RESEARCH ARTICLE

Bedside Ultrasonography for Early Diagnosis of Occult Radial Head Fractures in Emergency Room: A CT-Comparative Diagnostic Study

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Abstract

Background: Some of the Mason type I fractures cannot be detected on early radiographic images. These occult fractures are considered as a diagnostic challenge for physicians. Our aim was to determine the value of bedside ultrasonography for the detection of Mason I radial head fractures that are non-visible in early X-ray's.

Methods: A prospective blind single-center diagnostic study was conducted (from June 2012 till May 2013) concerning 23 patients who were clinically suspicious of having a radial head fracture. These patients were evaluated with a bedside high frequency ultrasound in the Emergency Room (E.R.). The two sonographic criteria that were considered to be diagnostic for fracture were: a. effusion besides the radial head-neck and b. cortical discontinuity of the radial head or neck. All patients also underwent a Computed Tomography (CT) as the gold standard imaging modality for diagnosis of occult radial head fractures.

Results: Fifteen out of 23 patients were diagnosed with radial head fracture using both ultrasound and CT. On the other hand, there were three patients with negative ultrasound and positive CT, in addition two patients were found positive in the ultrasonographic exam, while this result was not confirmed by the CT scan. In comparison with CT, ultrasound exam appeared to have 83.3% sensitivity, 60% specificity, 88.2% positive prognostic value and 50% negative prognostic value (when at least one diagnostic sonographic criterion was positive). The accuracy of the sonographic study for the diagnosis of the aforementioned fractures was 78.2%. Effusion in contact with the radial neck was the most sensitive sonographic sign (14/15 of the true positive radial head ultrasounds).

Conclusion: Bedside ultrasound in the E.R. was proven to be a sensitive tool for early (day-1) diagnosis of the occult radial head fractures. It could be used as an adjacent imaging modality in patients suspicious for radial head fracture, when the initial X-rays are negative.

Level of evidence: II

Keywords: Computed tomography, Early diagnosis, Elbow diagnostic ultrasound, Occult radial head fracture, Ultrasound

Introduction

The elbow joint is very susceptible to damage following trauma and can be radiographically challenging to diagnose. The mechanism of trauma for fractures around the elbow joint typically occurs when an axial force is applied to the forearm, hence causing the radial head to hit the capitellum

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of the humerus (1, 2). Radial head fractures have an annual incidence between 2.5 and 2.8 per 10.000 people, which correlates to approximately one-third of all elbow fractures (3-7). This kind of fracture is often accompanied by pain, swelling, and restricted range of motion (ROM) (8).

Although it has been 80 years since one of the first reports on radial head fractures was published in the New England Journal of Medicine; the radial head is still a topic for debate in the orthopedic and trauma literature (9). The radial head has been established as an important secondary stabilizer of the elbow, as it maintains the joint integrity when valgus or external rotation force is applied (10, 11). The prognosis of patients with radial head fractures depends largely on the severity of the fractures. Non-displaced fractures tend to share a good prognosis, whereas displaced fractures have worse clinical outcomes. To determine the clinical prognosis of these fractures, Mason proposed a classification system in 1954, which is widely accepted till nowadays. The classification distinguishes between undisplaced fractures (type I), displaced fractures (type II), and fractures that include comminuted displaced bone fragments (type III) (3). Type IV, which was later added by Johnston, describes a radial head fracture accompanied by elbow dislocation (12).

Special attention must be given to patients suffering from radial head fractures, due to the increased probability of associated injuries (5). Ligamentous injuries or capitellar bone bruise has been associated with incidences as high as 96% in patients with a radial head fracture (13, 14). Furthermore, Hausmann et al. reported that in Mason type I radial head fractures the interosseous membrane was partially torn (15). On the contrary, McGinley et al. did not find any tears in Mason type I. They documented that partial and complete tears were present only in the Mason types II and III (16).

