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Original Article

Conventional MR in rotator cuff pathology. Is it sufficient?

Mennatallah Hatem Shalaby [a,*], Khaled A. Ali Shehata [a], Mohamed Amr Farouk [b]

[a] Ain Shams University, Egypt
[b] Egyptian Medical Military Academy, Egypt

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ABSTRACT

Background: Magnetic resonance (MR) provides detailed information for the depiction of shoulder lesions. It allows a unique anatomical and tissue characterization providing a detailed evaluation of the rotator cuff (RC) and the surrounding bones.
Purpose: Our objective is to assess the diagnostic accuracy of MR in depiction of lesions encountered in shoulder impingement and rotator cuff (RC) degenerative lesions compared to shoulder arthroscopy.
Patients and methods: This study included 28 patients with shoulder impingement for which conventional MR was done followed by arthroscopy. The results of MR were compared to the results of surgical repair.
Results: MR was highly accurate in the diagnosis of full-thickness (FT) tears of the RC, showing 100% accuracy, 100% sensitivity, and 100% specificity. MR was capable of comprehensive evaluation of FT tears. MR had a high accuracy (96%) in the diagnosis of partial-thickness (PT) RC tears. It showed 100% specificity and 100% positive predictive value (PPV) with no false positive cases. MR revealed high specificity (100%) in the diagnosis of biceps abnormalities. It identified all the 20 negative cases that were confirmed surgically.
Conclusion: Conventional MR plays an adequate role in evaluation of different lesions encountered in shoulder impingement and RC degenerative disorders.

1. Introduction

MR proved to have an eminent role in assessment of shoulder lesions and depicting lesions that are challenging to clinicians. It is of high value in depicting lesions of the RC, biceps tendon and glenoid labrum and that's why it became the corner stone in the management of patients presenting with shoulder pain [1].

Shoulder pain is frequently caused by RC pathology with an underlying subacromial impingement syndrome leading to marked loss of shoulder function [2].

Impingement is not a radiologic diagnosis, it is usually diagnosed clinically, but patients are referred to MR unit to depict changes in both the tendons and the osseous structures where they are correlated with the patient's clinical findings [3].

Impingement syndrome was mainly established to include the whole spectrum of RC disorders because it was clearly recognised that RC tendinopathy, PT tears and FT tears were not confidently clinically diagnosed [4].

Subacromial impingement is usually caused by a long term repeated minor trauma to the common tendon of the RC as it courses under the coraco acromial arch. The dimensions of the subacromial space change variably according to the arm position if abducted or internally rotated causing marked RC tendon compression [2].

There is wide variety of causes that lead to impingement syndrome. There are two main categories: structural causes (including the acromion shape, acromioclavicular joint, coracoids process, bursa, humerus and RC) and functional causes [5].

It is well established that patients with chronic shoulder pain are further investigated by imaging procedures [6].

MR proved to be the best imaging modality that provides the essential data required for the diagnosis of sub-acromial pain, RC tears and degenerative changes of the shoulder. It offers a proper anatomical and tissue characterization with an accurate assessment of the RC and the surrounding bones [7].

MR is recommended when clinical examination as well as the sonographic and radiographic evaluation fail to delineate the cause of the sub-acromial pain especially if bony structures or gleno-

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* Corresponding author.
E-mail address: Mennatshalaby@yahoo.com (M.H. Shalaby).

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humeral pathology are suspected. Moreover, MR in assessment of muscle atrophy is one of the key factors that decides the proper management namely in extensive RC tears [7].

Arthroscopy is highly accurate than clinical examination in delineation of the underlying cause of pain as it properly depicts the extent of RC tears and their size [6]. It is also considered to be the gold standard for the evaluation of the glenohumeral cartilage [8].

Orthopaedic surgeons frequently use MR for preoperative planning and evaluation giving the opportunity for the musculoskeletal radiologist to compare the MR findings to the arthroscopic results and thus radiologists are informed of the lesions they might have missed or misinterpreted [9].

2. Objectives

The purpose of this study was to delineate the diagnostic accuracy of MR compared to the gold standard reference which is arthroscopy (or open surgery), in patients presenting with symptoms and signs of shoulder impingement and RC lesions.

