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Accuracy of High-Resolution Ultrasound of the Shoulder in Evaluation of Rotator Cuff Injuries in Comparison with Magnetic Resonance Imaging: A Prospective Study

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ABSTRACT
Rotator cuff injuries are a common cause of shoulder discomfort, with prevalence increasing with age, affecting 25% of individuals over 60 and 50% over 80. Accurate evaluation of rotator cuff tendons is vital for determining appropriate treatment. This study compared the diagnostic accuracy of high-resolution ultrasound (USG) with magnetic resonance imaging (MRI) in assessing rotator cuff injuries. This Prospective Cross-sectional study was done in the Department of Radio-diagnosis for a period of 2 years. Study included total 70 patients with suspected rotator cuff injuries, from both outpatients and inpatients, who were referred for HR-US and MRI scans of shoulder. Sociodemographic profile of patients, USG and MRI findings were recorded and were compared. The mean patient age was 42.14±14.07 years (range: 19-75 years), with most patients (40%) aged 36-50 years. Males constituted 78% of cases and 70% presented within six months of symptom onset (mean duration: 5.18±4.36 months). The right shoulder was more commonly affected (56%) and 84% had right-hand dominance. Supraspinatus was the most frequently affected tendon, detected in 62% by USG and 80% by MRI. USG demonstrated diagnostic accuracy (DA) of 76%, sensitivity (Sn) of 72.5%, specificity (Sp) of 90%, positive predictive value (PPV) of 96.67%, and negative predictive value (NPV) of 45% for Supraspinatus pathologies. Both USG and MRI were equally accurate in detecting Teres Minor pathologies. This study concluded that while USG is highly accurate for Teres Minor pathologies, MRI remains superior for other tendons, especially Supra spinatus.

INTRODUCTION

The rotator cuff, originating from the scapula and inserting into the humerus, stabilizes the shoulder joint[1]. Rotator cuff injuries are a common cause of shoulder pain, with prevalence ranging from 5-39% and increasing with age, affecting up to 80% of individuals over 80[2,3]. These injuries, including tendonitis and tears, may lead to degenerative conditions such as glenohumeral joint disease and rotator cuff arthropathy[4]. They cause significant pain, restricted mobility and joint damage, necessitating accurate diagnosis to guide treatment[5,6]. Magnetic resonance imaging (MRI), the gold standard for assessing rotator cuff injuries, detects tears through signal changes and tendon irregularities on T2 and PD-weighted images. Its advantages include high soft-tissue resolution and a non-invasive, radiation-free approach[7,8]. However, MRI is costly, time-consuming and contraindicated for patients with certain implants[9]. On the other hand, advancements in ultrasound (US) technology have positioned it as a cost-effective alternative to MRI, offering dynamic imaging, reduced wait times and lower healthcare costs[5,10]. US has shown comparable accuracy to MRI for diagnosing partial and full-thickness tears, with growing evidence supporting its utility[11-13]. A 2015 meta-analysis reported similar sensitivity and specificity for US and MRI in diagnosing rotator cuff tears[14]. Given the prevalence and economic burden of rotator cuff injuries, accurate, cost-effective diagnostics are essential for effective treatment strategies. This study compared the accuracy of high-resolution ultrasound HR-US and MRI in evaluating rotator cuff injuries.

MATERIALS AND METHODS

This prospective study was conducted in the department of Radiodiagnosis from July 2022 to June 2024 after obtaining approval from Institutional Ethical Committee. Study included total 50 patients, aged =18 years, with suspected rotator cuff injuries, from both outpatients and inpatients, who were referred for HR-US and MRI scans of shoulder. Patients with contraindication of MRI scan like cardiac pacemaker, ferromagnetic aneurysm clips, cochlear implants and metallic foreign bodies, Claustrophobia and post-operative cases were excluded from the study. Written informed consent was obtained from each patient prior to their enrolment in the study. Socio-demographic profile of patients and HR-US and MRI findings were recorded in preformed proformas and were compared.

