Diagnosis and Guided Reduction of Forearm Fractures in Children Using Bedside Ultrasound

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Background: Forearm fractures are common injuries in children. Displaced and angulated fractures usually require reduction. Ultrasound diagnosis and guided reduction offer several potential advantages: (1) the procedure does not involve ionizing radiation; (2) compared with fluoroscopy units, the newer ultrasound units are more portable; and (3) repeated studies can be obtained easily and quickly.
Objective: The primary objective was to investigate the accuracy of emergency department (ED) physician–performed ultrasound in the diagnosis and guided reduction of forearm fractures in children.
Methods: Children suspected of having forearm fractures were enrolled prospectively in an urban pediatric ED from June 2004 to November 2004. A bedside ultrasound of the forearm bones was performed by a pediatric emergency medicine physician. Ultrasound findings were compared with radiograph findings. Reductions were performed under ultrasound guidance. Postreduction radiographs were performed. Any need for further reduction was recorded.
Results: During the study period, 68 patients were enrolled. Radiographs revealed forearm fractures in 48 patients. Twenty-nine subjects had fractures of the radius alone; 17 had fractures of both the radius and the ulna, and 2 had fractures of the ulna alone. Ultrasound revealed the correct type and location of the fracture in 46 patients. The sensitivity for the detection of forearm fractures was 97% (95% confidence interval [CI], 89%–100%) using ultrasound. The specificity was 100% (95% CI, 83%–100%). Twenty-six subjects underwent reduction of their fractures in the ED. Two subjects required rereduction after the initial reduction. The initial success rate of ultrasound-guided reduction was 92% (95% CI, 75%–99%).
Conclusions: Bedside ultrasound performed by pediatric emergency medicine physicians is a reliable and convenient method of diagnosing forearm fractures in children. It is also useful in guiding the reduction of these fractures.

Key Words: emergency ultrasound, trauma, fractures

Pediatric emergency department patients often undergo radiographic studies to better delineate their injuries or disease processes. The past two decades have seen an exponential growth in the use of ionizing radiation, such as computed tomography and fluoroscopy. Although the ill effects of radiation from radiographs are not always readily apparent, recent evidence has suggested that levels of ionizing radiation previously thought safe may be associated with long-term effects on cognitive development and malignancy potential.[1,2]

Recently, the use of focused bedside ultrasound (US) performed by the clinician caring for the patient in the emergency department (ED) has become more widespread.[3] Acutely injured and ill children have also benefited from this technology.[4–7] Ultrasound offers several advantages over traditional radiographic techniques—many of which are especially relevant to pediatric patients. The technique is noninvasive, involves minimal contact, does not require the subject to remain motionless, and does not use ionizing radiation. It is an ideal modality for serial examinations involving disease processes without concern about cumulative radiation side effects. As bedside US equipment and training become more accessible, it may be possible to expand its use in the evaluation and management of sick and injured children.

Second only to the clavicle, the bones of the forearm are the most often fractured bones in children. Bedside US has been used in the diagnosis of long bone fractures in children.[8,9] Displaced and angulated fractures often require reduction. These reductions are usually performed in the ED under either regional nerve block or intravenous sedation. Reduction may be difficult, particularly when the positions of the fracture fragments are obscured by swelling of the arm. Repeated and prolonged attempts are frequently needed, increasing the likelihood of complications such as compartment syndrome. A portable fluoroscopy unit can be used during the reduction attempts. These instruments are large, cumbersome, and expensive, requiring shielding to minimize exposure to ionizing radiation for both patients and caretakers.

Ultrasound guidance during reduction attempt offers several potential advantages to fluoroscopy or blind reduction. The procedure does not involve ionizing radiation. Compared with fluoroscopy units, the newer portable US units are smaller and easier to set up in a crowded examination room. Ultrasound units are increasingly available for other applications in the ED, minimizing the need to purchase additional equipment. The study is performed at the bedside, eliminating the need to transport a sedated patient to a radiology suite. Dynamic images are provided throughout the reduction procedure, giving real-time visualization of the process. Repeated studies do not incur additional cost and can be performed relatively quickly.

