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

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Abstract: Bedside ultrasound has become a diagnostic tool that is commonly used in the emergency department. In trained hands, it can be used to diagnose multiple pathologies. In this case series, we describe the utility of ultrasound in diagnosing skull fractures in pediatric patients with scalp hematomas.

Key Words: head trauma, bedside ultrasound, skull fracture

(*Pediatr Emer Care* 2011;27: 312–314)

Decisions about neuroimaging in children presenting to the emergency department (ED) after a head injury are often challenging for the pediatric emergency physician. Signs and symptoms of intracranial injury (ICI) such as altered mental status, focal neurological findings, or loss of consciousness have been shown to be predictive of ICI,[1] but their absence does not exclude significant injury.[2] This is especially true in younger patients.[3] The presence of a scalp hematoma on examination in asymptomatic infants with a head injury has been shown to be predictive of skull fractures (SFs), and SFs have been shown to be correlated with ICI.[4] In addition, approximately 50% of patients with SF and ICI are asymptomatic.[5] It is this group of patients in which the clinician must manage the fine balance between the overuse of diagnostic imaging versus the potential for missing a significant ICI. Identifying SFs and associated ICI are also important to help prevent complications such as seizures and secondary brain injury, counsel parents, ensure long-term follow-up, and assess for child abuse. Even patients with SF in the absence of ICI need to be monitored for the development for leptomeningeal cysts.[2,6]

In children younger than 2 years, a consensus statement on the management of closed head injury includes the use of skull radiographs to identify patients with SF, the presence of which is a good predictor for ICI.[6] Skull radiographs are inexpensive and expose the patient to a small amount of radiation. However, they are difficult to interpret and may miss as many as 25% of SF.[7,8]

Computed tomography (CT) of the head is the diagnostic modality of choice for the symptomatic or high-risk patient because its sensitivity for diagnosing SF and ICI is excellent. Disadvantages for the use of CT scanning include cost, exposure to excessive and potentially harmful doses of radiation,[9,10] and the risk for sedation and monitoring outside the ED treatment areas. Obtaining a head CT scan in all asymptomatic patients may unnecessarily increase costs and risks and requires the clinician to seek an alternative approach to the management of patients with closed head injury.

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The authors have no financial disclosures or conflicts of interest.

ISSN: 0749-5161

A recent large study by Kupperman et al[11] derived and validated age-specific prediction rules for clinically important traumatic brain injury. The prediction rule for children younger than 2 years had 100% sensitivity and negative predictive value. Although useful clinically, one of the criteria for clinical clearance includes not having a scalp hematoma (except frontal). As shown in other articles, these scalp hematomas are known to be associated with SF and ICI.

Ultrasound is an imaging modality frequently used in the ED. It is an attractive alternative to CT scanning and radiographs in that it is reproducible, rapid, inexpensive, can be done at the bedside, and does not carry any risks of radiation. Ultrasound has been previously used in the pediatric ED in diagnosing bone fractures.[12–14] In this article, we present 6 cases where bedside ultrasound (BUS) was used to evaluate for SF in children.

TECHNIQUE

As with most scanning of superficial structures, imaging of the skull is best accomplished with a high-frequency linear probe set to a minimal depth. The entire area of interest under the hematoma should be scanned in 2 orthogonal planes. Copious amounts of gel can be used to minimize probe pressure and patient discomfort. The bony skull appears as a bright echogenic horizontal curvilinear structure. It should have no areas of discontinuity, except possibly over the cranial sutures. Knowledge of the appearance of cranial suture anatomy is important to understand the normal anatomy of the cranial bones because sutures can have a similar appearance to fractures.[14] Fractures appear as hypoechoic or dark defects in the bony cortex. If adjacent bony fragments are angulated, a possible displaced fracture is suggested. If a fracture is suspected, comparison with the contralateral side could help to differentiate from cranial sutures.

