Received:
7 January 2016

Revised:
30 March 2016

Accepted:
6 April 2016

<http://dx.doi.org/10.1259/bjr.20160028>

Cite this article as:

Magee T. Utility of pre- and post-MR arthrogram imaging of the shoulder: effect on patient care. *Br J Radiol* 2016; **89**: 20160028.

FULL PAPER

Utility of pre- and post-MR arthrogram imaging of the shoulder: effect on patient care

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Objective: MR arthrogram imaging of the shoulder is considered more accurate in assessing shoulder pathology than conventional MRI. Arthrography is a minimally invasive procedure. However, most patients prefer to have conventional MRI rather than MR arthrogram imaging. We report the benefit of assessing pre-arthrogram conventional MRI, to determine whether an MR arthrogram is needed for further evaluation.

Methods: 100 consecutive conventional shoulder MR and MR arthrography examinations performed on the same patients were reviewed retrospectively by independent reading of 2 musculoskeletal radiologists. Both conventional MR and MR arthrogram examinations were performed on each patient on the same day. Conventional MR and MR arthrogram examinations were assessed for labral tears and supraspinatus tendon tears. All patients went on to arthroscopy.

Results: Of these 100 patients, 43 patients had superior labral anterior to posterior (SLAP) tears, 28 patients had posterior labral tears, 23 patients had anterior labral tears and 47 patients had full-thickness supraspinatus tendon tears on conventional MR examination reading by Reader 1. There were 42 SLAP tears, 26 posterior labral tears, 24 anterior labral tears and 47 full-thickness supraspinatus tendon tears on conventional MR examination read by Reader 2. On MR arthrogram examination, 51 patients had SLAP tears, 33 patients had posterior labral tears, 29 patients had anterior labral tears and 49 patients had full-thickness supraspinatus tendon tears

on reading by Reader 1. On MR arthrogram examination, 50 patients had SLAP tears, 31 patients had posterior labral tears, 30 patients had anterior labral tears and 49 patients had full-thickness supraspinatus tendon tears read by Reader 2. MR arthrogram detected eight SLAP tears, five posterior labral tears, six anterior labral tears and two supraspinatus tendon tears not detected on conventional MR examination read by Reader 1. MR arthrogram detected eight SLAP tears, five posterior labral tears, six anterior labral tears and two supraspinatus tendon tears not detected on conventional MR examination read by Reader 2. 18 of the 21 patients with additional finding on MR arthrogram examination had normal appearing conventional MR examinations.

Conclusion: Use of pre- and post-MR arthrogram imaging may benefit patient care. When positive findings are demonstrated on MR examination, few additional findings are demonstrated on MR arthrogram examination. These patients may not need to proceed to MR arthrography. If the conventional MR examination is negative, then additional information may be obtained by proceeding to MR arthrography.

Advances in knowledge: When positive findings are demonstrated on MR examination, few additional findings are demonstrated on MR arthrogram examination. These patients may not need to proceed to MR arthrography. If the conventional MR examination is negative, then additional information may be obtained by proceeding to MR arthrography.

INTRODUCTION

MRI and MR arthrography have been shown to be highly accurate in the detection of rotator cuff and labral pathology.¹ A previous study demonstrated 98% sensitivity and 96% specificity for MRI detection of full-thickness rotator cuff tears, as compared with arthroscopy.² High sensitivity and specificity for the detection of labral tears as compared with arthroscopy with 3-T MRI has been reported.³ High sensitivity and specificity for the detection of labral tears at 1.5 T has also been reported.^{4,5}

A previous study demonstrated higher accuracy with MR arthrography than with conventional MR in a group of professional baseball players.⁶ Previous studies have demonstrated MR arthrography to have higher accuracy in the detection of labral tears than conventional MR examination.⁷⁻⁹

Based on the above findings, some researchers have advocated that MR arthrography be performed on all patients undergoing shoulder MRI.¹⁰ However, some patients may

be hesitant to undergo an invasive examination. Shoulder arthrography is commonly associated with post-procedural discomfort. It has been previously reported that shoulder discomfort post arthrography peaks at 12 h post procedure. This has been postulated to be a result of joint distension and the hyperosmolar contrast injected into the joint.¹¹ Both Gusmer et al⁴ and Hodler et al¹² stated that MR arthrography is an invasive procedure, limiting its wide acceptance.¹³

In this study, we sought to determine in which patient population 3-T MR arthrography demonstrates additional clinically relevant findings as compared with conventional 3-T MR. To address this question, we designed this study to look at both conventional MRI and MR arthrography in the same patient population and compare the results with arthroscopy. We report the benefit of assessing pre-arthrogram conventional MRI, to determine whether an MR arthrogram is needed for further evaluation.

