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A Prospective Comparative Study of High Resolution Ultrasound and MRI in the Diagnosis of Rotator Cuff Tears in a Tertiary Hospital of North India

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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Summary

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 rotator cuff injury.

Material/Methods: In this prospective comparative study, 40 patients with clinically suspected rotator cuff tears underwent both ultrasound and MRI of the shoulder. Out of these 40 patients, 31 patients who had positive findings for rotator cuff tears on ultrasound and/or MRI were finally included in the study while the remaining 9 patients with negative or unrelated findings were excluded. 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 excellent; USG showed a sensitivity of 86.7% and a specificity of 100% for full-thickness tears, and a sensitivity of 89.7% and a specificity of 98.8% for partial-thickness tears; observed accuracy for full thickness tears was 98.4% and 95.9% for partial thickness tears. The Kappa coefficient of association was 0.91 for full thickness tears and 0.90 for partial thickness tears.

Conclusions: Considering the comparable diagnostic accuracy 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-solving tool either following an equivocal shoulder USG or for delineation of anatomy in cases where surgical correction is needed.

MeSH Keywords: **Magnetic Resonance Imaging • Rotator Cuff • Shoulder Joint • Ultrasonography**

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Background

Shoulder pain is one of the common causes of musculoskeletal pain after low back and knee pain and results in significant disability and reduced quality of life [1]. Among the patients with shoulder pain, rotator cuff disease/injury is the most common cause, being present in approximately 85% of patients [2 3]. The prevalence of Rotator cuff tears (RCT) increases with increasing age and ranges from 5% to 39% based on cadaver and MRI studies [4,5]. The prevalence rates are expected to increase still further because of aging population, better healthcare facilities and less willingness to accept functional limitation [6].

Ultrasound (USG) used to visualize the shoulder area has many advantages like being relatively inexpensive, noninvasive and widely available. There is however inconsistency and variability in the reporting of diagnostic sensitivities and specificities of USG for evaluation of rotator cuff tears which range from more than 90% [4] to less than 50% [7].

MRI is also becoming a widely used imaging modality for RCT evaluation and now considered the gold standard for rotator cuff imaging. Contrary to USG, MRI is reported to have consistently high sensitivity (80–97%) and specificity (93–94%) for the diagnosis of rotator cuff pathology [8]. MRI provides excellent soft-tissue detail and multiplanar imaging capability besides providing information about tear dimensions, tear depth or thickness, tendon retraction, and tear shape. MRI in addition can give information about tear extension to adjacent structures, muscle atrophy, size of muscle, cross-sectional area, and fatty degeneration. MRI however has certain disadvantages like being more expensive, poorly available, and contraindicated in patients with implanted medical devices, claustrophobia etc.

The aim of this study was to compare the present-day state-of-the-art commercial ultrasound machines and MRI for detection of rotator cuff injury and to determine their accuracy.

Material and Methods

After clearance from the institutional ethics committee, a total of 40 patients fulfilling the inclusion criteria were included in this prospective comparative study spanning a period of 18 months. The inclusion criterion was patients with clinically suspected rotator cuff injury who presented in the outpatient clinic of Orthopedics Department of our institution. These patients subsequently underwent both USG and MRI in the Department of Radiology within one month after giving informed consent. Out of those 40 patients, 31 patients had findings positive for rotator cuff injury on USG and/or MRI and were finally included in the study while 9 patients with normal scans or unrelated findings were excluded. Exclusion criteria were as follows: patients with a previous history of surgery or prosthesis in the shoulder, patients with pacemakers, metal implants in their bodies, claustrophobic patients and patients not willing to participate in the study.

USG was performed using a high-frequency (12 L, 6–12 MHz) linear array transducer, in a dedicated musculoskeletal protocol. On USG each muscle was examined in at least two planes. MRI was performed on 1.5 T GE Signa Excite machine by putting a shoulder coil on the affected shoulder with the arm in external rotation.

