Original Article

Diagnostic Accuracy of High-Resolution Ultrasonogram Compared to Magnetic Resonance Imaging in Rotator Cuff Tears – A Prospective Comparative Study

Jayanth Murugan[1], Venkata Sai Kartheek A[2], Raam Mohan Selvarajan[3], Vignesh Siva Anand A[4], Sathish Muthu[5], Madhan Jeyaraman[6]

[1]Department of Radio Diagnosis, SRM Medical College Hospital and Research Centre, SRM Institute of Science and Technology, Chengalpattu, Tamil Nadu, [2]Department of Radio-Diagnosis, Narayana Hrudayalaya Institute of Medical Sciences, Bengaluru, Karnataka, [3]Department of Orthopaedics, ESI Hospital, Ayanavaram, Chennai, [4]Department of Orthopaedics, Government Stanley Medical College and Hospital, Chennai, [5]Department of Orthopaedics, Government Medical College and Hospital, Dindigul, [6]Department of Orthopaedics, ACS Medical College and Hospital, Dr. MGR Educational and Research Institute, Chennai, Tamil Nadu, India

Abstract

Background: One of the most common causes of shoulder pain is a rotator cuff tear. In the absence of surgery, rotator cuff tears can be detected using noninvasive diagnostic modalities such as magnetic resonance imaging (MRI) and ultrasound. High-resolution ultrasound (HRUS) and MRI were used in this study to compare the accuracy of their respective diagnostic methods in the detection of rotator cuff tears. **Materials and Methods:** MRI shoulder was used in this prospective study, which included patients who had been diagnosed with rotator cuff injuries and had been referred for the procedure. In addition to an MRI of the shoulder, an HRUS was performed. It was determined whether HRUS could reliably detect tears in individual components of the rotator cuff complex and whether it could also detect tears in the rotator cuff complex by comparing the results to those obtained with MRI findings. The diagnostic accuracy of the screening test was evaluated using Kappa statistics, which were combined with 95% confidence intervals to arrive at a conclusion. **Results:** A total of 90 patients were enrolled, with a mean age of the study population was 40.49 ± 14.69 years. The predictive validity of HRUS rotator cuff tendon tears in predicting MRI tendon tears had a diagnostic accuracy of 68.89%, 98.89%, 88.89%, and 97.78% for supraspinatus, infraspinatus, subscapularis, and teres minor, respectively. **Conclusion:** Although HRUS is operator dependent, it detects infraspinatus and subscapularis tendon tears with good sensitivity and specificity on par with MRI but not with tears of supraspinatus and teres minor. HRUS is equivalent to MRI in detecting peribicipital fluid, joint effusion, and subacromial impingement. Whereas HRUS did not substantially identify sub-coracoid impingement.

Keywords: High-resolution ultrasound, magnetic resonance imaging, rotator cuff tear, tendon injury

Introduction

The inability to lift one's arm overhead due to rotator cuff injury is a significant source of disability in adults and athletes.[1-3] It is critical to correctly diagnose these injuries in order to provide appropriate treatment.[4] Cuff strains, impingement syndromes, and rotator cuff tears are the three types of lesions that can cause shoulder pain and dysfunction.[5,6] Diagnostic modalities such as high-resolution ultrasonography (HRUS) or magnetic resonance imaging (MRI) are required to distinguish rotator cuff injuries from other conditions such as glenohumeral joint instability. HRUS and MRI are the two examples of such modalities MRI.[7-10] When it comes to diagnosing internal shoulder derangement, MRI is considered to be the gold standard because of its ability to detect other disorders as well, such as tendinosis, calcific tendinitis (calcific tendonitis), tears (muscle atrophy), and long head of biceps brachii tendon. The identification of these conditions necessitates consideration of rotator cuff treatment and prognosis.[11,12]

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Address for correspondence: Dr. Madhan Jeyaraman, Department of Orthopaedics, ACS Medical College and Hospital, Dr. MGR Educational and Research Institute, Chennai, Tamil Nadu, India. E-mail: madhanjeyaraman@gmail.com

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The other important technique, known as magnetic resonance arthrography, is also used to diagnose and treat instabilities.[13] Even though arthrography is more effective at detecting rotator cuff tears than other methods, its primary disadvantage is the invasive nature of the procedure, which causes discomfort for the patient.