METHODS AND MATERIALS

100 consecutive conventional shoulder MR and MR arthrography examinations performed between July 2014 and February 2015 on patients presenting with shoulder pain who went on to arthroscopy were retrospectively read independently by 2 musculoskeletal radiologists. All patients were referred from one orthopaedic group. The age range of the 100 patients was 21–73 years (mean, 49 years). Patients with post-operative shoulder were excluded from this study.

There were 61 male patients and 39 female patients. Surgery was performed on all patients within 72 days of the MR examination (range 4–72 days), with a mean time of 24 days between MR examination and surgery. All MR and MR arthrogram examinations were read prospectively by one of three musculoskeletal radiologists with over 15 years' experience. Institutional review board approval was obtained for this retrospective review and correlation with surgical records.

All patients were scanned in oblique coronal, oblique sagittal and axial planes on a 3.0-T GE Signa MR scanner (General Electric Medical Systems, Milwaukee, WI). Oblique coronal and sagittal fast spin-echo T_1 weighted [repetition time (TR)/echo time (TE), 550/10; number of excitations (NEX) of 2], oblique coronal and sagittal fast spin-echo fat-saturated T_2 weighted (TR/TE, 3850/55; NEX of 4) and fast spin-echo fat-saturated proton density axial (TR/TE, 3250/55; NEX of 3) sequences with a field of view of 12 cm on all images were used. Slice thickness was 4 mm with a 10% interslice gap on all sequences except for the fast spin-echo proton density axial sequence, which had 3-mm slice thickness. The echo train length was 10 on all T_2 weighted and proton density sequences and 3 on the T_1 weighted sequences. The bandwidth was 31.25 kHz on all sequences. The imaging time for the oblique coronal and sagittal T_2 weighted sequences was 4 min and 43 s. The imaging time for the proton density axial sequences was 3 min and 26 s, while the imaging time for the T_1 weighted sequences was 2 min and 28 s. The matrix for all T_2 weighted sequences was 320×320 and the matrix for all T_1 weighted sequences was 320×256 . A USA Instruments three-channel phased array shoulder coil (USA Instruments, Aurora, OH) was used.¹⁴

All patients also had MR arthrography performed immediately after the conventional MR examination. Pre- and post-arthrogram imaging is routinely performed in our institution. MR arthrography was performed with approximately 15 cm³ of a dilute Magnevist/saline mixture (Berlex Laboratories, NJ) with a concentration of 0.15 cm³ of Magnevist per 20 cm³ of normal saline. A 22-gauge needle was placed under fluoroscopic guidance into the glenohumeral joint *via* an anterior approach. The injection was performed by one of three musculoskeletal radiologists. The shoulder was exercised post injection and T_1 (TR 677, TE 12) fat-saturated oblique coronal, oblique sagittal and axial images were obtained. T_1 (TR 677, TE 12) fat-saturated oblique coronal images were taken prior to MR arthrography for direct comparison with images after MR arthrography. The imaging time for the T_1 weighted sequences was 2 min and 28 s. All MR arthrography images were performed with a 12-cm field of view and a 4-mm slice thickness (with a 10% interslice gap).

All 100 MR examinations were retrospectively reviewed by independent reading of 2 musculoskeletal radiologists each with over 10 years' experience in reading musculoskeletal MR examinations. The readers were blinded to arthroscopic findings at the time of consensus review. Retrospective MR readings were then correlated with arthroscopic results ($N=100$). The surgeons knew the prospective MR interpretations prior to arthroscopy. Retrospective reviews of conventional MR and MR arthrogram examinations were performed in separate sessions. Reviewers were blinded to names of patients, prospective MR reports and arthroscopy results.

MR and MR arthrography examinations were assessed for superior labral anterior to posterior (SLAP) tears and anterior or posterior labral tears. The MR criterion used for the diagnosis of labral tear was an abnormality of the glenoid labrum morphology and/or signal intensity. Labral tears were diagnosed on MR examination, when there was high signal intensity on T_2 weighted images in the labrum and/or an irregular or detached labrum. A SLAP tear was defined as superior labral irregularity and/or high signal on T_2 weighted images within the superior labrum.¹⁰ SLAP tears that extended anteriorly were defined as SLAP tears and not anterior labral tears. An anterior or posterior labral tear was defined as an area of abnormal increased signal on T_2 weighted images in the labrum and/or an irregular or detached labrum. The MR arthrography criterion for a labral tear also included high signal intensity within the labrum owing to gadolinium extending into the labrum on T_1 fat-saturated images.

