Rotator cuff tears: value of 3.0T MRI

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Abstract

Purpose. To demonstrate the value of 3.0T MR imaging for the detection of rotator cuff tendon tears and surgical planning by correlating imaging findings to surgical findings.

Materials and methods. Prospective follow-up of patients who underwent 3.0T MR imaging of the shoulder in our department between November 2005 and June 2007. Surgical findings were correlated to imaging findings for 48 patients who underwent surgery: detection, size, partial thickness or complete, and tendon edges.

Results. In this patient group, the positive predictive value of MRI for detecting surgical tears was 100% (100% of complete tears and 92% of partial thickness tears). No change in surgical management was recorded when arthroscopy was performed based on MRI findings (size of tear).

Conclusion. 3.0 T MRI is valuable for the detection of small tears, especially for partial thickness tears due to increased spatial resolution. The identification of surgical candidates and surgical planning are improved due to more accurate measurements of tear size and quality of the tendon edges.

Key words: MRI, shoulder. Rotator cuff tendons. 3.0 Tesla.

E valuation for rotator cuff tears is a routine task for radiologists. Several imaging techniques are available: US, CT arthrography, MRI and MR arthrography. The indications for each technique differ between centers and countries. Currently, CT arthrography remains the most frequently used modality for the presurgical planning of rotator cuff lesions. This technique is advantageous because it has been performed for a longer period of time and surgeons are very familiar with it. CT arthrography is highly sensitive for detection of complete tears and partial articular surface tears of the rotator cuff tendons. It also detects muscle atrophy, tendon retraction, labral tears and cartilage lesions (1). On the other hand, bursal surface tears and intrasubstance delamination tears cannot be detected with this technique. The accuracy of US for detection of rotator cuff tears has been demonstrated with sensitivity and specificity values similar to MRI while being more available and less expensive (2). US allows evaluation of the bursal surface an detection of delamination tears (3), and can be a complement to CT arthrography. However, the accuracy of US varies based on the expertise of the sonographer (4) and with the size of the tear (5). US is thus insufficient for presurgical planning, especially since image review is not available. MR arthrography is currently considered the gold standard throughout the world (1, 6, 7). However, it is expensive, invasive and not readily available in many centers. In routine practice, MR arthrography is frequently reserved for complicated cases and athletes (6, 7). Recent studies have demonstrated that conventional MRI is gaining grounds compared to MR arthrography with similar sensitivity values reported for the detection of complete cuff tears (7). MRI is advantageous because it is faster, less expensive and less invasive than MR arthrography. MR arthrography is mainly advantageous for detection of small partial articular surface tears (6-8). However, some authors report that such lesions usually do not modify the clinical management of most of these patients (8-10).

The reported sensitivity of conventional MRI (magnetic field of 1.5T or less) for detection of complete cuff tears varies between 80% and 100%, and between 35% and 87% for partial thickness tears with
specificity values between 83% and 98%, and 85% and 97% respectively (11-14). To our knowledge, only a single study assessed the value of 3.0T MRI (12). This study concluded that 3.0T MRI was slightly superior compared to previous studies (sensitivity and specificity of 98% and 96% for complete tears and 92% and 100% for partial thickness tears). The improved diagnostic accuracy afforded by the stronger magnetic field at 3.0T appears particularly significant for partial thickness tears. High field MRI thus appears to reduce the number of false negative results and increase the value of conventional MRI compared to MR arthrography.

The purpose of this study is to demonstrate the added value of 3.0T MRI in patients with rotator cuff tear by correlating the imaging findings to arthroscopic or open surgical results. We were mainly interested in assessing the value of the higher magnetic field and its improved spatial resolution for selection of surgical candidates and surgical planning.

Materials and methods

We have obtained prospective follow-up of patients who underwent shoulder MRI in our institution between November 2005 and June 2007. All MR examinations were performed using the same protocol on a Siemens Magnetom Trio 3.0T: fat-suppressed TSE T2W in 3 planes (TR/TE: 3000/59ms, number of excitations=2 in the axial plane and 1 for the other planes, FOV=180 mm, matrix=320 × 320, slice thickness=3 mm in the axial plane and 2 mm for the other planes (no interslice gap), echo train length=9, acquisition time=2 min 47 sec in the axial plane, 2 min 14 sec in the coronal plane and 2 min 05 sec in the sagittal plane). A sagittal T1W sequence was acquired to detect fatty muscle atrophy. A dedicated Siemens shoulder coil was used for all examinations.

All MR examinations were independently reviewed by two observers prior to surgery. An agreement was achieved by consensus review for discordant results. Surgical results were then correlated with MRI findings. The surgical procedures were performed by two surgeons using similar surgical techniques. Arthroscopy was performed in all cases of arthroscopic procedures. The imaging findings studied were the presence of a tear (complete or partial thickness) of the rotator cuff tendons (supraspinatus, infraspinatus, teres minor and subscapularis) and its size. The criterion for a complete tear was the presence of a full-thickness disruption in the tendon (hyperintense fluid signal) creating a communication between the glenohumeral joint and subacromial-subdeltoid bursa. The criterion for a partial thickness tear was the presence of partial disruption of the tendon thickness (hyperintense fluid signal) or irregularity at the articular or superficial surface of the tendon. Non- tendon hyperintensity or heterogeneous signal intensity (with or without tendon enlargement) was considered a differential diagnosis (tendinopathy).

