Imaging plays a critical role in the diagnostic evaluation and assessment of patients with problems at and around the Achilles tendon, both in the documentation and differential assessment of disease as well as in the staging of the extent and severity of disease present. Imaging may additionally provide important information regarding the status of the tendon and surrounding osseous and soft tissue structures following therapeutic intervention, and in some instances may provide prognostic information regarding ultimate tendon function.

In this chapter, we review the normal and pathologic imaging features of the Achilles tendon, highlighting the potential utility and limitations of various imaging techniques in the non-invasive assessment of the tendon and the potential impact of imaging findings on clinical patient care.

Conventional radiography is currently the mainstay of bone and joint imaging, particularly in trauma. As it lacks soft tissue contrast, radiography provides limited information regarding the soft tissues. However, conventional radiography is fast, inexpensive, and readily available and may still provide important information regarding the Achilles tendon and adjacent structures. On lateral projection conventional radiographs, the normal margination of the Achilles tendon and adjacent pre-Achilles fat pad (Kager’s triangle) is seen as a sharp soft tissue interface along the anterior (volar) margin of the tendon (Fig. 4.1). Rupture of the Achilles tendon, Achilles tendinopathy, or inflammation/hemorrhage within the pre-Achilles fat pad may obscure this sharp interface between the tendon and adjacent fat (Fig. 4.2). These findings may be subtle without the use of specific high-contrast (low-kilovolt) radiographic technique.

Morphologically, the normal Achilles tendon should be no more than 8 mm thick in the anteroposterior (AP) dimension, being thickest proximally and tapering slightly along its distal third to its insertion on the calcaneal tubercle. The normal retrocalcaneal bursa should produce a radiolucency anterior to the distal insertional fibers of the Achilles tendon that extends at least 2 mm below the superior surface of the calcaneus (Fig. 4.1). Bursitis or thickening of the tendon at its calcaneal insertion may obliterate this normal radiolucency on conventional radiography (Fig. 4.3). If adjacent erosions are seen to the posterior calcaneus in the region of the retrocalcaneal bursa, then an underlying inflammatory arthritis, such as rheumatoid arthritis or psoriatic arthritis, with inflammatory bursitis and pannus formation should be considered. Conventional radiography promptly reveals avulsive fractures, calcification, or ossification of the tendon and adjacent soft tissues. Ossification of the Achilles tendon is rare, with an ossific mass contained within the substance of the tendon, usually seen in patients prior to Achilles tendon rupture or chronic Achilles tendinopathy (Fig. 4.4). In contrast, ethesopathic ossification (spur formation) at the calcaneal insertion of the Achilles tendon is a fairly common finding of little clinical significance.

In contrast to conventional radiography, cross-sectional imaging techniques such as ultrasound and MRI have excellent soft tissue contrast imaging capabilities, and have thus become the...
FIGURE 4.1. Lateral conventional radiograph of a normal ankle demonstrating a well-defined anterior margin of the Achilles tendon (arrowheads), the pre-Achilles/Kager’s fat pad (*), and the retrocalcaneal bursal recess (solid arrow).

FIGURE 4.2. Lateral conventional radiograph of an ankle following rupture of the Achilles tendon. There is marked thickening of the Achilles tendon, loss of the normal sharp anterior border (arrowheads), and effacement of the pre-Achilles/Kager’s fat pad.

FIGURE 4.3. Lateral conventional radiograph of an ankle showing a thickened distal Achilles tendon (arrowheads), loss of the normal retrocalcaneal bursal recess, dystrophic insertional ossification (solid arrow), and a retrocalcaneal bursitis, replacing the normal low attenuation fat pad (*).

