[Imaging]

Pattern of Fascicular Involvement in Midportion Achilles Tendinopathy at Ultrasound

Peter Counsel, MBBS(Hons), FRANZCR, DCH,*† Jules Comin, MBBS(Hons), FRANZCR,† Marcus Davenport,† and David Connell, MBBS(Hons), MMed, FRANZCR, FFSEM(UK)†‡

Background: The Achilles tendon is composed of fascicles from the soleus and gastrocnemius muscles, which are identifiable as discrete components at anatomical dissection.

Hypothesis: The pattern of fascicular involvement in Achilles tendinopathy may be characterized at ultrasound, and this characterization is reliable between different observers.

Study Design: Cross-sectional diagnostic study.

Level of Evidence: Level 3.

Methods: One hundred cases of Achilles tendinopathy were retrospectively evaluated by 2 blinded musculoskeletal radiologists. Using a short-axis anatomical map, each case was categorized as involving the fascicular territories of the medial head of gastrocnemius, lateral head of gastrocnemius, soleus, or combinations of these, or as indeterminate.

Results: Both radiologists agreed on the fascicular involvement pattern in 93 of 100 cases; 20 involved only medial gastrocnemius territories, 8 lateral gastrocnemius, 15 soleus, 3 medial and lateral gastrocnemius, 21 medial gastrocnemius and soleus, 9 soleus and lateral gastrocnemius, and 16 the entire tendon, and 1 case was classified as indeterminate. In 7 cases, the interpretations were discordant. The kappa value was calculated as 0.92 (95% CI, 0.86-0.98) in keeping with a high level of interobserver agreement.

Conclusion: As assessed at ultrasound, most cases of Achilles tendinopathy involve the medial head of gastrocnemius and/or soleus fascicles.

Clinical Relevance: The provided observational data will increase understanding of patterns of Achilles tendinopathy.

Keywords: Achilles tendon; tendinopathy; ultrasound

Achilles tendinopathy is extremely common in runners, with an estimated annual incidence of 9%.[16] The lifetime risk is estimated at 52% for elite long-distance runners and 23.9% for athletes in general, in comparison with 5.9% for a control population drawn from a military conscription database.[14] The prevalence in the general population is at least 0.2% in general practice; this may underestimate true general population figures because many patients would present to sports physicians and physiotherapists.[9]

It is in the tendon midportion, typically 2 to 7 cm from the calcaneal insertion,[18] that blood supply is at its most tenuous and degeneration is most common.[6] At ultrasound, tendinopathy is characterized by thickening, hypoechogenicity, and neovascularity, although these changes may also be seen in asymptomatic tendons.[4,12] Achilles tendinopathy may also be insertional, with a variety of potential causes, although our study focused on midportion tendinopathy as this is the more common pattern we see at our institution.[18]

From †Imaging at Olympic Park, Melbourne, Victoria, Australia, and ‡Department of Medical Imaging, Faculty of Medicine, Nursing and Healthcare, Monash University, Melbourne, Victoria, Australia

*Address correspondence to Peter Counsel, MBBS(Hons), FRANZCR, DCH, Imaging at Olympic Park, 60 Olympic Boulevard, Melbourne, Victoria 3004, Australia (email: p.counsel@iop.net.au).

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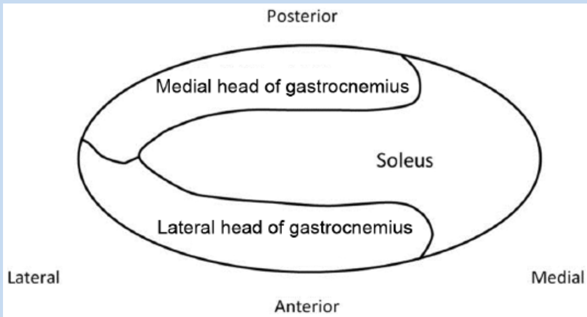

Figure 1. A short-axis diagram depicting the territories of the different fascicles making up the Achilles tendon, adapted from the work of Szaro et al.[17] The diagram is of the left Achilles tendon oriented in the prone position, as the patient would be during ultrasound assessment.

