Sonographic Diagnosis of Metaphyseal Forearm Fractures in Children

A Safe and Applicable Alternative to Standard X-Rays

Kolja Eckert, MD, Ole Ackermann, MD,† Bernd Schweiger, MD,‡ Elke Radeloff, MD,* and Peter Liedgens, MD**

Objective: Metaphyseal forearm fractures are very common in childhood. Radiography of the wrist is the standard diagnostic procedure. The aim of our study was to evaluate and confirm the safety and applicability of the ultrasound diagnostic procedure in comparison to x-ray diagnosis.

Methods: We investigated 76 patients aged between 1 and 14 years. After clinical assessment, patients with suspected forearm fractures first underwent ultrasound examination of the metaphyseal forearm followed by standard 2-view radiographs of the wrist. Ultrasound and radiographic findings were then compared, and sensitivity and specificity for ultrasound were calculated.

Results: Of 76 patients, we found 42 patients with 52 metaphyseal forearm fractures by x-rays. By ultrasound, we also diagnosed 52 fractures. All patients with no fractures were correctly diagnosed as well. Referring to x-ray, we calculated for ultrasound a sensitivity of 96.1% and a specificity of 97%. Comparing axis deviation of displaced fractures, we found a mean difference of 2.1 degrees between sonographic and x-ray values.

Conclusions: We confirm that ultrasound is an applicable and safe alternative tool to x-rays in nondisplaced or excluded metaphyseal forearm fractures in children.

Key Words: ultrasound, forearm fractures, standard x-rays

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Metaphyseal forearm fractures are very common in childhood. In many cases, they present as a nondisplaced or slightly displaced torus or compression fracture, and cast immobilization is the treatment of choice. Taking radiographs from the anteroposterior and lateral view of the wrist is still the criterion standard in fracture diagnosis. Diagnostic x-rays are the largest manmade source of radiation exposure to the general population, and the harmful effects of low-dose ionizing radiation are still debated. Thus, according to the ALARA (as low as reasonably achievable) principle, it is recommended to avoid or minimize the use of x-rays whenever it is possible. Therefore, especially in children, x-ray application is subject to strict review in every single case, because children are possibly more susceptible to the harmful effects of x-rays, because their bone tissues are proliferative.[1–7]

Recent studies[8–14] have shown the potential use of ultrasound in diagnosing juvenile fractures. In 1995, Rathfelder and Paar[9] described the possible application of ultrasound in diagnosing childhood fractures. In 2000, Williamson et al[10] diagnosed forearm fractures by ultrasound with a sensitivity and specificity of 100%, respectively, and Huebner et al[11] reached a sensitivity of 98.3% but a specificity of only 69.3% for sonographically diagnosed distal radius fractures. In 2006, Mack et al[12] calculated for ultrasound a sensitivity of 95% and a specificity of 100% for nondisplaced distal radius fractures. At least in 2010, Ackermann et al[13,14] reached a sensitivity of 94% and a specificity of 99% in juvenile forearm fractures. This group also conducted a comparative axis measurement of the radius in the anteroposterior direction and found a mean difference of only 1.6 degrees between sonographic and radiographic values.[13,14] Even ultrasound-guided reduction of pediatric forearm fractures with good results was reported by Durston and Seartzentruber,[15] Chen et al,[16] Wong et al,[17] and Chinnock et al.[18]

In our study, we compared the sonographic and x-ray-diagnoses of suspected metaphyseal forearm fractures to evaluate and confirm the safety and applicability of ultrasound in diagnosing these fractures under routine conditions of our pediatric emergency unit.

METHODS

From September 2009 to August 2010, we examined 76 patients aged between 1 and 14 years. Those patients were included with suspected distal forearm fracture defined by adequate trauma and appropriate clinical symptoms. Patients were excluded with open injuries, significant deformity, and neural and/or vascular lesions. After history taking and clinical assessment, patients at first underwent ultrasound examination. It was conducted with a 10-MHz linear array transducer from 6 standardized positions: longitudinal view of the radius and ulna from the radial/ulnar, dorsal, and palmar position as illustrated in (Fig. 1). After ultrasound examination, standard x-rays of the wrist from the anteroposterior and lateral view were taken. Existence of a fracture and fracture type diagnosed by ultrasound were noted and afterward compared with the x-ray diagnosis, independently reported on by a radiologist at a later date. The results were collected in a contingency table, and sensitivity and specificity of ultrasound in reference to x-ray were calculated.