In terms of cost, nonionizing nature, and ability to provide rapid real-time diagnosis of rotator cuff tears, HRUS is preferred to MRI. Nearly 90% accuracy, sensitivity, and specificity have been reported when it comes to rotator cuff tears, such as partial, full-thickness, and periarticular.[14-17] A rotator cuff tear can be mistaken for a variety of other conditions, including tendinitis, tendinnosis, calcific tendinitis, and subacromial-subdeltoid bursitis, which can all be detected with ultrasound.[15] HRUS is considered a low-cost alternative to MRI in terms of detecting rotator cuff tears, and it also offers the additional benefit of dynamic real-time assessment.[18] To determine whether HRUS or MRI is more accurate in detecting rotator cuff problems, this research compares the two imaging modalities.

Materials and Methods

After receiving approval from the Institutional Ethics Committee, Narayana Hrudayalaya Hospital, Bengaluru, a prospective study was conducted from in-patients undergoing MRI for shoulder injury between April 2019 and March 2020. The participants were enrolled after the study was approved. The sample size was calculated based on the sensitivity of HRUS in diagnosing rotator cuff injuries, which was determined in the study by Chauhan *et al*.[19] Regardless of age or gender, the study included all patients who were evaluated for rotator cuff injuries across all age groups and genders. We did not include patients who had pacemakers or electronic devices implanted in their chests or who had metal devices in their shoulders. Patients with a history of shoulder surgery, as well as those who were claustrophobic, were also excluded from the study.

T1W/proton density (PD) Fast spin-echo (FSE) sequence, coronal oblique fat-suppressed (FS) PD FSE/T2 – W FSE sequence, sagittal oblique T2 W gradient-echo (GE) sequence, axial T2– W GE sequence, and True fast impedance (TFI) sequences were taken. We used a 512 × 512 matrix with a field of view of 14–16 cm and slice thicknesses of 2–3 mm in a 512 × 512 matrix. A high-resolution probe was used to perform an ultrasound examination of the shoulder on a Philips Affiniti 70G ultrasound machine (12–3 MHz). The radiologist who performed the shoulder ultrasonography (USG) was not aware of the MRI findings. Any discrepancy in reporting was resolved through discussion until a consensus was reached between the two experienced radiologists who reviewed each patient's MRI findings individually. We utilized two sonologists and two radiographers with more than 5 years of experience to be involved in the study and the interobserver agreement was evaluated with kappa statistics. Any discrepancy in reporting was reolved with discussion.

Data analysis and interpretation of images

Bursal and articular surface tears are required for full-thickness tears, while only the bursal or intrasubstance surface of an articular joint can be torn in partial tears. The HRUS tear criteria were developed using the major and minor criteria outlined in Figures 1 and 2.

Major criteria

- Nonvisualization of the cuff tendon
- Focal nonvisualization
- Discontinuity of tendon
- Focal abnormal echogenicity due to granulation tissue, hypertrophied synovium, and hemorrhage.

Minor criteria

- Subdeltoid bursal effusion
- Concave subdeltoid bursal contour
- Joint effusion
- Echogenic band
- Abnormalities of Biceps tendon.

