Radiology

Recurrent Symptoms after Shoulder Instability Repair: Direct MR Arthrographic Assessment—Correlation with Second-Look Surgical Evaluation[1]

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Purpose: To retrospectively determine the accuracy of direct magnetic resonance (MR) arthrography of the shoulder in patients with recurrent or residual signs and/or symptoms of instability after prior instability repair, with surgical findings as the reference standard.

Materials and Methods: After institutional ethics review board approval was obtained and informed consent was waived, 40 patients (31 men, eight women; mean age, 28 years) with recurrent instability after previous instability repair who underwent direct shoulder MR arthrography before repeat surgery were studied. Two musculoskeletal radiologists reviewed direct MR arthrographic studies by using consensus agreement in a blinded fashion. MR assessment included evaluation of the labrum (overall, superior, anterior and anteroinferior, posterior and posteroinferior), rotator cuff, biceps tendon, articular cartilage, and presence or absence of a Hill-Sachs lesion. Mean interval between MR arthrography and repeat surgery was 6.2 months (range, 6 days to 36 months). Surgical reports were compared with MR arthrographic results, and accuracy, sensitivity, and specificity of direct MR arthrography were determined.

Results: Accuracy, sensitivity, and specificity, respectively, of direct MR arthrography in diagnosis of overall labral tears (n = 26) were 91.9%, 96.2%, and 81.8%; those of superior labral tears (n = 16) were 89.2%, 93.8%, and 85.7%; and those of anteroinferior tears (n = 17) were 91.9%, 100%, and 85%. Overall accuracy for detecting rotator cuff injury (n = 17) was 87.2% (sensitivity, 94.1%; specificity, 81.8%); accuracy for biceps injury (n = 7) was 95.7% (sensitivity, 85.7%; specificity, 100%); accuracy for glenoid and/or humeral articular cartilage abnormality (n = 15) was 76.2% (sensitivity, 73.3%; specificity, 83.3%); and accuracy for Hill-Sachs lesion (n = 14) was 93.3%.

Conclusion: Direct MR arthrography is accurate (91.9%) for assessing labral pathologic conditions and other internal derangements of the shoulder in patients with recurrent or residual signs and/or symptoms after prior shoulder instability repair.

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Many surgical procedures for shoulder instability are performed (1,2); however, recurrent signs and/or symptoms of instability occur after surgery in up to 20% of patients (1), often because of recurrent trauma or failure of the original surgical procedure (3–5). Patients complain of pain, clicking, limited range of motion, and recurrent subluxation and/or dislocation. Repeat surgical findings include labral, rotator cuff, biceps tendon, and articular cartilage abnormalities.

Magnetic resonance (MR) imaging studies (6–10) have revealed postsurgical appearances of the shoulder by using conventional MR imaging and direct and indirect MR arthrographic techniques. Limited literature exists on the accuracy of direct MR arthrography in patients with recurrent or residual signs and/or symptoms of instability after instability repair. Thus, the purpose of our study was to retrospectively determine the accuracy of direct MR arthrography of the shoulder in patients with recurrent or residual signs and/or symptoms of instability after prior instability repair, by using surgical findings as the reference standard.

Materials and Methods

Patients

Data in 39 consecutive patients (31 men, eight women; mean age [at time of direct MR arthrography], 28 years; range, 18–50 years) who were referred for direct MR arthrographic assessment of recurrent shoulder instability after previous instability repair and who underwent subsequent repeat surgery were retrospectively reviewed. Institutional ethics review board approval was obtained, and informed consent was waived. Patients were referred for imaging to the University Health Network or Mount Sinai Hospital, Toronto, Ontario, Canada between March 1998 and October 2004.

Chart Review

A chart review was performed (L.J.P., L.M.W.) to confirm prior instability repair, and signs and/or symptoms of recurrent instability were documented. The type of recurrent instability included anterior instability (27 patients), posterior instability (one patient), and multidirectional instability (11 patients). Twenty patients had sports-related causes for recurrent instability (one rollerblading, three basketball, six baseball, six hockey, two football, one skiing, and one wrestling incident[s]). Ten patients had causes for instability that were not related to sports, and the cause for recurrent instability was unknown in nine patients. Twenty-three patients had undergone one prior instability repair, and 16 had undergone more than one instability repair. Twenty-seven patients had undergone surgery on their right shoulder and 12 on their left.

Previous surgeries included arthroscopic procedures (19 patients), open procedures (14 patients), and both arthroscopic and open procedures (two patients). The type of prior procedure was unknown for four patients. The type of prior procedure related to stabilization or labral repair included capsular stabilization (18 patients), anteroinferior labral repair (11 patients), superior labral repair (six patients), posterior labral repair (two patients), and both anteroinferior and superior labral repair (two patients). Prior MR imaging studies were not documented or available for review. The mean interval between the most recent prior surgery and the direct MR arthrographic study was 4.3 years (range, 6 months to 29 years).

