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Professional Paper

COMPARATIVE RADIOLOGICAL DIAGNOSTICS OF ACUTE TRIANGULAR FIBROCARTILAGE COMPLEX INJURIES

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SUMMARY – The aim was to analyze patients with clinical diagnosis of triangular fibrocartilage complex (TFCC) lesion using standard x-ray, ultrasound, conventional magnetic resonance imaging (MRI) and MR arthrography (MRA); to evaluate the accuracy of MRA compared with MRI in the diagnosis of this lesion; and to evaluate ultrasound as a method of diagnosing TFCC lesion. We analyzed 72 patients (46 female and 26 male; age range, 22-61 years; mean age 37 years; 50 right and 22 left wrists) with suspected TFCC lesion with clinical examination, standard x-rays, and ultrasound. We confirmed patients with traumatic TFCC injury on MRI and MRA. Ultrasound found 13 lesions in 72 patients with suspected TFCC lesions. Conventional MRI found 66 and MRA 68 TFCC lesions. Ultrasound is useful for visualizing intra-articular effusion, soft tissue, bone surface, and for early detection of occult fractures. MRI is a better diagnostic modality, fully able to visualize the TFCC cartilage and ligaments. MRA is consistently and accurately able to visualize structural abnormalities of TFCC.

Key words: *Magnetic resonance imaging; Arthrography; Triangular fibrocartilage complex; Diagnostic imaging; Ultrasound*

Introduction

Visualizing and assessing the triangular fibrocartilage complex (TFCC) continues to challenge radiologists because of its structure complexity, their small size, and close relation to one another. In TFCC trauma, the injury pattern is varied and may be difficult to detect and differentiate from normal anatomical structures with high fluid signal intensity on magnetic resonance imaging (MRI)[1,2]. Lippmann's 1937 report first generated clinical interest in the triangular fibrocartilage (TFC) by stating that one of the primary causes of wrist instability following Colles' fracture was an injury to the TFC[1,3]. Palmer and Werner described the TFCC of the wrist as being composed of the articular disc (TFC proper), the dorsal and volar radioulnar ligaments, the meniscus homolog, the ulnar

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collateral ligament, the extensor carpi ulnaris sheath, the ulnolunate ligament, and the ulnotriquetral ligament[4]. TFC is typically torn as the result of a fall onto the outstretched upper extremity. A central or radial tear of the articular disc may occur when the ulna is driven distally and compresses the TFCC between itself and the lunate. This movement can also result in lunotriquetral tears of the TFC. TFCC disruption can cause distal radioulnar joint (DRUJ) instability and functional impairment involving ulnar-sided wrist pain and decreased grip strength[5,6]. This, in turn, could lead to painful ulnocarpal synovitis[7]. In other patients, the mechanism of injury is a twist of the wrist during racket sports; however, patients can present with idiopathic onset of pain and possibly a 'clicking' without a known traumatic event[6]. Based on a literature review and a retrospective study of patients with wrist pain, Palmer proposed a classification system for TFCC lesions[5,8]. Identifying TFCC has been enhanced with structures being directly visualized on MRI. However, magnetic resonance arthrography (MRA) is the preferred modality for imaging patients with internal derangement of the wrist in some medical centers[9,10].

The purpose of our study was to analyze patients with a clinical diagnosis of TFCC lesion using standard x-ray, ultrasound (US), conventional MRI and MRA findings; to evaluate MRA compared with MRI (without contrast) in the diagnosis of TFCC lesion; and to evaluate US as a screening method for TFCC injury. Because TFCC is frequently associated with fractures, and we were more concerned with the identification of isolated rupture, we eliminated patients with an obvious fracture from our study.

Patients and Methods

All patients presented to the emergency room with complaints of pain and swelling of the wrist joint. Clinical examination, standard radiograms and US were completed within 24 hours following trauma to the ulnar side of the wrist. Clinical examination was done by an experienced orthopedic/trauma surgeon. We performed a standard radiogram first. In the cases without obvious fracture we performed US, also in the emergency room. MRI and MRA were done within 14 days of injury. We analyzed patients with an acute traumatic wrist injury. The inclusion criterion for the study was clinical suspicion of a TFCC lesion.

