US in mid-portion Achilles tendon injury

Andrea Gervasio · Paola Bollani · Aurelio Biasio

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Abstract Ultrasound (US) is the primary imaging technique used to evaluate pathologies affecting the tendons, as the use of high frequency probes permits a detailed study of the structure and morphology of the area also during dynamic examinations. The mid-portion of the Achilles tendon is well evaluated both in normal and pathological conditions, such as tendinosis and peritendinitis as well as partial-thickness and full-thickness tears. The role of US is essential to the diagnosis and, therefore, also to treatment planning in major disorders affecting the Achilles tendon. US furthermore allows the clinician to monitor the effectiveness of treatment over time as well as the risk of recurrent rupture after surgery.

Keywords Achilles tendon · Ultrasound

Riassunto L'esame ecografico è la tecnica di prima istanza nella valutazione della patologia dei tendini grazie alle indicazioni morfologiche e strutturali dettagliate che derivano dall'uso di sonde ad elevata frequenza e alla possibilità di esaminare i tendini anche durante manovre dinamiche. Il ventre tendineo d'Achille è ben valutabile sia in condizioni normali che patologiche quali le tendinosi, peritendiniti, rotture parziali e a tutto spessore. L'ecografia riveste un ruolo essenziale nella diagnosi e quindi nell'impostazione terapeutica delle principali affezioni del tendine d'Achille; consente inoltre di monitorare nel tempo l'efficacia dei trattamenti e nel post-operatorio il rischio di rottura recidiva del tendine.

Anatomy

The Achilles tendon is the thickest and strongest tendon in the human body. It is 12–15 cm long; it originates from the aponeuroses of the medial, lateral and soleus gastrocnemius muscles (triceps surae) and is inserted into the posterior calcaneal tuberosity. It is the major plantar flexor of the foot and contributes to the maintenance of the upright position.

Anteriorly, the Achilles tendon is connected to the muscle belly of the flexor hallucis longus (from which it is separated by the interposition of a mass of adipose tissue occupying Kager's triangle) and in the pre-insertional area it is connected to the calcaneal tuberosity from which it is separated by a synovial bursa, referred to as the deep retrocalcaneal bursa. Superficially it is in contact with the subcutaneous adipose tissue at the calcaneal tuberosity by the interposition of a synovial bursa (superficial retrocalcaneal bursa) (Fig. 1).

In 90 % of cases the Achilles tendon is on the anterior-medial side in close relation to the tendon of the gracilis muscle, an accessory muscle whose tendon may insert on the posterior medial heel, the Achilles tendon or the flexor retinaculum of the ankle.

The Achilles tendon presents a ribbon-like morphology. At the origin it appears as a flat thin band, and when proceeding distally it becomes thicker and acquires a crescent-shaped morphology whose posterior margin is convex. The anterior margin is flat or slightly concave, and in the pre-insertional area the anterior margin is moderately convex. The tendon consists of longitudinal bundles of collagen fibrils and elastin embedded in a matrix consisting of proteoglycans, glycosaminoglycans, glycoproteins and water (endotenon). The tendon is surrounded by the peritenon, a sheath consisting of loose

A. Gervasio (✉) · P. Bollani · A. Biasio
Section of Radiology, Istituto Clinico Città di Brescia,
Gruppo Ospedaliero San Donato, Brescia, Italy
e-mail: andrea.gervasio@me.com

Fig. 1 US anatomy of the Achilles tendon. Longitudinal scan (a), axial scan (b), panoramic field-of-view scan (c). Longitudinal scan (a) shows linear and parallel, closely packed echoes giving the tendon a fibrillar appearance on the axial scan (b). The tendon structure is characterized by numerous closely packed punctate hyperechoic spots; the peritenon (arrows) appears as a thin hyperechoic line in continuity with the subcutaneous fat. The anterior margin of the tendon is flat both in the longitudinal (a) and the axial (b) scan. On the panoramic field-of-view scan (c) US shows the Achilles tendon (arrows) anteriorly in relation to the muscle belly of the flexor hallucis longus [1], to Kager's triangle [2] and in the pre-insertional area to the calcaneal tuberosity [3], to the posterior malleolus [4] and the posterior margin of the talus [5]

connective tissue which favors the sliding of the tendon and provides it with blood vessels which enter the tendon matrix at regular intervals.

