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Determination of rotator cuff tear reparability: an ultrasound-based investigation

Jacob L. Cox, MD[a,b], Mitzi S. Laughlin, PhD[a,b,*], Hussein A. Elkousy, MD[a,b,c], Hayley M. Baker, PA-C[d], Brian L. Badman, MD[e], Dean W. Ziegler, MD[f], Don A. Buford, MD[g], Kevin K. Kruse, MD[d]

[a]*Texas Education and Research Foundation for Shoulder and Elbow Surgery, Inc. (TERFSES), Houston, TX, USA*
[b]*Fondren Orthopedic Research Institute (FORI), Houston, TX, USA*
[c]*Fondren Orthopedic Group, Texas Orthopedic Hospital, Houston, TX, USA*
[d]*Texas Orthopaedic Associates, Dallas, TX, USA*
[e]*Optum Bone and Spine, Indianapolis, IN, USA*
[f]*Blount Orthopaedic Associates, Milwaukee, WI, USA*
[g]*The Texas Orthobiologic Institute, Dallas, TX, USA*

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Background: The use of ultrasound as a viable diagnostic tool for routine office visit evaluation of rotator cuff integrity is slowly gaining acceptance in orthopedic practice. However, the reliability of accurately assessing rotator cuff tear reparability by ultrasound has limited evidence in the literature. The purpose of this study was to compare preoperative assessment of cuff tear reparability via ultrasound with the arthroscopic determination of reparability at the time of surgery.

Methods: We prospectively collected preoperative ultrasound and arthroscopic imaging data on 145 patients (80 or 55% men and average age of 60.7 years) who underwent arthroscopic posterior superior rotator cuff repair. Three independent experienced orthopedic surgeons retrospectively reviewed all ultrasound studies and arthroscopic imaging and determined if the posterior superior rotator cuff tendon edge was able to be viewed via ultrasound and determined with the arthroscopic images if the tear was reparable.

Results: On review of the ultrasound and arthroscopic data, if the edge of the rotator cuff tendon was able to be viewed on the coronal ultrasound image, it was most likely reparable with a positive predictive value of 97.6% and a positive likelihood ratio of 5.8. Sensitivity was 84.4%, and specificity was 76.9%. The negative predictive value was 37.5%, and the negative likelihood ratio was 0.17. The interobserver reliability was 0.63, and the observers were unanimous in determining the tendon edge was able to be visualized in 99 of 145 cases (68%).

Conclusion: Preoperative ultrasound evaluation of the shoulder for posterior superior rotator cuff tears is a useful tool for assessing rotator cuff integrity and may help predict intraoperative reparability of the tendon. This study demonstrates that if the cuff tear edge is able to be visualized, there is a high probability of successful arthroscopic restoration of the tendon to its native attachment. Conversely, if the tear edge is unable to be visualized, there is a moderate chance of the tear being irreparable. These results help expand the knowledge base of the usefulness of in-office ultrasound performed by the surgeon in predicting the results of surgical intervention for rotator cuff tears.

Office-based ultrasound has emerged in recent years as an efficient and cost-effective[9] means to evaluate shoulder pathology and, more specifically, integrity of the rotator cuff. After first being demonstrated in 1977 by Mayer, the use of ultrasound in the outpatient setting has become more accepted and even risen to challenge the need of ordering advanced imaging modalities to evaluate the rotator cuff in some patients.[6]

A significant advantage exists that in a single clinical encounter, a patient with symptoms of a rotator cuff tear can be evaluated, images can be obtained, and an efficient and effective treatment plan can then be formulated. This is in comparison with the use of advanced imaging where often the patient would be required to leave the office setting, obtain a magnetic resonance imaging (MRI)

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*Corresponding author: Mitzi S. Laughlin, PhD, 7401 Main St., Houston, TX 77030, USA

E-mail address: Mitzi.Laughlin@gmail.com (M.S. Laughlin).