The natural course of Mason type-I fractures is benign in general (17). However, persistent complaints have been reported in up to 20% of patients (18). According to Burkhart et al., conservative treatment should be considered appropriate for Mason I fractures, but, close follow-up is indicated for the early recognition of possible complications and for the prevention of stiffness, chronic instabilities, and osteoarthritis (19). Hausmann et al. suggested that injuries of the interosseous membrane (IOM) are more frequent than generally expected in Mason I fractures (15).

High-frequency ultrasound is an imaging modality that appears to be promising for early detection of occult Mason type I fractures. Pavic et al. reported that diagnostic ultrasound might be an effective method for diagnosing occult fractures of the radial head and neck, even when the initial X-rays showed only intraarticular effusion (20). Although ultrasound remains operator-dependent, this type of imaging modality is a portable, cost-effective, radiation-free diagnostic tool that has been understudied as far as the occult radial head fractures are concerned. However, it has been proven that this type of imaging modality is operator-dependent (20).

Purpose

To investigate whether bedside ultrasound in the Emergency Room (E.R.) is a sensitive and accurate tool for early (day-1) diagnosis of occult radial head fractures.

Materials and Methods

A single-center prospective blind diagnostic study was performed between June 2012 and May 2013 concerning patients clinically suspicious of having radial head fracture (21). All patients expressing pain and tenderness along the lateral aspect of the elbow, as a result of an acute elbow injury with negative initial X-Rays were included in this study. These patients had limited elbow and/or forearm motion, particularly in supination/pronation. Patients with a previous ipsilateral elbow fracture or sprain and all those with radial head fracture in the initial X-Rays were excluded from the study. In addition, we did not include patients younger than 18 years old and those with a possible present elbow effusion, like rheumatoid arthritis or any other autoimmune disease, elbow osteoarthritis, malignancy, chronic kidney failure, chronic liver failure, chronic heart failure, chronic medication of diuretics or corticosteroids, Cushing's syndrome, and pregnancy.

All patients signed a detailed full written consent as a precondition to participate in our trial. We explained to them that we are going to assess the accuracy of an experimental, non-evidence-based diagnostic imaging modality, in order to detect a possible bone injury. The study protocol as well as the consent form was approved by the institutional ethics committee.

The patients were typically examined by a doctor immediately after admission at the emergency room. X-rays were performed in two levels (standard anteroposterior and standard lateral view), which illustrated no direct sign of fracture for the eligible patients of our study (20). Then, a high-resolution ultrasound was performed by another certified orthopedic surgeon with adequate experience in musculoskeletal ultrasound (4-year experience) using a grey-scale portable device (10-12 MHz, Linear Array, A6 portable Ultrasonic Diagnostic System, Sonoscape Company Limited, Shenzen, China) without Doppler (22).

Each patient underwent a standardized ultrasound elbow examination including longitudinal and transverse sections focused on the radial head and the radiocapitellar joint with the elbow in slight (45°) flexion (23). Both elbows of the patients were examined for comparison. At least one of the following sonographic diagnostic criteria should have been positive for confirmation of radial head fracture: a. subperiosteal hematoma upon the cortex of the radial head or radial neck; or b. cortical discontinuity of the radial head or neck, with or without step-off deformity (24) [Figure 1]. These findings were compared with the ultrasound image of the contralateral normal elbow. Afterwards, a CT scan was performed to confirm the primary suspicion of the fracture. The assessment of the CT imaging was done by a specialized radiologist working in the CT department, who was blinded to the sonographic results. The CT scan was the criterion upon which the sensitivity, specificity, positive and negative prognostic value of the early comparative