The vascular supply to the Achilles tendon is poor, especially in the area 2–6 cm from the calcaneal insertion, and this area is, therefore, the most vulnerable to mid-portion tendon disorders (the critical zone).

This article does not contain any studies with human or animal subjects performed by the any of the authors.

Us technique

For a correct US study of the tendon, the patient must be in the prone position with the foot resting on the bed in a position of dorsiflexion to induce tension of the tendon. If necessary, the tendon can be studied dynamically during flexion–extension by protruding the foot from the edge of the bed. US examination should include longitudinal and axial scans from the myotendinous junction to the insertion on the calcaneus [1].

US image of the tendon shows organization of collagen fibers immersed in the connective matrix of the endotenon. Longitudinal scans of a normal tendon are characterized by linear and parallel, closely packed echoes, which are hyperechoic on the background of weakly hypoechoic signals representing the interface between the collagen fibers and the endotenon septa that gives the tendon its fibrillar appearance (Fig. 1). Axial scans show the tendon characterized by numerous, closely packed hyperechoic punctiform spots. The peritenon appears as a thin hyperechoic line in continuity with the subcutaneous fat [1]. The collagen fiber organization of the tendon will show anisotropic artifacts if the US beam is not perpendicular to the tendon.

Disorders

Mid-portion Achilles tendon injuries can be divided into traumatic lesions, microtraumatic lesions due to functional overload and atraumatic lesions due to dysmetabolic or inflammatory disease.

From a pathological point of view, Achilles tendinopathy can be divided into tendinosis, peritendinitis and partial-thickness or full-thickness tendon tears.

Tendinosis (Fig. 2) is characterized by focal or diffuse spindle-shaped thickening of the tendon with disorganization of the fibrillar structure appearing as hypoechoic areas of mucoid and hypoxic degeneration, sometimes mixed with hyperechoic fibrocalcific areas and intratendinous ossification may occur [2].

Tendinosis most commonly affects the proximal middle third of the tendon; however, when the distal third is affected the disorder is frequently associated with deep retrocalcaneal bursitis [2]. In more severe cases, power-Doppler may show hypervascularization in the areas of tendinosis which can cause pain. Hypervascularization should be studied with the foot in plantar flexion to reduce tendon pressure (Figs. 2, 4) [3].

Metabolic diseases, such as gout and familial hypercholesterolemia, may cause focal or diffuse spindle-shaped thickening of the tendon with loss of fibrillar structure: in cases of gout because of tophaceous deposits and in cases

Fig. 2 Achilles tendinosis. Longitudinal panoramic field-of-view scan (a) shows spindle-shaped thickening of the tendon with disorganization of the fibrillar structure, which is replaced by hypoechoic areas of mucoid degeneration mixed with hyperechoic fibrocalcific areas (b); hypervascularity at color-Doppler (c)

of familial hypercholesterolemia due to xanthomatous deposits (triglycerides and cholesterol) [4].

Peritendinitis may occur as an isolated phenomenon or, more frequently, combined with tendinosis. In isolated cases of peritendinitis, tendon size and US pattern are normal. Peritendinitis is characterized by hypoechoic thickening of the peritenon due to edema (Fig. 3).

The Achilles tendon may be subject to partial or full-thickness tear. The main reason for tendon tear is hypoxia, and the lesion is typically located in the critical zone which receives less blood flow thereby predisposing to the formation of areas of tendinosis and consequent destruction of the collagen fibers. This degenerative process and the tendon tears are a continuum starting with partial-thickness tear and subsequently leading to full-thickness tear [5].

