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Research Article

Accuracy of Ultrasound in the Diagnosis of Skull Fractures in the Pediatric Emergency Department

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Abstract

Objective: The objective of this study was to identify the sensitivity, specificity, and predictive values of ultrasound for identifying skull fractures when compared to head CT scanning in pediatric patients with Head trauma.

Methods: The present study was a prospective cross-sectional observational study that was conducted over a six month period. In this review, clinical ultrasound in the diagnosis of skull fracture, 320 children under 14 years with minor trauma the head, was used. A cranial CT scans was performed on the patients. The ultrasound results were compared to the results of head CT scans (which are considered the gold standard for diagnosing skull fractures) for sensitivity, specificity, positive predictive value, and negative predictive.

Results: The age range of the study population was from 24 days to 14 years with average of 4.73 ± 3.29 years. Cranial fractures were seen on the CT scan in 28 (8.75%) of the 320 patients; 292 (91.25%) CT scans were interpreted as normal. Emergency ultrasound performs with 85.71% sensitivity (95% CI 75.3-99.5%) and 100% specificity (95% CI 83.1-99.9%) when compared to CT scan for the diagnosis of skull fractures. The positive and negative predictive values of emergency ultrasound for cranial fractures in our study group were 100% (95% CI 81.6-100%) and 98.64% (95% CI 82.1-99.9%), respectively.

Conclusions: Ultrasound might be a reliable, fast, safe, and noninvasive initial diagnostic tool and can be an alternative primary technique in the diagnosis of skull fractures, especially in children.

Keywords: CT scan; Ultrasound; Head trauma; pediatric patients

Introduction

In the USA, head trauma is one of the most common childhood injuries accounting for more than 500,000 emergency department visits, 95,000 hospital admissions, 7,000 deaths, and 29,000 permanent disabilities in children annually [1,2]. Most of patients (50-80%) presenting to the ED with head trauma have minor head trauma [2,3,4]. The American Academy of Pediatrics (AAP) defined children with minor head injury as "those who have normal mental status at the initial examination, who have no abnormal or focal findings on neurologic examination, and who have no physical evidence of skull fracture" [2]. Also, in various studies, the term "minor head trauma" refers to cases in which children have Glasgow Coma Scale (GCS) scores of 14-15 [1,2,5]. The importance of minor head trauma lies not only in numbers but in preventable mortality, because >50% of all intracranial injuries occurred in patients who were awake and alert [2]. It is estimated that 16% of children with minor head trauma may have skull fractures, and the presence of a skull fracture is associated with a fourfold increased risk of an underlying intracranial injury [6].

Computed Tomography (CT) is the gold standard diagnostic test for diagnosing traumatic brain injuries and its sensitivity for diagnosing skull fractures is excellent [2,7]. Children are the group most frequently (15-70%) assessed in EDs in the United States and Canada for minor head trauma undergoes head CT scanning [8,9]. Over the past decade the use of CT for minor head injury has become increasingly common. Between 1995 and 2005, CT use more than doubled in the United States and Canada [1,10]. Less than 10% of CT scans in children with minor head trauma, however, show traumatic brain injuries [4]. The cumulative risks from ionizing radiation of CT scans are present, yet difficult to quantify [11,12]. Children are considerably more sensitive to radiation than adults due to rapidly dividing cells associated with growth. Since children have longer life expectancies, they have more opportunity to express radiation damage, particularly cancer [9,13,14]. The estimated rate of lethal malignancies from CT is between 1 in 1000 and 1 in 5000 pediatric cranial CT scans, with risk increasing as age decreases [14,15]. The increased use of CT adds substantially to health care costs [6,16]. In addition, CT imaging of young children may require sedation, which carries risks including hypoxia, apnea, prolonged depressed level of consciousness, and aspiration [2]. Ultrasound has been shown to be an accurate instrument for fracture diagnosis such as ankle, wrist, and forearm fractures as well as nasal, zygomatic arch, sternal, rib, and clavicle trauma [16,17,18,19,]. Also, ultrasound is well tolerated by children, even in areas of injury [20,21]. A limited number of studies date have specifically compared ultrasound to CT for the detection of skull fractures in children with minor head trauma. The aim of this study was to evaluate the diagnostic value of ultrasonography in detecting skull fractures in children with minor head injury compared with CT as the reference method.

