Accepted Manuscript

Submission Date: 2024-05-13
Accepted Date: 2024-10-14
Accepted Manuscript online: 2024-10-18

Ultraschall in der Medizin - European Journal of Ultrasound

Ultrasonography can be more informative than computed tomography in diagnosing radial head fractures. An illustrative case series.

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DOI: 10.1055/a-2445-3611

Please cite this article as: Schöll E, Jakob M, Vach W. Ultrasonography can be more informative than computed tomography in diagnosing radial head fractures. An illustrative case series. Ultraschall in der Medizin - European Journal of Ultrasound 2024. doi: 10.1055/a-2445-3611

Conflict of Interest: The authors declare that they have no conflict of interest.

This study was supported by Merian Iselin Forschung AG

Abstract:
Abstract

Purpose: Ultrasonography is increasingly being discussed as an alternative to X-rays in emergency department settings. Systematic comparisons of the two modalities are often based on using computed tomography as a reference. In diagnosing patients with elbow trauma, the physicians at our emergency department experienced that ultrasonography can be more informative than cone beam computed tomography in identifying radial head fractures. Our purpose is to share this experience with the scientific community.

Materials and Methods: All patients diagnosed with a radial head fracture in our emergency department between January 2021 and November 2022 were identified. The images of eighteen cases, in which both point-of-care ultrasonography and cone beam computed tomography had been used were reviewed by us. Eight examples were selected illustrating the variation in coincidence or discrepancy between ultrasonography and computed tomography.

Results: The eight examples illustrate that ultrasonography can be more informative than cone beam computed tomography or vice versa.

Conclusion: The joint application of ultrasonography and computed tomography is advisable if a correct diagnosis of the extent and components of radial head fractures is of uttermost importance.

Zusammenfassung

Ziel: Sonographie wird zunehmend als Alternative zur Röntgenuntersuchung in der Notaufnahme diskutiert. Systematische Vergleiche der beiden Modalitäten basieren häufig auf der Verwendung der Computertomographie als Referenz. Bei der Diagnose von Patienten mit Ellenbogentrauma haben die Ärzte in unserer Notaufnahme die Erfahrung gemacht, dass der Ultraschall bei der Erkennung von Radiusköpfchenfrakturen informativer sein kann als die Kegelstrahl-Computertomographie. Unser Ziel ist es, diese Erfahrung mit der wissenschaftlichen Gemeinschaft zu teilen.

Material und Methoden: Alle Patienten, bei denen in unserer Notaufnahme zwischen Januar 2021 und November 2022 eine Radiusköpfchenfraktur diagnostiziert wurde, wurden ermittelt. Die Bilder von achtzehn Fällen, bei denen sowohl Ultraschall als auch eine Kegelstrahl-Computertomographie angewandt worden waren, wurden von uns nachuntersucht. Acht Beispiele wurden ausgewählt, um die Variation in Übereinstimmung oder Diskrepanz zwischen Ultraschall und Computertomographie zu veranschaulichen.

Ergebnisse: Die acht Beispiele zeigen, dass die Ultraschalluntersuchung informativer sein kann als die Kegelstrahl-Computertomographie oder umgekehrt.

Schlussfolgerung: Die gemeinsame Anwendung von Ultraschall und Computertomographie ist ratsam, wenn eine korrekte Diagnose des Ausmaßes und der Komponenten von Radiusköpfchenfrakturen von größter Bedeutung ist.

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Ultrasonography can be more informative than computed tomography in diagnosing radial head fractures. An illustrative case series.

Introduction

Indirect elbow trauma is caused by a fall onto the extended arm, which results in spraining of the elbow joint. The axial force is transmitted to all three bones involved in the joint. In case of a resulting fracture or dislocation, patients usually hold the affected elbow and forearm fixed with the opposite hand, so that movement in the injured joint is avoided.

The elbow joint is easily accessible for sonographic examination [1–4]. In addition to the disruption of osseous surfaces, hemarthrosis in the anterior and posterior joint areas can also be diagnosed very easily [5]. Such a hemarthrosis corresponds to the so-called "fat pad sign" in the conventional lateral radiograph and is considered an indirect fracture sign.

