The imaging of tendon injury can be troublesome from a number of perspectives. First, tendon injuries are extremely common, accounting for 30%–50% of all sports injuries, and are, therefore, seen frequently at imaging centres. Second, tendons have a unique histology and ultrastructure with a number of normal variations that can mimic pathologic conditions, of which the radiologist should be aware. Finally, although full-thickness tears are easily diagnosed both clinically and with imaging, imaging findings for partial tears overlap those of tendinosis and those of normal tendons, and this can be very troublesome for radiologists, clinicians and patients alike.

The objective of this article is to develop a practical approach to the magnetic resonance imaging (MRI) and analysis of tendons, both normal and pathologic, emphasizing the common features at different anatomic locations.

**Normal Tendons**

**Tendon anatomy**

Tendons are composed of densely packed, parallel collagen bundles embedded in a matrix or ground substance. It is the regular structure of tendon fibrils that causes changes in the rotational motion of water molecules, which reduces, but does not eliminate, tendon signal on all sequences. Most tendons are enclosed by a synovial membrane (tendon sheath), whereas others, such as the Achilles tendon, are enclosed only by loose areolar tissue called a paratenon.

The myotendinous junction is the weakest link when under acute strain, and it is most commonly injured in long fusiform muscles, those extending across 2 joints and those with eccentric contraction (e.g., the medial head of the gastrocnemius). Injuries to the tendon itself, however, occur almost exclusively as a result of long-term overuse, and those tendons with a curved course are particularly vulnerable because they are exposed to increased strain. It should be noted that chronically injured tendons lack inflammatory cells, and these injuries are better termed tendinosis or tendinopathy and not tendinitis. The pathophysiology of such chronic overuse injuries is not clear.

**Magic angle phenomenon**

Tendons demonstrate structural anisotropy, meaning that they have physical properties that vary with the direction of measurement. On ultrasonography (US), if the angle of the transducer is not parallel to the tendon fibres, artifacts of regions of decreased echogenicity can result, mimicking tendon injury. With MRI, tendons oriented at 55° to the main...
magnetic field demonstrate increased signal on short echo time (TE) sequences, most commonly spin-echo T₁-weighted, proton-density-weighted and gradient-echo sequences. Studies have demonstrated that as long as the TE is longer than 37 ms, the magic angle phenomenon will not be visible.² Typical tendons involved include those likely to adopt a 55° course to the main magnetic field such as the supraspinatus, infraspinatus, extensor pollicis longus, patellar tendon (Fig. 1), posterior tibialis, and peroneus longus and brevis. The solution in all cases is to be aware of the phenomenon and to ensure that the imaging protocol includes long TE sequences in which tendons should demonstrate a homogeneously low signal.

Incomplete fat saturation

Incomplete fat saturation occurs most commonly at the shoulder joint. It is caused by main magnetic field inhomogeneity at the greater tuberosity owing to the curved external surface of the shoulder. It is a particular problem in large patients who are off isocentre. Tendinosis or rotator cuff tears can be mimicked by spuriously increased signal. This artifact can be avoided by not using frequency-selective fat saturation and T₂-weighted sequences, but instead using short tau inversion recovery (STIR) sequences (Fig. 2) that do not rely on frequency-selective fat suppression.

Peritendinous fluid

A small amount of fluid surrounding tendons may be normal and is particularly seen in the wrist extensors (Fig. 3A) (extensor carpi radialis brevis and longus), the long head of the biceps brachialis tendon and the flexor hallucis longus tendon at the ankle. In the last 2 instances, there is communication of the tendon sheath with the joint space. This occurs in virtually all patients through the biceps tendon and in about 20% of patients through the flexor hallucis longus. The key point is that the amount of fluid in the tendon sheath should not greatly exceed that within the joint. The fluid surrounding the tendon should have a homogeneous bright signal and, importantly, the underlying tendon should be normal in thickness and signal. Fluid within the sheath that greatly exceeds that within the joint (Fig. 3B) suggests tenosynovitis, whereas complex collections of fluid with mixed low and high signal around tendons suggest stenosing tenosynovitis, which should be specifically reported, because such tendons are often at increased risk of rupture.³ If the tendon signal and thickness are increased, tenosynovitis is confirmed. It should be noted that any fluid around tendons without a sheath, such as the Achilles tendon, should be considered abnormal.