Data were collected and entered in MS Word 2007 and Excel 2007 and a descriptive statistical analysis was carried out in the present study. Results on continuous measurements were presented as Mean ±SD (Min-Max), while the results on categorical measurements were presented in numbers (%). Significance was assessed at 5% level of significance. Chi-square/Fisher Exact test was used to find the significance of study parameters on categorical scale between two or more groups. Diagnostic statistics viz. sensitivity, specificity, positive predictive value, negative predictive value and accuracy were computed to find the correlation of USG with MRI findings as standard reference.

Results

Out of 31 patients included in study, 21 were male patients and 10 female patients. The male: female ratio was 2.1:1. The age of patients in our study ranged from 20 to 79 years (mean age 51.9 years ±13.3).

The right-sided dominance was seen in 30 patients (96.8%) and left-sided dominance in 1 patient (3.2%) in our study. History of either minor or major trauma was seen in 24 out of 31 patients (77.4%) while in 7 patients (22.6%), there was no history of trauma; history of both trauma and diabetes mellitus was seen in 3 patients (9.7%), while no history of trauma or diabetes mellitus was seen in 2 patients (6.4%). Night pain was present in 16 patients out of 31 patients (51.6%) and absent in 15 patients (48.4%). Restricted range of motion was seen in 17 out of 31 patients (54.8%).

All the 31 patients had supraspinatus tears, out of which USG showed 9 full thickness tears and 22 partial thickness tears. On MRI, out of 31 patients, 10 patients demonstrated full thickness tears, 20 patients showed partial thickness tears and 1 patient had tendinosis. On comparing the USG findings with MRI findings, 1 patient with MRI-proven full thickness tear was found to have been falsely diagnosed on USG as grade 3 partial thickness tear, and 1 patient with MRI-proven tendinosis was falsely diagnosed as intrasubstance tear on USG. The USG also demonstrated associated tears in infraspinatus, subscapularis, and teres minor tendons in some cases. It showed 3 complete and 7 partial tears of infraspinatus compared with MRI which showed 4 complete and 8 partial tears for the same tendon. For suscapularis there was only one full tear on both USG and MRI while partial tear of subscapularis was seen in 8 patients on USG in comparison to 9 on MRI. There was only one patient with massive rotator cuff tear, having involvement of teres minor, which was accurately shown by both USG and MRI.

In our study, supraspinatus tendon tear was the most common one, followed by infraspinatus tear seen in 10 patients (32.3%) on USG and 12 patients (38.7%) on MRI.The subscapularis tendon was involved next in frequency to infraspinatus with 29.0% (9 patients) involvement on USG and 32.3% on MRI (10 patients). Teres minor was the least commonly affected tendon in patients with rotator cuff injury. Partial tear of teres minor was seen in one patient only (3.2%) both on USG and MRI (Table 1).

For full thickness tears USG showed sensitivity of 86.7%, specificity of 100%, PPV of 100%, and NPV of 98.2%; for partial thickness tears 89.7% sensitivity, 98.8% specificity, 97.2% PPV, and NPV of 95.5% respectively when compared to MRI. The accuracy of USG in diagnosing full thickness tear was 98.4% and 95.9% for partial thickness tears. The P-value came out to be <0.01 for both full and partial thickness tears. The agreement between the two methods was assessed by kappa coefficient. The kappa coefficient for full thickness tears was 0.919 and 0.904 for partial thickness tears (Table 2).

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

Table 1. Distribution of patients with full/partial thickness rotator cuff tears on USG and MRI.

Tendon (n=31)	USG/MRI	Rotator cuff tears				
		Full thickness	Partial thickness	Tendinosis	Normal	Total
Subscapularis	USG	1	8	0	22	31
	MRI	1	9	0	21	31
Supraspinatus	USG	9	22	0	0	31
	MRI	10	20	1	0	31
Infraspinatus	USG	3	7	0	22	31
	MRI	4	8	0	19	31
Teres minor	USG	0	1	0	30	31
	MRI	0	1	0	30	31

Table 2. Correlation of the USG findings for full and partial thickness tears with MRI.

