How to Cite:
Shaker, S. W., Osman, A. M., Arafa, H. M., & Sakr, H. (2022). Evaluation of non-articular causes of shoulder pain: A prospective study to determine the diagnostic accuracy of ultrasound in reference to conventional MRI. *International Journal of Health Sciences*, *6*(S4), 2843–2854. https://doi.org/10.53730/ijhs.v6nS4.7989

Evaluation of non-articular causes of shoulder pain: A prospective study to determine the diagnostic accuracy of ultrasound in reference to conventional MRI

Sarah Wagdy Shaker
Assistant Lecturer, Faculty of Medicine, Ain Shams University Hospital, Egypt
Corresponding author email: Sarah_wagdy101090@hotmail.com

Ahmed M. Osman
Professor of Radiology, Faculty of Medicine, Ain Shams University Hospital, Egypt

Hanan M. Arafa
Professor of Radiology, Faculty of Medicine, Ain Shams University Hospital, Egypt

Hossam Sakr
Professor of Radiology, Faculty of Medicine, Ain Shams University Hospital, Egypt

***Abstract*---**Background: To evaluate the accuracy of high resolution ultrasound (USG) and MRI in the diagnosis of rotator cuff tears (RCT) and to determine if high resolution USG compares favorably in sensitivity and specificity to MRI in the diagnosis of non-articular causes of joint pain. Material/Methods: In this prospective comparative study, 52 patients with clinically suspected rotator cuff tears underwent both ultrasound and MRI of the shoulder. The USG and MRI were interpreted by two radiologists experienced in musculoskeletal radiology and blinded to findings of each other. Comparison was done using MRI as a standard reference. Results: The agreement between USG and MRI for diagnosis of RCTs was statistically significant ; USG showed a sensitivity of 90.6% and a specificity of 75% for tendinopathy, a sensitivity of 64.3% and a specificity of 81.6% for partial-thickness tears, a sensitivity of 41.7% and a specificity of 90% for complete width full-thickness tears and a sensitivity of 40% and a specificity of 95.7% for incomplete width full-thickness tears; diagnostic efficacy for all cases with tears was 80.8%. Conclusion: Considering the comparable diagnostic efficacy of USG and MRI, the former modality can be used as a first-line investigation for diagnosis of RCT. MRI should be used secondarily as a problem-

International Journal of Health Sciences ISSN 2550-6978 E-ISSN 2550-696X © 2022.
Manuscript submitted: 27 March 2022, Manuscript revised: 09 April 2022, Accepted for publication: 18 May 2022

solving tool either following an equivocal shoulder USG or for delineation of anatomy in cases where surgical correction is needed.

***Keywords*---**rotator cuff tears, shoulder pain, supraspinatus tear, MRI shoulder, ultrasound shoulder**.**

Introduction

Shoulder pain is the third most common cause of joint pain after low back pain and knee joint pain[1] . Rotator cuff injury is the most common cause, present in approximately 85% of the cases [2, 3],Rotator cuff injuries range from simple inflammations to complete tears. The role of imaging is to guide treatment decision [4]. The diagnosis of rotator cuff injury, tendinopathy or partial or full thickness tear, and its extent can determine whether the patient will undergo surgery or just will be managed conservatively [5, 6].Also the surgical approach, open versus arthroscopic, is chosen based on the imaging diagnosis [6, 7].

MRI is now widely used and has the advantages of providing excellent soft tissue details, tendon retraction and extension of the tear to adjacent structures. MRI. However, has certain disadvantages like being expensive, not readily available, difficult to interpret when adjacent metallic implant is present due to artifacts and has many contraindications like claustrophobia etc,[8].

Shoulder ultrasound has the advantages of being readily available, relatively inexpensive and non-invasive. Ultrasound. However, having the disadvantages of being operator dependent, requiring standardized scanning technique and in comparison to MRI, it is constantly reported to have a lower sensitivity and specificity for detection of rotator cuff tears [9].

