Int J Burn Trauma 2022;12(6):261-268
www.IJBT.org /ISSN:2160-2026/IJBT0146215

Original Article

Investigation of clinical findings and CT scan in children with minor head trauma

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Received August 30, 2022; Accepted December 13, 2022; Epub December 15, 2022; Published December 30, 2022

Abstract: Background: The most common cause of death or severe impairment in children older than one-year-old is traumatic brain injury (TBI). Assessing TBI in children with minor head trauma (MHT) using clinical findings from history-taking and a physical exam is crucial to minimizing unnecessary brain CTs and more accurately predicting TBI. We aimed to evaluate the findings of brain CT scans in children with mild head trauma and their relationship with clinical signs and symptoms to avoid unnecessary interventions in many children with MHT. Methods: This cross-sectional-analytical study was performed to evaluate the findings of brain CT scans in children with MHT and their relationship with clinical signs and symptoms that were referred to Poursina Hospital in Rasht in the first half of 2021. Children were divided into two age groups: under two years and 2-12 years, and analyzed separately. Initially, a list containing all demographic information, patients' clinical signs, and symptoms were prepared. The collected data were then analyzed using SPSS software version 26. Results: According to the results, the mean age of patients was 66.01 months and 88 were boys (56.4%). The most common mechanism of injury was falling from a height. Most patients had isolated head injuries. Among the accompanying injuries, facial injuries were the most common. Among the clinical factors studied, cranial fracture on CT scan and GCS less than 15 were significantly associated with the occurrence of traumatic brain injury on CT scan. In addition, cranial fracture on CT scan, injury severity, and history of vomiting had the highest positive predictive value, respectively. Conclusion: Standard history and clinical examination are sufficient to identify high-risk cases of pediatric head injuries. GCS is the most important risk factor for pediatric MHT. Requesting a CT scan is not recommended without these risk factors.

Keywords: Minor head trauma, pediatrics, CT scan, clinical predictor

Introduction

The most common cause of death or severe impairment in children older than one year is traumatic brain injury (TBI) [1]. Many pediatric patients report to the ED with head injuries as their primary symptom, and 10% of these individuals require hospitalization. More than 800,000 children in the United States are evaluated in the emergency department (ED) each year for head injuries [2, 3]. Based on the Glasgow coma scale (GCS), TBI is often classified as mild, moderate, or severe. The GCS system has been developed to determine the level of consciousness (LOC) of patients with acute brain dysfunction, with a minimum of 3 and a maximum of 15 [4].

Most cases of head trauma in children are mild (GCS ≥14) and intracranial injuries are uncommon [5]. Therefore, on average, 5% of children's minor head traumas (MHT) result in TBI, with less than 1% requiring neurosurgical intervention [6]. Patients with MHT have a GSC between 14 and 15 and may initially experience brief LOC or amnesia but are admitted without focal neurological abnormalities. Falls and sports/recreational injuries are children's most common causes of TBI. Falls are particularly likely in very young children due to their undeveloped ambulatory skills paired with their disproportionately large heads, changed centers of gravity, and immature neck muscles [7, 8].

According to the American Congress of Rehabilitation Medicine (ACRM), a mild TBI results from the head being struck by an object, colliding with another object, or experiencing an acceleration and deceleration movement [9]. It is characterized by at least one of the following symptoms: A GCS score of 13 to 15; Any period of unconsciousness lasting up to 30 minutes; Post-traumatic amnesia lasting no longer than 24 hours; Any period of confusion or disorientation; or Temporary neurological abnormalities, such as focal signs, seizures, and non-surgical cerebral lesions (i.e., ranging from confusion to normal consciousness on the examination within 30 min after presentation).

Post-traumatic seizures, headaches, amnesia, scalp hematomas, skull fractures, vomiting after head trauma, and loss of consciousness are some signs and symptoms that raise the risk of TBI in children with head trauma [10, 11]. The typical clinical outcome of uncomplicated mild TBI identified in the emergency room (i.e., no brain lesions detected by CT scans) is confusion resolution within 24 hours. Most patients with moderate TBI see a progressive resolution of post-concussion symptoms over the next 12 weeks, including somatic (headaches, dizziness), cognitive (poor memory and attention), and emotional symptoms (irritability, depression).

