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Ultrasonography of symptomatic rotator cuff tears compared with MR imaging and surgery

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Abstract

Purpose: To compare the accuracy of ultrasonography and magnetic resonance imaging in the detection of rotator cuff tears.
Materials and methods: Ninety-six patients with clinically suspected rotator cuff pathology underwent ultrasonography and magnetic resonance imaging of the shoulder. The findings in 88 patients were compared with arthroscopy or open surgery.
Results: Full-thickness tear was confirmed in 57 cases, partial-thickness tear in 30 cases and degenerative changes without tear in 1. In all 57 cases of full-thickness tear and in 28 out of 30 cases of partial-thickness tear the supraspinatus tendon was involved. The accuracy in the detection of full-thickness tears was 98 and 100% for ultrasonography and magnetic resonance imaging, respectively. The accuracy in the detection of bursal or articular partial-thickness tears was 87 and 90% for ultrasonography and magnetic resonance imaging, respectively.
Conclusions: In experienced hands ultrasonography should be considered as an accurate modality for the initial investigation of rotator cuff, especially supraspinatus, tears.

Keywords: Rotator cuff/ultrasonography; Shoulder joint/ultrasonography; Rotator cuff/surgery; Magnetic resonance imaging; Arthroscopy

1. Introduction

Tears of the rotator cuff are a common cause of shoulder pain and disability. Early diagnosis allows proper surgical treatment planning that can prevent functional impairment [1–4]. Sonographic evaluation of the rotator cuff was initially attempted over two decades ago, not in a popular manner though among radiologists [5]. Early reports did not show favorable results of ultrasonography (US) [6]. Magnetic resonance (MR) imaging became rapidly the favored technique of preoperative shoulder joint evaluation and succeeded in the detection of partial- and full-thickness rotator cuff tears with high sensitivity and accuracy [7–11]. Thus, MR imaging has been considered the imaging modality of choice for evaluating the rotator cuff tears despite its relatively high cost and occasional limited availability.

The technological evolution of high-resolution ultrasound scanners during the last decade allowed substantial improvement in the quality of images and renewed the interest related to US evaluation of the rotator cuff [12]. US has been reported to be reliable in detecting full-thickness rotator cuff tears, compared with surgical findings and/or MR imaging, but detection of partial-thickness tears has been controversial [2,13–15].

The purpose of the present study was to compare the diagnostic efficacy of US and MR imaging in the detection of full- and partial-thickness rotator cuff tears in symptomatic patients

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using updated equipment, with arthroscopy or open surgery used as the reference standard.

2. Materials and methods

Ninety-six consecutive patients with clinical findings of impingement and suspected rotator cuff tear referred for US and MR imaging of the shoulder, were included in the study. Patients with claustrophobia, metal devices in the field of view, previous surgery, previous fracture or known inflammatory systemic arthropathy, were excluded from the study. The patients had pain at rest and during motion and a positive pain-provoking test. Two of them had weakness of the rotator cuff muscles. Eighty-eight of the ninety-six patients (47 men and 41 women, age range 35–72, mean age 57 years) underwent arthroscopy (51) or open cuff repair (37) and they formed the study group. Eight of the ninety-six patients showed clinical improvement while scheduled for surgery and refused any interventional treatment.

Eleven of the eighty-eight patients had a history of acute traumatic event and another eight were involved in sports pursuits with overhead throwing (two in a competitive level and six in a recreational level). In the remaining sixty-nine patients the predominant factors responsible for the rotator cuff lesions were considered to be chronic.

An attempt was made to simulate everyday clinical practice by not directing patients to specific treatment or physician. As a result, four experienced shoulder surgeons were involved, two of them performing mainly arthroscopy and two mainly open surgery. Informed consent was obtained from all patients.