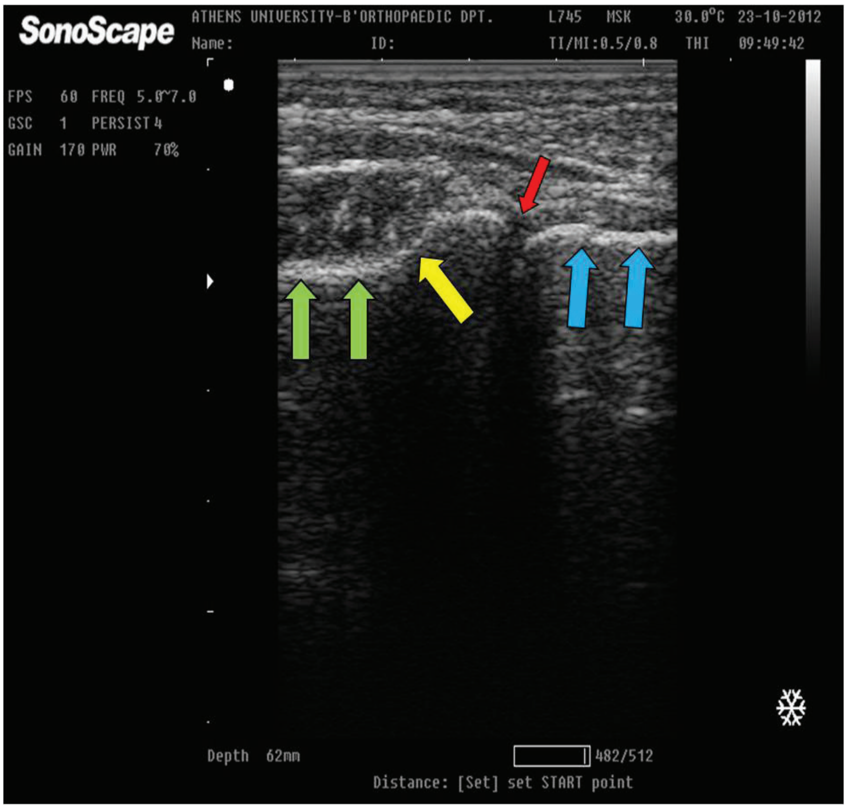

Figure 1. Longitudinal sonographic image of the radiocapitellar joint (red arrow), the proximal radius (green arrows) and the distal humerus (light blue arrows). Cortical discontinuity of the radial neck (yellow arrow) as a direct sign of a radiographically occult radial head fracture.

ultrasound in the diagnosis of the radial head fracture was based. In suspected cases with a negative CT scan and positive initial ultrasound we asked for an additional independent MRI examination at a private diagnostic center to exclude false-negative CT scan results (20, 25).

The patients were treated according to the CT-results (or MRI, when required). In the case of CT-positive patients, a dorsal elbow splint (with the elbow at flexion of 90°) was applied for 10-14 days in order to control pain and edema, protect the fracture site, minimize deconditioning and maintain the range in joints around the affected region (shoulder, wrist, fingers). After the removal of the splint the patients were advised to follow a physiotherapeutic protocol of protected active range of motion exercises (26).

Results

From an initial number of 31 patients with suspected radial head fracture, 23 adult patients agreed to sign and participate in our survey. The mean age of the patients was 33.8 years (range: 19-81 years). Almost half of the patients were men (11 males: 12 females). Ten patients were injured in their dominant hand (43.5%), whereas 13 in the non-dominant hand (56.5%). In addition, 12 patients had a right elbow injury (52.2%) and 11 patients were suffering from a left elbow injury (47.8%) [Table 1].

The mean time from injury to the initial exam was 2.9±2.1 hours. Furthermore, the mean time needed for the completion of the comparative ultrasound examination was 16.5±10.2 minutes for both elbows of each patient (no waiting time after negative X-rays as a bedside portable device was located in the E.R.), while the mean time of the CT scan was 57.4 minutes (including the waiting time, the time for the scan, and the time for the pick up of the results) [Table 2].

With the use of ultrasound, we easily differentiated subperiosteal hematoma, which was always lying on the radial neck or more distally along the radial diaphysis (especially in the longitudinal view), from the diffuse joint effusion which was encapsulated into the joint space [Figure 2]. No complaints were noted during or after the ultrasound examination of the injured elbows.

