Evaluation of the Glenoid Labrum With 3-T MRI: Is Intraarticular Contrast Necessary?

Nancy M. Major1,2
Jeffrey Browne2
Taymon Domzalski2
Roger L. Cothran2
Clyde A. Helms2

OBJECTIVE. The purpose of this study was to evaluate the diagnostic accuracy of 3-T MRI versus 3-T MR arthrography for assessing labral abnormalities in the shoulder using arthroscopy as the gold standard.

SUBJECTS AND METHODS. Forty-two patients (28 men, 14 women; mean age, 33 years) underwent MR arthrography and conventional MRI of the same shoulder. Two patients underwent bilateral shoulder examinations, for a total of 44 shoulder examinations. Twenty-two shoulders underwent arthroscopy. The results of arthroscopy were used as the reference standard. Three musculoskeletal radiologists prospectively and independently interpreted MRI and MR arthrography examinations. Differences in performance of conventional MRI and MR arthrography were analyzed for statistical significance by the two-tailed McNemar test.

RESULTS. Of the 22 arthroscopies performed, 26 labral tears were found in 18 shoulders and four shoulders were normal with respect to the labrum. There were 12 superior, nine posterior, and five anterior labral tears identified at arthroscopy. By consensus review, conventional MRI identified nine of 12 superior (sensitivity, 75%; specificity, 100%), seven of nine posterior (sensitivity, 78%; specificity, 92%), and three of five anterior (sensitivity, 60%; specificity, 94%) labral tears. MR arthrography identified nine of 12 superior (sensitivity, 75%; specificity, 100%), eight of nine posterior (sensitivity, 89%; specificity, 100%), and five of five anterior (sensitivity, 100%; specificity, 100%) labral tears.

CONCLUSION. Although the power of our preliminary study is small, the results suggest that intraarticular contrast material is helpful in diagnosing labral tears in the shoulder, particularly tears of the anterior labrum. Our preliminary results suggest that MR arthrography adds value for diagnosing labral tears in the shoulder compared with conventional MRI even at 3 T.

In several studies, investigators have advocated the use of direct MR arthrography for the detection of labral tears because of its higher sensitivity compared with conventional MRI at 1.5 T [1, 2]. Some reserve MR arthrography for patients younger than 40 years old because of the increase in shoulder instability in this patient population compared with the increased incidence of rotator cuff tears in the older population [3]. However, several factors beyond image quality need to be considered when choosing between conventional MRI and MR arthrography. These factors include the patient’s reluctance to undergo an invasive procedure, risk, time, cost, labor, and scheduling and coordination of fluoroscopy and MRI [4].

With the addition of high-field-strength 3-T MR systems to numerous institutions and clinics over the past several years comes a desire to stay competitive in an ever-growing market as well as the anticipated two-fold increase in signal-to-noise ratio (SNR). Many musculoskeletal radiologists are finding that the improved signal from 3 T generates substantially clearer images.

The purpose of this study was to prospectively evaluate the diagnostic accuracy of 3-T conventional MRI compared with 3-T MR arthrography in diagnosing labral abnormalities in the shoulder. Our hypothesis was that the improved SNR and spatial resolution of MRI at 3 T would increase the accuracy of this modality to make it comparable to 3-T MR arthrography.
Subjects and Methods

Subjects

Institutional review board approval was obtained for our HIPAA-compliant prospectively designed study. For study inclusion, subjects had to be at least 18 years old. Patients who presented with shoulder pain that was considered by the orthopedic surgeon to be suspicious for labral disease were enrolled and referred for diagnostic 3-T MR arthrography. Patients interested in participating were scheduled for a conventional MRI examination 1 hour before MR arthrography, with both studies being completed on the same scanner. All subjects were required to provide written informed consent. Subjects with a history of surgery on the affected shoulder were excluded.

