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Indirect MR arthrography of the shoulder in detection of rotator cuff ruptures

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Abstract The aim of this study was to compare the efficacy of indirect MR arthrography images obtained following intravenous contrast injection and conventional MR imaging in the diagnosis of rotator cuff tears. Twenty-four patients with clinically suspected rotator cuff disease were examined. Conventional MR images and post-contrast indirect MR arthrography images were obtained. All images were evaluated in a blinded fashion by two musculoskeletal radiologist. Results were than analyzed depending on surgical output. The correlation coefficient (Spearman rank correlation test) and the kappa values for agreement between surgery and imaging techniques were calculated. The correlation coefficients between indirect MR arthrography and surgery for reader 1 and reader 2 were 0.9137 and 0.9773, respectively. Whereas the agreement between conventional MR imaging and surgery was moderate ($\varkappa$ = 0.383–0.571), the agreement between indirect MR arthrography and surgery was excellent ($\varkappa$ = 0.873–0.936). We suggest the use of indirect MR arthrography technique when conventional MR images are equivocal in diagnosis of rotator cuff disease.

Key words Magnetic resonance imaging · Indirect MR arthrography · Shoulder · Rotator cuff rupture

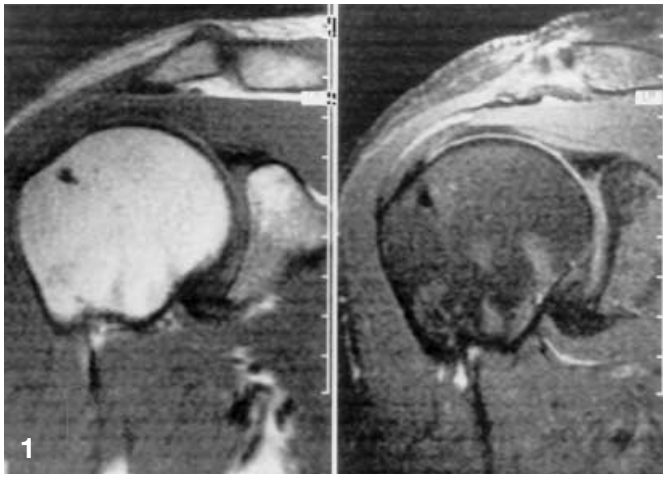
Introduction

Shoulder pain is a common clinical problem with numerous causes, including glenohumeral joint instability, subacromial impingement, and rotator cuff tendon failure [1]. These changes can be misdiagnosed clinically. In the absence of a precise diagnosis, treatment may fail to relieve the symptoms, resulting in chronic limitation of motion, atrophy, and persistent pain.

Magnetic resonance imaging has been shown to be accurate in the detection of these shoulder pathologies [2, 3]. Complete rotator cuff tears generally are easily diagnosed on MR images. Nevertheless, in some cases differentiation among complete rotator cuff tears, partial tears, tendinopathy, and degeneration is difficult [4, 5].

In MR imaging of shoulder, diagnostic success requires delineation of complex anatomic structures and demonstration of subtle abnormalities. Magnetic resonance arthrography extends the capabilities of conventional MR imaging because intra-articular contrast material outlines abnormalities. However, direct intra-articular injection of saline or paramagnetic contrast material is invasive and is complicated by the need for fluoroscopic guidance. It has recently been shown that intravenously administered gadopentetate dimeglumine also enhances the joint cavity [6]. This technique was proposed as a practical alternative to direct MR arthrography [7].

The purpose of this study was to prospectively compare the efficacy of conventional MR imaging and indirect MR arthrography in the diagnosis of rotator cuff tears.