Fifteen patients were diagnosed suffering from radial head fracture with the use of both the ultrasound and the CT. On the other hand, there were three patients with

Table 1. General characteristics of the patients included

Initial Number of patients	31
Final Number of patients	23
Mean age (years)	33.8 (range: 19-81)
Sex (males : females)	11 : 12
Dominant Hand : Non-dominant Hand	10 : 13
Right Hand : Left Hand	12 : 11
"White-collar" workers: "Blue-collar" workers: Pensioners	5 : 7 : 7
Simple Fall : Other reasons of injury	19 : 4

"White-collar" workers: non-manual workers; "Blue-collar" workers: manual workers; Pensioners: people not working due to retirement.

Table 2. Mean time from injury to the clinical examination and the mean duration of the ultrasound examination in comparison with the CT process

Mean time from injury to exam	2.9 hours (SD: +/-2.1)
Mean time of the ultrasound examination	16.5 minutes (SD: +/-10.2)
Mean time for the CT scan process	57.4 minutes (SD: +/-25.9)

Figure 2. Comparative ultrasound image: Left: Clear cortical discontinuity in the radial head junction (yellow arrow) combined with subperiosteal hematoma (anechoic area) lying distally on the radius cortex (green arrows). Right: Normal radial head (purple arrow) and radial metaphysis without any hematoma (light blue arrow) in the contralateral elbow of the same patient.

Table 3. Ultrasound for the diagnosis of occult radial head fractures (comparing with CT as gold standard). .four -fold table. Sensitivity: a/(a+c) x100=15/18 x100=83.3%, specificity: d/(b+d) x100=3/5 x100=60%, positive prognostic value (PV+): a/(a+b) x100=15/17 x100=88.2%, negative prognostic value (PV-): d/(c+d) x100=3/6 x100=50%, accuracy: (a+d)/(a+b+c+d) x100=18/23 x100=78.2%.

U/S diagnosis	Radial head fracture CT SCAN		
	yes	**no**	**total**
POSITIVE	True a=15	False b=2	a+b =17 test positive
NEGATIVE	False c=3	True d=3	c+d=6 test negative
TOTAL	a + c=18 disease	b +d =5 non disease	a+b+c+d =23

negative ultrasound and positive CT, while two patients depicted positive in the ultrasonographic study but without any CT confirmation of the possible fracture. These last two patients underwent an MRI examination, which was negative for radial head fracture (subcortical bone edema was found in both cases).

In comparison with the CT, ultrasound appeared to have 83.3% sensitivity, 60% specificity, 88.2% positive prognostic value and 50% negative prognostic value, when at least one diagnostic sonographic criterion (subperiosteal hematoma, cortical discontinuity) was found positive [Table 3]. The accuracy of the sonographic study for the diagnosis of the above-mentioned fractures was 78.2%.

Effusion in contact with the radial neck was the most sensitive sonographic sign (14/15 of the true positive radial head ultrasounds). The first sonographic diagnostic criterion (subperiosteal hematoma) had sensitivity, specificity, positive prognostic value, negative prognostic value, and accuracy of 77.8%, 60%, 87.5%, 42.9%, and 73.9%, respectively.

Seven out of 15 patients with effusion in contact with the radial head (first sonographic criterion) were also sonographically found with a cortical discontinuity of the radial neck or head. This second sonographic diagnostic criterion had sensitivity, specificity, positive prognostic value, negative prognostic value, and accuracy of 38.9%, 60%, 77.8%, 21.4%, and 43.5%, respectively.