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OBJECTIVE

We sought to determine the accuracy of bedside US diagnosis of children with suspected forearm injuries. Furthermore, we aimed to measure the success rate of reduction of forearm fractures with US guidance.

METHODS

Study Design

We conducted a prospective convenience sample study over a 7-month period from May 2004 to November 2004.

Setting

The setting was in an urban pediatric ED (PED).

Selection of Subject

Patients aged between 2 and 21 years presenting to the PED with suspected forearm fractures were enrolled when an investigator was available. Potential subjects were identified at triage. Children were excluded from the study if there was an open fracture, evidence of neurovascular compromise, or suspicion for associated elbow injuries. Informed consent was obtained from the guardian of the children.

Interventions

Before standard radiographs, an US was performed at the bedside in an attempt to diagnose the possible fracture. All US studies were performed using a Sonosite 180 (Sonosite Inc, Bothell, Wash). A high-frequency linear transducer, L38 (8–12 MHz; Sonosite Inc), was used to obtain the US images. Relevant portions of the study were recorded electronically. One investigator (L.C.) performed all the studies. The investigator obtained training in emergency US by taking an American College of Emergency Physicians–sponsored course. In addition, the investigator underwent hands-on training in the ED for 1 month.

Four views of the forearm bones were obtained. Longitudinal and sagittal views of the radius and ulna were obtained from the elbow to the wrist (Fig. 1). Interpretations of the findings were recorded immediately after the US was performed. Plain radiographs were performed, as was the standard of care. Efforts were made to perform the US studies before radiographs. However, patient care was not delayed for the purpose of the study. The decision for reduction was made by the attending physician in the PED, with the consultation of an orthopedic surgeon, based on the finding on plain radiographs. Reductions were performed by orthopedic surgeons under moderate sedation administered in the usual manner. Typical images are shown in Figures 2A and B.

FIGURE 1. Placement of probe on arm.

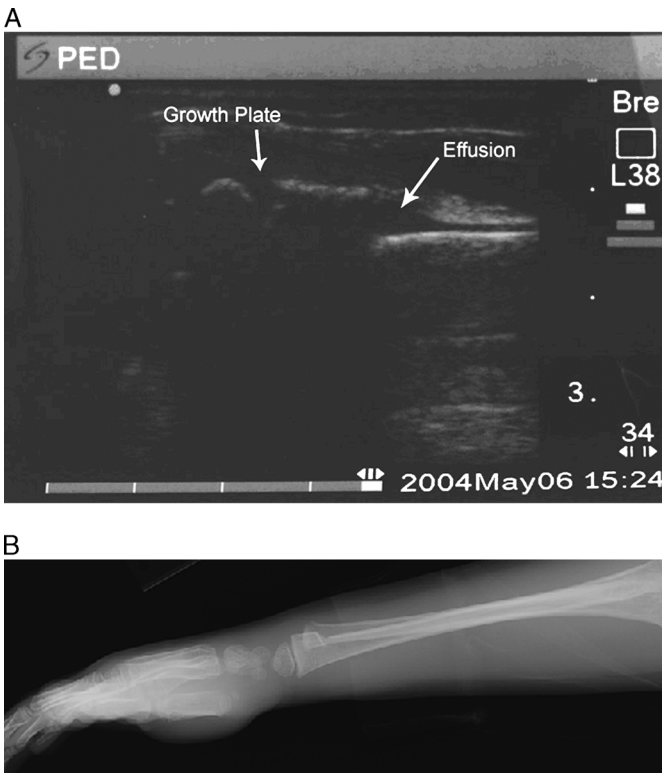

FIGURE 2. A, Ultrasound image in a child with radial metaphyseal buckle fracture. Note the appearance of growth plate and effusion. B, Corresponding radiograph of the same injury.

In patients who had fractures requiring reduction, US was used in place of fluoroscopy (or blind reduction) to guide the procedure. The alignment of the fracture fragments was assessed with US. The orthopedic surgeon performing the reduction was given visual feedback regarding the adequacy of the reduction throughout the attempt. The injury was splinted or casted when the surgeon determined that either the reduction was satisfactory or no further reduction was possible. Postreduction radiographs were performed, as was the standard of care. The surgeon had the prerogative, based on radiographic findings, to choose to revise the splint. The need for revision was recorded.