Over a 21-month interval, 42 patients (28 men, 14 women; mean age, 33 years) were recruited by physician referral from the orthopedic sports medicine clinics at our institution. Two patients underwent bilateral shoulder examinations. Twenty-two shoulders underwent arthroscopic shoulder surgery by one of the two participating surgeons. All patients had a delay of no more than 3 months between MRI and surgery. A review of the patients’ clinic notes revealed no new episodes of shoulder trauma between the time of the MRI and MR arthrography examinations and the time of arthroscopy.

MRI

Conventional 3-T MRI was performed first with a 3-T MR magnet (Signa HDxt 3T, GE Healthcare; or Trio Tim, Siemens Healthcare) with respective dedicated phased-array shoulder coils. The following conventional 3-T MR pulse sequences were performed: sagittal oblique T1-weighted spin echo (TR range/TE range, 500–800/8–15); axial, sagittal, and coronal oblique fat-suppressed T2-weighted fast spin echo (4000–6000/50–80); and axial, sagittal, and coronal oblique proton density (2000–3000/20–30). The technical parameters for the sequences were identical to those used for the conventional MR examination. Shoulder coils used included a phased-array coil and 4-channel coil.

Interpretation and Data Analysis

Three musculoskeletal radiologists with 6, 15, and 30 years of experience completed separate, independent reviews of the conventional MRI and MR arthrography examinations. The radiologists were blinded to all clinical information about the patients. The interpreters first evaluated the conventional MR images of the first 15 subjects enrolled, and after a delay of at least 1 week they interpreted the MR arthrography examinations of the first 15 subjects enrolled. This alternating schedule continued until all studies were reviewed.

The final interpretation of the labrum was based on a majority consensus. That is, if two of the three observers read the labrum as torn, it was considered torn. One of five attending radiologists in our department, which may have included one of the observers, provided an official report of the MR arthrography findings for the referring surgeon.

Criteria for Interpretations

Radiologists reviewing the examinations treated the glenoid rim as a clock face, with the superior labrum occupying the 11- to 1-o’clock position; the posterior labrum, the 2- to 6-o’clock position; and the anterior labrum, the 6- to 11-o’clock position. These three areas were scored separately, and thus a shoulder could have a tear in more than one location. The diagnostic criterion for a labral tear included the presence of high signal within the labrum extending to the articular surface. An additional criterion on MR arthrography was contrast material within the substance of the labrum. The labrum was considered to be detached if it was separated from the glenoid or from the remaining labral tissue. A labrocapsular injury was diagnosed if there was high signal or contrast material at the junction of the joint capsule and labrum. Labral contour irregularity or fraying of the free edge was designated as degeneration. The readers did not attempt to subcategorize superior labral anteroposterior (SLAP) tears according to the Snyder classification. For the purposes of data analysis, normal labra or degenerated labra were considered “normal,” whereas torn or detached labra or labrocapsular injuries were considered to be “labral tears.”

The 44 conventional MRI and MR arthrography shoulder examinations were analyzed for statistical significance using the two-tailed McNemar test; a p < 0.05 was considered statistically significant. Kappa estimates for the three observers’ evaluations of each portion of the labrum were performed to evaluate interobserver variability.

Arthroscopic Evaluation

Arthroscopic findings were used as the standard of reference. Surgery was performed by one of two fellowship-trained orthopedic surgeons with extensive experience in shoulder arthroscopy. The surgeons were blinded to the diagnostic reports or preoperative MR arthrography images and were given an independent interpretation at the time the patient initially presented for the study. Surgeons provided dictated operative reports about all patients who underwent surgery. Each report included an assessment of the integrity of the labrum and a description of the treatment administered. The labrum was considered abnormal if treated with debridement or repair and normal if described as intact and not addressed with surgical techniques.

The 22 patients who did not undergo arthroscopy were deemed not to have abnormalities warranting surgical intervention during the time course of the study.

The sensitivities and specificities of the MRI and MR arthrography examinations were calculated in the standard manner for the 22 shoulders that underwent arthroscopy using arthroscopy as the reference standard. Sensitivities and specificities were calculated for the anterior, posterior, and superior labrum for each type of MR examination. The Fisher exact test was used to evaluate for statistically significant differences in sensitivity and specificity between the MRI and MR arthrography examinations; a p < 0.05 was considered significant.

