



MR arthrography versus conventional MRI and diagnostic arthroscope in patients with chronic wrist pain

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ABSTRACT

Objective: To assess the diagnostic accuracy of direct wrist MR arthrography (MRA) compared to conventional MRI in diagnosis of different pathologic entities causing chronic wrist pain.

Materials and methods: 37 consecutive patients 22 males and 15 females, with age range from 16 to 49 years "mean age 28 years" complaining of unexplained chronic wrist pain were prospectively examined by using MRI and MRA with arthroscopic correlation in 25 of them. Findings were divided into 5 main groups of lesions including triangular fibrocartilage complex (TFCC) lesions, ligamentous injuries, osseous lesions, tendon pathology and ganglion.

Results: MRA picked up more ligamentous injuries and triangular fibrocartilage complex (TFCC) lesions that couldn't be detected on MRI study while both were equal in detection of other types of lesions. TFCC lesions were the most common pathologic findings in both MRI and MRA. Arthroscopic correlation in 25 suspected TFCC lesions (clinically, radiologically or both) revealed that the sensitivity / specificity / accuracy of MRI and MRA were 87.5% / 100% / 96% and 100% / 100% / 100% respectively for central lesions while were 71.4% / 81.3% / 76% and 100% / 90.9% / 96% respectively For peripheral lesions. Extra-capsular lesions, like tenosynovitis and fracture hook of hamate couldn't be confirmed arthroscopically.

Conclusion: MRA can replace both MRI and diagnostic arthroscopy in detecting causes of chronic wrist pain.

1. Introduction

The wrist represents the most complex joint as it is composed of small numerous structures, like ligaments that not exceed few millimeters in diameter. Chronic wrist pain is a common complaint with many causes contributing to this problem. Appropriate management needs high contrast and high resolution imaging to guide the best plan for orthopedic management [1].

Plain radiograph is often employed as the first line of investigation, but usually it does not provide information regarding radiolucent structures (for example ligaments and cartilage). Fluoroscopic arthrography has gained popularity in these patients as it can delineate the wrist ligaments, but it has a high incidence of false positive and false negative findings [2]. Also, ultrasound (US) allows a partial

visualization of triangular fibrocartilage complex (TFCC) because the size of the acoustic window varies with the size and the morphology of the ulnar styloid and the ulnar variance. Also, the articular disk assessment may be limited if there is a positive ulnar variance or if the ulnar styloid is Hypertrophic. For these reasons, US is not the modality of choice in order to assess TFCC integrity [3].

MRA is the modality of choice for TFCC assessment because it allows the combined advantages of MSCT arthrography (MSCTA) for depiction of chondral injuries and MRI for soft tissue abnormalities (like tendon injuries) and bone marrow edema [4].

The aim of this study was to assess the diagnostic accuracy of direct wrist MRA compared to conventional MRI in diagnosis of different pathologic entities affecting the wrist.

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2. Materials and methods

This study was approved by our institutional ethical committee. 37 patients were prospectively studied between October 2016 and December 2017.

2.1. Informed consent

“Informed consent was obtained from all individual participants included in the study.”

“Additional informed consent was obtained from all individual participants for whom identifying information is included in this article.”

Out of the 37 cases, 12 cases were not indicated clinically, radiologically or both to do arthroscopy while 25 cases were indicated and underwent arthroscopic management. Then, detailed arthroscopic findings for the 25 patients were reported and compared with MRI and MRA findings.

Patients were referred to our Radiodiagnosis department from the outpatient of the Orthopedics department, faculty of Medicine, Assuit University hospital; complaining of unexplained chronic wrist pain especially when plain radiograph is not conclusive. Written informed consent was obtained from all patients. All patients were subjected to history taking, plain X-ray (straight PA and lateral views), clinical provisional diagnosis, MRI and MRA of the wrist as a single shot examination (Performed by the same radiologist) and arthroscopic surgical procedure in 25 with suspected TFCC or ligamentous injuries clinically, radiologically or both.

MRI and MRA were performed by Philips Achieva 1.5 T MRI machine using wrist coil 8 elements. All Patients were positioned for MR study in the prone position with the arm above their head in the so-called “Superman” position.

2.2. Technique of MRA

2 to 4 ml of contrast mixture (formed of Gadopentetate dimeglumine 0.1 ml added to 5 ml non-ionic contrast medium, 5 ml xylocaine, and sterile saline solution was added to form a mixture of 20 ml) was injected through the dorsal posterior approach into the radiocarpal compartment which was the only injected compartment.

Introduction of the needle into the joint space was done by one of three techniques. 22 patients underwent US-guided injection and 10 patients underwent fluoroscopic-guided while in 5 patients, contrast was injected without imaging guidance (blind injection). Within 30 min after radiocarpal injection of contrast and exercise of the joint was advised, patients were moved to the same MR machine using the same surface coil and positioned again in the same position for MRA. MRI and MRA protocols include multiple pulse sequence and planes (Tables 1 and 2).

2.3. Image Analysis

MRI and MRA examinations were blindly, randomly and

Table 1
Shows Protocol for MRI imaging.

Parameter							
sequence	TR	TE	FOV(mm)	SL	Gap	Matrix	NSA
Axial (T ₁ WI)	450	22	80	3	0.3	268 × 199	4
Axial (T ₂ WI)	2333	100	80	3	0.3	272 × 210	6
Coronal (T ₂ FFE)	450	11	100	3	0.3	124 × 99	2
Sagittal (PD WI)	2300	30	90	3	0.3	256 × 197	4
Coronal (PD SPAIR)	487	22	80	2	0.2	268 × 199	4
Coronal (STIR)	3403	60	120	3	0.6	508 × 112	3

Table 2
Shows Protocol for MRA imaging.

Parameter							
sequence	TR	TE	FOV(mm)	SL	Gap	Matrix	NSA
Axial (T ₁ SPIR)	487	22	80	2	0.2	268 × 199	4
Sagittal (T ₁ SPIR)	487	22	80	2	0.2	268 × 199	4
Coronal (T ₁ SPIR)	487	22	80	2	0.2	268 × 199	4
Coronal (T ₂ FFE)	450	11	100	3	0.3	124 × 99	2
Axial (T ₂ WI)	2333	100	80	3	0.3	272 × 210	6
Coronal (PD SPAIR)	487	22	80	2	0.2	268 × 199	4

independently analyzed by two experienced musculoskeletal radiologists (Radiologist 1 with 12 years of experience, Radiologist 2 with 20 years) blinded to arthroscopic findings. They had access only to the clinical history. All decisions were made by means of consensus.

