Cite as: Mobasseri A, Noorifard P: Ultrasound in the diagnosis of pediatric distal radius fractures: does it really change the treatment policy? An orthopedic view. J Ultrason 2022; 22: e179–e182. doi: 10.15557/JoU.2022.0029.

Submitted: 07.01.2022
Accepted: 31.01.2022
Published: 11.07.2022

Ultrasound in the diagnosis of pediatric distal radius fractures: does it really change the treatment policy? An orthopedic view

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DOI: 10.15557/JoU.2022.0029

Keywords
pediatric; ultrasound; distal radius fracture; forearm fracture

Abstract

Background: Distal radius fractures are the most common pediatric fractures, increasing in number in recent decades. Although simple bi-planar radiographs are sufficient for diagnosis, wrist ultrasonography has been popularized in recent years for fracture detection, mostly because of the concern about children's radiation exposure. Despite its availability and diagnostic accuracy, ultrasound has not gained widespread acceptance and popularity among orthopedic surgeons. We asked about the reasons for its lack of acceptance as a diagnostic tool by orthopedic surgeons, and its failure to be incorporated into diagnostic algorithms. **Material and methods:** We reviewed the latest articles concerning the use of ultrasound in the diagnosis of pediatric distal radius fracture. Data extraction was performed from each study with a focus on the following items: the specialty field of the authors, number of patients, number of fractures, mean age of the patients, and the gold standard method of diagnosis. **Results:** Nine studies concerning the diagnostic accuracy of ultrasound in detecting distal radius fractures in children were included in the review. The most common field of practice of the authors was emergency medicine. Only two studies had an orthopedic surgeon among their authors. All studies employed X-ray imaging as the gold standard method. All studies were designed as prospective trials without randomization of patients. Generally, there was no independent blinded reviewer for the interpretation of ultrasound and X-ray images. **Conclusions:** Most studies were completed by emergency medicine physicians, without involving an orthopedic surgeon. Ultrasound evaluation was undertaken primarily by emergency medicine physicians with little experience. These studies were not randomized controlled trials, and knowledge of the history and clinical presentation of the subjects could have led to information bias. The relatively low number of included patients and lack of follow-up examinations were other limitations. As a result, we believe that ultrasound has not proven to be a suitable substitute for conventional X-ray imaging in the detection of pediatric distal radius fractures. We propose X-ray evaluation as the clinical gold standard method for pediatric wrist fractures.

Introduction

Distal radius fractures are the most common pediatric injuries, with increasing rates in the recent years as a result of earlier participation in sporting activities, increased rates of childhood obesity, and widespread osteomalacia.

The mechanism of fracture is usually a simple fall on an outstretched hand causing either dorsal or volar angulation, however direct trauma to the extremity could also cause such deformity. Compared to adults, softer bone and thicker periosteum in children create unique fracture patterns in this age group. Fractures of the distal radius in children are generally classified into four types: buckle fracture, greenstick fracture, growth plate fracture, and complete fracture. Ligamentous avulsion injuries of the wrist have also been proposed as a separate category by the AO foundation[1].

The diagnosis of distal radius fracture is usually based on history taking, physical examination, and conventional

wrist radiographies. However, a concept of using ultrasound for the detection of distal radius fracture as a substitute for conventional X-ray imaging has also evolved in recent decades. Ultrasound has some advantages over conventional radiography, including lower cost, higher availability, and being radiation free[2]. It is a dynamic diagnostic method which allows visualization of both radial and ulnar cortices, thus avoiding the overlapping of bones. Its real-time images of bone and soft tissue at different angles could easily detect any cortical disruption and subperiostal hematoma. It also gives the opportunity of contralateral wrist examination in controversial cases. In the pediatric population, conventional X-ray might be inadequate with buckle and Salter-Harris I fractures, while ultrasound had shown diagnostic superiority. The mobility of ultrasound machine is another advantage, facilitating bedside examination for multiple-trauma patients even in the non-hospital settings.

Although recent studies have reported high precision of ultrasound imaging in detecting distal radius fractures, it has not gained widespread clinical use and acceptance among orthopedic surgeons. Here, we look as an orthopedic surgeon at the results of previous studies concerning the origin of such reports and their failure to be incorporated into diagnostic algorithms despite their rational solutions. We also discuss the reasons for the popularity of conventional wrist radiographies and latest efforts on the reduction of radiation exposure as the most concerning point of X-ray imaging.

