# The Achilles Tendon: Imaging Diagnoses and Image-Guided Interventions—*AJR* Expert Panel Narrative Review

Bill Pass, MBChB[1], Philip Robinson, MBChB[1,2], Alice Ha, MD[3], Benjamin Levine, MD[4], Corrie M. Yablon, MD[5], Emma Rowbotham, MBChB[1,2]

**Musculoskeletal Imaging · *AJR* Expert Panel Narrative Review**

**Keywords**

Achilles tendon, intervention, MRI, rupture, tendinopathy, ultrasound

Submitted: Feb 27, 2022
Revision requested: Mar 12, 2022
Revision received: Apr 7, 2022
Accepted: Apr 22, 2022
First published online: May 4, 2022

The authors declare that they have no disclosures relevant to the subject matter of this article.

The views expressed are those of the authors and not necessarily those of the National Institute for Health Research (NIHR) or the Department of Health and Social Care.

Supported in part by the NIHR Leeds Biomedical Research Centre (P. Robinson and E. Rowbotham).

ARRS is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to provide continuing medical education activities for physicians. The ARRS designates this journal-based CME activity for a maximum of 1.00 AMA PRA Category 1 Credits™ and 1.00 American Board of Radiology©, MOC Part II, Self-Assessment CME (SA-CME). Physicians should claim only the credit commensurate with the extent of their participation in the activity. To access the article for credit, follow the prompts associated with the online version of this article.

doi.org/10.2214/AJR.22.27632

*AJR* 2022; 219:355–368

ISSN-L 0361–803X/22/2193–355



The Achilles tendon is commonly affected by both chronic repetitive overuse and traumatic injuries. Achilles tendon injuries can potentially affect any individual but have a particularly high incidence in professional athletes. Appropriate imaging evaluation and diagnosis are paramount to guiding appropriate management. In this *AJR* Expert Panel Narrative Review, we discuss the role of various imaging modalities (particularly ultrasound and MRI) in the assessment of Achilles tendon pathology, focusing on the modalities' relative advantages and technical considerations. We describe the most common diagnoses affecting the Achilles tendon and adjacent structures, highlighting key imaging findings and providing representative examples. Various image-guided interventions that may be used in the management of Achilles tendon pathology are also reviewed, including high-volume injection, tendon fenestration, prolotherapy, and corticosteroid injection. The limited evidence supporting such interventions are summarized, noting an overall paucity of large-scale studies showing benefit. Finally, a series of consensus statements by the panel on imaging and image-guided intervention for Achilles tendon pathology are provided.

The Achilles tendon is the body's thickest and strongest tendon, composed of fibers from the gastrocnemius and soleus muscles. Given its high tensile load, it is also among the body's most commonly injured tendons and can be affected by chronic repetitive overuse and traumatic injury. Although an Achilles tendon injury can potentially affect any individual, the incidence of Achilles tendon injury is particularly high in elite-level athletes [1]. Appropriate imaging evaluation and diagnosis are paramount to guiding appropriate management. This review describes the role of various imaging modalities (primarily ultrasound and MRI) in the assessment of the most common pathologies affecting the Achilles tendon and adjacent structures, highlighting key imaging findings. The article also reviews current techniques and supporting evidence regarding various image-guided interventions that may be used to manage Achilles tendon pathology.

## Anatomy

The Achilles tendon is approximately 15 cm in length and is formed by components of the gastrocnemii and soleus tendons. The tendon begins its formation in the mid calf starting with contributions from the medial and lateral heads of the gastrocnemii that gradually come together over a length of 3–4 cm. A component from the soleus then joins over a similar distance, and together they form the Achilles tendon proper at a distance of approximately 5–6 cm proximal to the calcaneal insertion [2]. As the tendon descends, the gastrocnemius fibers rotate laterally greater than 90°, such that the gastrocnemius fibers insert laterally toward the posterior calcaneus, and the soleus fibers insert anteriorly at the medial aspect of the calcaneus. The calcaneal insertion is a true enthesis with fibrocartilage intermeshing with the marrow of the calcaneus. This direct meshing of tendon fibrils into marrow provides significant strength at this site; thus, the site is a rare location of tendon failure [3]. The tendon has a normal thickness of 4–7 mm and on axial imaging should have a concave anterior margin throughout most of its course. Those involved in intense

[1]Department of Radiology, Leeds Teaching Hospitals, Musculoskeletal Centre, Chapel Allerton Hospital, Leeds LS7 4SA, UK. Address correspondence to E. Rowbotham (emma.rowbotham@nhs.net).

[2]National Institute for Health Research Leeds Biomedical Research Centre, Chapel Allerton Hospital, Leeds, UK.

[3]Department of Radiology, University of Washington, Seattle, WA.

[4]Department of Radiological Sciences, David Geffen School of Medicine, University of California at Los Angeles, Los Angeles, CA.

[5]Department of Radiology, University of Michigan Medical Center, Ann Arbor, MI.

athletic activity are expected to have a thicker tendon [4, 5]. The tendon lacks a true tendon sheath and is enveloped distally by a paratenon on its superficial surface that is highly vascularized and blends with the muscle fascia at its proximal aspect and the periosteum distally. The paratenon allows the tendon to glide relative to the adjacent soft tissues and also provides the tendon's blood supply. The paratenon's blood supply is primarily from the posterior tibial artery. The paratenon does not extend around the tendon's deep surface, where the Kager fat pad directly contacts the tendon itself. The resulting diminished vascularity, particularly in the tendon's midportion, leaves the tendon susceptible to injury and decreased healing ability [6].

The plantaris tendon is intimately related to the Achilles tendon. It originates from the lateral supracondylar ridge of the femur above the lateral head of the gastrocnemius muscle and is congenitally absent in approximately 7% of individuals [7]. From this origin, it passes obliquely between the gastrocnemius and soleus muscles with a small muscle belly measuring 7–10 cm in length. The distal plantaris tendon lies along the medial aspect of the Achilles tendon and has several insertion points, although most of its fibers insert at a distinct point on the posterior aspect of the superior calcaneus 1 cm anterior and medial to the Achilles tendon.

## Imaging Techniques

### *Radiography*

Radiography has an important role in the evaluation of heel and hind foot pain and is often a first-line investigation. Evaluation of heel pain can be clinically challenging, and radiography helps identify and exclude various causes including an acute or stress fracture, calcific tendinosis, or osteoarthritis. Assessment for Haglund deformity or tendon calcification is important in patients with insertional tendinopathy, though this can also be assessed by MRI. Loss of the usual lucency in the Kager fat pad is often a sign of regional edema. Such edema may relate to extension of the Achilles tendon into the fat pad as a result of the absence of a true sheath around the tendon or to inflammation associated with the retrocalcaneal bursa.

### *Ultrasound*

Ultrasound is highly accurate in evaluation of the Achilles tendon for tear [8]. Ultrasound is also highly sensitive for tendinopathy when performed by an experienced operator using a high-frequency linear transducer. The Achilles tendon should be scanned from its myotendinous junction to its calcaneal insertion in transverse and longitudinal planes. The Achilles tendon thickness should be measured on transverse images, because longitudinal images may yield measurement errors if the probe is tangential to the tendon [9]. When scanning the tendon in the short axis, the probe can be tilted on each side of the tendon to assess the peritendinous envelope. During this maneuver, the medial aspect of the plantaris and the retroachilles and retrocalcaneal bursas should be assessed [10]. If a tear is present, the dynamic capabilities of ultrasound allow evaluation of the tear in neutral and plantar flexion positions. As most tears are treated by casting in a plantar flexion position, it is useful for the clinical team to recognize any residual gap in the tendon and the torn fiber's proximity in this position (Fig. 1). This information can help guide the

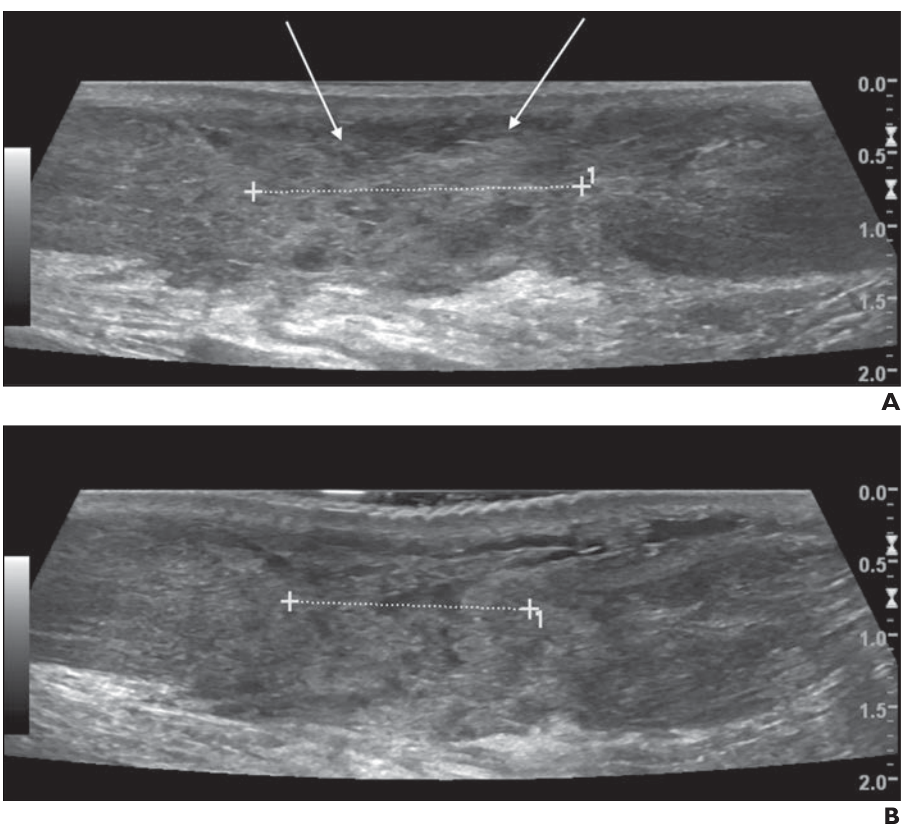



**Fig. 1—**49-year-old man with 6 weeks of calf ache and popping sensation in ankle 1 week before imaging.
**A,** Longitudinal ultrasound image obtained with patient in prone position and ankle in neutral position shows full-thickness Achilles tendon tear with 2.3-cm gap (between *calipers*, 1) between tendon ends and interposed hematoma (between *arrows*).
**B,** Longitudinal ultrasound image of Achilles tendon with patient in plantar flexion position shows closing of gap (between *calipers*, 1) to 1.7 cm.

decision between conservative and surgical management. Panoramic imaging can help assess the tear's exact location and its distance from the calcaneal tendon insertion.