Clinical symptoms of TFCC injury consist of ulnar-sided wrist pain, frequently with clicking, that typically occurs after a fall. Swelling over the ulnar aspects of the wrist with inflammation of the tendon of the extensor carpi ulnaris can also be present. Furthermore, point tenderness is present over the TFCC and distal ulna. There are several tests the examiner does during clinical examination of the patient including the TFCC compression test, TFCC stress test, press test, supination test, piano key test, and grind test. The TFCC compression test, consisting of ulna deviation and axial loading of the wrist, elicits a painful response and a click with forearm rotation. The TFCC stress test applies force across the ulna with the wrist in ulnar deviation to reproduce symptoms. During the press test, the patient lifts themselves out of a chair using the wrists in an extended position. Pain indicates a positive test. In the supination test, the patient grabs the underside of a table with the forearms supinated causing a load on the TFCC and dorsal impingement; pain will be experienced if there is a peripheral, dorsal tear. In the piano key test, the patient places both hands on an examination table and presses the palms on the table. If the distal ulna is prominent on the affected side, this suggests DRUJ instability, which can have associations with TFCC injury. If the ulnar head goes back to the normal position when the patient relaxes the palms, this is a positive test. The instability of DRUJ is assessed with the forearm in neutral rotation but is also checked in full supination and full pronation. The examiner stabilizes the distal radius with one hand and applies force to the distal ulna, moving it dorsal and volar, looking for increased motion or subluxation of the distal ulna relative to the radius and comparing it with the opposite uninjured wrist. Instability presents as laxity of the distal ulna with the positive piano key sign and dorsal prominence of the distal ulna. The grind test compresses the radius and ulna and has the patient rotate their forearm. However, pain in this test could indicate a degenerative process. Additionally, the fovea sign (point tenderness directly over the ulnar TFC origin) indicates a Palmer classification 1A or 1B TFC injury or ulnar extrinsic 1C type injury. We also checked other soft tissue structures around the wrist including the ulnar nerve, dorsal ulnar sensory nerve branch, and ulnar artery. Even though grip strength measurements using a Jamar dynamometer may be subjective, they are helpful in quantitating patient effort and a parameter to follow therapeutic progress.

All patients who met this criterion were included in the study; these patients underwent clinical exam-

ination, standard x-ray, US, MRI, and MRA diagnostics. Patients with an obvious fracture were excluded from the study because these patients were expected to have damage to the TFCC. Furthermore, patients were eliminated from the study if different ligament damage was found, leaving 72 patients included (46 female and 26 male; age range, 22-61 years; mean age 37 years; 50 right and 22 left wrists). All patients were informed about the study and signed a consent form before undergoing diagnostic procedures. This study was approved by the Ethics Committee of the author's institution, following the principles of the 1983 revised Helsinki Declaration guiding research on human subjects.

Ultrasound study was performed on a Shimadzu SDU 2200 using a high-resolution multi-frequency linear 7-15 MHz small hockey stick probe. Patients were examined according to the accepted standard Musculoskeletal Ultrasound Technical Guidelines published by the European Society of Musculoskeletal Radiology.

Conventional MRI and MRA were performed by raising a 1.5-T system (Magnetom Expert; Siemens, Erlangen, Germany) and a dedicated surface coil (Siemens, Erlangen, Germany). Conventional MRI was performed with 3-mm slice thickness, 12-16 cm FOV and 512x512 matrix; the following sequences were used: coronal proton density, axial proton density, coronal T2 with fat saturation and sagittal T2 with fat saturation, gradient echo T1 and short tau inversion recovery (STIR). The contrast media injection for MRA was performed by radiologists with at least 5 years of experience in arthrography. Contrast media were injected inside two compartments, i.e., distal radio-ulnar joint and radiocarpal joint. The intra-articular positioning of the 22-gauge needle was confirmed by injecting about 2 mL of iodinated contrast media (iopromide, Ultravist 300; Bayer, Leverkusen, Germany). Once the needle was in position, we injected about 3 mL of gadopentetate-di-meglumine (Dotarem; Guerbet LCC, Villepinte, France) diluted 1:200 with saline. MRA was performed within 45 minutes after contrast agent injection. Wrist MRA included axial, coronal, and sagittal T1 fat-saturated and STIR. The presence, location, and extent of TFCC, SL, and LT ligament lesions on T1 fat-saturated and STIR images were identified, compared, and analyzed.