X-rays (XR) are today the standard modality for the diagnosis of bone fractures in the lower or upper limbs in emergency departments (ED). However, point-of-care ultrasonography (POCUS) is a diagnostic alternative with some obvious advantages, especially in the ED setting. It does not require the patient to fix the bone of interest in a stable and uncomfortable position, allows to observe the bone and joints under movement by the patient or the sonographer, can be performed directly at bedside, and avoids the exposure to radiation. Indeed, in children POCUS is the standard modality for the diagnosis of bone fractures in the extremities, which is also supported by empirical evidence [6–8].

Recently, there has been increased focus on the role of POCUS in adult fracture detection, which is evident in overview papers, systematic reviews and guidelines [9–14]. A systematic review [10] still concludes that the current evidence is too limited to support the use of US as an initial diagnostic tool for fractures in adults.

When performing comparisons between XR and POCUS, computer tomography (CT) is typically used as reference standard. This choice reflects the implicit assumption that POCUS is not superior to CT. The case series presented in this paper tries to provide a more nuanced picture about the diagnostic information provided by POCUS and CT, respectively.

Elbow fractures are a specific group of fractures with high relevance for ED settings. The most common fracture among these injuries is a radial head fracture by far, as the axial force exerted by the capitulum humeri during indirect compression trauma leads to a bursting effect on the radial head. If there is no displacement of the radial head fragments, patients can still move the elbow to some extent. Often it is only later, after a hemarthrosis has formed, that significant limitations in mobility occur. As a result, patients frequently seek care in the ED hours later. In this emergency setting, an accurate diagnosis is essential for initiating appropriate treatment. Frequently, a conventional XR series of the Elbow (ap-/lateral-view and Norman view) is initially performed, and in cases of uncertainty, CT or magnetic resonance imaging is often employed.

In our ED, XR and/or US are routinely used as the primary diagnostic for all patients with indirect elbow trauma. The choice depends on the personal US-skills of the emergency physician in charge. In addition, often a cone beam CT (CBCT) is performed, if there are fracture signs visible in the US or XR. Plain radiographs and CBCT are evaluated routinely by the radiology department, whereas the US is evaluated directly by the emergency physician. This provided our ED staff with the opportunity to gain experience in the diagnostic utility of all three modalities.

Our emergency physicians noticed cases in which radial head fractures were just as clearly visible on US as on CBCT, while these fractures were not visible on XR (Fig. 1). In addition, they observed that US can be more informative than CBCT or vice versa the knowledge of the US image may change the interpretation of CBCT images. We decided to identify systematically cases illustrating these points in order to share this experience with the scientific community.

Methods

Sonographic examination

The sonographic examination of an injured elbow is performed in our ED as shown in Figures 2-4. The patient's forearm is comfortably positioned on a horizontal surface, with the elbow joint not resting on it. The images displayed depict the physiological conditions of an uninjured elbow. The fossa olecrani shown in Figure 2 contains no fluid in this case and appears sonographically hyperechoic. Figure 3a shows the circumference of the radial head in the short-axis view (SAX). If the pain situation allows, the hand of the affected arm can be rotated gently to observe whether the radial head moves within the annular ligament (Figure 3b). Figure 4 depicts the longitudinal position of the ultrasound probe (long-axis view, LAX), allowing assessment of both the radial head and neck. In this position as well, the hand can be rotated gently to visualize all sides of the radial head and neck.

Selection of patients for the case series

All 91 patients diagnosed in our ED with a radial head fracture between January 2021 and November 2022 have been identified. Forty-five patients were diagnosed using US, and 18 of these patients also received a CT-scan. The first author reviewed the US, XR and CBCT images of these patients and selected examples illustrating the variation in coincidence and discrepancy between US and CBCT. Ten patients were asked for consent to publish their image, and 8 gave their consent.