Imaging Studies

All MR imaging examinations were performed with a 1.5-T unit (Signa; GE Healthcare, Milwaukee, Wis) by using a dedicated phased-array shoulder extremity coil. Direct MR arthrography was performed immediately after intraarticular injection of 12–15 mL of a gadopentetate dimeglumine–saline solution (1 mL gadopentetate dimeglumine [Omniscan; GE Healthcare/Amersham, Princeton, NJ] in 250 mL normal saline solution). Intraarticular positioning of a 22-gauge needle was confirmed with fluoroscopic guidance (with an injection of <1 mL of iodinated contrast material [diatrizoate meglumine 60%, Hypaque; GE Healthcare/Amersham]. Injections were performed by a musculoskeletal radiologist or a musculoskeletal imaging fellow who was on duty at the time the study was performed; therefore, initials and years of experience cannot be assigned, although two authors (L.M.W. and D.C.S., 4 and 5 years of experience, respectively, at the time of the first injection in 1998) were included. For all patients, the following MR imaging

Advance in Knowledge

- Direct MR arthrography is an accurate diagnostic technique (overall labrum, 91.9%; overall rotator cuff, 87.2%; biceps abnormality, 95.7%; Hill-Sachs injury, 93.3%; and glenoid and/or humeral articular cartilage abnormality, 76.2%) for the assessment of intraarticular pathologic conditions of the shoulder in patients with recurrent or residual symptoms after prior shoulder instability repair.

Implication for Patient Care

- In patients with recurrent or residual symptoms after prior shoulder instability repair, MR arthrography can help to guide future treatment, in particular the need for surgical intervention.

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Abbreviations:
LHB = long head of biceps
NPV = negative predictive value
PPV = positive predictive value
SE = spin echo
SLAP = superior labral anterior posterior

Author contributions:
Guarantors of integrity of entire study, L.J.P., L.M.W.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; manuscript final version approval, all authors; literature research, L.J.P., L.M.W., D.C.S.; clinical studies, L.J.P., L.M.W., D.C.S., E.L.B.; statistical analysis, L.J.P., G.T.; and manuscript editing, all authors

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sequences were performed: transverse, coronal oblique, and sagittal oblique T1-weighted spin-echo (SE) sequences with fat saturation (repetition time msec/echo time msec, 500/<20; 4-mm section thickness; 0-mm spacing; 256 × 192 matrix; 14 × 14-cm field of view; three signals acquired) and a coronal oblique T2-weighted fast SE sequence with fat saturation (4000/85, echo train length of eight, 4-mm section thickness, 0-mm spacing, 256 × 192 matrix, 14 × 14-cm field of view, three signals acquired).

Image Analysis

By using consensus agreement, MR arthrograms were reviewed together by two experienced musculoskeletal radiologists (L.M.W. and D.C.S., 10 and 11 years of experience, respectively, at the time of review) who were blinded to surgical results. Reviewers were aware that each case was being reviewed for evaluation of recurrent or residual instability symptoms after prior instability repair. Labral tear diagnostic criteria included identification of gadolinium-based contrast material extending into a linear or complex tear cleft within the labrum; absence, truncation, or fragmentation of the labrum (7); or displacement of the labrum from its expected anatomic location. The labrum was divided into three anatomic locations: superior (including anterosuperior and posterosuperior labrum), anterior and anteroinferior, and posterior and posteroinferior. Reviewers determined the presence or absence of recurrent labral tears at each anatomic location for each case.

The presence or absence of partial- and/or full-thickness tears of each rotator cuff tendon (supraspinatus, infraspinatus, subscapularis, and teres minor) was determined. Full-thickness rotator cuff tear diagnostic criteria included visualization of tracking of gadolinium-based contrast material through the entire tendon focally or complete disruption of the tendon. Partial-thickness tears were diagnosed by identifying contrast material and/or fluid tracking into the tendon at the bursal or articular surface but not through the entire tendon thickness (11).

The presence or absence of long head of biceps (LHB) tendon abnormalities was determined. These were classified as tendinosis and/or partial tear (diagnosed by identifying the presence of increased intrasubstance signal intensity abnormality on T2-weighted fat-suppressed images or attenuation of the tendon) or complete tear or disruption of the tendon (12). Assessment of LHB tendon position was not performed because this was not commented on in enough surgical reports to enable meaningful statistical analysis.

Hill-Sachs lesions were diagnosed by identifying an impaction-type fracture (notched or flattening deformity) along the posterolateral superior humeral head (13). The presence or absence of glenoid and/or humeral articular cartilage abnormalities was determined by identifying thinning or complete cartilage loss (14).

Statistical Analysis

Surgical reports of repeat surgeries performed after direct MR arthrographic examinations were reviewed for surgical evaluation of each MR finding assessed. The mean interval between MR imaging and repeat surgery was 6.2 months (median, 4.1 months; range, 6 days to 36 months). Twenty-four patients underwent surgery within 6 months and 35 patients underwent surgery within 12 months after MR imaging.

The presence or absence of MR arthrographic findings was compared with surgical findings used as the reference standard for statistical correlation. Sensitivity, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV) of direct MR arthrography were calculated for the eval-

Figure 1

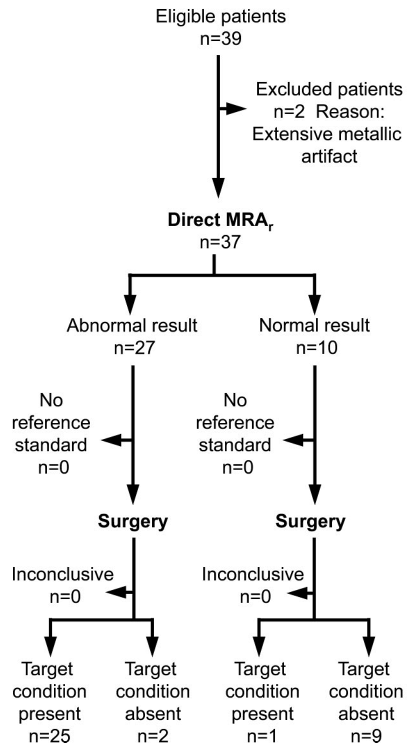


Figure 1: Flow diagram of patients in study for overall recurrent labral injury. *MRA$_r$* = MR arthrography.