Given the tendon's superficial location, a high-frequency linear probe (6–18 or 4–20 MHz) should be used to acquire highest-resolution images of the tendon and adjacent structures. Power Doppler should be used to assess for hyperemia within the tendon, a finding that can be seen in Achilles tendinopathy and can help guide intervention (Fig. 2). Hyperemia can also indicate subacute traumatic injury, with neovascularization representing recent healing. The normal tendon should not exhibit any vascularity.

Shear wave elastography has been shown to provide complementary biomechanical information and to be reproducible [11, 12]. However, it is not currently used in routine clinical practice.

### MRI

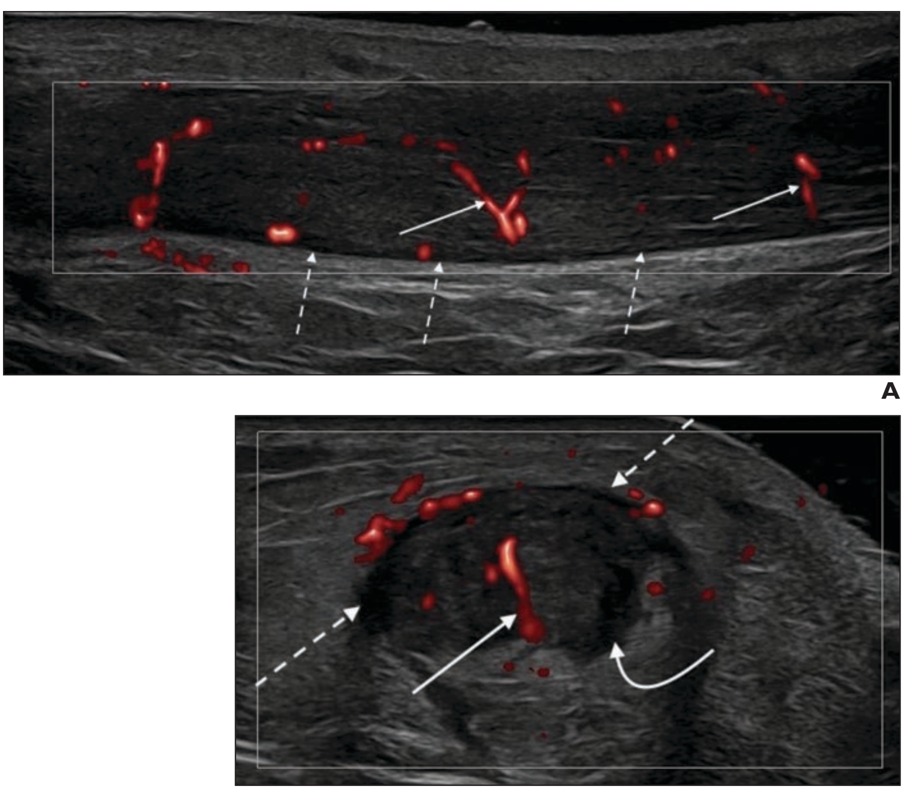
MRI, when performed using an extremity coil and a high-resolution matrix, is a comprehensive and highly accurate imaging modality for evaluating the Achilles tendon. The examination should ideally be performed at 3 T and should include sagittal and axial planes as well as a combination of fat-saturated sequences (e.g., STIR and fat-saturated T2-weighted or proton density–weighted sequences). T1-weighted sequences are also useful to assess the tendon, which should exhibit uniformly low T1-weighted signal throughout its course and the visualized bone marrow. Although the tendon is straight, it may be impacted by magic angle effect artifact through the altered angles of some of its traversing intratendinous bundle fibers. T2-weighted sequences are not affected by magic angle effect artifact and should be assessed if T1-weighted sequences show an apparent abnormality. Table 1 provides a sample MRI protocol for Achilles tendon evaluation.

### Postoperative Imaging

The most common complication after Achilles tendon surgery is rerupture [13]. Ultrasound is rapid and accurate in assessment for rerupture. Radiologists should recognize ultrasound features after different surgical procedures involving the Achilles tendon such as calcaneal osteotomy and flexor hallucis longus tendon transfer (Fig. 3). Potential limitations of ultrasound in postoperative assessment include limited access because of surgical dressings or postsurgical hematoma or collections. Limited access may necessitate use of a lower frequency on a linear transducer or use of a curvilinear transducer to fully evaluate the deeper soft tissues for collections. Dynamic assessment in these patients can be beneficial by allowing more accurate delineation of the ends of the tendon.

Ultrasound also readily assesses such findings as inflammation, infection, scarring, and calcification. Intratendinous vascularity is reduced in the immediate postoperative period and returns to approximately its baseline level after the first month; a period of hypervascularity is then observed in months 3–6 after surgery [14]. Intratendinous hypervascularity that persists after 6 months should be considered to represent pathologic scarring.

MRI in the postoperative period should include T1-weighted and fat-saturated T2-weighted sequences, with consideration of postcontrast imaging to aid identification of small fluid collections. If sutures or surgical material cause artifact, then STIR should be considered in place of fat-saturated T2-weighted sequences.



A

B

**Fig. 2—**23-year-old male amateur soccer player with Achilles tendon rupture 6 months prior and recent contralateral calf discomfort. Imaging was performed of calf with recent discomfort.
**A,** Longitudinal ultrasound image shows diffuse Achilles tendon hypoechogenicity and tendon thickening with concavity of anterior aspect of tendon (*dashed arrows*) and marked intrinsic vascularity (*solid arrows*). Findings are consistent with diffuse noninsertional Achilles tendinopathy.
**B,** Transverse ultrasound image shows diffuse heterogeneous hypoechogenicity (*curved arrow*) of Achilles tendon with prominent internal vascularity (*straight solid arrow*) and associated prominent thickening of paratenon (*dashed arrows*).

**TABLE 1: Suggested Parameters for MRI Performed for Achilles Tendon Evaluation**

| TSE Sequence, Plane | TR (ms) | TE (ms) | FOV (mm) | No. Signals Acquired | No. Concat. | Matrix | Slice Thickness (mm) | No. Slices | Interslice Gap (%) | Oversampling (%) | Scan Time (min:s) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PDW, axial | 3800 | 38 | 160 × 160 | 1 | 1 | 448 × 314 | 3 | 35 | 10 | 60 | 2:30 |
| FS PDW, coronal | 3940 | 33 | 160 × 132 | 2 | 1 | 352 × 203 | 3 | 32 | 10 | 100 | 3:58 |
| FS T2-weighted | | | | | | | | | | | |
| Sagittal | 4560 | 64 | 180 × 180 | 2 | 1 | 336 × 235 | 3 | 25 | 10 | 110 | 3:04 |
| Axial | 400 | 160 | 100 × 100 | 1 | 1 | 336 × 235 | 3 | 35 | 10 | 110 | 2:42 |
| T1-weighted, sagittal | 704 | 11 | 180 × 180 | 1 | 2 | 448 × 314 | 3 | 25 | 10 | 100 | 2:36 |

Note—TSE = turbo spin echo, concat. = concatenations, PDW = proton density–weighted, FS = fat-saturated.

## Imaging Diagnoses

### *Descriptive Terms*

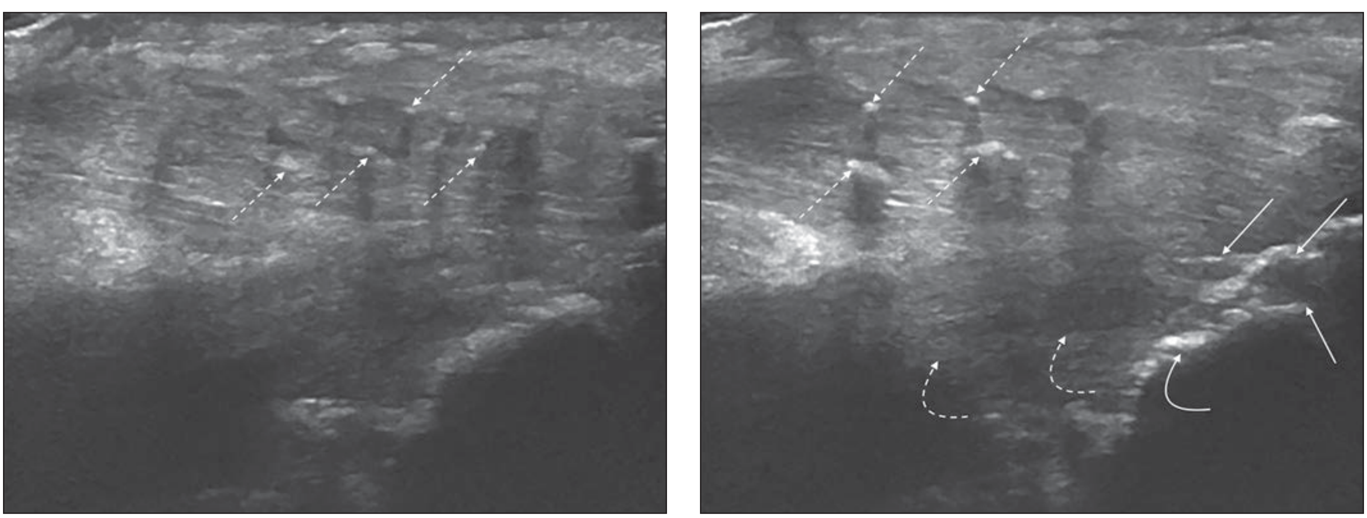
Descriptive terms relating to pathology of the Achilles tendon lack uniform agreement, and certain historic terms may lead to confusion when used in contemporary medical practice with their precise definitions. For the purpose of this article, we avoid the use of the term "tendinopathy" to describe a broad clinical entity encompassing essentially any painful condition of the tendon or tendon sheath including tendinosis, tendinitis, and tendon tear. Rather, we explicitly define tendinosis as a chronic tendon condition characterized histologically as collagen degeneration, tendinitis as tendon inflammation, paratenonitis as inflammation and fibrosis of the paratenon, and tendon tear as partial- or full-thickness tendon disruption [15].

### *Noninsertional Tendinopathy*

Noninsertional tendinopathy is of uncertain cause but is most likely a degenerative process with contributory factors including poor vascularity, overuse, and genetic and metabolic factors. The Achilles tendon can also be affected secondarily by inflammation from the retrocalcaneal bursa [3].

