Rotator Cuff Injury MRI

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Overview
Shoulder pain is a common complaint by patients during physician visits, and it can be due to a variety of causes. The major cause of shoulder pain in patients older than 40 years is rotator cuff impingement and tears. With the development of new arthroscopic techniques for treating rotator cuff disorders, magnetic resonance imaging (MRI) has played an increasingly important role as a noninvasive test for determining which patients may benefit from surgery. (See the images below.)\textsuperscript{[1, 2, 3, 4]}

![Partial-thickness tear seen better on angled oblique sagittal views.](image)

![Full-thickness tear.](image)

A French study by Lambert et al found the positive predictive value of 3.0T MRI to be 100% for the detection of rotator cuff tendon tears requiring surgery. In this prospective, follow-up study of 48 patients from 2005 through 2007, when arthroscopy was performed based on the MRI findings, there was no change in surgical management from that determined by MRI.\textsuperscript{[1]}

Yoo et al found that preoperative MRI variables may help to predict incomplete arthroscopic repair of large to massive rotator cuff tears. On preoperative MRIs of rotator cuff tears, the authors found that fatty degeneration index (FDI) values greater than 3 on sagittal oblique sections of the supraspinatus and values greater than 2 on sagittal oblique sections of the infraspinatus, with greater than 31 mm in coronal oblique tear distance (COTD) and 32 mm in sagittal oblique tear distance (SOTD), can help to predict incomplete arthroscopic repair of the torn tendon.\textsuperscript{[5, 6]}

Conventional MRI
Conventional MRI with T2-weighted images in the oblique coronal and oblique sagittal planes is the preferred technique for imaging the rotator cuff. Most authors have found that
fat-suppressed, fast spin-echo (FSE), T2-weighted images are the most accurate for detecting rotator cuff tears (RCTs); a sensitivity of 84-100% and a specificity of at least 77-97% for full-thickness tears can be expected with this pulse sequence.\(^\text{[7, 8, 9, 16, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20]}\)

Although most RCTs can be seen on oblique coronal images, Patten et al reported that oblique sagittal images provide approximately a 10% improvement in accuracy for detecting RCTs, although this was not statistically significant.\(^\text{[21]}\) The authors found that oblique sagittal images are especially helpful for identifying tears involving the anterior edge of the supraspinatus.

**Magnetic resonance arthrography**

Some people prefer to perform either direct or indirect MR arthrography for imaging the rotator cuff. The advantage of direct MR arthrography relative to MRI is that it distends the joint, thus forcing the contrast agent into a small defect. T1-weighted images, which are faster to acquire and have a superior signal-to-noise ratio, can also be used instead of T2-weighted images. The disadvantages of direct MR arthrography are that it is mildly invasive and may require imaging guidance to place a needle into the glenohumeral joint capsule. In addition, bursal-surface partial-thickness tears are not directly opacified.

Several authors have reported that direct MR arthrography is close to 100% sensitive and specific for full-thickness and articular-surface partial-thickness RCTs.\(^\text{[22]}\) A full-thickness tear will demonstrate the gadolinium contrast solution extending first through a defect in the cuff and then into the subacromial-subdeltoid bursa. Articular-surface partial-thickness tears show a focal extension of the contrast solution into the substance of the tendon. (See the image below.)

![Image of rim-rent or partial-thickness articular-surface tendon avulsion (PASTA) tear.](image)

When performing direct MR arthrography, it is important to use fat-suppression to decrease the signal intensity of the peribursal fat plane around the subacromial-subdeltoid bursa; without fat-suppression, the fat plane can mimic the contrast agent and lead to a false interpretation of an RCT.

In a meta-analysis of studies on MRI, MR arthrography, and ultrasonography for rotator cuff tears, de Jesus et al found MR arthrography to be more sensitive and specific than either MRI or ultrasonography for diagnosing both full-thickness and partial-thickness tears. MRI and ultrasonography showed no significant differences in sensitivity or specificity for full- or partial-thickness tears.\(^\text{[2]}\)

Indirect MR arthrography requires only an intravenous (IV) injection, but this modality has a disadvantage in that it does not distend the joint. As in direct MR arthrography, short scanning time T1-weighted images can be used instead of T2-weighted images. Several authors have
shown that compared with conventional MRIs of the rotator cuff, RCTs are better characterized on indirect MR arthrography and there is better correlation with surgical findings. One study reported that 2 radiologists improved their accuracy for detecting RCTs from 67% and 62% with conventional MRI to 92% and 96%, respectively, with indirect MR arthrography.[23] Again, use of fat suppression is important, but exercising the joint does not appear to improve accuracy.