The same experienced musculoskeletal radiologist who had 15 years of experience in musculoskeletal radiology evaluated all images. At the time of evaluation, patient identification, MRI and MRA results were not collated, so that each evaluation was individualized. The criteria used for Palmer's classification in the analysis of all MRI and MRA images had been established in previous studies.

We used the binomial test for comparison of US and MRI, US and MRA, as well as MRI and MRA. For further statistics comparing MRI and MRA, we used the Bhapkar marginal homogeneity test. Statistical significance was set at $p<0.05$.

Results

Following clinical examination, patients with a suspected TFCC lesion were referred to the radiology department. After all the patients were analyzed with standard x-rays and US, patients with obvious fractures and ligament injuries not related to TFCC injury were eliminated, and 72 patients remained. These patients were all examined with MRI and MRA. In 72 patients analyzed, 13 TFCC lesions were found by US, 66 TFCC lesions by MRI, and 68 TFCC lesions by MRA.

On the US, we found 3 lesions of the ulnolunate ligament (Fig. 1) and 2 lesions of the lunotriquetral ligament (Fig. 2). In 8 cases, we found lesions of both the ulnolunate and lunotriquetral ligaments, and 3 of these cases also displayed intra-articular effusion. Solely intra-articular effusion was found in 35 cases (Fig. 3). The numbers of patients with particular findings are shown in Table 1.

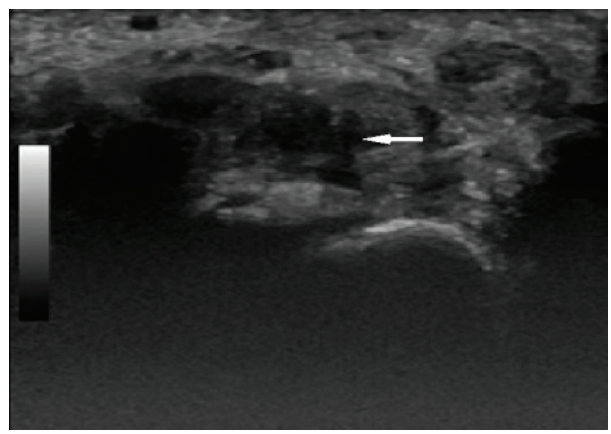

Fig. 1. US longitudinal scan – rupture of ulnolunate ligament.

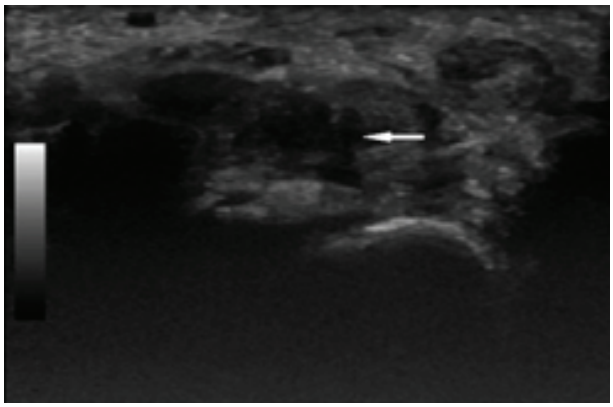

Fig. 2. US longitudinal scan – intra-articular effusion.

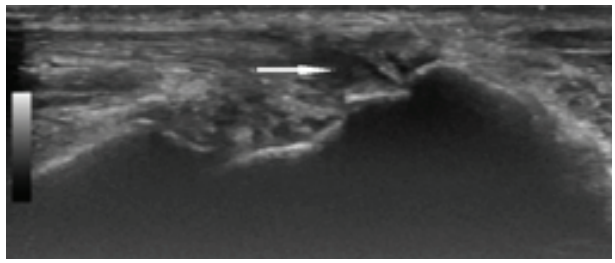

Fig. 3. US longitudinal scan – rupture of lunotriquetral ligament.

Table 1. Number of patients and results of MRI and MRA according to US findings

Ultrasound		Magnetic resonance imaging					Magnetic resonance arthrography				
		Normal	1A	1B	1C	1D	Normal	1A	1B	1C	1D
Normal	24	3	17	3	1	0	4	7	11	2	0
Effusion	35	2	10	12	5	6	0	8	9	11	7
Lesion	13	1	0	1	10	1	0	1	0	10	2

Analysis of 72 MRI findings (without intra-articular contrast media) yielded 27 patients with 1A lesions (traumatic tears or perforation of the TFC proper), 16 patients with 1B lesions (traumatic avulsions of the TFC from its attachment site on the ulnar fovea), 16 patients with 1C lesions (traumatic avulsions of the peripheral volar attachments of the TFCC, specifically the ulnolunate or ulnotriquetral ligament), and 7 patients with 1D lesions (traumatic avulsions of the radial attachment of the TFC in the region of the sigmoid notch). In six cases, MRI findings were normal.