3. Patients and methods

3.1. Patients

During the period from May 2015 till June 2016, a prospective study was primarily conducted on 82 patients (49 males and 33 females) presented with a complaint of persistent shoulder pain for more than 3 months and a clinical provisional diagnosis of shoulder impingement and RC degenerative lesions. Their ages ranged from 26 to 65 years with a mean age of 47.1 years ± 9.3 SD. They were referred to the MR unit by the orthopaedic surgeon to perform conventional MR of the shoulder.

After applying the exclusion criteria listed below, only 28 patients (19 males and 9 females) proceeded to surgery (arthroscopy or open surgery) in a period of 2 to 4 months after the MR study. Their ages ranged from 37 years to 61 years (mean age 49.3 years ± 6.8 SD). Twenty-three patients had shoulder arthroscopy and the remaining 5 patients had open surgery.

3.1.1. Inclusion criteria

- Age range between 25–65 years.
- Clinical presentation of persistent shoulder pain for more than 3 months duration.
- Positive clinical tests for shoulder impingement syndrome and RC degenerative lesions.

3.1.2. Exclusion criteria

- Patients below 25 years were excluded because it was less likely for the disease to be symptomatic.
- Patients above 65 years were also excluded because older age would have less chance for surgical intervention.
- Patients with previous shoulder surgery, history of shoulder dislocation and a history of shoulder girdle fracture or trauma or congenital or neoplastic lesions.
- Patients with loss of muscle bulk as they will not benefit from surgical repair.
- Patients with cardiac pacemakers, neuro-stimulators, insulin pumps and inner ear implants.
- Other factors related to economic reasons or lack of health insurance that hindered patients to proceed to surgical intervention.
- Non indicated cases for surgical intervention like bursitis and effusion or normal MR findings.

All patients were subjected to detailed history taking and had a provisional clinical diagnosis and then they were all submitted to conventional MR of the shoulder.

Two radiologists specialized in musculoskeletal radiology analyzed the MR findings for each patient. They were unaware of the surgical and arthroscopic results. The MR findings were then compared to the surgical and arthroscopic results.

3.2. Methods

3.2.1. Conventional shoulder MR protocol

No special patient preparation was needed, as this study was non contrast MRI shoulder study.

The procedure was performed using a Multisync LCD 2490 WUXI 1.5T closed Magnet (GE) with a phased array receive coil and two coil elements wrapped around the shoulder, 14-cm field of view, 4-mm section thickness with a 1 mm gap, and 205 × 512 matrix. All patients were placed in supine position with the head directed towards the scanner bore and arms rested to the side of the body. Sequences used were coronal oblique T1 weighted fast spin echo (fse) (TR 600, TE 16), coronal oblique T2 weighted fse (TR 4000, TE 85), coronal oblique proton density (PD) fat saturated (Fat Sat) (TR 2450, TE 37), axial gradient (TR 550, TE 13), axial PD Fat Sat (TR 2420, TE 41), sagittal PD Fat Sat (TR 3700, TE 43), sagittal T2 weighted fse (TR 3500, TE 88).

IBM SPSS statistics (V. 23.0, IBM Corp., USA, 2015) was used for data analysis. Data were expressed as Mean ± SD for quantitative parametric measures in addition to both number and percentage for categorized data.

Chi-square test was used to study the association between each 2 variables or comparison between 2 independent groups as regards the categorized data. The probability of error at 0.05 was considered signal, while at 0.01 and 0.001 are highly signal.

Diagnostic validity test was used including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and efficacy (accuracy).

4. Results

The study revealed that male patients (60%) predominated the female ones (40%), right side shoulder lesions showed marked predominance (65%) while left side only represented (35%).

4.1. RC FT tears

MR identified all the 5 diseased cases diagnosed by surgery and identified all the 23 negative cases. Chi square tests revealed statistically significant 100% agreement (P 0.000) between MR findings and surgical results. Diagnostic validity tests revealed: 100% sensitivity, 100% specificity, 100% negative predictive value (NPV), 100% PPV, and 100% accuracy (Figs. 1–3).