All images were viewed on a dedicated picture archiving and communication system (PACS), Paxera and Philips Achieva workstation.

The images were interpreted in 2 separate sessions. The MRI in the first session and MRA in the second session were evaluated individually. The various lesions were assessed independently on each. The radiologists analyzed the type of wrist pathology. Consensus was finally obtained in the case of initial disagreement.

We divided wrist findings in our study into 5 main groups of lesions:

- 1 TFCC lesions
- 2 Ligamentous injuries (Scapholunate ligament (SLL) tears and Lunotriquetral ligament (LTL) tears)
- 3 Osseous lesions (ulnar sided lunate changes, avascular necrosis (AVN), fractures and arthritic changes)
- 4 Tendon pathology (tenosynovitis)
- 5 Miscellaneous (Ganglion)

Each lesion was scored as present (1) or absent (0). Images were evaluated for the presence and location of TFCC, SLL and LTL tears, and imaging findings were compared with operative findings in 25 patients who underwent arthroscopy (gold standard).

TFCC lesions: the study included central and peripheral ulnar lesions. Central lesions were considered when located (2–3 mm) medial to the radial attachment of the TFCC (to differentiate them from radial tears). Once diagnosed, we attempted to describe TFCC tears according to Palmer's classification, taking in consideration location of the tear, associated degenerative changes and preceding history of trauma when available. Diagnostic criteria for TFCC lesions were absence of the TFCC or focal thickness defect as well as signal abnormalities within different portions of TFCC. Partial thickness tear was diagnosed when abnormal intermediate signal intensity detected within TFCC on T₁ SPIR images that increased on T₂ FFE and reaching to one of the articular surfaces of TFCC. Complete tear was diagnosed when the abnormal signal reaching both superior and inferior surfaces of TFCC. Fluid collecting in the DRUJ represents an important secondary sign, but the presence of fluid signal only is not indicative of a TFCC tear [5]. Both complete and partial tears were scored as positive.

The criteria for carpal abutment syndrome: were central TFCC lesions with ulnar sided lunate degenerative changes (hyperintense PD SPAIR of bone marrow edema and subarticular cystic degeneration) with or without positive ulnar variance. We consider central thinning of TFCC with ulnar sided lunate changes and positive ulnar variance as one of central TFCC lesions (Carpal abutment, palmer class IIB).

The criteria for diagnosis of Scapholunate ligament (SLL) and lunotriquetral ligament (LTL) were distinct areas of discontinuity within the ligament, or an absence, altogether, of the ligament. Fluid in the midcarpal joint is a sensitive, but nonspecific finding of ligament tears. MR images were analyzed in all three imaging planes to assess the

volar, membranous and dorsal portions of SL and LT ligaments. The axial image was the best.

The diagnostic criteria for AVN of scaphoid and lunate bone include: decreased T₁ and increased marrow signal intensity in fluid sensitive sequences (PD SPAIR).

Fracture: diagnosed when there was a low signal fracture line on all sequences, with or without surrounding marrow edema.

Arthritic changes include reduced irregular joint space and were seen at radiocarpal joint.

The criteria for diagnosis of tenosynovitis included fluid signal within the tendon sheath exhibiting hyperintense PD SPAIR signal.

2.4. Arthroscopy

Arthroscopy was performed using a 2.7 mm arthroscope. Among the 37 cases of the study, only 25 were indicated (clinically or radiologically) patients were subsequently underwent wrist arthroscopy, used as our reference standard in assessment of the diagnostic abilities of both MRI and MRA studies in these cases. Arthroscopic examinations were performed by an expert orthopedic surgeon specialized in wrist surgery. Arthroscopy was performed less than 1 month after imaging examinations. During arthroscopy, MRI and MRA images on film hard copy were available to the surgeon

The findings recorded in arthroscopy were: presence of TFCC or ligament tears, exact site of these tears, chondromalacia, synovitis, and degenerative changes in the joint. After the completion of surgery, the arthroscopic findings were incorporated on a standard form by the operator. The result for both MRI and MRA was compared with the intra-operative arthroscopic assessment.

2.5. Statistical analysis

Statistical analysis was performed using SPSS for Windows (version 16.0, SPSS). Regarding the arthroscopic findings as the gold standard in 25 cases of suspected TFCC lesions, the numbers of true-positive, true-negative, false-negative, and false-positive results of both imaging studies for each TFCC lesion were determined. For each subtype of TFCC lesion, the diagnostic performances of MRI and MR arthrography were quantified by the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy.

Statistically significant differences were calculated using the Chi-square test to detect correlation between MR arthrography and arthroscopy. Statistical significance was set at $p < 0.05$ (P value less than 0.05 was considered to indicate a statistically significant difference).

The strength of agreement between each imaging test and arthroscopy and between the two imaging tests for the detection and diagnosis was calculated by using Kappa coefficients.

3. Results

The 37 patients of the study revealed affection of males more than females ($n = 22$ males) and more affection of the dominant wrist ($n = 20$) with the slight majority having posttraumatic status ($n = 19$).

MRA picked up more ligamentous injuries and TFCC lesions that couldn't be detected on MRI while both were equal in detection of other types of lesions. TFCC lesion was the most common pathologic finding where tendon pathology was the least. MRA picked up more central and peripheral TFCC lesions (Table 3).

Among the 37 cases of the study, 25 cases were suspected clinically, radiologically or both to have TFCC or ligamentous injuries and underwent arthroscopic management. Extra-capsular lesions (tenosynovitis and fracture hook of hamate) couldn't be confirmed arthroscopically. Arthroscopy confirmed 34 lesions including 22 TFCC lesions (8 central lesions and 14 peripheral ulnar lesions), 3 ligamentous injuries, 7 ulnar side lunate changes and 2 ganglion cysts

Table 3

Detailed comparison between MRI and MRA findings.

Wrist pathological findings		MRI	MRA
1.TFCC lesions	Central TFCC lesions	7 = 19	8 = 23
	Peripheral ulnar TFCC lesions	12	15
2.ligamentous injuries	SLL lesions	1 = 1	2 = 3
	LTL lesions	0	1
3.Osseous lesions	Ulnar sided lunate changes	7	7
	AVN	2	2
	Fracture	6	6
	arthritic changes	1	1
4.Tendon pathology	Tenosynovitis	1	1
5.Miscellaneous	Ganglion cyst	9	9
Total ^a		46	52

^a Total lesions of study population.

