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Diagnostic Value of Diffusion Weighted MRI versus Conventional MRI in The Diagnosis of Rotator Cuff Tears

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Abstract:

Background: The rotator cuff is a group of four muscles and tendons that surround the shoulder joint. These muscles and tendons provide stability in the shoulder, attached around the head of the humerus bone, encircling it like a cuff. This study aimed to compare diagnostic value of diffusion-weighted MRI imaging to conventional MRI especially fat suppression imaging sequences in the detection of rotator cuff tears. **Methods:** This case control study included 70 participants who were divided into two groups; Case group: 50 patients with clinically suspected tear of rotator cuff tendons having history of trauma and Control group: 20 apparently healthy adult individuals with no history of trauma or significant shoulder pain as a control group. **Results:** According to conventional MRI, all 53 suspected rotator cuff tears were confirmed, giving high signal on T2/fat suppressed image while all controls gave normal low signal, with a statistically significant difference between both groups ($P < 0.001$). Conventional MRI had sensitivity of 100% and PPV of 100% with an overall accuracy of 100% for positive rotator cuff tears diagnosis. **Conclusion:** Diffusion MRI has good sensitivity and diagnostic accuracy in diagnosis of rotator cuff tears. However, the signal in diffusion MRI is greatly affected by time interval between insult and MRI examination so the earlier MRI can be done, the better the signal in diffusion images. ADC images correlation reveals T2 shine through artifacts rather than true diffusion restriction. In addition, diffusion MRI has lower spatial resolution and low image quality than conventional MRI images.

Keywords: Diffusion Weighted MRI; Conventional MRI; Rotator Cuff Tears.

Introduction

The rotator cuff is a group of four muscles and tendons that surround the shoulder joint. They provide stability in the shoulder being attached around the head of the humerus bone, encircling it like a cuff. These four muscles are : supraspinatus, infraspinatus, subscapularis and teres minor [(1)].

Rotator cuff tears are common musculoskeletal injuries and comprise about sixty percent of all shoulder pathologies. They can lead to functional impairment if poorly diagnosed and managed [(2)].

Rotator cuff tears can occur as a result from sport injuries in young patients or as a degenerative pathology in elderly patients. Most of these tears seem to occur in the tendon of supraspinatus muscle [(3)].

Rotator cuff tears are divided into full thickness and partial thickness tears. Partial thickness tears are further subdivided into bursal-sided, intra-tendinous, and articular-sided tears. Clinically, articular-sided tears are more common than bursal-sided tears [(3)].

Diagnosis of rotator cuff tears can be challenging. The patient usually complains of insidious onset pain that exacerbates by overhead activities and located in the deltoid region. Also, the patient may complain of weakness with loss of active range of motion but intact passive range of motion [(4)].

A variety of different radiological investigations have been recommended to assist in diagnosis. They have included plain X-ray, conventional X-ray arthrography, ultrasound (US) and magnetic resonance imaging (MRI) [(4)].

Currently, arthroscopy is considered the “reference standard” for the diagnosis of shoulder pathologies. However, arthroscopy is an invasive procedure that requires hospitalization and anaesthesia, and carries a risk of complications for example infection, damage to adjacent structures such as brachial plexus and anaesthesia related complications [(5)].

MRI with its good soft tissue resolution and multiplanar imaging capabilities has emerged as the investigation of choice in the preoperative evaluation of rotator cuff diseases. It can provides information about tear diameter and depth as well as being able to differentiate between tendinopathy, partial- and full-thickness rotator cuff tears which can influence the decision of treatment [(6)].

Unfortunately, some previous studies reported MRI to have lower sensitivity and specificity in the diagnosis of partial thickness rotator cuff tears than that of full thickness tears. Also, orthopedic surgeons showed poor agreement in assessing the grade of a partial-thickness tear when reviewing MRI for rotator cuff diseases [(7)].

MRI with fat-suppressed (FS) T2-weighted imaging (T2WI) has been used to increase the detection of rotator cuff tears; however, the results vary with the experience of the radiologist [(8)].