Correlation of USG findings with MRI findings							Kappa coefficient
(n=31)	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Accuracy	P value	
Full thickness tears	86.7	100.0	100.0	98.2	98.4	<0.001	0.919
Partial thickness tears	89.7	98.8	97.2	95.5	95.9	<0.001	0.904

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. The advancing age also causes tendons to degenerate, occurring most commonly in patients after the third decade and increases linearly thereafter [9]. 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" [10]. In our study too there was an increased prevalence of rotator cuff tears with advancing age, and 26 patients out of 31 (83.9%) were more than 40 years of age. Similar findings were reported in the study by Jerosch et al. [11].

The rotator cuff injury was more common in males with a gender ratio 2:1. 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 earlier studies [12,13].

Trauma was identified as the major etiological factor, present in 77.4% of RCT. Diabetes mellitus was seen in 8 out of 31 patients (25.8%), 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: male gender, right shoulder, dominant hand, advancing age, trauma, 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. 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 [14]. In our study, one patient had tendinosis of the supraspinatus on MRI, which was erroneously diagnosed as intrasubstance tear on USG.

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 1); b) bursal surface tear which communicates with subacromion subdeltoid (SASD) bursa (Figure 2) and c) intrasubstance tear which does not communicate neither with articular nor bursal surfaces and lies within the substance of the tendon.

On MRI, partial thickness tears are characterized by a focal region of fiber discontinuity filled with fluid signal

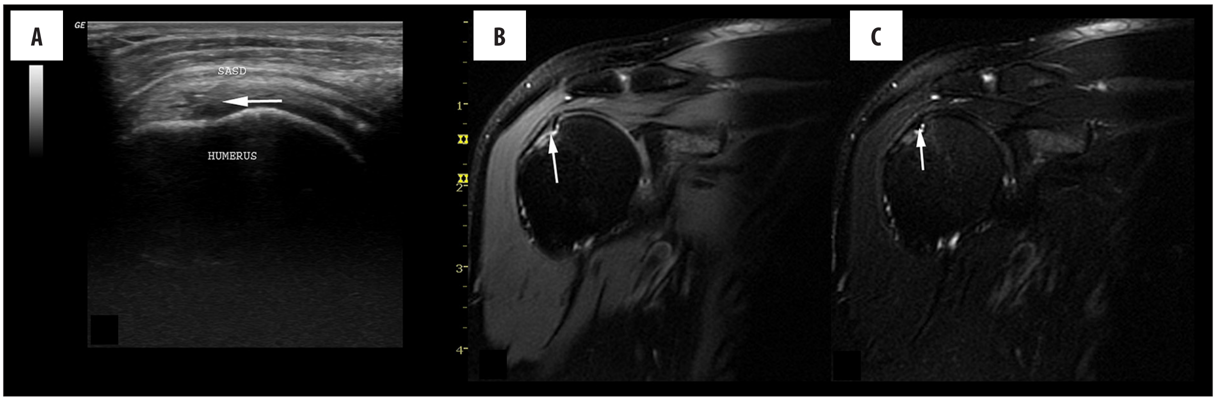

Figure 1. (**A**) USG of a patient showing articular surface partial thickness tear (white arrow) with intact superior tendon fibers. (**B, C**) Corresponding MRI oblique coronal PDFS (**B**) and coronal T2W FS (**C**) images showing a corresponding high signal in the articular surface of the supraspinatus tendon with torn tendon fibers. Note the absence of fluid in the SASD bursa.