Discussion

The diagnosis of radial head fractures is typically derived by radiographs, including anteroposterior (AP), oblique and lateral projection. A variable percentage of these non-displaced fractures are not directly detected through the standard radiographs (27). Indirect subjective radiographic signs, like the fat pad sign or the cortical irregularity in the transition zone of the radial head-neck, have been proposed by some authors, but further studies are required to confirm their diagnostic value (27, 28). Bruinsma et al. demonstrated that the interobserver reliability of the X-rays in clinically suspected radial head fractures is moderate (29). Some of the Mason type I fractures cannot be detected on early (first days) radiographic images. Especially these occult fractures are considered to be a diagnostic challenge for physicians. “Occult fractures” are described as fractures that are either radiologically undetectable or show subtle abnormalities that were missed by initial radiographs (30).

Soft-tissue findings of the X-rays, such as the fat pad sign, may only provide a suspicion of the fracture (30). Morewood suggested that if traumatic effusion of the elbow is present and a fracture is not visible at the initial radiological study, a control X-ray imaging should be repeated 7-14 days after the initial injury as up to 30% of fractures are missed on the initial radiological studies (31). Burton et al. also showed that early X-rays missed fractures that were visible with latter X-rays (32). However, the same authors concluded that subsequent radiological studies of isolated radial head fractures were not helpful and they led to overtreatment (32).

Acar et al. suggested that a more detailed investigation of suspected occult fractures with the use of a computed tomography (CT) scan should always be performed (33). This imaging modality depicts superior accuracy when compared with the standard X-rays (33). With the use of the modern 2-D and 3-D CT reconstruction of the radial head the diagnostic accuracy of occult fractures was improved. Despite that, Guitton et al. illustrated that the interobserver variation was still not reduced (34). Moreover, MRI has been used for the assessment of soft tissue injuries, the visualization of slight fracture lines within the bone, and the detection of intraosseous edema that can suggest a fracture (14). MRI is still not considered as a first line imaging modality, but, it is preferred only for highly suspicious cases with negative late X-rays (35).

The value of ultrasound examination in early detection of occult fractures has already been proven in the wrist (scaphoid fractures), ankle, and other anatomic regions (36-40). Ultrasound seems to be faster, cheaper, and more comfortable than CT or MRI, while it has the advantage of dynamic evaluation in motion. In addition, high-resolution ultrasound is emerging as an important imaging modality in fracture assessment due to its availability, ease of use and multiplanar capabilities. As for its clinical usefulness, the diagnostic ultrasound can be used for injury assessment when obtaining radiographs is not immediately available or contraindicated. For example, this diagnostic method could be of paramount importance in pregnant women with multiple trauma or suspected fractures, where an X-ray or CT scan is a contraindication. In addition, the ultrasound examination may detect small occult fractures that were undetectable on radiographs, while it can diagnose bone stress injuries before radiographic changes (41).

To the best of our knowledge, our study was the first observational trial comparing the sonographic findings with the CT results of patients suspicious for radial head fracture. Particularly, this prospective diagnostic trial was aimed to determine the value of bedside ultrasonography for the detection of the Mason type I radial head fractures that were non-visible in early X-rays.

We employed CT to compare our results with the ultrasound findings in contrast to Pavic et al. who used late X-rays (after 7-10 days) as the standard imaging modality to compare the efficacy of early ultrasonography (20). CT is considered to be the gold standard for the detection of the occult radial head fractures (42). So, from this point of view, our study was appeared to be more accurate than that of Pavic et al. (20).

As it was initially hypothesized, ultrasound was proven to be accurate in identifying the effusion besides the radial head and the cortical discontinuity of the radial neck or head (with or without step-off deformity). In this study we assessed test sensitivity, test specificity, test accuracy, positive predictive value, and negative predictive value. The sensitivity, the accuracy and the positive prognostic value of diagnostic ultrasound, when at least one sonographic diagnostic criterion was found positive, were high. On the other hand, the specificity and the negative prognostic value were relatively low. According to these findings, when subperiosteal hematoma and/or cortical discontinuity are present it seems that there is a high likelihood of a radial head fracture. On the contrary, if the ultrasound is negative the patient will likely require a CT or MRI for the early diagnosis.