Complete tears were measured in the axial, coronal and sagittal planes and then classified into 2 groups: “moderate” tears (long axis ≤15 mm) amenable to endoscopic repair, and “large” tears (long axis >15 mm) potentially requiring arthrotomy, or even patch repair depending on the degree of tendon retraction. In order to most accurately measure the size of the tears prior to surgical repair, we have qualified the appearance of the tendon margins. Tear measurements included the poor quality tendon margins (irregular, heterogeneous, lacerated...) up to normal appearing tendon (without signal or morphological abnormality) potentially usable for surgical suture.

Results

Between November 2005 and June 2007, 245 shoulder MRI examinations were performed in our institution. Prospective follow-up was available for 192 patients. Fifty-eight rotator cuff tendon tears were identified: 34 complete tears (fig. 1) and 24 partial thickness tears (fig. 2). Surgery was performed in 48 patients, 3 of which based on clinical findings alone (no rotator cuff tendon tear on MRI). Arthroscopy was performed in 36 patients and arthrotomy in 12 patients. At surgery, 33 tears were complete, 13 tears were partial thickness (10 along the articular surface) and 2 patients had no tear. The mean age of surgical patients was 56 years with a sex-ratio of 1.4. The mean time interval between MRI and surgery was 77.6 days (range: 22-169 days). Two of the 48 operated patients had recurrent tears after an initial surgery over four years previously.

For complete tears confirmed at surgery, 32 of 33 were identified on MRI (fig. 3). The only false negative was classified as a partial thickness tear on MRI. No false positive MRI result was identified. The positive predictive value of MRI for detection of complete rotator cuff tendon tears was 100%.

For partial thickness tears confirmed at surgery, 12 of 13 were identified on MRI. The only false negative was classified as tendinopathy on MRI whereas surgery confirmed the presence of a partial thickness bursal surface tear of the supraspinatus. The only false positive result was the case described above of a complete tear described as a partial tear on MRI. The positive predictive value of MRI for detection of partial thickness rotator cuff tendon tears was 92% (table I).

With regards to all rotator cuff tendon tears (complete and partial thickness), no...
false positive MRI result was noted. All 45 patients referred to surgery based on the presence of a tear on MRI had a tear confirmed at surgery (positive predictive value of 100%). Of the 32 complete tears detected on MRI, 17 were qualified as “moderate” in size (long axis ≤ 5 mm) and 15 as “large” in size (long axis > 15 mm) (fig. 4 and 5). Thirty-three complete tears were confirmed at surgery. Arthrotomy (including one case requiring arthroplasty due to advanced eccentric joint degeneration) was deemed necessary by the surgeon in 12 of 15 cases with “large” tear. Arthroscopic management was performed in 21 cases, including the 17 cases with moderate tears, the tear misdiagnosed as partial thickness tear on MRI, and 3 large tears on MRI with long axis measurements less than 22 mm. Conversion to open arthrotomy was never required for the lesions referred for arthroscopic management based on MRI findings. No surgical technique modification was required due to the good correlation between data measured from MRI and presurgical evaluation, especially with regards to the possibility of arthroscopic treatment.

**Discussion**

This study confirms the value of 3.0T MRI, in combination with standard clinical criteria, in the selection of patients that may benefit from arthroscopic surgery. The positive predictive value of 3.0T MRI is excellent for complete tears (100%), but also and especially for partial thickness tears (92%). A tear was confirmed at surgery in all operated patients. 3.0T MRI can reliably demonstrate the presence of a rotator cuff tendon tear, hence reducing the number of unnecessary arthroscopies. A single false positive result was noted. It was a case where MRI showed a partial thickness tear but surgery showed a complete tear. The complete tear could not be identified on retrospective review of the MRI even with knowledge of surgical findings. It is possible that a partial thickness tear progressed to a complete tear during the 3 month period between MRI and surgery. It may also be possible that fibrous tissue was filling a portion of the tear, especially since the patient had undergone previous cuff repair in 2003. This case does not reduce the positive predictive value of 3.0T MRI for the detection of rotator cuff tendon tears (100%) since this patient, with complete tear, did not undergo unnecessary surgery.