Intratendinous signal

It has been previously stated that normal tendons have homogeneous low signal on T₁-weighted images, but several recent articles have indicated that punctate or linear areas of increased signal on such sequences can be normal in tendons that are apparently aligned with the main magnetic field (Fig. 4A). In both normal Achilles⁴ and patellar tendons⁵ low-signal “lesions” were seen on T₁-weighted sequences. This appearance may be the result of a “micro–magic angle phenomenon,” because at the histologic and ultrastructural level all tendons’ fibres have a curved undulating

![Image](image_url)

**FIG. 1:** Magic angle phenomenon versus patellar tendinopathy in the same patient.
A: Gradient-echo T₂*-weighted sagittal magnetic resonance image (MRI) shows high signal in the proximal patellar tendon (upper arrow) and the distal patellar tendon (lower arrow) in this short echo time (TE) sequence.
B: Fast spin-echo T₂-weighted sagittal image demonstrates normal low signal in the distal patellar tendon (arrow) in this long TE sequence, indicating that high signal in this location in A was caused by the magic angle phenomenon.
C: Fast spin-echo T₂-weighted sagittal image shows persistent high signal (arrow) in the proximal patellar tendon, indicating patellar tendinopathy and not magic angle phenomenon.
It is not known whether these linear regions of low signal on MRI correspond to the hypoechoic lesions seen in asymptomatic patients in the patellar and Achilles (Fig. 4C) tendons. Regardless, these pseudolesions on MRI can be recognized as such, because the tendon should have a homogeneously low signal on T₂-weighted or STIR sequences (Fig. 4B).

Supernumerary muscles

Supernumerary muscles may be common, such as the peroneus quartus (seen in 22% of the population), or uncommon, such as the accessory soleus (seen in about 2% of the population). Their importance is that the muscle belly can mimic a soft-tissue mass, and as

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**FIG. 2:** Patient who has had a rotator cuff repair but has ongoing shoulder pain.

A: Sagittal fast spin-echo T₂-weighted image with fat saturation showing an extensive metallic artifact (upper arrow) and more focal high signal (lower arrow) that could be incomplete fat saturation or a partial intrasubstance supraspinatus tendon tear.

B: Sagittal short tau inversion recovery (STIR) image shows less metallic artifact (upper arrow) and more homogeneous fat suppression. The lower arrow indicates persistent high signal compatible with a partial intrasubstance tear.

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**FIG. 3:** Fast spin-echo T₂-weighted axial images of the wrist.

A: A small amount of fluid surrounds the extensor tendons (arrow) and is considered normal.

B: A large amount of fluid surrounds the extensor tendons (arrow) indicative of tenosynovitis, although the tendons themselves demonstrate a normal signal. No wrist effusion was present.
the muscle tapers to a tendon, the tendon can mimic a tendon split or longitudinal tear. Recognition of the supernumerary muscles’ typical location and their identical signal to muscle on all sequences prevents misdiagnosis. In addition, supernumerary muscles should be recognized because they can be symptomatic or of surgical importance. The tendon of the peroneus quartus muscle, for example, can be used in lateral ligament reconstruction of the ankle.

TENDON PATHOLOGY

Full-thickness tears

Full-thickness tears may occur in normal tendons, but usually the tendon is predisposed to injury through age-related degeneration, repetitive microtrauma, steroid injection or systemic disease such as gout, diabetes or rheumatoid arthritis. Imaging is often unnecessary, because the clinical examination is diagnostic. The clinician can readily palpate the defect in the tendon, and the retracted muscle is often visible as a pseudomass, with corresponding loss of function in the muscle group. Such findings on physical examination can be complicated by a subacute presentation or by a hematoma filling in the gap and, therefore, imaging can sometimes be useful.

The technical factors to keep in mind for imaging full-thickness tears include the appropriate plane of section in muscles such as the pectoralis major. In this instance, the 2 muscle bellies come together in an obliquely oriented tendon, and coronal images should also be oblique to best visualize the tears. As always, if the “mass” of the retracted muscle is palpated, it should be marked by the technologist and included in the field of view. Failure to do so may result in a false-negative finding on examination, because the absence of a retracted tendon in the field of view may not be noted (Fig. 5). Either a strongly T₂-weighted sequence with fat saturation or a STIR sequence is necessary to demonstrate the fluid-filled gap and free tendinous edge.

In full-thickness tears, it is most important to report the degree of retraction of the tendon edge (Fig. 6A) or myotendinous junction and the degree of fatty infiltration or atrophy of the corresponding muscle belly (Fig. 6B), because these may have a significant impact on the decision to perform surgery and the type of repair used. It should also be remembered that US is usually diagnostic of such full-thickness tears and provides additional information because of the dynamic nature of the examination.

Partial tears

Partial tears may be transversely or vertically oriented, and are often termed tendon splits in the latter case (see later). Again, a fast spin-echo T₂-weighted sequence with fat saturation or a STIR sequence is required for optimal assessment. Typical findings include focal increased signal on these sequences and fusiform thickening of the tendon. In certain sites, such as the hamstrings, a hematoma may be present, which is extremely helpful in confirming the diagnosis of a tear, partial or otherwise.