The images were reviewed for the presence or absence of anterior labral, posterior labral or SLAP tears and were not graded: *i.e.* on retrospective review, images were not graded for high- or low-grade SLAP or detached or non-detached labral tears but rather whether lesions were present or not.

RESULTS

Of the 100 patients, 43 patients had SLAP tears, 28 patients had posterior labral tears, 23 patients had anterior labral tears and 47 patients had full-thickness supraspinatus tendon tears on conventional MR reading by Reader 1 (Table 1).

Table 1. Findings on MRI vs MR arthrogram as compared with arthroscopy for Reader 1

	SLAP tear	Anterior labral tear	Posterior labral tear	Supraspinatus tendon tear
MR	43	23	28	47
MR arthrogram	51	29	33	49
Additional findings on MR arthrogram vs MR	8	6	5	2
Arthroscopy	52	31	34	49

SLAP, superior labral anterior to posterior.

Of these 100 patients, 42 patients had SLAP tears, 26 patients had posterior labral tears, 24 patients had anterior labral tears and 47 patients had full-thickness supraspinatus tendon tears on conventional MR reading by Reader 1 (Table 2).

On MR arthrogram examination, 51 patients had SLAP tears, 33 patients had posterior labral tears, 29 patients had anterior labral tears and 49 patients had full-thickness supraspinatus tendon tears on reading by Reader 1 (Table 1). On MR arthrogram examination, 50 patients had SLAP tears, 31 patients had posterior labral tears, 30 patients had anterior labral tears and 49 patients had full-thickness supraspinatus tendon tears on reading by Reader 2 (Table 2).

Sensitivities and specificities for MR readings of Reader 1 vs arthroscopy were as follows: SLAP tears were 83% sensitive and 100% specific, the anterior labral tear was 74% sensitive and 100% specific, the posterior labral tear was 82% sensitive and 100% specific and the supraspinatus tendon tear was 96% sensitive and 100% specific. Sensitivities and specificities for MR arthrogram readings of Reader 1 vs arthroscopy were as follows: SLAP tears were 98% sensitive and 100% specific, the anterior labral tear was 94% sensitive and 100% specific, the posterior labral tear was 97% sensitive and 100% specific and the supraspinatus tendon tear was 100% sensitive and 100% specific (Table 3).

Sensitivities and specificities for MR readings of Reader 2 vs arthroscopy were as follows: SLAP tears were 81% sensitive and 100% specific, the anterior labral tear was 77% sensitive and 100% specific, the posterior labral tear was 76% sensitive and 100% specific and the supraspinatus tendon tear was 96% sensitive and 100% specific. Sensitivities and specificities for MR arthrogram readings of Reader 1 vs arthroscopy were as follows: SLAP tears

were 96% sensitive and 100% specific, the anterior labral tear was 97% sensitive and 100% specific, the posterior labral tear was 91% sensitive and 100% specific and the supraspinatus tendon tear was 100% sensitive and 100% specific (Table 4).

The MR arthrogram detected eight SLAP tears, five posterior labral tears, six anterior labral tears and two supraspinatus tendon tears not detected on conventional MR examination for both Readers 1 and 2. There were two anterior labral tears, one SLAP tear and one posterior labral tear seen at arthroscopy not seen on MR or MR arthrography examination for Reader 1 (Table 1) and there was one anterior labral tear, two SLAP tears and three posterior labral tears seen at arthroscopy not seen on MR or MR arthrography examination for Reader 2 (see Table 2).

In this study, MR arthrography demonstrated abnormalities in 21 patients that were not seen on conventional MR examination. 18 of these 21 patients had normal appearing conventional MR examinations. When an abnormality was seen on conventional MR examination, very few additional findings were demonstrated on MR arthrography. Three patients with abnormalities on conventional MR examination demonstrated additional findings on MR arthrography.

18 of the 21 patients with additional findings on MR arthrogram examination had normal appearing conventional MR examinations. 48 patients had normal appearing conventional MR examinations. Normal appearing conventional MR examinations were those that did not have a labral tear or supraspinatus tendon tear. 18 (37%) of these 48 patients had additional findings on MR arthrogram examination. 52 patients had abnormalities on conventional MR examination. 3 (6%) of these 52 patients had additional findings on MR arthrography (Figures 1–4).

Table 2. Findings on MRI vs MR arthrogram as compared with arthroscopy for Reader 2

	SLAP tear	Anterior labral tear	Posterior labral tear	Supraspinatus tendon tear
MR	42	24	26	47
MR arthrogram	50	30	31	49
Additional findings on MR arthrogram vs MR	8	6	5	2
Arthroscopy	52	31	34	49

SLAP, superior labral anterior to posterior.