The Achilles tendon is the largest tendon in the body, formed by the confluence of the distal tendons of soleus as well as the medial and lateral heads of gastrocnemius (MHG and LHG, respectively). As the Achilles descends toward the calcaneus, there is rotation of these fascicles such that those from gastrocnemius rotate to the lateral side and those from soleus rotate medially.[19] Assessing 40 cadaveric Achilles tendons, Szaro et al[17] demonstrated that the fascicles remained distinct from each other and assumed a characteristic arrangement of tendinous components in the axial plane. The medial gastrocnemius fascicles formed the posterolateral as well as part of the posteromedial Achilles, the lateral gastrocnemius fascicles formed the anterolateral and a portion of the anteromedial Achilles, and the soleus fascicles formed the central and medial part of the tendon (Figure 1). Assessment at ultrasound has shown that degenerative changes of the tendon are frequently localized to only 1 part of the tendon in the axial plane, most often the posterior and medial portions.[10]

Achilles tendinopathy has traditionally been considered a homogeneous entity, although findings of involvement of particular territories within the tendon, in addition to differential electromyographic abnormalities, raise the possibility that rehabilitation could be targeted to individual components of the calf muscle complex.[21] However, this is theoretical, with no clinical evidence to support isolated therapy of individual calf muscle components.

The aim of this study was to identify the fascicular involvement pattern in midportion Achilles tendinopathy by correlating the pattern of tendinopathy in the short axis with a map of the fascicular territorial anatomy as described above, as well as the interobserver reliability for use of this map.

METHODS

Participants

A search was performed of all ultrasound examinations of the Achilles tendon, performed to investigate calf or heel pain, at our imaging center between January 2011 and March 2012. Institutional review board ethical approval was obtained for this retrospective study. Inclusion criteria were an ultrasound referral for calf or heel pain and subsequent findings of midportion tendinopathy, manifest as hypoechogenicity and architectural distortion. Exclusion criteria were a sonographically normal tendon or demonstration of other pathology such as Achilles tendon rupture, retrocalcaneal bursitis, enthesopathy, or abnormality of plantaris.

The first 100 consecutive cases demonstrating midportion Achilles tendinopathy, in the absence of exclusion criteria, were included for assessment. This represented approximately 24% of consecutive Achilles ultrasound referrals during this period, with a further 312 studies excluded.

Test Methods

All ultrasound examinations had been performed by a single operator following a standardized protocol of transverse and longitudinal images along the length of the tendon that was performed as a matter of routine clinical practice. All studies were performed on a Philips iU22 (Bothell) ultrasound machine using a 17.5-MHz linear probe.

Two musculoskeletal radiologists (J.C. and D.C.) then examined each image independently and in a blinded fashion, and described the pattern of tendinopathy as per the territorial distribution on a short axis map adapted from the description of Szaro et al.[17] Tendinopathy was described as affecting the MHG territory, LHG territory, soleus (S) territory, any combination of the above, or as indeterminate and not conforming to the described anatomical distribution. The indeterminate designation also included lack of satisfaction with image quality at the time of review.

Statistical Methods

The kappa value for interobserver agreement was calculated using an unweighted Cohen kappa.[8] The proportion of indeterminate cases was determined for each radiologist.

RESULTS

Participants

One hundred cases of midportion Achilles tendinopathy were identified in 95 patients, with some of the included patients having bilateral abnormality. There were 61 left and 39 right tendons, with an average age of 43.7 years (range, 17-89 years; median, 46 years). The breakdown of participants by sex was 66% male and 34% female.

Test Results

Agreement between the 2 examiners was present in 93 of 100 cases (93%) (Table 1). Examples of several cases are shown in Figures 2 through 5.