Many studies have been conducted to determine the accuracy of ultrasound in the detection of rotator cuff tears which proved to be of high accuracy in detection of full thickness tears but of relatively low accuracy in detection of partial thickness tears[10].

Other studies were conducted to compare the accuracy of ultrasound and unenhanced MRI in the detection[11] and follow up of rotator cuff tears [12].However, there is a need for more studies to determine the accuracy of ultrasound in detection of probable associated image findings, Its accuracy in diagnosis of tendinopathy and conclude possible criteria of patients in whom investigation by ultrasound could be addressed as the first line of investigation [11].

The primary outcome of this study is to compare the diagnostic accuracy of shoulder ultrasound in non-articular causes of shoulder pain with unenhanced shoulder MRI. Other secondary outcomes are to identify, retrospectively, possible risk factors contributing to non- articular causes of shoulder pain that the clinician can use to suggest USG as the first line of investigation to limit the need to the relatively expensive shoulder MRI.

Materials and Methods

A Prospective, comparative study was conducted in Ain Shams University Hospitals in the period between march and august 2017. 53 patients were included in the study, their age ranged rom 19 to 78 years old, were referred to the Radiology Department at Ain Shams University Hospitals. The study was approved by the local research ethical committee at the Faculty of Medicine, Ain Shams University.

Inclusion and exclusion criteria:

Inclusion criteria:

- Age from 20-75.
- Suspected non-articular cause of shoulder pain with positive findings in unenhanced MRI and/or ultrasound.
- Both sexes will be included.

Exclusion criteria:

- Previous surgery on the same shoulder.
- Medical contraindications to MRI such as claustrophobia, pacemakers, etc.
- Restriction of normal passive motion.
- BMI more than 35 (Ultrasound beams are attenuated by fat, and this attenuation limits image quality [13]).

The ultrasound and the MRI were interpreted by two different radiologists who have long experience in musculoskeletal imaging, both were blinded to patients' data and to the results of each other.

Patient preparation:

- Written consents were taken from the patients according to ethical committee regulations.
- No specific preparation was needed before ultrasound or MRI examination.

USG was performed using a high-frequency (12 L, 6–12 MHz) linear array transducer (Logiq 7, GE machine), in a dedicated musculoskeletal protocol. On USG, each muscle was examined in at least two planes. MRI was performed on a 1.5 T machine (Achieva, Philips medical system, Eindhoven, Netherlands) using 8 channel dedicated phased array shoulder coil. IBM SPSS statistics (V. 24.0, IBM Corp., USA, 2016) was used for data analysis. Data was expressed as Mean ±SD for quantitative parametric measures in addition to both number and percentage for categorized data.

The following tests were done:

1. Comparison between two independent mean groups for parametric data using Student t -test.

2. Chi-square test 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 significant, while at 0.01 and 0.001 are highly significant.
3. Diagnostic validity test: It includes:
   a. The diagnostic sensitivity: It is the percentage of diseased cases truly diagnosed (TP) among total diseased cases (TP+FN).
   b. The diagnostic specificity: It is the percentage of non-diseased truly excluded by the test (TN) among total non-diseased cases (TN+FP).
   c. The predictive value for a +ve test: It is the percentage of cases truly diagnosed among total positive cases.
   d. The predictive value for a -ve test: It is the percentage of cases truly negative among total negative cases.
   e. The efficacy or the diagnostic accuracy of the test: It is the percentage of cases truly diseased plus truly non-diseased among total cases.

Results

Out of 52 patients, the mean age of the patients ranged from 19 to 78 with +/- 10 SD. There were 18 males between selected patients representing 34.6%, while the rest were females representing 65.4% who represents the majority of the cases. The right shoulder joint was affected in 35 patients representing 67.3%with 37 were dominant joint representing 71.2%.

History of either minor or major trauma was seen in 20 out of 52 patients (38.5%); history of heavy use of the joint affected was seen in 36 cases (69.2%), history of diabetes mellitus was seen in 20 patients (38.5%). Night pain was present in 43 patients out of 52 patients (82.7%).