A recent systematic review highlighted nine clinical risk factors for Achilles tendinopathy including prior lower limb tendinopathy or fracture, use of quinolone antibiotics, moderate alcohol use, and training during cold weather [16]. Strong evidence indicates that diabetes is associated with Achilles tendinopathy [17]. Tendinopathy most often occurs 2–6 cm from the calcaneal insertion, the region where the tendon has least vascularity. Proximal to this region, the tendon receives its blood supply and nutrition from the adjacent musculotendinous junction of the gastrocnemius muscle [18]. Distal to this region, the tendon's blood supply is provided from the periosteal vessels near the calcaneal insertion [4]. Achilles tendinopathy is common in both athletes and nonathletes, most common in middle-distance runners [19], and multifactorial in origin. Treatment options vary, and the optimal treatment is debatable.

Imaging of noninsertional Achilles tendinopathy was historically reserved for recalcitrant or atypical cases but has become



A B

**Fig. 3**—58-year-old woman with prior surgical repair of Achilles tendon and Haglund deformity resulting from long-standing Achilles insertional tendinopathy refractory to conservative treatment.
**A,** Longitudinal ultrasound image shows postsurgical thickening of Achilles tendon, consistent with tendinopathy. Echogenic sutures (*arrows*) are seen along tendon course.
**B,** Longitudinal ultrasound image shows Achilles tendinopathy, with echogenic sutures (*straight dashed arrows*) along tendon course. Image also shows postsurgical changes of calcaneal osteotomy (*curved solid arrow*) with adjacent flexor hallucis longus tendon transfer (*curved dashed arrows*) and bone tunnel (*straight solid arrows*).


A

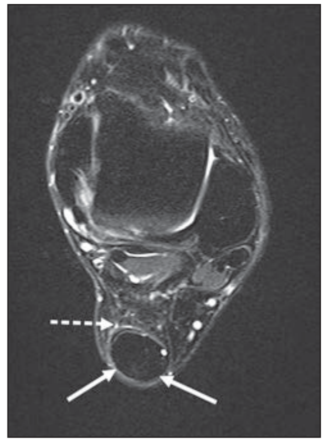

B

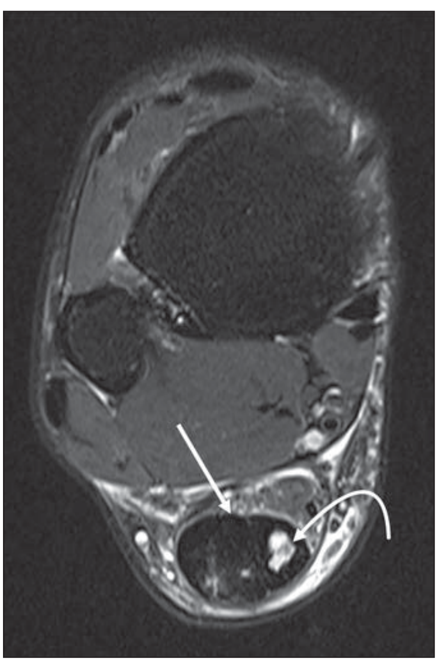
**Fig. 4**—52-year-old woman with calf pain.
**A,** Sagittal STIR image shows diffuse thickening of midportion of Achilles tendon with generalized increased signal posteriorly (*straight arrows*). More focal high signal centrally (*curved arrow*) is consistent with early mucoid degeneration. Findings are consistent with noninsertional tendinopathy.
**B,** Axial fat-saturated T2-weighted MR image shows diffuse tendon thickening (*solid arrows*) with loss of normal anterior concavity of tendon. No paratenon inflammation is present, and only minor edema (*dashed arrow*) is present in adjacent fat pad.

routine practice. Ultrasound provides dynamic imaging, including the ability to assess for hyperemia, which may help guide treatment decisions. Radiography has a limited role in assessing tendinopathy. Radiography may show an increase in tendon width where the tendon is bordered by the Kager fat pad anteriorly and subcutaneous fat posteriorly. Nonetheless, such assessment is not routinely performed by radiography, and other imaging modalities are more accurate.

Ultrasound in noninsertional tendinosis shows thickening of the affected portion of the tendon (usually in a fusiform pattern), loss of the fibrillary echotexture, and loss of the normal anterior concavity of the tendon on transverse images. The normal anteroposterior tendon diameter has a wide range, and a cutoff value for tendinosis has not been established. Neovascularity is thought to be associated with symptom severity and, when present, a poor clinical outcome [20, 21]. MRI shows similar features and generalized low signal throughout the tendon, generally occurring at a site 2 cm proximal to the calcaneal insertion and extending toward the musculotendinous junction (Fig. 4). Areas of mucoid degeneration can show increased signal on fluid-sensitive sequences; these areas can include small clefts or partial-thickness interstitial tears in severe cases (Fig. 5).

### Tendon Xanthomas

The Achilles tendon is the most common site of tendon xanthoma formation which often occurs in the setting of hypercho-


A


B

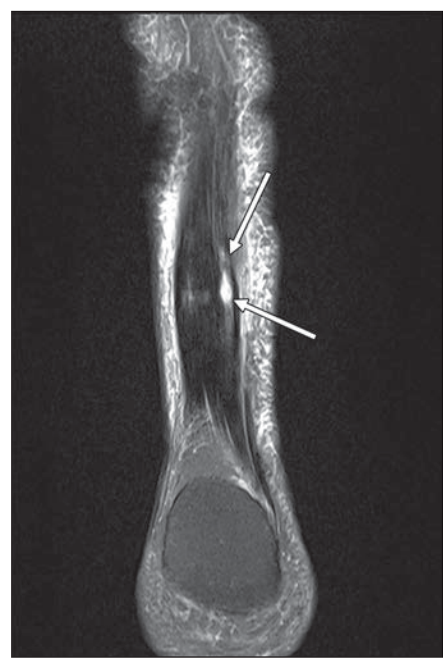

C

**Fig. 5**—67-year-old man with bilateral calf pain refractory to physiotherapy.
**A,** Axial fat-saturated T2-weighted MR image shows thickening of Achilles tendon with loss of its anterior concavity (*straight arrow*). Tendon shows heterogeneous increased signal posteriorly (*curved arrow*) resulting from mucoid degeneration with focal interstitial tear.
**B,** Axial proton density–weighted MR image shows increased signal (*straight arrow*) in posterior aspect of thickened Achilles tendon with areas of mucoid degeneration and small interstitial tear (*curved arrow*).
**C,** Coronal fat-saturated T2-weighted MR image shows area of interstitial tear (*arrows*) in medial aspect of mid Achilles tendon.

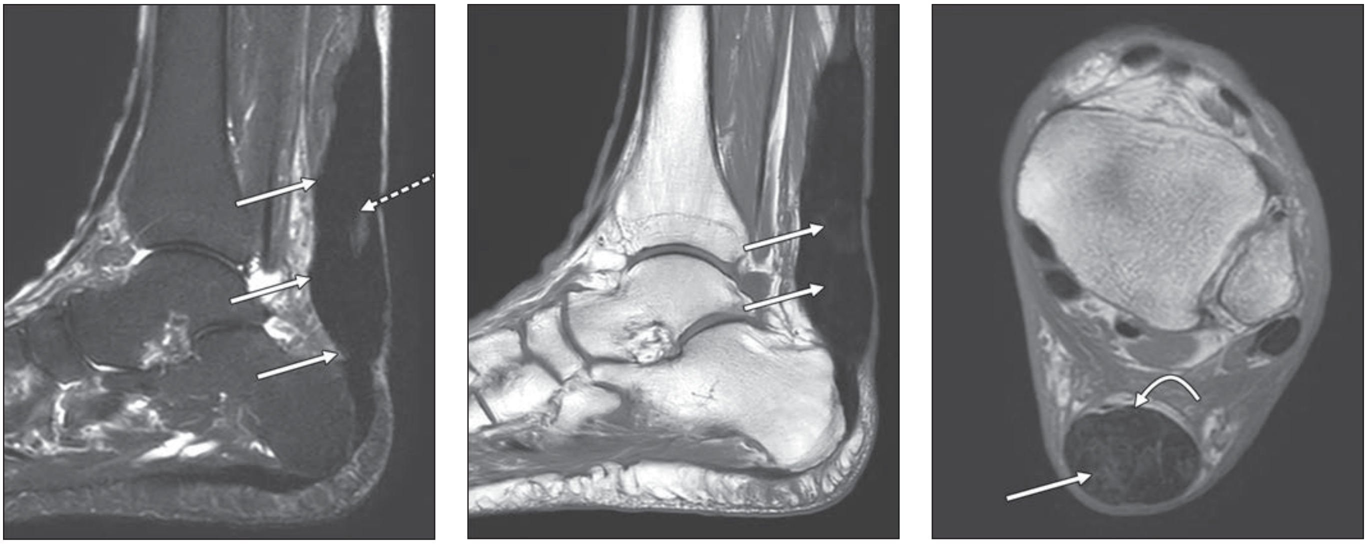



**Fig. 6—**87-year-old woman with history of hypercholesterolemia who presented with calf pain and swelling.
**A,** Sagittal fat-saturated T2-weighted MR image shows diffuse nonfusiform swelling of Achilles tendon (*solid arrows*) with small area of increased signal (*dashed arrow*).
**B,** Sagittal T1-weighted MR image shows areas of intrinsic signal (*arrows*) within Achilles tendon.
**C,** Axial proton density–weighted MR image shows increased tendon volume with loss of anterior concavity (*curved arrow*) and intrinsic striated appearance. Straight arrow indicates intrinsic signal change.

lesterolemia. Low-density lipoproteins accumulate within the tendon and present clinically as slowly progressive, diffuse, nonpainful tendon enlargement [22]. On ultrasound, the tendon exhibits a uniform nonfusiform increase in volume, with loss of its usual anterior concavity. On MRI, the tendon exhibits intermediate signal on T1- and T2-weighted images, with higher signal in comparison with a normal tendon. The tendon may exhibit a striated appearance because of the interposition of xanthoma between tendon fibers [23] (Fig. 6). A recent exploratory study suggested that Dixon MRI may be able to differentiate Achilles tendon xanthoma and tendinopathy [24].

## *Insertional Tendinopathy*

Focal tendinopathy that occurs near the calcaneus is usually a result of one of three causes: seronegative arthropathy, retrocalcaneal bursitis, or chronic traction injury.

