

ORIGINAL ARTICLE

# The prevalence of abnormal brain CT scans in pediatrics emergency department: two years single-center retrospective chart review study

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## ABSTRACT

**Background:** Traumatic head injury represents a substantial cause of trauma in pediatric emergency rooms (ER). This study aimed to calculate the prevalence of abnormal computed tomography (CT) scan reports (CT) in the pediatric ER at King Abdullah Specialized Children's Hospital (KASCH) in Riyadh. In addition, it examined different variables that are more likely associated with a normal CT scan.

**Methods:** This single-center retrospective chart review study was conducted using nonprobability convenience sampling; data were collected from the electronic health records of ER pediatric patients. Patients aged 0 to 14 years, who had a trauma and a brain CT scan ordered in KASCH ER, from May 2017 to May 2019 were included.

**Results:** In total, 502 CT scans were done due to a traumatic head-related event. About a third (34.5%,  $n = 173$ ) had an abnormal CT scan, with the majority of the group (69.4%,  $n = 120$ ) being male. The highest rate of abnormal CT scans (28.9%) was in the 2-5 years age group. The most common mechanism of injury was falling (55%), followed by motor vehicle accidents (33.5%). Falling, as a mechanism of injury, accounted for more than half of the injuries in both the normal (57.1%) and abnormal (50.9%) CT scans.

**Conclusion:** Two-thirds of the head CT included in this study resulted in normal CT findings and a considerable number of the abnormal findings were linear non-displaced fractures that can be detected by X-ray.

**Keywords:** Pediatric, trauma, head, CT, computed tomography.

## Introduction

Traumatic head injury represents a substantial cause of trauma in pediatric emergency rooms (ER). Globally, the incidence of pediatric traumatic brain injury (TBI) ranges from 12 (Sweden) to 486 (Australia) children per 100,000 [1], whereas in Saudi Arabia (SA), Alhabdan and colleagues stated that of 3,796 patients, a prevalence of 1,219 children (32.1%) suffered a head injury [2]. Akkam et al. [3] stated that a prevalence of 2,501 pediatric patients presented to the ER with head injuries. In both of the studies, motor vehicle accidents (MVA) were the most frequent mechanism resulting in a head injury. According to the WHO Global Status Report on Road

Safety in 2018, SA has the highest annual (28) MVA fatality rate per 100,000 people, which is the highest in the region and much higher than the other G-20 nations

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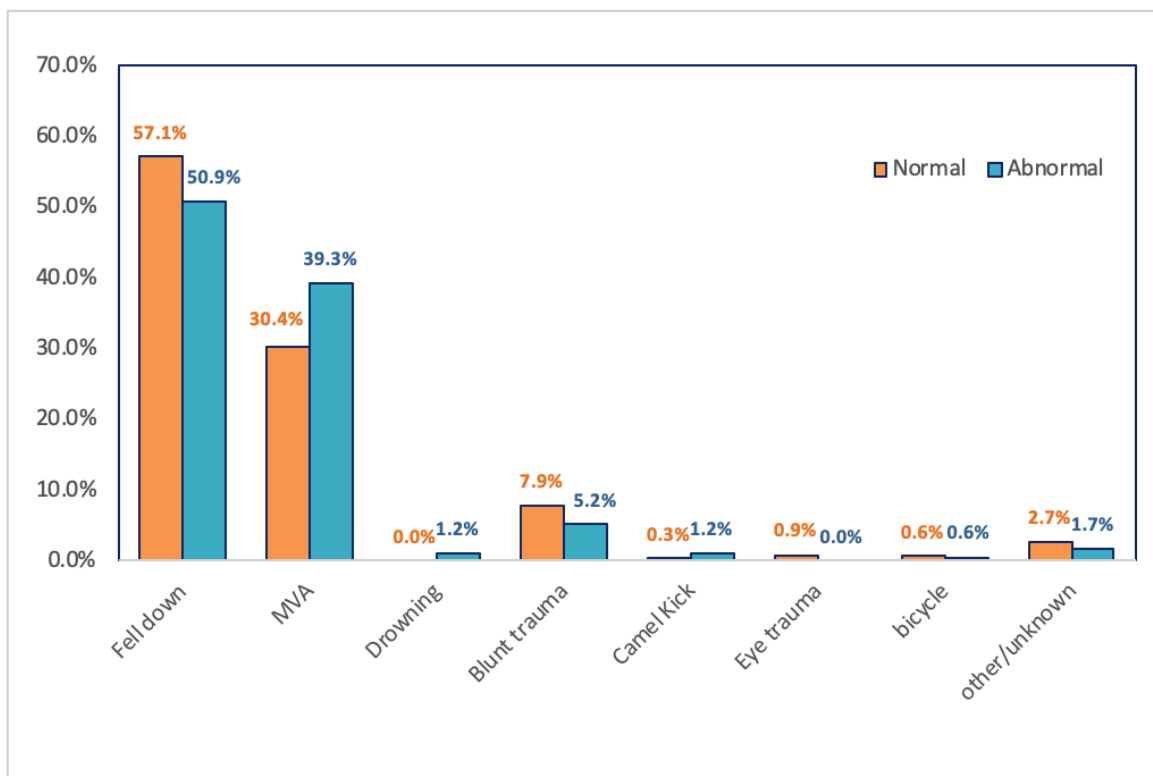
**Table 1.** Characteristics for children presenting with head injury in the ER.