4.2. RC PT tear

Only 26 cases were enrolled, 2 cases were excluded. These 2 cases were diagnosed as intra-substance tear which cannot be seen or diagnosed by arthroscopy (which in this situation not a standard for comparison). MR correctly identified all the 18 negative cases diagnosed by surgery but only identified 7 cases out of the 8 abnormal cases. Chi-square tests revealed statistically significant 96% agreement (P 0.000) between MRI findings and surgical results. Diagnostic validity tests revealed: 87.5% sensitivity, 100% specificity, 95% NPV, 100% PPV, and 96% accuracy (Figs. 4–7).

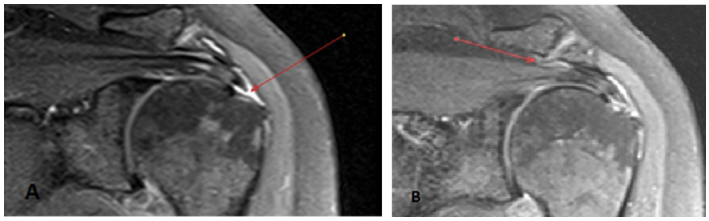

Fig. 1. Left shoulder coronal oblique PD Fat Sat MR image (A) showing supraspinatus full thickness tear (arrow), image (B) shows acromioclavicular osteoarthritic osteophytes indenting the supraspinatus at the musculo-tendinous junction (arrow).

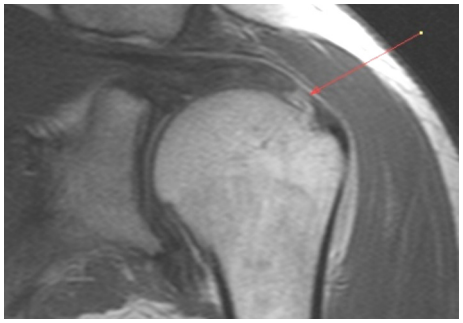

Fig. 2. Left shoulder Coronal oblique plane T2 WI showing a Supraspinatus FTT (long arrow) displaying fluid signal.

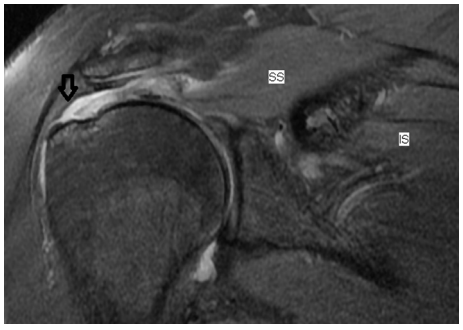

Fig. 3. Right shoulder PD Fat Sat coronal image, showing a FTT of supraspinatus tendon which is discontinuous and replaced by a fluid signal (arrowed), supraspinatus (SS), infraspinatus (IS).

4.3. Biceps lesions

MR correctly identified all the 20 negative cases diagnosed by surgery but only identified 6 cases out of the 8 abnormal cases. Chi-square tests revealed statistically significant 92.9% agreement (P 0.000) between MR findings and surgical results. Diagnostic validity tests revealed: 75% sensitivity, 100% specificity, 91% NPV, 100% PPV, and 92.9% accuracy (Figs. 5A and 8).

4.4. Acromio-clavicular osteoarthritis (AC OA)

AC OA is the most common aetiology of impingement syndrome, and easily diagnosed by conventional MR. MR identified all the 27 diseased cases diagnosed by surgery and identified the only negative case. Chi-square tests revealed statistically significant 100% agreement (P 0.000) between MR findings and surgical results. Diagnostic validity tests revealed: 100% sensitivity, 100% specificity, 100% NPV, 100% PPV, and 100% accuracy (Figs. 1B and 9).

4.5. Acromial abnormalities

MR correctly identified all the 11 negative cases diagnosed by surgery but only identified 16 cases out of the 17 abnormal cases. Chi-square tests revealed statistically significant 96.4% agreement (P 0.000) between MR findings and surgical results. Diagnostic validity tests revealed: 94.1% sensitivity, 100% specificity, 91.7% NPV, 100% PPV, and 96.4% accuracy (Figs. 4A, 5B, 10 and 11).

4.6. Bursitis

MR correctly identified all the 4 negative cases diagnosed by surgery but only identified 22 cases out of the 24 positive cases. Chi-square tests revealed statistically significant 92.9% agreement (P 0.000) between MR findings and surgical results. Diagnostic validity tests revealed: 91.7% sensitivity, 100% specificity, 66.7% NPV, 100% PPV, and 92.9% accuracy (Fig. 9).