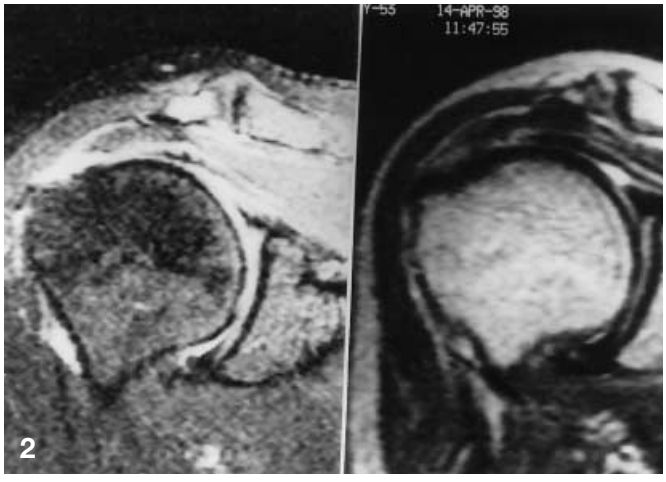


Fig. 1 Comparison of paracoronal T1-weighted SE *(left)* and fat-saturated T1-weighted post-contrast spin-echo *(right)* images. Anatomic contour delineation is superior on fat-saturated T1-weighted post-contrast image as compared with the image without fat suppression and contrast injection. Note contrast accumulation in subdeltoid bursa and glenoid cavity at right image

Fig. 2 T2-weighted paracoronal MR image *(right)* obtained prior to contrast injection and T1-weighted fat-saturated paracoronal image *(left)* at the same level following contrast administration. Note the massif rupture which is more conspicuous on right side but well-delineated on fat-saturated contrast image

Materials and methods

Between August 1997 and June 1998, 24 patients underwent both conventional MR imaging and indirect MR arthrography for clinically suspected labral or rotator cuff abnormalities. Arthroscopy ($n = 1$) or open surgery ($n = 23$) were performed in all of these patients. The patients were 16–73 years old (mean age 52 years; 17 women and 7 men). Informed consent was obtained from each patient.

The MR imaging was performed with a 1.0-T superconductive magnet (Magnetom SP 42, Siemens, Erlangen, Germany) and a shoulder surface coil. Firstly, standard unenhanced MR images were obtained. Imaging parameters for axial and paracoronal T1-weighted imaging were as follows: TR/TE = 600/15 ms; 160-mm field of view (FOV); 200 × 256 matrix; 3-mm slice thickness; 0.3-mm gap between slices; three signals averaged. Paracoronal T2-weighted images (TR/TE = 2000/25–70 ms) were obtained with a 160-mm FOV, 140 × 256 matrix, 4-mm slice thickness, 0.4-mm interslice gap, and two signals averaged. Parasagittal T2*-weighted gradient-echo fast imaging with steady-state precession (FISP) images (TR/TE/flip angle = 500/12 ms/15°) were obtained with a 160-mm FOV, a 140 × 256 matrix, 4-mm slice thickness, 0.4-mm interslice gap, and five signals averaged. The total duration of this routine conventional MR examination was approximately 35 min.

After routine MR imaging, each patient was imaged with indirect MR arthrography. In this procedure, 0.1 mmol/kg gadopentetate dimeglumine (Magnevist, Schering, Berlin, Germany) was injected intravenously, and the shoulder was exercised for an average 15 min (range 10–20 min). Following the exercise, spin-echo T1-weighted axial images were obtained once more. In addition, frequency-selective fat-suppressed T1-weighted (TR/TE = 975/22 ms) paracoronal and parasagittal images were obtained. Imaging parameters were: 160-mm FOV; 192 × 256 matrix; 3-mm slice thickness; 0.3-mm interslice gap; and two signals averaged. The total examination time of this indirect MR arthrography was approximately 25 min.

The duration between routine MR imaging and indirect MR arthrography examinations was approximately 11 days (range 0–27 days).

Unenhanced and enhanced images were interpreted independently by two experienced musculoskeletal radiologists without benefit of clinical data. Firstly, routine MR images, and 4 weeks later indirect MR arthrograms, were interpreted. Images were evaluated independently for abnormalities of rotator cuff, labrum, and capsular anatomy by using standard criteria established in recent literature.

The duration between indirect MR arthrography examination and surgery was approximately 7 days (range 1–23 days).