	No. (%) of patients	Normal CT	Abnormal CT
<b>CT Findings</b>	N = 502	329 (65.5%)	173 (34.5%)
<b>Gender</b>	N = 502		
Female	165 (32.9%)	112 (34.0%)	53 (30.6%)
Male	337 (67.1%)	217 (66.0%)	120 (69.4%)
<b>Age groups</b>	N = 502		
Mean ± SD	5.28 ± 4.11		
0-6 months	24 (4.8%)	6 (1.8%)	18 (10.4%)
6-12 months	31 (6.2%)	18 (5.5%)	13 (7.5%)
1-2 years	101 (20.1%)	73 (22.2%)	28 (16.2%)
2-5 years	145 (28.9%)	95 (28.9%)	50 (28.9%)
5-11 years	142 (28.3%)	96 (29.2%)	46 (26.6%)
11-14 years	59 (11.8%)	41 (12.5%)	18 (10.4%)
<b>GCS</b>	N = 443		
3-8	20 (4.5%)	3 (1.0%)	17 (11.1%)
9-12	21 (4.7%)	8 (2.8%)	13 (8.5%)
13	8 (1.8%)	1 (0.3%)	7 (4.6%)
14	16 (3.6%)	9 (3.1%)	7 (4.6%)
15	378 (85.3%)	269 (92.8%)	109 (71.2%)
<b>Mode of arrival</b>	N = 479		
Non-emergency vehicle	129 (26.9%)	75 (24.0%)	54 (32.5%)
Emergency vehicle/ambulance	350 (73.1%)	238 (76.0%)	112 (67.5%)
<b>Indication</b>	N = 502		
Vomiting	128 (25.5%)	88 (26.7%)	40 (23.1%)
Loss of consciousness	103 (20.5%)	71 (21.6%)	32 (18.5%)
Headache	30 (6.0%)	19 (5.8%)	11 (6.4%)
Disorientation of confusion	27 (5.4%)	17 (5.2%)	10 (5.8%)
Lethargy	28 (5.6%)	22 (6.7%)	6 (3.5%)
Seizure	13 (2.6%)	8 (2.4%)	5 (2.9%)
Irritability	14 (2.8%)	11 (3.3%)	3 (1.7%)
Pallor	4 (0.8%)	3 (0.9%)	1 (0.6%)
Visible fracture	0 (0.0%)	0 (0.0%)	0 (0.0%)
<b>Mechanism of injury</b>	N = 502		
Fell down	276 (55.0%)	188 (57.1%)	88 (50.9%)
MVA	168 (33.5%)	100 (30.4%)	68 (39.3%)
Blunt trauma	35 (7.0%)	26 (7.9%)	9 (5.2%)
Camel kick	3 (0.6%)	1 (0.3%)	2 (1.2%)
Eye trauma	3 (0.6%)	3 (0.9%)	0 (0.0%)
Bicycle	3 (0.6%)	2 (0.6%)	1 (0.6%)
Drowning	2 (0.4%)	0 (0.0%)	2 (1.2%)
Other	12 (2.4%)	9 (2.7%)	3 (1.7%)

[4]. According to a systematic review conducted in SA (including pediatric and adult patients), the most frequent site of injury due to MVA was head and neck, followed by upper and lower limbs [5]. An audit of Road Traffic Accidents over a 1-year period revealed that 16% of the victims were less than 10 years old, and 47% were between 11 and 30 years old.