Table 1

Recurrent Labral Injury at MR Arthrography

Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Any labral injury	96.2 (25/26)	81.8 (9/11)	92.6 (25/27)	90 (9/10)	91.9 (34/37)
Superior labral injury	93.8 (15/16)	85.7 (18/21)	83.3 (15/18)	94.7 (18/19)	89.2 (33/37)
Anterior and anteroinferior labral injury	100 (17/17)	85 (17/20)	85 (17/20)	100 (17/17)	91.9 (34/37)
Posterior and posteroinferior labral injury	100 (2/2)	97.1 (34/35)	66.7 (2/3)	100 (34/34)	97.3 (36/37)

Note.—Data in parentheses are numbers of labral tears used to calculate percentages.

uation of the presence or absence of a labral tear at each anatomic location and for overall assessment of the presence or absence of a tear in any labral component. A Student *t* test was used to compare the patient's age, sex, and number and side of prior surgeries with the presence of recurrent labral injury ($P \leq .05$).

Figure 2

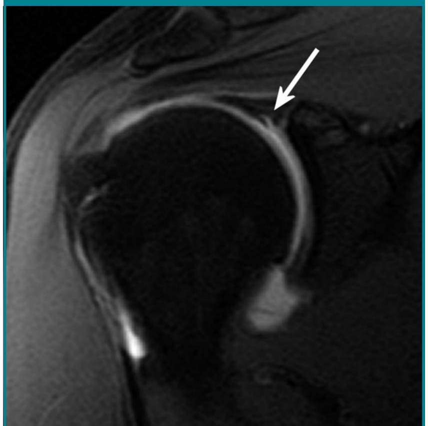


Figure 2: Coronal T1-weighted fat-suppressed SE (500/15) MR arthrographic image of right shoulder in 27-year-old man with recurrent right shoulder pain and instability after anterior instability and SLAP repair 1 year previously. SLAP tear (arrow) was diagnosed at MR arthrography and surgery.

For analysis based on the type of prior surgery, patient data were divided into the following categories: capsular stabilization surgery, anteroinferior labral repair, superior labral repair, and posterior labral repair. Two patients underwent both previous anteroinferior labral repair and superior labral repair and were included in both categories. MR arthrographic findings of instances in each category were compared with surgical findings at the location of prior surgery to determine which patients had MR arthrographic findings of recurrent or residual tears. Findings in patients who had undergone prior capsular stabilization surgery alone were compared with surgical findings of the anteroinferior labrum. The number of true-positive, true-negative, false-positive, and false-negative findings was determined for patients in each category of prior surgical repair.

Sensitivity, specificity, accuracy, PPV, and NPV were calculated for direct MR arthrographic assessment of the presence or absence of partial- and/or full-thickness tears for each rotator cuff tendon and for overall assessment of the presence or absence of any tear in any component of the rotator cuff.

Generalized estimating equation models were fitted to two sets of MR imaging outcomes for each patient. The three labral locations were modeled in one generalized estimating equation model, and the four rotator cuff locations were modeled in the other generalized estimating equation model. An exchangeable correlation structure was assumed. By using the generalized estimating equation approach for the labrum and rotator cuff separately, a common sensitivity and specificity was estimated. It was determined whether this overall sensitivity and specificity depended on the patient-specific factors of age, sex, and time between most recent surgery and MR arthrography.

Findings of LHB tendon abnormalities, presence or absence of a Hill-Sachs lesion, and presence or absence of glenoid and/or humeral articular cartilage abnormalities were compared with surgical findings, and sensitivity, specificity, accuracy, PPV, and NPV of MR arthrographic assessment were calculated.

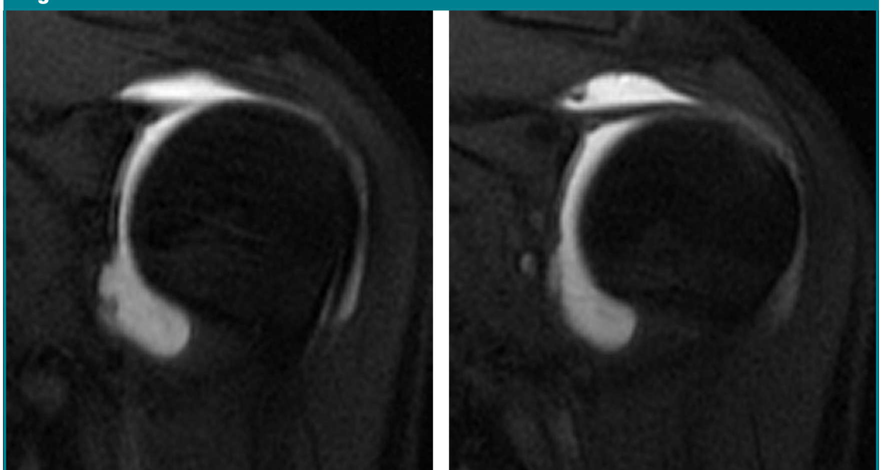
A *P* value of less than .05 was considered to indicate a significant difference. Statistical analysis for calculations was performed by using a statistical software package (R, version 2.2.0, 2005; R: Development Core Team, Vienna, Austria). Generalized estimating equation calculations were performed by using software (Generalized Estimation Equation Solver, R package, version 4.13–10; Vincent J. Carey; ported by Thomas Lumley [versions 3.13, 4.4] and Brian Ripley [version 4.13, 2002]).