CASE 1

A 12-month-old female infant presented after falling off her father's shoulder onto the floor, hitting her head, and back. She cried immediately and had no loss of consciousness, vomiting, or seizures. On examination, she was playful, responsive, and in no distress. There was a 3- to 4-cm round hematoma over the left parieto-occipital region. A BUS showed a subgaleal hematoma with a defect in the linear contour of the skull. The contralateral side was normal (Fig. 1). A CT scan confirmed the oblique nondisplaced fracture and was negative for ICI (Fig. 2).

CASE 2

A 9-month-old girl fell from her parents' bed. Parents heard the thump and found her on the floor crying. There was no loss of consciousness or vomiting. She was easily consolable and acting her usual self thereafter. On examination, she was alert and playful. She had a significant hematoma on her right parietal scalp. There were no other signs of trauma, and she had a normal neurological examination result. A BUS showed a scalp hematoma without underlying fracture. Head CT scan confirmed no fracture or ICI.

CASE 3

A 2-year-old otherwise healthy girl presented after an unwitnessed fall of 10 to 15 ft onto a hardwood floor. She was found crying and had no vomiting or changes in behavior. On examination, she was sleepy but arousable to name and pain, and her examination was significant for obvious swelling of the left temporoparietal area. A BUS showed a break in the contour of the skull under the area of swelling. A CT scan confirmed a nondepressed parietal SF. In addition, she was found to have punctate areas of contusion in the bilateral parietal lobes.

CASE 4

A 15-month-old boy presented 20 hours after a fall from the bed onto a carpeted floor during a diaper change. He was asymptomatic. On examination, he had a large fluctuant hematoma overlying the left parietal skull, which his parents reported had been increasing in size since the injury. A BUS showed a nondepressed fracture in the left parietal area. A CT was done, and the scan showed a nondisplaced left parietal bone fracture with a very small underlying left epidural hemorrhage.

CASE 5

A 9-month-old male infant with no past medical history presented after a witnessed 2.5-ft fall onto a carpeted floor. He cried immediately with no loss of consciousness or seizure activity. He initially had no emesis and tolerated food in the afternoon but subsequently vomited once. He had been acting at baseline, moving all extremities. Examination revealed a 2-cm hematoma of the left parietal area, which was very tender to palpation. No step-offs were noted beneath the hematoma. A BUS showed a break in the cortex of the skull in the left parietal area. A CT scan showed a minimally displaced fracture of the left parietal bone with overlying hematoma and no evidence of acute intracranial hemorrhage.

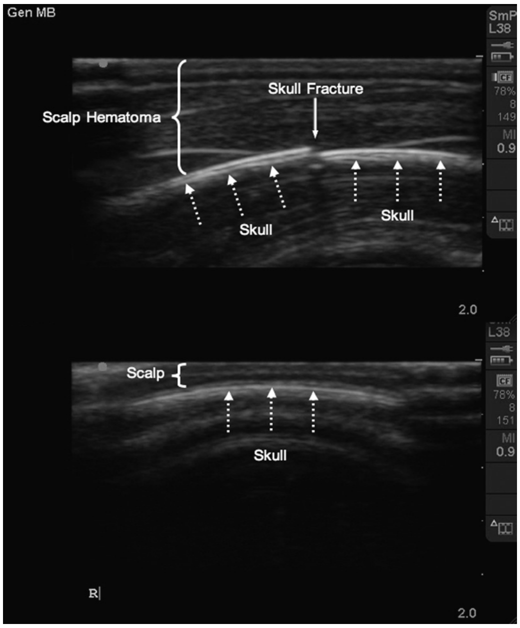

FIGURE 1. A high-frequency linear probe (MicroMaxx; SonoSite, Bothell, Wash) is used to scan a child's skull. In the upper ultrasound image, the solid white arrow points to a break in the cortex of the skull, which is identified by the dotted arrows. Note also the overlying hematoma, visible as a hyperechoic area that follows the contour of the skull and increases the distance between the probe and the skull. The normal contralateral side is shown below for comparison.