A single false negative was observed for partial thickness tears: Tendinopathy was diagnosed on MRI but arthroscopy, performed for persistent pain despite optimal medical management, demonstrated a subtle shallow erosion along the bursal surface of the supraspinatus tendon secondary to advanced AC joint degeneration with osteophytes. Previous published studies reported that most false negative results on MRI are related to shallow partial thickness tears of the rotator cuff tendons (8) (Ellman’s grade 1, or less than 3 mm (15), typically non-surgical). The high accuracy of 1.5T MRI for detection of complete tears has been demonstrated several times (11-14). 3.0T MRI is mainly valuable for the detection of small tears.
lesions, particularly partial thickness tears (12). The stronger magnetic field at 3.0T provides improved signal-to-noise and contrast-to-noise ratios. This enables the acquisition of thinner images with improved spatial resolution while maintaining enough signal. Contiguous 2 mm thick fat-suppressed T2W images can now be acquired. The improved spatial resolution allows detection of smaller tendon lesions with increased sensitivity and confidence. The improved diagnostic accuracy of 3.0T MRI for labral lesions has also been reported (16, 17). Advances with coils, especially phased-array coils, will further improve our ability to acquire high-resolution sequences due to improved SNR (18, 19). Studies could then be performed to determine the improved diagnostic accuracy due to better coils from that due to the stronger magnetic field.

The routine clinical use of high field 3.0T MRI units is relatively recent. The added diagnostic value became rapidly obvious for neuroimaging, MR angiography, and pelvic imaging. However, the added benefit for musculoskeletal imaging was slower because optimization of acquisition parameters was more complex (20). Correlation studies are not available to definitely confirm the added value of 3.0T MRI for musculoskeletal imaging (21). The higher magnetic field also enables the use of isotropic sub-millimeter (0.6 mm) sequences. These 3D DESS sequences, combined with conventional sequences, complement and complete the pre-surgical evaluation (cartilage lesions, intra-articular foreign bodies, nerves...). Relaxation parameters of soft tissue structures are different at 3.0T MRI. The T1 shortening is prolonged while the T2 relaxation time is shortened, requiring modifications to the acquisition parameters (Longer TR and shorter TE) in order to preserve a contrast similar to 1.5T MRI (20, 22).

The main advantage of improved spatial resolution at 3.0T MRI is the ability to obtain precise measurements of rotator cuff tendon tears in all 3 planes. The size of the tear is a consideration to establish the need for surgery (23) and is directly related to the postsurgical functional prognosis (24). In addition, some studies have demonstrated the value of MRI for pre-surgical planning, with the selection of the surgical approach depending on the size of the tear (25-27). Arthroscopic repair is usually possible up to 15 mm (sometimes 20 mm). Arthrotomy is frequently required for larger tears, and a patch is usually needed for tears around 40 mm in size (even though surgical indications vary between groups). During out study, no surgical technique conversion was needed when arthroscopic repair was selected based on MRI data. Due to its excellent spatial resolution, 3.0T MRI allows adequate evaluation of tendon edges thus avoiding under-estimation of tears.
by including poor quality tendon edges that may require resection at the time of repair. In 3 cases, arthroscopy was selected by the surgeons even though the lesions were “large” on MRI, but less than 22 mm wide. The ability to adequately plan the surgical approach with 3.0T MRI appears satisfactory, even for tears of borderline size, around 20-25 mm, for which 2 surgical approaches may be considered.

Lesion depth is typically estimated using Ellman’s classification divided into 3 grades (15). Some surgical groups consider that grade 3 lesions (> 50% tendon thickness) constitute a surgical indication (12). Theoretically, the thickness of the tear could be better determined at 3.0T MRI. However, the measurement appears to be poorly reproducible and cannot be used as a formal surgical indication (28).

The improved SNR at 3.0T not only improves spatial resolution due to the acquisition of thinner images, but also reduces the acquisition time. This is most helpful to reduce motion artifacts. Also, fat suppression is more effective at 3.0T because of the increased chemical shift at higher field. Finally, there is increased contrast of enhancing lesions at 3.0T MRI. On the other hand, some artifacts are increased at 3.0T, mainly related to increased chemical shift and magnetic susceptibility. Adjustment of some parameter reduces the impact of these artifacts, including an increase of the bandwidth (at the cost of reduced SNR). After a cuff repair, artifacts related to surgical materials do not significantly interfere with image interpretation (fig. 6). Finally, SAR (specific absorption rate) and acoustic noise are theoretically increased at 3.0T, as well as patient heating and displacement of ferromagnetic foreign bodies (20). In clinical practice, in our experience, this is unusual and the diagnostic quality of the examination is adequate.

The limitation of this study is the inability to obtain arthroscopic confirmation that rotator cuff tendons described as without tear on MRI were indeed without tear (ethical and financial concerns). This correlation would have enabled evaluation of the sensitivity and specificity of 3.0T MRI. In addition, the time delay between MRI and surgery was variable (22-169 days) and the surgeons were not blinded to MRI results prior to surgery.

**Conclusion**

3.0T MRI allows accurate detection of partial thickness rotator cuff tendon tears and small cuff lesions in all 3 planes due to its excellent spatial resolution. The ability to accurately measure the size of the tears and assess the quality of tendon edges can not only confidently establish the surgical indication, but also to achieve pre-surgical planning.

The authors have no conflict of interest to disclose.

**References**


J Radiol 2009;90