Sensitivity, specificity, and accuracy rates were calculated for each technique and reader. The results of MR techniques and surgery were compared using Spearman rank correlation coefficient test. The kappa ($\varkappa$) values for agreement between surgery and imaging techniques, and between readers, were calculated The $\varkappa$ values are interpreted as follows: 0.81–1.00, excellent agreement; 0.61–0.80, good agreement; 0.41–0.60, moderate agreement; 0.21–0.40, fair agreement; and 0.00–0.20, poor agreement.

Results

No complications were associated with intravenous injection of the gadopentetate dimeglumine. Exercises of shoulder were well tolerated by all patients, even in painful shoulders. The intravenous administration of gadopentetate dimeglumine produced marked enhancement of the joint cavity in all patients. Intravenously injected paramagnetic contrast material outlined the surface of rotator cuff (Fig. 1). Complete tears were identified by discontinuity of the tendon (Fig. 2). Partial tears were identified by irregularity of the surface of the cuff without actual discontinuity of the cuff tendon.

According to the surgery reports, there were 10 complete tears, 5 partial tears, and 9 rotator cuffs with

Table 1 Routine MR imaging vs surgery

Routine MR imaging	Surgery			
Reader 1	No tear	Partial tear	Complete tear	Total
No tear	8	2	2	12
Partial tear	0	0	0	0
Complete tear	1	3	8	12
Total	9	5	10	24
Reader 2				
No tear	6	2	1	9
Partial tear	1	0	0	1
Complete tear	2	3	9	14
Total	9	5	10	24

Table 2 Indirect MRA vs surgery

Indirect MRA	Surgery			
Reader 1	No tear	Partial tear	Complete tear	Total
No tear	7	0	0	7
Partial tear	2	5	0	7
Complete tear	0	0	10	10
Total	9	5	10	24
Reader 2				
No tear	8	0	0	8
Partial tear	1	5	0	6
Complete tear	0	0	10	10
Total	9	5	10	24

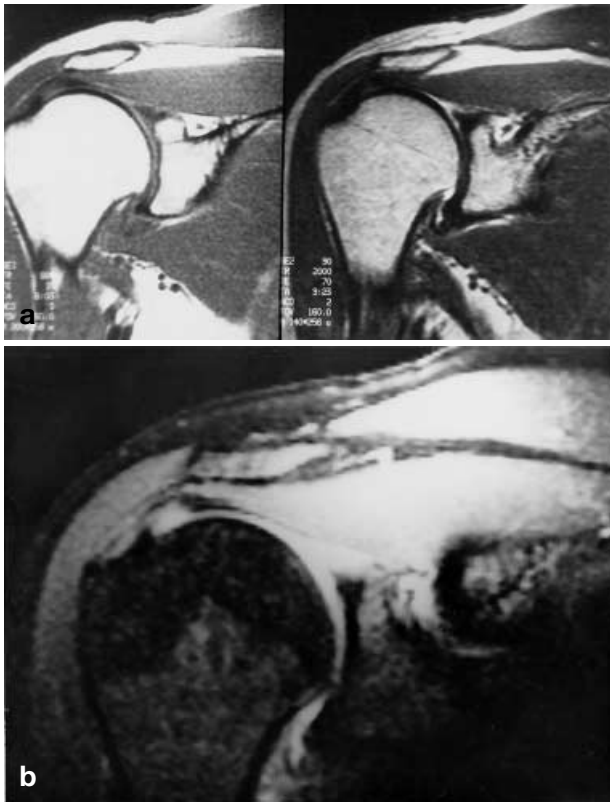


Fig. 3 **a** T1-weighted *(left)* and T2-weighted *(right)* paracoronal right shoulder MR images of the patient with partial rupture. **b** Fat-saturated T1-weighted post-contrast paracoronal image of the same patient at the same level as **a**. There is discontinuity of tendon fibers in articular surface of supraspinatus muscle due to partial rupture. This is seen best in **b**, but is obscure on T1- and T2-weighted images