Using MRI with diffusion-weighted imaging (DWI) can give molecular information about fluid motion in tissues and can enable acquisition of images that reflect histologic structure and cellularity. So, the tissue diffusivity may be changed in cases of rotator cuff tears and these changes may be detected using diffusion imaging sequence [(9)].

The purpose of this study was to compare diagnostic value of diffusion-weighted MRI imaging to conventional MRI

especially fat suppression imaging sequences in the detection of rotator cuff tears.

Patients and methods

This case control study included 70 participants who were referred from Orthopedic Clinics to the MRI unit, Radiology Department, Alahrar Teaching Hospital, Zagazig, Sharkia governorate-Ministry of health from January 2021 to December 2022.

An informed consent was taken from all the participants before taking any data or doing any imaging techniques. The study was approved by Benha university ethical committee (MD 25-2-2019).

Inclusion criteria were patients with clinical suspicion of rotator cuff tear, history of shoulder trauma, all age groups and both sexes.

Exclusion criteria were absolute contraindications for MR imaging (e.g. prosthetic heart valves, cardiac pacemaker, metallic implants), claustrophobic patients and all patients who do not approve to be a part of the study.

Grouping: Participants were divided into two groups**; Case group:** 50 patients with clinically suspected tear of rotator cuff tendons having history of trauma and **Control group**: 20 healthy adult individuals with no history of trauma or significant shoulder pain as a control group.

All studied participants were subjected to the following: Detailed history taking, including [patient's age, history of trauma, operative or arthroscopic history, complaints of shoulder pain and/or limitation of movement.].

MRI imaging:

All MRI examinations were performed with Phillips Achivia 1.5 Tesla MRI system using dedicated shoulder coil. MRI protocol included axial, sagittal and coronal T1 (TR= 500 ms, TE= 11 ms, slice thickness= 4 mm & FOV= 24x19 cm), T2 (TR= 2650 ms, TE= 80 ms, slice thickness= 4 mm & FOV= 24x19 cm) weighted images and fat suppressed T2-weighted images (TR= 2000 ms, TE= 38 ms, slice thickness= 4 mm & FOV= 24x19 cm). Axial & coronal DWIs (TR= 5300 ms, TE= 110 ms, slice thickness= 4 mm & FOV= 24x19 cm) at b values of 0 & 600 s/mm^2 were performed during the same MRI examination in all patients. The selection of a b value (600 s/ mm^2) was based on a compromise between the signal-to-noise ratio and adequate diffusion strength. Axial & coronal ADC images were obtained (TR= 5300 ms, TE= 110 ms, slice thickness= 4 mm & FOV= 24x19 cm).

Images were acquired with the patient in supine position and head pointing to the magnet. MRI contains no radiation. No side effects from the magnetic field or radio waves have been reported.

Interpretation of images:

Images were reviewed by consultant radiologist of many years of experience in shoulder MRI imaging using a commercial workstation (view forum workstation, Phillips Dicom). The MRI findings were correlated with the results of arthroscopy when done. Arthroscopy is considered the gold standard reference in those cases. Arthroscopy was not done in all cases because of patient refusal or decision of conservative management, and in such cases MRI findings were correlated with clinical data and ultrasound findings.

The final diagnosis was established based on MRI findings then the sensitivity, specificity, positive and negative predictive values of the analyzed data were

measured using commercially available PC-based software package. Tendon tear was diagnosed as a defect in tendon either partial or full thickness displayed as high signal intensity better seen in fat suppressed images.

In cases of full thickness tear: the involvement of insertion site, measurement of fluid gap, presence of tendon retraction and condition of muscle (either preserved muscle bulk or presence of fatty atrophic changes) as well as associated findings were reported. In cases of partial thickness tear: the surface of tendon involved and insertion site involvement as well as associated findings were reported.

The tendon tear was assessed at its corresponding site in diffusion images regarding presence of abnormal high signal as follows: If no abnormal high signal → no diffusion restriction. If abnormal high signal was present → the size and brightness of the signal were compared to that seen in fat suppressed images considering period of time between trauma and MRI examination.

The high signal in diffusion images was correlated with ADC images to differentiate between true diffusion restriction & T2 shine through artifact as follows: High signal in DWI & high or isointense signal in ADC → T2 shine through artifact. High signal in DWI and low signal in ADC → true diffusion restriction.