The gold standard for determining a TBI diagnosis is a cranial computed tomography (CT) scan. Choosing whether MHT patients require a brain CT has always been difficult, and determining whether it is necessary to treat children's head trauma is even more crucial [12]. The overuse of brain CT places a heavy financial burden on national healthcare systems, particularly in low- and middle-income countries. Unfortunately, access to CT is limited in these nations and occasionally only available in the capital cities [13]. As a result, patients in these situations are sent to major hospitals. Therefore, ordering pointless brain CT scans can place a significant strain on both individuals and healthcare systems. Also, a child may be more likely to get leukemia and brain tumors if exposed to radiation from a brain CT [14].

Given that MHT accounts for the majority of head trauma cases and more than 90% of CT scans do not reveal brain injury, it is critical to use clinical evidence to identify which patients are most vulnerable to TBI. Furthermore, investigations have demonstrated that the sensitivity and specificity of head trauma decision-making guidelines are low, so clinical judgment should not be restricted to these alone [1]. As a result, assessing the occurrence of TBI in children with MHT using clinical findings obtained from history-taking and physical examination is critical to avoid needless brain CTs and more accurately predict TBIs [5].

We aimed to evaluate the findings of brain CT scans in children with mild head trauma and their relationship with clinical signs and symptoms to avoid unnecessary interventions in a many children with MHT and keep them away from the possible side effects of this imaging. Simultaneously, children with significant injuries must be identified to prevent secondary injuries.

Method

Study design

This is a cross-sectional, analytical study that was performed to evaluate the findings of a brain CT scan in children with MHT and their relationship with clinical signs and symptoms to avoid unnecessary interventions in a large number of children with MHT referred to Poursina Hospital in Rasht in the first half of 2021. The current study was approved ethically by Guilan University of Medical Sciences (approval number: IR.GUMS.REC.1400.058).

Inclusion and exclusion criteria

Inclusion criteria include patients with MHT under 12 years and a GCS score of ≥14 who were hospitalized in Poursina Hospital in Rasht in the first half of 2021. In addition, written informed consent was obtained from parents or legal guardians. Exclusion criteria were determined, including patients with a GCS score of ≤13, penetrating head trauma, any history of anticoagulant therapy, and underlying cerebral diseases such as ischemic lesions, hemorrhagic lesions, or brain tumors.

Data collection and measurements

The data was obtained from the file of children with mild head trauma who visited the ED of the Poursina Hospital. Children were divided into two age groups: under 2 years and 2-12 years. Data were analyzed separately to ensure that the conclusion was accurate and took into account the different ways that GCS is assessed, the difficulty of children under 2 years old expressing symptoms like headaches, as well as the difference in head injury symptoms in infants compared to children. Demographic information collected from the patients included age and gender.

Primary evaluation

Information regarding the mechanism of traumatic damage was retrieved from patient files, which included cases of simultaneous injury (facial, chest, spine, pelvis, limbs) and injury severity. We also obtained data regarding the severity of injury according to the mechanism of injury. Traumatic events were classified into severe and not severe. Severe trauma was defined as falling from a height greater than 0.9 meters under 2 years and 1.5 meters over 2 years, accidents with vehicles resulting in the patient being thrown from the vehicle or the death of another passenger or resulting in a rollover; accidents as a pedestrian or cyclist without a helmet with a vehicle, head impact with a hard object.

Children with MHT were evaluated for their state of consciousness using the Pediatric Glasgow Coma Scale (PGCS) scores. The PGCS assesses children under 23 months, 2-5 years, and over five years in three parts: eye-opening, motor response, and verbal response [15, 16].

The PGCS consists of three tests like the GCS: visual, verbal, and motor responses. The three values are taken into account individually as well as collectively. The sum can be as low as 3 (death or a severe coma) or as high as 15 (a fully awake and aware person).

Patients' clinical symptoms included loss of consciousness, vomiting, headache, posttraumatic seizure, and posttraumatic amnesia. Physical examination findings included a scalp hematoma, a palpable skull fracture, acting abnormally to parents, and any bruising, abrasions, or lacerations on the face or scalp. Cerebrospinal fluid otorrhea or rhinorrhea, hemotympanum, raccoon eyes, and the battle sign were symptoms of a skull base fracture [15, 16].

The positive findings obtained from the CT scan defined the presence of lesions associated with head trauma, such as epidural hematoma (EDH), subarachnoid hemorrhage (SAH), subdural hematoma (SDH), contusion, skull fracture (depressed, skull-base, or linear), and intraparenchymal hemorrhage (IPH).