Waterbrook et al. evaluated 147 suspected long bone fractures by ultrasound with a sensitivity and specificity of 90% and 96%, respectively (43). Waterbrook et al. concluded that ultrasound was the most accurate when the fracture occurred within the diaphyseal or metaphyseal region, while it illustrated less accuracy when the fractures were located within the epiphyseal region (like in our study) (43). Our study reported 83.3% sensitivity and 60% specificity for the diagnostic ultrasound for the diagnosis of a specific type of fracture (occult radial head fractures) which was not the case in the study of Waterbrook et al (43). Even more, Waterbrook et al. used X-rays as the gold standard imaging modality to evaluate the ultrasound's diagnostic value and not CT scan as we did (43). On the other hand, Platon et al. assessed the diagnostic value of ultrasound in comparison with CT scan in the detection of suspected scaphoid fractures (36). They found out that the sensitivity and specificity of ultrasound were 100% and 67%, respectively (36). These values (high sensitivity and average specificity) were relatively similar with the respective values, which were reported in our study.

There were also some limitations in relation to our study. Weak points which merit mentioning include firstly, the small number of recruited patients which does not allow for a more comprehensive conclusions. Our study was experimental, because of some aspects concerning the medico legal status of a non-radiologist (in our scenario: an orthopaedic surgeon) who performs an ultrasound examination remain. Furthermore, the use of CT as the reference standard rather than MRI (not available in our hospital) could be considered as a weak point of our study (13, 14). We chose the CT scan, instead of the MRI, as the reference imaging modality for the diagnosis of occult radial head fractures, because our primary goal was to investigate the status of the radial bone and not to detect the subperiosteal hematoma (the MRI would be much more sufficient in detecting a hematoma or an effusion) or soft tissue injuries. Finally, the musculoskeletal ultra-sound depends on the experience, qualification, and ability of the physician-in charge in a way that we could characterize it as a rather subjective method. Additionally, we have to enlighten the need for further investigations concerning the needed time for the learning curve of musculoskeletal ultrasound in the hands of non-radiologists. The training that is required to assure acceptable diagnostic accuracy and reproducibility is still unknown and this could raise even medico legal consequences for the non-radiologists who perform this examination.

In summary, it is suggested that bedside grey-scale ultrasound in the E.R. is a valuable, fast and cost effective diagnostic method for early diagnosis of the occult radial head fractures. Regarding adult populations and especially pregnant women in whom X-rays are contraindicated, the increasing role of ultrasound in occult fractures must be further investigated.

Bedside ultrasound in the E.R. was proven to be a sensitive tool for the early (day-1) diagnosis of occult radial head fractures. It can be used as an adjacent imaging modality in patients suspi-cious for radial head fracture, when the initial X-rays are negative.

