RESEARCH ARTICLE

Evaluation of Diagnostic Precision of Ultrasound for Rotator Cuff Disorders in Patients with Shoulder Pain

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Abstract

Background: Rotator cuff disorders are a leading cause of shoulder symptoms. Accurate imaging, detecting the type of the involved muscle, and severity of the injury have important effects on the choice of treatment. Accordingly, the current study was conducted to evaluate the diagnostic accuracy of ultrasound for rotator cuff disorders in patients suffering from shoulder pain and to explore the precision of ultrasound in determining the exact dimensions of a tear in comparison with magnetic resonance imaging (MRI).

Methods: This prospective research was performed on patients clinically suspected of rotator cuff tendinopathy. An ultrasound of the shoulder was initially performed for the candidates. In this study, MRI was regarded as the modality of choice for examining the images of shoulder disorders. The European Society of Musculoskeletal Radiology (ESSR) guidelines were used to design the protocols and implement imaging measures. Based on the reference standard of MRI, the specificity and sensitivity as well as positive and negative predictive values of ultrasound in detection of rotator cuff disorders were calculated.

Results: A total of48 patients (22 women, 23 dominant right hands) with an average age of 51.6±8.3 years were enrolled in this study. Based on MRI findings, rotator cuff disorders were detected in 43 patients (89.5%). The most commonly observed disorders were partial-thickness rotator cuff tear (n=17, 35.4%), full-thickness rotator cuff tear (n=16, 33.3%), and tendinopathy (n=10, 20.8%). Among rotator cuff disorders, the highest sensitivity of ultrasound was observed in the detection of full-thickness tear (93.7%) and rotator cuff tendinopathy (90%). The highest specificity was found in the detection of full-thickness rotator cuff tear (100%) and partial-thickness rotator cuff tear (96.7%).

Conclusion: Based on our findings, ultrasound could be considered as a high-quality diagnostic tool to rule in partial and full-thickness rotator cuff tears and rule out the rotator cuff pathologies.

Level of evidence: I

Keywords: Diagnostic accuracy, Rotator cuff, Ultrasound

Introduction

Rotator cuff disorders including partial and full tendon tears as well as degenerative and inflammatory changes are the main factors of shoulder symptoms and account for more than half of the cases of chronic shoulder diseases (1). Detection of the type of injury and the involved muscles as well as the extent and severity of involvement plays an important role in the development of treatment plan (2). Moreover, early repairability of the rotator cuff tear, which is the most common rotator cuff disorder, is not possible in case of large tendon tear, severe fatty atrophy of supraspinatus muscle, and tendon retraction or

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immobilization. Therefore, precise preoperative imaging has an important role in determining the repairability of rotator cuff disorder as well as choosing the surgical approach– i.e. open or arthroscopic surgery (3, 4).

With respect to its proven accuracy and high sensitivity, magnetic resonance imaging (MRI) has been employed as a diagnostic gold standard for rotator cuff pathologies for a long time (5, 6). However, high cost and inaccessibility in all healthcare centers make it sometimes difficult to use (7). Ultrasound is another imaging modality with the ability to explore the position, size, retraction, and extent of the full-thickness rotator cuff tears, which address ultrasound as a promising imaging technique in the examination of rotator cuff tears (4). Although operator-dependent limitations of ultrasound findings are still a problem, a further benefit of ultrasound seems to be related to the improvements made in recent decades in transducer power, soft tissue penetration, and learning practices and experience exchanges (3, 8, 9). This diagnostic method is particularly associated with lower costs, higher access, and better patient tolerance. Considering the role of operators and evaluation protocols in performing an ultrasound and given the importance of ultrasound diagnostic value in different settings, it is necessary to conduct ultrasound studies in different settings, especially in the referral clinics for better delineation of the generalizability of the findings (4, 9). The present study was designed to evaluate the diagnostic accuracy of ultrasound in detecting rotator cuff disorders in patients suffering from shoulder pain and to examine the precision of ultrasound in determining the exact dimensions of musculotendinous tears compared to MRI.

Materials and Methods

Research design and setting

The current prospective research was performed on patients with shoulder pain who were referred to the orthopedic clinic at Imam Reza Hospital, Mashhad, Iran, from July 2017 to May 2018. This article was written based on 2015 guidelines of Standards for the Reporting of Diagnostic accuracy studies (STARD). Patients suspected of rotator cuff disorders were recruited into the study according to their history (shoulder pain at night and snapping scapula syndrome) and examination of findings (impingement tests) by an orthopedic surgeon. The discrepancy between clinical examinations and rotator cuff disorders and contraindication for shoulder MRI (presence of metal implants, pacemakers, etc.) were considered as exclusion criteria.

