 (35.8)	1182 (36.9)	
Gender				
Boy	2106 (80.8)	478 (80.7)	2584 (80.8)	0.98
Girl	501 (19.2)	114 (19.3)	615 (19.2)	
Mechanism of Injury				
Pedestrian vs. motor vehicle	916 (35.1)	216 (36.5)	1132 (35.4)	0.54
Bicycle vs. motor vehicle	305 (11.7)	67 (11.3)	372 (11.6)	
Car vs. car accident	105 (4.0)	32 (5.4)	137 (4.3)	
Motorcycle vs. motor vehicle	1102 (42.3)	239 (40.4)	1341 (41.9)	
Car rollover	74 (2.8)	11 (1.9)	85 (2.7)	
Fall ≥ 1 meter	17 (0.7)	5 (0.8)	22 (0.7)	
Fall < 1 meter	88 (3.4)	22 (3.7)	110 (3.4)	
Underlying disease[1]				
No	2288 (87.8)	475 (80.2)	2763 (86.4)	<0.0001
Yes	319 (12.2)	117 (19.8)	436 (13.6)	
Glasgow coma scale				
14	281 (10.8)	395 (66.7)	676 (21.1)	<0.0001
15	2326 (89.2)	197 (32.3)	2523 (78.9)	
Injury in other organ				
Face	30 (1.2)	6 (1.0)	36 (1.1)	0.78
Neck	15 (0.6)	87 (14.7)	102 (3.2)	<0.0001
Abdomen	123 (4.7)	20 (3.4)	143 (4.5)	0.15
Spine	168 (6.4)	27 (4.6)	195 (6.1)	0.42
Pelvic	100 (3.8)	21 (3.6)	121 (3.8)	0.74
Upper limb	504 (19.3)	105 (17.7)	609 (19.0)	0.37
Lower limb	1215 (46.6)	136 (23.0)	1351 (42.2)	<0.0001
Loss of conciseness				
No	2561 (98.2)	485 (81.9)	3046 (95.2)	<0.0001
Yes	46 (1.8)	107 (18.1)	153 (4.8)	
Altered mental status				
No	2507 (96.2)	446 (75.3)	2953 (92.3)	<0.0001
Yes	100 (3.8)	146 (24.7)	246 (8.0)	
Need to intubation				
No	2571 (98.6)	421 (71.1)	2992 (93.5)	<0.0001
Yes	36 (1.4)	171 (6.5)	207 (6.5)	
Nausea or vomiting				
No	2597 (99.6)	540 (91.2)	3137 (98.1)	<0.0001
Yes	10 (0.4)	52 (8.8)	62 (1.9)	
Sign of basilar skull fracture[2]				
No	2605 (99.9)	579 (97.8)	3184 (99.5)	<0.0001
Yes	2 (0.1)	13 (2.5)	15 (0.5)	
Scalp hematoma				
No	2597 (99.6)	584 (98.7)	3181 (99.4)	0.004
Yes	10 (0.4)	8 (1.3)	18 (0.6)	
Need to neurosurgery				
No	2599 (99.7)	592 (100.0)	3191 (99.8)	0.18
Yes	8 (0.3)	0 (0.0)	8 (0.2)	
TBI related hospitalization				
No	2596 (99.6)	561 (94.8)	3157 (98.7)	<0.0001
Yes	11 (0.4)	31 (5.2)	42 (1.3)	

[1], Including diabetes; hypertension; asthma, seizure and epilepsy; [2], Retro-auricular bruising, periorbital bruising, hemotympanum, cerebral spinal fluid otorrhoea, cerebral spinal fluid rhinorrhoea. TBI: Traumatic brain injury.

Table-2: Independent predictive factors of clinically important traumatic brain injury (ciTBI) in head injured children

Variables	Coefficient	Odds ratio	95% CI	P-value[4]	Weight[5]
History of loss of conciseness[1]	1.1	3.0	1.7 to 5.3	<0.0001	1
Underlying disease[2]	1.3	3.6	2.4 to 5.1	0.002	1
GCS score equal to 14	3.7	40.6	29.7 to 55.6	<0.0001	4
Altered mental status	3.0	19.1	12.0 to 30.4	<0.0001	3
Need to intubation	3.3	27.4	16.3 to 46.1	<0.0001	3
Presence of vomiting	2.0	7.3	2.4 to 22.9	0.001	2
Sign of basilar skull fracture[3]	3.2	25.9	2.5 to 272.5	0.007	3

[1], Including diabetes; hypertension; asthma, seizure and epilepsy; [2], Including retro-auricular bruising, periorbital bruising, hemotympanum, cerebral spinal fluid otorrhoea, cerebral spinal fluid rhinorrhoea; [4], Based on stepwise multivariate logistic regression; [5], Weight of each variable in pediatric traumatic brain injury prognostic rule. CI: Confidence interval; GCS: Glasgow coma scale.