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References

1. Pappas N, Bernstein J. Fractures in brief: radial head fractures. Clin Orthop Relat Res. 2010; 468(3):914-6.
2. Jarraya M, Hayashi D, Roemer FW, Crema MD, Diaz L, Conlin J, et al. Radiographically occult and subtle fractures: a pictorial review. Radiol Res Pract. 2013; 2013:370169.
3. Duckworth AD, Clement ND, Jenkins PJ, Will EM, Court-Brown CM, McQueen MM. Socioeconomics deprivation predicts outcome following radial head and neck fractures. Injury. 2012; 43(7):1102-6.
4. Kaas L, van Riet RP, Vroemen JP, Eygendaal D. The epidemiology of radial head frac-tures. J Shoulder Elbow Surg. 2010; 19(4):520-3.
5. Van Riet RP, Morrey BF, O'Driscoll SW, Van Glabbeek F. Associated injuries compli-cating radial head fractures: a demographic study. Clin Orthop Relat Res. 2005; 441(1):351-5.
6. Kodde IF, Kaas L, Flipsen M, van den Bekermon MP, Eygendaal D. Current concepts in the management of radial head fractures. World J Orthop. 2015; 6(11):954-60.
7. Duckworth AD, Clement ND, Jenkins PJ, Aitken SA, Court-Brown CM, McQueen MM. The epidemiology of radial head and neck fractures. J Hand Surg Am. 2012; 37(1):112-9.
8. Burkhard KJ, Wegmann K, Mueller LP, Gohlke FE. Fractures of the radial head. Hand Clin. 2015; 31(4):533-46.
9. Jones SG. Fractures of the head and neck of radius-separation of upper radial epiphysis. N Engl J Med. 1935; 212(20):914-7.
10. Morrey BF, An KN. Articular and ligamentous contributions to the stability of the elbow joint. Am J Sports Med. 1983; 11(5):315-9.
11. Morrey BF, Tanaka S, An KN. Valgus stability of the elbow. A definition of primary and secondary constraints. Clin Orthop Relat Res. 1991; 265(1): 187-95.
12. Johnston GW. A follow-up of one hundred cases of fracture of the head of the radius with a review of the literature. Ulster Med J. 1962; 31(1):51-6.
13. Itamura J, Roidis N, Mirzayan R, Vaishnav S, Learch T, Shean C. Radial head fractures: MRI evaluation of associated injuries. J Shoulder Elbow Surg. 2005; 14(4):421-4.
14. Kaas L, Turkenburg JL, van Riet RP, Vroemen JP, Eygendaal D. Magnetic resonance im-aging findings in 46 elbows with a radial head fracture. Acta Orthop. 2010; 81(3):373-6.
15. Hausmann JT, Vekszler G, Breitenseher M, Braunsteiner T, Vécsei V, Gäbler C. Mason type-I radial head fractures and interosseous membrane lesions--a prospective study. J Trauma. 2009; 66(2):457-61.
16. McGinley JC, Gold G, Cheung E, Yao J. MRI detection of forearm soft tissue injuries with radial head fractures. Hand (N Y). 2014; 9(1):87-92.
17. Kodde IF, Kaas L, van Es N, Mulder PG, van Dijk CN, Eygendaal D. The effect of trauma and patient related factors on radial head fractures and associated injuries in 440 patients. BMC Musculoskelet Disord. 2015; 16(1):135.
18. Smits AJ, Giannakopoulos GF, Zuidema WP. Long-term results and treatment modalities of conservatively treated Broberg-Morrey type 1 radial head fractures. Injury. 2014; 45(10):1564-8.
19. Burkhart KJ, Franke S, Wegmann K, Ries C, Dehlinger F, Müller LP, et al. Mason I frac-ture - a simple injury? Unfallchirurg. 2015; 118(1):9-17.
20. Pavic R, Margetic P, Hnatesen D. Diagnosis of occult radial head and neck fracture in adults. Injury. 2015; 46(Suppl 6):S119-24.
21. Yoon A, Athwal GS, Faber KJ, King GJ. Radial head fractures. J Hand Surg Am. 2012; 37(12):2626-34.
22. Naredo E, Bijlsma JW, Conaghan PG, Acebes C, Balint P, Berner-Hammer H, et al. Rec-ommendations for the content and conduct of European League Against Rheumatism (EULAR) musculoskeletal ultrasound courses. Ann Rheum Dis. 2008; 67(7):1017-22.
23. Dębek A, Nowicki P, Czyrny Z. Ultrasonographic diagnostics of pain in the lateral cubital compartment and proximal forearm. J Ultrason. 2012; 12(49): 188-201.
24. Eckert K, Ackermann O, Schweiger B, Radeloff E, Liedgens P. Ultrasound evaluation of elbow fractures in children. J Med Ultrason (2001). 2013; 40(4):443-51.
25. Cunningham PM. MR imaging of trauma: elbow and wrist. Semin Musculoskelet Radiol. 2006; 10(4): 284-92.
26. Gutierrez G. Management of radial head fracture. Am Fam Physician. 1997; 55(6):2213-6.
27. Leschinger T, Müller LP, Hackl M, Wegmann K. The cortical irregularity in the transition zone of the radial head and neck: a reliable radiographic sign of an occult radial head fracture. Arch Orthop Trauma Surg. 2016; 136(8):1115-20.
28. O'Dwyer H, O'Sullivan P, Fitzgerald D, Lee MJ, McGrath F, Logan PM. The fat pad sign following elbow trauma in adults: its usefulness and reliability in suspecting occult frac-ture. J Comput Assist Tomogr. 2004; 28(4):562-5.
29. Bruinsma WE, Guitton T, Ring D, Science Variation Group. Radiographic loss of contact between radial head fracture fragments is moderately reliable. Clin Orthop Relat Res. 2014; 472(7):2113-9.
30. Rineer CA, Guitton TG, Ring D. Radial head fractures: loss of cortical contact is associ-ated with concomitant fracture or dislocation. J Shoulder Elbow Surg. 2010; 19(1):21-5.
31. Morewood DJ. Incidence of unsuspected fractures in traumatic effusions of the elbow joint. Br Med J. 1987; 295(6590):109-10.
32. Burton KR, Mellema JJ, Menendez ME, Ring D,