"no tear" (Table 1). With conventional MR imaging, reader 1 and reader 2 interpreted 12 and 14 complete tears, 0 and 1 partial tears, as well as 12 and 9 rotator cuffs with "no tear", and accuracy rates were 66.7 and 62.5 %, respectively. None of the partial tears were diagnosed accurately with MR imaging. Three of five partial tears were interpreted as complete tear, one as tendinitis, and one normal by both of readers (Fig. 3). Agreement between MR imaging and surgery was moderate ($\varkappa = 0.383$–0.571). Interobserver agreement was good ($\varkappa = 0.760$). Sensitivity and specificity for detection of a cuff tear (partial or complete, together) by readers were 73.3–80.0 % and 88.9–66.7 %, respectively. The correlation coefficients between conventional MR and surgery for reader 1 and reader 2 were 0.8919 and 0.8956.

With indirect MR arthrography, no complete or partial tears were missed; however, three normal cases proven arthroscopically were misdiagnosed as partial tears (2 cases, reader one; 1 case, reader two; Table 2). Accuracy rates were 91.7 and 95.8 %, respectively. Agreement between indirect MR arthrography and surgery was excellent ($\varkappa = 0.873$–0.936). Interobserver agreement was excellent ($\varkappa = 0.936$). Sensitivity and specificity for detection of a cuff tear (partial or complete, together) by readers were 100 % and 77.8–88.9 %, respectively. The correlation coefficients between indirect MR and surgery for reader 1 and reader 2 were 0.9137 and 0.9773, respectively.

There were four rotator interval tears with "no tear" cuff tendons at surgery. With conventional MR imaging, only one of these four cases could be diagnosed by both of readers. With indirect MR arthrography, all four of these cases were diagnosed accurately; however, one case of normal rotator interval was misinterpreted as tear.

In this study there were two cases of Bankart lesion at surgery, which were also accurately detected by both imaging techniques.

Discussion

Evaluation of the labrum and the rotator cuff is often limited to conventional MR imaging. This study compared conventional MR imaging with indirect MR arthrography.

In the patient with suspected rotator cuff disorder, the decision to perform MR arthrography depended on the clinical need to identify and distinguish partial cuff tears from small complete tears. It is important to differentiate full-thickness from partial-thickness tears because treatment is different. Especially in athletes and younger patients in whom surgery would be performed to repair partial cuff tears and remove bony abnormalities of coracoacromial arch, MR arthrography can maximize anatomic resolution and diagnostic confidence.

Intravenous administration of gadolinium has been investigated as an alternative to direct intra-articular injection. The intravascular paramagnetic contrast material that leaks from capillary bed into interstitial space and diffuses from synovium into joint space is responsible for the arthrographic effect of intravenous technique. The rate and amount of diffusion is increased by any exercise of the joint after injection [6, 7, 8].

Movement of the joint is very important to produce a good arthrographic effect. Ten minutes of exercise is sufficient to get a stronger, faster, and homogeneous enhancement. Even in patients with restricted movement ability, mild exercise can be enough to increase signal intensity homogeneously [7, 8, 9].

Diagnostic accuracy is increased when fat-suppressed images are acquired. Partial and full-thickness cuff tears may not be distinguishable on standard T1-weighted images, because fat and gadolinium have similar signal intensities. This results in a poor contrast. The suppression of fat results in considerable increase in contrast between the enhanced joint fluid and surrounding soft tissues [8, 9, 10, 11].

Previously reported sensitivity and specificity for the interpretation of complete tears are 84–100 and 93–99 %, and for partial tears 35–92 and 85–97 %, respectively [5].