As regards the findings noted during the study

- 29 patients diagnosed to have supraspinatus tendinopathy by U/S out of 32 patients diagnosed by MRI with subsequent U/S sensitivity and specificity of 90.6% and 75% respectively. There was a high significant relation between the U/S and MRI in the diagnosis of supraspinatus tendinopathy (P value 0.000).
- Also, there was 1 case of calcific tendinitis diagnosed by MRI which was also correctly diagnosed by U/S leading U/S sensitivity and specificity of 100% and 98% respectively. With high significant relation between the U/S and MRI in the diagnosis of calcific tendinitis (P value 0.000).
- U/S had the highest sensitivity in detection of bursal surface tear (100%), while had the lowest sensitivity in diagnosis of interstitial tear (0%). Also, U/S showed highest specificity in detection of interstitial tear and lowest specificity in diagnosis of articular surface tear.
- As regards the total cases of partial thickness tear- regardless of its subtype- the overall sensitivity and specificity were 64.3% and 81.6% respectively. With high significant relation between the U/S and the MRI in the diagnosis of partial thickness tears (P value 0.001).
- U/S had no significant difference in the sensitivity of diagnosis between complete width and incomplete width full thickness tears being 41.7% and

40% respectively but U/S showed higher specificity in the detection of incomplete width full thickness tear being 95.7% in contrast to 90% specificity to the diagnosis of complete width full thickness tear.

- Regarding the overall cases with tears namely partial thickness and full thickness tears, the sensitivity and specificity were 84% and 77.8% respectively. There was a high significant relation between the U/S and MRI in the diagnosis of supraspinatus tear (P value 0.000).
- 37 patients diagnosed to have acromioclavicular joint osteoarthritis by U/S out of 39 patients diagnosed by MRI with subsequent U/S sensitivity and specificity of 94.9% and 84.6% respectively. There is high significant relation between the U/S and MRI in the diagnosis of acromioclavicular joint osteoarthritis (P value 0.000).
- Also, 8 cases were diagnosed by U/S as having sub acromial impingement out of 14 cases had the same diagnosis by MRI. There is high significant relation between the U/S in the diagnosis of sub acromial impingement (P value 0.008)
- U/S correctly detected 14 cases with sub acromial subdeltoid bursitis out of 17 cases diagnosed by MRI, while diagnosed additional 7 cases with bursitis which were negative by MRI, giving the U/S sensitivity and specificity 82.4% and 80% respectively.
- U/S detected only 9 cases of the 26 cases diagnosed as having shoulder joint effusion by MRI with additional 2 false positive cases giving the U/S sensitivity and specificity 34.6% and 91.1% respectively.
- Regarding the LHB tenosynovitis, U/S detected 5 cases out of the 6 cases diagnosed by MRI, with additional 5 false positive cases making the US sensitivity and specificity 83.3% and 89.1% respectively.
- The U/S and the MRI showed highly significant relation in the diagnosis of sub acromial subdeltoid bursitis and LHB tenosynovitis (P values 0.000 for both), while significant relation in the diagnosis of shoulder joint effusion.
- U/S had the highest sensitivity in detection of Subscapularis tear (100%), and the lowest sensitivity in diagnosis of infraspinatus tendinopathy (40%). While U/S showed highest specificity in detection of infraspinatus tendinopathy and lowest specificity in diagnosis of Subscapularis tendinopathy (table 12 a &b).

N.B: 2 cases were diagnosed as having Labral tear by MRI, which were missed by U/S. while the rest of the 50 cases were negative by both MRI and US.

