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Diagnostic accuracy of shoulder ultrasound performed by a single operator

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SUMMARY

Both diagnostic ultrasound and magnetic resonance imaging (MRI) are used for investigation of the presence and severity of rotator cuff lesions. There is no consensus as to which is the more accurate and cost-effective study. We sought to examine the sensitivity of ultrasound, when used by one experienced radiologist with modern equipment. We compared the ultrasound and surgical results obtained from 68 patients. Ultrasound showed a sensitivity of 89% and specificity of 100% (Positive Predictive Value 100%) for full-thickness tears, and a sensitivity of 79% and specificity of 94% (Positive Predictive Value 87%) for partial-thickness tears. We found that shoulder ultrasound, in the hands of an experienced radiologist with the use of modern high-resolution equipment, is highly sensitive in differentiating complete tears and partial-thickness tears. Our results are similar to the best published results for MRI and given that ultrasound is significantly cheaper and more available, ultrasound by an experienced radiologist should be considered as a primary diagnostic tool for imaging the rotator cuff.

Key words: *cuff tear; musculoskeletal imaging; rotator cuff, shoulder; ultrasound*.

INTRODUCTION

Rotator cuff pathology is the most common cause of pain and dysfunction in the shoulder.[1,2] Rotator cuff tear is a condition in which there is a range of severity, varying from small partial-thickness to large retracted full-thickness tears. In formulating the most appropriate treatment for any given individual it is important to ascertain the nature and extent of the rotator cuff disorder.

Although clinical examination is indispensable in the assessment of the patient it cannot reliably determine the full extent of the rotator cuff pathology. Clinicians require some form of investigative tool to confirm the clinical diagnosis, but also to determine the severity of the pathology. Several methods have been used in assessing rotator cuff pathology, including plain and CT arthrograms, shoulder ultrasound and more recently MRI. The latter two methods have the advantage of being non-invasive and do not involve exposing the patient to ionizing radiation.

Shoulder ultrasound has the advantage of being relatively inexpensive and widely available and permits dynamic imaging. However, several papers have reported wide variability in the ability of ultrasound to accurately differentiate between partial-thickness and full-thickness rotator cuff tears, particularly between observers.[1,3–6] In the published work there has been reports of diagnostic sensitivities and specificities in excess of 90%[2,7] whereas other publications report sensitivities of less than 50% for the detection of partial-thickness tears.[1,3–5] The variability in previous papers has been attributed to poor operator technique, lack of expertise, poor ultrasound criteria, low patient numbers and multiple observers.[1,3–6] The inconsistency of accuracy in the published work has discouraged many in the use of shoulder ultrasound as a diagnostic tool in rotator cuff pathology.

Magnetic resonance imaging has been reported to have consistently high sensitivity (80–97%) and specificity (93–94%) for the diagnosis of rotator cuff pathology.[8] MRI provides excellent

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soft-tissue detail and has multiplanar capability, but interpretation of intra-substance lesions remains problematic.[2,5,9–11] Several publications have reported poor results in diagnosis of partial-thickness tears and the results have also been shown to rely on operator skill and expertise.[1,9,11] MRI has several significant disadvantages in that it is not as readily available as is ultrasound in the community, it is substantially more expensive, it is problematic for patients with claustrophobia and is contraindicated in several patients with inserted medical devices, all of which restrict its availability.

Many previous published reports referring to shoulder ultrasound and rotator cuff pathology were carried out several years ago on equipment that has since been superseded. The advent of high-resolution (8–12 mHz) linear transducers have resulted in improved spatial resolution. With the increase in published work on normal and pathological findings with ultrasound, a stricter diagnostic criteria of partial-thickness and full-thickness rotator cuff tears has evolved.[2,3,7]

The aim of this study is to show that shoulder ultrasound carried out by a single trained, experienced radiologist using modern high-resolution equipment and diagnostic criteria is both sensitive and specific in the diagnosis of rotator cuff injury, including partial-thickness tears.

MATERIALS AND METHODS

From July 1999 until August 2002, all patients who had an ultrasound study by one radiologist and subsequent operation by a single orthopaedic surgeon were selected for the study. Indications for surgery were based on failure of conservative treatment in the presence of presumed rotator cuff pathology with supportive radiologic and sonographic imaging. The surgeon was not blinded to these findings as the information formed part of the preoperative assessment.