Structure of case descriptions

The routine description of the US findings by the emergency physician was compared with the routine description of the CBCT scan by the radiologist. In the following, for each patient we present first the diagnostic findings from US under the heading “US” and then report the coincidences and discrepancies with the routine description under the heading “r-CBCT”. In case a reevaluation of the CBCT performed by us in knowledge of the US findings allowed to confirm additional US findings, they are reported under the heading “CBCT+”. Completely new findings are noted under the heading “CBCT++”.

Case descriptions

Case 1 (Fig. 5): A 24-year-old patient who fell off his bike the day before and landed on his left arm. The left elbow was swollen and discoloured bluish. There was tenderness over the radial head, and limited pronation and supination of the hand. US: Pronounced fresh hemarthrosis in the olecranon fossa and bony contour disruption of the circumference of the radial head,

which, however, rotated easily in the annular ligament. In addition, a periosteal hematoma at the radial neck as a sign of fracture extension to the radial neck. r-CBCT: Only the fracture of the radial head but not that of the neck was diagnosed. CBCT+: Osseous step of the radial neck (red arrow in sagittal view).

Case 2 (Fig. 6): A 41-year-old patient fell off her bike 9 days ago and landed on her right elbow. X-rays taken on the same day at an external ED showed no pathology. Due to persistent pain and limited movement of the elbow, she presented to our ED. US: Distinct but already hypoechoic hemarthrosis in the olecranon fossa and 0.7 mm step in the circumference of the radial head, which rotated easily in the annular ligament. r-CBCT: Only a subcapital radial neck fracture was diagnosed without involvement of the articular surface (arrow in the sagittal view), which has not been seen in the US. CBCT+: Step in the circumference of the radial head (red arrow in the axial view).

Case 3 (Fig. 7): A 48-year-old patient was referred to our ED by a general practitioner after slipping and falling on her right arm. The painful right elbow had previously been X-rayed and found to be inconspicuous. The elbow showed no external abnormalities, but the joint mobility was slightly restricted in every direction. US: Pronounced hemarthrosis in the olecranon fossa and the coronoid fossa, as well as a chimney phenomenon and minimal osseous contour interruption of the circumference of the radial head. r-CBCT: Confirmation of the non-displaced intra-articular radial head fracture and joint effusion.

Case 4 (Fig. 8): The 38-year-old patient fell off his skateboard and landed on the right arm. The elbow showed no external injuries but was painful and movement-restricted in every direction. US: Pronounced hemarthrosis over the trochlea humeri and in the olecranon fossa, as well as minimal contour interruption of the circumference of the radial head with a small chimney phenomenon. r-CBCT: The diagnosis of a non-displaced intra-articular radial head fracture. CBCT++. Extension of the fracture into the radial neck (red arrow in the coronar view).

Case 5 (Fig. 9): The 77-year-old patient stumbled over a curb and caught herself with her left arm, resulting in an elbow extension deficit. She presented to our ED several hours later. US: Significant hyperechoic hemarthrosis in the olecranon fossa, as well as an irregularity of the radial neck. The circumference of the radial head was unaffected. r-CBCT: The subcapital, non-intraarticular fracture of the radial head was confirmed.

Case 6 (Fig. 10): The 63-year-old patient fell off her bicycle and caught herself with her left arm, resulting in increasing restriction of movement and pain in the left elbow. US: Hemarthrosis in the olecranon fossa, small step in the area of the collum radii and an undisplaced contour interruption of the circumference of the radial head. r-CBCT: Only the intraarticular fracture of the radial head could be confirmed, but it was described as mildly displaced and impacted. CBCT+: Fissure in the radial neck (red arrow in the coronar view).

Case 7 (Fig. 11): The 75-year-old patient slipped on wet ground and fell on her left side. Over the next few hours, she complained of increasing pain in her left elbow. Clinically, tenderness was found over the radial head, and mobility of the joint was restricted in every direction. US: Hemarthrosis in the olecranon fossa, as well as contour interruption of the radial head and step in the radial neck. r-CBCT: Slightly displaced subcapital extra-articular fracture of the radial head, as well as of the circumference. In addition, small bony avulsions from the radial epicondyle, as well as a lateral avulsion of the proximal ulna were noted (red arrow in coronar view), which were not seen in US.