Results

Recurrent or Residual Labral Tear

In two of 39 patients, the labrum was obscured by extensive metallic artifact from prior surgery, and these patients were excluded from labral evaluation (Fig 1). Of these patients, one had no labral tear at surgery and the second

Figure 3



a. b.

Figure 3: Consecutive coronal T1-weighted fat-suppressed SE (500/15) MR arthrographic images of left shoulder in 22-year-old woman with recurrent left shoulder pain and instability after anterior instability and SLAP repair 1 year previously. **(a, b)** SLAP tear was diagnosed at surgery but not at MR arthrography, consistent with a false-negative case. At surgery, SLAP tear had no more than 2 mm of displacement and was possibly too small to be depicted at MR arthrography.

had a large superior labral anterior posterior (SLAP) tear.

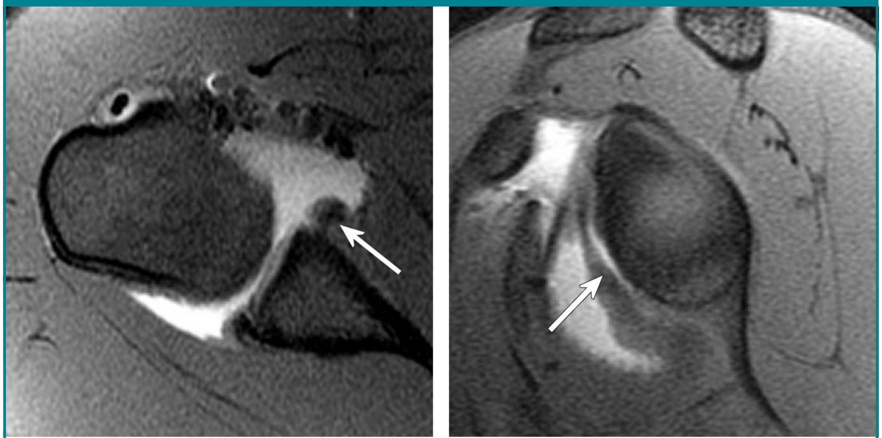
Superior labrum.—Sixteen of 37 patients had surgically proved tears of the superior labrum. Of these, 15 tears were diagnosed by using direct MR arthrography (Fig 2) (one false-negative [Fig 3], three false-positive, and 18 true-negative instances). This resulted in a sensitivity of 93.8% (15 of 16), specificity of 85.7% (18 of 21), PPV of 83.3% (15 of 18), NPV of 94.7% (18 of 19), and accuracy of 89.2% (33 of 37) for direct MR arthrographic evaluation of the superior labrum (Table 1).

Anterior and anteroinferior labrum.—Tears of the anterior and anteroinferior labrum were identified at arthroscopy in 17 of 37 patients. All of these tears were correctly identified at direct MR arthrography (Figs 4, 5) (no false-negative, three false-positive, and 17 true-negative instances) (Fig 6). This resulted in a sensitivity of 100% (17 of 17), specificity of 85% (17 of 20), PPV of 85% (17 of 20), NPV of 100% (17 of 17), and accuracy 91.9% of (34 of 37) for direct MR arthrographic evaluation of the anterior and anteroinferior labrum (Table 1).

Posterior and posteroinferior labrum.—Two tears of the posterior and posteroinferior labrum in two of 37 patients were seen at arthroscopy, and both tears were identified at direct MR arthrography (Fig 7) (no false-negative, one false-positive [Fig 8], and 34 true-negative instances). This resulted in a sensitivity of 100% (two of two), specificity of 97.1% (34 of 35), PPV of 66.7% (two of three), NPV of 100% (34 of 34), and accuracy of 97.3% (36 of 37) for direct MR arthrographic evaluation of the posterior and posteroinferior labrum (Table 1).

Overall labrum.—When any labral tear was considered per patient, a total of 26 of 37 patients had labral tears. Twenty-five of these patients were identified at direct MR arthrography (one false-negative, two false-positive, and nine true-negative instances). This resulted in a sensitivity of 96.2% (25 of 26), specificity of 81.8% (nine of 11), PPV of 92.6% (25 of 27), NPV of 90% (nine of 10), and accuracy of 91.9% (34 of 37) for overall direct MR arthrographic evaluation of the labrum (Table 1).

Figure 4



a. b.

Figure 4: **(a)** Transverse and **(b)** sagittal T1-weighted fat-suppressed SE (500/15) MR arthrographic images of right shoulder in 18-year-old man with recurrent right shoulder instability after anterior instability and Bankart repair 1 year previously. **(a)** Fibrocartilagenous anteroinferior labral tear was diagnosed at MR arthrography and at surgery. Anterior and anteroinferior labrum (arrow) is displaced medially along anterior glenoid and is globular in appearance. **(b)** A cleft of contrast material (arrow) is seen beneath displaced anterior and anteroinferior labral fragment.