Not all children who present with head trauma would have a TBI; however, prompt computed tomography (CT) imaging remains the gold standard in ruling out intracranial pathologies [6]. Despite the importance of

CT scans and their role in the prevention of mortality, using such a powerful radiation-emitting machine on the developing bodies of children is a formidable risk. The doses of ionizing radiation delivered by a CT scan are 100-500 times higher than a conventional radiography and, as a result, are linked to increased cancer risk [7]. Mathews et al. [8] investigated 60,000 patients and reported that the incidence of cancer increased by 24% for people who received a CT scan, compared to the non-CT group. Moreover, a retrospective cohort study conducted in Great Britain, which included ~170,000 patients, reported that exceeding 2-3 head CT's (~60



\* MVA: Motor Vehicle Accident

Figure 1. Mechanism of injury for normal and abnormal traumatic head CTs (2017-2019).

mGy) radiation exposure can lead to three times the risk of having brain tumors [9]. In addition to the risks of radiation, CT scans increase the economic burden, according to a study done in the US (United States), cost savings from reducing the usage of CT scans were ~120 million dollars annually [10],

Pediatric emergency physicians in SA use internationally established guidelines such as the PECARN, CATCH, and CHALICE when electing a brain CT scan. In the Alharthy study [11], a single-center retrospective study conducted in SA, the number of abnormal brain CT scans was less than 5% and none of them required neurosurgery or surgical intervention. Ordering a CT scan must be based on clear, and validated guidelines that rely on local-based data and relative clinical findings.

Referring to major international studies that investigated standardized benchmarks to order a brain CT for pediatric trauma, a large number of the children included in all three major studies were normal, especially in the low-risk groups. For example, in the CATCH study, of the 3,866 children, who had a brain CT due to head trauma, only 159 (4.1%) had abnormal findings (TBI) [12]. In PECARN, 56% of the sample were in the low-risk group and a CT scan of the head was not indicated [13]. The results in the CATCH and PECARN are comparable to the CHALICE study, which stated that of 22,772 children with a brain CT to rule out trauma, only 281 had abnormalities [14]. All these results provide essential insight into the importance of having well-defined objective clinical indicators supporting the decision to order a brain CT.

This study aimed to identify the prevalence of abnormal CT scans in the pediatric ER at King Abdullah Specialized Children's Hospital (KASCH) in Riyadh which will, in turn, help to recognize variables that have a higher chance of resulting in an abnormal result. Thus, supporting the physician in the decision-making process to be more comfortable choosing to observe patients rather than opting for CT where applicable.

## Subjects and Methods

This cross-sectional study was retrospectively conducted from May 2017 to May 2019, using nonprobability convenience sampling to pool data from the electronic medical records of pediatric ER patients. The data collection was performed by pre-trained physicians from the ER department. The study extracted data from Pediatrics ER medical records at KASCH in Riyadh, SA. KASCH is a trauma center, it is one of six hospitals belonging to the Ministry of National Guard Health Affairs (MNGHA). The MNGHA hospitals are government-funded tertiary care hospitals providing medical care to Saudi National Guard soldiers, dependents, and employees. KASCH is SA most advanced pediatric hospital, it has a bed capacity of 600,60 of which are pediatric ER beds with an average occupancy rate of 72.36%.

All pediatric patients, aged 0 to 14 years, who underwent a head CT scan in the KASCH ER were eligible for inclusion in the study. On the other hand, patients above 14 years of age, presenting with non-head related injuries,

or with inconclusive files, such as missing CT results, were excluded from the final analysis.

The categorical variables were presented as frequency and percentage, and the continuous variables as mean and standard deviation. Odds ratio was used to determine the association between the variables and abnormal CT scans. KASCH associations were compared to the corresponding associations in the CATCH and PECARN studies after pooling the data from the two studies [12,13]. SPSS (Version 27.0. Armonk, NY: IBM Corp) was used for all statistical analyses.

## Results

In the study period, 502 pediatric patients underwent a CT scan due to a traumatic head-related incident (Table 1). The CT scans revealed abnormal results in 173 (34.5%) of the sample, with males accounting for 120 (69.4%) of the abnormal scans.

Falling accounted for more than half of the injuries in both the normal (57.1%) and abnormal (50.9%) CT scans, followed by MVA (30.4%, 39.3%, respectively; Figure 1). Only 56 (11.8%) of the cases triggered the activation of the trauma team.