The following criteria, based on those established in the literature were employed for interpretation of MRI examination:[20]

1. Subacromial-subdeltoid bursitis was found when the fat around the bursa was completely or partially gone and was replaced by a low-signal-intensity tissue element on all pulse sequences, or when fluid buildup was seen in the bursa on T2-weighted and PD FS images
2. Whether a full-thickness or partial tear of the rotator cuff was found, the condition was mainly defined by the change

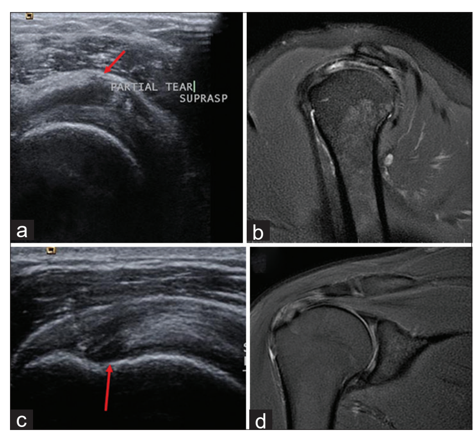

Figure 1: Illustrative image of supraspinatus tear with (a) demonstrating HFUS stare focal discontinuity along the articular surface of supraspinatus near its insertion (red arrow indicates partial tear of supraspinatus tendon near its insertion), (b) Showing MRI images show focal hyper intensity along articular surface on PDFS coronal images suggestive of partial tear, (c) Showing focal discontinuity with anechoic fluid along articular surface of supraspinatus tendon in HFUS suggestive of partial tear (red arrow indicates partial tear of supraspinatus tendon), and (d) Showing focal hyper intensity along articular surface of supraspinatus tendon on sagittal PD FS sagittal images suggestive of partial tear. HFUS: High frequency ultrasound; MRI: Magnetic resonance imaging; PD: Proton density; FS: Fat-suppressed

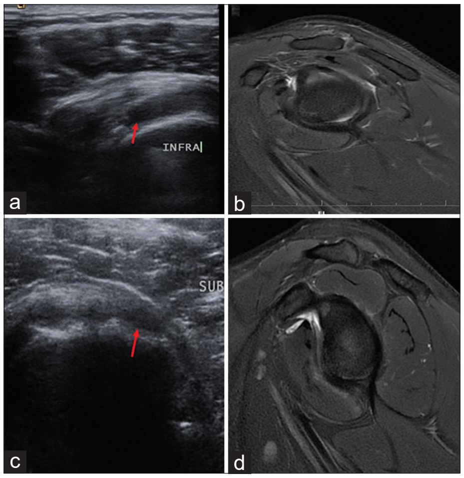

Figure 2: Illustrative image (a) The focal discontinuity shown in the HFUS near the infraspinatus attachment with anechoic fluid (red arrow indicates partial tear of infraspinatus tendon at the attachment), (b) Showing hyperintensity along infraspinatus tendon on PD FS sagittal MRI images suggestive of partial tear and PD FS sagittal images show acromio-clavicular joint degenerative changes, (c) Showing focal discontinuity in the HFUS with anechoic fluid along subscapularis tendon suggestive of partial tear (red arrow indicates partial tear along subscapularis), and (d) Showing focal hyper intensity along near its insertion on sagittal PD FS images suggestive of partial tear. HFUS: High frequency ultrasound; MRI: Magnetic resonance imaging; PD: Proton density; FS: Fat-suppressed

in the tendon's shape, which was shown by a strong or very strong increase in signal intensity on T2 weighted and PDFS images. As shown in Figures 1 and 2

3. It was decided that secondary signs like fluid in the subacromial-subdeltoid bursa, retraction of the musculotendinous junction, and superior translation of the humeral head could help with the diagnosis but were not necessary
4. In order to diagnose tendinitis or tendon degeneration, the tendon must show increased signal intensity on PD images (long repetition time/short time to echo) and, to a lesser extent, T2-weighted images, without showing signs of tendon rupture.

The data were entered into a Microsoft Excel datasheet and analyzed using the (SPSS for Windows Inc. Version 25. Chicago), Illinois version of the programme. The results of an MRI were held up as the gold standard in the medical community. The results of an ultrasound were viewed as a preliminary check. Evaluations were made of the screening test's diagnostic accuracy and sensitivity, as well as the test's positive predictive value (PPV), negative predictive value, as well as the test's confidence intervals (CI). The Kappa statistics was also used to measure the level of agreement between the participants. The quantitative variables were described using mean and standard deviation, whereas categorical variables were described utilizing frequency and proportion. Comparing categorical outcomes between study groups with differing characteristics, the Chi-square test was used. Kappa statistics were used to determine the screening test's diagnostic accuracy, as well as its 95% CI and P value. Statistical significance was defined as a $P < 0.05$.