Sample size

The minimum sample size was estimated as 37 patients considering alpha=0.05 and beta=0.2 using the data from the Fisher *et al*. study in which ultrasound sensitivity was 90% in detecting rotator cuff tear. Also, the prevalence of 30% for rotator cuff tear among patients suffering from shoulder pain was considered (10). The samples were selected by convenience sampling.

The sample size was calculated based on the following formula.

$$n = \frac{z^{2}_{1-\frac{\alpha}{2}}\, pq}{d^{2}}$$

After calculating the initial sample size (n=11) it was divided by 0.30 (the estimated prevalence of rotator cuff tear among patients suffering from shoulder pain) and the final sample size was calculated.

Data collection tools

Initially, the gender, age, body mass index (BMI), and patients' related history were recorded. An orthopedic surgeon examined the patients and prescribed imaging for patients with clinical suspicion of rotator cuff tendinopathy. Shoulder ultrasound was performed for the candidates before MRI (Avanto scanner 1.5 T, Siemens).

Reference standard (RF)

In this study, MRI was considered as the reference standard imaging method for shoulder disorders. A radiologist unaware of ultrasound findings explored all MRI images and the findings were recorded. The guidelines of European Society of Musculoskeletal Radiology (ESSR) were used to design protocols and implement imaging measures (11). In short, the patients were placed in the supine position with their arms along the body and then in the external rotation position. The appropriate shoulder array coil was used and the images were acquired in axial, sagittal, oblique, and coronal planes according to the protocol.

The criteria for detection of rotator cuff tendons and the long head of biceps muscle in MRI images have been presented in previous studies (3, 9). Thus, full-thickness tear of the tendon was defined as presence of a defect in the muscle-tendon path from articular to bursal surface with the replacement of the tendon with a fluid signal. The partial-thickness rotator cuff tear is a non-continuity region of the tendon fibers with the fluid signal inside the tendon on either articular or bursal surface or in the middle of the tendon. In each case of tear observation, the diameters were measured in anteroposterior, mediolateral, and depth dimensions in partial tears as well as anteroposterior and mediolateral dimensions in full-thickness tear. The rotator cuff tendinopathy and the long head of biceps muscle were diagnosed by the presence of a high signal in the tendon in T1w and T2w images without any evidence of tear or non-continuity of tendon fibers. The cases of tendon deformity including increased or decreased thickness were also included in this group. The effusion in subacromial/subdeltoid and subcoracoid bursae or shoulder joint as well as degenerative changes were also recorded.

Index test

Ultrasound was considered as the index test. Based on a protocol contained in ESSR guidelines, an experienced radiologist unaware of MRI findings performed the shoulder ultrasound (Aplio 300, Toshiba) using a 10 MHz

linear probe (11). The ultrasound examination included biceps, supraspinatus, and subscapularis muscle tendons from the anterior shoulder and infraspinatus as well as teres minor muscle tendons from the posterior shoulder. Appropriate planes for each tendon were prepared according to ESSR guidelines. The effusion in subacromial/subdeltoid and subcoracoid bursitis or shoulder joint and also the degenerative changes were recorded. A hypoechoic area in the tendon that was visible in two different planes was defined as the criterion for tear in biceps and rotator cuff muscle tendons. Accordingly, the diagnostic criteria were: a hypoechoic gap in the tendon with expansion from the articular to bursal surface (full-thickness tear), hypoechoic focal area on one side of the tendon without full-thickness involvement (partial-thickness tear), and echoic changes or deformation in the tendon including altered thickness without evidence of tear or non-continuity of the tendon fibres (tendinopathy).

Ethical considerations

This study was conducted observationally and therefore no invasive intervention was taken for patients. Written consent forms were signed by patients after complete explanation of the method and objectives of the study. The patients' information was kept confidential and the relevant data were encoded in the statistical software. This research project was approved by the Ethics Committee of Mashhad University of Medical Sciences (IR.mums.fm.REC.1396.785). The patients were fully supported in case of any research-related complications.