More than half of abnormal cases (56.1%) resulted in more than one outcome requiring management. Of the 173 abnormal cases, 127 (73.4%) resulted in a skull fracture of which 35 (20.2%) were accompanied by a subgaleal hematoma. Extra-axial hematomas accounted for 56 (32.4%) of the outcomes, with 17 (9.8%) subdural, 16 (9.2%) epidural, and 4 (2.3%) subarachnoid (Table 2).

The association between the variables and an abnormal brain CT scan in the sample is displayed in Table 3. There was an association in patients that arrived with an emergency vehicle (1.53). Only three of the nine indications demonstrated a positive association for an increased chance of an abnormal CT scan, headache (1.19), disorientation or confusion (1.14), and seizure (1.21). Patients involved in an MVA (1.48) were at a higher chance of presenting with an abnormal CT, compared with the group who sustained their injuries through other mechanisms of injury.

Comparison of KASCH data with CATCH (2001-2005) and PECARN (2004-2006) benchmarks is shown in Table 4. KASCH data indicate a higher association of abnormal CTs for age (0.97) than CATCH (-0.97) using logistic regression, PECARN did not report this data. The Glasgow Coma Scale (GCS) scores in the CATCH (3.52-5.55) and PECARN (2.76) had a higher association with abnormal CTs than the KASCH (0.06-0.52). The CATCH study had a significant association with abnormal CTs in seven of the eight indications, compared with the PECARN in one indication, and KASCH in three indications. The association between the mechanism of injury and abnormal CTs has not recorded by the PECARN study, while CATCH data shows increased association on all mechanisms of injuries and in KASCH, the association is higher in only MVAs and camel kicks. Both the KASCH and CATCH odds ratios cross the one in the 95% confidence interval, indicating that an increase or decrease in the association

**Table 2.** Management & outcome of CT patients.

	No. (%) of patients
<b>Case presenting with outcomes</b>	
Cases presenting with 1 outcome	73 (42.2%)
Cases presenting with 2 outcomes	70 (40.5%)
Cases presenting with 3 or more outcomes	27 (15.6%)
<b>Outcome</b>	
Extra-axial hematoma	56 (32.4%)
Unspecified extra-axial	19 (11.0%)
Subdural	17 (9.8%)
Epidural	16 (9.2%)
Subarachnoid	4 (2.3%)
Fractures	127 (73.4%)
Non-displaced	99 (57.2%)
Displaced	17 (9.8%)
Depressed	11 (6.4%)
Fracture with subgaleal hematoma	35 (20.2%)
Brain contusion	6 (3.5%)
Brain edema	5 (2.9%)
Pneumocephalus	2 (1.2%)
Other findings	11 (6.4%)
Hyperdensities	6 (3.5%)
Subcutaneous deem and thickening	3 (1.7%)
Intra-orbital hematoma	1 (0.6%)
Orbital tissue swelling	1 (0.6%)
Incidental Findings not related to trauma	13 (7.5%)
Sinus tissue swelling or disease	6 (3.5%)
Opacified mastoid air cells	2 (1.2%)
Mass lesion	2 (1.2%)
Cerebral calcification	1 (0.6%)
Bone erosion	1 (0.6%)
Periventricular leukomalacia	1 (0.6%)
<b>Trauma team activation</b>	<b>N = 473</b>
No	417 (88.2%)
Yes	56 (11.8%)

is not significant, while the PECARN demonstrated a significant decrease of the association between abnormal CTs and loss of consciousness and headache.

## Discussion

This study was conducted with the aim of examining the high usage of a brain CT scan in the pediatric ER in trauma patients. It demonstrated that of 502 pediatric traumatic brain CT scans, two-thirds resulted in a normal CT report. In addition, more than half of the abnormal reports were simple linear non-displaced skull fractures that could be detected by plain radiographs.