There was no significant association between patient age (P = .918), sex (P = .174), side of surgery (P = .694), and number of prior surgeries (P = .716) and the presence of recurrent labral injury.

When we compared type of previous surgery with residual or recurrent injury at each labral location, the following results were obtained: 18 patients had undergone prior capsular stabilization surgery (two patients were excluded because of artifact), and, among these patients, there were eight true-positive, seven true-negative, one false-positive, and no false-negative findings at direct MR arthrographic evaluation of the anterior and anteroinferior labrum. Thirteen patients had undergone prior anteroinferior labral repair, and, among these patients, there were seven true-positive, five true-negative, one false-positive, and no false-negative findings at direct MR arthrographic evaluation of the anterior and anteroinferior labrum. Eight patients had undergone prior superior labral repair, and, among these patients, there were six true-positive, one true-negative, one false-positive, and no false-negative findings at direct MR arthrographic evaluation of the superior labrum. Two patients had undergone prior posterior labral repair, and, among these patients, there

Figure 5

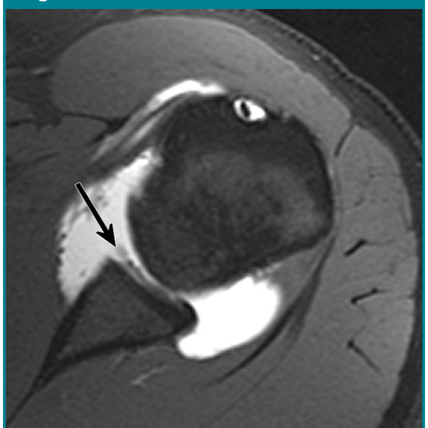


Figure 5: Transverse T1-weighted fat-suppressed SE (500/15) MR arthrographic image of left shoulder in 24-year-old man with recurrent left shoulder instability after two prior instability repairs, with most recent surgery 8 years previously. Fibrocartilagenous anteroinferior labral tear was diagnosed at MR arthrography and surgery. Anterior and anteroinferior labrum (arrow) is markedly diminutive or absent.

Figure 6

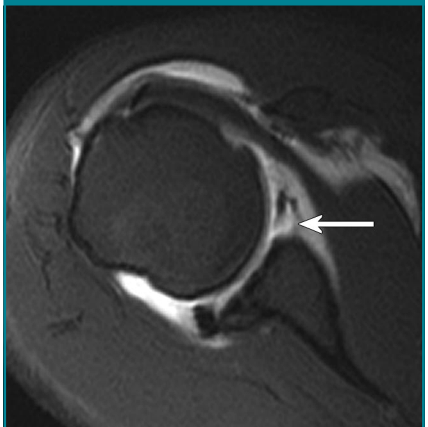


Figure 6: Transverse T1-weighted fat-suppressed SE (500/15) MR arthrographic image of right shoulder in 40-year-old woman with recurrent right shoulder instability after instability repair 24 years previously. Fibrocartilagenous anteroinferior labral tear was diagnosed at MR arthrography; however, at surgery no soft-tissue labral injury was identified, consistent with a false-positive case. There is truncation of anterior and anteroinferior labrum, with a cleft of contrast material (arrow) and displacement of labral tissue anteriorly.

were no true-positive, one true-negative, one false-positive, and no false-negative findings at direct MR arthrographic evaluation of the posterior labrum (Table 2).

Rotator Cuff Injury

Supraspinatus tendon.—Twelve of 39 patients had surgically proved abnormalities of the supraspinatus tendon (eight partial- and four full-thickness tears); all abnormalities were identified at direct MR arthrography (Figs 9, 10) (no false-negative, three false-positive, and 24 true-negative findings). This resulted in a sensitivity of 100% (12 of 12), specificity of 88.9% (24 of 27), PPV of 80% (12 of 15), NPV of 100% (24 of 24), and accuracy of 92.3% (36 of 39) for direct MR arthrographic evaluation of the supraspinatus tendon (Table 3).

Infraspinatus tendon.—Two of 39 patients had surgically proved abnormalities of the infraspinatus tendon (no partial- and two full-thickness tears); both abnormalities were identified at direct MR arthrography (no false-positive or false-negative instances and 37 true-negative instances). This resulted in a sensitivity (two of two), specificity (37 of 37), PPV (two of two), NPV (37 of 37), and accuracy of 100% (39 of 39) for direct MR arthrographic evaluation of the infraspinatus tendon (Table 3).

Subscapularis tendon.—Six of 39 patients had surgically proved abnormalities of the subscapularis tendon (two partial- and four full-thickness tears), and five of these abnormalities were identified at direct MR arthrography (Fig 11) (one false-negative, three false-positive, and 30 true-negative findings). This resulted in a sensitivity of 83.3% (five of six), specificity of 90.9% (30 of 33), PPV of 62.5% (five of eight), NPV of 96.8% (30 of 31), and accuracy of 89.7% (35 of 39) for direct MR arthrographic evaluation of the subscapularis tendon (Table 3).

Teres minor tendon.—There were no surgically proved abnormalities of the teres minor tendon, with 39 true-negative instances. Sensitivity and PPV were not calculated (denominator of 0). However, this resulted in a specificity, NPV, and accuracy of 100% (39 of 39) for direct MR arthrographic evaluation of the teres minor tendon (Table 3).