Statistical analysis

Statistical analysis was done by SPSS v26 (IBM Inc., Armonk, NY, USA). Quantitative variables were presented as Median and IQR. Qualitative variables were presented as frequency and percentage (%) and were analyzed utilizing the Chi-square test or Fisher's exact test when appropriate. A two tailed P value < 0.05 was considered statistically significant.

Results

There was a statistically significant difference between both groups in terms of shoulder side (P=0.004). According to conventional MRI, all 53 suspected rotator cuff tears were confirmed, giving high signal on T2/fat suppressed image while all controls gave normal low signal, with a statistically significant difference between both groups (P < 0.001). Table 1

In comparison to arthroscopy (our gold standard) results, conventional MRI had sensitivity of 100% and PPV of 100% with an overall accuracy of 100% for positive rotator cuff tears diagnosis.

In supraspinatus muscle, Out of the 37 tears, 30% had full thickness tear and 70 % had partial thickness tear. Out of the 26 partial thickness tears, the interstitial (intra-tendinous) type was the most common (46%). Articular surface involvement with or without intra-tendinous extension was (31%). Bursal surface involvement with or without intra-tendinous extension was (7.7%). In infraspinatus muscle, Out of the 13 tears, 46% had full thickness tear and 54 % had partial thickness tear. Out of the 7 partial thickness tears, the interstitial type was (42.9%) while articular type with or without intra-tendinous extension was (57.1%). Regarding diffusion weighted images findings of cases, the majority of suspected tears (81.1%), showed high signal while 1.9% showed low signal and 17% gave no signal. As for ADC images findings, 50.9% of tears elicited high signal, 17% and 15.1% gave iso intense and iso to high signal respectively while 7.5% showed no signal. In conclusion, the positive results (81.1%) were T2 shine

through artifact which were false positive and 18.9% showed free or facilitated diffusion. There was a statistically significant difference between the results of cases and controls who gave no signal on diffusion and ADC images. Table 2

Table 1: Baseline characteristics and Conventional MRI results of the studied participants

		Case group (n=50)	Control group (n=20)	P value
Sex	Male	25 (50%)	8 (40%)	0.449
	Female	25 (50%)	12 (60%)	
Age (years)	< 20	1 (2%)	0 (0%)	0.712
	20 – 40	22 (44%)	11 (55%)	
	41 – 60	27 (54%)	9 (45%)	
	Median (IQR)	43.5 (32 - 53.25)	39 (30.25 - 48.75)	0.298
Side of shoulder	Right	43 (86%)	10 (50%)	0.004*
	Left	7 (14%)	10 (50%)	
T2/Fat suppressed image	Normal low signal	0 (0%)	20 (100%)	< 0.001*
	High signal	53 (100%)	0 (0%)	

Data are presented as frequency (%) unless otherwise mentioned, *: Statistically significant as P value < 0.05.

Table 2: Types & incidence of rotator cuff tears in each muscle and Diffusion MRI results of the studied groups

		Supraspinatus tendon tear (n= 37)	Infraspinatus tendon tear (n= 13)	Subscapularis tendon tear (n=3)
= Full thickness tear		11 (30%)	6 (46%)	0 (0%)
= Partial thickness tear		26 (70%)	7 (54%)	3 (100%)
- **Interstitial (intra-tendinous)**		12 (46%)	3 (42.9%)	0 (0%)
- **Articular surface +/- intra-tendinous extension**		8 (31%)	4 (57.1%)	3 (100%)
- **Bursal surface +/- intra-tendinous extension**		6 (23%)	0	0 (0%)
		Case group (n=53)	**Control group (n=20)**	**P value**
Diffusion weighted image	No signal	9 (17%)	20 (100%)	< 0.001*
	Low signal	1 (1.9%)	0 (0%)	
	High signal	43 (81.1%)	0 (0%)	
ADC image	No signal	4 (7.5%)	20 (100%)	< 0.001*
	Iso intense signal	9 (17%)	0 (0%)	
	Iso to high signal	8 (15.1%)	0 (0%)	
	High signal	27 (50.9%)	0 (0%)	
	Low signal	0 (0%)	0 (0%)	
	Not done	5 (9.4%)	0 (0%)	
Results	Diffusion restriction	0 (0%)	0 (0%)	< 0.001*
	T2 shine through artifact	43 (81.1%)	0 (0%)	
	No or facilitated diffusion	10 (18.9%)	20 (100%)	