3. US

One examiner with 2 years of experience on musculoskeletal US performed all studies, using a high-resolution linear-array transducer with variable high frequency (8–13 MHz) (Siemens Antares Sonoline System 5.0 Release 2001, syngo system, Germany). The sonographic evaluation of the rotator cuff was performed according to a standard protocol [16]. The depth of the ultrasound beam was adjusted to accommodate for differences in soft-tissue mass among the patients and ranged from 3 to 5 cm. The ultrasound examinations were performed with both the patient and the examiner seated on backless stools facing each other. Ultrasound gel was liberally applied to the shoulder. The patient positioned the arm at the side with the elbow bent to 90°. By positioning the transducer around the curvature of the humeral head in the oblique transverse plane, the biceps was viewed in its osseous groove. Once located, the biceps could be followed longitudinally, parallel to its fibers. Dynamic images of the subscapularis tendon were recorded while the patient actively rotated the shoulder from internal to external rotation. The transducer was oriented transverse to the arm to allow the longitudinal extent of the subscapularis tendon to be seen as the tendon inserts on the lesser tuberosity. The subscapularis tendon was viewed longitudinally, parallel to its primary fiber orientation. On transverse images the individual tendon slips were seen. Dynamic images of the supraspinatus tendon were recorded with the arm in extension and internal rotation, as the patient placed his or her hand on the buttock or lower lumbar spine. The US transducer was placed anterior to the acromioclavicular joint and oriented 45° to demonstrate the longitudinal course of the supraspinatus tendon. The course of the spine of the scapula was a useful reference plane. The transducer was then rotated 90° to demonstrate the tendon in the transverse plane. The infraspinatus was also viewed longitudinally with the arm at the side of the body, and dynamic images were recorded with internal and external rotation of the shoulder. The transducer was positioned just inferior and parallel to the spine of the scapula. The infraspinatus muscle was then followed laterally as it crossed the posterior glenohumeral joint and became the tendon.

The ultrasound criteria for the diagnosis of full-thickness rotator cuff tears were [1,15,17]: (a) non-visualization of the supraspinatus tendon due to retraction under the acromioclavicular joint, (b) localized absence or focal discontinuity of the cuff, with consecutive loss of the normal anterior arc of the subdeltoid bursa, (c) loss of normal supraspinatus substance with widening of the gap between the supraspinatus and biceps tendon and exposure of a bare area of bone and cartilage, (d) a hypoechoic or anechoic cleft extending through the entire substance of the cuff, (e) coexistence of fluid in the subacromial subdeltoid bursa and/or the presence of fluid in the sheath of the long head of biceps tendon. The presence of intra-articular fluid, contained within the biceps tendon sheath, when associated with bursal effusion, has been shown to have a sensitivity of 22%, a specificity of 99% and a positive predictive value of 95% for the detection of full-thickness rotator cuff tears [1]. Partial-thickness tears were diagnosed when there was a focal hypoechoic or anechoic defect in the tendon, involving either the bursal or the articular surface and manifested in two perpendicular planes [17]. Intra-tendinous tears not extending to the bursal or articular surface were not recorded in any patient, since they cannot be confirmed with surgery. The size of the tear was measured in centimeters directly on freeze-frame images with the use of the cursor software function.

4. MR imaging

MR imaging was performed within 3 weeks after US. Two experienced musculoskeletal radiologists with 15 and 6 years of experience, respectively, who were blinded to the US findings, interpreted separately the MR images.

All MR imaging scans were performed with a 1.5 T system (Siemens Magnetom Symphony, Germany) with a shoulder array coil. Slice thickness was 3–4 mm, the field of view was 16-cm and the imaging matrix was 256 mm × 192 mm or higher. The sequences performed in all patients were the following: oblique coronal T1-w (TR = 641, TE = 12) and fat suppressed proton-density TSE (TR = 2790, TE = 14), oblique sagittal T2-w TSE (TR = 4000, TE = 58) and transverse proton-density TSE (TR = 2750, TE = 12). Additional transverse T1-w spin-echo images with fat suppression (TR = 440, TE = 21) and coronal T1 inversion recovery images (TI = 150, TR = 4130, TE = 29) 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 or coronal oblique images that extended through the entire thickness of the tendon or that of a complete disruption of all tendon fibers with retraction [18–20]. A partial-thickness tear was defined as an increase in the signal noted on the T1-w images with brighter signal on the T2-w images, as well as an identification of a focal defect on either the bursal or the articular surface of the involved tendon [2,21]. Abnormal signal intensity fluid within the tendon substance, that did not extend to either the articular or bursal surface, was defined as intra-substance partial-thickness tear and was not recorded.