Table 4

Detailed arthroscopic findings of the 34 lesions.

Arthroscopic findings		No.
1.TFCC lesions	Central TFCC lesions	8 = 22
	Peripheral ulnar TFCC lesions	14
2.ligamentous injuries	SLL lesions	2
	LTL lesions	1
3.Osseous lesions	Lunate chondromalacia	7
4.Miscellaneous	Ganglion cyst	2
Total		34

(Table 4). Comparison between MRI and MRA based on arthroscopic findings was done in 25 cases (Table 5). Diagnostic performance of MRI and MRA versus arthroscopy in diagnosis of TFCC lesions was obtained and represented by chart for both central and peripheral TFCC lesions (Table 6). As for SLL and LTL tears no adequate number of cases was detected in our study to allow satisfactory statistical analysis.

Correlation between MRA and arthroscopy was statistically significant (p value = 0.01). Considering central TFCC and peripheral ulnar subtypes of TFCC lesions separately, correlation between MRA and arthroscopy was highly statistically significant (p value = 0.000).

MRI & arthroscopy agreement was slight for total TFCC lesions, almost perfect for central and moderate for ulnar. MRA & arthroscopy agreement was substantial for total TFCC lesions and almost perfect for both central and ulnar respectively (Table 7).

4. Discussion

In this study we compared MRA diagnostic performance in 37 patients complaining of chronic wrist pain compared to conventional MR and diagnostic arthroscopy. Although a little is known in the literatures about the effect of age, hand dominance and gender on the prevalence of wrist problems, our results show male predilection and posttraumatic status seems to be risk factors which is in agreement with the study of Pahwa et al. [8] which was performed on 53 patients for comparison of conventional MRI and MRA in evaluation of wrist ligaments with arthroscopic correlation in 16 of his study population. This can be attributed to occupational overuse and sports injuries.

Our choice of direct MRA over indirect MRA because this technique fully distends the joint cavity, outlines ligament defects and can depict the precise location of the ligamentous defect. Also, in term of cost effectiveness direct MRA needs very much lower concentration of contrast compared to indirect MRA. On the other hand indirect MRA is less invasive with a major advantage in detection of abnormalities other than the internal derangements as tenosynovitis [9].

In the current study, the radiocarpal compartment was the only injected compartment. This is in agreement with Lynne et al. [10] and Suraj et al. [11] who supported sufficiency of single radiocarpal injection followed by fat suppressed gadolinium sensitive sequences while

Table 5

Comparison of MRI and MRA for detecting lesions based on operative (arthroscopic) findings in the 25 cases.

Pathology		Operative findings ^a (n = 34)	Modality	True positive	True negative	False positive	False negative
TFCC lesions	Any TFCC lesion	22	MRI	17	1	2	5
			MRA	22	2	1	0
	Central TFCC lesion	8	MRI	7	17	0	1
			MRA	8	17	0	0
	Peripheral ulnar TFCC lesion	14	MRI	10	9	2	4
			MRA	14	10	1	0
SL lesions		2	MRI	1	23	0	1
			MRA	2	23	0	0
LT lesions		1	MRI	0	24	0	1
			MRA	1	24	0	0
			MRI	7	18	0	0
Ulnar sided lunate changes		7	MRA	7	18	0	0
			MRI	2	23	0	0
Ganglion		2	MRI	2	23	0	0
			MRA	2	23	0	0

^a 34 lesions on arthroscopy of 25 wrist joints.**Table 6**

Calculated sensitivity, specificity, positive and negative predictive values and accuracy of MRI and MRA for TFCC lesions.

Imaging test	Central TFCC lesion	Peripheral ulnar TFCC lesion
MRI, %		
Sensitivity	87.5	71.4
Specificity	100	81.8
PPV	100	83.3
NPV	94.4	69.2
Accuracy	96	76
MRA, %		
Sensitivity	100	100
Specificity	100	90.9
PPV	100	93.3
NPV	100	100
Accuracy	100	96

Table 7

Agreement between MRI, MRA, and Arthroscopic Findings for each TFCC lesion considering various types of TFCC lesion.

Parameter			
Lesion	MRI versus arthroscopy	MRA versus arthroscopy	MRI versus MRA
Any TFCC lesion	0.07	0.78	0.15
Central TFCC lesion	0.91	1.00	0.91
Ulnar TFCC lesion	0.52	0.92	0.60

Schmitt et al. [12] supported double injection into the midcarpal and radiocarpal joint compartments.

We considered multiple compartment injection (either double or triple) had many drawbacks as it is expected to be unaffordable by many patients as well as it yields more contrast extravasation into tendon sheaths that obviously could affect the diagnostic performance. This is in accordance with Amrami et al. [7] who considered the single compartment arthrography planned with the referring surgeon to be more definitive as there is no available “subtraction” technique and it can be difficult to sort out which ligaments are completely or partially torn and what the direction of the contrast flow has been.

On the other hand, Marco et al. [4] supported triple compartment injection for better delineation of peripheral partial TFCC tears.

The dorsal approach was chosen in our study because it is the method most often taught to radiologists during training and is accepted as both safe and reliable [13].

We compared the diagnostic accuracy of MRI sequences and direct MRA in the detection of TFCC lesions using arthroscopy as a reference standard in 25 cases, and tried to develop the most appropriate MR

imaging protocols for detection of these lesions.

Regarding technical points, sequences and planes, our practice in this study demonstrated that all the components of TFCC complex were consistently visualized on non enhanced MRI as well as MRA while the SLL and LTL were consistently visualized on non-enhanced MRI as well as MRA, but the individual components of these ligaments were best evaluated by axial images on MRA. This in agreement with the preceding practice of Pahwa et al. [8] in his study.

In the present study, as suggested in previous reports by Moser et al. [14] the coronal plane was classic for wrist imaging, but the transverse plane was essential for analyzing the dorsal and palmar portions of SLL and LTL as well as fractures of hook of hamate. Sagittal images were considered of less value but provided useful information about carpal alignment and the extent of TFCC tears.

We believed that axial plane was important in localization of the individual components of SLL and LTL (volar, membranous and dorsal), fracture hook of hamate, relations and intra-articular extension of ganglion cysts and localization of tenosynovitis.