Table (1) Distribution of patients with tendinopathy, incomplete, complete full thickness and partial thickness rotator cuff tears on USG and MRI

	USG/MRI	Tendinopathy	Rotator cuff tears		
			In complete Full thickness	Complete width full thickness	Partial thickness
Supraspinatus	USG	34	4	8	14
	MRI	32	5	6	16
Subscapularis	USG	7	-	-	4
	MRI	5	-	-	1

Infraspinatus	USG	2	-	-	-
	MRI	5	-	-	-

Discussion

The etiology of rotator cuff injury is multifactorial, contributed both by extrinsic and intrinsic factors. The extrinsic factors can be anatomical factors, like the acromion shape, coracoacromial ligament impingement, os acromiale and acromial spurs, or environmental factors like shoulder overuse, smoking, obesity, and diabetes mellitus. The intrinsic factors include repetitive microtraumas, areas of hypoperfusion in the tendons, inflammation, and cellular changes in the collagen. Aging also causes tendons to degenerate, occurring most commonly in patients after the third decade and increases linearly thereafter [14]. Initially there is partial thickness tear which typically progresses from partial thickness tear to full thickness tear in a zipper-like fashion known as "zipper phenomenon"[15]. In our study, there was also an increased prevalence of rotator cuff tears with advancing age. Similar findings were reported in the study carried by Jerosch et al.[16].

The rotator cuff injury was more common in females. The right shoulder and the dominant arm were more commonly affected than the left shoulder and the non-dominant arm in patients with rotator cuff injury in our study. These findings are also in agreement with those of earlier studies[17]. History of heavy use of the affected joint was identified as the major etiological factor, present in 69.2% of rotator cuff tear (RCT). Diabetes mellitus was seen in 20 out of 52 patients (38.5%), suggesting that DM can also be a significant factor predisposing the rotator tendons to tear. This is because in diabetes there can be degeneration of inherently weak tendon fibers, leading to tendon failure and rupture. The risk factors for rotator cuff injury identified in our study were therefore: female gender, right shoulder, dominant hand, advancing age, and underlying diabetes mellitus.

The pathology of supraspinatus is classified with increasing severity into tendinosis, partial thickness tears and full thickness tears. Tendinosis is the degeneration of tendon without inflammation and gives a thickened and heterogeneously hypoechoic appearance on USG (*Figure 1A)*. On MRI, tendinosis/tendinopathy appears as moderately increased focal, irregular or diffuse intermediate intrasubstance signal intensity on T1W and T2W images with a thickened tendon. However, this altered MRI signal does not increase to fluid signal intensity on T2W images *(Figure 1B)* [18] In our study, 32 patients had tendinosis of the supraspinatus on MRI, 29 were correctly diagnosed on USG, and 5 cases were diagnosed as tendinopathy by ultrasound, yet MRI exam revealed normal tendon in 2 cases and articular surface tear in one case which was not detected by ultrasound.

Figure 1 A, B. A) coronal T2 weighted image of the right shoulder joint reveals, the supra spinatus tendon shows focal increase intra substance signal (white arrow) b) supraspinatus tendon shows inhomogeneous texture denoting mild degenerative changes (white arrow).

On USG, partial supraspinatus tear appears as focal area of decreased or occasionally increased echogenicity with irregular borders in the tendon. Partial tear can be classified as – a) articular surface tear which communicates with joint space *(Figure 2);* b) bursal surface tear which communicates with subacromion subdeltoid (SASD) bursa and c) intrasubstance tear which does not communicate neither with articular nor bursal surfaces and lies within the substance of the tendon.

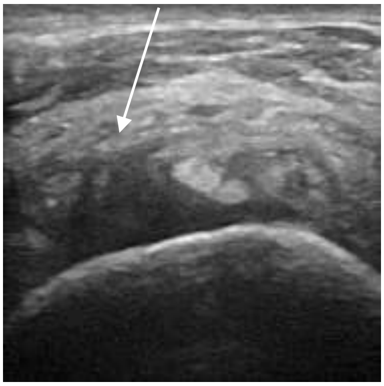


Figure 2. USG of a ptient showing articular surface partial thickness tear of the supraspinatus tendon (white arrow).