5. Statistical analysis

Cross tabulations of US and MR imaging interpretations with surgical or arthroscopic findings were performed and diagnostic accuracy along with 95% confidence interval was calculated.

Kappa values were calculated in order to show the agreement between radiologists with regard to MR imaging of rotator cuff tears. McNemar test was performed in order to detect significant differences between the US and MR imaging findings. Additional calculations were performed either by considering together a full- and a partial-thickness tear as tear. The statistical testing was performed on the SPSS version 13.

6. Results

Among the 88 operated patients, 51 underwent arthroscopy and 37 underwent open surgery by four experienced shoulder surgeons. Fifty-seven patients had surgically proven full-thickness rotator cuff tears (35 were found on arthroscopy and 22 on open surgery). Among these patients, 21 had surgically proven massive supraspinatus tears (Fig. 1), 18 had smaller supraspinatus tears and 5 had a full-thickness tear of the supraspinatus, the infraspinatus and the subscapularis. In 8 patients there was a full-thickness tear of the supraspinatus and infraspinatus, in 4 a full-thickness tear of the supraspinatus and a partial-thickness tear of the subscapularis, whereas in 1 patient a full-thickness tear of the supraspinatus and a partial-thickness tear of the infraspinatus was found. There was no statistically significant difference between the two readers in the detection of partial- or full-thickness tears (*K* value: 0.85) with MR imaging. All massive supraspinatus tears were correctly diagnosed with both US and MR imaging. There was one false-negative study with US, since a full-thickness tear of the supraspinatus was incorrectly interpreted as a partial-thickness tear (Table 1). All 13 full-thickness tears of the infraspinatus and 5 full-thickness tears of the subscapularis found on surgery were correctly diagnosed by both imaging modalities.

Table 1
The number of full-thickness tears is shown with both US and MR imaging, correlated with the surgical findings

	TP	TN	FP	FN	Total
US	56	0	0	1	57
MRI	57	0	0	0	57
Surgery	57	0	0	0	57

Table 2
The number of bursal and/or articular partial-thickness tears is shown with both US and MR imaging, correlated with the surgical findings

	TP	TN	FP	FN	Total
US	27	0	1	3	31
MRI	28	0	2	1	31
Surgery	30	1	0	0	31

The results on each method with regard to the 30 partial-thickness tears, either articular (Fig. 2) or bursal (Fig. 3), found on arthroscopy or open surgery (22 and 8, respectively), are shown in Table 2. One patient underwent arthroscopy for a bursal partial-thickness tear of the supraspinatus diagnosed on both US and MR imaging, which proved to be tendinopathy. US showed a sensitivity of 90%, since one patient proved to have extensive tendinopathy of the supraspinatus without a tear. Twenty-eight patients had a partial-thickness tear of the supraspinatus, whereas 2 of them had also a partial-thickness tear of the subscapularis, found on arthroscopy. There were 2 false-negative ultrasound studies, which detected tendinopathy of the supraspinatus in one case and a normal cuff in the second patient, rather than a partial-thickness tear. There was also 1 false-positive US study, which diagnosed a full-thickness tear of the supraspinatus instead of a partial-thickness tear (Fig. 4).

MR imaging correctly depicted 28 (93%) partial-thickness tears. There was 1 false-negative study, which showed no abnormality in a case of a partial-thickness tear of the supraspinatus. This patient was also considered normal in

