Clinical judgment versus PECARN in detecting the need for computed tomography scan in minor pediatric head trauma

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Background and objective
Head trauma occurs commonly in childhood. Most head trauma in children is minor and not associated with brain injury or long-term sequelae. However, a small number of children who appear to be at low risk may have a clinically important traumatic brain injury.
The objective of this study was to detect the overuse of computed tomography (CT) scan, based on comparing personal clinical judgment of emergency physician to PECARN tool after minor blunt head injury among pediatric patients in the Emergency Department.
Patients and methods
In this prospective observational study, 50 pediatric patients aged from 2 to 18 years old with minor blunt head trauma at the Emergency Department were enrolled. All patients were investigated using CT.
Results
Clinical judgment alone was associated with an increase in using CT scan in all enrolled patients compared with using a clinical decision tool like 'PECARN.'
Conclusion
CT scan for evaluation of minor blunt head trauma in children is currently overused, thus exposing children to unnecessary radiations.

Keywords:
clinically important traumatic brain injury, Glasgow Coma Score, head computed tomography scan, head trauma in children, nonclinically important traumatic brain injury, PECARN rule

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Introduction

Traumatic brain injury (TBI) is the leading cause of death and disability in children more than 1-year old [1].

Children have their unique challenges [2]:

(1) Anatomical:
   (a) Larger and heavier head in proportion to total body mass.
   (b) Presence of fontanels.
   (c) More pliable cranium, so more parenchymal injury without skull fractures.
   (d) Less myelinated brain with higher water contents.
(2) Logistical:
   (a) Had higher possibility for second-chance radiation.
   (b) Long-term consequences of radiations.
   (c) Technical difficulties due to patient's size and cooperativity.

The clinical challenge for evaluating minor head trauma in pediatric patients is to identify those infants and children with clinically important traumatic brain injury (ciTBI) while limiting unnecessary radiographic imaging and radiation exposure. Neuroimaging, usually with computed tomography (CT), is highly sensitive for identifying brain injury requiring acute intervention. Meanwhile, individual clinical predictors for ciTBI are often nonspecific, particularly in young children. Thus, evaluation for high-risk findings and the use of a clinical decision rule like the 'PECARN' tool can provide a balanced approach that identifies almost all infants and children with ciTBI after minor head trauma without overuse of CT [3,4].

Most infants and children with minor head trauma can be safely discharged home after careful evaluation without undergoing imaging. If neuroimaging is performed, those patients with normal clinical findings and imaging may also be discharged home [5].

Patients and methods

After approval of the medical ethics committee of Alexandria Faculty of Medicine, an informed consent was taken from the patient's next of kin.

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This study was carried out on 50 pediatric patients (n=50) who were admitted to the Emergency Department (ED), Alexandria Main University Hospital, from November 1, 2016 to November 1, 2017 with isolated head trauma.

Inclusion criteria

(1) Age group between 2 and 18 years old.
(2) Closed TBI.
(3) Mild TBI [Glasgow Coma Scale (GCS) between 14 and 15].
(4) Presentation within 24 h after injury.

Exclusion criteria

(1) Polytrauma.
(2) Penetrating TBI.
(3) Cerebrospinal fluid leakage or significant facial trauma.
(4) Previous neurosurgery intervention.

Study design

Prospective observational study.

All enrolled patients (n=50) were subjected directly to the following:

(1) Data collection and initial assessment:
  (a) Complete history and demographic data taking, age, sex, mechanism of trauma, medical, drug, etc.
  (b) Complete physical examination, temperature, blood pressure, heart rate, respiratory rate, and chest auscultation.
  (c) Primary survey: airway, breathing, circulation, disability, and exposure.
  (d) Secondary survey:
    (1) Full examination of the whole body.
    (2) GCS modified for pediatric patients [6].
    (3) Neurologic function assessment.
(4) Clinical judgment:
  (a) All patients were clinically assessed by the attending treating physician in ED to determine the need for CT. This decision was considered as a personal clinical judgment.
(5) Decision rule (PECARN):
  (a) Pediatric Emergency Care Applied Research Network (PECARN) rule was applied to determine the need for CT according to the following criteria [4,7].
  (b) Children more than or equal to 2 years old have low likelihood of ciTBI if all of:
    (1) Normal mental status.
    (2) No loss of consciousness.
    (3) No vomiting.
    (4) Nonsevere mechanism of injury.
    (5) No signs of basilar skull fracture (such as hemotympanum, raccoon eyes, battle sign, and cerebrospinal fluid otorhinorrhea).
    (6) No severe headache.
  (c) For children not meeting criteria:
    (1) Base decision to order CT on clinical judgment.
    (2) Having altered mental status or clinical findings of skull fracture carries the greatest risk of ciTBI.
  (d) Severe mechanism of injury defined as any of:
    (1) Motor vehicle crash involving ejection of patient, death of another passenger, or rollover.
    (2) Pedestrian or bicyclist without a helmet struck by motor vehicle.
    (3) Fall more than 0.9 m (3 feet) in children less than 2 years old, or more than 1.5 m (5 feet) in children more than or equal to 2 years' old.
    (4) Head struck by high-impact object.
(5) Radiological investigations:
  (a) Regardless both decisions (clinical judgment and PECARN rule), all patients were radiologically investigated using CT. Then, interpretations were confirmed with the attending neurosurgeon.
(6) Follow-up:
  (a) All enrolled patients were followed up during their stay until referral to another department or discharge.
(7) Measuring outcomes:
  (a) The measured outcome was the presence of ciTBI according to CT findings.

Statistical analysis of the data [8]

Data were fed to the computer and analyzed using IBM SPSS software package, version 20.0 (Armonk, NY: IBM Corp.) [9]. Qualitative data were described using number and percent. Quantitative data were described using range (minimum and maximum), mean, SD, and median. Significance of the obtained results was judged at the 5% level.

The used tests were:

(1) χ^2 test:

For categorical variables, to compare between different groups.

(2) Fisher's exact or Monte Carlo correction:
Correction for χ^2 when more than 20% of the cells have expected count less than 5.

(3) Student t test:
For normally quantitative variables, to compare between two studied groups.

(4) Receiver-operating characteristic curve (ROC):
It is generated by plotting sensitivity (TP) on Y axis versus 1-specificity (FP) on X axis at different cutoff values. The area under the ROC curve denotes the diagnostic performance of the test. Area more than 50% gives acceptable performance and area about 100% is the best performance for the test. The ROC curve allows also a comparison of performance between two tests.

Results

(1) Demographics:
  (a) The mean age of all enrolled patients was 10.6 years.
  (b) The number of males (33/50, 66%) was higher than the number of females (17/50, 34%).
  (c) There were no statistically significant differences between the two studied groups in their age (P=0.390) or sex (P=0.757).

(2) Identification of ciTBI versus nonclinically important traumatic brain injury (nciTBI) according to CT scan findings:
  (a) CT scan was unremarkable in 34 (68%) patients, these patients constituted the nciTBI.
  (b) CT scan was positive in 16 (32%) patients, these patients were nominated as ciTBI group; where 4% had brain edema, 4% had mixed findings, 8% had skull fractures, and 16% had hemorrhages and contusions.

(3) Mechanism of trauma
In total, 19 (38%) out of 50 patients were presented after heavy-object trauma, while only 34% were presented due to falling. In total, 14 (28%) patients were presented with alleged assault.
There was not a statistically significant difference between the ciTBI group and the nciTBI group regarding the mechanism of trauma (P=0.604).

(4) Clinical suspicion.

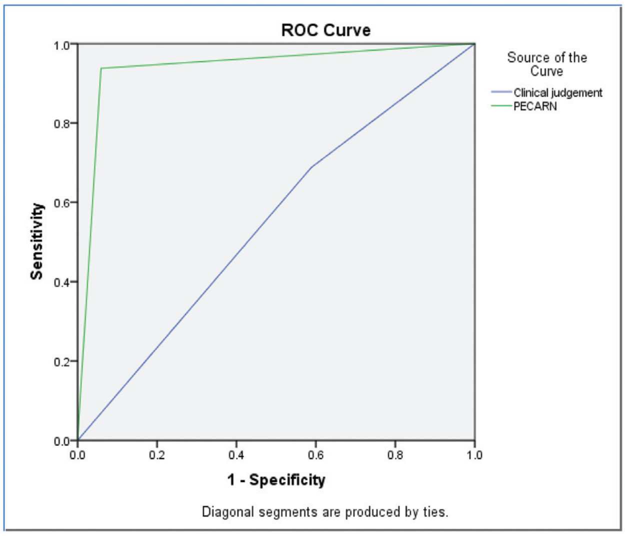
(5) Signs and symptoms.