On MRI, partial thickness tears are characterized by a focal region of fiber discontinuity filled with fluid signal demonstrated on T2W imaging ***(Figure 3)***. Fat-suppressed T2W imaging can increase lesion conspicuity by better demonstrating the fluid-filled tendon defect. Beside focal tendon defect, additional findings may include surface fraying or changes in tendon caliber.

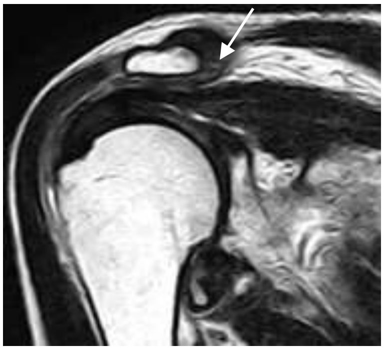
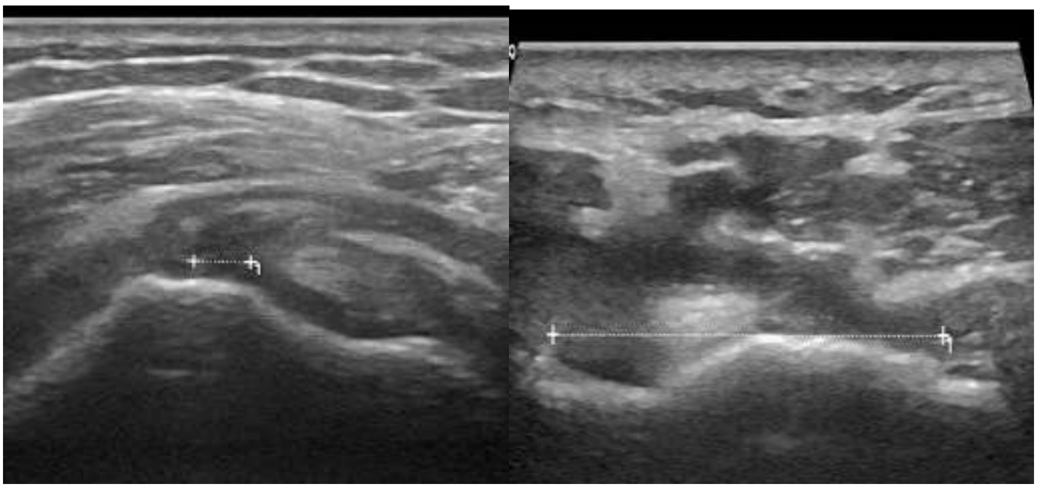


Figure 3. coronal T2 weighted image shows linear fluid signal at the articular surface of the supraspinatus tendon (white arrow).

Among partial thickness tears, articular surface tears were more common (12 patients or 85.7%) in comparison to bursal surface tears (1 patient or 0.07%). These findings are in agreement with other similar studies which showed common occurrence of articular surface partial tears in comparison to bursal surface partial tears [19, 20].

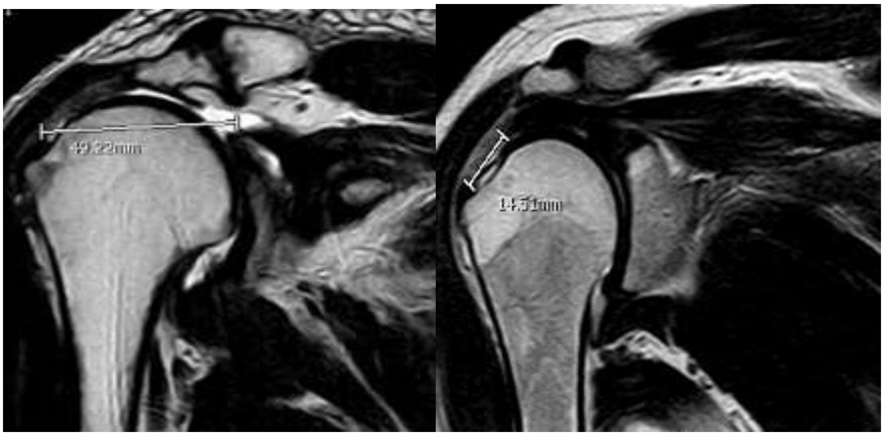
Full-thickness tears represent complete discontinuity of rotator cuff fibers, resulting in communication between the articular and bursal surfaces. On USG, the direct signs of complete tear are non-visualization of the cuff, focal tendon defect, retraction of tendon, and the indirect signs are flattening of the bursal surface of the tendon, thinning of the cuff, cortical irregularity of the greater tuberosity, cartilage interface sign, glenohumeral joint effusion and SASD bursa fluid. Depression of peribursal fat may occur into a gap created by the retracted tendon resulting in the sagging peribursal fat sign. Majority of these signs were present in our study *(Figures 4 A-B)*