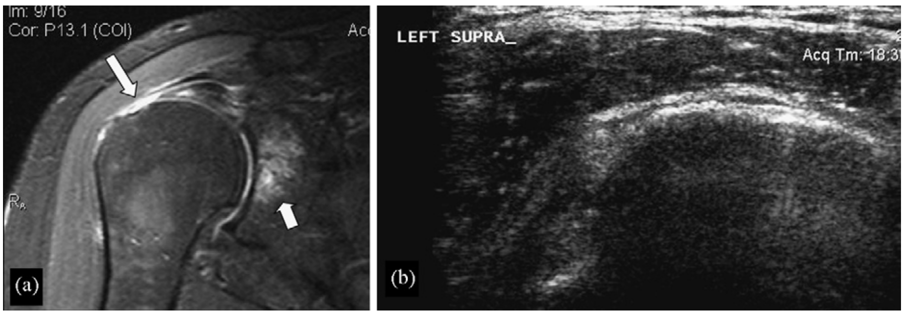

Fig. 1. A 49-year-old woman with a recent fall and a surgically repaired massive full-thickness tear. (a) The coronal STIR MR image shows high signal intensity fluid replacing the insertion of the supraspinatus tendon at the greater tuberosity (arrow). There is also bone bruise in the subarticular bone marrow of the scapula (short arrow). (b) In the longitudinal sonogram, with the transducer placed anterior to the acromioclavicular joint and oriented 45°, the supraspinatus tendon is not visualized. Instead, the deltoid muscle is seen lying on the cortex of the humeral head.

Fig. 2. A 35-year-old athlete with pain during throwing. (a) The coronal STIR MR image demonstrates high signal intensity at the articular side of the supraspinatus tendon in keeping with an articular surface partial-thickness tear (arrow). There is also fluid into the subacromial-subdeltoid bursa. (b) The corresponding sonogram shows an anechoic gap located at the articular surface of the supraspinatus tendon (arrows).

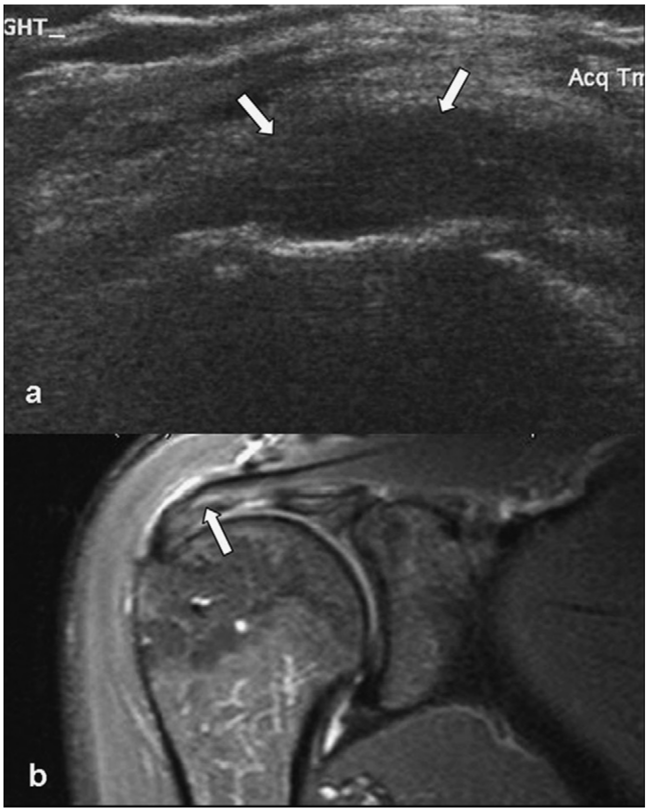

Fig. 4. A 56-year-old male patient with clinically suspected rotator cuff tear. (a) The longitudinal sonogram along the course of the supraspinatus, demonstrates a large hypoechoic area extending through the entire substance of the supraspinatus tendon (arrows). A full-thickness tear was diagnosed. (b) The coronal STIR MR image shows high signal intensity at the bursal surface of the supraspinatus tendon (arrow). The diagnosis of a bursal surface partial-thickness tear was confirmed by arthroscopy.

the previously performed US, but arthroscopy demonstrated an articular surface partial-thickness tear. There were also two false-positive studies that detected full-thickness tear and partial-thickness tear of the supraspinatus, instead of partial-thickness tear and tendinopathy, respectively. MR imaging detected correctly one bursal surface partial-thickness tear of the supraspinatus, which was diagnosed as a full-thickness tear in the US and another partial-thickness tear of the supraspinatus that was misinterpreted as tendinopathy in the US (Table 2). All six partial-thickness tears of the subscapularis and the partial-thickness tear of the infraspinatus found on surgery were correctly depicted by both imaging modalities.