The current literature recommends acquiring PD SPAIR images in coronal plane to evaluate TFCC and to compare the signal abnormality to the signal of T₂ FFE. Also, PD SPAIR sequence was helpful in assessing marrow signal abnormalities as seen in ulnocarpal abutment syndrome, fractures, and avascular necrosis of bone. So, we recommend replacing STIR sequence in our institute by PD SPAIR in imaging of the wrist as it can assess TFCC and ligamentous injuries as well as marrow signal abnormalities.

PD SPAIR sequence exquisitely depicted TFCC and ligament morphology on non enhanced MRI. MRA consistently picked up more tears, and it either completely excluded the possibility of a tear or provided a higher diagnostic confidence level. We employed T₂ FFE sequence as a reference for abnormal signal detected on non enhanced PD SPAIR or post arthrographic T₁ SPIR sequences.

In the current study, TFCC lesion was the most common pathologic finding (17 detected on MRI & 22 on MRA and confirmed arthroscopically), which is consistent with the study of Basiouny Alghannam et al. [1] which assessed the role of MRI and MR arthrography in evaluation of wrist pain and stated that TFCC and ligamentous injury was the most common finding in their study.

In disagreement with Asaad et al. [15] who considered only full thickness TFCC tears in his study, our work was dependent on signal abnormalities and we included both partial and complete thickness TFCC tears.

In the current study, based on signal abnormalities described by Cerezal et al. [5] we depended mainly on signal abnormalities detected on PD SPAIR (MRI) and T₁ SPIR (MRA) with parallel comparison of these signal abnormalities to signals obtained on T₂ FFE sequence.

The location and configuration of the tear play an important role for

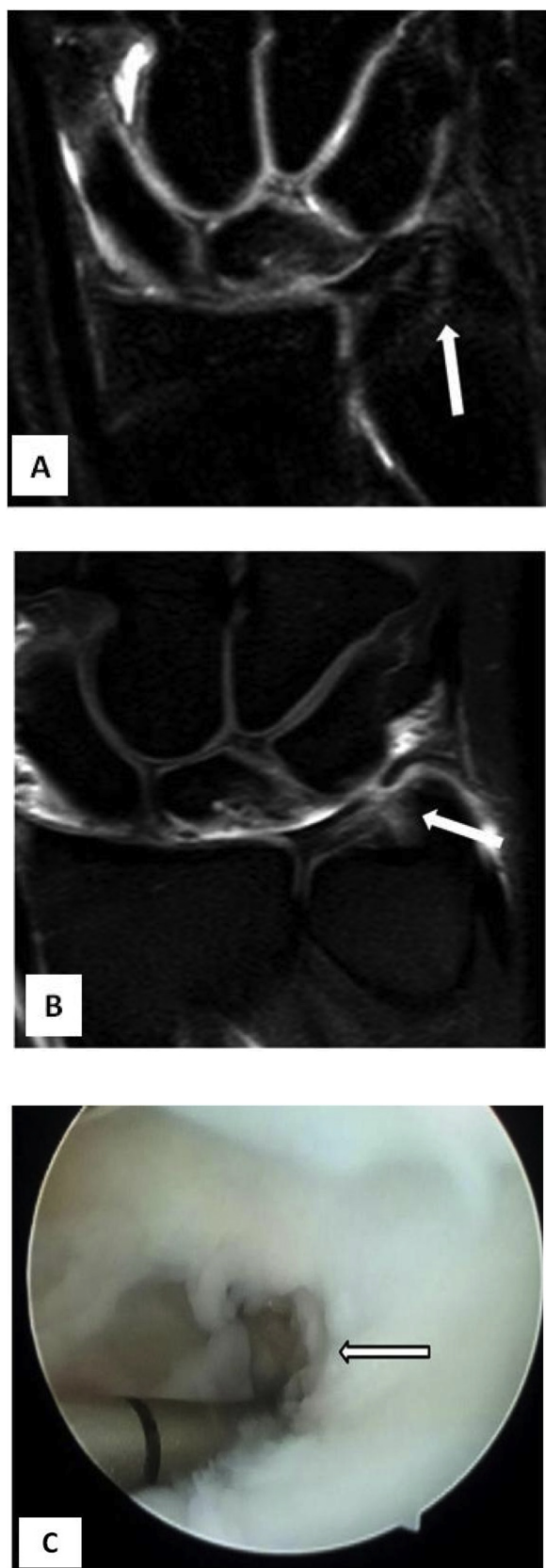


Fig. 1. Female patient, 17 years old presented with chronic right ulnar sided wrist pain. No history of trauma. **Conventional MRI study:** Coronal PD SPAIR image (A) showed intact TFCC (arrow). **Direct MRA study:** Coronal T₁ SPIR image (B) showed abnormal hyperintense signal intensity involving ulno-apical attachment of TFCC suggesting partial thickness peripheral ulnar TFCC tear (arrow) with no detected leakage to DRUJ. **Arthroscopy** image (C): confirmed the diagnosis of peripheral ulnar TFCC lesion.

the hand surgeons. The treatment of TFCC tears is complex and ongoing. Central tears are treated with arthroscopic debridement by enlarging the tear in such a way that the fibrocartilage flaps can no longer make contact [16]. If a tear is associated with an ulna-plus, simple debridement of the tear is insufficient and a formal ulnar shortening or an arthroscopic resection of the dome of the ulnar head (the so-called “arthroscopic wafer” procedure) is most appropriate [17]. As for central tear, correction of a concomitant ulna-plus is mandatory: repair of a tear without considerations of the ulna discrepancy leads to failure of the procedure [6]. Avulsion of the TFCC from the very edge of the radius (class ID) should be differentiated from the central-most type IA because the latter is not repairable. In class ID, however, the TFCC can be successfully reinserted into the radius and repaired with an open procedure or arthroscopic method [18].

In agreement with other studies by Moser et al. [14] as well as Pahwa et al. [8] & Abdelsattar et al. [20] we tried to classify TFCC lesions according to Palmer's classification [19]. We essentially differentiated the most common central and peripheral tears. Central tears were mostly considered degenerative (Palmer IIB and IIC) except when there is obvious history of trauma and no associated degenerative ulnar sided lunate changes where central traumatic tear is suggested (Palmer IA) whereas ulnar tears (Palmer IB) involving ulnar attachment are usually traumatic. Other subtypes are less frequent and were not detected in our study.