Figures 4 A-B. Right shoulder ultrasound, supraspinatous tendon complete tear with fluid filled gap

On MRI, complete RCT appear as areas of fluid signal intensity with irregular borders on T2W images involving the whole thickness of the tendon *(Figures 5A-*

B); however, in about 10% of tears, the region of tendon discontinuity was seen as a low signal on T2W images due to chronic scarring[21]. Fluid is also seen in the SASD bursa and glenohumeral joint. Supraspinatus tears that are greater than 2.5 cm in antero-posterior dimension often extend into the infraspinatus or the subscapularis tendon. Massive tears of the rotator cuff are commonly associated with tendon retraction, involving supraspinatus, infraspinatus, and subscapularis.



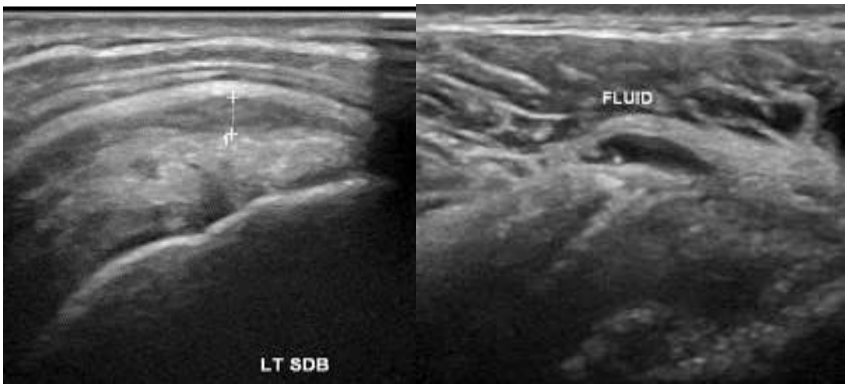
Figures 5 A.B. a) coronal T2 weighted image showing Full thickness tear of the supraspinatus tendon with retraction of its fibers medially forming large fluid filled gap 5 cm. b) coronal T2 weighted image shows Full thickness incomplete tear of the supraspinatus tendon with gap 1.5 cm filled with fluid, no atrophy of muscle, with mild OA of acromiocalvicular joint

Our study showed high sensitivity, specificity, PPV, and NPV for high resolution USG when compared to MRI for complete width, incomplete width full thickness and partial thickness tears. The efficacy of USG in diagnosing a complete width full thickness tear is 78.8%, incomplete width full thickness tear 90.4% and 76.9% for partial thickness tears. The P value was <0.01 for both complete /incomplete full and partial thickness tears suggesting very strong presumption against a null hypothesis. The agreement between the two methods for complete full thickness tears was 78.8%, for the incomplete full thickness tear 90.4% and 76.9%for partial thickness tears (Table 2).

	Agreement %	Disagreement %	Specificity %	Sensitivity %	Predictive -ve %	Predictive +ve %	Efficacy %	P value
SS complete width complete full thickness tear	78.8	21.2	90.0	41.7	83.7	55.6	78.8	.011
SS incomplete width full thickness tear	90.4	9.6	95.7	40.0	93.8	50.0	90.4	.004
SS total cases with partial tears	76.9	23.1	81.6	64.3	86.1	56.3	76.9	.001

Similar results were obtained by Rutten et al.[22].who reported a high agreement and comparable diagnostic performances of high-resolution USG and MRI in the detection of partial and full thickness tears of the rotator cuff. Another similar study by T Kobayashi et al.[23] showed comparable results. Among the associated findings, fluid around the long head of the biceps tendon (LHBT) was the most common finding in our study and was witnessed both on USG and MRI. However, it had a low sensitivity as a variable amount of fluid is normally present in the biceps tendon sheath.