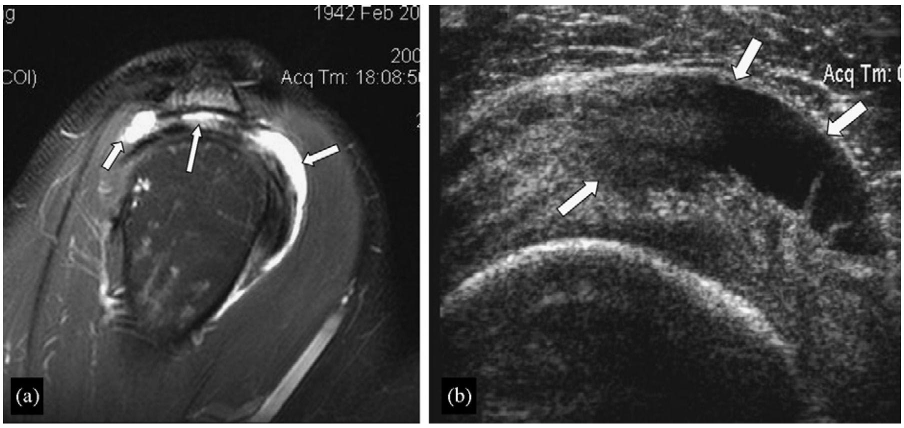

Fig. 3. A 64-year-old male patient with clinically suspected rotator cuff pathology. (a) The fat suppressed T2-w TSE oblique sagittal MR image shows high signal intensity and fraying involving the bursal side of the supraspinatus tendon (long arrow) and high signal intensity fluid inside the bursa itself (arrows), in keeping with a bursal surface partial-thickness tear. (b) The longitudinal sonogram shows to better advantage an anechoic area involving the bursal surface of the supraspinatus tendon (arrows).

The above results yielded an accuracy of 98 and 100% in the detection of full-thickness tears and 87 and 90% in the detection of partial-thickness tears for US and MR imaging, respectively. When data on partial-thickness or no tear were gathered in a single pool, no significant difference was found between US and MR imaging ($p > 0.05$). The overall accuracy for all tears depiction was 94% for US and 97% for MR imaging.

7. Discussion

Rotator cuff lesions have been reported to represent up to 60% of shoulder pathology [20,21]. Arthroscopic studies have suggested that 10% of painful shoulders are attributed to full-thickness tears, whereas the rest consist of partial-thickness tears, bursal thickening, tendinopathy and labral tears [21]. The detection of a full-thickness rotator cuff tear by imaging is regarded as a major parameter in the surgical decision-making [20,21]. Few surgeons proceed to surgery when patients have partial-thickness rotator cuff tears associated with mild to moderate symptoms, as at least 50% of patients get pain relief with physiotherapy [21]. Nevertheless, a study by Fukuda et al. [22] has shown that a partial-thickness rotator cuff tear is an important cause of shoulder disability. When conservative treatment fails, the depiction of rotator cuff pathology is essential for the planning of surgical repair.

Arthrography has long been accepted as the gold standard for the detection of full-thickness rotator cuff tears. Double-contrast shoulder arthrography studies have reported sensitivities ranging from 71 to 100%. However, the procedure is invasive with well-recognized risks [23]. After initial reports on the use of US for the assessment of the rotator cuff and that for MR imaging, both modalities have gradually replaced the role of arthrography in diagnosing rotator cuff tears [5,19]. At present, both US and MR imaging are used for the detection of rotator cuff tears and neither is the definitely accepted method of choice [20]. The advantages of US are related to its wide availability, low cost and the ability for dynamic performance with simultaneous clinical evaluation of the patients. Drawbacks though of US, include false-positive or false-negative results caused by technique, anatomy or disease and operator-dependence which can be limited down to a low level of inter-observer variability if only experienced radiologists are involved [21]. Although excellent correlation exists between US and MR imaging in depicting full-thickness tears, previous studies have reported variable accuracy of US in diagnosing partial-thickness tears [13,14].

The present study was designed to evaluate any kind of rotator cuff tears, with emphasis on partial-thickness ones, with updated US equipment to determine its diagnostic accuracy in the typical clinical setting. Thus, the orthopaedic surgeons were not blinded to the results of the US and MR imaging studies for the benefit of the patients. The intra-substance partial-thickness tears found in either imaging modality were not recorded at all, as there was no way to confirm their presence surgically.