Despite these studies, MR arthrography has not been as widely accepted for evaluating the rotator cuff as it has been for imaging the glenoid labrum. Direct MR arthrography does improve the depiction of posterior articular-surface partial-thickness tears that are observed in overhead-throwing athletes, particularly if the shoulder is scanned in abduction and external rotation. However, most authors have found that fat-suppressed, FSE, T2-weighted images obtained with a quality shoulder coil are fairly accurate for most RCTs and that conventional MRI is adequate for routine imaging of the rotator cuff.

Conventional arthrography was the traditional technique for detecting RCTs. However, arthrography itself does not demonstrate bursal-sided, partial-thickness tears, and it may be difficult at times to determine the size of a tear using this modality. With improvements in computed tomography (CT) scanners, oblique coronal reformatted CT arthrogram images can provide excellent images of the rotator cuff in patients who are unable to undergo an MRI.

Limitations of techniques

MRI is contraindicated in patients who have a cardiac pacemaker, ferromagnetic foreign bodies (particularly in the orbit), and some cochlear implants. Some patients are extremely claustrophobic in high-field-strength MRI scanners, although many of these patients can be scanned in open MRI scanners after administration of a mild sedative.

MR arthrography is mildly invasive, and because the off-label use of gadolinium is not currently approved by the US Food and Drug Administration (FDA) for intra-articular injection, it may require written, informed patient consent. Imaging is also usually necessary to correctly position the arthrogram needle within the joint capsule. Fluoroscopy is the most common method of imaging guidance, but needle placement also can be performed under CT scanning, by ultrasound, or within the MRI scanner. Conventional arthrography is also mildly invasive and has the limitation of not being a tomographic technique.

Gadolinium-based contrast agents (gadopentetate dimeglumine [Magnevist], gadobenate dimeglumine [MultiHance], gadodiamide [Omniscan], gadoversetamide [OptiMARK], gadoteridol [ProHance]) have been linked to the development of nephrogenic systemic fibrosis (NSF) or nephrogenic fibrosing dermopathy (NFD). For more information, see the eMedicine topic Nephrogenic Systemic Fibrosis. The disease has occurred in patients with moderate to end-stage renal disease after being given a gadolinium-based contrast agent to enhance MRI or MRA scans.

NSF/NFD is a debilitating and sometimes fatal disease. Characteristics include red or dark patches on the skin; burning, itching, swelling, hardening, and tightening of the skin; yellow spots on the whites of the eyes; joint stiffness with trouble moving or straightening the arms, hands, legs, or feet; pain deep in the hip bones or ribs; and muscle weakness. For more information, see Medscape.

Magic-angle effect

The histology of the rotator cuff contributes to one of the difficulties of rotator cuff MRI interpretation, the magic-angle effect or angular anisotropy. This effect is an MRI artifact in
which normally low-signal structures that are made of organized collagen fibers appear as a higher signal intensity on images that are obtained with a short echo time (TE). The artifact occurs when the long axes of the collagen fibers are oriented at 55° to the main magnetic field.

In most high-field MRI scanners, the main magnetic field is oriented along the direction of the bore (the central tunnel where the patient lies). The well-organized collagen fibers in the outer portions of the rotator cuff are organized longitudinally; therefore, these normally low-signal fibers have increased signal intensity on short-TE images as the fibers curve and become oriented at the magic angle.

Unfortunately, this effect occurs in the region of the critical zone where RCTs and degenerative tendinopathy are prevalent. However, the magic angle’s high signal intensity diminishes with increasing TE; thus, it is not usually a problem on the fat-suppressed, FSE, T2-weighted MRIs most radiologists currently use to image the rotator cuff.

For excellent patient education resources, visit eMedicine's Breaks, Fractures, and Dislocations Center. Also, see eMedicine's patient education articles, Shoulder Dislocation, Shoulder Separation, and Magnetic Resonance Imaging (MRI).

**Magnetic Resonance Imaging**

This section discusses the use of MRI in the assessment of full- and partial-thickness RCT tears.