Table 3. Sensitivity and specificity of MR and MR arthrogram readings vs arthroscopy for Reader 1

	Sensitivity vs arthroscopy	Specificity vs arthroscopy
SLAP on MR examination	83%	100%
SLAP on MR arthrogram examination	98%	100%
Anterior labral tear on MR examination	74%	100%
Anterior labral tear on MR arthrogram examination	94%	100%
Posterior labral tear on MR examination	82%	100%
Posterior labral tear on MR arthrogram examination	97%	100%
Supraspinatus tendon tear on MR examination	96%	100%
Supraspinatus tendon tear on MR arthrogram examination	100%	100%

SLAP, superior labral anterior to posterior.

The average age of patients with labral tears seen on MR arthrogram that were not seen on conventional MR examination was 29 years. The average age of patients with supraspinatus tendon tears seen on MR arthrogram but not seen on conventional MR examination was 62 years.

DISCUSSION

In this study, patients with an abnormality on conventional MR examination rarely demonstrated additional findings on MR arthrography. Only 3 patients out of the 52 patients with abnormalities on conventional MR examination demonstrated additional findings on MR arthrography.

In this study, patients with normal conventional MR examinations often had abnormalities demonstrated on MR arthrogram examination. These patients often had labral tears and/or supraspinatus tendon tears that were not visible on conventional MR examination. These patients were divided into two distinct groups.

The labral tears seen on MR arthrogram that were not seen on conventional MR examination occurred in a younger patient group. These patients averaged 29 years and all had injuries that occurred 5 months or less prior to the MR examination. The

labral tears in this group of patients were acute/subacute injuries with tears that displaced when the joint was distended with intra-articular contrast, allowing the tear to be visualized. Non-displaced labral tears may be difficult to visualize on conventional MR examination.^{15,16} The edges of labral tears may coalesce, making them difficult to visualize without fluid distention. On MR arthrography, fluid may extend into a tear, making it visible. This simulates conditions present at surgery.^{13,15,16}

The supraspinatus tendon tears seen on MR arthrogram that were not seen on conventional MR examination occurred in an older group of patients. These patients averaged 62 years of age. The patients could not describe a specific injury but did have shoulder pain for more than 9 months before the MR examination was performed. These tears may not have been seen on conventional MR examination owing to scar tissue forming in the area of tear, simulating an intact tendon. In this scenario, fluid signal in the region of tear may not be present but rather replaced by scarring with signal characteristics very similar to that of the native supraspinatus tendon. It may be difficult to see the tears without fluid distending the joint.¹³

In this study, very few patients with abnormal conventional MR examinations demonstrated additional findings on MR arthrogram.

Table 4. Sensitivity and specificity of MR and MR arthrogram readings vs arthroscopy for Reader 2

	Sensitivity vs arthroscopy	Specificity vs arthroscopy
SLAP on MR examination	81%	100%
SLAP on MR arthrogram examination	96%	100%
Anterior labral tear on MR examination	77%	100%
Anterior labral tear on MR arthrogram examination	97%	100%
Posterior labral tear on MR examination	76%	100%
Posterior labral tear on MR arthrogram examination	91%	100%
Supraspinatus tendon tear on MR examination	96%	100%
Supraspinatus tendon tear on MR arthrogram examination	100%	100%

SLAP, superior labral anterior to posterior.

Figure 1. A 29-year-old male with shoulder pain. (a) T_2 weighted axial MR image [repetition time (TR)/echo time (TE), 3250/55] showing a normal appearing anterior labrum (arrow). (b) T_1 weighted fat-saturated axial MR arthrogram image (TR/TE, 677/12) showing an anterior labral tear (arrow). This was found to be a labral tear at arthroscopy.

This may be owing to the types of labral and/or supraspinatus tendon tears present in this population. The tears were well seen on conventional MR examination. MR arthrography yielded very little additional information in this group of patients. In this group, the joint distension was not necessary to detect the labral and/or supraspinatus tendon tears.

In the group of patients with abnormal conventional MR examinations, there were three additional findings on MR arthrography not seen on conventional MR examination. Two of these findings were SLAP tears and one was a posterior labral tear. These additional findings were seen by both Readers 1 and 2. The surgeons were asked whether the additional findings on MR arthrography influenced surgical management in these cases. The SLAP tears and posterior labral tears were debrided. The surgeons indicated that these additional findings would have been seen at arthroscopy regardless of the findings on the original MR report. These lesions would have been debrided regardless of what the MR report stated. In addition, the surgeons would have proceeded to surgery based

on the conventional MR report findings. In this group of patients, the addition of MR arthrography to an already abnormal conventional MR examination did not impact surgical management.