Material and Methods

All patients provided informed consent to participate in the study. This study was approved by the Ethics Committee of the University of Medical Sciences.

The present study was a prospective cross-sectional observational study that was conducted over a six month period in Emergency Department of Shahid Beheshti Educational Hospitals, Tehran, Iran. In this review, clinical ultrasound in the diagnosis of skull fracture, 320 children under 14 years with minor trauma the head, was used. Patients with hemodynamic instability, age more than 14 years, open deformity or the need for surgery and interventions such as intubation were excluded from our study. Initially, ultrasonography was performed by Emergency Physicians in children under 14 years who had a minor head injury. Emergency Physicians were blind to the clinical scenario. A cranial CT scans was performed on the patients by radiologists. Radiologists were not aware of ultrasound findings at the time of their dictation. Patient history, injury mechanism, and symptoms and signs were recorded on a standardized data form by Emergency Physicians. The research study protocol did not interfere with the clinical care of enrolled patients. The sonologist recorded a real-time interpretation of the ultrasound as either positive or negative for a skull fracture on the data collection sheet. The ultrasound results were compared to the results of head CT scans (which are considered the gold standard for diagnosing skull fractures) for sensitivity, specificity, positive predictive value, and negative predictive. Sensitivity was calculated using the following formula (TP, true-positive results; FN, false-negative results):

Sensitivity = TP/ (Tp + TN)

Specificity was calculated using the following formula (TN, true negative results; FP, false-positive results):

Specificity = TN/ (TN+FP)

Positive predictive value (PPV) and negative predictive value (NPV) were calculated using:

Positive predictive value (PPV) = TP/ (TP+FP)

Negative predictive value (NPV) = TN/ (FN+TN)

Continuous variables were expressed as mean ± standard deviation and categorical values were expressed in relative frequency. The SPSS 21 computer software program (SPSS Inc., Chicago, IL) was used for statistical analysis. P>0.05 was considered as non-statistically significant. The χ^2 test was applied to the data to assess statistical significance.

Results

320 patients (120 males and 32 females) were evaluated in this study. The age range of the study population was from 24 days to 14 years with average of 4.73 ± 3.29 years. The most common injury mechanism of trauma in the patients was traffic accidents involving: pedestrian car accident (n=49, 45.37%), motorcycle accident (n=27, 25%), car accident (n=14, 12.96%), pedestrian motorcycle accident (n=10, 9.26%) and car rollover (n=8, 7.41%). The others were falling (n=108, 33.75%) and collision with a hard object (n=70, 21.87%) (Table 1). Among the 320 patients studied, 304 (95%) had a score of >14 on the Glasgow Coma Scale, and 16 (5%) had a score of <14. Hematoma or ecchymosis was observed in 264 (82.5%) patients. Cranial fractures were seen on the CT scan in 28 (8.75%) of the 320 patients; 292 (91.25%) CT scans were interpreted as normal. Emergency ultrasound performs with 85.71% sensitivity (95% CI 75.3-99.5%) and 100% specificity (95% CI 83.1-99.9%) when compared to CT scan for the diagnosis of skull fractures. The positive and negative predictive values of emergency ultrasound for cranial fractures in our study group were 100% (95% CI 81.6-100%) and 98.64% (95% CI 82.1-99.9%), respectively. Weighted Kappa was estimated 0.861 (95% CI 0.76-0.96).

Cause of Injury		**No. of Patient**	**Percent**
Traffic accident	Pedestrian Car Accident	49	45.37
	Motorcycle Accident	27	25
	Car Accident	14	12.96
	Pedestrian Motorcycle Accident	10	9.26
	Car Rollover	8	7.41
Falling		108	33.75
Collision with a hard object		70	21.87

Table 1: Mechanism of injury.