modalities of choice for imaging assessment of the Achilles tendon. Musculoskeletal ultrasound (MSK US) is frequently utilized for assessment of myotendinous disorders, particularly in Europe where its use has been extremely popular and widespread. Constant improvement in technology, with higher frequency transducers (15 MHz), smaller footprint probes, power Doppler (Fig. 4.5), extended field of view capabilities, 3D imaging, and tissue harmonics have all contributed in part to this popularity. In comparison with MR imaging, MSK US has several advantages in assessment of the Achilles tendon: it is readily assessable, has a relatively quick scan time, and has better patient tolerability. MSK US also allows easy contralateral comparison. In addition, the personal interaction with the patient can produce a more patient-directed examination, tailored to the investigation of specific clinical complaints or symptoms. However, MSK US is operator
dependent, with a long learning curve. Appropriate training and experience are required for accurate and efficient use of this modality in clinical practice. Higher frequency musculoskeletal ultrasound transducers provide better spatial resolution, and thus more detailed delineation of normal and abnormal superficial soft tissues, but are of limited value in the assessment of deeper structures due to poor return of echoes. As a result, MSK US has been increasingly used in the evaluation of the superficial tendon, and in particular the Achilles tendon, in the assessment of tendinopathy and rupture to post-treatment follow-up.7–18

For optimal ultrasonographic evaluation, tendons should be interrogated/scanned along both their long and short axes,9,19 orientating the ultrasound probe so that the ultrasonic waves reach the tendon perpendicularly. The highly ordered pattern of parallel collagen tendon fibers shows the highest echogenicity when examined perpendicular to the ultrasound beam (Fig. 4.6). If this is not the case, the majority of the reflected ultrasonic waves will not be received by the transducer and tendons will appear hypoechoic or anechoic (Fig. 4.7). This angle-dependent appearance of tissue structures is referred to as acoustic fiber anisotropy.20 Imaging artifacts related to fiber anisotropy can mimic the ultrasonographic appearance of tendon pathology. Awareness of the normal curvature of tendons and proper
Ultrasonographic investigation, including dynamic real-time imaging in more than one plane, are essential to avoid this potential imaging pitfall.\textsuperscript{21} Except for its insertion on to the calcaneus, the Achilles tendon has a relatively straight course, compared with other ankle tendons, and is thus less susceptible to anisotropy at US evaluation. Nevertheless, careful examination of the Achilles, particularly at the tendon’s calcaneal insertion, with cranial and caudal angulation of the probe is necessary to assess the inherent ultrastructural integrity and echogenicity of the tendon.

The normal Achilles tendon has an echogenic pattern of parallel fibrillar lines in the longitudinal plane and an echogenic round-to-ovoid shape in the transverse plane (Fig. 4.8). The number of echogenic lines visible in the tendon with ultrasound is simply a correlate of the ultrasound anisotropy. When the ultrasound beam is perpendicular to the tendon, reflected waves return to the transducer. If the tendon is off perpendicular, then the majority of the reflected waves will not be received by the transducer.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{anisotropy.png}
\caption{Diagrammatic representation of anisotropy. When the ultrasound beam is perpendicular to the tendon, reflected waves return to the transducer. If the tendon is off perpendicular, then the majority of the reflected waves will not be received by the transducer.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figures.png}
\caption{Transverse ultrasound images of a normal Achilles tendon. (A) Probe orientated at 90° to the tendon demonstrating a normal oval echobright tendon (arrowheads). (B) Probe angled off perpendicular to the tendon demonstrating a hypoechoic (dark) tendon (arrowheads).}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figures.png}
\caption{(A) Longitudinal ultrasonographic image of a normal Achilles tendon. Note the echogenic, parallel fibrillar pattern (between arrowheads). (B) Transverse ultrasonographic image of a normal Achilles tendon showing echogenic ovoid shape (arrowheads).}
\end{figure}
On transverse imaging, the normal Achilles tendon has a flat to concave anterior surface and measures 4–6 mm in anterior to posterior (AP) diameter. While 6 mm is generally accepted as the upper limit of normal for AP dimension, the measurement can be somewhat variable due to anatomical variation in the shape of the Achilles tendon. Proximal to its calcaneal insertion, the Achilles tendon lies immediately superficial to the pre-Achilles fat pad, a triangular area of adipose tissue known as Kager’s triangle. At ultrasound imaging, the pre-Achilles fat pad shows low mottled echogenicity relative to the normally echogenic tendon. Further anterior to this pre-Achilles fat pad is the deep flexor compartment of the calf, predominantly composed of the flexor hallucis longus muscle, which overlies the echobright acoustical interface of the posterior tibial and talar cortices (Fig. 4.9). Two bursae can be present around the insertion of the Achilles tendon onto the calcaneus. Both are well delineated at ultrasonography. The pre-Achilles bursa, also referred to as the retrocalcaneal bursa, lies deep to the Achilles tendon between the Achilles tendon and the subjacent calcaneus. This bursa is commonly seen in normal subjects, and may vary considerably in appearance and relative dimensions with flexion and extension of the ankle. The superficial tendo-Achilles bursa or retro-Achilles bursa is an acquired bursa occurring in the potential soft tissue interval superficial to the distal tendon between it and the dorsal subcutaneous tissues. This bursa is not seen in normal individuals, and its presence is typically post-traumatic or inflammatory in etiology.