Acromioclavicular joint (ACJ) arthrosis is also a common associated finding in patients with rotator cuff tear. The increasing failure of cuff tendon fibers causes an increased load on the acromioclavicular joint causing its degeneration and hypertrophy of capsule with spur formation. USG showed ACJ arthrosis in 37 patients (94.4%) in comparison to 39 patients on MRI, suggesting that USG is less accurate but still useful for ACJ evaluation. In our study, USG accurately showed fluid in subacromial subdeltoid bursa (SASD) in 82.4% of patients *(Figures 6 A, B)*



Figures 6 A, B. show thickening and fluid in the subdeltoid bursa

Patient interaction and dynamic examination are added advantages of USG. The patient can point to the area of maximum pain and tenderness, which can be focused for examination, increasing the satisfaction level of the patient. Impingement and instability of the tendons can also be studied by dynamic examination. Subacromial impingement is associated with supraspinatus tear and subcoracoid impingement associated with subscapularis tear. Instability of LHBT can be examined by externally rotating the arm and observing the subluxation of tendon from the bicipital groove medially. This is commonly seen with subscapularis tear when the transverse humeral ligament is also torn.

Current study limitations

This study was conducted in a single institute which doesn't necessarily represents the general population. Furthermore, the ultrasound examinations were performed by one observer which is a subjective and operator dependent examination.

Current study recommendation

Our study recommendations coincide with the fore mentioned articles, and reviews: High resolution ultrasonography diagnostic ability in different shoulder pathologies shows nearly perfect agreement with MRI results for assessment of muscular pathologies (rotator cuff tears and tendinopathy, long head of biceps tenosynovitis), Joint effusion and synovitis. Ultrasonography still has limited role in evaluation of deeply seated structures (glenoid labrum, deep articular cartilage), with inability to assess bone marrow lesions.

Ultrasound shows many advantages over MRI in easiness of the procedure for the patient, less expensive , less time consuming, and available for the patient with contraindications for MRI (Pace maker, cochlear implant, claustrophobia). Also ability of dynamic assessment of affected tendon and muscle, Doppler evaluation of various lesions, higher resolution (assess of small focal lesions up to 0.5 mm), examination of parts near metallic hardware, in addition gives the operator the ability to compare diseased joint with the contra lateral healthy one, assessment of the exact point of tenderness/pain depending on patient directions, and further extension of the examinations to other remote part of the limb where patient was complaining from too. Further studies are needed to determine the effect of the location of the rotator cuff tear, whether at the insertion site or at the myotendinous junction, on the accuracy of ultrasound in its detection.

Conclusion

High resolution ultrasound is a good alternative to other radiological methods as MRI, for diagnosis tendon and joints pathology. The most important limitations lie in its limited field of view and penetration, which potentially can result in incomplete evaluation of bony and joint anatomy. High resolution ultrasound technique can be used as first line of examination, and if no abnormalities could be detected by it and the patient is still complaining, complementary MRI should be done. If ultrasound findings are positive and are going with the patient clinical diagnosis, no further investigations are needed.