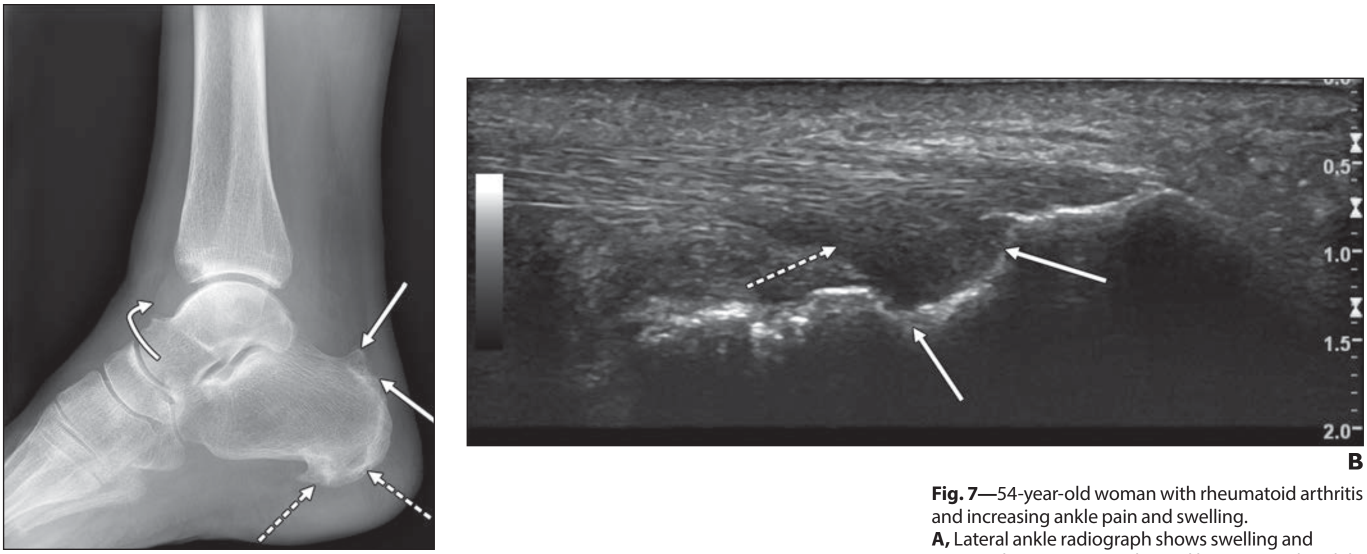
*Seronegative arthropathy*—Seronegative arthropathy represents an inflammatory reactive insertional tendinitis and is variably associated with concurrent retrocalcaneal bursitis. Erosions may be present at the calcaneal insertion and aid differentiation of this entity from tractional causes of tendon injury (Fig. 7). Indeed, ultrasound and MRI cannot accurately differentiate inflammatory tendinitis from other causes of tendinitis in the absence of erosions [25]. On MRI, erosions are present in one- to two-thirds of patients with spondyloarthropathy. MRI may also show bone marrow edema at the tendon insertion, possibly related to the level of human leukocyte antigen B27 (HLA-B27) [26]. Finally, foci of calcification may occur within the tendon just adjacent to its insertion.

*Retrocalcaneal bursitis*—The normal retrocalcaneal bursa is visible on MRI and may contain up to 1 mL of fluid. Its posterior border is represented by the Achilles tendon. The bursa should measure less than 6 mm from superior to inferior, less than 3 mm from medial to lateral, and less than 2 mm from anterior to posterior [27].

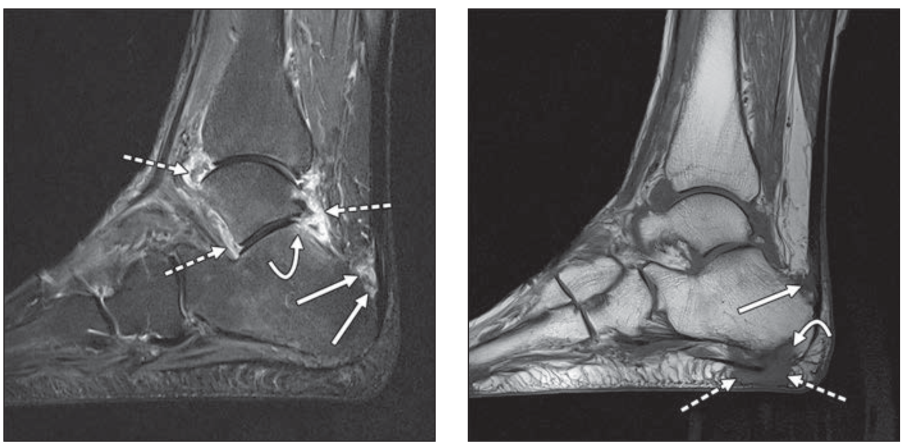
The retrocalcaneal bursa serves to protect the distal Achilles tendon from the frictional wear of the adjacent calcaneus. In Haglund syndrome, a Haglund deformity (i.e., bony enlargement of the posterior calcaneus) compresses the retrocalcaneal bursa and the overlying Achilles tendon. This compression in turn causes inflammation of the retrocalcaneal bursa and tendon, potentially stimulating further bony irregularity and bone growth with associated further compression and irritation. Bursal findings include increased fluid volume and minor inflammatory edema in the adjacent soft tissues.

Other causes of retrocalcaneal bursitis include athletic overactivity in ballet dancers and runners as well as inflammatory arthropathy. The bursa is intimately related to the enthesis and therefore can be involved in inflammatory insertional tendinopathy [3]. Seronegative insertional tendinopathy exhibits similar imaging findings as found in Haglund syndrome, including distention of a fluid-filled bursa with minor adjacent inflammation. Bone changes in an inflammatory condition are likely to be erosive, in contrast with the bony hypertrophy that occurs in Haglund syndrome (Fig. 7).

*Chronic traction injury*—Chronic traction injury is the most commonly encountered Achilles tendon injury in athletes or other physically active individuals, occurring most commonly in runners. Chronic traction injury relates to chronic repetitive strain at the tendon's calcaneal insertion. Imaging shows tendinosis with thickening of the Achilles tendon and new bone formation at the enthesis (i.e., enthesophytes). Ultrasound may show regional neovascularity and can clearly identify enthesophytes, which may then be further evaluated with radiographs. On MRI, T1-weighted sequences are the most useful sequences to identify new bone formation, though small areas of calcification within the tendon can be more reliably identified by radiograph (or CT if the referring physician desires cross-sectional imaging for oper-




A B



C D

**Fig. 7**—54-year-old woman with rheumatoid arthritis and increasing ankle pain and swelling.
**A,** Lateral ankle radiograph shows swelling and erosive change in retrocalcaneal bursa (*straight solid arrows*). Prominent soft-tissue swelling is present over proximal plantar fascia with erosive change in calcaneum at its insertion (*dashed arrows*). Large tibiotalar joint effusion and swelling (*curved arrow*) are also present.
**B,** Longitudinal ultrasound image at Achilles tendon insertion shows fluid in retrocalcaneal bursa (*dashed arrow*) and erosion of adjacent posterior calcaneus (*solid arrows*).
**C,** Sagittal STIR image shows fluid and inflammation in retrocalcaneal bursa with adjacent calcaneal erosive change (*solid straight arrows*). Also present are tibiotalar and subtalar joint synovitis (*dashed arrows*) and associated calcaneal bone edema (*curved arrow*).
**D,** Sagittal T1-weighted MR image shows retrocalcaneal inflammation and adjacent calcaneal erosion (*straight solid arrow*). Also present are rheumatoid plantar nodule at calcaneal plantar fascia insertion with associated soft-tissue change (*dashed arrows*) and calcaneal erosion (*curved arrow*).

ative planning). MRI also shows general tendon thickening with possible increased signal on T2-weighted sequences, consistent with low-grade inflammation.

### Superficial or Retroachilles Bursitis

The retrocalcaneal bursa is the only true bursa of the ankle. However, an additional bursa acquired through inflammation or trauma is located superficial to the distal Achilles tendon and deep to the overlying skin. This bursa may normally contain a small volume of fluid and be visible on both ultrasound and MRI. Nonetheless, the bursa normally measures less than 2 mm in anteroposterior diameter. A greater size of the bursa may be considered to represent bursitis [27].

### Paratenonitis

Although the Achilles tendon cannot be involved in tenosynovitis because of its lack of a tendon sheath, the surrounding paratenon, a loose network of connective tissue, can become inflamed, described as paratenonitis. The paratenon can become inflamed in isolation (i.e., without Achilles tendon pathology), for example in inflammatory conditions including rheumatoid arthritis, seronegative arthropathy, and gout [28]. The paratenon can also become inflamed in conjunction with Achilles tendinosis; in this context, the swelling of the Achilles tendon is considered to reduce the tendon's smooth gliding within the paratenon. In such patients, the paratenon shows increased signal as a result of edema and vascularization, and patients experience secondary pain given the paratenon's rich nerve supply [29].

In paratenonitis, ultrasound shows a thickened hypoechoic paratenon, with possible fluid between the tendon and the paratenon that is particularly observed in the acute phase. Doppler imaging may show increased vascularity. On MRI, fat-suppressed fluid-sensitive sequences show increased signal intensity in the paratenon, most pronounced posteriorly. Inflammation can be shown in the adjacent soft tissues extending into the Kager fat pad anteriorly (Fig. 8). The paratenon may show thickening after chronic inflammation. Adhesions have been reported during surgical evaluation but are difficult to identify on imaging [30].

### Plantaris Friction Syndrome

Several small case studies have indicated a role of the plantaris tendon in the development of tendinopathy of the mid Achilles

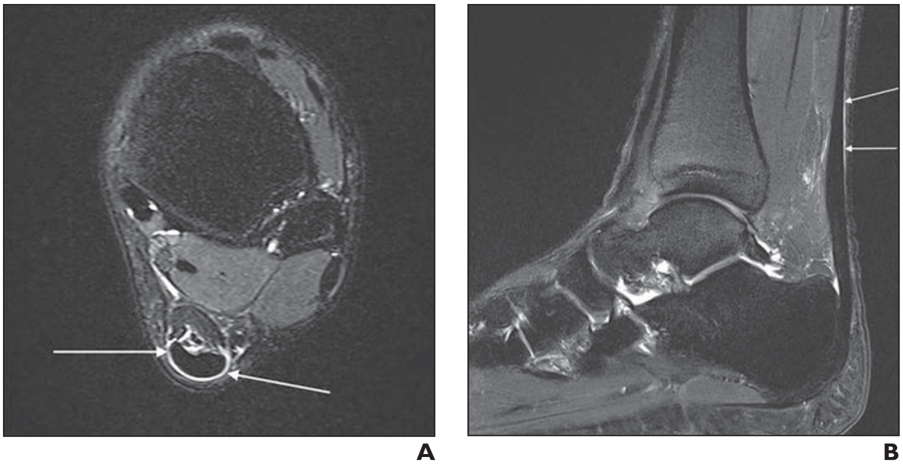



**Fig. 8—**27-year-old male professional soccer player with 2-week history of gradual onset calf pain.
**A,** Axial fat-saturated T2-weighted MR image shows thickening and edema around Achilles tendon (*arrows*), consistent with paratenonitis.
**B,** Sagittal fat-saturated T2-weighted MR image shows paratenon inflammation (*arrows*) along posterior aspect of tendon.

tendon and describe this process as plantaris friction syndrome [31–33]. The exact role of the plantaris tendon in friction syndrome is poorly understood. One study indicates that the plantaris tendon is stiffer and stronger than the Achilles tendon [34]. Thus, the plantaris tendon may tether to the Achilles tendon, causing a compressive force or adjacent inflammation in the tendon. Alfredson [31] described tendinopathic changes in the plantaris tendon at surgery, similar to the changes found in the Achilles tendon. However, such changes were not observed by Calder et al. [35], leading to the hypothesis that the plantaris tendon has primarily a tractional role [35, 36].