By comparing the findings obtained by conventional MR to that obtained by diagnostic arthroscopy (as a gold standard), conventional MR showed excellent specificity in the diagnosis of different causative factors and sequelae encountered in cases of shoulder impingement (Fig. 12). The study revealed **100% specificity** (no false +ve cases) with (100%) +ve predictive index in diagnosis of all compared lesions namely: RC FT tear, RC PT tear, biceps lesions, AC OA, acromial abnormalities, and bursitis.

In our study, conventional MR showed high sensitivity in most of the different causative factors and sequelae encountered in cases of subacromial impingement (Fig. 7). The study revealed **100% sensitivity** in diagnosis of RC FT tear, and AC OA, **94% sensitivity** in

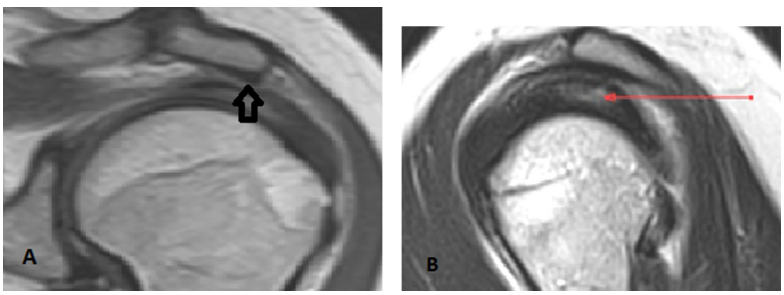

Fig. 4. Left shoulder Coronal oblique plane: A. T2WI showing subacromial Keel spur indenting the underlying supraspinatus tendon (arrowed) with subsequent intrasubstance tear in (B) sagittal T2WI, showing abnormal high signal (arrowed) inside the traversing supraspinatus tendon (Intrasubstance tear).

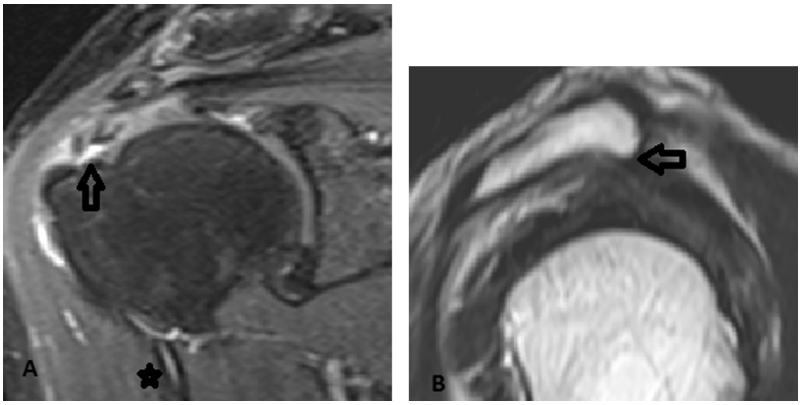

Fig. 5. Right shoulder coronal oblique PD Fat Sat (A) showing supraspinatus tendon partial articular surface tear (arrowed). Note the high signal in biceps tendon (star), (B) sagittal T2WI, showing type III acromion mildly impinging on the supraspinatus tendon (arrow).

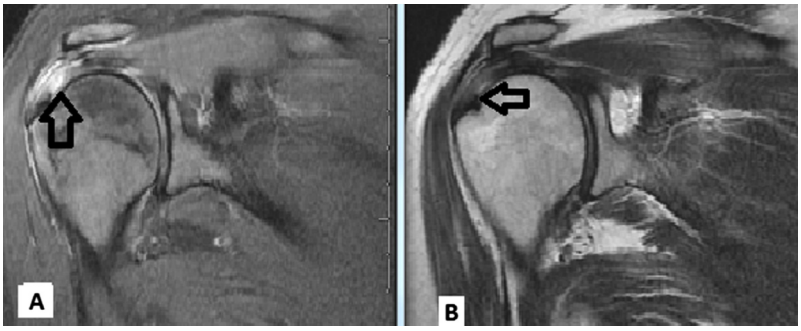

Fig. 6. Right shoulder Coronal oblique PD fat sat weighted image (A) and T2WI (B) showing supraspinatus tendon abnormal high signal in both sequences suggestive of partial intrasubstance tear (arrow).