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study in another imaging center, and then reschedule for repeat evaluation and discussion of the imaging results, leading to a significant delay in treatment time and a potentially excessive use of medical system resources.[1]

Cost is also a concern when discussing these imaging modalities. Initially, ultrasound equipment was costly, massive, and cumbersome. However, as the technology has matured over the last four decades, the individual costs of the units, although still expensive, have decreased, whereas the capabilities have been expanded. Initially, some devices weighed greater than 45 kg (100 lbs) and ranged from $100,000 to $200,000[4] in price, but have now become the size of a laptop or smaller and are more affordable by clinical practices. This is in stark contrast to the large capital expenses required to purchase, staff, and use MRI imaging suites at hospital-based or independent imaging centers that can often swell into the millions of dollars. In addition, the individual cost of an MRI study is significant.[9]

The ease of use, lack of risk, and low cost are all significant strengths of office-based dynamic ultrasound.[2,4] However, in a survey of American Shoulder and Elbow Surgeons, many surgeons were not using ultrasound because of a lack of confidence in the ability to quantify fatty infiltration, muscle atrophy, and ultimately determining reparability of the tear.[6] To this end, the purpose of this study is to investigate the use of office-based ultrasound in determining the reparability of a symptomatic rotator cuff tear and compare these findings with the ultimate intraoperative findings at the time of shoulder arthroscopy.

Materials and methods

Patient selection

Institutional review board approval (WIRB protocol #20180476) was obtained before enrolling patients into this multicentered, prospective study. Potential subjects were all adults (≥18 years) and presented at one of five fellowship-trained orthopedic surgeon's practices with a history and examination suggestive of rotator cuff pathology between 2018 and 2020. After completing informed consent, a consecutive cohort of 175 patients underwent a preoperative in-office diagnostic ultrasound of the rotator cuff by the treating physician. Each subject ultimately underwent arthroscopic rotator cuff repair for a symptomatic rotator cuff tear. Other pathologies may have been addressed at the time of surgery, including long head biceps pathology, but that was not assessed with this study. Intraoperative photographic and video graphic documentation of the rotator cuff tear was obtained for study and later analysis. Of the 175 consented patients, 145 patients had complete preoperative ultrasound images and intraoperative images and video available for inclusion in this study.

Ultrasound image capture

The ultrasound examination was standardized among all the participating surgeons and included single plane images. They are eleven images of the long- and short-axis views of all four rotator cuff muscles (teres minor, subscapularis, supraspinatus, and infraspinatus) and the long head of the biceps tendon as well as documentation of the bicipital groove. In addition, a 10-15 second video recording of the long axis of the supraspinatus and infraspinatus was performed.

Arthroscopic image capture

Images and video were obtained in a standardized fashion from each routine diagnostic intra-articular and extra-articular shoulder arthroscopy before proceeding with any significant releases, biceps tenotomy or tenodesis, or rotator cuff débridement and repair. Initial intra-articular views from a 30-degree arthroscope included evaluating the subscapularis, bicipital pulley, biceps tendon, and articular-sided evaluation of the supraspinatus and infraspinatus tendons. Extra-articular views, again with a 30-degree arthroscope, were used to provide en face images of the rotator cuff tear, video of the dynamic manipulation and attempted reapproximation of the tendon tear edge back to the anatomic footprint on the tuberosity, and en face view of the final repair construct.

Image review and evaluation

The ultrasound and arthroscopic images were anonymized and provided to each of three experienced orthopedic surgeon reviewers for evaluation, who were blinded to the identity of the patients as well as details of the surgical files. The reviewers graded each ultrasound study on whether or not the lateral edge of the torn supraspinatus and infraspinatus tendons were clearly visualized lateral to the acromion (Fig. 1, *A*). The specific tear pattern of each tendon was documented. Arthroscopic images and video were subsequently evaluated to determine if the visualized intraoperative rotator cuff tear represented a reparable tear or an irreparable tear (Fig. 1, *B* and *C*). Determination of a reparable tear was made from the prerepair images and videos (extra-articular view and dynamic manipulation) as well as clinical judgment on the part of the treating surgeon. The arthroscopic images were taken before attempting surgical repair of the rotator cuff tendons. Postrepair images were not used to determine reparability because on some occasions the surgeon may have used extraordinary technique to achieve a repair, but the repair is under such tension that healing is not predictable.