There were 3 cases that one examiner described as MHG involvement and the other examiner described as diffuse (MHG + LHG + S), 2 with disagreement as to whether there was an

Table 1. Breakdown of cases demonstrating agreement between the 2 examiners

Fascicular Territory	Number (%)
MHG only	20 (21.5)
LHG only	8 (8.6)
S only	15 (16.1)
MHG + LHG	3 (3.2)
MHG + S	21 (22.6)
LHG + S	9 (9.7)
MHG + LHG + S	16 (17.2)
Indeterminate	1 (1.1)
Total	**93**

LHG, lateral head of gastrocnemius; MHG, medial head of gastrocnemius; S, soleus.

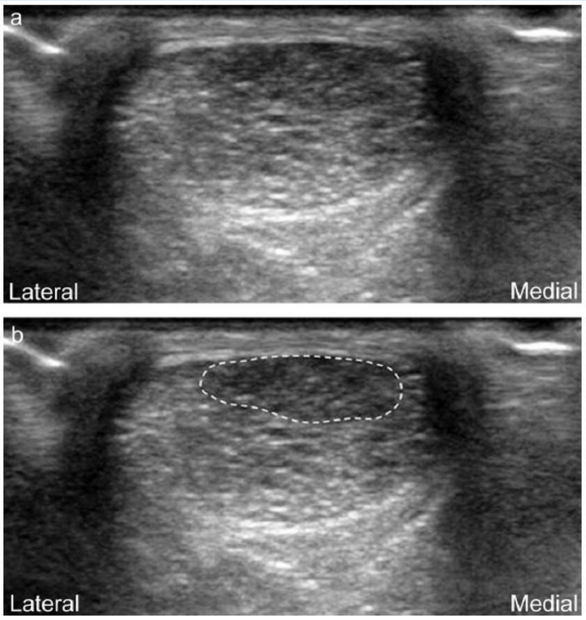

Figure 2. (a) Achilles tendinopathy with hypoechogenicity within the Achilles tendon posteriorly, corresponding to the territory of the fascicles of the medial head of gastrocnemius as depicted in the short-axis map and (b) with accompanying marking of the same image outlining the area of abnormality.

MHG + S versus just an MHG pattern, and 1 case of an LHG vs LHG + S pattern. There was no case where the description involved a completely different pattern (eg, 1 examiner determining MHG and the other determining LHG).

One of the radiologists described 1 case as indeterminate, and the other radiologist noted 2 indeterminate cases, 1 of which was the same case that the first radiologist identified. The case that both readers called indeterminate was considered as agreement, and the other as a discrepancy.

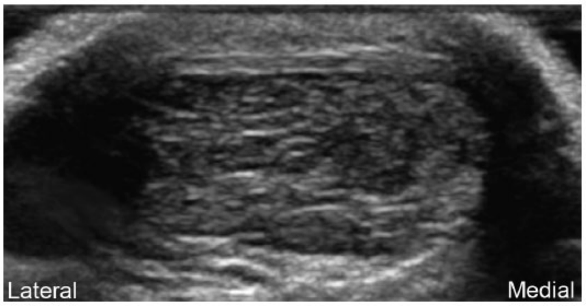

Figure 3. Tendinopathy within the Achilles tendon centrally and medially, corresponding to the territory of the fascicles of soleus.

Figure 4. A posterior and central pattern of Achilles tendinopathy overlapping the territories of the fascicles of the medial head of gastrocnemius and soleus.

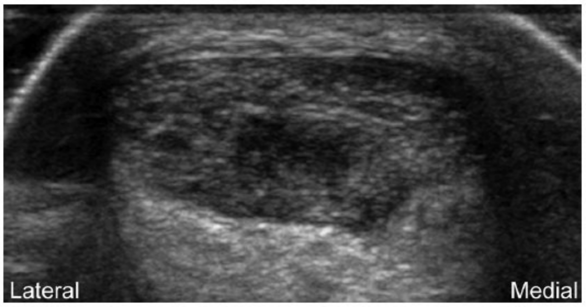

Figure 5. Tendinopathy within the Achilles tendon centrally and anteriorly, with overlapping of the territories of the fascicles of the lateral head of gastrocnemius and soleus.