Data are presented as frequency (%), *: Statistically significant as P value < 0.05

In comparison to conventional MRI, diffusion MRI elicited abnormal signal with sensitivity of 81.13%, specificity of 0%, PPV of 100%, NPV of 0% and an

overall accuracy of 81.13%, however this signal was indicative of artefacts (false positive results) not diffusion restriction. Table 3

We detected a statistically significant relation between time interval from trauma to doing MRI and abnormal signal in diffusion images (P <0.001) as in some cases, the earlier MRI was conducted after trauma, the larger and brighter signal was. Also, the later MRI was conducted, the smaller and less bright signal was. Table ٤

Female patient, 52 years old, history of falling downstairs 2 days ago, complaining of severe pain in right shoulder and limitation of movement of her arm. Figure 1

Table 3: Diagnostic performance of diffusion MRI in comparison to conventional MRI for positive rotator cuff tears, Size & brightness of signal in diffusion image compared to T2/fat suppressed image results of rotator cuff tears

	Value	
Sensitivity	81.13	
Specificity	0	
PPV	100	
NPV	0	
Diagnostic accuracy	81.13	
Size & brightness of signal		
	N	**%**
No signal	10	18.9
Same size and brightness	32	60.4
Signal is smaller and/or less bright	6	11.3
Signal is larger and/or brighter	5	9.4

PPV: Positive predictive value, NPV: Negative predictive value.

Table 4: Relation between time interval and presence, degree of brightness and size of abnormal signal in diffusion images compared to fat suppressed images

	Time interval between trauma & MRI			
	< 1 week (n=32)	**1 – 2 weeks (n=11)**	**> 2 weeks (n=10)**	**P value**
No signal	0 (0%)	0 (0%)	10 (100%)	**< 0.001***
Same size and brightness	27 (84.4%)	5 (45.5%)	0 (0%)	
Signal is smaller and/or less bright	0 (0%)	6 (54.5%)	0 (0%)	
Signal is larger and/or brighter	5 (15.6%)	0 (0%)	0 (0%)	
Associated findings			N	%
No			20	40
Yes			30	60
Joint effusion			20	40
Bone marrow contusion			6	12
Sub-acromial bursitis			5	10
Sub-coracoid bursitis			3	6
Deltoid muscle strain			2	4
Supraspinatus muscle strain			1	2
Supraspinatus muscle atrophy			1	2
Acromioclavicular joint arthropathy			2	4

Data are presented as frequency (%), *: Statistically significant as P value < 0.05