The ultrasound examination took about 3 to 4 minutes and was safe and harmless without considerable strain or stress for the children. Patients and/or parents gave informed consent to participate in the study and the scientific use of the anonymized data. Each child was treated in the most appropriate way

From the *Department of Pediatric Surgery, Elisabeth Hospital Essen, Essen; †Department of Orthopaedics and Trauma Surgery, Klinikum Duisburg, Duisburg; and ‡Department of Radiology and Neuroradiology, University of Duisburg-Essen, Essen, Germany.

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Reprints: Kolja Eckert, MD, Department of Pediatric Surgery, Elisabeth Hospital Essen, Germany Klara-Kopp-Weg 1, 45138 Essen, Germany (e-mail: eckert.kolja@arcor.de).

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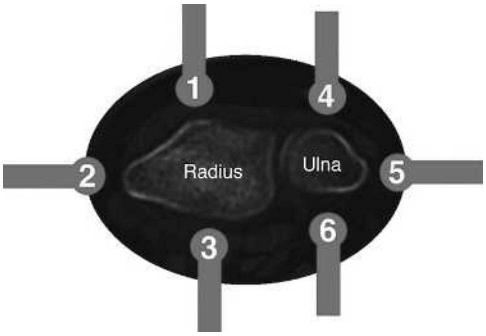

FIGURE 1. Transducer positions on the distal forearm.

according to their injury, as determined by their clinical and radiographic findings.

RESULTS

Seventy-six patients aged between 1 and 14 years were examined (mean age, 8.8 years; 39 male and 37 female patients). By x-ray, we found 42 patients with 52 metaphyseal forearm fractures. There were 31 isolated fractures of the radius (Fig. 2), including 2 Aitken-1 fractures (Fig. 3), 10 combined fractures of the radius and ulna (Fig. 4), and 1 isolated fracture of the ulna. By ultrasound also, 52 fractures were found, and all patients without a fracture were correctly diagnosed. All radiologically diagnosed isolated radius fractures were detected by ultrasound. Only 1 sonographically diagnosed radius fracture was not confirmed radiographically. Of 11 radiologically diagnosed ulna fractures, we diagnosed 9 also by ultrasound. The isolated ulna fracture was correctly diagnosed sonographically. But 2 concomitant ulna fractures that were diagnosed by x-rays were not seen sonographically. Moreover, we found 2 concomitant ulna fractures by ultrasound that were not confirmed by radiographs. Referring to x-ray, we calculated for the ultrasound method a sensitivity of 96.1% and specificity of 97% with a positive predictive value of 94.3% and negative predictive value of 97.9%. In 9 patients with significant (> 10 degrees) axis deviation, we comparatively measured its degree radiographically and by ultrasound. We found a mean difference of about 2.1 degrees (for example, see Fig. 5).

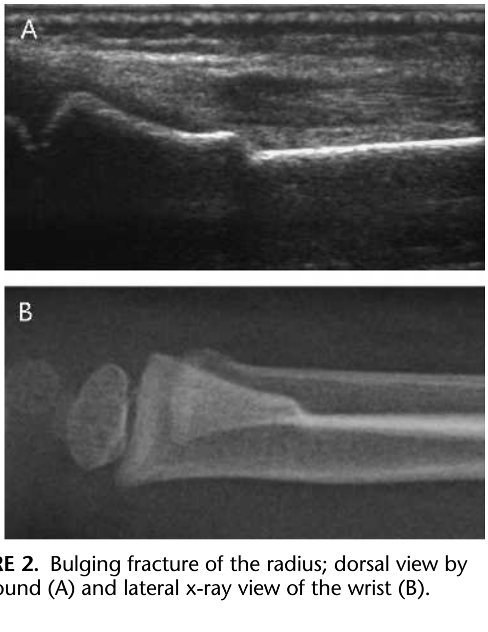

FIGURE 2. Bulging fracture of the radius; dorsal view by ultrasound (A) and lateral x-ray view of the wrist (B).