(6) GCS:
  (a) About 74% of patients were presented with a GCS of 15, while only 26% of them were presented with a GCS of 14.
  (b) ciTBI group was presented with a statistically significant lower GCS than nciTBI group (P=0.002), where 56.25% of ciTBI group had GCS less than or equal to 14, in comparison with 11.76% in the nciTBI.

(7) Methods of prediction:

Figure 1 and Tables 1–4.

Figure 1



Receiver-operating characteristic (ROC) curve.

Table 1 Comparison between the two groups according to clinical suspicion

	ciTBI (N=16) [n (%)]	nciTBI (N=34) [n (%)]	Test of significance	P
Suspected severe mechanism of trauma				
Yes	10 (62.5)	7 (20.58)	χ^2=8.517	0.009
No	6 (37.5)	27 (79.41)		
Suspected LOC +/− amnesia				
Yes	9 (56.25)	7 (20.58)	χ^2=6.359	0.021
No	7 (43.75)	27 (79.41)		
Suspected depressed fracture				
Yes	5 (31.25)	4 (11.76)	χ^2=2.799	0.124
No	11 (68.75)	30 (88.23)		

ciTBI, clinically important traumatic brain injury; LOC, loss of consciousness; nciTBI, nonclinically important traumatic brain injury. χ^2, P: χ^2 and P values for Fisher exact test for comparing between the two groups. P value is significant when less than or equal to 0.05.

Table 2 Comparison between the two groups according to the signs and symptoms

	ciTBI (*N*=16) [*n* (%)]	nciTBI (*N*=34) [*n* (%)]	Test of significance	*P*
Headache/irritability				
Yes	5 (31.25)	8 (23.52)	χ^2=0.337	0.731
No	11 (68.75)	26 (76.47)		
Vomiting				
Yes	6 (37.5)	8 (23.52)	χ^2=1.053	0.330
No	10 (62.5)	26 (76.47)		
Basilar skull fracture				
Yes	8 (50)	4 (11.76)	χ^2=8.720	0.010
No	8 (50)	30 (88.23)		
Cephalohematoma				
Yes	7 (43.75)	12 (35.29)	χ^2=0.330	0.756
No	9 (56.25)	22 (64.7)		
Convulsions				
Yes	2 (12.5)	2 (5.88)	χ^2=0.647	0.584
No	14 (87.5)	32 (94.11)		

ciTBI, clinically important traumatic brain injury; nciTBI, nonclinically important traumatic brain injury. χ^2, *P*: χ^2 and *P* values for Fisher exact test for comparing between the two groups. *P* value is significant when less than or equal to 0.05.

Table 3 Comparison between the two groups according to the results of the prediction methods

	ciTBI (*N*=16) [*n* (%)]	nciTBI (*N*=34) [*n* (%)]	Test of significance	*P*
Clinical judgment				
Need CT	11 (86.75)	20 (58.82)	χ^2=0.445	0.549
No need	5 (31.25)	14 (76.47)		
PECARN rule				
Need CT	15 (37.5)	2 (23.52)	χ^2=37.434	<0.0001
No need	1 (62.5)	32 (76.47)		

ciTBI, clinically important traumatic brain injury; CT, computed tomography; nciTBI, nonclinically important traumatic brain injury. χ^2, *P*: χ^2 and *P* values for Fisher exact test for comparing between the two groups. *P* value is significant when less than or equal to 0.05.

Table 4 Sensitivity and specificity for methods of prediction to rule out the need of computed tomography scan

Tool of assessment	AUC	*P* value	95% CI		Sensitivity	Specificity	PPV	NPV
			LL	UL				
Clinical judgment	0.550	0.574	0.379	0.720	86.8	73.7	35.5	41.2
PECARN rule	0.939*	<0.0001*	0.856	1.000	88.2	97.0	93.8	94.1

AUC, area under a curve; CI, confidence intervals; LL, lower limit; NPV, negative predictive value; UL, upper limit. *Statistically significant at *P* value less than or equal to 0.05.