Discussion

The results of our study show that head ultrasound scans performed on pediatric patients with minor head trauma may be accurate in diagnosing skull fractures. In the present study, 320 patients with minor head trauma underwent ultrasonography and all the ultrasounds were evaluated by 1 radiologist. In this study, ultrasound technique demonstrated sensitivity and specificity rates of 85.71% and 100%, respectively. The positive and negative predictive values of emergency ultrasound for cranial fractures in our study group were 100% and 98.64%, respectively. In current study, head CT serves as the gold standard diagnostic test to evaluate for skull fractures and intracranial bleeding after head trauma. Computed tomographic scans confirmed the ultrasound findings. Only four patients of the 320 in our study were identified as being a false negative when the ultrasound and CT scan interpretations were discordant.

CT scan has become very common for evaluating skull fracture due to its advantage of visualizing acute intracranial pathology [22]. CT scans are the source of two thirds of the collective radiation from diagnostic imaging; an estimated one million children every year in the United States are unnecessarily imaged with CT scans [1]. There is growing concern that early exposure to ionizing radiation may result in a substantial rise in lifetime risk of fatal cancer. Brenner et al. [23] estimated that the lifetime cancer mortality risk attributable to the ionizing radiation to which a one-year-old child would be exposed through a single CT scan of the head was about 1 in 1500; they estimated the corresponding mortality risk for 10-year-olds as about 1 in 5000. In addition, Hall et al [24] recently reported that low doses of ionizing radiation to the brain in infancy may influence cognitive abilities in adulthood.

There are several potential advantages of using point-of-care ultrasound in the detection of skull fractures. First, ultrasound can be usually performed quicker than obtaining a CT scan, which can allow earlier detection of skull fracture as a marker for suspected intracranial injury and neurosurgical consultation [6,7,8]. Second, ultrasound could also potentially reduce the use of CT when the BUS shows no fracture underlying a scalp hematoma [4]. Children are also the most sensitive to the effects of ionizing radiation by CT scan. In addition, ultrasound can also be performed in young children without the need for sedation [25]. Ultrasound, in general, has been shown to shorten the length of hospital stay and to lower the cost of inappropriate studies [26].

The results of this study are in agreement with the findings of Parri et al. [8]. In that research, they studied 55 patients with minor head trauma and concluded that ultrasound is an accurate diagnostic tool with 100% sensitivity (95% confidence interval [CI] 88.2–100%) and 95% specificity (95% CI 75.0–99.9%) when compared to CT scan for the diagnosis of skull fractures. Positive and negative predictive values were 97.2% (95% CI 84.6–99.9%) and 100% (95% CI 80.2–100%), respectively.

Rabiner et al. [6] compared ultrasound and CT techniques in the diagnosis of skull fractures patients ≤21 years of age that presented to the emergency department with head injuries or suspected skull fractures. In that study, point-of-care ultrasound for skull fracture had a sensitivity of 88% (95% CI: 53%–98%), a specificity of 97% (95% CI: 89%–99%), a positive likelihood ratio of 27 (95% CI: 7–107), and a negative likelihood ratio of 0.13 (95% CI: 0.02–0.81). Finally, they introduced ultrasonography as a primary technique for the diagnosis of skull fractures in children with high specificity.

Riera et al. [11] have shown that ultrasonography can be used by pediatric emergency medicine physicians to detect skull fractures in children with closed head injury. In that study, ultrasound had a sensitivity of 82%, specificity of 94%, positive predictive value of 82%, and negative predictive value of 94%. Trenchs et al. [27] have shown that transfontanellar ultrasound is a valid and reliable alternative to CT for minor head trauma in infants with skull fractures. Its innocuousness and cost-effectiveness in comparison with CT makes it a good choice in this situation.

Conclusion

Ultrasound might be a reliable, fast, safe, and noninvasive initial diagnostic tool and Larger studies are needed to identify how best to incorporate ultrasound into clinical practice guidelines.

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