Analysis of 72 MRA findings revealed 16 patients with 1A lesion, 20 patients with 1B lesion, 23 patients with 1C lesion, and 9 patients with 1D lesion. In four cases, MRA findings were normal. MRA showed 11 patients with 1A lesion less than MRI (Fig. 4). These were determined by MRA to be categorized as 4 patients with 1B (Fig. 5), 7 patients with 1C (Fig. 6), and 2 patients with 1D (Fig. 7). Normal findings on MRI were confirmed by MRA in only 33% of cases, whereas in 67% MRA found 1A lesions. Comparing MRI with MRA, 44% of 1B lesions and 56% of 1C lesions were found on MRA. 1C lesions were confirmed in 88% of cases, whereas MRA found 1D lesion in 12% of cases. 1D lesions were confirmed in all cases.

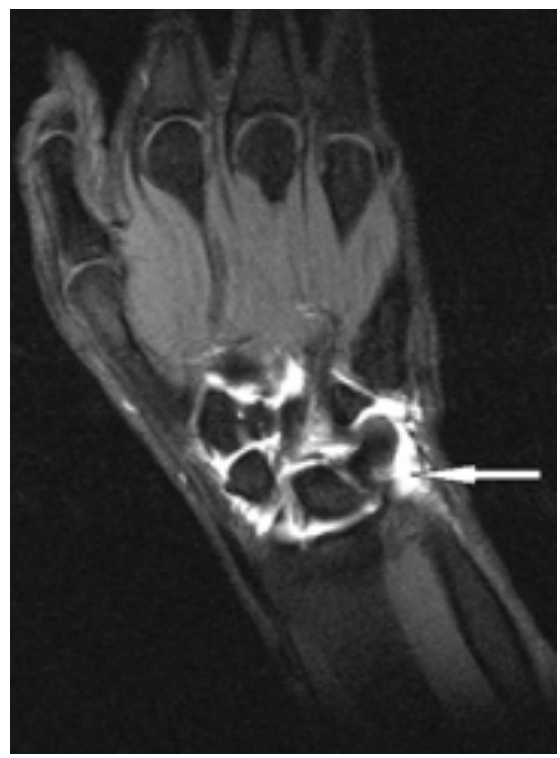

Fig. 4. TFCC 1A lesion – central perforation of TFCC disc proper (MRA, coronal plane, T1fs).

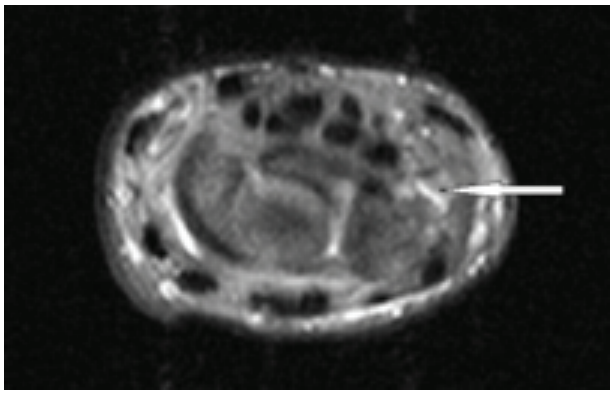

Fig. 5. TFCC 1B lesion – ulnar avulsion without distal ulnar fracture (MRI, transverse plane, STIR).