Overall rotator cuff.—When any rotator cuff abnormality was considered per patient, there were 17 of 39 patients with rotator cuff abnormalities (partial- and/or full-thickness tears). Abnormalities in 16 of 17 patients were identified at direct MR arthrography (one false-negative, four false-positive, and 18 true-negative findings). This resulted in a sensitivity of 94.1% (16 of 17), specificity of 81.8% (18 of 22), PPV of 80% (16 of 20), NPV of 94.7% (18 of 19), and accuracy of 87.2% (34 of 39) for overall direct MR arthrographic evaluation of the rotator cuff (Table 3).

Generalized Estimating Equations

Using generalized estimating equations, we found that the overall sensitivity of MR arthrography for labral injuries was 97.1% (95% confidence interval [CI]: 80.9%, 99.6%), and specificity was 90.8% (95% CI: 81.3%, 95.7%). For the rotator cuff, overall sensitivity was 95.6% (95% CI: 91.0%, 97.9%), and specificity was 95.0% (95% CI: 71.6%, 91.3%). Age, sex, and time since most recent surgery did not have a significant

Figure 7

Figure 7: Transverse T1-weighted fat-suppressed SE (500/15) MR arthrographic image of right shoulder in 21-year-old man with recurrent right shoulder pain and instability after instability repair 6 months previously. Fibrocartilagenous posteroinferior labral tear was diagnosed at MR arthrography and surgery. A cleft of contrast material (arrow) is seen in posterior and posteroinferior labrum, consistent with a tear.

Figure 8

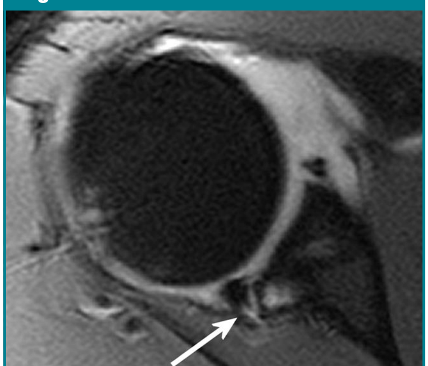


Figure 8: Transverse T1-weighted fat-suppressed SE (500/15) MR arthrographic image of right shoulder in 27-year-old man with recurrent right shoulder instability after posterior labral repair 2 years previously. Posteroinferior labral tear was diagnosed at MR arthrography, but no tear was identified at surgery, consistent with a false-positive case. There was metallic artifact (arrow) related to prior surgery, which caused the appearance of a tear.

Figure 9

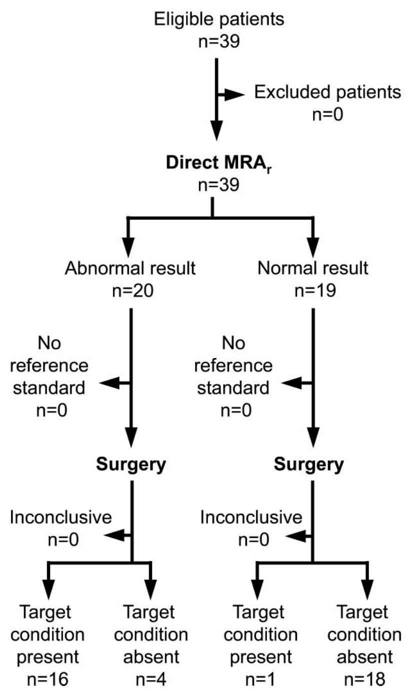


Figure 9: Flow diagram shows patients in study for overall rotator cuff injury. *MRA$_r$* = MR arthrography.

Figure 10

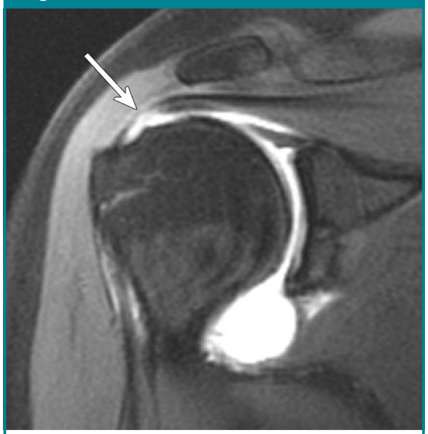
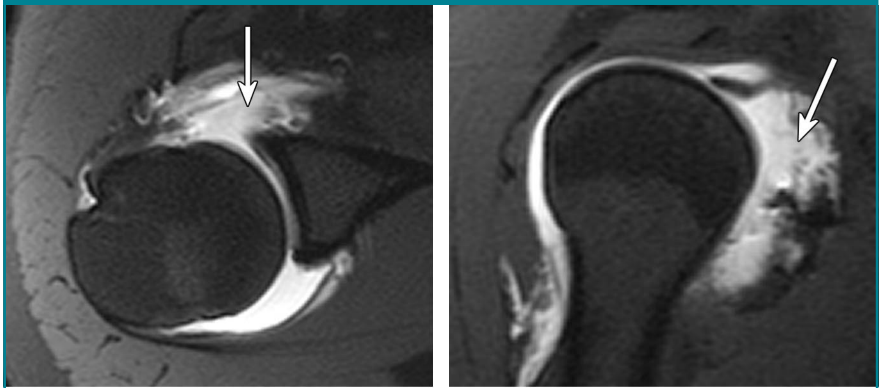


Figure 10: Coronal T1-weighted fat-suppressed SE (500/15) MR arthrographic image of right shoulder in 28-year-old woman with recurrent right shoulder pain, impingement, and instability after instability repair 5 years previously. Partial articular-sided tear (arrow) of supraspinatus tendon was diagnosed at MR arthrography, with contrast material seen to track partway through tendon. Partial articular-sided tear of supraspinatus tendon was diagnosed at surgery.