Partial-thickness tear is characterized by marked intrinsic tendon abnormalities. US image shows anechoic spindle-shaped collections parallel to the long axis of the tendon or thinning of the mid-portion of the tendon while

Fig. 3 Achilles peritendinitis and tendinosis. Longitudinal panoramic field-of-view scan (a) and axial scan (b). Peritendinitis appears as hypoechoic thickening of the peritenon due to edema (arrows); the tendon is thickened and inhomogeneous due to tendinosis

the proximal and distal portions are thickened due to tendinosis (Fig. 4). This picture suggests partial rupture associated with tendinosis if there is marked thickening of the tendon (>1 cm) and the contours of the anterior surface of the tendon appear irregular and wavy [5].

Full-thickness tear is characterized by retraction of the two tendon stumps that may be juxtaposed or more often separated by a gap containing hypo-anechoic heterogeneous material due to hematoma; sometimes Kager's fat pad may invade the gap between the two stumps. At the end of each stump the US image often shows shadow cones due to refraction of the US beams (Fig. 5). In doubtful cases, this sign is helpful in differentiating full-thickness from partial-thickness tears [5].

The gap between the stumps may increase during dorsiflexion of the foot protruding from the bed. In most cases of full-thickness tear, the peritenon remains intact.

In full-thickness tears it is advisable to locate the gracilis tendon which typically remains intact and may be responsible for an erroneous diagnosis of partial-thickness tear because it tends to occupy the gap between the two stumps. Recognition and evaluation of the integrity of the

Fig. 4 Partial-thickness tear of the Achilles tendon. Marked intrinsic tendon abnormalities (*arrows*) appearing on the US axial scan as rounded anechoic collections (**a**) which are spindle shaped and parallel to the long axis of the tendon in the longitudinal scan (**b**); hypervascularization should be studied with the foot in plantar flexion in order to reduce tendon pressure (**c**)

gracilis tendon is furthermore important as it may be sacrificed in the repair of the Achilles tendon tear. Isolated tear of the gracilis tendon may occur, although it is rare.

Fig. 5 Full-thickness tear of the Achilles tendon is evident in longitudinal scans (**a**, **b**) showing a gap between the two stumps; the gap is filled with heterogeneous hypo-anechoic material due to hematoma. At the end of each stump, US image often shows shadow cones due to refraction of the US beams; sometimes the hyperechoic fat tissue of Kager's fat pad may invade the gap between the two stumps (*arrow* in **b**). The axial scan (**c**) shows that the tendon is frayed while the peritenon is intact (*arrows*)

Treatment of partial-thickness tear is conservative whereas full-thickness tear is most often treated surgically. US examination is useful in the follow-up to assess the risk of recurrence.

Postoperatively, the Achilles tendon is always thicker than normal. The structure is heterogeneous and US image may show stitches appearing in a bilaminar hyperechoic pattern with comet tail artifacts or shadow cones (Fig. 6). One month after surgery power Doppler will show vascular signals; the peak of hypervascularization will occur within the first 3–4 months and be reduced after 6 months [6].

During follow-up, hypoechoic areas surrounding the stitches may be found in the first 6 months after surgery. Appearance or persistence of peritendinous or intrasubstance anechoic fluid collections and thinning of the tendon are warning indicators of recurrent partial-thickness tear.

Fig. 6 Achilles tendon after surgery. Longitudinal (a) and axial (b) scans showing the thickened tendon, the heterogeneous structure and the stitches (arrows) appearing in a bilaminar hyperechoic pattern with shadow cones

Persistence of hypervascularity of the tendon exceeding 6 months after surgery and the appearance of calcifications are signs of tendon disease activity [7].

Conclusions

US is effective in the diagnosis, treatment planning and monitoring of treatment outcome in patients with Achilles

tendon disorders. US should, therefore, be preferred to costlier methods such as magnetic resonance imaging (MRI) because of the widespread availability of US equipment, the low cost and repeatability of the examination.

Conflict of interest Andrea Gervasio, Paola Bollani and Aurelio Biasio declare that they have no conflict of interest related to this paper.

Informed consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). All patients provided (written) informed consent to enrolment in the study and to the inclusion in this article of information that could potentially lead to their identification.

Human and animal studies The study was conducted in accordance with all institutional and national guidelines for the care and use of laboratory animals.

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