Interobserver Agreement in the Classification of Rotator Cuff Tears Using Magnetic Resonance Imaging

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Background: Although magnetic resonance imaging (MRI) is a standard method of assessing the extent and features of rotator cuff disease, the authors are not aware of any studies that have assessed the interobserver agreement among orthopaedic surgeons reviewing MRI scans for rotator cuff disease.

Hypothesis: Fellowship-trained orthopaedic shoulder surgeons will have good interobserver agreement in predicting the more salient features of rotator cuff disease such as tear type (full thickness versus partial thickness), tear size, and number of tendons involved but only fair agreement with more complex features such as muscle volume, fat content, and the grade of partial-thickness cuff tears.

Study Design: Cohort study (diagnosis); Level of evidence, 3.

Methods: Ten fellowship-trained orthopaedic surgery shoulder specialists reviewed 27 MRI scans of 27 shoulders from patients with surgically confirmed rotator cuff disease. The ability to interpret full-thickness versus partial-thickness tears, acromion type, acromioclavicular joint spurs or signal changes, biceps lesions, size and grade of partial-thickness tears, acromiohumeral distance, number of tendons involved and amount of retraction for full-thickness tears, size of full-thickness tears, and individual muscle fatty infiltration and atrophy were assessed. Surgeons completed a standard evaluation form for each MRI scan. Interobserver agreement was determined and a kappa level was derived.

Results: Interobserver agreement was highest (>80%) for predicting full- versus partial-thickness tears of the rotator cuff, and for quantity of the teres minor tendon. Agreement was slightly less (>70%) for detecting signal in the acromioclavicular joint, the side of the partial-thickness tear, the number of tendons involved in a full-thickness tear, and the quantity of the subscapularis and infraspinatus muscle bellies. Agreement was less yet (60%) for detecting the presence of spurs at the acromioclavicular joint, a tear of the long head of the biceps tendon, amount of retraction of a full-thickness tear, and the quantity of the supraspinatus. The best kappa statistics were found for detecting the difference between a full- and partial-thickness rotator cuff tear (0.77), and for the number of tendons involved for full-thickness tears (0.55). Kappa for predicting the involved side of a partial-thickness tear was 0.44; for predicting the grade of a partial-thickness tear, it was –0.11.

Conclusions: Fellowship-trained, experienced orthopaedic surgeons had good agreement for predicting full-thickness rotator cuff tears and the number of tendons involved and moderate agreement in predicting the involved side of a partial-thickness rotator cuff tear, but poor agreement in predicting the grade of a partial-thickness tear.

Keywords: rotator cuff tears; magnetic resonance imaging (MRI); interobserver agreement

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Although prior studies have assessed the efficacy of magnetic resonance imaging (MRI) in detecting rotator cuff abnormality,[3,4,12,23] only 2 have evaluated the interobserver agreement in reviewing the MRI scans.[1,17] Determining interobserver agreement is important as more emphasis is being placed on the MRI appearance of the rotator cuff to determine reparability.[22,24] In addition, many studies have investigated the influence of the integrity and quantity of the muscle bellies of the rotator cuff on outcome after repair.[7,8,13,14,18,20,25,26,28] Three studies have evaluated the interobserver agreement among radiologists in determining rotator cuff lesions,[1,17,21] but to our knowledge there are no studies evaluating the interobserver agreement among orthopaedic surgeons assessing rotator cuff lesions by MRI. The purpose of this study is to determine the interobserver agreement among fellowship-trained orthopaedic surgeons who perform at least 30 rotator cuff repairs per year with regard to rotator cuff lesions, associated pathologic changes in the acromioclavicular joint, muscle atrophy, acromion type, and biceps and osseous abnormalities. We hypothesized that fellowship-trained orthopaedic shoulder surgeons will have good interobserver agreement in predicting the more salient features of rotator cuff disease such as tear type (full thickness versus partial thickness), tear size, and number of tendons involved but only fair agreement with more complex features such as muscle volume, fat content, and the grade of partial-thickness cuff tears.