At 2 sites, the supraspinatus tendon and the hamstring tendons, focal increased signal equal to that of adjacent fluid may be helpful in distinguishing horizontal partial tears from tendinosis (Fig. 7). Otherwise, there is significant overlap in MRI findings of partial tears and tendinosis and, unfortunately, the presence of coexisting peritendinous fluid collections, bursitis or bone marrow edema is not helpful in differentiating these entities. The sensitivity and specificity of MRI in the detection of partial tears varies widely with location and has been best studied in the rotator cuff, where sensitivity is estimated to be 35%–90%.

FIG. 4: Intratendinous “pseudolesions” in asymptomatic patients. A: Sagittal T₁-weighted image shows a linear region of increased signal (arrow) in the Achilles tendon. B: Sagittal STIR image in the same patient as in A demonstrats normal low signal (arrow) at the site of the high signal in A, confirming the latter to be a pseudolesion. C: Sonogram of the Achilles tendon in another asymptomatic patient. The calipers (+) mark an oval hypoechoic pseudolesion.
Tendinosis

Tendinosis or tendinopathy is a condition of chronic overuse of a tendon in which no inflammatory cells are present. Histopathology of numerous tendons, including the Achilles, patellar, rotator cuff and posterior tibial tendons, has consistently demonstrated disorganized, discontinuous collagen fibres with increased ground substance, termed mucoid degeneration, and sometimes calcium. MRI typically shows fusiform swelling, increased signal on T1-weighted and proton-density-weighted sequences, and increased signal on T2-weighted sequences, which is less than that of fluid (Fig. 7). Fluid may be seen in the tendon sheath or adjacent bursa, and bone marrow edema may occur. A particular form of tendinosis that warrants mention is stenosing tenosynovitis, as seen in the first dorsal compartment of the wrist, termed de Quervain’s tenosynovitis (Fig. 8). Typically, the abductor pollicis longus and extensor pollicis brevis tendons are thickened, demonstrating increased signal on T2-weighted sequences. This form of tenosynovitis is complicated by regions of low signal within the sheath, thereby distinguishing this abnormality from uncomplicated tenosynovitis.

Calcium deposits may also occur in cases of tendinosis (Fig. 9A) and are painful in about 30%–45% of patients. They may be the result of hypovascularity seen in the critical zone of such tendons, (e.g., supraspinatus). These calcium deposits are most easily diagnosed on plain films and on MRI are distinguished by focal regions of low signal (Fig. 9B).

It is important to restate that it may be impossible to differentiate tendinosis from partial tears, but often this does not affect management, because only the most persistently symptomatic partial tears refractive to conservative therapy are treated surgically. In addition, it is important for the radiologist and clinician to
remember that it is common to have both false-positive and false-negative findings using MRI and US for chronic tendinopathy (Fig. 10). Shalaby and Almekinders, who evaluated the significance of MRI findings in patients with chronic patellar tendinopathy, found the sensitivity and specificity of MRI to be 75% and 29%, respectively. In another study, the accuracy of MRI and US in diagnosing Achilles tendinopathy compared with an objective clinical gold standard was only 0.67 (Fig. 10).

Tendon dislocations

Tendon dislocations, which are easily diagnosed using US or MRI, occur in tendons constrained by bony anatomy. The most frequent examples are proximal biceps tendon and peroneal tendon dislocations. The proximal biceps tendon always dislocates medially, usually to an intra-articular position (Fig. 11). As such, a full-thickness subscapularis tear is usually present. The dislocated biceps tendon in its intra-
articular position can mimic a labral fragment or thickened middle glenohumeral ligament, and this differentiation should be kept in mind.

The second common location for dislocation is the peroneal tendons, and predisposed patients are those with chronic ankle instability, which in turn is the result of superior peroneal retinacular (SPR) laxity. It is important to make the diagnosis through imaging, because this entity may be misdiagnosed clinically as an ankle sprain. Computed tomography and plain films can occasionally show a flake fracture of the distal fibular metaphysis representing the avulsed insertion of the SPR. MRI shows the tendons to be anterolaterally dislocated out of the retromalleolar groove of the distal fibula, which in itself may be poorly formed. Typically the tendon or tendons lie in a pouch lateral to the distal fibula formed by the SPR, which has been peeled off its fibular insertion.11

Both biceps and peroneal tendon locations often require surgical intervention.

**FIG. 9:** Calcific supraspinatus tendinosis shown in 2 patients. 
A: Plain radiograph. 
B: T1-weighted oblique coronal image.