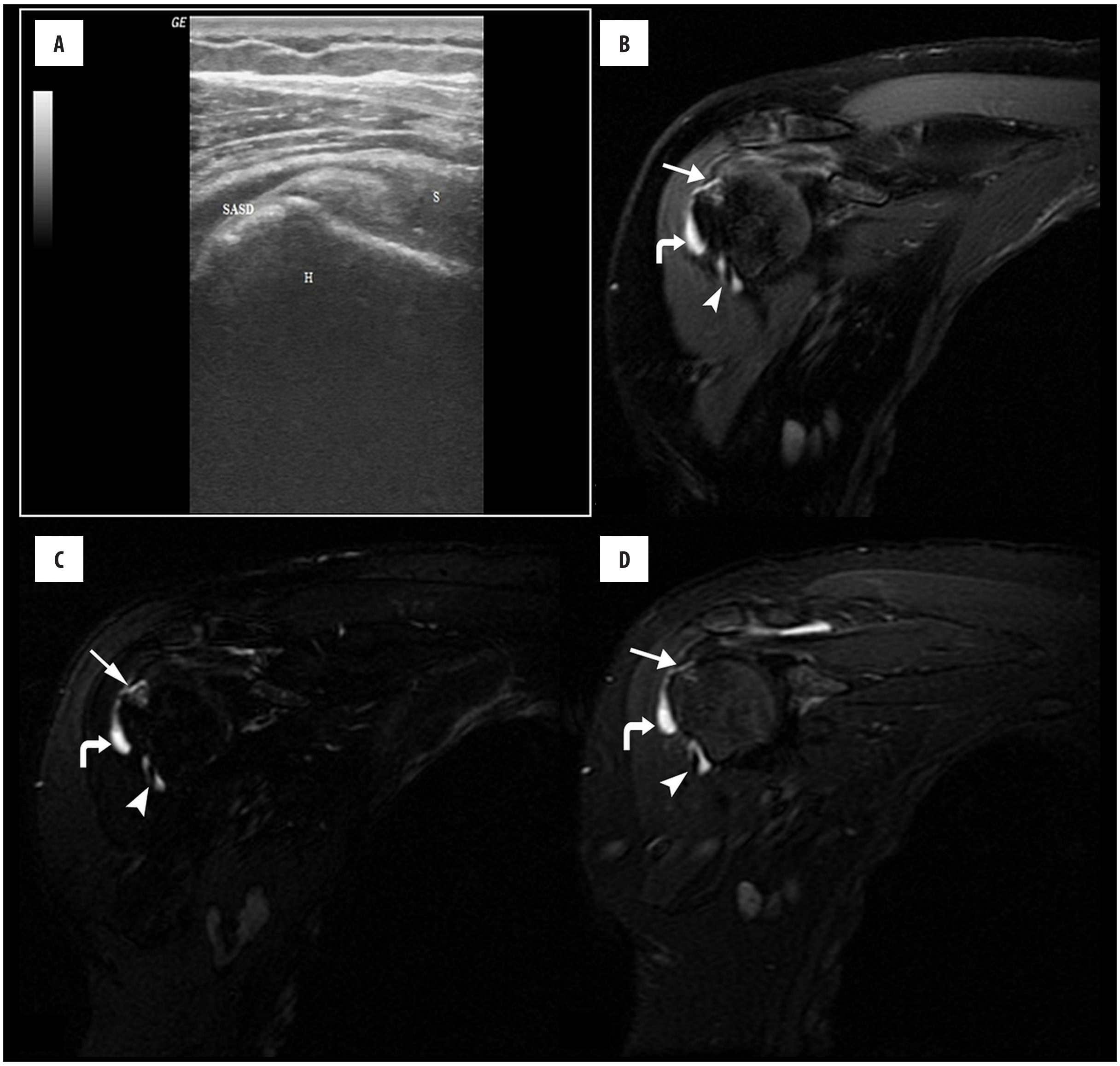

Figure 2. (**A**) USG of a patient showing fluid seen in the SASD bursa (**A**). S is supraspinatus tendon and H is humerus. (**B–D**) Corresponding MRI oblique coronal PDFS (**B**), oblique coronal T2W FS (**C**) and oblique coronal STIR images (**D**) showing the bursal puddle sign (curved arrow) characteristic of bursal surface partial thickness tear of the supraspinatus tendon (straight white arrow). Fluid is also seen along LHBT (arrowhead)