References

1. Urwin, M. et al., (1998): *Estimating the burden of musculoskeletal disorders in the community: the comparative prevalence of symptoms at different anatomical sites, and the relation to social deprivation.* Ann Rheum Dis,. 57(11): p. 649-55.
2. Ostor, A.J. et al., (2005): *Diagnosis and relation to general health of shoulder disorders presenting to primary care.* Rheumatology (Oxford),. 44(6): p. 800-5.
3. Naredo, E. et al., (2002): *Painful shoulder: comparison of physical examination and ultrasonographic findings.* Ann Rheum Dis,. 61(2): p. 132-6.
4. Post, M., R. Silver, and M. Singh, (1983): *Rotator cuff tear. Diagnosis and treatment.* Clin Orthop Relat Res, (173): p. 78-91.
5. Ruotolo, C. and W.M. Nottage, (2002): *Surgical and nonsurgical management of rotator cuff tears.* Arthroscopy,. 18(5): p. 527-31.
6. Mantone, J.K., W.Z. Burkhead, Jr., and J. Noonan, Jr., (2000): *Nonoperative treatment of rotator cuff tears.* Orthop Clin North Am,. 31(2): p. 295-311.
7. Gartsman, G.M., M. Khan, and S.M. Hammerman, (1998): *Arthroscopic repair of full-thickness tears of the rotator cuff.* J Bone Joint Surg Am,. 80(6): p. 832-40.

8. Dill, T., (2008): *Contraindications to magnetic resonance imaging.* Heart,. 94(7): p. 943-948.
9. Needell, S.D. and M.B. Zlatkin, (1997): *Comparison of fat-saturation fast spin echo versus conventional spin-echo MRI in the detection of rotator cuff pathology.* J Magn Reson Imaging,. 7(4): p. 674-7.
10. Dinnes, J. et al., (2003):*The effectiveness of diagnostic tests for the assessment of shoulder pain due to soft tissue disorders: a systematic review.* Health Technol Assess,. 7(29): p. iii, 1-166.
11. Chauhan, N.S. et al., (2016): *A Prospective Comparative Study of High Resolution Ultrasound and MRI in the Diagnosis of Rotator Cuff Tears in a Tertiary Hospital of North India.* Pol J Radiol,. 81: p. 491-497.
12. Collin, P. et al., (2015): *Evaluating postoperative rotator cuff healing: Prospective comparison of MRI and ultrasound.* Orthop Traumatol Surg Res,. 101(6 Suppl): p. S265-8.
13. Uppot, R.N., (2007): *Impact of obesity on radiology.* Radiologic clinics of North America,. 45(2): p. 231-246.
14. Murrell, G.A. and J.R. Walton, (2001): *Diagnosis of rotator cuff tears.* Lancet, 357(9258): p. 769-70.
15. Matsen, F., (1998): *Rotator cuff.* The shoulder,: p. 755-839.
16. Jerosch, J., T. Muller, and W.H. Castro, (1991): *The incidence of rotator cuff rupture. An anatomic study.* Acta Orthop Belg, 57(2): p. 124-9.
17. Yamamoto, A. et al., (2010): *Prevalence and risk factors of a rotator cuff tear in the general population.* J Shoulder Elbow Surg, 19(1): p. 116-20.
18. Rafii, M. et al., (1990): *Rotator cuff lesions: signal patterns at MR imaging.* Radiology,. 177(3): p. 817-23.
19. Vinson, E.N., C.A. Helms, and L.D. Higgins, (2007): *Rim-rent tear of the rotator cuff: a common and easily overlooked partial tear.* AJR Am J Roentgenol,. 189(4): p. 943-6.
20. Weber, S.C., (1999): *Arthroscopic debridement and acromioplasty versus mini-open repair in the treatment of significant partial-thickness rotator cuff tears.* Arthroscopy, 15(2): p. 126-31.
21. Buck, F.M. et al., (2010): *Magnetic resonance histologic correlation in rotator cuff tendons.* J Magn Reson Imaging, 32(1): p. 165-72.
22. Rutten, M.J. et al., (2010): *Detection of rotator cuff tears: the value of MRI following ultrasound.* Eur Radiol, 20(2): p. 450-7.
23. Kobayashi, T. et al., (2013): *Surgeon-operated in-office ultrasonography for the diagnosis of rotator cuff tears: A comparison with magnetic resonance imaging.* Surgical Science,. 4(09): p. 6.