Tendon thickening and hypoechochogenicity are the most common abnormalities encountered in clinical ultrasonographic assessment of the Achilles tendon. Focal or diffuse thickening of the Achilles tendon is most commonly seen in

![Figure 4.9](image-url)
association with tendinopathy (Fig. 4.10). Prior investigations have documented tendon thickening ranging from 7 to 16 mm in patients with a clinical diagnosis of tendinopathy. Similarly, in athletes with a clinical diagnosis of Achilles tendinopathy, affected tendons were on average 78% thicker than the contralateral unaffected tendon. Focal hypoechoic areas within the normally echo-bright tendon represent areas of tendinopathic lesions. Many of the so-called spontaneous tendon ruptures are due to progressive degeneration of the tendon. Thickening of the tendon and focal hypoechoic areas are seen with both tendinopathy and partial tearing, thus making the differentiation between the two difficult. However, Åström proposed that thickening of the tendon >10 mm and severe intratendinous abnormalities indirectly suggested partial rupture. However, true partial tears are rare at surgery, and potential differentiating imaging features can at times be misleading.

In contrast to potential difficulties encountered in the differential evaluation of partial tears versus tendinopathy, ultrasound is highly accurate in the diagnosis of full thickness tears of the Achilles tendon. Paavola et al. correctly diagnosed 25 of 26 full thickness tears before surgery, and Hartgerink et al. showed that ultrasound can be effective in the differentiation of full versus partial thickness tears or tendinopathy, with a sensitivity and specificity of 100% and 83%, respectively, and an accuracy of 92%. Undetectable tendon at the site of injury, tendon retraction, and posterior acoustic shadowing at the site of a tendon tear have been described as ultrasonographic signs of a full thickness tear (Fig. 4.11). Posterior acoustic shadowing deep to the torn tendon margins is thought to occur secondary to sound beam refraction by frayed/torn tendon ends. A potential pitfall in the ultrasound evaluation of a complete full thickness tear of the Achilles tendon is visualization of an intact plantaris tendon medial to...
the torn fibers of the Achilles (Fig. 4.12). The normal plantaris tendon may be mistaken for residual intact Achilles tendon fibers, and can lead to a false diagnosis of a high-grade partial tear rather than a complete tendon tear. Dynamic ultrasound assessment of a complete Achilles tendon rupture can further reveal whether the retracted torn tendon ends can be approximated to one another on plantar flexion. This may be of use when deciding between conservative versus surgical treatment.

Following successful management of Achilles tendon rupture and tendinopathy, tendon abnormalities can persist on ultrasound despite resolution of patient symptoms. Following conservatively or surgically treated Achilles tendon ruptures, the tendon can continue to appear thickened and irregular with focal hypoechoic areas at ultrasound evaluation. Rupp et al. tried to correlate long-term clinical outcome after surgery for Achilles tendon rupture with ultrasound morphology of the tendon, but found that, while ultrasound is able to reveal long-lasting changes of the morphology of the tendon, it was of only limited value in evaluation of the functional result. Calcifications may also occur at the site of a prior tear: they are seen as hyperechoic areas casting acoustic shadowing (Fig. 4.13). Despite the ability of ultrasound to accurately depict structural abnormalities of the Achilles tendon, only moderate correlation exists between ultrasound appearance and clinical assessment of chronic Achilles tendinopathy. In addition, Khan and co-workers showed that the baseline ultrasound appearance of the tendon, in the setting of chronic tendinopathy, was a poor predictor of subsequent

**Figure 4.11.** (A) Longitudinal extended field of view ultrasonographic image of a complete tendon tear showing the gap in the tendon (*) and the torn tendon ends (solid arrows). The muscle belly of flexor hallucis longus is well seen deep to the tear. (B) Longitudinal extended field of view ultrasonographic image of a complete tendon tear. Note more retraction, compared to case A, with a larger gap in the tendon, torn tendon ends (solid arrows), and echogenic (bright) fat herniating into the tendon gap (*).
FIGURE 4.12. Transverse (A) and longitudinal (B) ultrasonographic images of a full thickness tear of the Achilles tendon, demonstrating an intact echogenic plantaris tendon (solid arrows).