US Evaluation: US beam depth was adjusted (3-5 cm) to account for soft-tissue variations. Examinations were performed with patient and examiner seated on backless stools, facing each other. US gel was applied and patient's arm was positioned at the side with a 90° elbow bend. Biceps tendon was located in its osseous groove by positioning transducer in an oblique transverse plane and followed longitudinally. Subscapularis tendon dynamics were captured during shoulder rotation, with transducer aligned to visualize tendon insertion on lesser tuberosity. The supraspinatus tendon was assessed dynamically with arm in extension and internal rotation, using scapular spine as a reference. Transducer was rotated 90° to view tendon transversely[1]. The infraspinatus tendon was imaged longitudinally, with dynamic views during shoulder rotation and followed laterally to its insertion. Criteria for diagnosing full- thickness rotator cuff tears included: (a) non-visualization of the supraspinatus tendon due to retraction., (b) localized absence or focal discontinuity with loss of the subdeltoid bursa's anterior arc., (c) widening of the gap between the supraspinatus and biceps tendons with bare bone exposure., (d) hypoechoic or anechoic cleft through the cuff and (e) fluid in the subacromial subdeltoid bursa and/or biceps tendon sheath[1].

MRI Evaluation: All MR imaging scans were performed with a 1.5 T system (Philips) with a shoulder array coil. Slice thickness was 3-4 mm, the field of view was 16-cm and the imaging matrix was 256X192 mm or higher. The sequences performed in all patients were the following: oblique coronal T1-w and fat suppressed proton-density TSE, oblique sagittal T2-w TSE and transverse proton-density TSE. Additional transverse T1-w spin-echo images with fat suppression and coronal T1 inversion recovery images were also acquired. A full-thickness tear of the rotator cuff was diagnosed when there was a fluid-filled gap on the T2-w sagittal[1].

Statistical Analysis: Statistical analysis will be performed with the help of Epi Info (TM) 7.2.2.2. Chi-square test was used to test the association of different study variables. Z-test (Standard Normal Deviate) was used to test the significant difference between two proportions. t-test was used to compare the means. Diagnostic accuracy (DA), sensitivity (Sn), specificity (Sp), Positive Predictive Value (PPV) and Negative Predictive Value (NPV) were calculated to find the efficacy of diagnostic tools. $p<0.05$ was considered to be statistically significant.

RESULTS AND DISCUSSIONS

Mean age of patients was 42.14±14.07 years and age range were 19 to 75 years, with majority of patients in the age group of 36-50 years (40%). (Table 1) 39 of 50 patients were male, with a male: female ratio of 3.5:1. Duration of symptoms was less than 6 months in 70% of patients. Right hand (56.0%) was more commonly affected than left hand (44.0%), with right hand being the dominant hand in 42 patients ($p<0.0001$). The most

Table 1: Characteristics of Study Patients

Parameters		Number (50)	%	Z- test	p-value
Age (Years)	≤20	3	6.0%	2.10	0.034
	21-35	13	26.0%		
	36 -50	20	40.0%		
	51-65	13	26.0%		
	>65	1	2.0%		
	Mean± s.d.	42.14±14.07			
	Median	42			
	Range	19-75			
Gender	Male	39	78.0%	7.91	<0.0001
	Female	11	22.0%		
	Male: Female	3.5:1.0			
Duration of symptoms (Months)	<6.0	35	70.0%	5.65	<0.0001
	6.0- 12.0	13	26.0%		
	12.1-24.0	2	4.0%		
	Mean± s.d.	5.18±4.36			
	Median	4			
	Range	0.5-24			
Affected hand	Left	22	44.0%	1.69	0.08
	Right	28	56.0%		
Dominant hand	Left	8	16.0%	9.61	<0.0001
	Right	42	84.0%		

Table 2: Comparison of HR-US vs MRI Findings for Rotator Cuff Tendon Pathologies in Study Patients

		Tendon Pathologies				
Affected Tendon	USG/ MRI	Normal	Tendinosis	Partial tear	Full thickness tear	Tendinosi s and Partial Tear
Supraspinatus	USG	19 (38%)	10 (20%)	12 (24%)	8 (16%)	1 (2%)
	MRI	10 (20%)	20 (40%)	9 (18%)	9 (18%)	2 (4%)
Infraspinatus	USG	49 (98%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)
	MRI	46 (92%)	2 (4%)	2 (4%)	0 (0%)	0 (0%)
Teres Minor	USG	49 (98%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)
	MRI	49 (98%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)
Subscapularis	USG	48 (96%)	0 (0%)	2 (4%)	0 (0%)	0 (0%)
	MRI	47 (94%)	1 (2%)	1 (2%)	1 (2%)	0 (0%)
Biceps Tendon	USG	49 (98%)	1 (2%)	0(0%)	0(0%)	0 (0%)
	MRI	49 (98%)	1 (2%)	0(0%)	0(0%)	0 (0%)