Figure 11



a. b.

Figure 11: **(a)** Transverse and **(b)** sagittal T1-weighted fat-suppressed SE (500/15) MR arthrographic images of right shoulder in 29-year-old woman with recurrent right shoulder pain, instability, and a positive finding at lift-off testing for subscapularis integrity after two prior instability repairs, with most recent surgery 3 years previously. Full-thickness tear of subscapularis tendon was diagnosed at MR arthrography and arthroscopy. Full-thickness defect (arrows) in middle subscapularis tendon is seen, with tracking of contrast material through defect.

Table 2

Correlation of Type of Prior Surgery with Residual or Recurrent Injury

Prior Surgery	No. of True-Positive Findings	No. of True-Negative Findings	No. of False-Positive Findings	No. of False-Negative Findings
	Anteroinferior Labral Tear			
Capsular stabilization (n = 18)*	8	7	1	0
Anteroinferior labral repair (n = 13)	7	5	1	0
	Superior Labral Recurrent or Residual Tear			
Superior labral repair (n = 8)	6	1	1	0
	Posterior Labral Recurrent or Residual Tear			
Posterior labral repair (n = 2)	0	1	1	0

* Two patients excluded because of artifact.

effect on sensitivity or specificity for either rotator cuff or labral injuries.

LHB Tendon

Status of the LHB tendon was described in surgical reports for 23 of 39 patients. Seven of 23 patients had surgically proved LHB abnormalities (six partial tears and one complete tear), and six of seven abnormalities were diagnosed at direct MR arthrography (one false-negative, no false-positive, and 16 true-negative findings). This resulted in a sensitivity of 85.7% (six of seven), specificity of 100% (16 of 16), PPV of 100% (six of six), NPV of 94.1% (16 of 17), and accuracy of 95.7% (22 of 23) for direct MR arthrographic evaluation of the LHB tendon (Table 4).

Hill-Sachs Injury

The presence or absence of a Hill-Sachs lesion was described in surgical reports for 15 of 39 patients. Fourteen of 15 lesions were identified at arthroscopy, and all were diagnosed at direct MR arthrography (no false-negative or true-negative findings and one false-positive finding). NPV was not calculated (denominator of 0). This resulted in a sensitivity of 100% (14 of 14), specificity of 0% (zero of one), PPV of 93.3% (14 of 15), and accuracy of 93.3% (14 of 15) for direct MR arthrographic evaluation of the presence or absence of a Hill-Sachs lesion (Table 4).

Figure 12

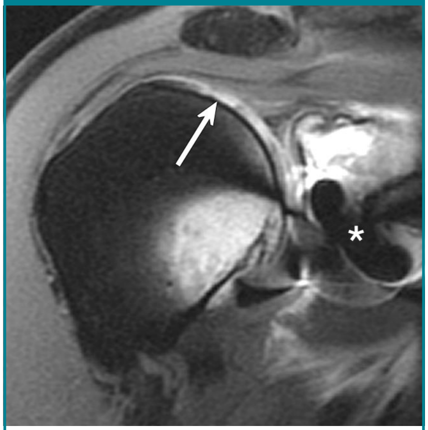


Figure 12: Coronal T1-weighted fat-suppressed SE (500/15) MR arthrographic image of right shoulder in 50-year-old man with recurrent right shoulder pain and instability after instability repair 3 years previously. Defect (arrow) of humeral articular cartilage was diagnosed at MR arthrography and surgery. Note metallic artifact (∗) related to prior staple capsulorrhaphy.

Humeral and/or Glenoid Articular Cartilage

Status of the glenoid and/or humeral articular cartilage was described in 21 of 39 surgical reports. Fifteen of 21 patients had surgically proved abnormalities of the glenoid and/or humeral articular cartilage, and 11 of 15 abnormalities were diagnosed at direct MR arthrography (Fig 12) (four false-negative, one false-positive, and five true-negative findings). This resulted in a sensitivity of 73.3% (11 of 15), specificity of 83.3% (five of six), PPV of 91.7% (11 of 12), NPV of 55.6% (five of nine), and accuracy of 76.2% (16 of 21) for direct MR arthrographic evaluation of the presence or absence of humeral and/or glenoid articular cartilage abnormalities (Table 4).

Discussion

MR arthrography is accurate for the presurgical evaluation of patients with glenohumeral instability (9). Postsurgical conventional MR imaging (10,15) and MR arthrographic (1,2) findings of the glenohumeral joint, capsule, and labroligamentous complex have been described. Direct MR arthrography enables capsular distention and improved contrast resolution in the postsurgical shoulder (1,15).

In our study, recurrent labral tears were diagnosed at direct MR arthrography in patients with prior shoulder instability repair, with a sensitivity and specificity similar to those reported in the literature on the diagnosis of labral tears in patients without prior surgery (16,17). This was unanticipated because MR imaging evaluation of the postsurgical labrum is complicated by morphologic and signal intensity changes resulting from prior surgery (1).