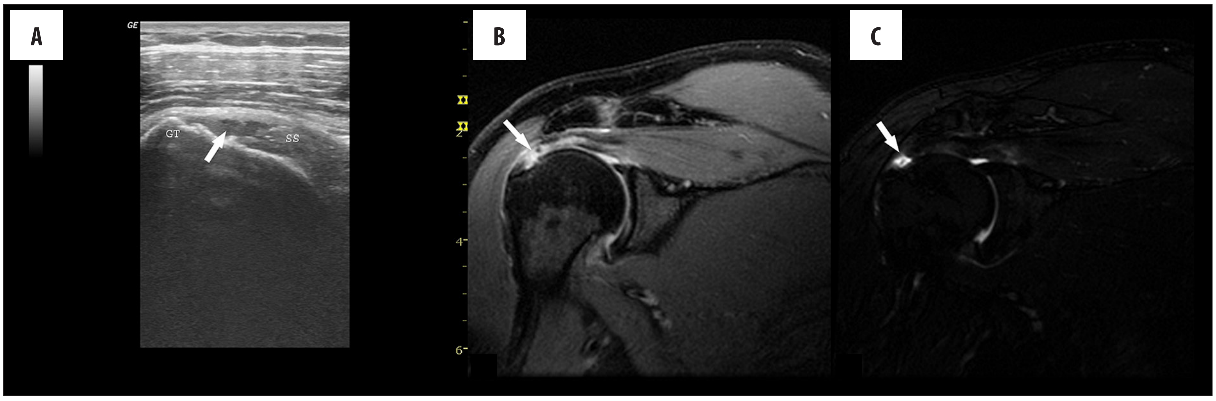

Figure 3. (**A**) USG showing grade I full thickness tear of supraspinatus tendon (white arrow) with mild retraction of tendon. GT represents greater tuberosity of humerus. (**B, C**) Corresponding MRI oblique coronal PDFS (**B**) and T2W FS (**C**) images showing full thickness tear of the supraspinatus tendon at corresponding site with mild retraction of tendon (white arrow).

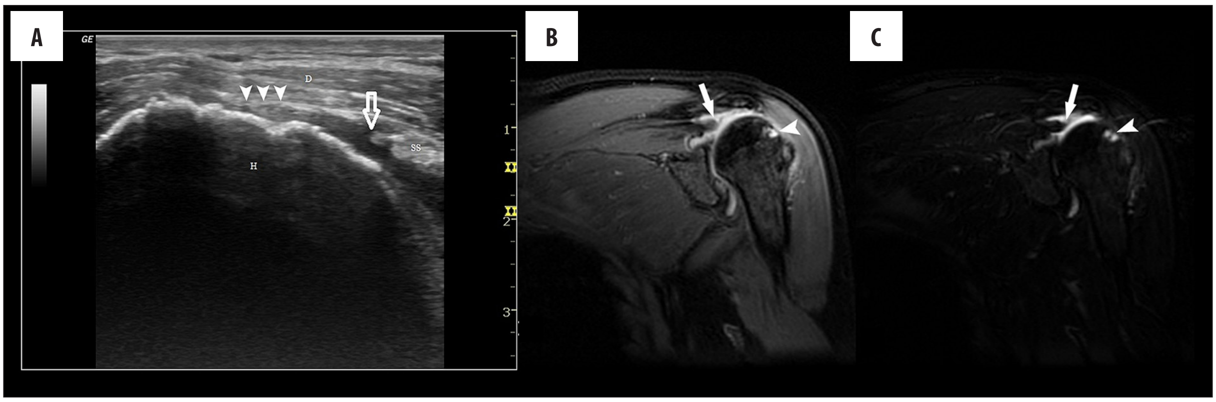

Figure 4. (**A**) USG showing full thickness tear (grade 2) with retraction of the supraspinatus tendon (SS) (white open arrow). Sagging peribursal fat sign is also seen (arrow heads). Note the cortical irregularity seen at greater tuberosity of the humeral head (H). (**B, C**) Corresponding MRI oblique coronal PDFS (**B**) and oblique coronal T2 FS (**C**) MR Images in a patient of grade 2 full thickness tear with retraction of the supraspinatus tendon (straight white arrow) lying above the humeral head. Subchondral cysts are also seen at humeral head (arrowhead).

demonstrated on T2W imaging. 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.

Partial thickness tears were more common in our study and their incidence was twice as that of full thickness tears. Among partial thickness tears, bursal surface tears were more common (12 patients or 38.7%) in comparison to articular surface tears (5 patients or 16.1%). These findings are not in agreement with other similar studies which have shown more common occurrence of articular surface partial tears in comparison to bursal surface partial tears [15,16]. The possible explanation could be inhomogeneous nature of a sample, nonrandomisation, and small sample size comprising of 31 patients. Another reason could be that bursal surface tears, which are more painful, force the patients to seek early medical consultation, while the articular surface tears, being relatively less painful or asymptomatic, allow for a consultation to be delayed [17].