Table 3: Comparison of HR-US vs MRI Findings for Joint Fluid and Pathology in Study Patients

		Fluid	
Bursitis	USG/MRI	Present	Absent
SA-SD	USG	15 (30%)	35 (70%)
	MRI	24 (48%)	26 (52%)
SC	USG	5 (10%)	45 (90%)
	MRI	10 (20%)	40 (80%)
Peri-bicipital Tendon	USG	26 (52%)	24 (48%)
	MRI	27 (54%)	23 (46%)

Table 4: Comparison of Accuracy of HR-US and MRI in Detecting Rotator Cuff Tendon Pathologies in Study Patients

Tendon/ joint Affected	Diagnostic Accuracy (%)	Sensitivity (%)	Specificity (%)	Positive Predictive Value (%)	Negative Predictive Value (%)
Supraspinatus	76	72.50	90	96.67	45
Infraspinatus	94	25	100	100	93.88
Teres Minor	100	100	100	100	100
Subscapularis	98	66.67	100	100	97.92
Biceps Tendon	96	0.00	97.96	0.00	97.96
SA-SD Bursitis	78	58.33	96.15	93.33	71.43
SC Bursitis	82	30	95	60	84.44
Peri-bicipital Tendon Fluid	86	85.19	86.96	88.46	83.33
ACJ Pathology	78.05	0.00	100	0.00	78.05

commonly affected tendon by rotator cuff pathology was Supraspinatus as detected by both HR-US (62%) and MRI (80%). (Table 2) (Fig. 1 and 2) Both HR-US and MRI were equally accurate in detecting partial thickness tear in Teres Minor and tendinosis in Biceps Tendon in study patients. HR-US findings showed presence of subacromial-subdeltoid (SA-SD) bursitis in 15 patients (Fig. 1), Subacromial (SC) bursitis in 5 patients and Peri-bicipital Tendon Fluid in 26 study patients, while MRI findings showed presence of SA-SD bursitis in 24 patients, SC Bursitis in 10 patients, Peri-bicipital Tendon Fluid in 27 patients. (Table 3) (Fig. 3) HR-US failed to detect ACJ pathology in any of the study patients, whereas MRI detected ACJ pathology in 22% of study patients. The diagnostic accuracy (DA), sensitivity (Sn), specificity (Sp), positive predictive value (PPV) and negative predictive value (NPV) of HR-US in comparison to MRI for detecting pathologies in Supraspinatus were 76%, 72.50%, 90%, 96.67% and 45%, respectively. Similarly, the DA, Sn, Sp, PPV and NPV of HR-US for different tendon pathologies are presented in (Table 4).

Fig 1: HR-US Images Showing Supraspinatus Tendon Pathology:
(a) Full Thickness Tear with Retraction of Tendon Ends
(b) Partial Thickness Tear on the Articular Surface
(c) Tendinosis

Fig 2: MRI Images Showing Tendon Pathologies Supraspinatus Tendon Pathology:
(a) Full Thickness Tear with Retraction of Tendon Ends
(b) Partial Thickness Tear on the Articular Surface
(c) Tendinosis

Fig 3: (a) HR-US Image Showing Peri-Bicipital Tendon Fluid
(b) MRI Image Showing Fluid in SA-SD Bursa