FIGURE 4.13. (A) Longitudinal extended field of view ultrasonographic image of an insertional Achilles tendinosis with echogenic (bright) calcification (solid arrows) in the thickened distal Achilles tendon. (B) Transverse ultrasonographic image of a previously torn Achilles tendon. There are focal echogenic (bright) areas of calcification (solid arrow) with posterior acoustic shadowing (arrowheads). The Achilles tendon is thickened, hypoechoic, and heterogeneous.

clinical outcome. Conversely, other investigators have shown that tendon inhomogeneity can be used to predict clinical outcome in painful Achilles tendons. Nehrer et al. additionally reported that patients with a clinical diagnosis of Achilles tendinopathy, with a normal ultrasound appearance of the Achilles tendon, had a significantly better clinical outcome, compared to individuals with abnormal findings at ultrasound. They also documented that patients with tendon thickening and focal hypoechoic areas had higher rates of subsequent spontaneous tendon rupture.

The recent addition of color and power Doppler imaging to ultrasound has allowed for the noninvasive study of blood flow and vascularity within and surrounding the Achilles tendon (Fig. 4.5). In patellar tendinopathy, color Doppler has demonstrated increased vascularity in the setting of an abnormal tendon, suggesting neovascularization. Zanetti et al. demonstrated that the presence of neovascularization is a relatively specific sign for a clinically painful tendon. However, the presence of neovascularization did not affect the patient’s outcome adversely.

The multiplanar imaging capabilities of MRI combined with its excellent soft tissue contrast characteristics make it ideally suited for imaging of the Achilles tendon. Sagittal and axial planes are most useful in the evaluation of the Achilles tendon commonly using a combination of T1 and T2 weighted imaging sequences. In general, T1 or intermediate weighted sequences provide optimal delineation of anatomic detail, and T2 weighted sequences are most sensitive to the abnormal increase in fluid signal that accompanies most pathological conditions of the tendon. Short tau inversion recovery (STIR) and fat satu-
ration T2 weighted sequences may additionally serve to increase signal contrast between free water and the surrounding fat and adjacent tendon.

On sagittal MR images, the anterior and posterior aspects of the normal Achilles tendon should be parallel to one another distal to the soleus insertion (see reference 43). The normal average AP dimension of the Achilles tendon on MRI is 6 mm. At axial imaging, the anterior aspect of the tendon should be flat to concave (Fig. 4.14). The length of the Achilles tendon is variable, ranging from 20 to 120 mm between the musculotendinous origin and the calcaneal insertion of the tendon. The presence of an accessory soleus muscle produces an apparently shorter Achilles tendon, as the accessory soleus may have an insertion directly onto the anterior margin of the Achilles tendon, mimicking a more distal musculotendinous origin (Fig. 4.15). The normal Achilles tendon is of low signal (black) on all MR imaging sequences, reflecting its ultrastructural composition of compact parallel arrangements of collagen fibers and its low intrinsic water content (Fig. 4.16). However, the magic angle phenomenon can produce areas of increased signal within normal tendons, observed as tendon fibers approach an orientation angle of 55° relative to the main magnetic field. While the Achilles has a relatively straight course, this effect can occur as
the Achilles fibers spiral internally. The magic angle effect is usually seen with echo times of less than 20 msec (e.g., T1 weighted and proton density/intermediate acquisitions), but the effect should not be present on T2 weighted (long echo time) acquisitions. Recently MR magic angle imaging has been used to advantage in imaging of the Achilles tendon. With this technique the Achilles tendon is imaged at 55° relative to the main magnetic field rather than at the usual 0°. In this way, signal related to the magic angle phenomenon becomes detectable within the tendon. Using this method, intratendinous STIR signal change was more apparent, and contrast enhancement was much more evident within the tendon.