Results

A total of 90 patients were enrolled and the mean age of the study population was 40.49 ± 14.69 years. 67 (74.44%) participants were male and the remaining 23 (25.56%) were female. Seventy-nine (87.78%) participants were right-hand dominant. The right side was affected in 56 (62.22%) participants and 14 (15.56%) had a history of trauma. Both the sonologists and radiologists who reviewed the HRUS and MRI images had an excellent inter-observer agreement value of 0.94 and 0.96, respectively. The HRUS and MRI findings noted in the included patients are presented in Table 1. Predictive validity of HRUS tendon tears in predicting MRI tendon tears is presented in Table 2.

Apart from identifying rotator cuff tears, high-frequency ultrasound demonstrated statistically significant identification of bicipital tendon fluid ($P < 0.05$), subacromial-subdeltoid bursal fluid ($P < 0.05$), and joint effusion ($P < 0.001$) equivalent to that of MRI findings. On further evaluation, HRUS demonstrated significant identification of subacromial impingement ($P < 0.05$), acromioclavicular joint pathology ($P < 0.05$), and tendon tears ($P < 0.05$) as that of MRI but missed to identify sub-coracoid impingement ($P < 0.05$) significantly.

Discussion

Evaluating the correct cause of shoulder pain is crucial in devising the treatment plan especially for rotator cuff disrders. X-ray, USG, arthrography, computed tomography (CT) scan, and MRI are the commonly available modalities in evaluating patients with shoulder pain.[21-23] The soft tissues around the shoulder form a complex arrangement in multiple planes. This multiplanar arrangement can be efficiently imaged with MRI while CT has only single plane capability which makes it inferior to MRI which has a multi-planar capability with proper visualization of the rotator cuff muscles separately and the identification of individual central tendons.[24] Even though being a gold standard technique, arthrography has the disadvantage of being invasive. Although MRI is highly effective, its high cost makes it less preferable as the first line of investigation. USG solves all these drawbacks in being noninvasive, highly effective evaluation modality as well as very cost-effective. This makes it an ideal first line of investigation.

In our study, the order of involvement is as follows. The first being supraspinatus (64.4%), followed by subscapularis (36.6%), teres minor (4.4%), and infraspinatus (5.6%). These findings were comparable with the study by Jerosch *et al*.[25] Of 122 dissected specimen of shoulder joints, 78% cases had isolated involvement of supraspinatus.[25] The sensitivity of ultrasound, when compared with to MRI findings, showed that ultrasound is fair in detecting supraspinatus injuries (69.8%), very good in detecting infraspinatus (83.4%), subscapularis

Table 1: High-resolution ultrasound and magnetic resonance imaging findings in the study population (*n*=90)

Parameters	Frequency (%)	
	HRUS	MRI
Tendon tears		
Supraspinatus		
Articular surface partial tear	17 (18.89)	19 (21.11)
Bursal surface partial tear	31 (34.44)	44 (48.89)
Full thickness tear	5 (5.56)	8 (8.89)
Partial tear	2 (2.22)	1 (1.11)
Tendinosism	2 (2.22)	3 (3.33)
Mid-substance tear	1 (1.11)	1 (1.11)
Absent	32 (35.56)	14 (15.56)
Infraspinatus		
Partial tear	4 (4.44)	5 (5.56)
Full thickness tear	1 (1.11)	1 (1.11)
Absent	85 (94.44)	84 (93.33)
Subscapularis		
Partial tear	31 (34.44)	33 (36.67)
Full thickness tear	2 (2.22)	2 (2.22)
Absent	57 (63.33)	55 (61.11)
Teres minor		
Partial tear	4 (4.44)	6 (6.67)
Absent	86 (95.56)	84 (93.33)
Peri bicipital tendon fluid		
Present	20 (22.22)	26 (28.89)
Absent	70 (77.78)	64 (71.11)
Bursal fluid		
Subacromial-subdeltoid		
Present	20 (22.22)	21 (23.33)
Absent	70 (77.78)	69 (76.67)
Sub coracoid bursal fluid		
Present	29 (32.22)	34 (37.78)
Absent	61 (67.78)	56 (62.22)
Joint effusion		
Present	48 (53.33)	58 (64.44)
Absent	42 (46.67)	32 (35.56)
Impingement		
Subacromial impingement		
Present	38 (42.22)	34 (37.78)
Absent	52 (57.78)	56 (62.22)
Sub coracoid impingement		
Present	4 (4.44)	7 (7.78)
Absent	86 (95.56)	83 (92.22)
Acromion clavicular joint pathology		
Present	10 (11.11)	16 (17.78)
Absent	80 (88.89)	74 (82.22)