Material and methods

The PubMed/MEDLINE, Web of Science and the Cochrane Library databases were searched for studies concerning the diagnosis of distal radius fractures in pediatric patients by using ultrasound, from January 2011 to September 2020. To identify eligible studies, MeSH headings and key words were combined as follows: (ultrasonography or ultrasound imaging) + (children or pediatrics or juvenile) + (distal radius or forearm or wrist fractures). We also supplemented the results by manually reviewing the reference lists of all the retrieved studies. In the next step, the studies which included the reduction of the deformity by ultrasound were excluded. We also eliminated systematic reviews, non-English articles, and publications on other long bone fractures.

Data extraction from each study was performed with a focus on the following items: the specialty field of the authors, number of patients, number of fractures, mean age of the patients, and the gold standard method of diagnosis.

Results

Nine studies devoted to the diagnostic accuracy of ultrasound in detecting distal radius fractures in children were included in the review. The most common field of practice of the authors was emergency medicine. Only two studies had an orthopedic surgeon among their authors. All studies implanted X-ray imaging as the gold standard method. All studies were designed as prospective trials without randomization of patients. Generally, there was no independent blinded reviewer for the interpretation of ultrasound and X-ray images. Table 1 lists the characteristics of the studies on the application of ultrasound for the diagnosis of pediatric distal radius fractures.

Discussion

In this study, we reviewed recent articles concerning the use of ultrasound imaging in detecting distal radius fractures in children. We aimed at reviewing those articles in more detail beside the accuracy of the new detection method. Primary results showed that most trials were conducted by emergency medicine physicians, without involving an orthopedic surgeon. Ultrasound evaluation was mostly undertaken by emergency medicine physicians with little experience. The studies were not randomized controlled trials, and knowledge of the history and clinical presentation of the subjects could have led to information bias. The relatively low number of included patients and lack of follow-up examinations were other limitations. Even though X-ray was used as the gold standard, distal radius fractures could be missed by X-ray evaluation due to under-mineralized physis, overlapping structures, and non-perpendicular

Tab. 1. *Characteristics of studies concerning the use of ultrasound imaging for the diagnosis of pediatric distal radius fractures*

Study	Authors' field	Study design	No. of patients (No. of fractures)	Mean age (years)	Gold standard
Chaar-Alvarez *et al.*[3] (2011)	Pediatric emergency medicine	Prospective tertiary	101 (46)	10.3	X-ray
Eckert *et al.*[4] (2012)	Pediatric surgery	Prospective	76 (52)	8.8	X-ray
Herren *et al.*[5] (2015)	Orthopedic surgery Radiology	Prospective multicenter	201 (104)	9.5	X-ray
Poonai *et al.*[6] (2017)	Emergency medicine	Prospective	169 (76)	11	X-ray
Hedelin *et al.*[7] (2017)	Orthopedic surgery Radiology	Prospective	115 (75)	11	X-ray
Ahmed *et al.*[8] (2018)	Emergency medicine	Prospective	42 (30)	7.2	X-ray
Epema *et al.*[9] (2019)	Emergency medicine Clinical epidemiology	Prospective	100	9.5	X-ray
Laka *et al.*[10] (2019)	Pediatric emergency medicine	Prospective	115 (72)	9.1	X-ray
Ko *et al.*[11] (2019)	Sports medicine	Prospective	51 (34)	9.9	X-ray

beam to the fracture line. Similarly, ligamentous avulsion injures are not visible by X-ray, and thus the modality is a flawed reference standard which results in biased estimates of ultrasound accuracy. Due to lack of parameters for adequate reduction by ultrasound, the application of this modality is limited to the patients who do not need fracture reduction or surgical intervention. As a result, we believe that ultrasound has not proven to be a suitable substitute for conventional X-ray imaging in the detection of pediatric distal radius fractures. However, ultrasound performed by an experienced radiologist may still be used in those occult fractures with normal X-ray findings.

On the other hand, X-ray imaging has some advantages over ultrasound in pediatric patients. Young children do not need to show the exact location of pain, and an X-ray scan of the whole extremity is sufficient. Because of the children's higher sensibility to pain and fear, X-ray imaging could be all that is needed, eliminating any further diagnostic evaluations from the process in this patient group. These images are also quickly obtained, saved and ready for additional reviewing, and are not operator-dependent. The procedure does not require close contact to the injured limb and can be obtained in cases of open fracture or bandaged extremity. X-ray has a greater field of view for detecting associated carpal and metacarpal fractures. Due to the complicated nature of joint anatomy, ultrasound may not be as accurate as conventional radiology in the diagnosis of juxta-articular fractures[12]. X-ray parameters including volar tilt, radial inclination, and radial height are validated indices which determine the quality of joint restoration in cases where patients need reduction or follow-up visits.