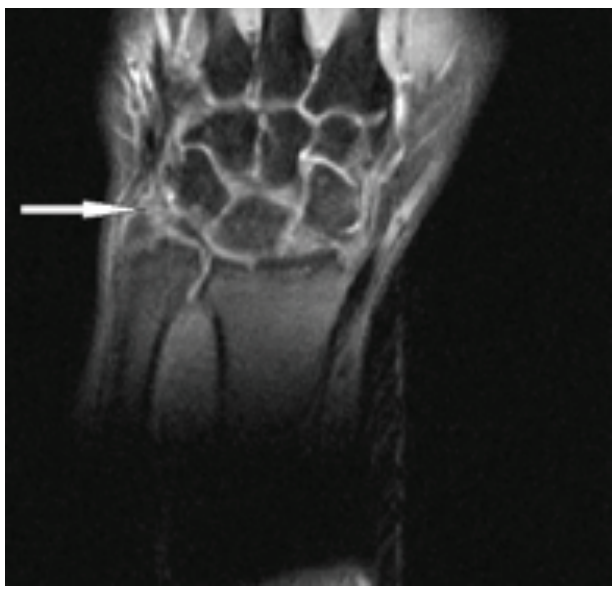

Fig. 6. TFCC 1C lesion – rupture of ulnotriquetral ligament (MRA, coronal plane).

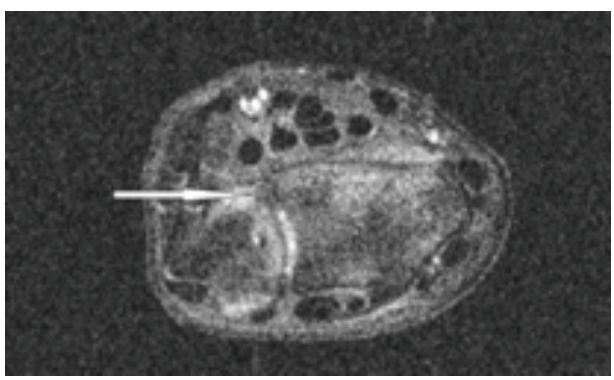

Fig. 7. TFCC 1D lesion – radial avulsion of TFCC disc proper (MRI, transverse plane, STIR).

The binomial test confirmed the statistically significant differences between US and MRI, as well as between US and MRA ($p<0.001$ both). MRI and MRA diagnosed TFCC equally well. We did not find statistical significance between MRI and MRA using the binomial test ($p=0.33$). However, using the Bhapkar marginal homogeneity test, we found a statistically significant difference ($p=1.41e-07$, $p<0.000001$) between MRI and MRA in diagnosing TFCC lesion.

Discussion

We analyzed patients with clinical suspicion of TFCC lesion; patients with an obvious fracture of wrist bones were not included in the study. Koman *et al*. report that TFCC lesions were incompletely diagnosed preoperatively in 62% of their 53 patients[5,11]. The incidence of a TFCC injury associated with a distal radius fracture ranges from 39% to 84%[12].

To evaluate whether US could be used for screening TFCC lesions was one of the points examined in this study. When there are associated fractures, TFCC damage is expected; however, when a patient presents no obvious fracture but fits the requirements for TFCC damage, there needs to be a way to identify the injury quickly so that the patient can be treated effectively. US can accurately analyze ulnolunate and lunotriquetral ligament lesions. It has been shown that US can be a valuable diagnostic tool in identifying ligament tears[13-15]. In this study, US was first performed to eliminate possible ligament lesions, unrelated to TFCC lesions. Of the patients who had TFCC associated lesions, 4% had ulnolunate ligament lesions, 3% had lunotriquetral ligament lesions and 11% had both ulnolunate and lunotriquetral ligament lesions. US can be very accurate in diagnosing intra-articular effusion, which can be an indirect sign of TFCC lesion. In 53% of the 72 patients, US findings showed intra-articular effusion. Hess *et al*. published a study in 2012 in which they used US to measure the degree of instability in the DRUJ. They measured the shift of the distal radius and ulna and from these results indirectly concluded on the existence of TFCC damage. However, they did not analyze the morphology of the TFCC structure[16]. Our study was based on the analysis of traumatic changes in the anatomical structure of TFCC. By using US, we analyzed the lesions in the ligamentous TFCC structures and the presence of intra-articular excretion. By its very nature, US is easi-

ly used to diagnose and monitor post-traumatic and degenerative changes in muscles, tendons, ligaments, and capsules. US cannot visualize intra-osseous abnormalities but due to the use of sound waves, there is no limit to patient exposure, making this method well tolerated by patients. When US showed ligament lesion, MRI confirmed injury in 92.31% of cases and MRA confirmed injury in all cases (100%). In our study, results showed that US found 13, MRI 66, and MRA 68 TFCC lesions in the 72 patients analyzed. Comparing US with MRI and MRA, we found that both methods showed (77%) traumatic ulnolunate or ulnotriquetral ligament avulsions, 1C lesion, in most cases. In cases of US effusion, MRI found a Palmer classification in 95% and MRA in 100% of cases. However, when US was considered unremarkable, MRI found a Palmer classification in 87.50% of cases, while MRA showed it in 83.33% of cases. Overall, US is not a conclusive screening method for TFCC injuries. Although US will continue to be part of our routine examination, the number of cases that showed absence of effusion and then were shown to be a Palmer classified injury negates its absolute usefulness in detecting TFCC lesion.