The kappa value was calculated as 0.92 (95% CI, 0.86-0.98), in keeping with a high level of interobserver agreement.

DISCUSSION

Our findings are in agreement with a previous ultrasound study describing tendinopathy occurring most commonly in the posteromedial part of the Achilles tendon,[10] which if correlated with the short-axis map, would correspond to the territories of the MHG and soleus.

In addition to differential anterior and posterior forces, shear forces may also result from the varying contribution of the gastrocnemius muscles and soleus to the Achilles tendon.[2,5,7] An uneven mediolateral force distribution has been shown experimentally in a cadaveric biomechanical study, showing that the mediolateral force distribution was dependent on relative loading of the different calf muscles.[3]

Potential reasons for the MHG- and soleus-dominant pattern of involvement include hyperpronation of the foot[9] and the proximity of the plantaris tendon to the MHG.[1,15,20] Muscle strains and tears also more commonly involve MHG and the medial part of the soleus, also suggesting an increased load across the medial musculature.[13] In the series by Koulouris et al,[13] 86% (68 of 79) of calf injury sites involved the MHG or soleus, and of the soleus injuries, 85% (29 of 34) were medial.

In a series of 73 patients undergoing operative treatment of midportion Achilles tendinopathy, 58 were found to have an invaginated or closely related plantaris tendon.[1] In a cadaver study, the plantaris tendon was found to be stiffer, stronger, and less extensible, which creates the opportunity for differential motion and shear stresses as a possible mechanism of action.[15] In another cadaver study, in addition to 2.8% of plantaris tendons inserting in the Achilles tendon as a recognized normal variant, a further 10% had firm connections to the Achilles in the midportion that the authors postulated were acquired adhesions.[20] The authors suggested that since the plantaris crosses the knee joint while soleus does not, resultant differential motion may induce subsequent traction on the paratenon.

There are several limitations of this study in addition to its retrospective design. There is variable torsion of the Achilles tendon, in that the fascicles rotate to different degrees from patient to patient, with this measured as a mean of 37° and range of 11° to 65° in an anatomical study.[19] As this measurement was to the insertion, this would be expected to be somewhat less at the level where the midportion tendinopathy was characterized.

There is also a slight difference in the level of tendinopathy from that of the territorial map, which was established by Szaro et al[17] at 1 cm above the calcaneus. The result of this would likely be an overestimation of the LHG relative to the soleus and an underestimation of the MHG relative to the soleus. In view of the numbers reported in each group, this might favor MHG involvement being slightly more common.

Outside of cadaveric studies, there is a lack of a practical gold standard comparison. Diffusion tensor imaging and magnetic resonance tractography would be a possibility, but this does not appear to be validated for this purpose.[11]

Active tracing of the tendon fascicles distally from the musculotendinous junction is achievable with ultrasound but would need prospective acquisition as well as validation against a gold standard. This may be time-consuming for accuracy, which could limit its applicability in clinical practice; but if this is the case, it could still serve as a useful research tool, such as for prospective validation of the short-axis fascicular map, including fine-tuning of its territories based on the slight difference in level.

Given the recent suggestion of plantaris as a cause of medial Achilles tendinopathy,[1] assessment of its course and relation to the Achilles tendon may also be of benefit in future studies. Another factor worth assessing would be the presence of tears or atrophy involving the calf muscles corresponding to the abnormal fascicular territory, which we have anecdotally observed but not formally assessed.

CONCLUSION

The most frequent pattern of fascicular involvement in Achilles tendinopathy is that of the MHG, soleus, or both. Interpretation using a standardized short-axis fascicle map shows a high level of interobserver reliability. Further assessment is needed as to whether this imaging distinction can aid in clinical management, such as rehabilitation targeting the muscles corresponding to the abnormal tendon territories, as well as the possibility of direct fascicular tracing using methods such as real-time ultrasound or diffusion tensor imaging.

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