All diagnostic studies were carried out by a single, Fellowship-trained musculoskeletal radiologist with 7 years of clinical experience. Imaging of all tendons was carried out in two perpendicular planes, using an ATL HDI 5000 scanner (Bothwell, Washington, DC, USA) and a linear 5–12 MHz probe with compound imaging.[2,3]

Ultrasound – diagnostic criteria: bursitis was diagnosed if any fluid was seen within the subacromial subdeltoid bursa or the bursa was seen as parallel echogenic interfaces with a readily discernable hypoechoic space centrally. The criteria used for the diagnosis of full-thickness tears was complete absence of the tendon, an anechoic or hypoechoic defect of non-fibrillar tissue extending from the articular to the bursal surface or a contour defect of the subdeltoid fat plane extending medial to the junction of the humeral head and greater tuberosity. The criteria used for the diagnosis for partial-thickness tear was a hypoechoic, mixed hypoechoic or echogenic defect incompletely traversing the tendon, but extending to the articular or bursal surface or a contour defect of the subdeltoid fat plane not extending medial to the junction of the humeral head and greater tuberosity.[2,3]

The sonographic and surgical findings were documented with regard to the presence or absence of bursitis, partial-thickness or full-thickness rotator cuff tears. One patient was excluded from the study as the sonographic study was more than 12 months before the date of the surgical procedure.

RESULTS

Sixty-eight patients were included in the study. All had preoperative ultrasound carried out by one radiologist and subsequent surgery within 12 months of the study, by one orthopaedic surgeon. Age range of the patients was 33–81 (mean 56 years). There were 46 men and 22 women. Time from ultrasound until surgery ranged from 0 to 12 months (mean 2.2 months).

At surgery 28 of 68 patients were found to have a full-thickness tear, 14 had a partial-thickness tear and 26 had bursitis with no evidence of a rotator cuff tear.

Shoulder ultrasound correctly identified 25 of the 28 full-thickness tears (Table 1). There were no false positives. Ultrasound failed to identify three full-thickness tears, one of which had been reported as having florid bursitis where the examiner stated 'the bursal thickening was as thick as the underlying tendon and difficult to visualise' (Fig. 1). The other two patients were reported as having high-grade partial-thickness tears with associated moderate tendinopathy (Fig. 2).

Eleven of the 13 partial-thickness tears reported were correct (Table 2). Two reported as high-grade partial tears were full-thickness tears. Three small partial-thickness tears were not seen at sonography. Each of these three cases had been reported as 'supraspinatus tendinopathy and associated bursal thickening'.

In this study of 68 patients, ultrasound showed a sensitivity of 89%, specificity of 100% and Positive Predictive Value (PPV) 100% for full-thickness tears and a sensitivity of 79%, specificity of 94% and PPV 87% for partial-thickness tears.

DISCUSSION

Currently, many clinicians prefer to investigate patients with presumed rotator cuff pathology with MRI rather than ultrasound. Previous studies on shoulder ultrasound have reported high sensitivity and specificity for full-thickness rotator cuff

Table 1. Ultrasound versus surgical results for full-thickness rotator cuff tears

Ultrasound	Surgery for full-thickness tear		
	Positive	Negative	Total
Positive	25	0	25
Negative	3	37	40
Total	28	37	65

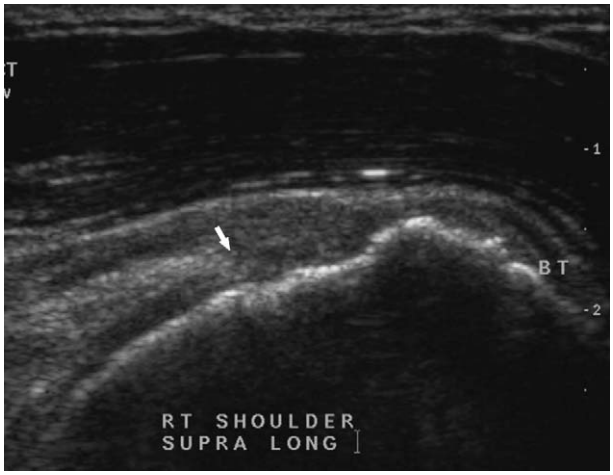

Fig. 1. Longitudinal ultrasound image of the supraspinatus tendon. There is a full-thickness tear, the tendon (arrow) retracted medial to the junction of the humeral head and greater tuberosity. Hypoechoic bursal thickening fills the defect created by the tendon retraction, but can be so thick as to mimic tendon tissue.

tears, but much reduced figures for partial-thickness tears.[2–4,7] There have been many reports stating that accuracy of ultrasound is heavily dependent on the experience of the operator and previous studies used lower resolution equipment and less rigid diagnostic criteria.[1,3–6]

This study differs from those previous studies in that all patients were examined by a single, Fellowship-trained, experienced musculoskeletal radiologist, using modern, high-resolution