In the current study, TFCC lesions according to Palmer's classification detected on MRA study and confirmed arthroscopically included (1) IIB, (6) IIC, (1) IA and (14) IB.

However, as explained by Pahwa et al. [8] as a result of not remembering the traumatic event that caused a TFCC tear (e.g., lifting a heavy weight) by patients who usually present with unexplained chronic wrist pain. So, we also described the location of tear, presence of any associated intrinsic ligament tears and degenerative changes, if any, in every case.

When we considered central subtype of TFCC lesion individually; conventional MRI study correctly diagnosed (7) central TFCC lesions and missed (1) central TFCC lesion, while MRA study made correct diagnosis of all central TFCC lesions (8). This missed central tear on MRI study was very small and looks like flap tear and appeared only after distension of joint by intra-articular contrast injection on MRA study with obvious secondary leakage of contrast into DRUJ.

In the current study, 3 ligamentous injuries (2 scapholunate and 1 lunotriquetral ligament injuries) were detected arthroscopically out of which 1 SLL injury was detected on MRI study while all were visualized on MRA study which made correct localization of them on its axial T₁ SPIR sequences easily.

There is wide variation in literature regarding the diagnostic accuracy of MRI and MRA [5,20–24]. Reported sensitivity of conventional MRI is 52–89% for detecting TFCC tears [20]. For MR arthrography, different studies have shown sensitivity in the range of 90–100% for detecting TFCC tears [5].

Our results of MRI for central TFCC lesions (showed sensitivity and specificity 87.5% & 100% respectively) are nearer to those described by Oneson et al. [24] that used the same scanner field strength (1.5 T) and revealed sensitivity and specificity for central TFCC lesions being (91% & 87% for observer I and 91% & 79% for observer II respectively). Also our results are comparable with results of the recent study of Pahwa et al. [8] that shows sensitivity and specificity of MRA being (83% & 100%) as their study didn't encounter any peripheral ulnar TFCC lesions.

Our results of MRA using direct intra-articular contrast injection for central TFCC lesions (showed sensitivity and specificity 100% & 100% respectively) are higher than the indirect (intravenous) wrist MRA results of Haims et al. [22] who used 1.5 T scanner and reported sensitivity and specificity in assessment of the central disk of TFCC (83% & 91% respectively). Recently, Asaad et al. [15] who used also single radiocarpal injection and a 1.5 T scanner revealed sensitivity and

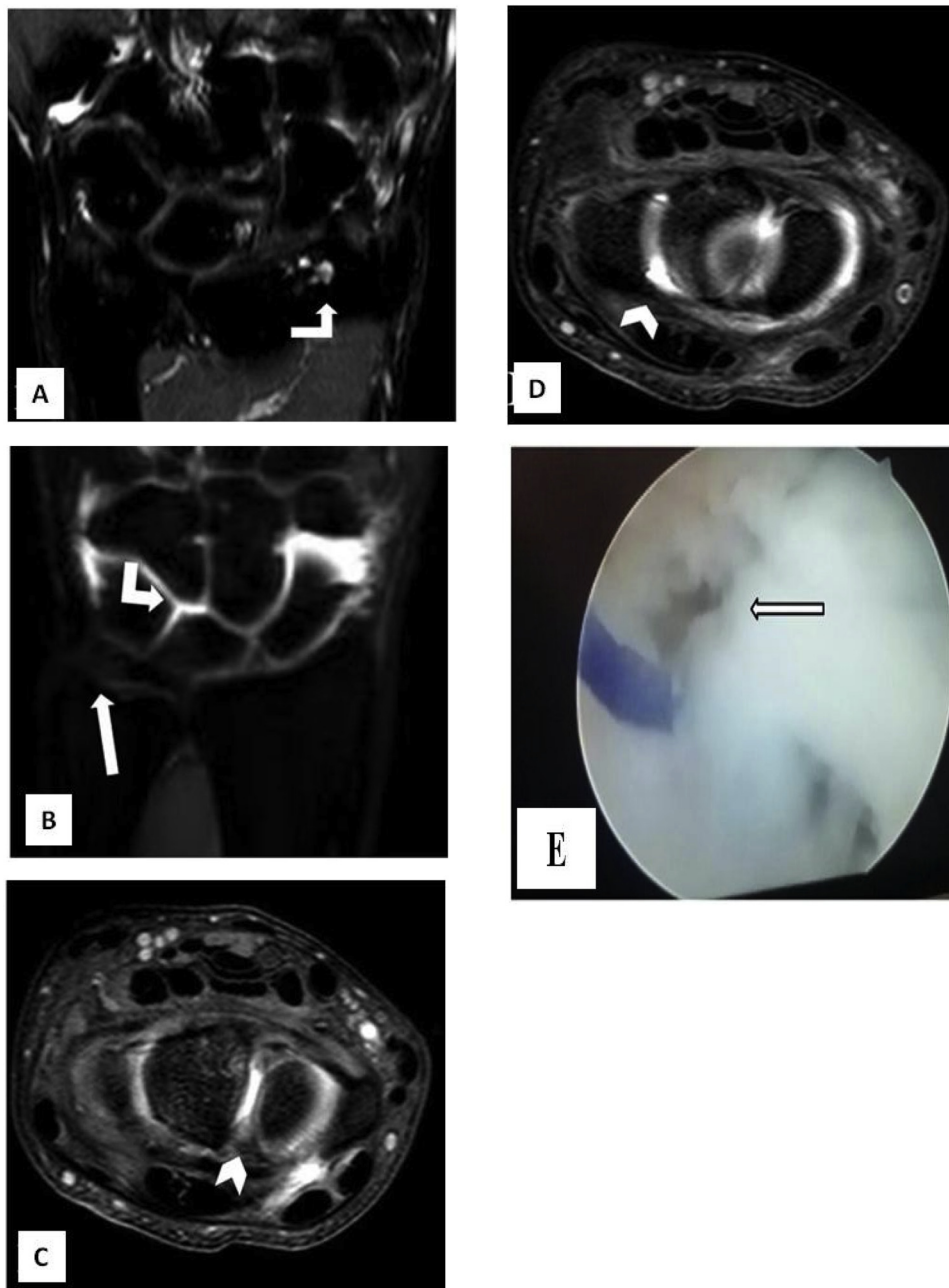


Fig. 2. Male patient, 30 years old presented with chronic right wrist pain following trauma. **Conventional MRI study:** Coronal PD SPAIR image (A) showed intact TFCC and radiocarpal joint arthritic changes in term of reduced joint space and subarticular cystic degeneration seen just proximal to SLL (curved arrow). **Direct MRA study:** Coronal T₁ SPIR image (B) showed intermediate signal intensity involving the peripheral ulnar portion of TFCC (straight arrow) and showed leakage to mid carpal compartment (curved arrow) which is coincident with SLL and LTL tears. Axial T₁ SPIR image (C) showed SLL tear involving its membranous portion (arrow head). Axial T₁ SPIR image (D) showed LTL tear involving its dorsal portion (arrow head). **Arthroscopy** image (E): confirmed the diagnosis of peripheral ulnar TFCC lesion.

specificity (89% & 91% respectively) for central TFCC lesions being lower when compared to our results which can be attributed to their detection of Full thickness TFCC tears only.