Ultrasound has been described as the most accurate assessment for plantaris friction syndrome given its high special resolution and ability to use power Doppler to assess vascularity [37]. Ultrasound findings include focal medial Achilles tendinosis with tendon hypoechogenicity and hyperemia. Koh et al. [37] advocate the use of a plantaris window during ultrasound to aid diagnosis, whereby the ultrasound probe is placed over the medial aspect of the Achilles tendon using a gel standoff. In patients with plantaris friction syndrome, MRI may show focal increased signal of the Achilles tendon medially in close relation to the plantaris tendon (Fig. 9).

Ultrasound tissue characterization provides a potential diagnostic adjunct in patients with suspected plantaris friction syndrome [38]. The technique allows further evaluation of the tendon structure and matrix integrity [39]. Such assessments provide accurate and earlier diagnosis of plantaris friction syndrome by the identification of areas of architectural disorganization in the medial mid Achilles tendon [37, 38].

## *Tendon Tears*

Achilles tendinopathy is thought to represent the end result of intrasubstance degeneration and is proposed to be a precursor to Achilles tendon rupture. However, the literature evaluating this theory is limited, and one study using a national database found a 4% rupture rate in patients with Achilles tendinopathy [40].

Tendon tears can be categorized on a spectrum as microtears, interstitial tears along the tendon, partial-thickness tears, and complete ruptures. Achilles tendon tears are generally thought to result from intratendinous degeneration, which includes four described mechanisms: hypoxic fibromatosis and myxoid, lipoid, and osseus calcific degeneration [41].

Most tears occur in the less vascularized zone of the Achilles tendon, located 2–6 cm from its calcaneal insertion. However, tears may also occur proximally and distally. The proximal tear is essentially a musculotendinous junction injury and is therefore more common in muscles that have fast-twitch fibers and that cross two joints. Thus, proximal tears often involve the gastrocnemius muscle (most commonly its medial head) and rarely involve the soleus muscle. Distal tears (i.e., at the calcaneal insertion) are rare because of the protective enthesis that results from fibrocartilage intermeshing with the calcaneal bone marrow. Insertional Achilles tendinopathy may contribute to distal tears.

On ultrasound, Achilles tendon tears, whether full or partial thickness, show disruption of the tendon fibers with a hypoechoic gap between the torn fibers; hematoma may be present at the site of injury and may be hyperechoic (Fig. 10). Ultrasound is particularly useful to help differentiate partial- and full-thickness tears because of the ability to image dynamically during ankle plantar flexion and dorsiflexion to better define the tendon anatomy. In full-thickness tears, the tendon usually exhibits a degree of retraction, with a gap present between the tendon ends. The gap may increase during dorsiflexion, aiding evaluation (Fig. 1). A secondary feature of a full-thickness tear is fat herniation of the Kager fat pad into the tendon gap (Fig. 10).

The plantaris tendon is not necessarily involved in an Achilles tendon tear and may remain intact. On ultrasound, an intact plantaris tendon should not be mistaken for intact residual Achilles tendon fibers.

On MRI, the most common finding of tendon tear is increased T2-weighted signal [42]. Interstitial tears typically show a longitudinal orientation and are thought to result from myxoid degeneration (Fig. 5). Partial-thickness tears show disruption of tendon fibers with heterogeneous signal between the fibers (Fig. 11). Retraction of tendon fibers with buckling may be present, but some fibers remain intact. Full-thickness tears involve all fibers, with a fluid-filled gap at the injury site and the tendon fibers either retracted or overlapping [43] (Fig. 12). Over time, the hematoma between the tendon ends resolves, and granulation and scar tissue form.

## Management

A recent European Delphi-based consensus statement concluded that there is currently insufficient evidence to establish that image-guided interventions are superior to conservative

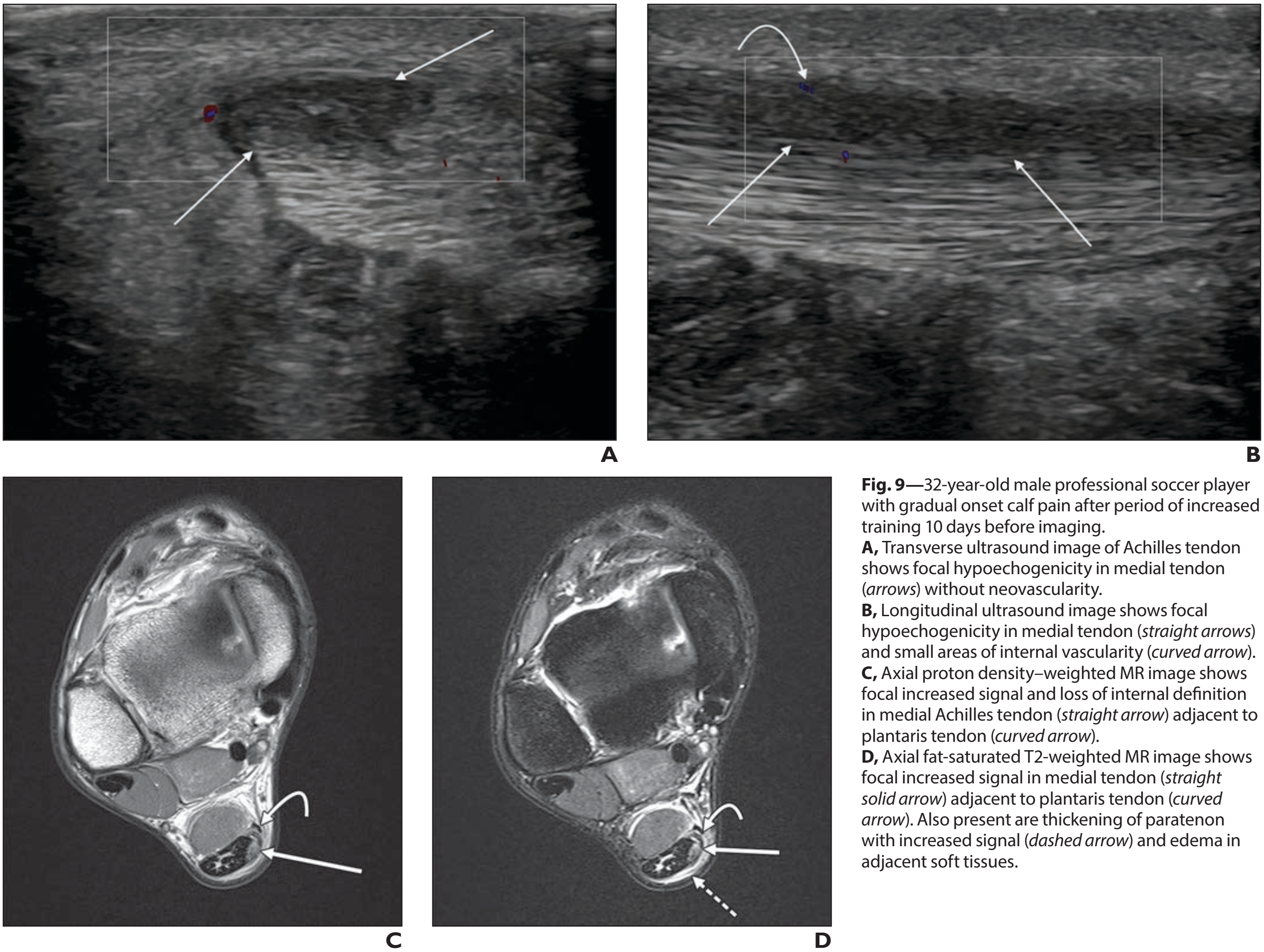



**Fig. 9—**32-year-old male professional soccer player with gradual onset calf pain after period of increased training 10 days before imaging.
**A,** Transverse ultrasound image of Achilles tendon shows focal hypoechogenicity in medial tendon (*arrows*) without neovascularity.
**B,** Longitudinal ultrasound image shows focal hypoechogenicity in medial tendon (*straight arrows*) and small areas of internal vascularity (*curved arrow*).
**C,** Axial proton density–weighted MR image shows focal increased signal and loss of internal definition in medial Achilles tendon (*straight arrow*) adjacent to plantaris tendon (*curved arrow*).
**D,** Axial fat-saturated T2-weighted MR image shows focal increased signal in medial tendon (*straight solid arrow*) adjacent to plantaris tendon (*curved arrow*). Also present are thickening of paratenon with increased signal (*dashed arrow*) and edema in adjacent soft tissues.