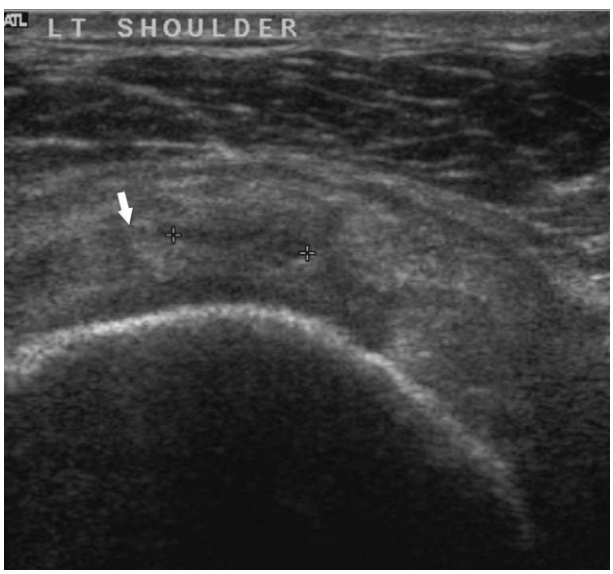

Fig. 2. Transverse ultrasound image just posterior to the rotator cuff interval. The calipers were placed defining a hypoechoic region that was thought to be a partial-thickness tear. At surgery the tear was full thickness, and in retrospect the echogenic material filling the defect is consistent with thickened bursa with the more anterior border of the tendon evident as a slightly more echogenic structure (arrow).

Table 2. Ultrasound versus surgical results for partial-thickness rotator cuff tears

Ultrasound	Surgery for partial-thickness tear		
	Positive	Negative	Total
Positive	11	2	13
Negative	3	51	54
Total	14	53	67

equipment. The results were correlated with the findings at surgery only, which used arthroscopy such that both the joint and bursal side of the rotator cuff could be adequately seen.

The results of this study shows that shoulder ultrasound in trained hands is highly sensitive (89%) and specific (100%) for full-thickness rotator cuff tears and for partial-thickness tears (79 and 94%, respectively).

Two of the three misdiagnosed full-thickness rotator cuff tears had been reported as high-grade partial-thickness tears. It is thought that this indicates difficulty at sonography of distinguishing the junction of the articular surface of the humeral head and greater tuberosity in a large partial-thickness tear and therefore the most medial extent of the supraspinatus tendon insertion.[2,3,7] There is also difficulty in distinguishing between thickened subacromial bursa and residual tendinopathic tendon fibres.[1] One full-thickness rotator cuff tear was misdiagnosed as florid-thickened bursitis. False negatives in MRI are often because of similar problems with the rotator cuff defect filled with bursa or debris rather than fluid.[1]

Of the partial-thickness rotator cuff tears diagnosed at arthroscopy, three were reported as supraspinatus tendinopathies with associated subacromial bursal thickening. At surgery the findings of these three patients was of small partial-thickness tears that, in the opinion of the surgeon, did not necessitate formal repair. All three of these patients had subacromial stenosis and underwent an arthroscopic acromioplasty and a subsequent rehabilitation programme.

Shoulder ultrasound in this study assisted the clinicians in distinguishing those individuals with high-grade partial-thickness and full-thickness rotator cuff tears who required surgical rotator cuff repair from those individuals with no or low-grade partial-thickness cuff tear who would be better off initially undergoing a conservative rehabilitation programme.[7]

The findings of this study are in line with many others in reporting a high level of sensitivity and specificity for full-thickness rotator cuff tears.[2–4,6,7,12] These results are equivalent to those obtained by MRI.[8,10] The level of sensitivity (79%) and specificity (94%) in the diagnosis of partial-thickness rotator cuff tears are similar to those of Van Holsbeeck *et al.* (sensitivity 93%) and Wiener and Seitz (sensitivity 94%),[2,7] but are in contrast to the findings of Teefey *et al.* (sensitivity 67%) and Martin-Hervas *et al.* (sensitivity 12.5–45.5%).[1,3]

Goldberg *et al.* compared ultrasound with arthrographic and surgical findings in 336 cases.[13] The ultrasounds were carried out by 109 different radiologists using a 7.5 MHz linear array transducer during May 1996 and December 1997. They reported a poor accuracy rate of 0.38 for ultrasound of rotator cuff tears. The authors state they were unaware of the experience of the radiologists involved and the purpose of this study was not to determine the potential reliability of sonography in a specialized unit, but to assess its role in the general Australian community. Also, only 67% of patients underwent surgery and thus arthrogram was otherwise considered as the definitive diagnostic method.[13]