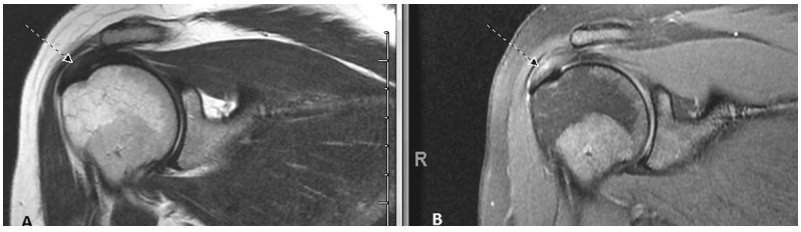

Fig. 7. Right shoulder Coronal oblique T2WI (A) and PD Fat Sat image (B) showing supraspinatus tendon abnormal high signal in both sequences with fraying of bursal suface (arrowed) suggestive of partial bursal surface tear.

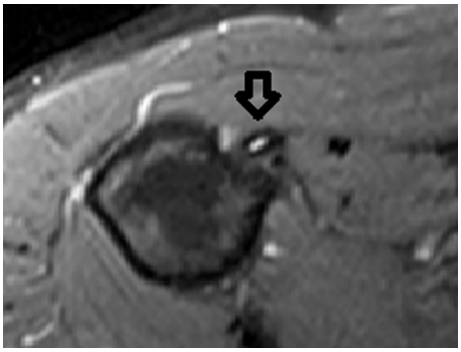

Fig. 8. Right shoulder Axial PD Fat Sat MR image, showing high signal inside biceps tendon (arrowed) likely biceps intrasubstance tear. Arthroscopy revealed acromio-clavicular biceps tenosynovitis.

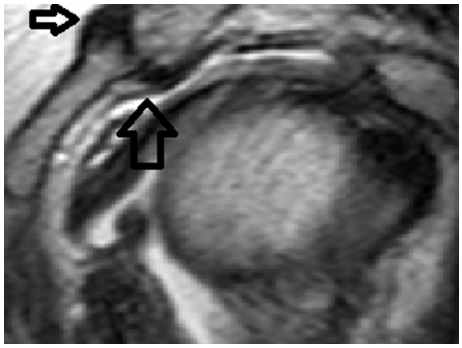

Fig. 9. Right shoulder sagittal T2WI, showing hypertrophic AC OA (small arrow) causing subacromial impingement and subacromial bursitis (big arrow).

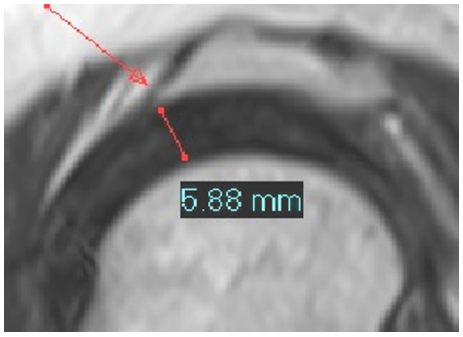

Fig. 10. Left shoulder sagittal T2WI showing anterior lateral acromial hook (Type 3 acromion) (arrowed) impinging on the supraspinatus tendon and narrowing the subacromial space.

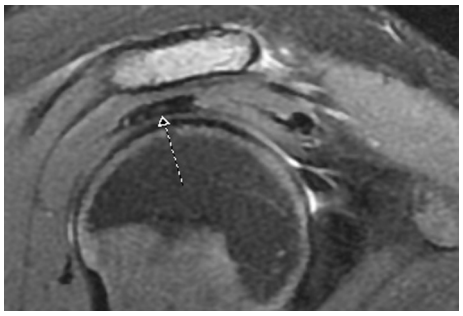

Fig. 11. Right shoulder Sagittal T2WI, showing Type IV acromion (convex lower surface) impinging on the infraspinatus muscle which shows central tendon abnormal signal of tendinopathy (arrowed).