Statistical analysis

The continuous and categorical variables were expressed as mean±SD and numbers/percentages, respectively. The specificity and sensitivity as well as positive and negative predictive values of ultrasound for detecting rotator cuff disorders were estimated in accordance with the reference standard of MRI. In addition, Cohen's kappa coefficient was used to measure the conformity between the findings of ultrasound and MRI. Pearson's correlation test estimated the correlation of measured tears between the two instruments. The data were analyzed in SPSS software, version 17 (Chicago, IL, USA). A $P<0.05$ was regarded as statistically significant.

Results

Baseline characteristics

This study was performed on 48 patients (22 women, 23 dominant right hands) with a mean age of 51.6±8.3 years and a BMI of 27.0±2.8 kg/m^2. The shoulder pain was reported in the left shoulder in 25 patients (52.1%) and the right shoulder in 23 cases (47.9%). The history of shoulder trauma was found in 16 patients (33.3%), which were occurred in 12 cases (25.0%) over the past three weeks and in four cases (8.3%) more than three weeks ago. In addition, seven patients (14.6%) had regular exercise, six of whom (12.5%) had trauma during exercise; nine patients (18.8%) had a history of osteoarthritis, five patients (10.4%) had a history of rheumatoid arthritis, and six patients (12.5%) had a history of diabetes. Corticosteroids were also consumed by only four patients (8.3%).

MRI findings

Rotator cuff disorders

Based on MRI findings, rotator cuff disorders were observed in 43 patients (89.5%). The most commonly experienced disorders were partial-thickness rotator cuff tear (n=17, 35.4%), full-thickness tear (n=16, 33.3%), and tendinopathy (n=10, 20.8%). Moreover, the most frequently involved muscles were supraspinatus (n=42, 87.5%), infraspinatus (n=13, 27.1%), subscapularis (n = 14.6%), and teres minor (n=0).

Other disorders

Based on MRI findings, subacromial/subdeltoid bursitis (n=39, 81.3%) and subcoracoid bursitis (n=19, 39.6%) were other diagnosed disorders. In addition, 41 patients had shoulder joint effusion (85.4%), 13 patients (27.1%) showed degenerative changes in the glenohumeral joint, and 28 patients (58.3%) had degenerative changes in the acromioclavicular joint. Calcific tendonitis was observed in three patients (6.3%). A patient (2.1%) also showed a greater tuberosity fracture of the humerus. According to MRI findings, disorder in the long head of biceps tendon was seen in 19 patients, the most frequent being tendinopathy (n=39, 27.1%), followed by tendon dislocation in three cases (6.3%). The full-thickness tear was reported in two patients (4.2%) and partial-thickness tear in three patients (6.3%).

Ultrasound findings

Rotator cuff disorders

Based on ultrasound findings, 43 patients (89.5%) had rotator cuff disorders. The most commonly observed disorders were tendinopathy (n=18, 37.5%), full-thickness tear (n=15, 31.3%) and partial-thickness tear (n=10, 20.8%). The most frequently involved muscles were supraspinatus (n=43, 89.6%), infraspinatus (n=9, 18.8%), subscapularis (n=3, 6.3%), and teres minor (n = 0).

Other disorders

Other findings of ultrasound include joint effusion (n=37, 77.1%), subacromial/subdeltoid bursitis (n=37, 77.1%), subcoracoid bursitis (n=5, 10.4%), degenerative changes in glenohumeral joint (n=11, 22.9%) as well as in acromioclavicular joint (n=20, 41.7%). Greater tuberosity fracture of the humerus was observed in one subject (2.1%).

Pathology of long head of biceps tendon

According to MRI findings, disorders in the long head of biceps tendon were observed in 17 patients, the most common being tendinopathy (n=14, 29.2%) and tendon dislocation in three cases (6.3%). Full-thickness tear was reported in two patients (4.2%) and partial-thickness tear in one patient (2.1%).

The diagnostic value of ultrasound in rotator cuff disorders

Cohen's kappa coefficient was statistically significant

Table 1. Frequency of rotator cuff disorders observed in ultrasound and MRI

	Type of disorder	Ultrasound n (%)	MRI n (%)	Kappa coefficient	*P-value*
Rotator cuff disorders	Total disorder	43 (89.6)	43 (89.6)	-	-
	Full-thickness tear	15 (31.3)	16 (33.3)	0.51	<0.001
	Partial-thickness tear	10 (20.8)	17 (35.4)	0.55	<0.001
	Tendinopathy	18 (37.5)	10 (20.8)	0.95	<0.001

Table 2. Parameters related to diagnostic value of ultrasound in detection of rotator cuff disorders