Locally, Alharthy et al. [11] reported that only 4.8% of their patients had an abnormal CT scan, compared to 34.5% in the current study. The lower number of abnormal CT findings in Alharthy's study compared to this study is most likely due to Alharthy's study did not include all skull fracture types but only included basal,

**Table 3.** Association between variables and presence of abnormal brain CT in pediatric patients with head trauma.

	Normal CT	Abnormal CT	OR (95% CI)
<b>Age (Mean±SD)</b>	5.28 ± 4.11		0.97 (0.93-1.02)
Gender male (v. female)	217 (66.0%)	120 (69.4%)	1.17 (1.079-1.74)
Arrived by emergency vehicle (v. non-emergency vehicle)	75 (24.0%)	54 (32.5%)	1.53 (1.01-2.32)
<b>Glasgow coma scale</b>			
13	1 (0.3%)	7 (4.6%)	0.06 (0.01-0.48)
14	9 (3.1%)	7 (4.6%)	0.52 (0.19-1.43)
15	269 (92.8%)	109 (71.2%)	1.00 (reference)
<b>Indication (v. non-indication)</b>			
Vomiting	88 (26.7%)	40 (23.1%)	0.83 (0.54-1.28)
Loss of consciousness	71 (21.6%)	32 (18.5%)	0.83 (0.52-1.33)
Headache	19 (5.8%)	11 (6.4%)	1.19 (0.52-2.41)
Disorientation or confusion	17 (5.2%)	10 (5.8%)	1.14 (0.51-2.54)
Lethargy	22 (6.7%)	6 (3.5%)	0.51 (0.20-1.27)
Seizure	8 (2.4%)	5 (2.9%)	1.21 (0.39-3.74)
Irritability	11 (3.3%)	3 (1.7%)	0.52 (0.14-1.87)
Pallor	3 (0.9%)	1 (0.6%)	0.64 (0.07-6.17)
Visible fracture	0 (0.0%)	0 (0.0%)	-
<b>Mechanism of injury</b>			
Fell down	188 (57.1%)	88 (50.9%)	0.78 (0.54-1.12)
MVA	100 (30.4%)	68 (39.3%)	1.48 (1.01-2.18)
Blunt trauma	26 (7.9%)	9 (5.2%)	0.64 (0.29-1.40)
Camel kick	1 (0.3%)	2 (1.2%)	3.84 (0.35-42.61)
Eye trauma	3 (0.9%)	0 (0.0%)	-
Bicycle	2 (0.6%)	1 (0.6%)	0.95 (0.09-10.56)
Drowning	0 (0.0%)	2 (1.2%)	-
Other	9 (2.7%)	3 (1.7%)	0.63 (0.17-2.35)

depressed, and complicated fractures as an abnormal outcome as contrast to the present study, which included all types of fractures as abnormal outcome. In this study, males had a higher chance of undergoing a CT scan with an abnormal scan (69.4%), which is supported by the literature [11,15,16].

Regarding the mechanism of injury, children injuring themselves through falling are prevalent globally; therefore, falling was the most frequent mechanism of injury in this population, followed by MVA which is consistent with comparable studies [11-13]. Although MVAs were second in the current study, it was significantly higher than other studies, locally and internationally. Camels and camel breeding are considered a cultural heritage in SA, but injuries related to camels are barely mentioned in local literature; however, a study done in the United Arab Emirates investigating camel-related injuries, concluded that head injuries are the most frequent outcome due to an accident involving direct camel contact [17]. In the current study, two out of three with camel injury had an abnormal brain CT scan. Drowning is a known leading cause of death in children and can result in brain damage [18]. Two patients in this study presented with drowning and both had abnormal CT scan results. According to a study conducted in San Diego children's hospital, 156 patients who drowned (18%) had an abnormal CT scan result [19].

In terms of the outcomes, three-fourths of the abnormal CT scans were due to a skull fracture, which is higher than Alharthy et al. [11]. Extra-axial hematomas accounted for nearly a third of the abnormal results. In comparison, the number of subdural hematomas in this study was almost ten times higher than the Alharthy's study.

Most of the patients presented with vomiting and loss of consciousness as initial symptoms. However, two variables, being male and transported by an emergency vehicle, had a significant association with an abnormal result. In comparison to the PECARN [13] and CATCH [12], loss of consciousness, vomiting, and headache were not statistically significant with an abnormal CT result. The clinical symptoms associated with an increased incidence of an abnormal CT were seizure, headache, and disorientation or confusion. The mechanism of injury with an increased incidence of an abnormal scan was MVAs. Although falling was the most frequent mechanism of injury, it was not statistically significant with an abnormal scan. This suggests that some variables should be cautiously approached when discussing the options to choose a CT scan versus observing the patient. Two large prospective observational studies indicated that observing the patient reduces the rate of CT scan ordering in children with minor brain injury. The first being a multicenter study which enrolled around 40k patients, the second being a prospective single-center study which included ~1,400 patients [20,21].