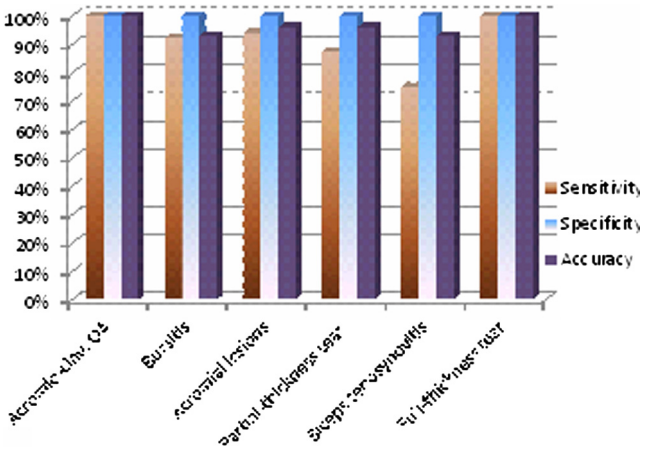

Fig. 12. Column chart showing summary of the results.

acromial abnormalities, **92% sensitivity** in bursitis, **87.5% sensitivity** in RC PT tear, **75% sensitivity** in biceps lesions.

Conventional MR proved high diagnostic efficacy (accuracy) in most of the different causative factors and sequalae encountered in cases of subacromial impingement (Fig. 12). The study revealed **100% accuracy** in diagnosis of RC FT tear, and AC OA and **96% accuracy** in diagnosis of acromial abnormalities and RC PT tear **93% accuracy** in diagnosis of biceps lesions and bursitis.

Although conventional MR is less sensitive than arthroscopy in diagnosis of RC partial thickness tears (87.5% sensitive), yet it has the ability to diagnose intra-substance tear which cannot be diagnosed by arthroscopy.

MR showed definite lesser sensitivity than arthroscopy in detection of biceps lesions, as among 8 cases detected by arthroscopy, only 6 cases of them could be detected by conventional MR.

5. Discussion

Patients who present with shoulder pain have a variety of treatment options, either medical treatment or physiotherapy or open surgery. Imaging guides the clinician in his management whether surgical and non surgical. The best imaging tool should have high index of sensitivity and specificity to avoid non indicated surgery [10].

Our results showed that the frequency of different pathological injuries in patients below 49.3 years showed higher incidence of intrinsic factors of impingement with RC tendinopathy and acromial abnormalities, while those above 49.3 years had higher incidence of extrinsic factors, especially the hypertrophic AC OA, with higher incidence of FT RC tendon tears which are consistent with Stoller et al. [3] description of impingement pathogenesis.

We also depicted that there was a predominance of male patients over female ones, (60% and 40% respectively) which could be due to male predominance at the manual work with shoulder joint over use conforming to the results of Freygant et al. [11].

This study revealed right side lesions marked predominance (65%) while left side lesions only presented (35%), this result supports the role of intrinsic impingement (overuse), as most patients are right handed. This coincides with Jobe et al. [12] description of impingement pathogenesis.

AC OA represented the highest frequency and percentage (96%) among the study cases, followed by subacromial bursitis (85%), then acromial abnormalities (61%), PT tears (36%), biceps tenosynovitis (28%), and FT tear (18%), ongoing with Bredella and Tirman [13] and Stoller et al. [3] description of impingement pathogenesis and epidimiology.

This study found that conventional MR is highly accurate in the diagnosis of RC FT tears, showing 100% accuracy, 100% sensitivity, and 100% specificity as correlated to the gold standard surgical results.

These unusual high figures are likely attributed to patients' selection where only 28 patients were selected for arthroscopy out of the original study population. This explains the paucity of false negative cases.

MR was an accurate tool in the detailed assessment of FT tears, including the retraction gap distance, tear width, and associated loss of muscle bulk which was consistent with the studies of Hitachi et al., Adams et al. and Lambert et al. [14–16] that reported 100% specificity of shoulder MR in detection of FT RC tears.

MR is very helpful in the decision making of therapeutic arthroscopy in patients with FT RC tear by assessment of the supraspinatus muscle bulk. Patients with muscle atrophy and loss of bulk aren't candidates for arthroscopic repair [3].