**Full-thickness tears**

For many orthopedic surgeons, the main role of shoulder MRI is to detect a full-thickness rotator cuff tear (RCT). The most common appearance of a full-thickness tear is high signal intensity on a T2-weighted image that extends from the articular surface of the rotator cuff to the subacromial-subdeltoid bursa. (See the image below.)

![Supraspinatus tendon](image-url)

Supraspinatus tendon. Reprinted with permission from Michael Tuite, MD.

Rafii et al reported that high signal was observed in approximately 90% of full-thickness tears proven at surgery.  

In chronic RCTs in which the shoulder joint has little or no effusion, the humeral head may be high riding, such that not much high signal is seen at the tear site. (See the image below.)
Normal intratendinous signal.

Some patients may also develop fibrous thickening of the subacromial-subdeltoid bursa, which can mimic an intact tendon in the absence of an effusion; therefore, it is important to trace a low-signal structure as it passes over the humeral head. Rotator cuff fibers will end at their insertion on the greater tuberosity, whereas fibrous thickening of the bursa will continue deep to the deltoid muscle below the greater tuberosity.

In addition, acute RCTs can hemorrhage at the tear site, with the blood mimicking some intact fibers. It is important to distinguish the smoothly curving, low-signal surfaces of the rotator cuff from the disorganized low-signal surfaces of fibrin and other blood products.

Most small full-thickness tears arise in the anterior aspect of the supraspinatus tendon in the critical zone. (See the images below.)

Partial-thickness tear seen better on angled oblique sagittal views.

Full-thickness tear.
Localizing a small full-thickness tear to the rotator cuff crescent may be helpful for the shoulder surgeon, who may then decide to only debride, but not repair, the cuff defect. Although RCTs often begin in the critical zone, resorption of the tendon stump at the greater tuberosity may occur if chronic full-thickness tears are left untreated. Full-thickness avulsion tears of the tendon away from the greater tuberosity are less common. Massive tears often extend posteriorly to involve the infraspinatus tendon or extend anteriorly to tear the anterior interval and subscapularis tendon.

If a full-thickness tear is observed, it is important to document whether or not the entire anterior-to-posterior width of the supraspinatus tendon is involved. In RCTs that involve the entire tendon, the tendon edge can retract medial to the glenoid, where it becomes extremely difficult to grasp and to reattach to the greater tuberosity.

Long-standing RCTs can also result in the development of muscle atrophy and fatty degeneration that may prevent successful repair. It is important to expeditiously obtain imaging studies in patients who have a possible acute full-thickness, complete-width, supraspinatus tendon tear. If an acute complete supraspinatus tendon tear is identified, surgery is often scheduled within the next several days so that the tendon can be repaired before the development of retraction or atrophy.

**Partial-thickness tears**

Partial-thickness tears can be classified as articular, bursal, or intratendinous. Intratendinous tears may be a cause of shoulder pain, but they are not observed at routine arthroscopy and are rarely treated surgically. Articular-surface partial-thickness tears are more common than bursal-surface tears (at an approximately 3:1 incidence rate). Many patients with a bursal-surface tear also have an articular-surface tear.

The accuracy of MRI for partial-thickness tears is lower than that for full-thickness tears. Although some authors have reported a sensitivity greater than 0.90 for partial-thickness tears, others have reported sensitivities as low as 0.17-0.56. Reinus et al were unable to correctly identify the side of the affected rotator cuff (articular vs bursal) in 50% of their patients with a partial-thickness tear. One reason for the low accuracy is that a high-signal defect on T2-weighted images is a less common finding in partial-thickness tears than in full-thickness tears; in a study by Rafii et al, this high-signal defect was seen in only 7 of 16 cases of partial-thickness tears.

Partial-thickness tears often appear on MRI as only an intermediate signal, isointense to muscle, which disrupts the normal low-signal surface of the rotator cuff. Absence of fluid in an RCT on MRI may be from the presence of a poor-quality scar or granulation tissue within the defect, and this can be difficult to distinguish from tendon degeneration or a healed RCT. Partial-thickness tears may also have smooth margins that taper gradually so that the rotator cuff appears to be only somewhat thinned. (See the image below.)
Although most partial-thickness tears occur in the critical zone of the supraspinatus tendon, some RCTs occur in less common locations. In younger patients, a small articular-surface avulsion-type partial-thickness tear can occur adjacent to the greater tuberosity; this is termed a rim-rent tear. (See the image below.)

Rim-rent or partial-thickness articular-surface tendon avulsion (PASTA) tear.