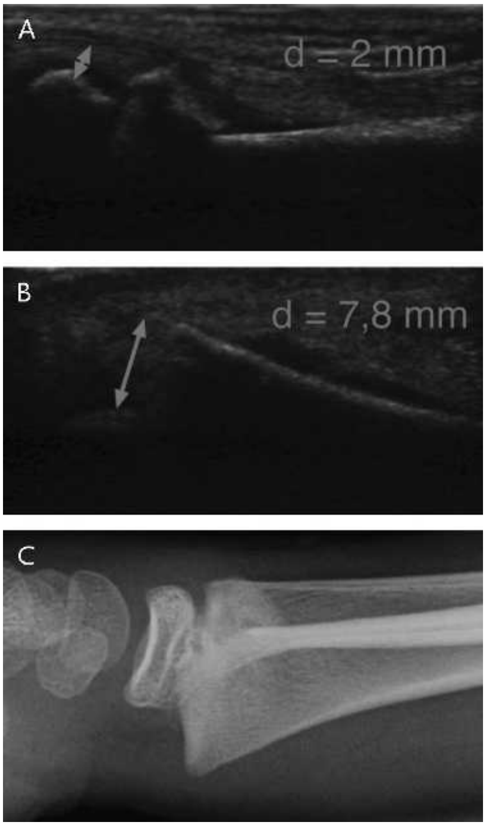

FIGURE 3. Aitken-1 fracture of the distal radius; dorsal (A) and palmar (B) view by ultrasound and lateral x-ray view (C).

DISCUSSION

Ultrasound examination was conducted with a linear scanner from 6 standardized positions (Fig. 1). Hereby, the proximal corticalis of the bone can clearly be identified as a bright white line because of total reflection of the ultrasound beam. The epiphyseal cartilage and plate appear anechoic to hypoechoic with the hyperechoic epiphyseal core in the center.

In our study, all radiologically diagnosed radius fractures and all patients with no fractures were correctly diagnosed by ultrasound. Even very discrete fractures could be visualized.

There were 5 patients differing in their sonographic and radiographic diagnosis. Thus, we took a second comparative review of every single case to elucidate the cause for the different diagnosis.

In case of 1 sonographically diagnosed torus fracture of the radius, which was not radiologically confirmed, we still needed to ascertain a minimal but typical torus deformation, indicating a fracture of the dorsal radius by ultrasound. The radiographs were not able to visualize the fracture because of overlayered dorsal ulnar and radial corticalis. Nevertheless, in combination with the history and clinical symptoms, it was interpreted as a fracture, and in this case, the treatment followed the ultrasound diagnosis.

The 2 sonographically misdiagnosed fractures were concomitant ulna fractures: 1 minimal torus fracture located on the radial edge of the ulna and 1 nondisplaced fracture of the processus styloideus ulnae. The radial edge of the ulna and ulnar edge of the radius were not routinely depicted in our study. But as recently published by Ackermann et al,[13,14] the standardized views can be supported by 4 oblique views from ulnodorsal and ulnovolar (for the ulnar edge oft the ulna) and from radiodorsal and radiovolar (for the radial edge of the ulna), and pathologic findings can be documented, if required.[1,2] In the second case of the fracture of the processus styloideus ulnae, the misdiagnosis is caused by a noncomplete visualization/documentation of the epiphyseal and articular part of the ulna. But as part of a learning curve, we expect that this failure could be eliminated in future examinations.

In contrast, by ultrasound, there were 2 concomitant ulna fractures diagnosed showing the typical cortical torus deformation, which could not be visualized by radiographs. In the first case, the radiographs were not able to visualize the fracture because of a nonexact lateral view of the wrist, so the dorsal corticalis was not fully depicted. In the second case, a nonexact lateral view of the wrist is combined with overlayered radial and ulnar corticalis, so the ulnar lesion could not be visualized.