Our results of MRI for peripheral ulnar TFCC tears individually (showed sensitivity and specificity 71.4%, 81.8% respectively) are superior to those reported by Oneson et al. [24] in an MR imaging study of TFCC tears that underwent arthroscopic evaluation, who had a poor sensitivity to ulnar tears for two observers (25% and 50%, respectively). Haims et al. [22] more recently confirmed the limitations of conventional MR imaging in the diagnosis of peripheral ulnar-sided tears of the TFC. They found the evaluation sensitivity, specificity and accuracy of tears of the peripheral TFCC to be 17%, 79% and 64% respectively. The poor diagnostic accuracy was attributed to the presence of normal striated fascicles at the periphery of the TFCC and fluid that collected on the ulnar aspect of the wrist [22,24].

Our results of MRA for peripheral ulnar TFCC lesions revealed sensitivity and specificity being 100% & 90.9% respectively are

superior to those detected by Asaad et al. [15] who used single radiocarpal injection and a 1.5 T scanner revealed lower sensitivity and specificity for peripheral ulnar TFCC lesions (83% & 80% respectively). He attributed his lower sensitivity of MRA for peripheral ulnar TFCC tears than central to the more complex anatomy of the peripheral region of the TFCC, and the possibility that associated focal synovitis at the injured ulnar TFCC attachment might impede the passage of contrast [15].

In an article by Ruegger et al. [25] that evaluate the accuracy of MRA of the distal radioulnar joint in depiction of peripheral tears of the TFCC using a 1.5 T scanner and DRUJ contrast injection then adding midcarpal injection if no communication with radiocarpal established (different technique for injection), reported sensitivity and specificity for peripheral ulnar TFCC tears (being 85% and 76%) which are lower than our results for ulnar TFCC lesions. We attribute that to our dependence on signal abnormalities within TFCC as well as secondary leakage.

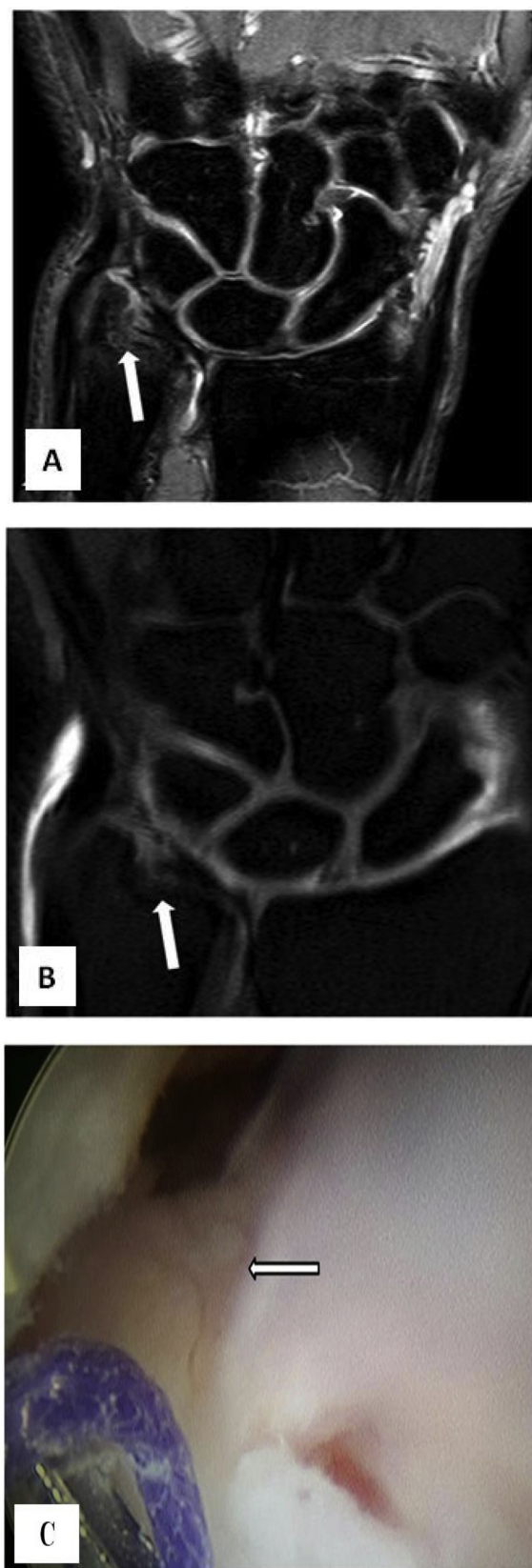


Fig. 3. Male patient, 30 years old presented with chronic right wrist pain & clicking following trauma. **Conventional MRI study:** Coronal PD SPAIR image (A) showed abnormal intermediate signal intensity involving both ulno-basal and ulno-apical attachments of TFCC, peripheral ulnar TFCC tear (arrow) with abnormal hyperintense signal intensity of bone marrow edema involving the distal ulna. **Direct MRA study:** Coronal T₁ SPIR image (B) showed abnormal intermediate signal intensity involving both ulno-basal and ulno-apical attachments of TFCC, peripheral ulnar TFCC tear (arrow) with no detected leakage into DRUJ. **Arthroscopy** image (C) confirmed the diagnosis of peripheral ulnar TFCC lesion (arrow).

MRA (100% sensitivity for peripheral ulnar tears) but higher than ours of MRI (being 71.4% for peripheral ulnar tears). This can be attributed to that he considered only communicating tears and excluded partial thickness tear while we considered both partial and complete thickness tears.