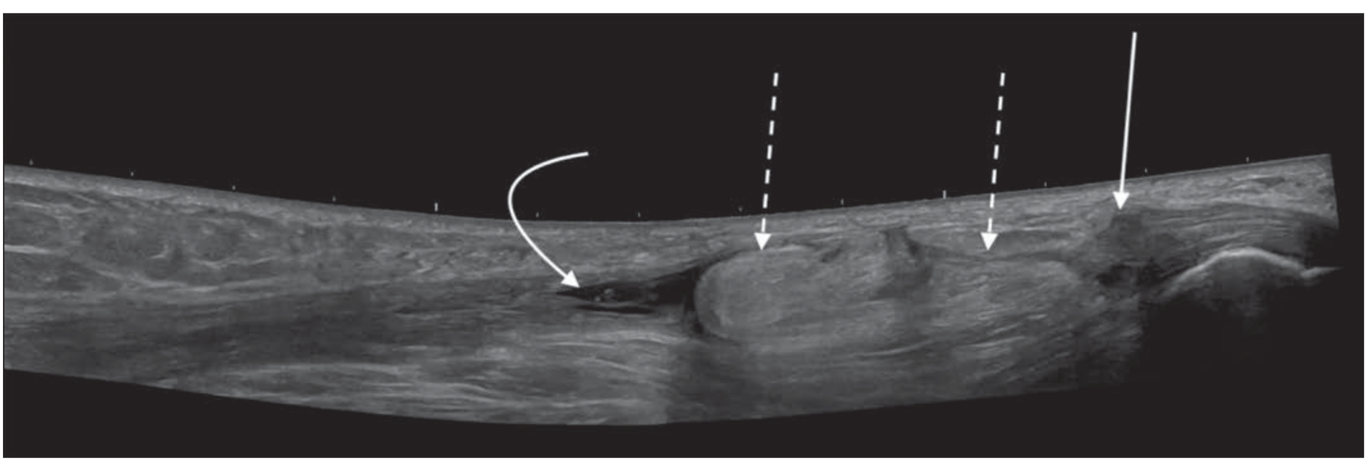
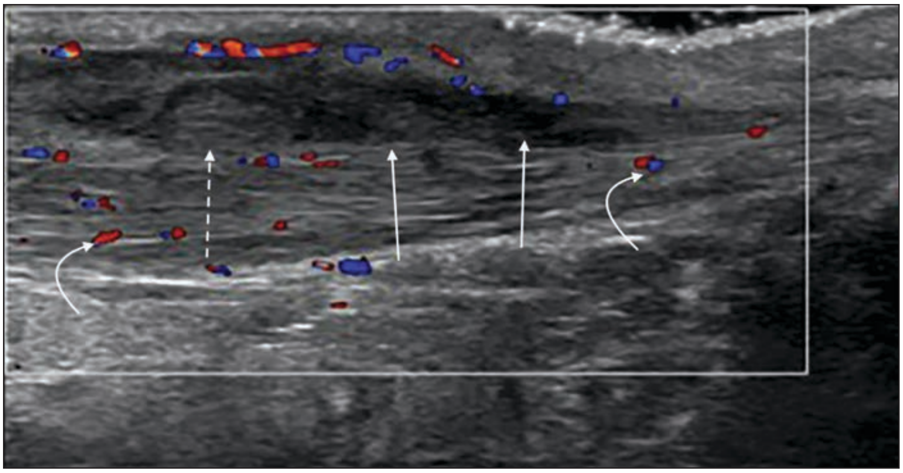
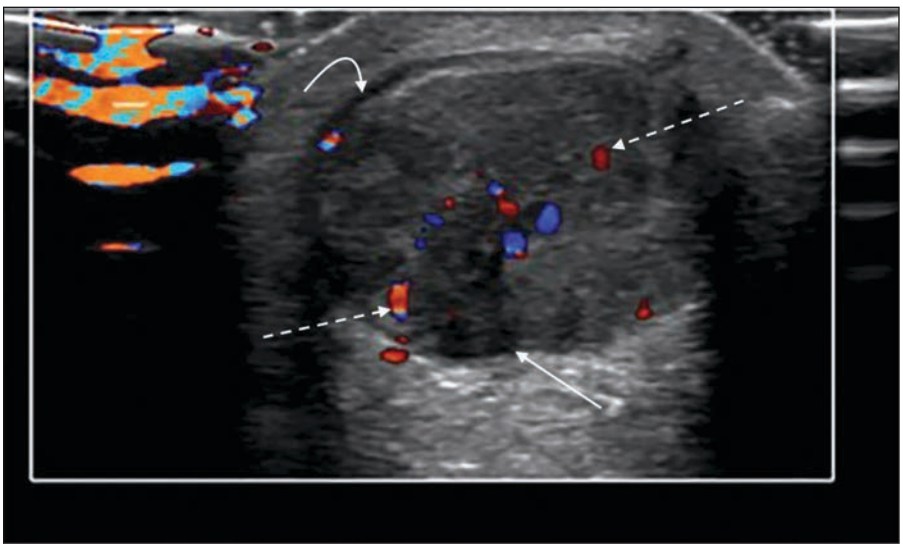


**Fig. 10—**52-year-old woman who described lower leg weakness after experiencing popping sensation when descending stairs 4 months earlier. Longitudinal ultrasound image shows chronic full-thickness Achilles tendon tear. Distal end of tendon (*straight solid arrow*) is in normal position. Proximal end (*curved arrow*) is retracted with adjacent fluid. Fat from Kager fat pad (*dashed arrows*) is interposed in gap.



A



B

**Fig. 11—**58-year-old man with sudden-onset heel pain while playing volleyball.
**A,** Longitudinal ultrasound image shows tearing of superficial tendon fibers (*straight solid arrows*) with retraction of this portion of tendon (*dashed arrow*). Color Doppler shows background of increased vascularity (*curved arrows*), consistent with Achilles tendinopathy.
**B,** Axial ultrasound image shows hypoechogenicity (*straight solid arrow*) and increased vascularity (*dashed arrows*) with paratenon thickening (*curved arrow*), consistent with tendinopathy.

management, and thus they should be considered a second-line approach for treating patients with Achilles tendinopathy [44]. The consensus statement also concluded that the current evidence is unchanged from a previous Cochrane and systematic review in 2015 [45, 46].

## Conservative Management

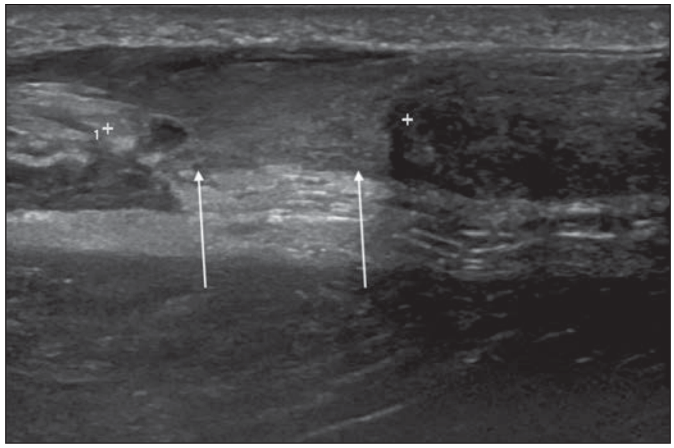
Most patients with Achilles tendinopathy are managed conservatively. Eccentric loading represents the mainstay of management and achieves reasonable long-term results in noninsertional tendinopathy [47].

Recent studies have shown that the addition of shockwave therapy to eccentric exercises improved patient outcomes over a 4-month period in comparison with eccentric exercises alone [48]. Eccentric loading has shown less favorable results in patients with insertional tendinopathy, and a randomized controlled trial showed better results from shockwave therapy in such patients [49].

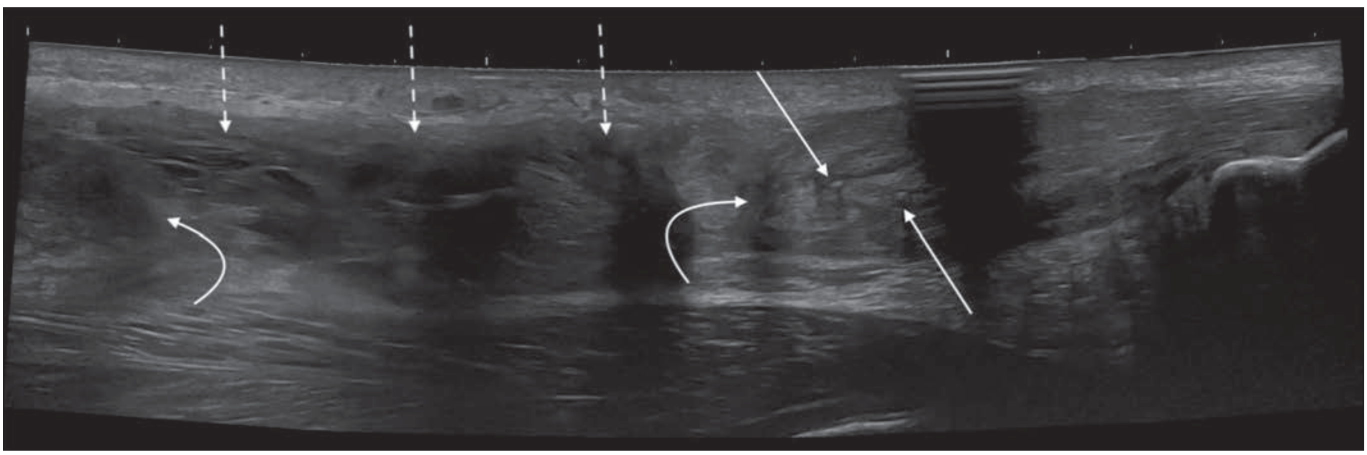
A recent meta-analysis of the effectiveness of different treatments for patients with Achilles tendinopathy showed a high degree of bias in the published studies, with 76% of included studies found to be at high risk of bias [50]. For midportion Achilles tendinopathy, all treatments were superior to no treatment at 3-month follow-up. However, results from various active treatments were not different at 3- or 12-month follow-up [50].