In our study sensitivity and specificity for the diagnosis of any rotator cuff tear (partial or complete) were 73.3–80.0 and 66.7–88.9 %, respectively, with conventional MR imaging; however, MR imaging was insensitive for partial cuff tears (0 of 5) in our patient group. Partial tears were misdiagnosed as normal (l of 5), tendinitis (1 of 5), or full-thickness tear (3 of 5), by both readers. A case with "no tear" at surgery was misinterpreted as partial tear by reader 2. Two complete cuff tears were missed by reader 1, and one case was also missed by reader 2. One case of tendinitis was misinterpreted as complete tear by reader 1 and two cases by reader 2. Agreement between MR imaging and surgery was moderate, and interobserver agreement was good. The correlation between MR and surgery were satisfactory for both techniques; however, the correlation coefficient was higher in indirect MR arthrography than in conventional MR imaging. The magnetic field strength and sequences used in this study may be the cause of our major limitations.

In a study of 25 patients by Vahlensieck et al., sensitivity and specificity in the detection of rotator cuff tears were reported as 60 and 70 %, respectively, using sonography; 66 and 100 % with conventional MR imaging; and 100 and 86 % for indirect MR arthrography [12].

In our study sensitivity and specificity for the diagnosis of any rotator cuff tear (partial or complete) were 100 and 77.8–88.9 %, respectively, with indirect MR arthrography. Agreement between indirect MR arthrography and surgery, and interobserver agreement, were excellent.

Two cases with "no tear" at surgery were misinterpreted as partial tear by reader 1 and one case by reader 2. In a surgically "no tear" reported case, both readers misinterpreted as a partial cuff tear, even after they had learned the report of the surgeon.

Intravenous injection of gadolinium creates new diagnostic problems because, normal or abnormal, all vascularized structures, synovial structures such as bursae, and tendon sheaths enhance. This has to be taken into account when analyzing such images. In this false-positive case, the rotator cuff may be enhanced because of an inflammation or granulation tissue and scarring. On the other hand, a shallow partial tear in the articular surface of supraspinatus tendon may not be felt by the surgeon.

The rotator interval refers to the ligamentous region between supraspinatus and subscapularis tendons. The presence of this interval is due to the protrusion of the coracoid process between supraspinatus and subscapularis muscles, which results in an "interval" within the cuff in which there is no tendon [13].

In our study there were four rotator interval tears with "no tear" cuff tendons at surgery. Three of them were referred to our department as shoulder instability, and one case was a patient with impingement clinically. With conventional MR imaging, only one of these four cases was diagnosed by both readers. With indirect MR arthrography, all four cases were diagnosed accurately; however, one case of normal rotator interval was misinterpreted as tear. Indirect MR arthrography seems to be a more sensitive and accurate technique for detection of rotator interval tears.

Rotator interval tear is an uncommon but clinically important subtype of rotator cuff tear. The difficulty in diagnosing rotator interval tears with MR imaging is a reflection of the configuration of the tear and its location within the cuff. Rotator interval tears are thin and

longitudinal, and are not associated with muscle retraction. Interval tears are therefore imaged as a thin band of fluid. However, demonstration of fluid in the interval is not diagnostic because normal synovium and capsule may herniate through this space in the absence of a tear. Differentiation of a true rotator interval tear from normal synovium and capsule in this space may not be possible with MR imaging and indirect MR arthrography.

Due to the limited number of cases with shoulder instability and confirmed labral lesion, in this study we did not compare the efficiency of both techniques in detection of labral pathologies. Nevertheless, intra-articular paramagnetic contrast material that outlined labrum, glenoid cartilage, and glenohumeral ligaments seemed to increase the self-confidence of both radiologists in evaluation of labrum. Sommer et al. reported high sensitivity and specificity values for detection of labral lesions with indirect MR arthrography [14].

According to our findings, in the evaluation of rotator cuff disease, particularly in detection of partial cuff tears, conventional MR imaging has limited diagnostic accuracy and sensitivity. Small partial tears may be misinterpreted as tendinitis, and large ones as full-thickness cuff tears. In indirect MR arthrography, paramagnetic contrast material in the bursal and articular surface outlines rotator cuff tendon and leaks into partial tears; thus, tears missed at conventional MR imaging can be diagnosed accurately.

In conclusion, we suggest use of indirect intravenous MR arthrography technique when conventional MR images are equivocal in diagnosis of rotator cuff disease.

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