As stated by Ackermann et al[13,14] and also confirmed by our observation, ultrasound is not painful, and metaphyseal fractures could be easily seen by their disrupted or bulged corticalis. Even reliable estimation of displacement seems to be possible by ultrasound, which needs to be verified by further studies. In 9 patients, we measured axis deviation of the fractured forearm comparatively by ultrasound and x-ray and found a mean difference of 2.1 degrees, so grossly displaced fractures could be reliably detected by ultrasound and for now were taken to standard x-ray examination to determine further therapeutic procedure.

Alzen et al[1] already referred to the high discrepancy between the number of taken radiographs in children with suspected fractures and at last identified fractures. In our study, 34 patients (44.7%) indeed presented without a fracture. Considering these patients and because of the high prevalence of uncomplicated metaphyseal forearm fractures, ultrasound could lower radiation burden in children significantly.

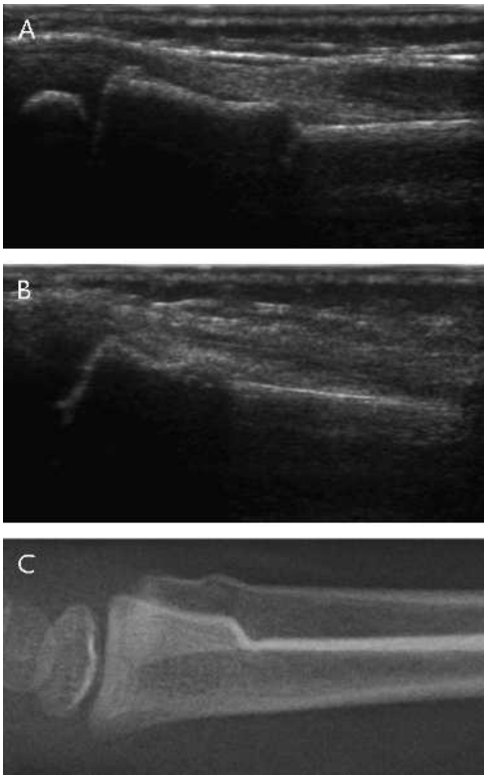

FIGURE 4. Bulging fracture of the radius and ulna; dorsal view of the radius (A) and ulna (B) by ultrasound and lateral x-ray view of the wrist (C).

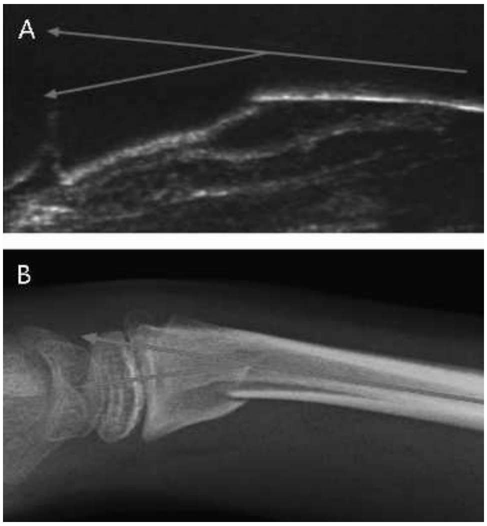

FIGURE 5. Axis measurement by ultrasound (16.4 degrees) (A) and x-ray (17.41 degrees) (B).

Ultrasound as a dynamic examination allows single visualization of the radial and ulnar corticalis avoiding overlayering of bones commonly seen in radiographs. In problematic cases, ultrasound allows the comparative examination of the healthy contralateral wrist, avoiding additional ionizing radiation. Under circumstances of our pediatric emergency unit, ultrasound accelerates the diagnostic procedure, because it is done immediately after clinical assessment, avoiding another waiting period to do the x-ray-examination.

CONCLUSIONS

Ultrasound is a reliable and convenient method in evaluating suspected metaphyseal forearm fractures in children. In nondisplaced or excluded fractures, ultrasound is capable of replacing radiographic imaging. Grossly displaced fractures could be reliably identified and taken to standard x-ray examination without much loss of time. Therefore, we suppose ultrasound possibly accelerates the diagnostic procedure and lowers the x-ray burden in children significantly and maybe costs if an ultrasound device is in existence.

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