MRI: Magnetic resonance imaging, HRUS: High-resolution ultrasound

muscle (82.9%) and fair in teres minor (66.6%). Specificity was supraspinatus (64.29%), infraspinatus (100%), subscapularis muscle (92.73%), and teres minor (100%). Supraspinatus tears had the lowest diagnostic accuracy (68.9%), while infraspinatus (98.9%) and teres minor injuries had the highest (97.8%). Both imaging techniques were highly specific, but USG was more sensitive than both, according to Martín-Hervás *et al*.[26]

Tears can be thin or thick, depending on their depth. However, intrasubstance tears, such as bursal surface tears and articular surface tears, are also included in this category. There are full-thickness tears that extend from one side to the other. Subacromial – subdeltoid fluid is a common finding. Supraspinatus tears with a complete thickness tear are more common.[27]

In our study it was found that HRUS are highly sensitive (75.64%), highly specific (58.03%), highly predictive (92.19%), and highly accurate (73.33%). According to the study by Cynthia Miller *et al*. in which a total of 56 patients were examined for rotator cuff tears, USG was found to have a specificity of 93%, an overall predictive value of 72%, and an accuracy rate of 58%. A positive sonographic reading is more trustworthy than a negative one, according to these findings.[28] When Brandt *et al*. evaluated the clinical importance of rotator-cuff sonography, they found that ultrasound had only 57% sensitivity, and 76% specificity, which suggests that the sonologist's subjective skills in detecting various shoulder pathologies are at risk.[29] 77 patients with shoulder pain were studied by Sipola *et al*. using ultrasound and MRI. It was found that the tear size was overestimated by a factor of about 15 mm when compared to an MRI. When looking for rotator cuff problems, they came to the conclusion that ultrasound should only be used as screening rather than diagnostic.[30]

Twenty-six of the patients in our research had fluid around the peri bicipital tendon (28.8%). One hundred and twenty-five (96.1%) of the patients have supraspinatus tears, 18 (70.2%) have subscapularis tears, and four have infraspinatus tears (15.3%). Blackstein *et al*. reported that free fluid around tendon represents degenerative pathology either partial or complete rupture of tendon or infective in nature. USG report degenerative pathology of shoulder with 92% sensitivity and 95% specificity.[31]

Although HRUS and MRI are nearly equal in detecting subacromial, subdeltoid, and joint effusions, MRI has a slight advantage over HRUS. The presence of both bursal and joint fluid increases the specificity and PPV for rotator cuff tears; therefore, proper rotator cuff evaluation is required in the presence of joint or bursal effusion.[32]

In our study, MRI found 34 (3.7%) of 90 patients to be positive for subacromial impingement, whereas HRUS found 38 cases (42.2%). There was a statistically significant difference between ultrasound and MRI for detecting subacromial impingement ($P = 0.05$). As a result, HRUS had a high specificity. Similarly, MRI revealed 7 (7.7%) positive cases of subcoracoid impingement out of 90, while HRUS revealed 4 (4.4%) cases of subcoracoid impingement. There was a statistically significant difference between HRUS and MRI in detecting subcoracoid impingement ($P = 0.05$), and MRI was better than HRUS in detecting subcoracoid impingement. In our study, dynamic HRUS had a sensitivity of 42.1%