As with ultrasonographic assessment, a pre-Achilles/retrocalcaneal bursa can be seen in asymptomatic individuals at MR evaluation. The bursa normally measures up to 6 mm craniocaudally, 3 mm medial to lateral, and 2 mm anterior to posterior. Achilles paratendinopathy manifests as linear or reticular areas of increased signal on T2 weighted images, paralleling the deep margin of the Achilles tendon, representing areas of edema or increased vascularity. However, both ultrasound and MRI evaluation are unreliable in the assessment of the paratenon.

Classic MR imaging features of Achilles tendinopathy include morphologic findings of a fusiform tendon shape, AP tendon thickening, convex bulging of the anterior tendon margin, and areas of increased intratendinous signal on T1 and T2 weighted sequences (Fig. 4.17). Areas of increased signal within the tendon on T2 weighted sequences are thought to represent more severe areas of collagen disruption and partial tearing. AP thickening of the tendon greater than 10 mm correlates with pathological findings of partial tendon tearing.

Full thickness tearing of the Achilles tendon is manifest on MR imaging as complete disruption of the tendon fibers with tendon discontinuity and high signal intensity within the tendon gap acutely on T2 weighted images (Fig. 4.18). MR imaging with plantar flexion, when feasible, may provide additional information regarding separation of the torn tendon ends and potential apposition of the tear margins. Potential diagnostic difficulties may arise in the MR imaging differentiation of chronic tendinopathic changes with a complete non-retracted tendon tear from cases of chronic tendinopathy with partial tendon tearing. As with ultrasound examination, MRI following Achilles tendon repair typically illustrates tendon thickening and intrasubstance imaging heterogeneity (Fig. 4.19). A decrease in intrasubstance signal, together with an increased tendon size, may gradually progress over one to two years after surgery, possibly

**Figure 4.16.** Sagittal T1 (A) and T2 with fat saturation (B) images, of a normal Achilles tendon. Note the parallel anterior and posterior tendon surfaces (arrowheads) and its low signal (black) appearance on both sequences.
FIGURE 4.17. Sagittal T1 (A) and sagittal T2 with fat saturation (B) images showing fusiform thickening of the Achilles tendon and abnormal intratendinous signal dorsally (solid arrows).

FIGURE 4.18. Sagittal T1 (A) and sagittal T2 with fat saturation (B) weighted images in a patient with an Achilles tendon rupture. Note discontinuity of fibers, high signal within the tendon gap (arrowheads), and the torn tendon ends (solid arrows).
reflecting progressive scar maturation at the repair site.

Despite the acknowledged benefits and widespread use of MR imaging in the assessment of the Achilles tendon, there is some debate as to the utility of MRI in examination in this regard. Karjalainen et al. examined 117 Achilles tendons with MRI and documented the overall sensitivity of MR imaging in the detection of abnormalities in cases of painful Achilles tendon to be 94%, with a specificity of 81%, and overall accuracy of 89%. The interobserver agreement for the MR imaging findings evaluated was good in all categories. However, several authors demonstrated an overlap of imaging findings in symptomatic and asymptomatic individuals. Signal heterogeneity and subtle focal increases in intrasubstance signal with distal longitudinal striations or small punctate foci of increased T1 weighted signal may represent normal fascial anatomy or possibly small vessels in normal Achilles tendons. This fascicular signal should be less apparent on STIR/T2 weighted images and the tendon should maintain a normal morphologic appearance with a concave anterior surface on axial imaging. Areas of mild increased T2 weighted signal visualized within the Achilles tendon in asymptomatic patients have been described and postulated by Haims and co-workers to represent areas of subclinical tendinopathy/mucoid degeneration. In contrast, areas of intense T2 weighted signal and thickened tendons were associated with chronic symptoms and tendon tears. Unlike ultrasound, Khan et al. did show that graded MRI did correlate with 12-month clinical outcome in patients with tendinopathy.

In conclusion, the Achilles tendon is the most commonly injured tendon in the foot and ankle, with injuries commonly related to sports/athletic activities. Imaging modalities most commonly employed in the diagnostic assessment of the Achilles include conventional radiography, ultrasonography, and magnetic resonance imaging. Cross-sectional imaging, including ultrasound and MR imaging, plays an important role in the documentation and staging of disease of the Achilles, and provides a noninvasive means of assessing the tendon’s response to therapy or progression of disease.
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