Results

Of the 22 shoulders that underwent arthroscopy, 26 labral tears were found in 18 shoulders and the remaining four shoulders were normal with respect to the labrum. Of the 18 cases with arthroscopically diagnosed tears, a labral tear was detected with conventional MRI in 12 of the 18 cases (67%) and with MR arthrography in 15 of the 18 cases (83%) (p = 0.82); therefore, the difference in performance was not statistically significant.

There were 12 superior, nine posterior, and five anterior labral tears identified at arthroscopy. Conventional MRI identified nine of 12 superior (sensitivity, 75%; specificity, 100%), seven of nine posterior (sensitivity, 78%; specificity, 92%), and three of five anterior (sensitivity, 60%; specificity, 94%) labral tears. MR arthrography identified nine of 12 superior (sensitivity, 75%; specificity, 100%), eight of nine posterior (sensitivity, 89%; spec-
ificity, 100%), and five of five anterior (sensitivity, 100%; specificity, 100%) labral tears (Fig. 1 and Table 1). There were no statistically significant differences in calculated sensitivities or specificities between the MRI and MR arthrography examinations for the anterior, posterior, or superior labrum.

Seven tears were not identified with conventional MRI and four tears were not diagnosed using MR arthrography. All four of the tears missed on MR arthrography were also missed on conventional MRI. There were no tears in the study that were missed on MR arthrography and diagnosed at conventional MRI. The four tears that were missed by both conventional MRI and MR arthrography included one posterior labral tear (Fig. 2) and three superior labral tears. The three additional tears that were missed only by conventional MRI included two anterior tears (Fig. 3) and one posterior tear. There were no labral tears erroneously diagnosed on either MRI or MR arthrography found at surgery.

For the arthroscope, interobserver variability was calculated using only proven cases and kappa statistics and was averaged over the three pairs of observers for each portion of the labrum studied. The kappa estimates for the arthrogram readings were as follows: superior labrum, 0.7 (standard error [SE], 0.112); anterior labrum, 0.563 (SE, 0.135); and posterior labrum, 0.585 (SE, 0.127). The kappa estimates for nonarthrogram readings were as follows: superior labrum, 0.429 (SE, 0.152); anterior labrum, 0.520 (SE, 0.152); and posterior labrum, 0.523 (SE, 0.156).

**Discussion**

Imaging of the glenoid labrum in the past has relied on a variety of techniques including arthrography, CT arthrography, conventional MRI, and more recently direct and indirect MR arthrography. In recent years, several investigators have evaluated the sensitivity, specificity, and accuracy of conventional MRI and direct MR arthrography in the evaluation of glenoid labral abnormalities. MR arthrography at 1.5 T has been shown to be a reliable method to define and detect superior labral tears, with a sensitivity of approximately 90% [5, 6]. In a retrospective study that compared direct MR arthrography with conventional MRI in professional baseball players, Magee et al. [2] concluded that professional athletes may be a subset of patients that would benefit more from MR arthrography than from conventional MRI. Based on these studies and others, the authors of a recent meta-analysis recommended that direct MR arthrography be reserved for young athletes (< 40 years) who present with chronic injuries or instability because they tend to have smaller labral tears in greater number and frequency [4]. To our knowledge, only

![Fig. 1—33-year-old man with type 2 superior labral anteroposterior (SLAP) tear at surgery. A and B, Conventional coronal fast spin-echo T2-weighted image (A) and coronal T1-weighted MR arthrography image with fat suppression (B) both show high signal extending into superior labrum (arrows) and were called tears prospectively.](image)