	Sensitivity	Specialty	Positive predictive value	Negative predictive value	Accuracy
Full-thickness tear	93.7	100	100	96.6	97.9
Partial-thickness tear	52.9	96.7	90.0	78.9	81.2
Tendinopathy	90	76.3	50	96.6	79.1

for ultrasound and MRI in the detection of all types of musculoskeletal disorders in rotator cuff muscle [Table 1]. The highest ultrasound sensitivity in the detection of rotator cuff disorders were related to full-thickness rotator cuff tear (93.7%) and rotator cuff tendinopathy (90%). The highest specificity was found in the detection of full-thickness rotator cuff tear (100%) followed by partial-thickness tear (96.7%) [Table 2].

Correlation between MRI and ultrasound findings in relation to rotator cuff tears

Based on Spearman correlation coefficient, the values measured by ultrasound had a significant correlation with MRI findings for anteroposterior diameters of full-thickness tear (r=0.972, *P=0.001*) and partial-thickness tear (r=0.710, *P=0.001*), as well as mediolateral diameters of full-thickness tear (r=0.977, *P=0.001*) and partial-thickness tear (r=0.724, *P=0.001*). The partial-thickness tear diameter, measured by ultrasound, was also significantly correlated with MRI (r=0.672, *P=0.001*).

Discussion

Main outcomes

The current research aimed to estimate the diagnostic value of ultrasound in detecting rotator cuff disorders among patients with shoulder pain. The results showed that ultrasound can detect full- and partial-thickness rotator cuff tears with >90% specificity and positive predictive value. On the other hand, our study showed >90% sensitivity and negative predictive value of ultrasound in detecting rotator cuff tendinopathy. The high level of specificity and predictive value of ultrasound in the detection of rotator cuff tears indicates its aptitude to rule out the disease. High positive predictive values also reveal the high accuracy of screening tests based on ultrasound reports in detecting rotator cuff tears.

Comparison with similar studies

The present research is the first attempt to examine the diagnostic value of ultrasound in assessing the causes of shoulder pain. As this study includes results from an Iranian referral center with inaccurate information about the diagnostic power of ultrasound, our findings can be of high importance. Especially, a main limitation of ultrasound is the dependence of its results on operator-centered factors, the implementation center and the instruments under consideration. Our findings are consistent with other studies and can complete the ultrasound efficiency puzzles in detection of rotator cuff pathologies, this time in an Iranian center (12). In line with our research, a recent study indicated that the ultrasound with high diagnostic value and sensitivity of nearly 100% is an invaluable tool in the investigation of rotator cuff tears and tendinopathies (10). Another study also found that ultrasound could be considered as a tool with high sensitivity in detecting rotator cuff large size tears, but had no significant diagnostic sensitivity in detecting small tears (13). Although we did not study the effect of tear size on diagnostic value of ultrasound, our research examined the correlation between quantitative results reported by ultrasound and MRI in addition to providing quantitative parameters related to the diagnostic value of ultrasound. Our results showed that ultrasound values were significantly correlated with MRI in the majority of partial and full-thickness rotator cuff tears, which can emphasize the value of ultrasound in the early examination of rotator cuff muscle disorders. In line with our findings, Okoroha *et al.* showed a statistically significant relationship between the measured values of rotator cuff muscle tear in ultrasound and MRI (1). Similarly, a study on an Iranian population considering the surgical results as the gold standard reported that the sensitivity and specificity of ultrasound were similar to those reported by MRI and there was no significant difference between the

two methods in over 90% of cases (14). A meta-analysis performed on 35 studies found the sensitivity and the specificity of ultrasound as 91% and 86%, respectively, in detecting the rotator cuff tear, which is close to our findings while the same values for MRI and arthroscopy were nearly 90% (15). Another meta-analysis (2018) revealed that three-dimensional ultrasound of shoulder was able to detect full and partial-thickness rotator cuff tears with the sensitivity of 83% and specificity of 94% (16). This meta-analysis was performed on seven studies and a total of 282 patients. The important point of this study was that arthroscopy was mainly intended as a diagnostic gold standard, while MRI was the diagnostic gold standard in our study (16). However, no significant difference was found between the findings of our study and this meta-analysis, and consistent with our research, it was shown that the diagnostic value of ultrasound for partial-thickness tears was less than full-thickness tear (16). However, it should also be noted that the use of a 3D ultrasound greatly improves its diagnostic value to detect tears (especially partial tears). Despite the implementation of 2D ultrasound in our study, the findings were almost similar to 3D ultrasound (17, 18).