The other outcome of the patients (admission to the neurosurgery department, discharge, any neurosurgical procedures, leaving the hospital with personal consent) and physical examinations of the patients, including clinical evidence of skull fracture, soft tissue damage to the head and face, and focal neurological deficits, were obtained from the patient's file.

Secondary evaluation

In this study, the sensitivity of clinical findings is measured by their capacity to detect all individuals with brain injury. Specificity refers to the absence of the required characteristic in CT scans of patients without a brain injury. The negative predictive value was considered the ratio of subjects diagnosed as negative to all those with negative test results. The positive predictive value was defined as the ratio of patients diagnosed as positive to those with positive test results. The sensitivity was considered the probability of the positive test, conditioned on truly having the condition. The specificity was the ability of the test to identify people without the disease correctly.

Statistical analysis

After collecting the study data, they were entered into SPSS software (version 26, IBM Corporation, Armonk, NY) and analyzed. The results are expressed as mean ± standard deviation. Qualitative variables were compared in different groups using the chi-square test. For

Table 1. Frequency distribution of demographic information and CT scan findings in patients

Variables		N (%) or mean ± SD	Abnormal CT scan findings, N (%)	*P*-value
Age (months)		66±39	9 (5.8)	0.385
Age groups (year)	<2	20 (12.8)	2 (10)	
	2-12	136 (87.2)	7 (5.1)	
Gender	Male	88 (56.4)	4 (4.5)	0.456
	Female	68 (43.6)	5 (7.4)	
Trauma mechanism	Fall from height	75 (49)	55.6%	0.215
	Motor vehicle accident	34 (22.2)	11.1%	
	Head impact with a hard object	18 (11.8)	-	
	Bicycle-related accidents	17 (11.1)	11.1%	
	Pedestrian hit by car	8 (5.2)	22.2%	
	Hitting injury	1 (0.7)	-	
Trauma location	Without accompanying injuries	116 (74.3)	9 (7.8)	0.857
	Face	14 (8.9)	-	
	Upper limb	8 (5.1)	-	
	Pelvic	4 (2.5)	-	
	Lower limb	8 (5.1)	-	
	Abdomen and lower limbs	1 (0.6)	-	
	Face and upper limb	2 (1.2)	-	
	Face and lower limb	3 (1.9)	-	

categorical data, Fisher's exact test was employed to analyze the link between outcomes and predictive factors. *P*-value <0.05 was considered as the significance threshold.

Result

Study population

Information about 156 patients is presented in this chapter. The average age of the patients was 66 months, with a standard deviation of 39 and a range of 1 to 144 months. In general, 20 patients (12.8%) were in the age group under two years, and 136 (87.2%) were in the age group of 2 to 12 years. Eighty-eight (56.4%) patients were male, and 68 (43.6%) were female.

Primary outcome

Among 156 patients, nine patients (5.8%) had evidence of TBI in a CT scan. As shown in **Table 1**, there was no significant difference in the occurrence of TBI in the two defined age groups (P>0.05). Similarly, no significant difference was observed between the gender of patients and the occurrence of TBI (P>0.05).

According to the frequency distribution of the mechanism of injury among 153 patients for whom file information regarding the mechanism of injury was available, falling from a height was the most prevalent mechanism of injury, occurring in 75 patients (**Table 1**).

Regarding the outcome of the patients, 135 (86.5%), patients were discharged from the emergency medical service. Thirteen patients (8.3%) left the hospital by personal consent. Eight patients (5.1%) were admitted to the neurosurgery department for further investigations and diagnostic-therapeutic procedures. None of the patients underwent neurosurgical interventions. Fortunately, none of the patients died.

Among 156 patients, 40 (25.6%) had simultaneous damage to other body parts. Thus, 14 patients (9%) had facial injuries at the same time. Lower and upper limb damage was seen similarly in eight (5.1%) patients. Neck, spine, chest, and abdomen were not affected in any patients. As demonstrated in **Table 1**, there is no significant difference between the two groups with and without brain injury regarding the type of simultaneous injury (P>0.05).