In this work, the five surgically diagnosed cases having a FT RC tear were all detected and evaluated by MR and they had no muscle atrophy and therefore proceeded to arthroscopy.

In the current study, we found out that MR has a high accuracy (96%) in the diagnosis of PT RC tears. It showed 100% specificity and 100% PPV with no false positive cases. Seven cases were diagnosed by conventional MR to have PT tears and were confirmed by arthroscopy. This agreed with studies conducted by Magee, Teefey et al. and Lambert et al. that reported 100%, 98% and 97% specificity respectively [17,18,16].

However, the results of the present study revealed less sensitivity (87.5%) with acceptable NPV (95%) showing only one false negative case among 19 MR diagnosed negative cases. This agreed with studies of Vlychou et al. that reported 86% sensitivity and Yamakawa et al. that reported 83% sensitivity [19,20].

The intra-substance RC pathology is readily depicted by MR compared to arthroscopy which cannot confirm such intra-substance changes [3]. In the current study, two cases were

diagnosed by MR as partial intra-substance tear to which arthroscopy is not sensitive. The orthopaedic surgeon relied on MR diagnosis to take the decision of therapeutic arthroscopy. This explains why MR is an indispensable tool in depiction of partial intra-substance RC tear.

In our study, MR revealed high specificity (100%) in the diagnosis of biceps abnormalities. It identified all the 20 negative cases that were confirmed surgically. However, it was not very sensitive (75%) to detect biceps abnormalities. It detected 6 positive cases out of the 8 cases diagnosed surgically. Overall accuracy was 92.9%. This conformed to Razmjou et al. [21] that reported 100% specificity and 83% sensitivity.

AC OA was described by Stoller et al. [3] as the most common cause of shoulder impingement. In the current study, AC OA represented the highest frequency (27 patients) and percentage (96%) among the study population (28 patients).

Our results showed that MR had a very high accuracy (100%), sensitivity (100%), and specificity (100%) for the diagnosis of AC OA. This result was higher than Mohtadi et al. [22] results that reported 77% accuracy, 86% sensitivity and 65% specificity.

In the setting of AC OA, MR doesn't offer the dynamic evaluation of the RC where it only detects the pathology in the resting state where the osteophytes are seen indenting the supraspinatus or on the musculo-tendinous junction and not on the actual tear [23].

Acromial lesions assessed in the study were: acromial type, acromial slope, keel spur, and os acromial. MR was very effective in diagnosis of acromial lesions impinging on the osseous outlet of RC tendons. It showed diagnostic accuracy of 96.4%, sensitivity of 94.1% and specificity of 100%. MR identified all the 11 negative cases diagnosed by surgery but only identified 16 cases out of the 17 abnormal cases. These results were close to the series conducted by Mohtadi et al. that reported 100% specificity, and 88% sensitivity [22].

In our study, acromial Keel spur cases (3 cases) represented only 17% of all acromial abnormalities cases (17 cases), denoting low incidence. However, all Keel spur cases were associated with RC PT tears, proving the important role of these spurs in pathogenesis and development of RC tears which is in alignment with stoller et al. [3] who reported that it has a higher PPV for RC pathology (Fig. 4A).

To depict it, we recommend that the inferior surface of the acromion is fully inspected in both sagittal and coronal planes as they can be easily missed especially if small.

The current study showed high diagnostic specificity (100%) of MR to rule out bursitis. MR identified the 4 negative cases diagnosed by surgery. However, it was not very sensitive in detecting minimal fluid in subacromial subdeltoid bursa. It only identified 22 out of the 24 abnormal cases with 2 false negative cases. Sensitivity was only 66.7% and overall accuracy was 92.9%. This agreed with Melanie et al. and Teefey et al. that reported that MR has a lower sensitivity than ultrasound in detection of minimal bursal fluid [23,24].

6. Conclusion

Conventional MR is adequate in full assessment of different lesions encountered in shoulder impingement syndrome and RC degenerative disorders with high accuracy and specificity yet with moderate sensitivity. It is crucial in decision making for therapeutic arthroscopy in partial intra-substance tear as well as in patients with muscle atrophy who will not benefit from arthroscopy.

Notes

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Conflict of interest

The authors declare that there is no conflict of interest.

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