MATERIALS AND METHODS

Ten fellowship-trained orthopaedic shoulder specialists who each perform more than 30 rotator cuff repairs per year reviewed 27 MRI scans of 27 shoulders from patients with surgically confirmed rotator cuff lesions. The 27 patients represented a consecutive series of patients who had surgery at an outpatient surgery center over a 3-month period by 1 surgeon (E.E.S.). Thirty patients were initially included but 3 were excluded as they had previous surgery. We did not include the revision cases as their MRI scans were more difficult to read secondary to implant artifact. Twelve partial-thickness tears and 15 full-thickness tears were included. The age of the patients averaged 59 years (range, 35-71). All surgeons had been in practice for a minimum of 3 years and had completed at least a 1-year shoulder and elbow or sports medicine fellowship. All MRI was performed with a 1.5-T unit (GE Excite Scanner, GE Healthcare Technologies, Waukesha, Wis) with a dedicated transmit-receive shoulder coil and fast spin-echo sequencing. Axial proton density (PD) imaging used a 14-cm field of view (FOV) and a 4-mm section thickness with a 0.5-mm gap with repetition time (TR) of 3500 msec and echo time (TE) of 45 msec. Coronal section used both T2-weighted images with fat suppression and PD images. The T2-weighted images had a 16-cm FOV and a 3-mm section thickness with a 0.4-mm gap and TR of 3500 msec and TE of 85 msec. The PD images had a 14-cm FOV and a 4-mm section thickness with a 0.5-mm gap and TR of 3500 msec and TE of 45 msec. Sagittal imaging used T2- and T1-weighted techniques. The T2-weighted images had a 16-cm FOV with a 4-mm section thickness with a 0.4-mm gap and a TR of 4000 msec and a TE of 85 msec. The T1-weighted images had a 16-cm FOV and a 7-mm section thickness with a 3-mm gap and a TR of 500 and minimal TE. Each scan had a measurement scale in centimeters.

Surgeons completed a standard evaluation form developed by the authors for this study for each MRI scan (see Appendix, available in the online version of this article at http://ajsm.sagepub.com/supplemental). The MRI scans were sent to each surgeon on a compact disc to be read at their leisure. The surgeons knew that all scans belonged to patients who had some type of rotator cuff tear confirmed at surgery but were blinded to the detailed surgical findings. Before the study, the surgeons had several face-to-face group meetings and subsequent conference calls in which the MRI criteria were developed and refined. The ability to detect full-thickness versus partial-thickness tears, acromion type, acromioclavicular joint spurs or signal changes, biceps lesions, size and grade of partial-thickness tears, acromiohumeral distance, number of tendons involved and amount of retraction for full-thickness tears, size of full-thickness tears, and individual muscle fatty infiltration and atrophy were assessed. The acromial type was assessed in the sagittal plane according to the classification system of Bigliani et al[2] and in the coronal plane in the same fashion with flat, curved, or hooked. The quality of the muscle was assessed according to the classification system of Goutallier et al.[9] Atrophy of the supraspinatus muscle was assessed at the "Y-shaped" view on the T1-weighted sagittal cut that included both the scapular spine and the corocoid using a tangent sign. The tangent sign is positive for atrophy if the superior border of the supraspinatus muscle is below a line drawn from the superior aspects of the scapular spine and corocoid.[28] The other rotator cuff muscle bellies were also assessed on this same slice with each surgeon subjectively determining the percentage decrease in muscle cross-sectional area, which is similar to other proposed systems.[6,14,25] Full-thickness rotator cuff tears were measured on the sagittal (at the tuberosities) and coronal images and classified into the numbers of tendons torn. Partial-thickness rotator cuff tears were graded in a binary fashion as either grade 1 (less than 50% torn) or grade 2 (more than 50% torn) and according to the side torn (either articular or bursal).

Statistical Methods

Multirater kappa statistics were used to measure interobserver reliability among 10 surgeons. Kappa statistics measure agreement beyond the agreement due to chance alone. Two measures contribute to the kappa statistic: expected agreement and observed agreement. Expected agreement is the probability that 2 surgeons provide the same response to a question for any given patient (chance agreement). Observed agreement is the probability that 2 surgeons provide the same response to a question for a specific patient. Kappa (κ) is the amount of observed agreement that is beyond the agreement expected due to chance alone.

A kappa of 0.0 represents agreement due to random chance alone, while a kappa of 1.0 represents perfect agreement. A negative kappa represents agreement worse than what would be expected due to chance alone, and a

TABLE 1
MRI Features of Rotator Cuff Tears Ranked by Interobserver Agreement[a]

Variable	Observed Agreement	Kappa
Teres minor quantity	0.9	0
Full thickness vs partial thickness	0.89	0.77
AC joint signal change (increased)	0.78	0.33
Subscapularis quantity	0.78	0.04
Number of tendons involved	0.72	0.55
Side of partial-thickness tear	0.72	0.44
Infraspinatus quantity	0.72	0.22
Biceps tear	0.68	0.19
AC joint spur	0.66	0.32
Degree of retraction	0.63	0.44
Biceps signal change (increased)	0.6	0.2
Supraspinatus quantity	0.59	0.25
Acromiohumeral distance	0.52	0.26
Acromial morphology (sagittal)	0.5	0.16
Partial-thickness tear grade	0.46	–0.11
Acromial morphology (coronal)	0.43	0.06
Size of tear (sagittal)	0.42	0.26
Size of tear (coronal)	0.42	0.24
Muscle quality (Goutallier)	0.36	0.1

[a]MRI, magnetic resonance imaging; AC, acromioclavicular

kappa of –1.0 represents complete discordance between observers. Analyses were performed using SAS for Windows, version 9.1 (SAS Institute, Cary, NC). The kappa values were interpreted according to the guidelines adapted from Landis and Koch.[19] Excellent agreement occurred when the kappa value was between 0.81 and 1.00, good was between 0.61 and 0.80, moderate was between 0.41 and 0.60, fair was between 0.21 and 0.40, and poor was less than 0.20.