Table 2. Determination of sensitivity, specificity, positive and negative predictive value and Odds Ratio related to minor head trauma

Predictive risk factor	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	OR[1] (95% CI)	*P*-value
Injury severity	5,97	93.8	44.44	54.7	1.036	0.959
Head and face soft tissue damage	5.63	94.12	44.44	54.42	1.05	0.947
GCS[2] <15	50	95.39	22.22	98.94	0.048	-
Signs of change in consciousness	-	93.88	-	93.88	0.939	0.577
History of LOC[3]	25	94.74	11.11	97.96	0.167	0.001
Systemic injury	-	93.08	-	82.31	0.823	0.167
Signs of cranial fracture	-	93.84	-	93.2	0.932	0.419
Cranial fracture on CT[4] scan	-	94	-	95.92	0.959	-
History of vomiting	12.12	95.93	44.44	80.27	0.307	0.078
Focal neurological deficit	-	94.12	-	97.96	0.980	0.665
Posttraumatic seizure	-	94.23	-	100	-	-
Posttraumatic amnesia	-	94.16	-	98.64	0.986	0.725
Headache in 2-12 age group	9.09	96.12	42.86	76.74	0.404	0.239
Predictive group	-	94.23	-	100	-	-

[1]OR: Odds Ratio; [2]GCS: Glasgow coma scale; [3]LOC: Loss of consciousness; [4]CT: Computed tomography.

Secondary outcome

According to **Table 2**, GSC less than 15, headache in the 2-12 age group, injury severity, and posttraumatic seizure have the highest sensitivity, specificity, positive predictive value, and negative predictive value, respectively. Among the investigated risk factors, GCS less than 15, cranial fracture in CT scan and history of LOC had a significant relationship with traumatic brain injury in CT scan (P<0.05).

In addition, **Table 3** shows the clinical features and CT scan findings in children with MHT with TBI in CT scan.

Discussion

Minor head trauma is a common problem in children. In some cases, blunt MHT may be associated with TBI. Because managing and requesting brain CT in children with MHT is controversial, physicians usually tend to order a brain CT for most children with MHT, while TBI is seen only in a few cases [17, 18]. On the other hand, undergoing a CT scan is associated with drawbacks such as an increased risk of fatal malignancies in children and greater costs to the healthcare system [19].

In our study, 156 children with MHT were evaluated on the findings of brain CT scans in children with MHT and their relationship with clinical signs and symptoms. In the primary evaluation, we determined the severity of injury according to the mechanism of injury, level of consciousness with GCS, clinical symptoms, and positive findings of the CT scan. The sensitivity of the clinical conclusions is measured in secondary evaluation by their ability to detect all individuals with brain injury. Also, we calculated the positive and negative predictive values of the power of the stated clinical data to distinguish between actual cases and patients without TBI. Our study showed that the most common mechanism of injury was falling from a height. Most patients had blunt head injuries. Among the accompanying injuries, facial injuries were the most common. Among the clinical factors studied, cranial fracture on CT scan and GCS less than 15 were significantly associated with the occurrence of TBI on CT scan. Also, cranial fracture on CT scan, injury severity, and history of vomiting had the highest positive predictive value, respectively.

Tabrizi and colleagues [20] conducted a retrospective cohort analysis in 2021 to assess the prevalence of positive CT findings in children with MHT and their relationship to clinical signs and symptoms. Three hundred and eighty patients were enrolled in this study. Regarding CT scan findings, fractures were found in 11.8% of patients, SAH in 6.1%, and ICH in 5.5%. Positive CT findings correlated positively with raccoon eyes, battle sign, raccoon vomiting,

Table 3. Clinical features and CT scan findings in children with minor head trauma with traumatic brain damage in CT scan

Age (months)	Trauma mechanism	Signs and symptoms	CT[i] scan findings	Neurological procedure
84	Fall off the swing	GCS[ii] = 14, lethargy, headache, and vomiting	Skull fracture in right occipital without hematoma and hydrocephalus	Conservative
1	Falling from a height of 0.5 m	Vomiting and right parietal swelling	Left parietal contusion without hydrocephalus and midline shift	Conservative
36	Thrown from the car following an accident	Head and face soft tissue damage and vomiting	Skull fracture in the left occipital, pneumocephalus, continent without hydrocephalus and midline shift	Conservative
60	Fall down steps	Headache	Left occipital EDH[iii] (1 cc) along with a skull fracture in the left occipital without hydrocephalus and shift	Conservative
144	Pedestrian hit by car	-	Left temporal EDH (2 cc) with right parietal contusion and left temporal skull fracture without hydrocephalus and shift	Conservative
6	Falling from a height of 1 m	Vomiting	Right parietal SDH[iv] with skull fracture in the right parietal	Conservative
84	Fall from bike	Headache	Left frontoparietal SDH without hydrocephalus and shift	Conservative
72	Bicycle-related accidents	Head and face soft tissue damage and history of LOC[v]	EDH of the temporal base (2 cc) without hydrocephalus and shift	Conservative
96	Motor vehicle accident	GCS less than 15, head and face soft tissue damage, and history of LOC	EDH of the left and right frontal (2 cc), pneumocephalus, and frontal skull fracture without hydrocephalus and shift	Conservative