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 (Figure 3–5).

On MRI, complete RCT appear as areas of fluid signal intensity with irregular borders on T2W images involving the whole thickness of the tendon; however, in about 10% of tears, the region of tendon discontinuity is seen as a low signal on T2W images due to chronic scarring [18]. Fluid is also seen in the SASD bursa and glenohumeral joint. Supraspinatus tears that are greater than 2.5 cm in anteroposterior 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.

Our study showed high sensitivity, specificity, PPV, and NPV for high resolution USG when compared to MRI for both full thickness and partial thickness tears. The accuracy of USG in diagnosing a full thickness tear is 98.4% and 95.9% for partial thickness tears. The P value was <0.01

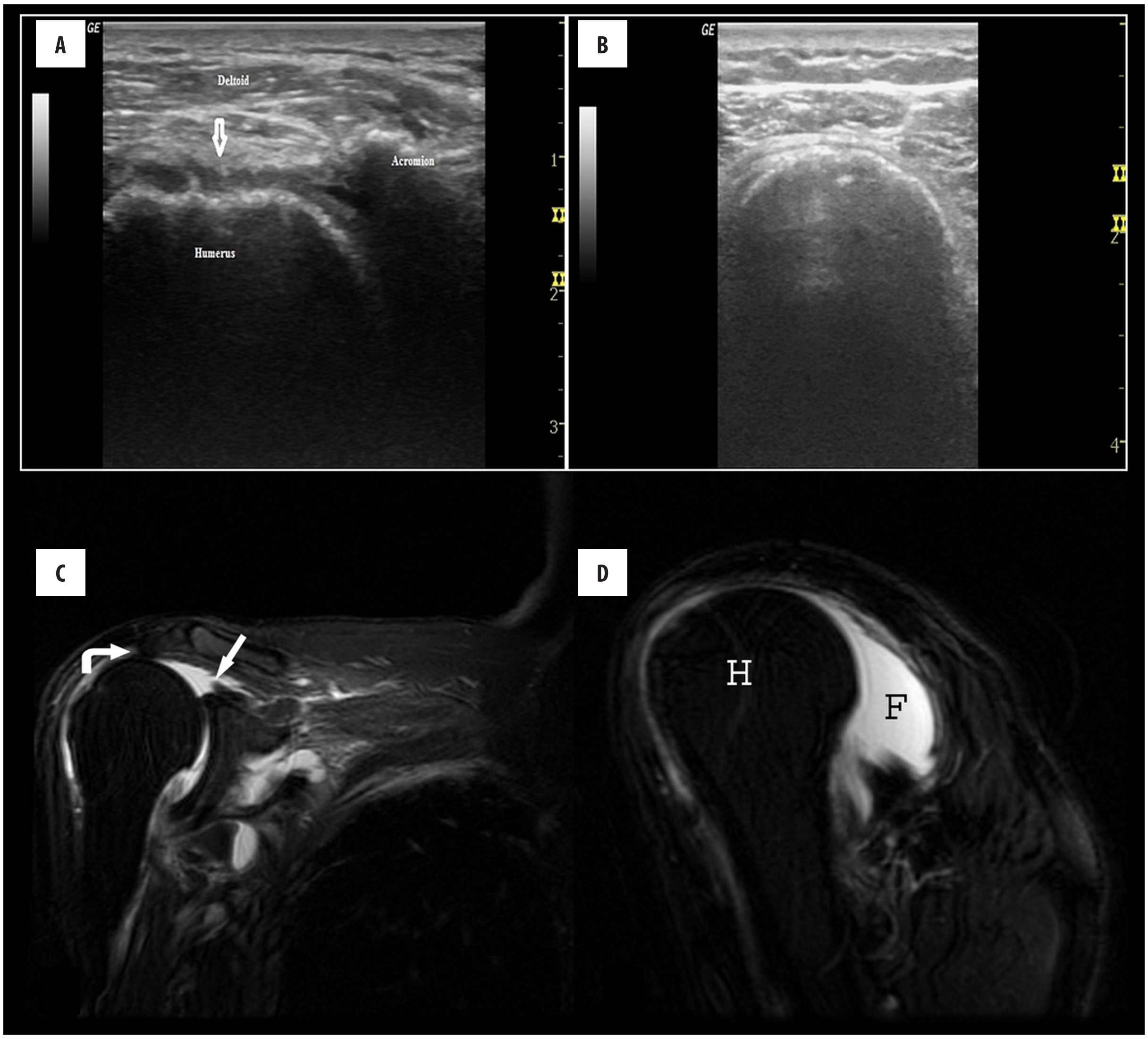

Figure 5. (**A, B**) USG in coronal plane (**A**) showing non-visualized rotator cuff with sagging peribursal fat sign (open white arrow) consistent with full thickness rotator cuff tear with fluid in the glenohumeral joint. USG in saggital plane (**B**) also shows non-visualization of the rotator cuff (arrows). (**C**) Corresponding MRI oblique coronal T2W FS image (**C**) showing retraction of the supraspinatus tendon lying at the level of the glenoid (white arrow) with superior migration of the humerus and resultant reduced acromiohumeral distance (curved white arrow). Fluid is also seen in the SASD bursa and glenohumeral joint. (**D**) Oblique sagittal PDFS MRI image also shows complete non-visualization of the rotator cuff. Humeral head is represented by H and fluid by F.

for both full and partial thickness tears suggesting very strong presumption against a null hypothesis. The agreement between the two methods is assessed by kappa coefficient. The kappa coefficient for full thickness tears is 0.919 and 0.904 for partial thickness tears (Table 2). The strength of agreement between USG and MRI for the diagnosis of rotator cuff tears is excellent and in almost perfect agreement between the two. Similar results were obtained by Rutten et al. [19].They reported high agreement (with the kappa coefficient of 0.78) 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. [20] showed comparable results with a kappa coefficient of 0.73.

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. In our study, the dynamic examination during USG proved helpful in revealing subluxation of LHBT in one patient.