Rotator cuff tears (RCTs) are a prevalent cause of shoulder discomfort, leading to about 4.5 million patient visits annually in the United States[13,15]. In addition to physical examinations, imaging techniques like USG and MRI are often required to diagnose RCT[16]. Research has shown that both USG and MRI offer comparable accuracy in diagnosing RCTs prior to surgery, although USG accuracy can vary based on the operator's expertise[17,18]. Due to its efficiency, lower cost, and minimal risk, USG is a suitable initial method for detecting RCTs. While studies support the effectiveness of USG in diagnosing full-thickness RCTs, there is ongoing debate regarding its accuracy in identifying partial-thickness tears and other RCT characteristics[13,18]. This study was conducted to investigate and compare the accuracy HR-US of the shoulder with MRI in assessing rotator cuff injuries. In this study, RCTs were mostly prevalent in the age group of 36-50 years (40%), followed by 51-65 years (26%), similar to previous studies[19,20]. (Table 1) Only 6% of patients were below 20 years and 2% were above 65 years of age in this study, which is in accordance with the study by Maravi[1]. In this study, mean age of patients was 42.14±14.07 years. These findings are in agreement with previous literature[1,3,21-24]. In this study, proportion of male (78%) was significantly higher than females (22%) in this study, suggesting that males are at a significantly higher risk of suffering from shoulder RCT than females ($p<0.0001$). (Table 1) Similarly, male dominance among patients with rotator cuff injuries was observed in previous studies[1,3,6,9,21,22,24]. The mean duration of symptoms in our study was 5.18±4.36 months and the range was 15 days to 24 months. In majority of study patients, duration of symptoms was less than 6 months (70.0%) ($p<0.0001$). (Table 1) Similar observations were made in the studies by Lohith[19] and Vinay[20]. We observed that right shoulder (56.0%) was more commonly affected with rotator cuff injury than left shoulder (44.0%) and right hand was the dominant hand in most of the study patients (84.0.0%) ($p<0.0001$). (Table 1) Similarly, right shoulder was more commonly affected in previously reported studies[3,19,20,23,24]. In this study, both HR-US and MRI showed that most commonly affected tendon by rotator cuff pathology was Supraspinatus, (Table 2) which is in accordance with previous literature[1,3,19,23,25]. We observed that, among the pathologies affecting Supraspinatus in our study, the most commonly detected pathology by HR-US was partial thickness tear (24%), followed by tendinosis (20%), full thickness tear (16%) and both tendinosis and partial thickness tear in 2% of patients. However, the most commonly detected pathology of Supraspinatus by MRI was tendinosis (40%), followed by partial thickness tear (18%), full thickness tear (18%) and both tendinosis and partial thickness tear (4%).

Partial thickness tear followed by full thickness tear were most commonly detected Supraspinatus pathologies by both USG and MRI in previously reported studies[1,6,19,21,24]. The only pathology detected by HR-US in infraspinatus was tendinosis, which was observed in 2% of patients in this study, while previous studies have observed partial thickness and full thickness tear in infraspinatus tendon in rotator cuff injury patients[21,24]. In this study, MRI detected partial tear and tendinosis in 4% of patients each. Similarly, in other studies, Infraspinatus pathology detected by MRI were partial thickness tear[1,21] and full thickness tear[21]. Among the two patients with tendon pathology in Subscapularis detected by HR-US in this study, both showed partial thickness tear, one patient with Teres Minor pathology showed partial thickness tear and one patient with Biceps Tendon pathology showed tendinosis. In a similar study by Gupta[6], USG detected partial tear in 12% and tendinosis in 12% of patients in Subscapularis tendon, whereas, in the study by Selvaraj[21], USG detected partial thickness tear in Subscapularis in 6% and full thickness tear in Subscapularis in 2% of their study patients. MRI detected Subscapularis pathology in three patients in this study, among which one patient showed full thickness tear, one showed partial thickness tear and one showed tendinosis, while one patient was detected with partial thickness tear in Teres Minor and one patient with tendinosis in Biceps Tendon. Similar observations were made in previous study[24]. In this study, both HR-US and MRI were able to detect SA-SD bursitis, SC bursitis and presence of Peri -bicipital Tendon Fluid, (Table 3) similar to previously reported literature[19,24]. Though HR-US was unable to detect ACJ pathology in any patient in this study, MRI was able to detect ACJ pathology in 22% of patients, similar to previous studies[1,24]. These observations suggested that MRI was more accurate in detecting rotator cuff pathologies as compared to USG, which has been observed in several studies[6,19,23,24]. We investigated the DA, Sn, Sp, PPV and NPV of HR-US in comparison to MRI for detecting pathologies in all the tendons and joints involved in rotator cuff injuries. (Table 4) We observed that DA of HR-US was highest for detecting pathologies in Teres Minor tendon (100%), followed by Subscapularis tendon (98%), Biceps Tendon (96%), Infraspinatus tendon (94%), Supraspinatus tendon (76%), Peri-bicipital Tendon Fluid (86%), SC Bursitis (82%), ACJ pathology (78.05%) and SA-SD Bursitis (78%). Being a single center study and smaller sample size are two limitations of this study.

CONCLUSION

Rotator cuff issues are the leading cause of shoulder pain and restricted movement, commonly affecting middle-aged males, particularly in the dominant hand. The supraspinatus tendon is most frequently involved. While HR-US is cost-effective and widely used as a first-line diagnostic tool, its accuracy is lower than MRI for most tendon pathologies, except for the Teres Minor, where it achieves 100% accuracy.

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