Statistics

Characteristics of the patient cohort such as age, gender, and body mass index were evaluated with descriptive statistics and reported as means with standard deviations or counts with percentages, as appropriate. Preoperative ultrasound and intraoperative images were assessed by 3 independent reviewers, and intraclass correlations were calculated to assess the interobserver reliability of interpretation of the images. To evaluate our main hypothesis, the positive predictive value (PPV) was calculated, and this determined the rate of rotator cuff reparability when the tendon was able to be visualized on ultrasound. In addition, likelihood ratios, sensitivity, and specificity for ultrasound visualization and reparability of the rotator cuff were used to evaluate the overall suitability of ultrasound in determining rotator cuff reparability.

Results

The 145 patients in this study cohort included 80 (55%) men and 65 (45%) women (Table I). At presentation to the clinic, the mean age was 60.7 ± 10.3 years and the average body mass index was 29.6 (±5.5; range 19.5 to 51.5). The results of the imaging review were collated from the 3 reviewers (Table II) and revealed that visualization of the lateral edge of the torn tendon lateral to the acromion was unanimous in 99 of 145 cases (68%), whereas the interobserver reliability was considered moderate at 0.63. On average, the reviewers found that 116 of the patients had tears in which the lateral edge of the tendon could be visualized lateral to the acromion with ultrasound. The torn tendon was considered reparable in 124 cases as per the intraoperative images and videos taken before attempting surgical repair. This corresponds to an average PPV of 97.6%. The average positive likelihood ratio

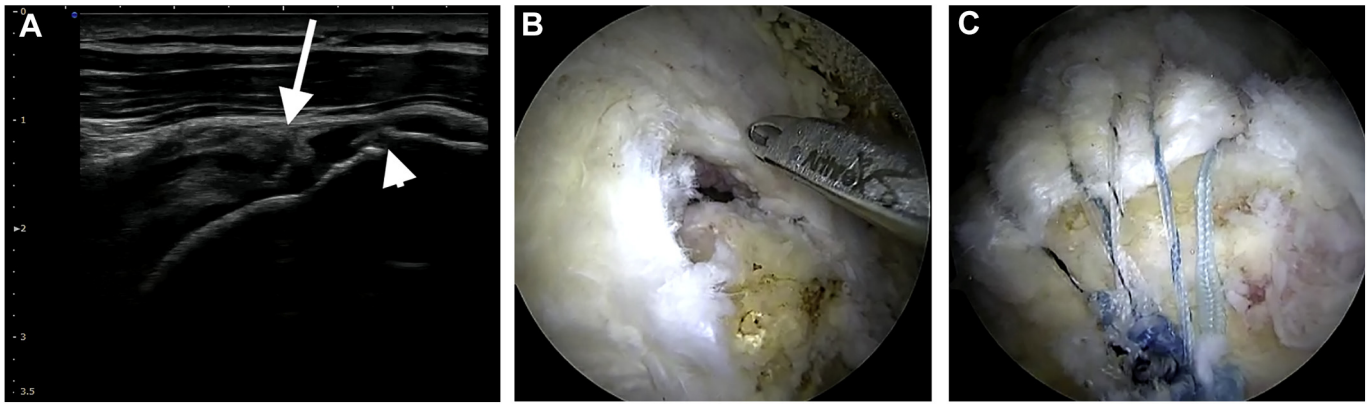

Figure 1 (**A**) The coronal long-axis ultrasound image demonstrating torn supraspinatus tendon stump (arrow) retracted from greater tuberosity insertion (arrowhead). (**B**) The intraoperative arthroscopic image from a posterolateral viewing portal demonstrating a full-thickness tear of the supraspinatus. (**C**) The intraoperative arthroscopic image from a lateral viewing portal demonstrating repair of the rotator cuff tear with a lateral suture anchor.