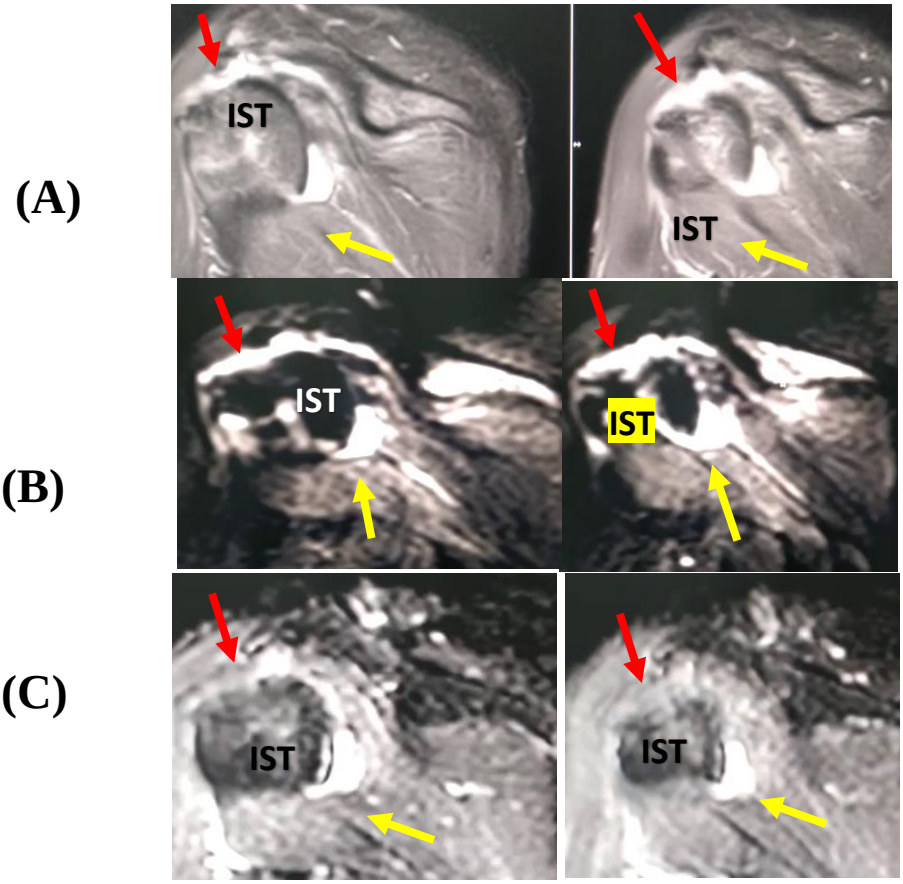

Figure 1: (A) Coronal STIR & **(B) Coronal diffusion weighted images of right shoulder** show abnormal bright signal intensity gap at insertion site of infraspinatus tendon (IST) (red arrows) measuring about 3.3 cm in length with tendon retraction in keeping with full thickness tendon tear. Muscle bulk is preserved with no fatty changes. Another abnormal bright signal intensity is seen within joint space (yellow arrows) indicating joint effusion.
(C) Corresponding coronal ADC images show iso to high signal intensity at site of tendon tear (red arrows) indicating T2 shine through artifact (no true diffusion restriction). Persistent bright signal intensity is noted at site of joint effusion (yellow arrows) in keeping with T2 shine through artifact (no true diffusion restriction).

Discussion

A retrospective study done by Brockmeyer M. et al (2017) compared preoperative MRI findings of rotator cuff tears with the intraoperative arthroscopic findings as the gold standard and found that sensitivity of MRI to identify partial thickness tear was 51.6%, the specificity was 77.2%, positive predictive value was 41.3% and negative predictive value was 83.7%. Based on these values, this study concluded that MRI imaging does not improve diagnostic accuracy [10]. However, a meta-analysis study published in 2019 by Li W. et al used evidence-based approach to assess accuracy of MRI in diagnosing rotator cuff tears. This study included 18 surveys that comprised 984 patients. The results of this study were as follow: the overall sensitivity of MRI to identify any rotator cuff tear was 93%,

sensitivity for full thickness tears was 87% and sensitivity for partial thickness tears was 80% so, the sensitivity for detection of full thickness tears was higher than that for partial thickness tears. In addition, the overall specificity of MRI for identifying full thickness tears (93%) was higher than that for partial thickness tears (83%) [(11)].

The main result of our study is that diffusion MRI has good sensitivity (81.13%), and diagnostic accuracy (81.13%) regarding diagnosis of rotator cuff tears when compared to conventional MRI images especially T2/fat suppressed images. These results are in agreement with study done by Lo H.-C. et al that claimed sensitivity and diagnostic accuracy of diffusion MRI were 89.1% & 87.7% respectively in diagnosis of rotator cuff tears [(12)].

In addition, for comparing diagnostic performance of DWI & T2/fat suppression, parameters like lesion/muscle signal intensity ratio in diffusion and T2/fat suppressed images, ADC signal intensity ratio and receiving operating characteristic curve analysis were used in Lo H.-C. et al (2016) study where signal intensity & ADC values were measured at the lesion and the muscle and the ratios were obtained. The results showed that diffusion is superior to T2/fat suppression in diagnosis of rotator cuff tears because the difference in the corresponding areas under receiving operating characteristic curves was significant but ADC values of the partial tear group were not significantly different from those of the normal group and mean lesion ADC represents high signal denoting presence of T2 shine through artifacts. Although in the current study, those parameters were not used, and only the signal in ADC images was assessed subjectively, there is agreement between both studies in that based on ADC results; signal in diffusion is likely to be T2 shine through artifact and not true diffusion restriction [(12)].