RESULTS

The results are presented in Table 1. Interobserver agreement was highest (>80%) for detecting full- versus partial-thickness tears of the rotator cuff, and for quantity of the teres minor tendon. Agreement was slightly less (>70%) for detecting signal in the acromioclavicular joint, the side of the partial-thickness tear, the number of tendons involved in a full-thickness tear, and the quantity of the subscapularis and infraspinatus muscle bellies. Agreement was less (> 60%) for detecting the presence of spurs at the acromioclavicular joint, a tear of the long head of the biceps tendon, and the amount of retraction of a full-thickness tear. The kappa statistics provide a more true reflection of the agreement. The kappa statistics were good for detecting the difference between a full- and partial-thickness rotator cuff tear (0.77), and moderate for the number of tendons involved for full-thickness tears (0.55), the side of the partial-thickness tear (0.44), and the degree of retraction (0.44). Fair agreement was found with regard to the acromioclavicular joint signal change and presence of a spur, infraspinatus and supraspinatus quantity, acromiohumeral distance, and the size of the tear in the sagittal and coronal planes. The remaining features had poor agreement.

DISCUSSION

The utility of a diagnostic test depends on its accuracy (reflected by sensitivity and specificity—the ability to detect a disease when one exists and to rule out a disease when it is not present) and its reliability (the ability to produce the same findings with repeated application of the test or when interpreted by different individuals). Assessment of the interobserver agreement is an important part of determining the reliability of a diagnostic test. This study was designed to assess the interobserver agreement among experienced shoulder surgeons interpreting the MRI findings of patients with rotator cuff disease. Although the surgeons involved did not have any formal training in the interpretation of magnetic resonance images by way of a radiology residency, the interpretation of such images was part of each of the fellowship training programs.

In this study, the interobserver agreement was highest in determining full-thickness tears from partial-thickness tears. This is similar to other studies in which radiologists read the MRI scans.[1,17,21] Robertson et al[17] reported the interobserver agreement among four radiologists who evaluated the magnetic resonance images of 97 patients. Of these 97 cases, 74 had open surgery to confirm the diagnosis. They reported poor agreement in the 21 partial-thickness rotator cuff tears and good agreement in the 26 full-thickness tears. In this study, no attempt was made to determine the side or grade of the partial tear and because the surgery was open, articular surface tears could not be evaluated at all. A second study by Balich et al[1] reported on the interobserver agreement among 5 radiologists who evaluated the magnetic resonance images of 222 patients who had pathologic changes confirmed with arthroscopy (only 141 had arthroscopic inspection of both the articular and bursal surfaces of the rotator cuff). The agreement was again good in the 45 full-thickness rotator cuff tears but poor in the 26 partial-thickness tears. No attempt was made to determine the side of the partial tear or the grade but they did note better agreement among the more experienced radiologists. The final study, by Singson et al,[21] reported on the agreement between 2 musculoskeletal radiologists who evaluated the magnetic resonance images of 177 patients. Forty-three of these patients had pathologic changes surgically confirmed. The agreement was excellent in the 33 full-thickness rotator cuff tears and good in the 40 partial-thickness tears. Actual numbers for agreement were not given regarding the side and grade of the partial-thickness tears, but it was stated that no significant difference was found in the grading of the partial tears when fat suppression was used. However, they did state that there were 21 partial tears that were diagnosed with fat suppression that were not diagnosed without fat suppression. With regard to partial-thickness rotator cuff tears, the current study, which used fat suppression techniques, yielded moderate agreement in determining the side of the tear (articular vs bursal) and only fair agreement in determining the grade. To our knowledge, the current study is the only one to evaluate the interobserver agreement regarding the side and grade of partial-thickness rotator cuff tears. The lower levels of agreement in determining the side and grade of partial thickness tears might be secondary to the high sensitivity and specificity of MRI in determining the presence of a full-thickness rotator cuff tear,[12,23] while the ability of MRI to predict a partial-thickness rotator cuff tear has been much lower.[3,23] Furthermore, using fat suppression might affect the ability to predict the character of a partial-thickness tear.[21]

Some authors have emphasized the importance of the quality and quantity of the rotator cuff muscle in determining the postoperative rotator cuff integrity and function.[7,10,24,28] In this study, the interobserver agreement in determining the quantity of the muscle varied from 59% for the supraspinatus to 90% for the teres minor. Other studies have produced better agreement with software that measures cross-sectional area on the MRI scans,[6,14] but this might not be readily available in the office setting. In addition, this study demonstrated poor agreement with regard to the quality of the muscle according to the Goutallier 5-grade system.[9] Fuchs et al[6] found that if a 3-tiered system was used, in which grades 0 and 1 were considered normal, grade 2 was considered moderately pathologic, and grades 3 and 4 were considered to represent advanced degeneration, that the agreement was good to excellent.