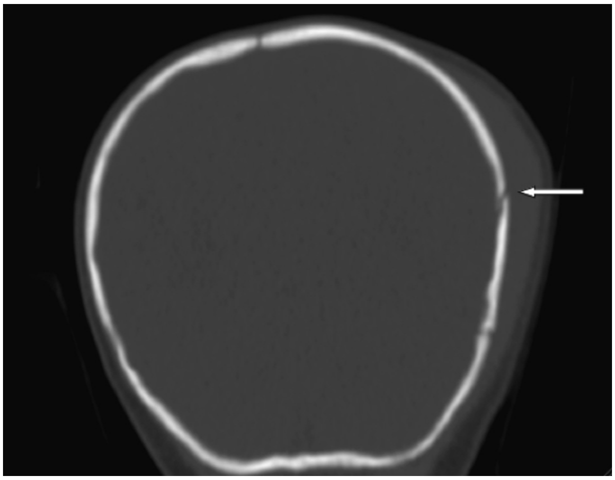

FIGURE 2. A coronal slice of the CT scan showing the nondisplaced oblique fracture (solid white arrow).

CASE 6

A 6-month-old female infant was brought to the ED by her parents after rolling back from a seated position and hitting her head against the corner of a chair. The patient had been completely asymptomatic and behaving appropriately. Her examination was remarkable for right parietal scalp edema and tenderness. A $4 \times 4\text{-cm}^2$ nonboggy parietal hematoma was present. A BUS showed a hypoechoic break in the contour of the skull consistent with a fracture. A subsequent head CT scan showed a right parietal fracture with a small subarachnoid hemorrhage.

DISCUSSION

Ultrasound is a useful tool in the evaluation of patients in the ED. It is reproducible and safe and can be learned by emergency physicians. It is taught in emergency medicine residencies and pediatric emergency medicine fellowship programs.[15] The use of BUS to assess for bony injuries in the pediatric ED has been shown.[12–14]

This case series describes 5 patients with head trauma whose SFs were apparent on BUS, and 1 case in which BUS correctly ruled out a SF. In all cases, the area under the hematoma was scanned, and in 5 cases, a fracture was identified, suggesting a correlation between hematoma and fracture location. Computed tomographic scans confirmed the BUS findings. The correlation of hematoma and SF in asymptomatic children younger than 2 years has been supported by the literature.[4,5]

There are 3 potential roles of BUS in the identification of SF: replacement of skull radiographs, rapid identification of SF prompting expedited management, and ruling out a SF and hence potentially eliminating the need for CT. First, BUS could potentially replace the use of skull radiographs in assessing for fractures. The role of radiographs in assessing for fracture is controversial as the sensitivity is poor, missing up to 25% of SF.[8] The patients in this case series did not have skull radiographs performed as part of their workup, so we are unable to comment on how BUS compares to skull radiographs. Also, the diagnostic performance of BUS was not assessed, so the sensitivity and specificity in identifying SF are unknown. Studies comparing

BUS to skull radiographs are needed, and if shown to be comparable or superior, BUS would be preferable as an initial imaging modality because it is faster, nonradiating, and does not involve transport of the patient out of the ED.

Second, rapid identification of SF is of great benefit to the emergency physician. It has been shown that children with SF are at a higher risk for ICI and that ICI in the absence of SF in the pediatric population is rare.[5] Having this information rapidly in the ED could prompt for closer monitoring and earlier CT, intervention, consultation, and disposition.