Case 8 (Fig. 12): The 45-year-old patient fell off his bicycle and landed on his right side. Due to painful movement restriction in his right elbow, he came to our ED. Clinically, a contusion mark was found over the radial epicondyle of the humerus as well as tenderness over the head of the radius. Pronation and supination were painful and limited. US: Significant hemarthrosis in all planes, as well as a disruption of the contour of the circumference of the radial head without any disruptions of the radial neck. r-CBCT: A non-displaced subcapital extra-articular fracture of the head confirmed the US finding. In addition, the involvement of the neck of the radius could be diagnosed which was not seen in US (red arrows in coronar and saggital views).

Discussion

Accurate diagnosis of indirect elbow injuries is essential in the ED to initiate adequate initial treatment. If patients can still move the painful elbow, albeit with limitations, an initial diagnostic US can be quite useful. Ultrasound machines are typically available in most EDs today, and even inexperienced emergency physicians can easily diagnose hemarthrosis in the olecranon fossa through US. If such hemarthrosis is present, the intra-articular fracture should be consistently sought.

Barret et al. [4] have already demonstrated that immediate sonographic examination of traumatized elbows in EDs by orthopedic specialists is feasible. However, their case series primarily focused on injuries to ligamentous and tendinous structures, which are less relevant for initiating emergency treatment since conservative approaches are generally employed. The examination time in their study was relatively long, ranging from 24 to 30 minutes.

We, therefore, directed our attention to osseous injuries. Our case series highlights that in clinical routine of diagnosing elbow fractures POCUS can be more informative than CBCT or vice versa and that knowledge obtained from the US examination can help to interpret CBCT images correctly. Actually, in two patients POCUS was more informative than the routine description of the CBCT (cases 1 and 6), in two patients POCUS was less informative (cases 7 and 8), they were equally informative in 3 patients (cases 3, 4, and 5), and each modality made a contribution of its own in one patient (case 2). In addition, knowledge of US improved the interpretation of CT images in 3 patients (cases 1, 2 and 6).

This suggest that the joint application of US and CT is advisable if correct diagnosis of the extent and components of the fracture is of uttermost importance. This may apply in research settings. In the clinical setting, the most accurate diagnosis of fracture extent may be less relevant as the choice of treatment will usually remain conservative. Indeed, in none of the eight cases included in this case series, the clinical consequences would have been impacted by the choice of the diagnosing modality.

It is noteworthy, that in one of the 18 patients, a suspicion of a nondisplaced radial head fracture was raised in the routine report based on the CBCT finding, whereas neither hemarthrosis nor any other fracture signs could be depicted sonographically. Only in our retrospective analysis it was revealed that the subtle fracture lines in the CBCT were caused by significant motion artifacts during the examination. This highlights the advantage of POCUS of allowing an accurate examination of the elbow irrespective of its current movement. Furthermore, the joint can be comfortably positioned during the US examination. In addition, for a CBCT examination, the elbow joint needs to be almost fully extended, which can be associated with significant pain in cases of intra-articular fractures. US can be performed in the flexed position of the elbow, preferred by the patients. In addition to avoiding radiation exposure, these aspects should be taken into account in comparing the clinical value of both modalities.

However, an absolute prerequisite for sonographic examination is the precise anatomical and sonographic knowledge of emergency physicians. This requires corresponding educational efforts [10, 7].

With respect to the long-term perspective of using US to detect radial head fractures, the potential role of artificial intelligence (AI) has to be taken into account. Today, AI approaches for detecting fractures on radiographs are already widely available [15]. However, investigations with respect to combining AI techniques with sonography are still limited [16, 17]. This may reflect that the crucial issue with sonography is less the task of image interpretation but more the art of generating interpretable images. Furthermore, these two cited studies compare the reliability of AI-assisted US with conventional X-rays for paediatric radius fractures. CT-scans are less relevant in this group, as a radiation-sparing examination method is of utmost importance. Additionally, in the examination of wrist injuries, US can be performed with the forearm completely immobilized. Pronation and supination, as required in our investigations, are not necessary in this context.

To date, there is no reliable study on the use of AI in the US-examination of radial head fractures.

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