Table I
Baseline characteristics of our patient cohort (n = 145).

Characteristic	Mean ± SD	Range
Age	60.7 ± 10.3	31-90
Sex	80 (55.2%) male	NA
BMI	29.6 ± 5.5	19.5-51.5

BMI, body mass index; *SD*, standard deviation.

Table II
Reviewer results after analysis of the preoperative ultrasound studies and intraoperative findings.

Statistic	Reviewer 1	Reviewer 2	Reviewer 3	Average
Sensitivity	95.6%	75.8%	81.8%	84.4%
Specificity	53.9%	92.3%	84.6%	76.9%
PPV	95.6%	99.0%	98.2%	97.6%
NPV	53.9%	27.3%	31.4%	37.5%
LR+	2.1	9.9	5.3	5.8
LR-	.05	.26	.21	.17
Able to be visualized	136	101	110	115.7
Reparable	139	98	134	123.6

PPV, positive predictive value; *NPV*, negative predictive value; *LR+*, positive likelihood ratio; *LR-*, negative likelihood ratio.
Sensitivity represents the probability of visualizing the tendon when the rotator cuff is deemed reparable.

was 5.8; conversely, the average negative predictive value was 37.5%.

Furthermore, if the lateral edge of the torn tendon was lateral to the acromion and visible on ultrasound, it was likely to be deemed repairable with a sensitivity average of 84.4%. Likewise, the specificity average of 76.9% represented that if the tendon was not able to be visualized lateral of the acromion on ultrasound, it was likely to be found to be irreparable during surgery.

Discussion

Ultrasound evaluation of rotator cuff pathology in the outpatient setting has gained widespread acceptance outside of the United States. However, surgeons in the United States have been hesitant to adopt it for a variety of reasons, including clinic efficiency, limited return on investment in the office, and questions on accuracy or utility of the findings. Initially, the debate of effectiveness of office-based ultrasound use centered on the modality's ability to detect rotator cuff tears at all. A recent Cochrane review[7] found no evidence in the large review to suggest differences existed in the detection rate between MRI and ultrasound for the detection of full-thickness tears. Although identifying a tear in the outpatient setting is useful, determining its reparability is also of utmost importance.

This study demonstrates that ultrasound can be useful in the outpatient setting by orthopedic surgeons in the United States. In this study, we found 116 of 145 patients had torn tendons that could be visualized with ultrasound, whereas the torn tendon in 124 patients was considered reparable as per the intraoperative images and videos (Fig. 1) taken before attempting surgical repair. This corresponds to an average PPV of 97.6%, signifying a high probability that the rotator cuff tendon tear is reparable if it is visualized on ultrasound. The average positive likelihood ratio of 5.8 demonstrates that a patient with a visualized torn tendon edge on ultrasound is 5.8 times more likely to have a reparable tendon. Conversely, the average negative predictive value of 37.5% illustrates the probability of not being able to repair the tendon if it is not able to be visualized on preoperative ultrasound images and correlates with an average negative likelihood ratio of 0.17. Thus, ultrasound imaging may be sufficient if the tendon is visible, but complementary imaging may be necessary if the tendon is not visible.

It has been argued that MRI studies are sought at a precipitous rate in the care of patients with shoulder pain in the primary care setting.[3,8] This investigation illustrates the usefulness of ultrasound in the outpatient setting as a more cost effective screening tool in a subset of patients. This subset may be defined by several parameters of history and examination that can be assessed by an orthopedic specialist as was performed in this study. MRI use can be reserved for cases when the differential diagnosis is not clear, intra-articular structures need more detailed assessment, or more detail is needed on the status of rotator cuff muscles. Consistent use of ultrasound could lead to a more timely diagnosis of patients with a symptomatic rotator cuff tear and predict their surgical success at an earlier time point. It can also save money for our health care system by reducing the need for MRI as a routine screening tool for all patients with shoulder pain in a primary care setting.