The additional findings like fluid in SASD bursa, concave contour of SASD bursa and cortical irregularity at greater tuberosity had a high probable association with RCT [21]. In our study, USG accurately showed fluid in SASD in 86.9% of patients and the cortical irregularity was better picked up on USG than MRI (Figures 2A, 4A). However, some associated findings were picked only on MRI and could not be demonstrated on USG. Those included findings like subchondral cysts at greater tuberosity (Figure 4B, 4C), bone contusions, Hill-Sachs lesion, Bankart lesion and labral tears.

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 25 patients (86.2%) in comparison to 29 patients (93.5%) on MRI, suggesting that USG is less accurate but still useful for ACJ evaluation.

Another significant associated finding of RCT is muscle atrophy. As the ability of muscles to contract is lost due to atrophy, recognition of this finding is important for predicting the return of function after surgical correction. MR imaging is helpful in this regard as it can quantify the degree of muscle atrophy by assessing the occupancy ratio of the supraspinatus muscle in the supraspinatus fossa [22]. On MRI it is best depicted on oblique sagittal T1W and indicates chronicity of a rotator cuff injury. Muscle atrophy with fatty infiltration can be also depicted on USG. It may be seen as decreased muscle bulk, hyperechoic appearance of muscle, loss of visibility of the central tendon and loss of typical muscle pinnate pattern [23].

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. We were able to demonstrate LHBT sublxation in one patient using this maneuver.

Conclusions

Our study demonstrated high sensitivity and specificity of high resolution USG when compared to MRI for diagnosis of both full thickness and partial thickness rotator cuff tears with accuracy of 98.4% for full thickness and 95.9% for partial thickness tears. Thus, considering the comparable diagnostic accuracy of both these modalities, high resolution USG can be used as the first-line investigation for diagnosis of RCT whereas MRI can be used secondarily as a problem-solving tool, either following an equivocal shoulder USG or for delineation of anatomy in cases where surgical correction is needed.

Conflict of interest

None.

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