Palmer's classification was based on x-ray, MRI, and MRA. That is why we could not exactly compare US findings and MRI and MRA. We could just relatively compare findings because MRI with and without contrast can visualize more structures than US. US classification of TFCC lesions is separated into traumatic (class I) and degenerative (class II) lesions. Traumatic class 1 includes A, central tear of the articular disc (hypoechoic cleft inside the articular disc); B, ulnar attachment tear of the articular disc; C, radial attachment tear of the articular disc; D, horizontal tear of the articular disc; and E, injury of the TFCC other than the articular disc, i.e., meniscus homolog, radioulnar, lunotriquetral and ulnar collateral ligaments or extensor carpi ulnaris tendon subsheath. Oneson *et al*. described the types of Palmer classifications seen on MRI[5,17]. Class 1A and 1B lesions were more prevalent. This study did not observe Palmer class 2, degenerative lesions; the patient sample was not suffering from degenerative injuries. Oneson *et al*. report what the radiologist observes when a normal TFCC is observed on MRI: "… the articular disc (the TFC) appears as a thick band of low signal intensity with all pulse sequences. The disc appears biconcave in the sagittal plane; the peripheral margins are much thicker and stronger than the central zone. The ulnar attachment of the TFC has a striated appearance on MR images. The meniscal homologue and the associated ulnar extensor tendon subsheath and ulnar collateral ligament are not consistently seen in MR imaging". The ulnolunate and ulnotriquetral ligaments can be seen[5]. Tears or damage to the TFCC should be visible when evaluated by a radiologist; however, there are times when nothing out of the ordinary is seen.

Magnetic resonance arthrography of the wrist is a complex procedure. The three main types of arthrography injections are midcarpal, radiocarpal, and DRUJ. These are ideally performed with a C-arm which can be rotated to profile to view the scapholunate and lunotriquetral joints in turn. A midcarpal injection is used to assess the integrity of the intrinsic ligaments. Injecting the contrast material into the midcarpal joint first provides enhanced ligament visualization compared to initially injecting into the radiocarpal joint[18]. If the TFCC tear is unremarkable with the radiocarpal injection, an additional DRUJ arthrogram may detect partial tears and/or tears of the foveal attachment[19]. Joint distension by contrast injection, visualization of contrast leak, or contrast imbibition allows better evaluation of subtle abnormalities such as partial ligamentous tear or cartilage defect[20]. Using contrast injections on MRA, smaller injuries to the TFCC are likely to be more visible. Comparing our MRI and MRA findings, we found a statistically significant difference in diagnosing TFCC lesions.

However, discussion as to which, MRI or MRA, is the most reliable method for TFCC lesions has not been decided. Roth and Haddad found that only 70% of 37 confirmed TFCC lesions were identified with arthrography[5,21]. Then, Van den Eynde *et al*. showed a 52% sensitivity and 50% specificity for TFCC lesions when arthrography was performed with radiocarpal injection; their results yielded a positive predictive value of 92% and negative predictive value of 8%[5,22]. Oneson *et al*. believe that MRI could supplant arthrography because it is noninvasive, and accurately demonstrates perforation of the TFCC[5]. In our study, MRA identified TFCC lesions in 92%, showing that MRA could differentiate small post-traumatic changes of TFCC better than MRI without contrast. We found that MRA showed 11 1A lesions less than MRI. Also, MRA identified 5 1B, 6 1C and 2 1D lesions more than MRI. In our opinion, MRA can visualize small post-traumatic changes of the TFCC more accurately than MRI without intra-articular contrast media injection.