<table>
<thead>
<tr>
<th>Imaging Modality</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior</td>
<td>75 (9/12)</td>
<td>100 (10/10)</td>
</tr>
<tr>
<td>Posterior</td>
<td>78 (7/9)</td>
<td>92 (12/13)</td>
</tr>
<tr>
<td>Anterior</td>
<td>60 (3/5)</td>
<td>94 (16/17)</td>
</tr>
<tr>
<td>MR arthrography</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior</td>
<td>75 (9/12)</td>
<td>100 (10/10)</td>
</tr>
<tr>
<td>Posterior</td>
<td>89 (8/9)</td>
<td>100 (13/13)</td>
</tr>
<tr>
<td>Anterior</td>
<td>100 (5/5)</td>
<td>100 (17/17)</td>
</tr>
</tbody>
</table>

Note—Data are based on 22 arthroscopies performed: 26 labral tears were identified in 18 shoulders and the glenoid labrum was normal in four shoulders. Numbers in parentheses are the data used to determine the percentage.
one retrospective study evaluates the sensitivity and specificity of 3-T conventional MRI for glenoid labral tears. In a study of the 46 labral tears diagnosed at arthroscopy, Magee and Williams [7] reported that MRI sensitivity for the detection of SLAP tears was 90% (19/21); for posterior tears, 86% (6/7); and for anterior tears, 89% (16/18).

With the addition of several 3-T clinical MR magnets to our department, we wanted to determine if the increased SNR, spatial resolution, and contrast-to-noise ratio afforded by higher field strength would make conventional 3-T MRI comparable to MR arthrography in diagnosing labral abnormalities. With regard to the superior and posterior labrum for patients with arthroscopically proven tears, an additional posterior tear was identified by MR arthrography and was confirmed surgically. The posterior tear was described as a “posterior labral cleft” at arthroscopy. MR arthrography accurately identified and was interpreted as a small cleft in the posterior labrum that was not apparent.

![Fig. 2—21-year-old collegiate football player with posterior labral tear and paralabral cyst at arthroscopy.](image1)
A and B, Conventional axial fast spin-echo T2-weighted MR image (A) and axial T1-weighted MR arthrography image with fat suppression (B) both show high signal extending through posterior labrum (arrows). Paralabral cyst (arrowhead, A) better shown on conventional MR image, did not fill with gadolinium.

![Fig. 3—21-year-old woman with arthroscopically proven posterior labral tear.](image2)
A and B, Conventional axial fast spin-echo T2-weighted MR image (A) and axial T1-weighted MR arthrography image with fat suppression (B) both show normal-appearing posterior labrum.
3-T MRI of the Glenoid Labrum

on the conventional MRI even on retrospective review.

In our patients with arthroscopically proven tears, 3-T MR arthrography identified two additional anterior labral tears missed by conventional MRI. Coincidentally, both anterior labral tears were in the same patient who had a history of recurrent shoulder instability due to documented bilateral anterior shoulder dislocations in the past. At arthroscopy and on MR arthrography, the anterior labrum was displaced and scarred to the anterior band of the inferior glenohumeral ligament in both shoulders. Without distention of the joint capsule with contrast material, the anterior labrum assumed its normal position on the anterior glenoid rim on conventional MRI (Fig. 4). No Hill-Sachs deformity could be identified—even in retrospect—to assist in making the diagnosis.

With respect to the superior labrum, both conventional MRI and MR arthrography had identical sensitivities of 75%. Although a sensitivity of 90% for superior labral tears has been reported for conventional MRI at 3 T [7], other authors have reported sensitivities of conventional MRI and MR arthrography at 1.5 T for superior labral tears [5, 8] similar to this study.

Our results are in keeping with the results of a study performed by Magee [9] in which patients were evaluated with and without intraarticular contrast material. Whereas his study evaluated additional shoulder abnormalities, our study focused exclusively on the labrum. Nevertheless, the results of his study similarly indicated that tears of the superior labrum and anterior labrum were more often identified on examinations obtained using intraarticular contrast material.