From these reports and ours, it would seem that the sensitivity and specificity of the direct MRA in detecting TFCC tears is superior to that of MRI. Also, that the sensitivity of wrist MRA in detecting peripheral TFCC tears is lower than its sensitivity in detecting central TFCC tears. Direct MRA using single radiocarpal injection has higher sensitivity for TFCC lesions than unenhanced MRI even at a higher scanner (3 T).

In our study, the MRA showed almost perfect agreement with arthroscopy for both central and ulnar TFCC tears (1.00 & 1.92 respectively) with highly statistically correlation between MRA and arthroscopy (p value = 0.000).

These results are nearer to study of Pahwa et al. [8] in which the strength of agreement between MRA and arthroscopy for delineating the location of tear was good ($\kappa = 0.999$), and the correlation between MRA and arthroscopy was significant ($P = 0.0003$), especially when taking into consideration that they didn't encountered any ulnar TFCC tear in their study.

4.1. Advantages of MRA

4.1.1. MRA superior to clinical diagnosis

2 patients with clinically diagnosis of TFCC lesions and ganglion cysts while their MRA revealed only ganglion underwent arthroscopy which confirmed integrity of TFCC.

4.1.2. MRA superior to MRI

MRA could diagnose and localize all arthroscopically confirmed TFCC and ligamentous lesions with much higher accuracy as well as other causes of wrist pathologies that were picked up by MRI.

4.1.3. MRA superior to arthroscopy

MRA is a comprehensive diagnostic tool as it could easily depict both intra and extra-capsular lesions while arthroscopy couldn't detect associated extra-capsular lesions as tenosynovitis and fracture hook of hamate. Also, both superior and inferior surfaces of TFCC could be easily depicted on MRA.

One of the advantages of our study is avoiding a bias of previous retrospective studies based on arthroscopic reports that showed insufficient representation of wrists with normal or partially torn ligaments, leading to overestimation of the diagnostic accuracy of imaging techniques.

Another advantage of our study to be considered that we do not perform any cadaveric correlation, making our study probably more representative of clinical practice and characteristics of the study population than those of a cadaveric population. Also, this makes our imaging data more realistic because of technical issues such as movement artifacts, especially with the long acquisition times of MRA (Figs. 1–5).

Magee et al. [26] used a 3 T scanner and single radiocarpal injection comparing MRI and MRA in TFCC lesions with arthroscopic correlation and reported sensitivity of MRI and MRA 75% and 88% for peripheral ulnar tears respectively. These results are comparable to our results of