Publications using MRI in the diagnosis of partial-thickness rotator cuff tears have suggested improved accuracy.[8,10] However, many of these studies were compared to arthrography or the findings at open surgery, rather than arthroscopy.[11,14] Many studies have indicated that like ultrasound, the results of MRI are dependent on the skill and experience of the operator.[4,9,11] It was also noted that there were difficulties differentiating tendinopathy from partial-thickness rotator cuff tears.[2,9–11]

This study has shown that shoulder ultrasound in the hands of a well-trained, experienced musculoskeletal radiologist using current, high-resolution equipment can be a reliable and accurate investigative tool in the diagnosis of rotator cuff tears. This study has shown a higher sensitivity and specificity for partial-thickness rotator cuff tears than previous reports, the results of which are similar to the MRI findings of published reports.[8,10] It has the noted advantage of being considerably cheaper and more available than MRI.

The limitations of this study are a time lag in some patients between investigation and surgery during which time the rotator cuff pathology may have progressed. Arthroscopic evaluation of rotator cuff pathology has the limitation of being unable to assess the presence or otherwise of intra-substance rotator cuff tears. In addition, patients who had ultrasound but did not proceed to surgery cannot be reported here and as such the negative predictive value of sonography cannot be stated.

We believe that this study differs from many of those that precede it, in that this study employed a single, Fellowship-trained experienced musculoskeletal radiologist using modern sonographic equipment. In this setting ultrasound can provide high accuracy for the presence of full-thickness and partial-thickness rotator cuff tears. Given the relative cost of ultrasound and MRI we believe ultrasound should be considered as a primary imaging tool for investigation of the presence and severity of rotator cuff lesions.

REFERENCES

1. Martin-Hervas C, Romero J, Navas-Acien A, Reboiras JJ, Munuera L. Ultrasonographic and magnetic resonance images of rotator cuff lesions compared with arthroscopy or open surgery findings. *J Shoulder Elbow Surg* 2001; **10**: 410–15.
2. Van Holsbeeck MT, Kolowich PA, Eyler WR *et al.* US depiction of partial-thickness tear of the rotator cuff. *Radiology* 1995; **197**: 443–6.
3. Teefey SA, Hasan SA, Middleton WD, Patel M, Wright RW, Yamaguchi K. Ultrasonography of the rotator cuff. *J Bone Joint Surg Am* 2000; **82**: 498–504.
4. Read JW, Perko M. Shoulder ultrasound: diagnostic accuracy for impingement syndrome, rotator cuff tear, and biceps tendon pathology. *J Shoulder Elbow Surg* 1998; **7**: 264–71.
5. Sonnabend DH, Hughes JS, Giuffre BM, Farrell R. The clinical role of shoulder ultrasound. *Aust N Z J Surg* 1997; **67**: 630–33.
6. Hodler J, Fretz CJ, Terrier F, Gerber C. Rotator cuff tears: correlation of sonographic and surgical findings. *Radiology* 1988; **169**: 791–4.
7. Wiener SN, Seitz WH. Sonography of the shoulder in patients with tears of the rotator cuff: accuracy and value of selecting surgical options. *AJR* 1993; **160**: 103–7.
8. Needell SD, Zlatkin MB. Comparison of fat-saturation fast spin echo versus conventional spin-echo MRI in the detection of rotator cuff pathology. *J Magn Reson Imaging* 1997; **7**: 674–7.
9. Balich SM, Sheley RC, Brown TR, Sauser DD, Quinn SF. MR imaging of the rotator cuff tendon: interobserver agreement and analysis of interpretive errors. *Radiology* 1997; **204**: 191–4.
10. Singson RD, Hoang T, Dan S, Friedman M. MR evaluation of rotator cuff pathology using T2-weighted fast spin-echo technique with and without fat suppression. *AJR* 1996; **166**: 1061–5.
11. Wnorowski DC, Levinsohn EM, Chamberlain BC, McAndrew DL. Magnetic resonance imaging assessment of the rotator cuff: is it really accurate? *Arthroscopy* 1997; **13**: 710–19.
12. Mack LA, Gannon MK, Kilcoyne RF, Matsen RA 3rd. Sonographic evaluation of the rotator cuff: accuracy in patients without prior surgery. *Clin Orthop* 1988; **234**: 21–7.
13. Goldberg JA, Bruce WJ, Walsh W, Sonnabend DH. Role of community diagnostic ultrasound examination in the diagnosis of full-thickness rotator cuff tears. *ANZ J Surg* 2003; **73**: 797–9.
14. Zlatkin MB, Hoffman C, Shellock FG. Assessment of the rotator cuff and glenoid labrum using an extremity MR system: MR results compared to surgical findings from a multi-center study. *J Magn Reson Imaging* 2004; **19**: 623–31.