Tears isolated to the infraspinatus tendon occur in 1-7% of patients with RCTs, but these tears are more common in athletes who perform overhead activities.\[^{29}\] MR arthrography in which the patient is positioned with the arm in abduction and external rotation is the best technique for identifying these infraspinatus articular-surface partial-thickness tears, which often are associated with adjacent glenoid labral fraying.

Although the most important MRI criterion of a partial-thickness tear is the presence of an increased signal that disrupts the normally low-signal surface of the rotator cuff, some authors have described some secondary signs that may be helpful in improving the accuracy of MRI. Sanders et al demonstrated that an intramuscular cyst, typically in the supraspinatus muscle, is always associated with articular-surface involvement by a tear.\[^{30}\] The authors suggested that when such cysts are present, associated rotator cuff pathology should be investigated.

Inferiorly directed acromioclavicular joint osteophytes, a hooked anterior acromion, and an os acromiale have all been associated with a higher incidence of RCTs; therefore, these findings should prompt a careful evaluation of the rotator cuff. Subacromial-subdeltoid fluid is common in full-thickness tears, but a small amount can be observed in patients without a bursal-surface tear; thus, the presence of this fluid is not an accurate secondary sign of a bursal-surface partial-thickness tear.
**Degree of confidence**

Studies investigating the use of fat-suppressed, FSE imaging have reported a sensitivity of 84-100% and a specificity of 77-97% for full-thickness tears\[10, 11, 12, 13\], however, the accuracy for partial-thickness tears is lower. MR arthrography may be helpful for better demonstrating articular-surface partial-thickness tears. Angling the oblique coronal or oblique sagittal images to the rotator cuff surface at the suspected tear site can improve the accuracy of conventional MRI.

**False positives/negatives**

There are 3 other abnormalities of the rotator cuff that can mimic an RCT: degeneration, tendinopathy, and cuff strain. Rotator cuff degeneration is common in older individuals and appears as an ill-defined area of increased signal on T2-weighted MRIs within the substance of the cuff. All rotator cuffs undergo age-related degeneration in which the normally compact and well-organized collagen fibers are replaced by intermediate-signal myxoid and eosinophilic material.

As aging progresses and the rotator cuff is put under repeated stress, small fissures can develop within the cuff substance and appear as thin areas of fluid on MRI. If the MRI contrast and brightness are set too high (ie, windowed too tightly), these fissures can occasionally bloom and appear as a tear that extends to the surface of the cuff. (See the image below.)

![Articular- and bursal-surface partial-thickness tears.](image)

Tendinopathy, occasionally incorrectly termed tendinitis, is a related intratendinous process that is histologically similar to rotator cuff degeneration. Although the term tendinopathy is occasionally used interchangeably with age-related cuff degeneration, some clinicians reserve the term for younger symptomatic patients.

As with patellar "tendinitis," tendinopathy is not truly an inflammatory process, because there is no edema, vascular invasion, or acute inflammatory cells. Instead, what occurs pathologically is severe mucoid and eosinophilic degeneration with intratendinous clefts, often causing focal tendon swelling and, occasionally, surface fibrillation. If windowed incorrectly during imaging, tendinopathy can also appear to extend to involve the surface of the rotator cuff. (See the images below.)
Tendinopathy.

Intramuscular cyst and partial-thickness tear.

Rotator cuff strain after acute trauma has been described as another potential cause of increased intratendinous signal on MRI. This typically occurs in younger patients (< 35 y) who have an associated bone bruise and focal increased signal intensity in the posterior aspect of the supraspinatus tendon, as distinguished from cuff degeneration, which involves a larger area that is centered in the anterior critical zone. Patients with presumed rotator cuff strain as demonstrated on MRI are less likely to require surgery than older patients who develop shoulder pain after acute trauma.

In summary, fat-suppressed, FSE, T2-weighted images obtained with a quality shoulder coil are accurate for diagnosing RCTs. False-negative full-thickness tears typically occur when the patient does not have an effusion and when the subdeltoid bursal capsule is thickened. False-negative partial-thickness tears are fairly common, especially for tears that are not very deep. Failure to diagnose partial-thickness tears can be minimized by radiologists carefully inspecting the low-signal surfaces of the rotator cuff and noting whether the low-signal surface layers are disrupted, as well as by use of both intra-articular and IV gadolinium to enhance the conspicuity of these lesions.
References