Yeranosian et al evaluated the PearlDiver database (PearlDiver Technologies Inc, Colorado Springs, CO, USA) to evaluate costs of care for rotator cuff tears before surgical repair for 92,688 patients between 2004 and 2009.[9] The total cost of care was $161,993,100 in the 90 days before surgical repair which equates to a per patient average of $1748. Of this, 65% ($1136 per patient) was allocated for imaging, with MRI alone averaging $986 per patient. Patients averaged 2.3 preoperative physician visits before surgery which

accounted for 18% of total costs, and physical therapy accounted for 8.5%.[9] This study only references surgical patients. The cost savings would be realized on those patients who have routine MRIs ordered by a primary care physician for shoulder pain. MRI could then be reserved for more complicated operative planning or in cases of diagnostic uncertainty.[5]

Recent review of the literature of ultrasound use by orthopedic surgeons in the outpatient setting[6] with an accompanying survey of practicing surgeons in the American Shoulder and Elbow Surgeons revealed increasing acceptance and utilization of ultrasound. However, many surgeons continue to employ use of the ultrasound in the clinic sparingly and often defer to MRI evaluation despite the stated benefits of ultrasound evaluation in the outpatient setting. The results of this study will help to provide additional education into the effectiveness of ultrasound in the diagnosis and determination of reparability of rotator cuff tears.

Although we carefully planned this study, we acknowledge that there are limitations to this investigation. First, this study included patients from 5 fellowship-trained orthopedic surgeons in either sports medicine or shoulder and elbow. Patients with rotator cuff tears account for a large volume of patients in these physician practices, and thus, generalists or physicians with fewer patients with rotator cuff tears may not obtain the predictive value with ultrasound imaging. In addition, patients in this study all underwent surgical intervention for their rotator cuff tear, and this study does not represent patients who elect conservative treatment. Furthermore, the average PPV of 97.6% from our patient population may not accurately represent the patients who elect conservative treatment. Another limitation to the study was the moderate level of interobserver reliability when evaluating the ultrasound images. Increasing the number of reviewers would increase the reliability; however, the three reviewers were all fellowship trained and have extensive experience in the assessment of rotator cuff disease with ultrasound which highlights the existence of variability even among experts in the field.

Conclusion

This study demonstrates the usefulness of in-office ultrasound to determine the reparability of posterior superior rotator cuff tears. We have found that if the cuff tear edge is able to be visualized, there is a high probability of successful arthroscopic restoration of the tendon to its native attachment. Conversely, if the tear edge is unable to be visualized, there is a moderate chance of the tear being irreparable. These results allow the surgeon to have confidence in the outcome of surgical intervention in the case of rotator cuff pathology.

Disclaimers:

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Conflicts of interest: Dr. Elkousy has received publication royalties from Elsevier. The commercial entity was not involved in any aspect of this study. Dr. Badman has received IP royalties/worked as a consultant for DJO Surgical and has worked as a consultant for CTM Biomedical. None of the commercial entities were involved in any aspect of the study. Dr. Ziegler has worked as a consultant for Wright Medical Technology, Inc. He is also a board or committee member of the American Shoulder and Elbow Surgeons. None of the commercial entities were involved in any aspect of the study. Dr. Buford has been a paid presenter for Orthotalk, Inc. and Trice Medical. He has also worked as a consultant and received stock or stock options with Trice Medical. He is on the editorial or governing board of Biologic Orthopedics Journal and a board or committee member for Interventional Orthobiologics. He also has received research support from Celling Biosciences. None of the commercial entities were involved in any aspect of the study. Dr. Kruse has worked as a consultant for Arthrex, Inc. The commercial entity was not involved in any aspect of this study. The other authors, their immediate families, and any research foundation with which they are affiliated did not receive any financial payments or other benefits from any commercial entity related to the subject of this article.

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