The low diagnostic value of ultrasound in partial- versus full-thickness tear is a topic that has also been mentioned in other studies (19). A study by Vlychou showed that ultrasound had a diagnostic accuracy of 98.5% and 96%, respectively, in comparison with MRI to detect full and partial-thickness tears (20). In our research, these values were nearly 98% and 81% for full and partial-thickness tears, respectively. It seems that the lower diagnostic accuracy of a partial-thickness tear in our study can be attributed to the small sample size. We assume that the reported values for partial-thickness tear would improve with a higher sample size. Additionally, the small size of partial tears can be another reason for lowering ultrasound sensitivity in detecting partial tears. Our clinical experience suggests that small dimensions of partial tears, especially in obese subjects, lead to the ignorance of partial tears and misdiagnosis as tendinopathy.

In addition, the difference in statistical samples is another reason for slight differences reported between the findings of various studies. Although the impact of factors such as age, gender, and underlying pathology on the diagnostic value of imaging tools is not fully understood, the mean age of our subjects was close to 50 years but 30-60 years in other studies (14, 21). The differences in the diagnostic gold standard in shoulder pain, different ultrasound and MRI systems, and various techniques for assessing shoulder by ultrasound appear to be the possible reasons for partial difference between the findings of various studies (9, 16, 21). However, it should be noted that ultrasound, especially the shoulder ultrasound, is highly dependent on the operator. A recent study found that a short training session could dramatically improve the diagnostic value of shoulder pathologies by ultrasound (8). It seems that the position of ultrasound in detecting shoulder pathologies can be considered beyond the current status as an alternative.

Other important points

In addition to providing parameters related to diagnostic value of ultrasound, our study examined the correlation between quantitative values reported by ultrasound with MRI. The results of our research showed that the measured ultrasound parameters had a significant correlation with MRI in the majority of full and partial-thickness tears. This finding can also enhance the value of ultrasound in the early examination of rotator cuff muscle disorders. In patients who are not surgical candidates, the ultrasound can be used as a convenient and inexpensive method to evaluate the response to non-surgical treatments and follow-up of patients. In line with our findings, Kelechi *et al*. demonstrated a significant relationship between the measured values of rotator cuff tears (17). Like our study, Fischer *et al*. used Cohen's kappa coefficient and found a correlation between the findings of ultrasound and MRI in the detection of various rotator cuff muscle pathologies (10). Based on these results, it should be generally acknowledged that although ultrasound is sufficient in many cases to evaluate complaints of shoulder pain, further imaging is sometimes needed. For example, our study, like many investigations, did not manage to demonstrate the diagnostic accuracy of ultrasound for the detection of calcific tendonitis because the frequency of people with this disorder was low in our study. Based on imaging studies, the prevalence of calcium phosphate crystal deposition varies between 2-10% in rotator cuff tendons. The etiology and pathogenesis of calcific tendonitis are relatively unknown in many patients and most patients with calcific tendonitis are asymptomatic (4).

However, our experience in similar cases shows that the pain associated with calcific deposition is debilitating, and observation of calcification with and without posterior acoustic shadowing as an echogenic state can be suggested for the detection of calcific tendonitis. Although MRI is a great diagnostic tool, high costs, lack of access in all areas, long waiting times, and occasional exposure to contrast agents are among the limitations of this technique. According to the findings of this study, the use of ultrasound can provide essential clinical information with high sensitivity and specificity without the need for high costs over a shorter period. Additionally, if the ultrasound fails to show all the required information, it can be the minimum guideline to determine the most relevant and definitive imaging action required for further examination and/or follow-up (3, 9).

Study limitations

The present study had a number of limitations. The first limitation was the small sample size, so that the frequency reached about 10 patients in some pathologies, reducing the generalizability of the findings. The second limitation was the fact that arthroscopy was not chosen as a diagnostic gold standard. However, MRI is considered as the diagnostic gold standard of rotator cuff pathologies and a reliable diagnostic tool in more than dozens of studies over the past decade.

The results of the current study showed that ultrasound

could be considered as a high-quality diagnostic tool to rule in partial and full-thickness rotator cuff tears and rule out the rotator cuff pathologies. The effect of epidemiological factors as well as indicators related to tear status such as tear size, the presence of pathologies such as calcific tendonitis, and their effect on the diagnostic value of ultrasound is a subject that needs to be addressed in subsequent studies.

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