**Table 4.** Benchmark between KASCH (2017-2019), CATCH (2001-2005), and PECARN (2004-2006).

	KASCH	CATCH	PECARN
Age (Mean ± SD)	0.97 (0.93-1.02)	-0.97 (-1.74 to -0.18)	
Gender male (v. female)	1.17 (1.079-1.74)	0.97 (0.70-1.35)	
Arrived by emergency vehicle (v. non-emergency vehicle)	1.53 (1.01- 2.32)	3.51 (2.51-4.93)	
<b>Glasgow coma scale</b>			
13	0.06 (0.01- 0.48)	5.55 (3.10-9.93)	
14	0.52 (0.19-1.43)	3.52 (2.31-5.37)	2.76 (2.11- 3.65)
15	1.00 (reference)	1.00 (reference)	
<b>Indication</b>			
loss of consciousness	0.83 (0.52-1.33)	0.97 (0.67-1.41)	0.73 (0.56- 0.95)
Disorientation or confusion	1.14 (0.51-2.54)	1.31 (0.91-1.89)	
Vomiting	0.83 (0.54-1.28)	1.37 (1.00-1.89)	1.81 (0.39-2.34)
Headache	1.19 (0.52-2.41)	2.24 (1.51-3.32)	0.36 (0.26-0.49)
Seizure	1.21 (0.39-3.74)	1.13 (0.52-2.46)	
Lethargy	0.51 (0.20- 1.27)	5.16 (3.74-7.13)	
Pallor	0.64 (0.07- 6.17)	2.41 (1.73-3.36)	
Irritability	0.52 (0.14- 1.87)	4.70 (3.33-6.64)	
<b>Mechanism of injury</b>			
fell down	0.78 (0.54- 1.12)	8.56 (4.44-16.50)	
MVA	1.48 (1.01- 2.18)	10.78 (4.64-25.05)	
Blunt force head trauma	0.64 (0.29- 1.40)	24.68 (7.05-86.38)	
drowning	-		
Bicycle accident	0.95 (0.09-10.56)	16.33 (5.71-46.75)	
Camel kick	3.84 (0.35- 42.61)		
Eye trauma	-		
Other	0.63 (0.17-2.35)	-	

Despite the high number of abnormal CT scans, the analysis of the outcomes and CT findings showed that more than half of these abnormal outcomes were simple non-displaced fractures, which could be detected by a safer mode of imaging such as a plain radiography. Lessening the number of unnecessary CT scans in the local pediatric ER is achievable as it has been demonstrated by studies done in the US and Finland, where it has been noticed that the decrease in using CT during the last two decades has simultaneously increased the rate of non-radiating imaging such as ultrasound and MRI scans [15,16,22].

The sample size of the current study was reasonable. Due to the retrospective nature of the study, patients were not followed up and some data were not included in the main objectives of the study, for example, whether the patients were admitted or had an operation after their abnormal CT scan results. Some important variables could not be extracted properly due to inconsistent documentation in the patient files such as GCS and the exact height of falls.

## Conclusion

Two thirds of the head CT included in this study resulted in unremarkable findings and a considerable number of the abnormal findings could be detected by plain radiographs such as fractures with less radiation exposure. Although indications to opt for urgent CT of the head have been clear in the discussed international guidelines, there is still a grey area where the physician

judgment is required to either opt for a CT versus clinical observation. This study sought to identify findings that might assist physicians to be more confident to choose clinical observation and thus avoid scanning. The authors believe that physicians can use some of the patient's characteristics and variables that are associated with an abnormal result in their population alongside the utilization of internationally available resources in the decision-making process. A newly developed check list that includes patients' variables should be implemented and filled by the physician prior to ordering a CT scan of the head to allow for future prospective researches to then establish more specific guidelines for our region.

## List of Abbreviations

CT	Computed tomography
ER	Emergency room
GCS	Glasgow Coma Scale
KASCH	King Abdullah Specialized Children's Hospital
MVA	Motor vehicle accident
SA	Saudi Arabia
TBI	Traumatic brain injury

## Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

## Funding

None.

## Consent to participate

Informed consent was obtained.

## Ethical approval

Ethical approval was obtained from KAIMRC, with letter number RC19/300/R, dated: 07/17/2019.

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