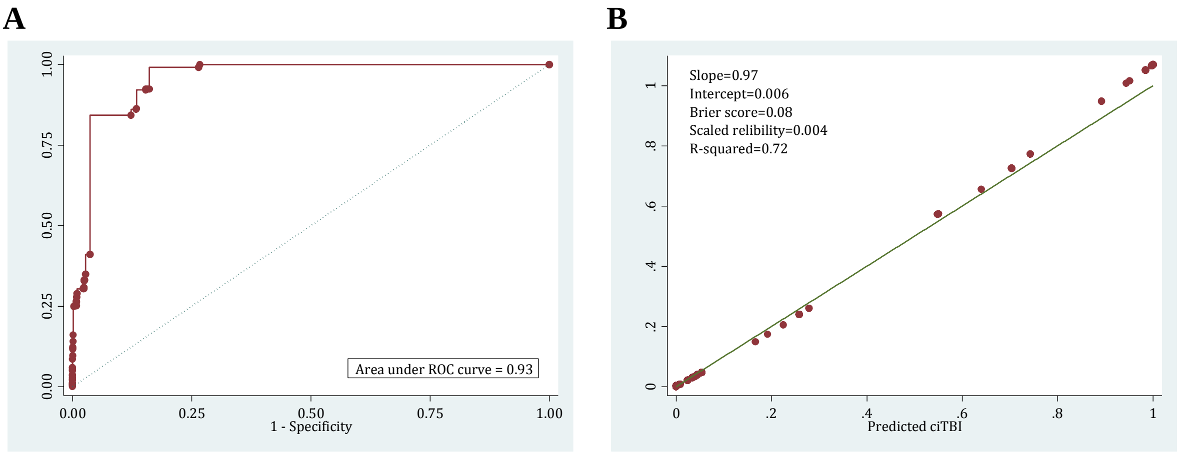

Fig.2: Area under the receiver operating characteristics (ROC) curve (A) and calibration plot (B) of pediatric traumatic brain injury (PTBI) prognostic rule in prediction of clinically important traumatic brain injury (ciTBI).

Table-3: Performance of pediatric traumatic brain injury prognostic rule in prediction of clinically important traumatic brain injury

Performance	Value (95% CI)
True positive	592
True negative	1919
False positive	688
False negative	0
Sensitivity	100.0 (99.2 to 100.0)
Specificity	73.6 (71.9 to 75.3)
Positive predictive value	46.2 (43.5 to 49.0)
Negative predictive value	100.0 (99.8 to 100.0)
Positive likelihood ratio	3.8 (3.6 to 4.0)
Negative likelihood ratio	0.0 (0.0 to 0.0)

CI: Confidence interval.