Although conventional bi-planar X-ray imaging is generally considered as the gold standard, it could be argued that it has some limitations. Conventional X-ray imaging could detect torus, greenstick and complete fractures, but not probably all growth plate fractures. MR imaging could be considered as the gold standard in detecting those occult fractures, however its clinical use in distal radius fractures is neither necessary nor practical. Orthopedic surgeons typically challenge a clinically suspected scaphoid fracture in the same way. Patients usually describe radial-sided wrist pain after falling onto an outstretched hand causing wrist hyperextension. Combination of the three most precise physical examination tests (anatomical snuff box tenderness, scaphoid tubercle tenderness, and pain on axial compression of the thumb) makes the clinician suspicious enough to request initial wrist radiographies. However, initial radiography could only detect two-thirds of non-displaced scaphoid fractures. In cases of suspected scaphoid fracture where the initial radiographs are negative, the clinician could either request further imaging modalities including CT scan or MRI, or immobilize the wrist in a cast or splint for two weeks, followed by repeated clinical and radiological examination. This clinical example clearly shows the value of through history taking, clinical examination tests, and primary radiographies, accompanied by simple therapeutic methods including splinting or casting. In cases of non-angulated distal radius fractures in children, even though X-ray imaging is not the diagnostic gold standard, it could be considered as the clinical gold standard and standard of care for diagnosis and intervention. Generally, orthopedic surgeons immobilize the limb in cases of suspected or non-angulated distal radius fractures for three to four weeks without the need of follow-up radiography. Children with continued symptoms may be referred for MRI evaluation or simply continue immobilization.

Efforts have been made to reduce the amount of children's radiation exposure. The guidelines are now available for ankle and cervical spine injury. Recently, the Amsterdam Pediatric Wrist Rules have been developed and validated for the use of plain radiography in children with acute wrist injury. The guideline combines patient's demographic data with clinical findings including wrist swelling, deformity, tenderness, and motion restriction to select patients with acute wrist injury for radiographic evaluation. It has been shown that the implementation of the guideline has resulted in 15.3% wrist radiographies reduction, 34 minutes' time saving, and more than €200,000 in cost saving[13]. However, the guideline is not expected to replace the clinical experience and judgment of orthopedic surgeons.

There are some state-of-the-art strategies for those patients who are selected for further evaluation by radiography. The anatomical location of the wrist gives a unique opportunity for the use of out-of-field contact shielding and patients radiation protection. Lightweight double-sided lead aprons, thyroid shields as well as leaded glasses are now available in pediatric sizes, which ensures better radiation protection and improves patient comfort. Although the latest studies have shown little or no benefit of lead shielding for diagnostic radiology imaging[14], we believe that further studies are needed among pediatric patients, so we do not recommend the use of no-shield practice.

Other significant attempts have been made for radiation protection. The ALARA (as low as reasonably achievable) principle attempts to optimize radiation without reducing image quality. X-ray machine modifications – beside precise collimation, specific automated detectors, and accurate patient positioning – have also resulted in a reduction of radiation dosage. Technical regulations including pulsed radiation, removable scattered-radiation grid, and use of sighting device are also essential for lowering radiation levels[15]. The AO foundation recommends to position the X-ray source under the table and the intensifier above to decrease the amount of scattered radiation by half. It is also recommended to place the patient as close as possible to the intensifier and further away from the X-ray tube to reduce scattered radiation[16].

It is important to note that diagnostic X-ray imaging contributes 14% of total annual exposure worldwide and much of radiation exposure comes from background radiation including cosmic rays, radioactive rocks, and radioactive materials in food and water. It is estimated that a single-limb X-ray (less than 0.01 mSv) is equivalent to 1.5 days of natural background radiation and one-fourth of the equivalent dose of flying from one coast of the USA to the other

(0.035 mSv). A single-limb X-ray has the half equivalent dose of chest X-ray (0.02 mSv) and much less equivalent dose of pelvic X-ray (0.7 mSv)[17]. As stated by two professional medical societies, radiation risks below an individual dose of 50 mSv for single procedures or 100 mSv for multiple procedures are either too small to be observed or are nonexistent[18].

Conclusion

Although half of all pediatric patients with wrist trauma could have normal plain radiographs,[19] combination of detailed history taking, precise physical examination, careful patient selection for imaging, and involvement of an orthopedic surgeon who delivers the most suitable therapeutic plans even in the absence of positive radiographic findings, contributes to the best management of pediatric patients with distal radius fractures. No other imaging modality could ever substitute the clinical judgement of an orthopedic surgeon who manages the patient's current fracture and focuses on his/her future well-being.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organizations which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

Author contributions

Original concept of study: AM. Writing of manuscript: AM. Analysis and interpretation of data: AM. Final acceptation of manuscript: AM. Collection, recording and/or compilation of data: AM. Critical review of manuscript: AM, PN.

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