Another study done by Aydin H. et al examined the efficacy of diffusion MRI in evaluation of tendon injuries in ankle and foot not in rotator cuff and claimed to be the first in literature to do that. This study found that diffusion has superiority over conventional MRI in evaluation of rupture and partial tear of ankle tendons with sensitivity more than 90% over conventional MRI. It concluded that diffusion can add beneficial data to diagnosis of tendon injuries and should be included in routine MRI of the ankle for more appropriate evaluation. This study did not include control group and there was no mention of correlation of diffusion results to ADC, which is essential for assessment of diffusion. Both studies are in agreement regarding good sensitivity of diffusion [(13)].

In the current study, there was equal number of both sexes in the case group (25 each), no significant difference in range of age between case and control groups (19 to 60 & 24 to 55 years respectively), young mean age (39.5 years) and axial MRI sections were done in addition to coronal sections to overcome limitations mentioned in the previous study done by Lo H.-C. et al where most of the patients were middle-aged men, mean age was higher (48.3 years) and only coronal sections were available [(12)].

Most affected age group in our study was (41 to 60 years) by 54%. This result is in agreement with study done by Kognati et al., that mentioned age group above 40 years was more affected by 22% & 78% respectively [(14)].

The most common involved muscle in our study was supraspinatus 35 out of 51 (69%) followed by infraspinatus and subscapularis (13 out of 51 "25 %" & 3 out of 51 "6%" respectively). These results are in agreement with study done by Sharma G. et al (2017) where supraspinatus was most involved 45 out of 45 (100%), then infraspinatus 11 out of 45 (24.4%) & subscapularis 9 out of 45 (20%) [(15)].

In the study done by Kognati et al, partial thickness tears were 27 out of 50 (54%) of which 18 (36%) involved supraspinatus tendon and full thickness tears were 6 out of 50 (12%) of which 4 (8%) involved supraspinatus tendon. In our study, partial thickness tears were 36 out of 53 (68%) were more common than full thickness tear were 17 out of 53 (32%) and both types of tears were more common in supraspinatus muscle than in other rotator cuff muscles where partial thickness tears in supraspinatus muscle account for 26 out of 53 (49%) while full thickness tears account for 11 out of 53 (21%) [(14)]. The results of both studies are in agreement regarding more common partial thickness tears and more involvement of supraspinatus muscle.

MRI findings in the study done by Sharma G. et al., had good agreement with arthroscopic findings where MRI showed a sensitivity of 89.6%, positive predictive value of 100% and diagnostic accuracy of 93.1% for the diagnosis of full thickness rotator cuff tears. For partial thickness tears, MRI showed a sensitivity of 100%, positive predictive value of 78.9% and diagnostic accuracy of 91.1% [(15)]. In our study, although not all cases underwent arthroscopy, however the percentage of cases that performed arthroscopy (58%), all of them gave positive results for tear supporting MRI findings reflecting good agreement between the two modalities.

The most common associated finding in our study was joint effusion 20 out of 50 (40%) followed by bone marrow contusion and sub-acromial bursitis (6 out of 50 "12%" & 5 out of 50 "10%" respectively). These results are in disagreement with study done by Sharma G. et al where most common finding was sub-acromial bursitis 25 out of 45 "55.5%" followed by sub-coracoid bursitis & joint effusion 23 out of 45 "51%" & 19 out of 45 "42 %" respectively [(15).]

Conclusion

Diffusion MRI has good sensitivity and diagnostic accuracy in diagnosis of rotator cuff tears and do not add much time to MRI examination. However, the signal in diffusion MRI is greatly affected by time interval between insult and MRI examination so the earlier MRI can be done, the better the signal in diffusion images. ADC images correlation reveals T2 shine through artifacts rather than true diffusion restriction. In addition, diffusion MRI has lower spatial resolution and low image quality than conventional MRI images. Therefore, diffusion can be used as a helpful tool in diagnosis of rotator cuff tear in addition to conventional MRI but cannot replace it.

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