## Image-Guided Treatments

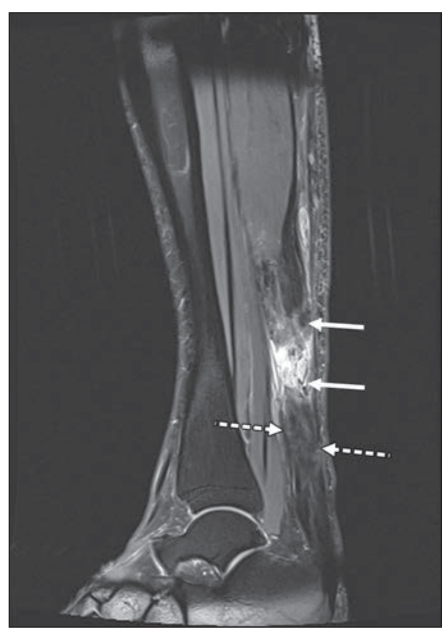
*High-volume injection*—High-volume injections involve the placement of a needle anterior to the Achilles tendon using ultrasound guidance with the subsequent installation of a large volume of fluid deep to the tendon and superficial to the underlying fat pad. The procedure is generally performed immediately after a diagnostic ultrasound examination to allow targeting of areas of neovascularity. The injectate typically includes saline and long-acting local anesthetic, though may include a steroid. The injected volume is usually between 20–30 mL. A study of a small sample of patients in 2008 by Chan et al. [51] showed improved function in patients who received high-volume injection in comparison with control patients, though the presence of corticosteroid in the injectate may have affected the results. Furthermore, in a randomized double-blinded prospective study in 2017 by Boesen et al. [52], high-volume injection that included a steroid in combination with eccentric training was more effective




A



B



C

**Fig. 12**—29-year-old male professional rugby league player presenting with sudden-onset calf pain.
**A,** Longitudinal ultrasound image shows acute tear of midportion of Achilles tendon, with gap observed between proximal and distal ends (*calipers*, 1). Internal hemorrhage is present within gap (between *arrows*). Patient underwent tendon repair.
**B,** Patient experienced acute onset of pain 6 months after repair. Longitudinal ultrasound image shows retear of Achilles tendon; tendon ends are marked by curved arrows. Site of retear is proximal to site of earlier repair as indicated by sutures (*straight solid arrows*). Hemorrhage is present between dashed arrows.
**C,** Sagittal fat-saturated T2-weighted MR image confirms site of retear (between *solid arrows*) proximal to site of earlier repair (between *dashed arrows*). Entire Achilles tendon is thickened, consistent with tendinopathy.

in reducing pain, improving activity level, and reducing tendon thickness and intratendinous vascularity in comparison with eccentric training alone. Yet, in a double-blinded placebo-controlled randomized clinical trial in 2020 by van der Vlist et al. [53], high-volume injection without steroid showed no benefit in patients with midportion Achilles tendinopathy in comparison with a placebo injection consisting of 2 mL of 1% lidocaine and saline. Thus, further study remains warranted.

*Prolotherapy*—Prolotherapy involves the injection of a small volume of an irritant substance, usually hyperosmolar dextrose, around the site of a tendon injury or a tendon or ligament insertion to initiate a local inflammatory response. Initial nonblinded studies in patients with Achilles tendinopathy without a control group have shown a good clinical response to prolotherapy with injection into the areas of tendinosis [54–56]. A small blinded study showed similar pain reduction in patients with Achilles tendinopathy between injection of the sclerosant polidocanol into areas of neovascularity and an injection comprising lidocaine and adrenaline [57]. To our knowledge, no large-scale studies have confirmed these findings.

*Tendon fenestration*—Tendon fenestration, or dry needling, refers to the repeated passing of a needle through a tendon, causing bleeding and inflammation, which in turn increase the presence of growth factors and other substances that promote healing. The needle is usually passed 20–30 times through the region of tendinosis under local anesthetic, targeting areas of neovascularity under ultrasound guidance. This approach is most strongly supported when applied around the common extensor tendon origin of the elbow [58, 59]. The additional use of steroid has been shown not to improve results of tendon fenestration to treat common extensor tendinosis of the elbow, presumably because the steroid's antiinflammatory properties counteract the inflammation-promoting effect of the fenestration [59]. To our knowledge, no good-quality studies have evaluated tendon fenestration in the management of Achilles tendinopathy [60].

*Platelet-rich plasma*—Platelet-rich plasma (PRP) is thought to promote tendon repair by delivering growth factors directly to the site of pathology. Tendon fenestration is often combined with autologous blood or PRP injections. Though preparations vary widely among manufacturers, the use of more concentrated platelets may improve clinical response. The potential benefits remain controversial. The current available evidence overall supports a lack of efficacy of PRP in Achilles tendinopathy [61–63]. The use of PRP has also been assessed in patients with Achilles tendon rupture [64–66]. However, a randomized control trial showed no improvement with this technique, and a systematic review concluded that the available data do not clearly indicate a significant effect of PRP for the treatment of Achilles tendon rupture [64, 66].

*Corticosteroids*—Corticosteroids are commonly used in the management of tendinopathy and have been reported to reduce pain and swelling in the short term [67]. However, the role of inflammation in chronic tendinopathy is unclear, and the use of antiinflammatory injections in the management of Achilles tendinopathy is controversial [67]. The absence of long-term benefit may reflect the injection's targeting of only the superficial aspect of the tendon. Thus, the deep tendon, which is largely hypovascular, is often not targeted. Some trials have reported adverse effects after corticosteroid injection, including tendon rupture and atrophy with decreased tendon strength [68–70], such that any initial benefit of steroid use needs to be balanced against the potential risks [71, 72]. Good-quality data are lacking.

Steroids are commonly used in the management of retrocalcaneal bursitis as the retrocalcaneal bursa is easily targeted under ultrasound guidance. However, a paucity of evidence supports its use [72–74]. A recently published small-scale retrospective study showed a significant short-term decrease in pain score in most patients with retrocalcaneal bursitis who were treated with corticosteroid injection [74]. That study reported a tendon rupture rate of 1.8%, which, although important, is significantly lower than the rupture rate reported for insertional Achilles tendinopathy, a diagnosis which was also present in all patients [40].

## Consensus Statements

- Achilles tendinopathy is a degenerative process that is often a precursor to tendon rupture.
- Retrocalcaneal bursitis is strongly associated with inflammatory arthropathy.
- Both ultrasound and MRI are highly accurate imaging modalities for evaluating the Achilles tendon for both tendinopathy and tear.
- Ultrasound is particularly useful to help differentiate partial- and full-thickness tears because of the ability to image dynamically during ankle plantar flexion and dorsiflexion, thereby better defining the tendon anatomy.
- Large-scale randomized controlled trials supporting the use of high-volume injection, prolotherapy, tendon fenestration, or PRP for treatment of Achilles tendinopathy are lacking.
- Evidence shows short-term benefit of corticosteroid injection for treatment of Achilles tendinopathy, though long-term benefits have not been established.

## References


1. Kujala UM, Sarna S, Kaprio J. Cumulative incidence of Achilles tendon rupture and tendinopathy in male former elite athletes. *Clin J Sport Med* 2005; 15:133–135
2. Szaro P, Witkowski G, Śmigielski R, Krajewski P, Ciszek B. Fascicles of the adult human Achilles tendon: an anatomical study. *Ann Anat* 2009; 191:583–593
3. Frey C, Rosenberg Z, Shereff MJ, Kim H. The retrocalcaneal bursa: anatomy and bursography. *Foot Ankle* 1992; 13:203–207
4. Schweitzer ME, Karasick D. MR imaging of disorders of the Achilles tendon. *AJR* 2000; 175:613–625
5. Kainberger FM, Engel A, Barton P, Huebsch P, Neuhold A, Salomonowitz E. Injury of the Achilles tendon: diagnosis with sonography. *AJR* 1990; 155:1031–1036
6. Chen TM, Rozen WM. Pan WR, Ashton MW, Richardson MD, Taylor GI. The arterial anatomy of the Achilles tendon: anatomical study and clinical implications. *Clin Anat* 2009; 22:377–385
7. Simpson SL, Hertzog MS, Barja RH. The plantaris tendon graft: an ultrasound study. *J Hand Surg Am* 1991; 16:708–711
8. Dams OC, Reininga IHF, Gielen JL, van den Akker-Scheek I, Zwerver J. Imaging modalities in the diagnosis and monitoring of Achilles tendon rup-