Normal variations of the superior labrum and the difficulty in distinguishing it from labral tears may account for at least part of the lower-than-expected sensitivities for superior labral tears in our study. Two of the three superior tears that were misdiagnosed were interpreted as normal with a normal sublabral recess. A sublabral recess is defined as a smooth, medially curved line of increased signal between the glenoid and superior labrum. Although signs evaluating the width of high signal in the superior labrum as well as the presence or absence of signal posterior to the biceps tendon have been evaluated, a study has shown these signs to have limited specificity and predictive value [10]. Because of the presence of superior labral recesses, diagnosing a superior labral tear at surgery and with MRI can be somewhat subjective. The prevalence of overdiagnosis and potential for

![Fig. 4](image)

18-year-old man with history of anterior shoulder dislocation several years earlier.

A, Axial conventional fast spin-echo T2-weighted MR image shows only minimal signal undercutting (arrow) otherwise normal-appearing anterior labrum.

B and C, Axial T1-weighted MR arthrography images show detached anterior labrum (arrows) that is scarred to anterior band of inferior glenohumeral ligament. Arthroscopy confirmed these findings.
overdiagnosis of superior labral abnormalities are known topics of debate among orthopedists [10]. Although the threshold for surgical repair differs among surgeons, most will agree that if the labrum appears “torn off” or appears frayed on the undersurface with exposure of bone and cartilage loss, then surgical repair of the superior labrum is warranted.

Fifty percent of the shoulders (n = 22 shoulders) examined in our study did not undergo arthroscopy as the reference standard. In this group of patients, MR arthrography diagnosed six additional tears (five posterior, one anterior). Although no reference standard was available, the 100% specificity of MR arthrography in the population with subsequent arthroscopy suggests that these interpretations have a higher likelihood of being true-positives rather than false-positives.

Tears in this population were likely deemed not significant enough to warrant surgery during the time course of this study.

Identifiable limitations of this study are the small number of patients that were enrolled as well as the lack of arthroscopic correlation for all patients. These limitations suggest that statistical values should be interpreted with caution. Nevertheless, early studies suggest that the use of intraarticular contrast material even when performing examinations on a 3-T system yields improved sensitivity and specificity over conventional MRI.

A confidence scale for each individual reader’s interpretations of MRI versus MR arthrography in the evaluation of the labrum was not performed and may have provided more accurate comparison of the utility of 3-T conventional MRI versus 3-T MR arthrography. Individual variability and interobserver variability were not reported because of the small number of tears in the study population. A misinterpretation by a reviewer could have erroneously produced a dramatic change in statistics.

Although the principal factor influencing MR arthrography versus conventional MRI in our daily practice is the preference of the radiologist and referring orthopedic surgeon, it should not be the only consideration. Several factors such as the simplicity of conventional MRI and avoidance of potential risks, increased cost, increased time, and patient reluctance associated with arthrography should be considered. Most importantly, radiologists and referring surgeons should consider the contribution MR arthrography will have in altering a patient’s management [11]. In our patients with arthroscopic follow-up, the addition of MR arthrography potentially altered management in three of the 22 cases (14%). In comparison with results at 1.5 T, the increased SNR and spatial resolution of 3-T MRI may narrow the gap between conventional MRI and MR arthrography, although some tears are simply better identified with intraarticular contrast material, as shown by the displaced and scarred anterior labral tears in this series as well as the posterior labral tears.

The scope of this study was to evaluate the need for intraarticular contrast material as it relates to the diagnosis of labral tears using a 3-T system. Given the advantages of 3 T, especially for musculoskeletal application increasing SNR and spatial resolution, 3-T imaging would seem the ideal modality for assessing small structures such as the labrum. The results of our study suggest that—even at 3 T—the use of intraarticular contrast material not only is useful, but also may be necessary for evaluation of labral abnormalities.

Is intraarticular contrast material necessary at 3 T? Our preliminary results show that fewer labral tears were missed with MR arthrography and thus justify its use in all shoulders with suspected labral tears. Despite the improvements that 3-T imaging affords for the evaluation of small structures, certain abnormalities may be better evaluated with intraarticular contrast material; MR arthrography findings may ultimately affect the treatment plan for patients by yielding better, more accurate information for the orthopedic surgeon, thereby resulting in improved patient care.

References

Major et al.