Discussion

Head trauma occurs commonly in childhood. Most head trauma in children is minor and not associated with brain injury or long-term sequelae. However, a small number of children who appear to be at low risk may have a ciTBI [10].

On the other hand, in Egypt, head trauma in infants and children is significant, consequently, overuse of CT scan in children has a dual-negative impact on the medical service. In the short term, it is costly, especially in a low-income country, and in the long term, it exposes children to major health problems in their adulthood later on.

This study tried to detect the overuse of CT scans, based on personal clinical judgment of the emergency physician alone after minor blunt head injury (mild TBI) among pediatric patients in the ED. This was compared with the decision for neuroimaging after using a clinical decision tool like the 'PECARN' tool.

It was found that clinical judgment alone was associated with 30% increase in unnecessary CT scans in all studied patients. While PECARN tool was associated with only 2% increase.

After literature review, it was revealed that lots of debate are unsettled, whether patients should be initially evaluated with CT scan, or hospitalized and monitored for a defined time period in an attempt to decrease unnecessary CTs, are still unanswered inquiries.

Kobe *et al.* [11] studied the proportion of head CT scans done for children with mild head injury and the disposition of patients from casualty after the introduction of PECARN head CT rules compared with the period before. They enrolled 85 patients below 18 years with a median of age 5 years. The number of head CT scans ordered reduced (33–56%) without missing any ciTBI.

In contrast to these findings, Nakhjavan-Shahraki *et al.* [12] in a prospective cross-sectional study, 594 children (mean age: 7.9±5.3 years, 79.3% males) with mild TBI brought to ED of 2 healthcare centers, were assessed. PECARN checklist was filled for all patients and children were divided into three groups of low, intermediate, and high risks. Patients were followed for 2 weeks by phone to assess their ciTBI status. At the end, discrimination power, calibration, and overall performance of PECARN rule were assessed. The results showed that CT scanning was not necessary for 265 (44.6%) children according to physicians' decision and this amount increased to 295 (49.6%) children if PECARN rule was used.

In agreement with Kobe and colleagues, the current study showed that regarding the ability to rule out the need for brain CT scan, clinical judgment was not a statistically significant tool (P=0.574). PECARN rule was a statistically significant excellent tool to rule out the need for CT [area under a curve =0.939, 95% confidence interval (CI): 85.6–100] (P? 0.0001). It showed a good sensitivity (88.2%) and specificity (97.0). Its negative predictive value was 94.1%.

The different findings revealed by Nakhjavan-Shahraki and colleagues may be attributed to the different methodology, involving two healthcare centers, and longer follow-up period.

High sensitivity is a feature of an appropriate screening tool and leads to a reduction in the number of false negatives. Therefore, it results in faster management and more efficient triage in emergency wards. In the field of pediatrics, PECARN was a good screening tool in the identification of high-risk children with mild TBI.

Point-of-care ultrasound (POCUS) is a safe, portable, cost-effective, and easily reproducible triaging and diagnostic tool in the ED. Its importance and applications are increasing daily. Moreover, it is well tolerated by children.

Some studies suggested that it may be accurate for diagnosing pediatric skull fractures, few others suggest that it may help in detecting traumatic brain hemorrhages [13,14].

In one study, ultrasound was performed using a 2–5-MHz transducer, phased-array probe. Children were divided into three age groups: patients under 2 years old, 2–6 years old, and 6–18 years old. At 2-year-old point, the closure of anterior fontanel is expected as it is known to occur between 18 and 24 months. The ossification further continues, so that the sapheno-ethmoidal synchondrosis is lost at 6–7 years. This produces another cutoff as the cranium is 90% of the adult size at this time.

Bilateral transtemporal approach was used. In infants, anterior and posterior fontanels were also used as fine acoustic windows to the cranial vault. Subdural and epidural hematomas commonly present as hypoechoic fluid collections surrounding the brain parenchyma [15].