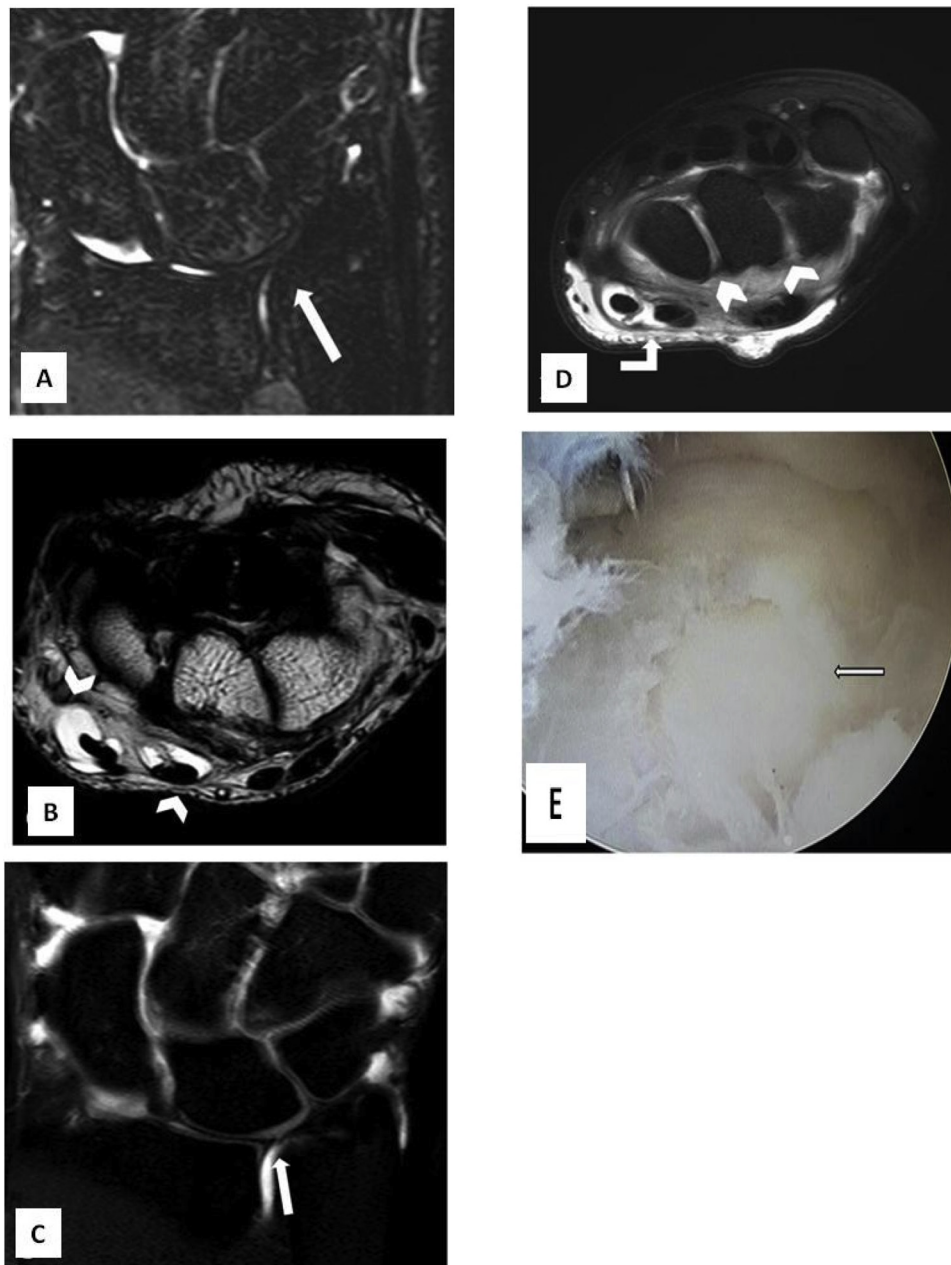


Fig. 4. Male patient, 21 years old presented with chronic right ulnar sided wrist pain. No history of trauma. **Conventional MRI study:** Coronal STIR image (A) showed intact TFCC. Axial T₂WI (B) showed abnormal fluid collection (arrow head) within the 2nd & 3rd extensor compartment. **Direct MRA study:** Coronal T₁ SPIR image (C) showed very small central TFCC tear that looks like flap tear (arrow). Axial T₁ SPIR (D) showed intact SLL and LTL (arrow head) as well as abnormal fluid collection (curved arrow) within the tendon sheath of the extensor pollicis longus (3rd extensor compartment) as it crosses the extensor carpi radialis brevis which shows also abnormal fluid collection within its tendon sheath as well as the extensor carpi radialis longus (the 2nd extensor compartment) just distal to Lister's tubercle, Distal intersection syndrome was suggested. **Arthroscopy** image (E): confirmed the diagnosis of central TFCC lesion.

5. Limitations

Several limitations should be considered in this study. First, although arthroscopy was the best reference standard available for this study, it remains an operator-dependent method has inter observer or even intra observer variability.

Second, because the decision to perform arthroscopy was based not only on clinical symptoms but also on preoperative imaging findings, a verification bias might have been introduced. Arthroscopic findings could, in particular, have been biased by the availability of MRI and MRA findings to the surgeon during surgery.

Third, because all MRI and MRA examinations were analyzed by two radiologists in consensus, we do not assess inter observer variability or agreement.

Fifth, although the number of patients included in this work was nearer to those in previously published prospective studies, especially when considering the time interval of our work being only one year (Pahwa et al. [8] assessed 53 patients over a period of 2 years with

arthroscopic correlation in 16 patients only & Abdelsattar et al. [20] assessed 51 patients over a period of 3 years with arthroscopic correlation in 44 patients), the number of each elemental lesion was small to allow further statistical analysis. This limitation may be attributed to several causes. First, in the present study we compared the diagnostic efficacies of both MRI and MRA for various wrist problems causing chronic wrist pain and not only TFCC lesions, including ligamentous injuries, fractures, AVN, and tenosynovitis, and not confined to certain point of these wrist problems. Second, regarding this comparative study, a relatively small number of wrists were evaluated because we could not obtain MRI, MRA and arthroscopy simultaneously in large number of patients owing to ethical consideration. Furthermore, a large number of patients who examined by single shot MRI and MRA were excluded from the study due to incomplete operative data, wide gap of time between imaging and arthroscopic examinations, either due to the long waiting list in the arthroscopy and sport injuries unit of our institution or due to economic status of the patients.

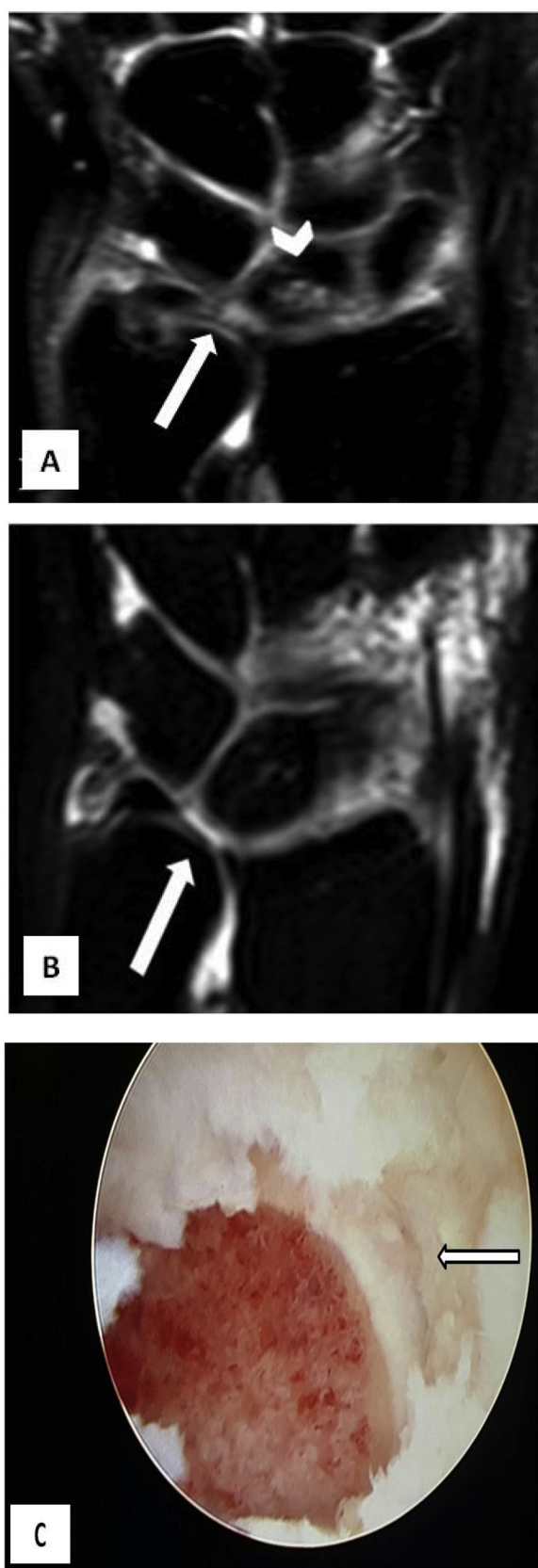


Fig. 5. Female patient, 29 years old presented with chronic right sided wrist pain. No history of trauma. **Conventional MRI study:** Coronal PD SPAIR image (A) showed central TFCC tear (arrow) with evident abnormal hyperintense signal of bone marrow edema of ulnar side of the lunate bone (arrow head) in association of minimal element of positive ulnar variance. **Direct MRA study:** Coronal T₁ SPIR image (B) showed large central TFCC tear (arrows) with detected leakage into DRUJ compartment in association with ulnar sided lunate chondromalacia and minimal element of positive ulnar variance. **Arthroscopy** image (C) confirmed the diagnosis of central TFCC lesion (arrow).

6. Conclusion

Clinical assessment of chronic wrist pain must be followed by MRA to guide the orthopedic interference.

We recommend MRA to replace MRI and arthroscopy in diagnosing causes of chronic wrist pain.

Ethical approval

“All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.”

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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