Primary Data Analysis

Final readings of the plain radiographs by attending radiologists were compared with the US interpretation by the

TABLE 1. Demographics of Subjects

Subject No.	68
Male subjects	41 (60%)
Mean age, yr	10
Subjects with fractures	48 (71%)
Radial fracture only	29
Ulnar fracture only	2
Both	17
Reduction in PED	26

investigators. Presence of angulation, displacement, and overlap (bayoneting) of the fracture fragments were compared using radiographs and recorded portions of the US. Sensitivity and specificity of US diagnosis of forearm fractures were calculated, using plain radiographs as the comparison standard. The success rate of US-guided reduction of these fractures was assessed. All statistical analyses were performed using SPSS Version 11.5 for Windows (SPSS Inc, Chicago, Ill).

RESULTS

During the study period, 68 patients were enrolled. Their demographic information is shown in Table 1. In all subjects, US studies were performed before radiographs being obtained. Radiographs revealed 65 forearm fractures in 48 patients. Twenty-nine subjects had fractures of the radius alone; 17 had fractures of both the radius and the ulna; 2 had fractures of the ulna alone (Table 1). Ultrasound revealed the correct type and location of the injury in 63 fractures in 46 patients. Based on the number of bones examined, the sensitivity for the detection of forearm fractures was 97% (95% confidence interval [CI], 89%–100%) using US. The specificity was 100% (95% CI, 83%–100%). In 2 subjects with fractures of both radial metaphysis and ulnar styloid, the US missed the ulnar styloid fractures. All US studies were performed in less than 2 minutes.

In 3 subjects where there was no radiological evidence of fractures, effusions were seen on US. Based on clinical findings, these children were diagnosed with nondisplaced Salter-Harris I fractures.

Twenty-six subjects underwent reduction of their fractures in the PED. Only 2 subjects required rereduction after the initial reduction, giving an initial success rate for US-guided reduction of 92% (95% CI, 75%–99%). None of the children in the study required reduction in the operating room.

DISCUSSION

The diagnosis and guided reduction of forearm fracture in children with US has been previously described.[8–10] Our study adds to the body of evidence on the use of this modality by enrolling a large number of patients with a variety of different injuries.

Using bedside US, pediatric emergency medicine physicians identified 97% of the forearm fractures. In the 2 cases where the injuries were not visualized on US, the fractures were ulnar styloid fractures. Both subjects also had radial metaphyseal fractures that were identified on US. Accordingly, the management of these patients was not altered because of the missed diagnoses.

Several children were diagnosed clinically to have nondisplaced Salter-Harris I fractures of the distal radius. Typically, these subjects had normal radiographs with clinical evidence of tenderness over the physis. Interestingly, small amounts of effusions were noted in these patients on US. Although the subject number was small, there is some evidence to suggest that US might offer additional evidence of subtle physeal injuries with small amounts of internal bleeding, which would have been difficult to visualize with plain radiographs.

LIMITATIONS

Ultrasound imaging of bones has some limitations. One significant limitation of this modality is that it is more suited for long bones. Although the humerus may be very amenable to US examination, we believed that it was not a suitable modality to evaluate for bony injuries in a complex joint such as the elbow. Therefore, we excluded children with suspected elbow injuries. Another disadvantage of ultrasonography is that it cannot be used once the cast material is applied. For the 2 cases where the reductions were repeated, it was probable that the fracture fragments moved after the cast material was placed. Furthermore, no data are available on the success rates of blind reduction or reduction under fluoroscopy. It is unclear whether US guidance offers superior results. Future randomized studies are needed to address this.

Because the US probe needs to make direct contact with the subjects, there was initial concern that it may cause the subjects additional pain. During the course of the study, it quickly became apparent that with care and liberal application of US transmission gel, it was easy to obtain high-quality images without applying significant pressure to the arm. No additional pain medications were needed for any of the subjects for the purposes of the US study.

CONCLUSIONS

Bedside US performed by pediatric emergency medicine physicians is an accurate and convenient method of diagnosing forearm fractures in children. It is also useful in guiding the reduction of these fractures.

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