**FIG. 10:** STIR sagittal images of 2 patients with chronic Achilles tendinopathy. The patients were equally symptomatic. 
A: A tendon with normal signal and calibre. 
B: A diffusely enlarged tendon with increased intratendinous signal (arrow).
Tendon splits

Splits are longitudinal tears in tendons and, most typically, involve the peroneus brevis tendon. It is an overuse syndrome seen in dancers and runners and is probably the result of SPR laxity and repeated tendon

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**FIG. 11:** Axial gradient-echo $T_2^*$-weighted images of normal (A) and dislocated (B) biceps tendons. The vertical arrows demonstrate the biceps tendon in the normal (A) and dislocated intra-articular (B) positions. The lower arrows show the normal (A) and completely torn (B) subscapularis tendons. Note the normal middle glenohumeral ligament (thick arrow) in each image, which should not be confused with the dislocated biceps tendon.

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**FIG. 12A:** Fast spin-echo $T_1$-weighted axial image showing the normal appearance of the peroneus brevis (black arrow) and longus (white arrow) tendons.

**B:** $T_1$-weighted axial image demonstrating the C-shaped appearance of a longitudinally split peroneus brevis tendon (black arrow) and a normal peroneus longus tendon (white arrow).
subluxations. MRI shows a bisected or C-shaped tendon (Fig. 12), which is often thinned and demonstrates a high T₂ signal. Bony changes can include a shallow retromalleolar groove and small bony spur. In 30% of cases, a tear of the peroneus longus tendon may also be present.

Full-thickness tears: 2 special cases

Two locations of full-thickness tendon tears deserve particular mention, because they can change the surgical approach taken or indeed influence the need to perform surgery at all.

The subscapularis tendon is most commonly torn in association with a large rotator cuff tear. These tendon tears can be missed surgically if the usual superolateral arthroscopic approach is used for a rotator cuff repair. The presence of a full-thickness subscapularis tear changes the surgical approach to a more anterior deltopectoral one. On imaging, one sees abnormal increased signal within the tendon, discontinuity and, possibly, retraction of a tendinous free edge (Fig. 11B), with medial dislocation of the long head of the biceps tendon in 50% of cases.

The popliteus tendon is the main lateral stabilizer of the knee. About 10% of tears of this tendon are isolated. The tendon is usually torn in association with other injuries, such as cruciate ligament tears, meniscal tears and tears of the lateral/collateral ligament, biceps femoris or capsule. Popliteus tendon tears can be an indicator of a posterolateral corner injury (Fig. 13), which is an important cause of instability and can be difficult to distinguish on clinical examination. In addition, such tears can be a cause of failure of anterior or posterior cruciate ligament repairs and of chronic knee instability. With MRI, one sees high signal within the tendon or muscle and possibly retraction of the myotendinous junction mimicking a mass. Furthermore, the presence of significant fluid posterior to the popliteus tendon, bearing in mind the popliteus hiatus, which can be fluid-filled, is suggestive of a posterolateral corner injury.

CONCLUSION

The following 8 rules can be used to avoid “trouble” when diagnosing tendon injury with MRI:

• The magic angle phenomenon can cause increased signal on short TE sequences at both the microscopic and macroscopic level, but the normal tendon signal is always low on long TE sequences.

• Incomplete fat saturation is common at the curved surface of the greater tuberosity of the shoulder, and the use of STIR sequences is helpful to avoid the pitfall of diagnosing artifactually increased signal within a tendon as a tear.

• The volume of fluid around tendons should not greatly exceed that within the joint, and it should be homogeneously increased in signal on T₂-weighted sequences. The underlying tendon should be normal in signal and thickness. Remember that the biceps tendon sheath communicates with the joint routinely.

FIG. 13: Fast spin-echo T₂-weighted sagittal images of the lateral knee with a posterolateral corner injury. A: The white circle indicates the magnified view in B. B: The popliteus tendon is torn (arrowhead) and, as is typical of such injuries, there is also a lateral meniscal tear (upper arrow) and a full-thickness anterior cruciate ligament tear (not shown). The lower arrow indicates the normal, more proximal popliteus tendon, and the broken arrow, the excessive amount of fluid posterior to the popliteus tendon.
and the flexor hallucis longus tendon sheath communicates with the joint in about 20% of cases. Both of these tendon sheaths may have particularly large amounts of fluid in the presence of joint effusions.

- Supernumerary muscles can mimic soft-tissue masses and tendon splits, have a predictable location and have an identical signal to muscle on all sequences (i.e., low T₁ signal).
- For full-thickness tears, always report the amount of retraction and atrophy for surgical planning. Ensure that a large field of view is used to image a pseudo-mass of retracted muscle and include the retracted tendon in the images.
- MRI findings in partial tears overlap those of tendinosis, which also overlap those of normal tendons; therefore, it is important to know the limitations of your imaging technique.
- Tendon splits and dislocations are easily evaluated by MRI and may require surgical intervention.
- Certain full-thickness tears such as those involving subscapularis and popliteus tendons can change the surgical approach taken or influence the need for surgery.

References