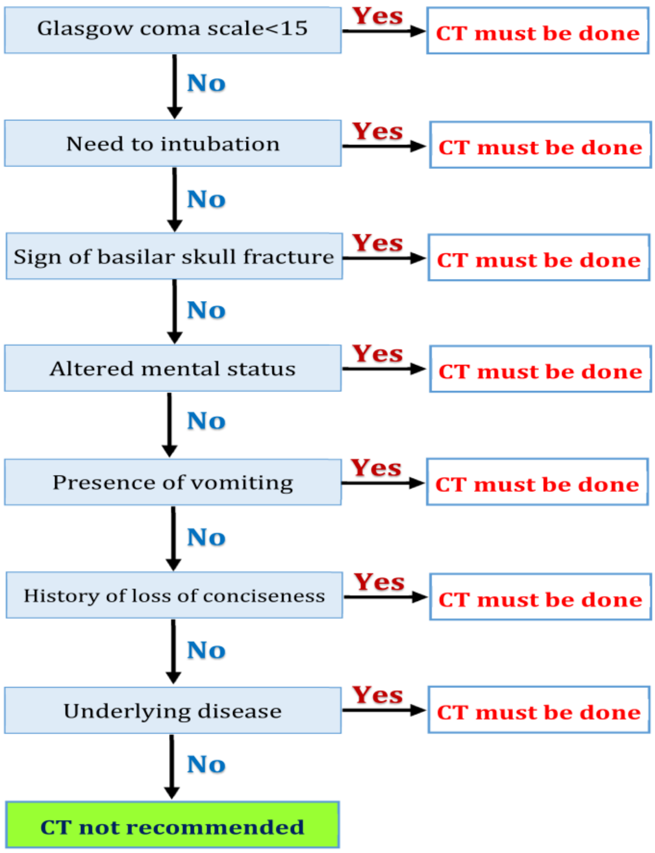

Fig.3: Decision tree of choosing the minor head injury children to perform computed tomography (CT) scan based on pediatric traumatic brain injury prognostic rule (PTBI). Underlying disease: Including diabetes; hypertension; asthma, seizure and epilepsy. Sign of basilar skull fracture: Including retro-auricular bruising, periorbital bruising, hemotympanum, cerebral spinal fluid otorrhoea, and cerebral spinal fluid rhinorrhoea. CT: computed tomography scan.

4- DISCUSSION

In the present study, PTBI prognostic rule is designed by identifying predictors of ciTBI in children with mild TBI. This rule which is a decision tree for identifying high risk children who need a CT scan, had a sensitivity of 100% and it may be used as a screening tool in clinics.

Pediatric Emergency Care Applied Research Network (PECARN) prediction rules is one of the proposed scoring systems for identification of high risk children (4, 16). Although, the validity of this model is assessed in modern countries and had an appropriate value in almost all studies (3, 4, 10, 15, 16), its validity has not been studied in developing countries where the mechanism of trauma is different. In the present study, the association between mechanism of trauma and scalp hematoma (two predictors presenting in PECARN rule), and ciTBI were not significant. On the contrary, the presence of an underlying disease such as diabetes, hypertension, asthma, seizure and epilepsy was associated with an increase in the risk of ciTBI. Therefore, some modifications were made and PTBI was then proposed for Iranian children. This rule had a sensitivity of 100% in prediction of ciTBI. Calibration of PTBI prognostic rule in the studied patient was proper. However, it seems that this model underestimates the risk of ciTBI in high risk patients. Achieving a model with ideal calibration is very difficult and almost all scoring systems either overestimate or underestimate the risk prediction (3, 10, 11, 17, 18). But as brier score and scaled reliability of PTBI were in a proper level it can be said that PTBI has an appropriate overall performance. In the hospitals included in the study, a CT scan was performed for 70.3% of children and 19.3% of children had positive findings. These amounts are much larger from amounts reported in other studies. For example, in the study by Atabaki et al., a CT scan was performed for 33.6% of individuals, but only 6.3% had TBI (15). Additionally, in the study by Schonfeld et al., a CT scan was performed for 15% of children of which 18% of them had positive findings (4). It seems that emergency medicine physicians in the studied health care centers prefer to do a CT scan for most children in order to avoid medical malpractice. Although, it can reduce medical malpractice, however, high cost of a CT scan, increased risk of cancer with exposure and its challenges in children under 2 years leads to an increase in the burden of unnecessary CT scans (19, 20). The present study shows that PTBI rule can identify high risk children and avoids 73.6% of unnecessary CT cans.

4-1. Limitations of the study

One of the most important limitations of this study was its retrospective quality. A retrospective design is always accompanied by a lower precision in data gathering. Exclusion of 6.6% of files due to incomplete filing was one of the limitations. In order to assess the effect of exclusion of these files from the study, a missing analysis was performed. The analysis showed that demographic and baseline characteristics of included and excluded files were not different (P>0.05). Therefore, it seems that exclusion of these data from the study have not influenced the results. At the end, it should be noted that selection bias is unavoidable in observational studies.

5- CONCLUSION

The present study showed that a few percent of children with mild TBI will have clinically important traumatic brain injury at the end and a CT scan is not necessary for all children. We designed PTBI prognostic rule to identify high risk children with mild TBI. According to this model, if none of PTBI predictors are present a CT scan is not advised.

6- INFORMED CONSENT

Informed consent was obtained from all individual participants included in the study.

7- CONFLICT OF INTEREST

Babak Nakhjavan-Shahraki, Mahmoud Yousefifard, Mohammad Javad Hajighanbari, Alireza Oraii, Saeed Safari and Mostafa Hosseini declare that they have no conflict of interest.

8- ACKNOWLEDGEMENT

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