Table 2: Predictive validity of high-resolution ultrasound tendon tears in predicting magnetic resonance imaging tendon tears (*n*=90)

Parameter	Supraspinatus (%)	Infraspinatus, (%)	Subscapularis (%)	Teres minor (%)
Sensitivity	69.74 (58.13-79.75)	83.33 (35.88-99.58)	82.86 (66.35-94.44)	66.67 (22.28-95.67)
Specificity	64.29 (35.14-87.24)	100.00 (95.70-100)	92.73 (82.41-97.98)	100.00 (95.70-100)
False positive rate	35.71 (12.76-64.86)	0.00 (0.00-4.30)	7.27 (82.41-97.98)	0.00 (0.00-4.30)
False negative rate	30.26 (20.25-41.87)	16.67 (0.42-64.12)	17.14 (2.02-17.59)	33.33 (4.33-77.72)
PPV	91.38 (81.02-97.14)	100.00 (47.82-100.00)	87.88 (6.56-33.65)	100 (39.76-100.00)
NPV	28.13 (13.75-46.75)	98.82 (93.62-99.97)	89.47 (71.80-96.6)	97.67 (91.85-99.72)
Diagnostic accuracy	68.89 (58.26- 78.23)	98.89 (98.89-93.96)	88.89 (78.48-96.04)	97.78 (92.20-99.73)

PPV: Positive predictive value, NPV: Negative predictive value

for detecting impingement, while MRI had a sensitivity of 38.1%. The above findings were consistent with the findings of a study conducted by Read and Perko which confirmed the utility of dynamic ultrasound for clinical diagnosis in cases of impingement.[33]

The different types of acromion are Type I to III which respectively are flat, curved, and hooked according to Bigliani *et al*.[34] Shoulder impingement is common with Type II and III. The study conducted by Bigliani *et al*. showed that full-thickness tear is most commonly associated with Type II acromion. Another study conducted by Bigliani *et al*. has shown that pathological lesions are common if there is abnormal contact between the acromion and soft tissues and hence increasing the space beneath the coracoacromial arch should be the aim of surgical procedures to reduce wear on the rotator cuff.[34] In our study, rotator cuff pathology association was most common in Type II acromion found in 72 patients (80.0%) followed by Type I in 14 (15.5%) then Type III in 4 (4.4%). Of these, Type II acromion had 65 tears (90.27%), Type I had 7 tears (50%), and patients with Type III acromion had 100% tears which is consistent with the literature.

There were some limitations in our study. We considered MRI as the reference standard which has its limitations. We did not surgically confirm the findings of the MRI to assess its validity. Another major drawback inherent to the ultrasound evaluation of musculoskeletal injuries is that the investigation is operator-dependent and depends on the skill level of the radiologist performing the investigation.

Conclusion

Although HRUS is operator dependant, it detects infraspinatus and subscapularis tendon tears with good sensitivity and specificity on par with MRI but not so with tears of supraspinatus and teres minor. HRUS is equivalent to MRI in detecting peribicipital fluid, joint effusion, and subacromial impingement. Whereas HRUS did not substantially identify sub-coracoid impingement.

Conflicts of interest

There are no conflicts of interest.

Institutional Ethical Committee Approval

NHH/AEC-CL-2020-593, Narayana Hrudayalaya Hospital, Bengaluru on 12.10.2020.

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Author contributions

(I) Conception and design: Venkata Sai Kartheek A, Sathish Muthu and Madhan Jeyaraman; (II) Administrative support: Jayanth M, Venkata Sai Kartheek A, Raam Mohan, and Vignesh Siva Anand A; (III) Provision of study materials or patients: Venkata Sai Kartheek A and Madhan Jeyaraman; (IV) Collection and assembly of data: Sathish Muthu and Madhan Jeyaraman; (V) Data analysis and interpretation: All authors; and (VI) Manuscript writing: All authors. All authors have read and agreed to the published version of the manuscript.

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