Sensitivity and specificity of bedside ultrasound in detection of hemorrhage were 85.71% (42.13–99.64%) and 97.99% (94.23–99.58%) for children below the age of 2. These measures were 80.00% (51.91–95.67%) and 97.97% (94.88–99.44%), respectively, for those between 2 and 6 years old and 46.67% (21.27–73.41%) and 92.90% (87.66–96.40%), respectively, for those above the age of 6 [15].

In a systematic review performed on July 17, 2020 in Ovid Medline, Cochrane Library, Google Scholar, Web of Science, and Embase; prospective studies reporting skull fractures diagnosed with ultrasound in children younger than 18 years due to blunt head injury were included. Studies that did not confirm the fracture with CT were excluded. The included studies demonstrated minor methodological limitations. Overall, the evidence suggested that POCUS is a valid option for diagnosing skull fractures in children visiting the ED after blunt head injury [16].

Another study aimed to evaluate the accuracy of POCUS in diagnosing skull fracture in children with closed head injury in comparison with CT scan. This prospective cross-sectional study was conducted on children (0–14 years old). A total of 168 children were enrolled. The most affected areas in the skull were the frontal (34.5%) and occipital areas (33.3%). POCUS had a sensitivity and specificity of 81.8% (95% CI: 48.2–97.7%) and 100% (95% CI:

97.7–100%), respectively. Positive and negative predictive values were 100 and 98.7%, with an accuracy of 98.8% in comparison with CT scan in the diagnosis of skull fracture [17].

In the current study, ultrasound role in diagnosing intracranial hemorrhage or skull fractures was not addressed, because this tool was not feasible at the time of the study, also, it needs sufficient training and special ultrasound equipment with certain probes before conducting a research. But, it is a very important point to recommend future research.

A pilot study was done to evaluate the Quick Brain MRI protocol in assessing ciTBI in children. This was a retrospective cohort study of pediatric patients who presented to the ED for an evaluation of head trauma from February 2010 to December 2013. Quick Brain MRI (qbMRI) includes rapid acquisition of axial, sagittal, and coronal T2-weighted fast spin-echo images. Images can be obtained in ~1–3 min. This pilot study found that qbMRI has reasonable sensitivity for the identification of pediatric TBI. Additional work in this area and advances in MRI technology might ultimately validate the qbMRI modality for the initial evaluation of children suspected of having TBI, which would further reduce the risk of their exposure to ionizing radiation [18].Newer MRI techniques have proven to be more sensitive in identifying subtle findings of brain injury. Specifically, MRI has been used in differentiating subacute and chronic brain injury, and identifying the extent of encephalopathy, reactive gliosis, and hemorrhage related to the insult, consequently, it plays a key role in classifying the severity of TBI, and in determining the prognosis.

A literature review was done from Medline and PubMed for all peer-reviewed manuscripts from January 1990 to December 2018 using several keywords, including pediatric head trauma, pediatric TBI, imaging in head trauma, MRI in head trauma evaluation, and long-term effects of pediatric head trauma. It was found that MRI has greater sensitivity in the detection of most types of head injuries, in comparison with CT – except skull fractures, in addition to detecting more brain pathologies, playing a key prognostic role [19].

Regarding the current research, the availability of MRI as an investigation in the acute setting of the ED is not practical as it is time consuming, expensive, and needs special planning. Currently MRI is available for the group of patients with ciTBI who are admitted in the critical care or neurosurgery critical care. Maybe in the future, it will be available for certain indications hopefully, pediatric head injury can be one of them.

Conclusion

CT scans for evaluation of minor blunt head trauma in children (aging from 2 to 18 years) are currently overused, thus exposing children to unnecessary radiations, which may have an unpleasant impact on their health in the long term.

Recommendations

It is not recommended for the emergency physician to use clinical judgment alone in assessment of children with minor blunt head trauma, but it should be combined with validated decision rules such as PECARN to rule out the need for brain CT scans to avoid unnecessary radiations.

Neurosurgery consultation should be considered also before planning for CT scan in ED.

Further research is required on the role of POCUS as a diagnostic and triaging tool for pediatric head trauma in the ED.

Moreover, quick brain MRI and MRI protocols need to be applied and validated in emergency as a diagnostic and prognostic tool for pediatric head trauma.

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Conflicts of interest

There are no conflicts of interest.

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