Indirect MR arthrography (i.v. injection of contrast prior to performance of MR examination) was not assessed in this study. We do not perform indirect MR arthrography at our institution. In this study, the additional findings demonstrated on MR arthrography as compared with conventional MR were seen owing to joint distension afforded by direct injection of contrast into the joint. Indirect MR arthrography does not allow for the same degree of joint distension as direct MR arthrography.

Magee et al⁶ compared shoulder MR arthrography vs conventional MR on a 1.5-T scanner. A group of professional athletes were compared with an age-matched group of non-professional athletes. All patients had both conventional MR and MR arthrography examinations performed. MR arthrography demonstrated additional findings as compared with conventional MR examination

Figure 2. A 35-year-old male with shoulder pain. (a) T_2 weighted coronal MR image [repetition time (TR)/echo time (TE), 3250/55] showing a normal appearing superior labrum (arrow). (b) T_1 weighted fat-saturated coronal MR arthrogram image (TR/TE, 677/12) showing a superior labral anterior to posterior tear (arrow). This was found to be torn at arthroscopy.

Figure 3. A 62-year-old female with shoulder pain. (a) T_2 weighted coronal MR image [repetition time (TR)/echo time (TE), 3250/55] showing an intact appearing supraspinatus tendon (arrow). (b) T_2 weighted sagittal MR image (TR/TE, 3250/55) showing an intact appearing supraspinatus tendon (arrow). (c) T_1 weighted fat-saturated coronal MR arthrogram image (TR/TE, 677/12) showing a full-thickness supraspinatus tendon tear (arrow). This was found to be torn at arthroscopy. (d) T_1 weighted fat-saturated sagittal MR arthrogram image (TR/TE, 677/12) showing a full-thickness supraspinatus tendon tear (arrow). This was found to be torn at arthroscopy.

in 14 out of 20 professional athletes, while there were only 5 additional findings in the control group of 50 patients. MR arthrography was found to be useful in the group of throwing athletes. Shoulder MR arthrography was more sensitive than conventional shoulder MRI in the general population also. However, it was uncertain whether the added benefit warranted performing arthrography in the general population.⁶ Normal appearing conventional MR examinations were not assessed in this study.

There are some instances in which MR arthrography may provide additional information useful to the surgeon, despite an abnormal conventional MR examination. The addition of MR arthrography to an MR examination demonstrating a labral tear may demonstrate the motion of the tear on MR arthrography, indicating an unstable labral tear. This may influence the surgeon's decision to proceed with surgery to tack an unstable labral tear.¹⁷

Figure 4. A 33-year-old male with shoulder pain. (a) T_2 weighted axial MR image [repetition time (TR)/echo time (TE), 3250/55] showing an anterior labral tear (arrow). (b) T_1 weighted fat-saturated axial MR arthrogram image (TR/TE, 677/12) showing an anterior labral tear (arrow). This was found to be torn at arthroscopy.

Assessment of conventional MR images to determine who would most benefit from MR arthrography would benefit patient care. MR arthrography could be used in a more selective fashion, if conventional MR could help determine those who would benefit most from MR arthrography vs those who may not need it. Although arthrography is a minimally invasive procedure, most patients would prefer not to have an arthrogram performed. Patients commonly experience discomfort post procedure. In addition, there is a small risk of infection post arthrogram.¹¹

In this study, there was a high prevalence of positive findings on both MRI and MR arthrography. This is partly owing to the fact that all patients underwent surgery. 70 of the 100 patients had a labral tear and/or a supraspinatus tendon tear at surgery (many patients had more than one finding at surgery). 30 patients did not have a labral tear or a full-thickness supraspinatus tendon tear but had other findings on physical examination and/or imaging that made the surgeon feel surgery was warranted.

There are limitations to this study. This study included only those who went on to surgery. This can introduce some study bias with respect to the patient population.

In conclusion, use of pre- and post-MR arthrogram imaging may benefit patient care. Review of pre-arthrogram images by the radiologist may help determine those who would benefit from performing an MR arthrogram. If the conventional MR examination is normal, then it would be prudent to proceed to MR arthrogram. In this study, 18 (37%) of 48 patients had additional findings on MR arthrography when conventional MR was normal. If the conventional MR examination demonstrates an abnormality, the likelihood of finding additional abnormalities on MR arthrography is small. In this study, only 3 (6%) of 42 patients with abnormalities on conventional MR examination demonstrated additional findings on MR arthrography. In this group of patients, proceeding to MR arthrography may not be necessary.

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