In the present study, 21/57 patients had a massive supraspinatus tear. The sign seen on US images was non-visualization of the tendon and direct contact between the humeral head and the deltoid muscle, due to retraction of the tendon below the acromion. The most frequent sign of non-massive full-thickness tear of the rotator cuff seen on US, was localized absence or focal discontinuity of the cuff, with consecutive loss of the normal anterior arc of the subdeltoid bursa, seen in 9 of our patients. Other US signs of full-thickness tears included widening of the gap between the supraspinatus and the biceps tendon with exposure of a bare area of bone, seen in 4 patients, and a hypoechoic or anechoic cleft extending through the entire substance of the cuff, seen in 2 patients. US incorrectly identified a partial- instead of a full-thickness tear of the supraspinatus in one case. US also misinterpreted one case of a partial-thickness tear of the supraspinatus as tendinopathy and one case with tendinopathy as a partial-thickness tear. A possible explanation for these misinterpretations could be the chronic nature of the partial-thickness tears. Thus, the margins of chronic degeneration were poorly defined and the differential diagnosis from tendinopathy was difficult. The role of dynamic scan in these cases appeared helpful but not always decisive. In total, US exhibited an accuracy of 98% for the full-thickness rotator cuff tears, of 87% for the partial-thickness tears and an overall accuracy of 94%. The corresponding values for MR imaging were 100, 90 and 97%, respectively. The US results are similar to those reported by others with regard to full-thickness tears [3,20]. With regard to partial-thickness tears though, accuracy was better in the present study than that previously reported [13,24]. This might be explained in the context of updated equipment and technique as well as better clarification of the diagnosing criteria. Indeed, more recent studies showed comparable results to ours. Milosavjevic et al. [23] have reported a sensitivity of 80%, a specificity of 94%, a positive predictive value of 86%, a negative predictive value of 91% and an accuracy of 90% for US diagnosis of partial-thickness rotator cuff tears. Furthermore, Iannotti et al. [15] reported that ultrasound correctly diagnosed 88% of full-thickness tears and 70% of partial-thickness tears. Kenn et al. [24] reported a comparative study dedicated to partial-thickness lesions and small complete ruptures and concluded that US and MR imaging demonstrated comparable accuracy.

Causes of failure to detect partial-thickness tears appear to correlate with their acute or chronic nature [25]. A recent, large tear of the cuff with some effusion can be easily visualized whereas a chronic lesion without effusion and heterogeneous US appearance may mimic tendinopathy [26]. Another possible explanation for the discrepancies in the reported studies may be attributed to studies selection bias. Different criteria and different population of patients participate in each study, thus the role of imaging is influenced by a number of factors such as the age of the patient and the mechanism of injury. For instance, in the present study almost all shoulders proved to have positive findings in surgery and the cases of full-thickness tears outnumbered the cases of partial-thickness tears, perhaps because we included young athletic patients with acute trauma. It is important also to emphasize that a tear of the rotator cuff may be an incidental finding in an otherwise minimally impaired shoulder of an elderly patient [27].

A limitation of the present study is that about 10% of the patients who were studied with both modalities, did not undergo surgical confirmation and thus determination of a false-negative rate and specificity was not possible. Another possible limitation of the study is the fact that two operative approaches, open and arthroscopy, were applied according to the preferences and the experience of four shoulder surgeons. However, this methodology simulates the every day clinical practice where no single technique, modality or surgical planning exists. Finally, the study has a disproportionate number of massive tears and partial-thickness tears, where the controversy of US compared to MR imaging on the diagnostic accuracy still exists in the literature. Finally, although limited in number as compared to supraspinatus, either tear of the infraspinatus or subscapularis tendons was correctly diagnosed in all cases and this underlines the good performance of US in studying them.

8. Conclusion

The present study supports that US and MR imaging have comparable and high accuracy for detecting full- and partial-thickness tears. US evaluation of the rotator cuff is a dynamic, real-time examination that is well tolerated from patients, is less expensive and less time-consuming than MR imaging and may be repeated if necessary. Therefore, US should be considered as the imaging modality of choice for the initial detection of full- and partial-thickness rotator cuff tears, in patients with history and clinical findings not suggesting any other intra-articular disorder.

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