Clinicians must understand the clinical applications and limitations of this imaging modality. Although it may be useful in documenting the presence of SF, there is currently no role for US in determining the presence or absence of ICI. In patients with a documented SF and any concern for ICI, CT scans remain the imaging modality of choice. Also, ultrasound use in this case series was limited to patients who presented with a scalp finding. In patients without scalp findings, an ultrasound might have limited value. It is important to remember that patients without a hematoma might still have an occult ICI, especially infants younger than 3 months.[5] A BUS has limited utility in the evaluation of suspected child abuse, which should follow current imaging protocols.[16]

Last, BUS could also potentially reduce the use of CT when the BUS shows no fracture underlying a scalp hematoma. This would avoid the monitoring and sedation required to complete CT scans, decrease in potentially harmful radiation exposure,[9,10] and likely reduce cost. In only 1 patient (case 2) was BUS used to rule out a SF. Again, it is not known how sensitive BUS is in ruling out SF, and studies need to be done to assess the role of ultrasound in pediatric head trauma.

CONCLUSIONS

Ultrasound could potentially be used to diagnose and rule out SFs in pediatric patients with head injury and might be a reliable, fast, safe, and noninvasive initial diagnostic tool with which to assess patients with scalp hematomas. Further studies are required to identify how best to incorporate ultrasound into clinical practice guidelines.

REFERENCES

1. Quayle KS, Jaffe DM, Kuppermann N, et al. Diagnostic testing for acute head injury in children: when are head computed tomography and skull radiographs indicated? *Pediatrics*. 1997;99:E11.
2. Gruskin KD, Schutzman SA. Head trauma in children younger than 2 years: are there predictors for complications? *Arch Pediatr Adolesc Med*. 1999;153:15–20.
3. Greenes DS, Schutzman SA. Occult intracranial injury in infants. *Ann Emerg Med*. 1998;32:680–686.
4. Greenes DS, Schutzman SA. Clinical indicators of intracranial injury in head-injured infants. *Pediatrics*. 1999;104:861–867.
5. Greenes DS, Schutzman SA. Clinical significance of scalp abnormalities in asymptomatic head-injured infants. *Pediatr Emerg Care*. 2001;17:88–92.
6. Schutzman SA, Barnes P, Duhaime AC, et al. Evaluation and management of children younger than two years old with apparently minor head trauma: proposed guidelines. *Pediatrics*. 2001;107:983–993.
7. Lloyd DA, Carty H, Patterson M, et al. Predictive value of skull radiography for intracranial injury in children with blunt head injury. *Lancet*. 1997;349:821–824.
8. Chung S, Schamban N, Wypij D, et al. Skull radiograph interpretation of children younger than two years: how good are pediatric emergency physicians? *Ann Emerg Med*. 2004;43:718–722.
9. Brenner D, Elliston C, Hall E, et al. Estimated risks of radiation-induced fatal cancer from pediatric CT. *AJR Am J Roentgenol*. 2001;176: 289–296.
10. Brenner DJ. Estimating cancer risks from pediatric CT: going from the qualitative to the quantitative. *Pediatr Radiol*. 2002;32:228–233; discussion 242–244.
11. Kupperman N, Holmes, JF, Dayan PS, et al. Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. *Lancet*. 2009;374:1160–1170.
12. Patel DD, Blumberg SM, Crain EF. The utility of bedside ultrasonography in identifying fractures and guiding fracture reduction in children. *Pediatr Emerg Care*. 2009;25:221–225.
13. Chen L, Kim Y, Moore CL. Diagnosis and guided reduction of forearm fractures in children using bedside ultrasound. *Pediatr Emerg Care*. 2007;23:528–531.
14. Williams H. Lumps, bumps and funny shaped heads. *Arch Dis Child Educ Pract Ed*. 2008;93:120–128.
15. Ramirez-Schrempp D, Dorfman DH, Tien I, et al. Bedside ultrasound in pediatric emergency medicine fellowship programs in the united states: little formal training. *Pediatr Emerg Care*. 2008;24:664–667.
16. Section on Radiology, American Academy of Pediatrics. Diagnostic imaging of child abuse. *Pediatrics*. 2009;123:1430–1435.