One false-negative case involved a 2-mm SLAP tear reported at surgery that was possibly too small for detection at direct MR arthrography. In one of the three false-positive instances, there was a 14.3-month delay between direct MR arthrography and revision surgery, with possible interval healing. Metallic artifact obscured labral visualization in two instances. This was uncommon because nonmetallic or bioabsorbable suture anchors were used in most patients (6). However, metallic artifact resulted in a

Table 3

Rotator Cuff Abnormality at MR Arthrography

Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Any rotator cuff abnormality	94.1 (16/17)	81.8 (18/22)	80 (16/20)	94.7 (18/19)	87.2 (34/39)
Supraspinatus tendon abnormality	100 (12/12)	88.9 (24/27)	80 (12/15)	100 (24/24)	92.3 (36/39)
Infraspinatus tendon abnormality	100 (2/2)	100 (37/37)	100 (2/2)	100 (37/37)	100 (39/39)
Subscapularis tendon abnormality	83.3 (5/6)	90.9 (30/33)	62.5 (5/8)	96.8 (30/31)	89.7 (35/39)
Teres minor tendon abnormality	NA	100 (39/39)	NA	100 (39/39)	100 (39/39)

Note.—Data in parentheses are numbers of rotator cuff abnormalities used to calculate percentages. NA = not applicable.

Table 4

Biceps, Hill-Sachs, or Glenoid and/or Humeral Articular Cartilage Abnormality at MR Arthrography

Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Biceps abnormality	85.7 (6/7)	100 (16/16)	100 (6/6)	94.1 (16/17)	95.7 (22/23)
Hill-Sachs injury	100 (14/14)	0 (0/1)	93.3 (14/15)	NA	93.3 (14/15)
Glenoid and/or humeral articular cartilage abnormality	73.3 (11/15)	83.3 (5/6)	91.7 (11/12)	55.6 (5/9)	76.2 (16/21)

Note.—Data in parentheses are numbers of abnormalities used to calculate percentages. NA = not applicable.

false-positive finding for a posterior labral tear.

Anteroinferior labral tears were most common, followed by superior labral tears. SLAP lesions can cause, or result from, glenohumeral instability (18); not surprisingly, these labral injuries occurred with similar frequency in patients with recurrent shoulder instability. When we correlated location of prior surgery with recurrent or residual injury in each labral location, we found that there was a relatively high number of true-positive and true-negative instances for the anteroinferior and superior labrum that occurred with similar frequencies. Small sample sizes limited further statistical analysis.

Our results are within the ranges previously reported for the diagnosis of rotator cuff tears (19). Rotator cuff abnormalities were overestimated, possibly because tendon signal intensity changes related to prior surgery were interpreted as partial tears. The capsule should be watertight after stabilization surgery, although not necessarily after rotator cuff repair (20). Patients who had undergone prior rotator cuff repair in addition to prior stabilization surgery were not separately assessed. Small rotator cuff defects in these patients may be "normal" postsurgical MR imaging findings and are of uncertain clinical importance (21–23).

For LHB tendon evaluation, one false-negative case involved a large displaced SLAP tear that was correctly identified at MR arthrography. Displacement may have distorted the biceps anchor, which limited visualization. Direct MR arthrography had high specificity and accuracy for LHB tendon assessment.

MR imaging is very accurate for Hill-Sachs lesion evaluation (13), demonstrating in some instances perfect correlation (24). While Hill-Sachs lesions may be related to previous instability, we included this analysis because the presence or absence of Hill-Sachs lesions can be useful for surgical planning.

Articular cartilage lesions occur frequently but are rarely diagnosed and are diagnosed with variable accuracy at MR arthrography (14). Thin glenohumeral cartilage makes subtle surface irregularities and signal intensity changes difficult to diagnose (14). Our results for the evaluation of humeral and glenoid articular cartilage lesions are within the ranges reported in the literature (14). Sequences to enhance detection of cartilage defects (ie, fat-suppressed three-dimensional spoiled gradient echo) were not employed in our routine direct MR arthrographic protocol.

Limitations of our study included incomplete details regarding the initial injury, previous surgery, and cause and type of recurrent or residual instability. Prior rotator cuff and LHB tendon injury and related symptoms were unknown. However, these structures were evaluated, given the importance for surgical planning. Prior MR imaging studies were not available for review because all patients were referred to our tertiary care center for revision assessment and repair. This reflects the retrospective nature of the study; however, it is often the scenario faced by clinicians in daily practice. Surgical reports were limited for LHB tendon abnormality, Hill-Sachs injury, and cartilage analysis. There was a large range between MR imaging and subsequent surgery (up to 36 months); however, 25 patients had undergone surgery within 6 months and 36 patients had undergone surgery within 12 months after MR imaging.

Our sample size was relatively small, although it was larger than previously published reports. Readers were aware that all patients being reviewed presented with signs and symptoms of recurrent instability after prior instability repair, causing potential diagnostic bias. However, this bias is faced in clinical day-to-day scenarios when such patients are evaluated. Only patients undergoing subsequent surgery were included, creating potential bias because prospective MR arthrographic results may have influenced the decision to proceed or defer surgery. A larger prospective study would be a useful future study.

In conclusion, direct MR arthrography is accurate (91.9%) in the diagnosis of pathologic labral conditions in patients with recurrent or residual symptoms after prior shoulder instability repair. It is also accurate for depicting rotator cuff tendon injury (87.2%), Hill-Sachs lesions (93.3%), and LHB tendon abnormalities, as well as glenoid and/or humeral articular cartilage abnormalities (76.2%), in this unique and challenging patient population.

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