Chen NC. The yield of subsequent radi-ographs during nonoperative treatment of radial head and neck fractures. J Shoulder El-bow Surg. 2016; 25(8):1216-22.
33. Acar K, Aksay E, Oray D, Imamoglu T, Gunay E. Utility of computed tomography in el-bow trauma patients with normal x-ray study and positive elbow extension test. J Emerg Med. 2016; 50(3):444-8.
34. Sheps DM, Kiefer KR, Boorman RS, Donaghy J, Lalani A, Walker R, et al. The interob-server reliability of classification systems for radial head fractures: the Hotchkiss modifi-cation of the Mason classification and the AO classification systems. Can J Surg. 2009; 52(4):277-82.
35. Kaas L, van Riet RP, Turkenburg JL, Vroemen JP, van Dijk CN, Eygendaal D. Magnetic resonance imaging in radial head fractures: most associated injuries are not clinically rele-vant. J Shoulder Elbow Surg. 2011; 20(8):1282-8.
36. Platon A, Poletti PA, Van Aaken J, Fusetti C, Della Santa D, Beaulieu JY, et al. Occult fractures of the scaphoid: the role of ultrasonography in the emergency department. Skel-etal Radiol. 2011; 40(7):869-75.
37. Yıldırım A, Unlüer EE, Vandenberk N, Karagöz A. The role of bedside ultrasonography for occult scaphoid fractures in the emergency department. Ulus Travma Acil Cerrahi Derg. 2013; 19(3):241-5.
38. Hsu CY, Chiang YP, Liao CT, Hong YC. Sonographic diagnosis of a medial talar avul-sion fracture. J Clin Ultrasound. 2013; 41(9):570-3.
39. Warkentine FH, Horowitz R, Pierce MC. The use of ultrasound to detect occult or unsus-pected fractures in child abuse. Pediatr Emerg Care. 2014; 30(1):43-6.
40. Najaf-Zadeh A, Nectoux E, Dubos F, Happiette L, Demondion X, Gnansounou M, et al. Prevalence and clinical significance of occult fractures in children with radiograph-negative acute ankle injury. A meta-analysis. Acta Orthop. 2014; 85(5):518-24.
41. Hoffman DF, Adams E, Bianchi S. Ultrasonography of fractures in sports medicine. Br J Sports Med. 2015; 49(3):152-60.
42. van Leeuwen DH, Guitton TG, Lambers K, Ring D. Quantitative measurement of radial head fracture location. J Shoulder Elbow Surg. 2012; 21(8):1013-7.
43. Waterbrook AL, Adhikari S, Stolz U, Adrion C. The accuracy of point-of-care ultrasound to diagnose long bone fractures in the ED. Am J Emerg Med. 2013; 31(9):1352-6.