[i]CT: Computed tomography; [ii]GSC: Glasgow coma scale; [iii]EDH: Epidural hematoma; [IV]SDH: Subdural hematoma; [V]LOC: Loss of consciousness.

seizures, nausea, vomiting, and GCS less than 15. Additionally, there was no correlation between a positive CT with the trauma's etiology or age group. In conclusion, they determined that patients' clinical signs and symptoms, as well as their level of consciousness, should be evaluated before to CT scan. Our study is in line with this study. However, in our study, patients were divided into two groups ages (<2 years and ≥2 years) to ensure that the conclusion was accurate and took into account the different ways that GCS is assessed, the difficulty of children under two years old expressing symptoms.

In 2021, Sadegh and colleagues [21] evaluated the clinical and imaging findings of 234 children with mild TBI. Physical examination of the patients showed that 0.4% had palpable skull fractures, 6.8% had parietal scalp hematomas, 4.7% had occipital scalp hematomas, and 3% had temporal scalp hematomas. In 32.05% of cases, CT scans revealed linear skull fractures. CT scans were normal in 38.46% of patients. In patients with positive clinical examination findings, 23.2% had a positive CT finding, but only 7.3% of patients with no clinical symptoms had a positive CT finding, showing a substantial difference. In contrast to Tabrizi and colleagues and our study, there was a correlation between a positive CT and the age of the patients. Patients with positive CT scan results had a much lower average age. Overall, they found that a brain CT scan appears unnecessary in most cases; nonetheless, physicians should evaluate all clinical factors before requesting a CT scan. Our study is in line with this study. However, in contrast to our research, this study only evaluated patients under two years with MHT.

In another study [22], 1,711 children (aged ≤6 years) with mild TBI were evaluated. TBI with abnormal CT results was found in 75 of the 1,711 patients. The correlation with brain injury was stronger in patients who had fallen from a height of 1 meter or higher, had posttraumatic scalp swelling, or had posttraumatic irritability. Therefore, patients with MHT and the mentioned risk factors may require additional screening for TBI. In addition, Mizu and others [23] demonstrated that pediatric brain injuries with GCS scores of 15 rarely necessitate surgical intervention, even when CT scans reveal abnormalities. In this study, 99 patients with a range of 0 to 15 years old were enrolled. Hospitalizations accounted for 87% of patients, with a median stay of 1 day. Repeat CTs were performed on 69% of the patients, and 18% (12 patients) had radiographic progression. These 12 patients all developed subdural or epidural hematomas, and two needed surgery. Neither radiological nor clinical deterioration was observed in patients with isolated subarachnoid hemorrhage or isolated skull fracture. A prospective cohort study conducted in 2021 by Naghibi and colleagues [15] found that clinical findings might be used to predict the requirement for a brain CT scan in MHT children. Two hundred children were enrolled in this study. Brain CT was performed on a total of 91 patients. Regarding symptoms and causes, headaches and falling from a height were the most common. In 3.5 percent of patients, positive results from brain CT scans were found. According to the researchers, these three variables (headache, decreased consciousness, and vomiting) were found to be predictive of an abnormal brain CT.

Our study is in line with the studies mentioned above. However, the point of our study is the evaluation of sensitivity, specificity, positive and negative predictive value, and odds ratio related to MHT, that others did not mention.

However, our study has some limitations. The limitations of the present study were its retrospective design and small sample size. It is encouraged to conduct multicenter studies with larger sample sizes in other university centers and research and intervention studies to present high-confidence risk cases for future medical decisions.

Conclusion

Standard history and clinical examination are sufficient to identify high-risk cases of pediatric head injuries. Risks in pediatric MHT include altered consciousness, decreased GCS, the severity of the injury, history of vomiting, LOC, and head and facial soft tissue injury. Of these, GCS is the most critical risk factor. Requesting a CT scan is not recommended without these risk factors.

Disclosure of conflict of interest

None.

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