Pahwa *et al*. published a study where they compared conventional MRI and direct MRA in the evaluation of TFCC and intrinsic wrist ligament tears. They analyzed 53 patients and found MRA to be the most sensitive and specific imaging modality for the evaluation of wrist ligament tears[23]. We found US to be a sensitive and valuable diagnostic method for the evaluation of intrinsic wrist ligaments, ulnolunate and lunotriquetral. Even though US did not predict TFCC injury in a satisfactory number of cases, the evaluation of wrist ligament damage was quite sensitive. Zlatkin *et al*. and Cerofolini *et al*. found tears of the TFCC to be detected equally well with MRI and MRA performed with radiocarpal and three-compartment injection[5,10,24,25]. We found that MRA showed two lesions more than MRI. Our experience has led us to a conclusion that MRA is the best and most specific diagnostic method for TFCC lesions. Other studies have shown excellent accuracy of direct MRA for tears of the TFCC, as well as the scapholunate and lunotriquetral ligaments, similar to the present study[26-28].

We statistically compared MRI with MRA in diagnosing TFCC lesions. Although MRI has accuracy for detection of central post-traumatic defects and radial-sided slit-like perforations, after an intra-articular injection of contrast media, there is better visualization of the TFC proper, as well as the ulnolunate and lunotriquetral ligaments. In our experience, MRI without contrast can show post-traumatic chondral changes, tendon changes, neurovascular changes, and post-traumatic bone marrow changes. However, we agree with other authors that MRA is superior in diagnosing small post-traumatic cartilage and ligament lesions of TFCC, and in the accuracy of detecting the intrinsic wrist ligaments, and TFCC tears are statistically enhanced using MRA[1,29].

The ability of MRI to accurately localize a peripheral tear is questionable and is dependent on the experience of the musculoskeletal radiologist reading the films[30]. All MRI images, in our study, were evaluated by one musculoskeletal radiologist, therefore we did not assess inter-observer variation. However, several studies report that even though the images were analyzed by multiple radiologists, all decisions were made by consensus[18,20,23,31-33].

Ultrasound is a viable screening method, especially if the patient presents with a fresh injury, and because it is a cost-effective, easy-to-use, and radiation-free method, we recommend it for early detection of ligament lesions. However, for definitive evaluation of TFCC lesion, MRI is a better diagnostic modality. MRI can fully visualize the TFCC cartilage and ligaments. In the case of bone fracture, MRI can analyze bone marrow edema. MRA is still considered the best diagnostic method for prospective evaluation of TFCC and related ligament lesions, as it is able to consistently and accurately visualize structural abnormalities, especially if there is a question in the MRI result.

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Sažetak

USPOREDBENA RADIOLOŠKA DIJAGNOSTIKA AKUTNIH OZLJEDA TROKUTASTOG VEZIVNO-HRSKAVIČNOG KOMPLEKSA

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Cilj istraživanja bio je analizirati bolesnike s dijagnozom ozljede trokutastog vezivno-hrskavičnog kompleksa (*triangular fibrocartilage complex*, TFCC) pomoću standardnih radiograma, ultrazvuka, magnetske rezonancije (MR) i MR artrografije (MRA); procijeniti vrijednost MRA u usporedbi s MR u dijagnosticiranju ozljeda TFCC; procijeniti vrijednost ultrazvuka (UZV) kao metode izbora u dijagnosticiranju ozljeda TFCC. Analizirali smo 72 bolesnika (46 žena i 26 muškaraca u dobi od 22-61 godine, srednja dob 37 godina; 50 desnih ručnih zglobova i 22 lijeva ručna zgloba) s kliničkom sumnjom na ozljedu TFCC pomoću standardnih radiograma i UZV. Naposljetku smo potvrdili ozljedu TFCC pomoću MR i MRA. UZV je potvrdio 13 ozljeda od 72 analizirana bolesnika kod kojih se sumnjalo na ozljedu TFCC. Konvencionalna MR ih je potvrdila 66, dok ih je MRA potvrdila 68. Zaključeno je kako je UZV vrijedna metoda za prikaz intraartikularnog izljeva, mekih česti, površine kosti, kao i za ranu dijagnostiku prijeloma koji nisu bili vidljivi standardnim rtg snimkama. MR je bolja dijagnostička metoda za prikaz struktura, ali za pouzdan i točan prikaz TFCC i pripadajućih patoloških traumatskih promjena metoda izbora je MRA.

Ključne riječi: *Magnetska rezonancija; Artrografija; Trokutasti vezivno-hrskavični kompleks; Slikovna dijagnostika; Ultrazvuk*