tures: a systematic review. *Injury* 2017; 48:2383–2399
9. Nadeau MJ, Desrochers A, Lamontagne M, Larivière C, Gagnon DH. Quantitative ultrasound imaging of Achilles tendon integrity in symptomatic and asymptomatic individuals: reliability and minimal detectable change. *J Foot Ankle Res* 2016; 9:30
10. Beggs I, Bianchi S, Bueno A. ESSR musculoskeletal ultrasound technical guidelines. VI. Ankle. European Society of MusculoSkeletal Radiology website. essr.org/content-essr/uploads/2016/10/ankle.pdf. Published 2016. Accessed January 14, 2022
11. Chen XM, Cui LG, He P, Shen WW, Qian YJ, Wang JR. Shear wave elastographic characterization of normal and torn Achilles tendons: a pilot study. *J Ultrasound Med* 2013; 32:449–455
12. Payne C, Watt P, Cercignani M, Webborn N. Reproducibility of shear wave elastography measures of the Achilles tendon. *Skeletal Radiol* 2018; 47:779–784
13. Khan RJK. Treatment of acute Achilles tendon ruptures: a meta-analysis of randomized, controlled trials. *J Bone Joint Surg Am* 2005; 87:2202–2010
14. Zanetti M, Metzdorf A, Kundert HP, et al. Achilles tendons: clinical relevance of neovascularization diagnosed with power Doppler US. *Radiology* 2003; 227:556–560
15. Hall MM, Allen GM, Allison S, et al. Recommended musculoskeletal and sports ultrasound terminology: a Delphi-based consensus statement. *Br J Sports Med* 2022; 56:310–319
16. van der Vlist AC, Breda SJ, Oei EHG, Verhaar JAN, de Vos RJ. Clinical risk factors for Achilles tendinopathy: a systematic review. *Br J Sports Med* 2019; 53:1352–1361
17 Ranger TA, Wong AMY, Cook JL, Gaida JE. Is there an association between tendinopathy and diabetes mellitus? A systematic review with meta-analysis. *Br J Sports Med* 2016; 50:982–989
18. Carr AJ, Norris SH. The blood supply of the calcaneal tendon. *J Bone Joint Surg Br* 1989; 71:100–101
19. Lysholm J, Wiklander J. Injuries in runners. *Am J Sports Med* 1987; 15:168–171
20. Yang X, Coleman DP, Pugh ND, Nokes LDM. The volume of the neovascularity and its clinical implications in Achilles tendinopathy. *Ultrasound Med Biol* 2012; 38:1887–1895
21. De Jonge S, Warnaars JLF, De Vos RJ, et al. Relationship between neovascularization and clinical severity in Achilles tendinopathy in 556 paired measurements. *Scand J Med Sci Sports* 2014; 24:773–778
22. Tsouli SG, Kiortsis DN, Argyropoulou MI, Mikhailidis DP, Elisaf MS. Pathogenesis, detection and treatment of Achilles tendon xanthomas. *Eur J Clin Invest* 2005; 35:236–244
23. Kelman CG, Disler DG, Kremer JM, Jennings TA. Xanthomatous infiltration of ankle tendons. *Skeletal Radiol* 1997; 26:256–259
24. Zahradnik TM, Cresswell M, Squier K, et al. Can Achilles tendon xanthoma be distinguished from Achilles tendinopathy using Dixon method MRI? A cross-sectional exploratory study. *BMC Musculoskelet Disord* 2021; 22:627
25. Baraliakos X, Kiltz U, Appel H, et al. Chronic but not inflammatory changes at the Achilles' tendon differentiate patients with peripheral spondyloarthritis from other diagnoses: results from a prospective clinical trial. *RMD Open* 2017; 3:e000541
26. McGonagle D, Marzo-Ortega H, O'Connor P, et al. The role of biomechanical factors and HLA-B27 in magnetic resonance imaging-determined bone changes in plantar fascia enthesopathy. *Arthritis Rheum* 2002; 46:489–493
27. Bottger BA, Schweitzer ME, El-Noueam KI, Desai M. MR imaging of the normal and abnormal retrocalcaneal bursae. *AJR* 1998; 170:1239–1241
28. Stiskal M, Szolar DH, Stenzel I, et al. Magnetic resonance imaging of Achilles tendon in patients with rheumatoid arthritis. *Invest Radiol* 1997; 32:602–608
29. Knobloch K, Kraemer R, Lichtenberg A, et al. Achilles tendon and paratendon microcirculation in midportion and insertional tendinopathy in athletes. *Am J Sports Med* 2006; 34:92–97
30. Calleja M, Connell DA. The Achilles tendon. *Semin Musculoskelet Radiol* 2010; 14:307–322
31. Alfredson H. Midportion Achilles tendinosis and the plantaris tendon. *Br J Sports Med* 2011; 45:1023–1025
32. Calder JDF, Freeman R, Pollock N. Plantaris excision in the treatment of non-insertional Achilles tendinopathy in elite athletes. *Br J Sports Med* 2015; 49:1532–1534
33 van Sterkenburg MN, Kerkhoffs GMMJ, Kleipool RP, Niek van Dijk C. The plantaris tendon and a potential role in mid-portion Achilles tendinopathy: an observational anatomical study. *J Anat* 2011; 218:336–341
34. Lintz F, Higgs A, Millett M, et al. The role of plantaris longus in Achilles tendinopathy: a biomechanical study. *Foot Ankle Surg* 2011; 17:252–255
35 Calder JDF, Stephen JM, van Dijk CN. Plantaris excision reduces pain in midportion Achilles tendinopathy even in the absence of plantaris tendinosis. *Orthop J Sports Med* 2016; 4:2325967116673978
36. Spang C, Alfredson H, Ferguson M, Roos B, Bagge J, Forsgren S. The plantaris tendon in association with mid-portion Achilles tendinosis: tendinosis-like morphological features and presence of a non-neuronal cholinergic system. *Histol Histopathol* 2013; 28:623–632
37. Koh E, Mason M, Tan S, Boyle J. Imaging of plantaris friction syndrome. *Clin Radiol* 2018; 73:855–864
38. Masci L, Spang C, van Schie HTM, Alfredson H. How to diagnose plantaris tendon involvement in midportion Achilles tendinopathy: clinical and imaging findings. *BMC Musculoskelet Disord* 2016; 17:97
39. van Schie HTM, de Vos RJ, de Jonge S, et al. Ultrasonographic tissue characterisation of human Achilles tendons: quantification of tendon structure through a novel non-invasive approach. *Br J Sports Med* 2010; 44:1153–1159
40. Yasui Y, Tonogai I, Rosenbaum AJ, Shimozono Y, Kawano H, Kennedy JG. The risk of Achilles tendon rupture in the patients with Achilles tendinopathy: healthcare database analysis in the United States. *BioMed Res Int* 2017; 2017:7021862
41. Józsa L, Bálint BJ, Réffy A, Demel Z. Hypoxic alterations of tenocytes in degenerative tendinopathy. *Arch Orthop Trauma Surg* 1982; 99:243–246
42. Aström M, Gentz CF, Nilsson P, Rausing A, Sjöberg S, Westlin N. Imaging in chronic Achilles tendinopathy: a comparison of ultrasonography, magnetic resonance imaging and surgical findings in 27 histologically verified cases. *Skeletal Radiol* 1996; 25:615–620
43. Lawrence DA, Rolen MF, Morshed KA, Moukaddam H. MRI of heel pain. *AJR* 2013; 200:845–855
44. Sconfienza LM, Adriaensen M, Albano D, et al. Clinical indications for image-guided interventional procedures in the musculoskeletal system: a Delphi-based consensus paper from the European Society of Musculoskeletal Radiology (ESSR). Part VI. Foot and ankle. *Eur Radiol* 2022; 32:1384–1394
45. Maffulli N, Papalia R, D'Adamio S, Diaz Balzani L, Denaro V. Pharmacological interventions for the treatment of Achilles tendinopathy: a systematic review of randomized controlled trials. *Br Med Bull* 2015; 113:101–115
46. Kearney RS, Parsons N, Metcalfe D, Costa ML. Injection therapies for Achilles tendinopathy. *Cochrane Database Syst Rev* 2015 May 26 [published online]
47. Alfredson H, Pietilä T, Jonsson P, Lorentzon R. Heavy-load eccentric calf muscle training for the treatment of chronic Achilles tendinosis. *Am J Sports Med* 1998; 26:360–366
48. Rompe JD, Furia J, Maffulli N. Eccentric loading versus eccentric loading plus shock-wave treatment for midportion Achilles tendinopathy: a randomized controlled trial. *Am J Sports Med* 2009; 37:463–470
49. Rompe JD, Furia J, Maffulli N. Eccentric loading compared with shock wave treatment for chronic insertional Achilles tendinopathy: a randomized, controlled trial. *J Bone Joint Surg Am* 2008; 90:52–61

50. van der Vlist AC, Winters M, Weir A, et al. Which treatment is most effective for patients with Achilles tendinopathy? A living systematic review with network meta-analysis of 29 randomised controlled trials. *Br J Sports Med* 2021; 55:249–256
51. Chan O, O'Dowd D, Padhiar N, et al. High volume image guided injections in chronic Achilles tendinopathy. *Disabil Rehabil* 2008; 30:1697–1708
52. Boesen AP, Hansen R, Boesen MI, Malliaras P, Langberg H. Effect of high-volume injection, platelet-rich plasma, and sham treatment in chronic midportion Achilles tendinopathy: a randomized double-blinded prospective study. *Am J Sports Med* 2017; 45:2034–2043
53. van der Vlist AC, van Oosterom RF, van Veldhoven PLJ, et al. Effectiveness of a high volume injection as treatment for chronic Achilles tendinopathy: randomised controlled trial. *BMJ* 2020; 370:m3027
54. Ryan M, Wong A, Taunton J. Favorable outcomes after sonographically guided intratendinous injection of hyperosmolar dextrose for chronic insertional and midportion Achilles tendinosis. *AJR* 2010; 194:1047–1053
55. Maxwell NJ, Ryan MB, Taunton JE, Gillies JH, Wong AD. Sonographically guided intratendinous injection of hyperosmolar dextrose to treat chronic tendinosis of the Achilles tendon: a pilot study. *AJR* 2007; 189:[web]W215–W220
56. Distel LM, Best TM. Prolotherapy: a clinical review of its role in treating chronic musculoskeletal pain. *PM R* 2011; 3(suppl 1):S78–S81
57. Alfredson H, Öhberg L. Sclerosing injections to areas of neo-vascularisation reduce pain in chronic Achilles tendinopathy: a double-blind randomised controlled trial. *Knee Surg Sports Traumatol Arthrosc* 2005; 13:338–344
58. Connell DA, Ali KE, Ahmad M, Lambert S, Corbett S, Curtis M. Ultrasound-guided autologous blood injection for tennis elbow. *Skeletal Radiol* 2006; 35:371–377
59. McShane JM, Shah VN, Nazarian LN. Sonographically guided percutaneous needle tenotomy for treatment of common extensor tendinosis in the elbow: is a corticosteroid necessary? *J Ultrasound Med* 2008; 27:1137–1144
60. Davidson J, Jayaraman S. Guided interventions in musculoskeletal ultrasound: what's the evidence? *Clin Radiol* 2011; 66:140–152
61. Le ADK, Enweze L, DeBaun MR, Dragoo JL. Current clinical recommendations for use of platelet-rich plasma. *Curr Rev Musculoskelet Med* 2018; 11:624–634
62. de Jonge S, de Vos RJ, Weir A, et al. One-year follow-up of platelet-rich plasma treatment in chronic Achilles tendinopathy: a double-blind randomized placebo-controlled trial. *Am J Sports Med* 2011; 39:1623–1629
63. Nauwelaers AK, Van Oost L, Peers K. Evidence for the use of PRP in chronic midsubstance Achilles tendinopathy: a systematic review with meta-analysis. *Foot Ankle Surg* 2021; 27:486–495
64. Daley P, Menu P, Louguet B, Crenn V, Dauty M, Fouasson-Chailloux A. Interest of platelet rich plasma in Achilles tendon rupture management: a systematic review. *Phys Sportsmed* 2021 Aug 26 [published online]
65. Wang C, Fan H, Li Y, Yun Z, Zhang Z, Zhu Q. Effectiveness of platelet-rich plasma injections for the treatment of acute Achilles tendon rupture: a systematic review and meta-analysis. *Medicine (Baltimore)* 2021; 100:e27526
66. Boesen AP, Boesen MI, Hansen R, et al. Effect of platelet-rich plasma on nonsurgically treated acute Achilles tendon ruptures: a randomized, double-blinded prospective study. *Am J Sports Med* 2020; 48:2268–2276
67. Coombes BK, Bisset L, Vicenzino B. Efficacy and safety of corticosteroid injections and other injections for management of tendinopathy: a systematic review of randomised controlled trials. *Lancet* 2010; 376:1751–1767
68. Mahler F, Fritschy D. Partial and complete ruptures of the Achilles tendon and local corticosteroid injections. *Br J Sports Med* 1992; 26:7–14
69. Ford LT, DeBender J. Tendon rupture after local steroid injection. *South Med J* 1979; 72:827–830
70. Chen SK, Lu CC, Chou PH, Guo LY, Wu WL. Patellar tendon ruptures in weight lifters after local steroid injections. *Arch Orthop Trauma Surg* 2009; 129:369–372
71. Hart L. Corticosteroid and other injections in the management of tendinopathies: a review. *Clin J Sport Med* 2011; 21:540–541
72. Shrier I, Matheson GO, Kohl HW 3rd. Achilles tendonitis: are corticosteroid injections useful or harmful? *Clin J Sport Med* 1996; 6:245–250
73. Checa A. Chun W, Pappu R. Ultrasound-guided diagnostic and therapeutic approach to retrocalcaneal bursitis. *J Rheumatol* 2011; 38:391–392
74. Boone SL, Uzor R, Walter E, et al. Safety and efficacy of image-guided retrocalcaneal bursa corticosteroid injection for the treatment of retrocalcaneal bursitis. *Skeletal Radiol* 2021; 50:2471–2482