With regard to elucidating those factors that are important to determine on a preoperative study, several things need to be considered. The first is determining those factors that help predict postoperative outcome. Although our knowledge of these factors continues to evolve, the size of the tear (including the number of tendons involved and which tendons are involved), the degree of retraction, and the quality and quantity of the muscle have all been described as features that may affect the clinical and radiographic outcome.[7,9,11,14,24]

The second issue is determining how accurate the preoperative study (in our case, MRI) is in assessing these factors. Magnetic resonance imaging has been shown to have a sensitivity from 90% to 100% in detecting full-thickness tears, but with regard to partial-thickness tears the sensitivity is anywhere from 35% to 82%.[12,15,16,23] Magnetic resonance arthrography considerably improved the ability to correctly diagnose both full- and partial-thickness rotator cuff tears, yet is more invasive.[5,27] Magnetic resonance imaging has been shown to be accurate in demonstrating atrophy and fatty infiltration.[6,28] Therefore, MRI seems to be a good study to evaluate the rotator cuff.

The final consideration is determining how consistently we agree on measuring these factors. In this group of fellowship-trained shoulder surgeons, we had good agreement in determining if the tear was full thickness versus partial thickness. We had moderate agreement in determining the side of the partial-thickness tear, the number of tendons involved, and the degree of retraction. We had fair agreement in determining the size of the tear, the acromial type, the acromiohumeral distance, and the quantity of the supraspinatus and infraspinatus muscle. It would seem that the more complex the grading system (more choices) and the more subjective the grading system (eg, how much fat vs muscle or acromial type), the less agreement we had. Because a classification system is only as good as the surgeons who use it, any classification system of rotator cuff tears based on MRI appearance should take into account the findings of this study.

More studies are needed to determine the predictive value of the features evaluated in this study. If the MRI feature is found to be important in determining the outcome, then a scoring/rating system that has fewer choices (more dichotomous) would have better interobserver agreement. In addition, a more objective measurement of the features found to affect outcome would also improve the agreement. With advanced digital workstations becoming more prevalent, programs that allow angle, length, and volume measurements should be applied to improve agreement.

This study is not without limitations. We did not use any software to help measure the cross-sectional area of rotator cuff muscle of the "Y" view. Some offices now have digital workstations on which one can manipulate and measure many of the features evaluated in this study, including the cross-sectional area. The use of these more advanced workstations would probably increase the agreement in evaluating these features and emphasizes that this is somewhat of a moving target that changes with improved technology. Also, a 1.5-T scanner was used in this study; however, some centers are currently using 3.0-T scanners, which could improve rotator cuff image quality. Furthermore, the authors have various levels of experience corresponding to years of practice but all were fellowship-trained and performed at least 30 rotator cuff repairs per year. Perhaps more education regarding the interpretation of MRI scans would affect the results; however, our results do not significantly differ from those studies performed by radiologists. Another potential limitation is that each reader knew that a tear was present before reading the MRI scan (as this was an inclusion criteria). This would introduce "pretest" bias if the goal of the study was to determine the presence or absence of a tear. However, the goal of this study was to determine the agreement among orthopaedic surgeons in classifying the tear and associated injuries. We do, however, acknowledge that if a reader already knows that a tear is present, he or she might be more likely to "overcall" other pathologic changes. Finally, we did not correlate the MRI interpretations with the intraoperative findings to determine the sensitivity and specificity as this was not the goal of the study. The goal of the study was to determine which features on MRI had the highest interobserver agreement and thus could be reliably used in scoring systems or study analysis.

Despite these limitations, this study demonstrated that experienced fellowship-trained orthopaedic surgeons had variable interobserver agreement in interpreting the MRI scans of patients with rotator cuff disease. The best agreement was found when distinguishing between partial- and full-thickness tears, and when assessing the number of tendons involved in full-thickness tears. Interestingly, some of the poorest agreement was seen for features commonly described in the literature, namely acromion type and the size of the tear. We believe that more studies are needed to determine the predictive value of these features and guide design of MRI-based scoring systems that are more dichotomous and objective. Future studies and rating systems using MRI on populations of patients with rotator cuff tears should report those features that have the best agreement to improve the reliability of the data.

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