RESEARCH ARTICLE

Achilles tendon elasticity decreases with intermittent claudication in patients by Acoustic Radiation Force Impulse Imaging (ARFI)

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Abstract

Objective: To investigate the value of Acoustic Radiation Force Impulse elastography and its application in Achilles tendon elasticity of intermittent claudication due to lower extremity arterial ischaemia.

Methods: This prospective case-control study was conducted at the Department of Radiology, Faculty of Medicine, Baskent University, Istanbul, Turkey, from October 2015 to January 2016, and comprised bilateral Achilles tendons of patients with intermittent claudication and healthy individuals. Shear-Wave Velocity (SWV) of each tendon was measured using Acoustic Radiation Force Impulse elastography. Arterial Doppler ultrasonography at tibialis posterior artery was performed to establish the diagnosis of occlusive arterial disease, and the degree of obstruction was recorded. SPSS 16 was used for data analysis.

Results: Of the 84 subjects, 42(50%) were patients and 42(50%) were controls. The number of bilateral Achilles tendons was 168, i.e. 84(50%) of patients and 84(50%) of controls. SWV of the Achilles tendon were different between the two groups ($p<0.05$). The mean SWV was 5.24±0.45 m/s in the relaxed state in the patients and 2.83±0.56 m/s in the controls. No monophasic flow pattern was observed in 23(54.8%) posterior tibial artery and SWV was 4.94±0.40 m/s in the relaxed state Achilles tendon in patients. Monophasic flow pattern was observed in 61(72.6%) posterior tibial artery and SWV was 5.35±0.42 m/s in the relaxed state Achilles tendon in patients. SWV values were higher in monophasic flow patterns in the posterior tibial artery than in those without monophasic flow patterns in patients group ($p<0.01$).

Conclusion: The elasticity of healthy tendon decreased with intermittent claudication in patients.

Keywords: Achilles tendon, Acoustic Radiation Force Impulse, Intermittent claudication, Doppler ultrasound. (JPMA 68: 16; 2018)

Introduction

Intermittent claudication due to peripheral arterial disease (PAD) is one of the common problems that affect the limb mobility and quality of life. The symptoms are usually characterized by leg pain on walking. The Achilles tendon (AT) is one of the thickest and strongest tendons in the body which is formed from the tendinous contributions of the gastrocnemius and soleus muscles coalescing approximately 15 cm proximal to its insertion. Along with its course in the posterior aspect of the leg, the tendon spirals 30-150° until it inserts into the calcaneal tuberosity on an area without a periosteal layer.[1] The gliding ability of the AT is aided by a thin sheath of paratenon rather than a true synovial sheath. The tendon derives its blood supply from three sources: the musculotendinous junction, the surrounding connective tissue through the paratenon and the bone-tendon junction at the insertion site.[2] Although the posterior tibial artery provides the majority of the blood supply, the angiographic and histologic studies have shown that the AT has a poor blood supply throughout its length, as determined by the small number of the blood vessels per cross-sectional area.[3] Lagergren et al. reported that the area of tendon typically prone to rupture is relatively avascular compared with the rest of the tendon.[4] The AT has been shown to thicken in response to increased activity, however, the morphologic changes such as decreased cell density, decreased collagen fibril density, and loss of fibril waviness that occur with aging predispose the tendon to injury.[5]

Elasticity values vary between body tissues and or in different pathological conditions affecting tissues. The differences in elasticity changes are difficult to detect with only B-mode ultrasound because the echogenicity of the affected tissue and the neighbouring healthy tissue is the same. Several ultrasound-based non-invasive methods have been developed for elasticity evaluation in the last decade, such as transient elastography, real-time elastography, and Acoustic Radiation Force Impulse (ARFI) elastography imaging. ARFI elastography is an ultrasonography-based

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technique of propagation of acoustic waves in attenuating tissues to establish values of elasticity. With increasing acoustic frequencies, the tissue does not respond fast enough to the transitions between positive and negative pressures and with this technique we have more valuable information about the stiffness of tissue applied to. The Shear Wave Velocity (SWV) within the tissue can be calculated (measured in meters per second) by measuring the time to peak displacement at each lateral location, which is proportional to the square root of tissue elasticity. VTQ enables objective quantitative assessment of tissue stiffness.[6,7] The current study was planned to determine whether arterial ischaemia may increase tendon rupture risk by changing tendon stiffness. It is useful to take protective measures to prevent tendon rupture. To date, ARFI elastography has not been applied to study AT in ischaemic lower limbs.

Patients and Methods

This prospective case-control study was conducted at the Department of Radiology, Faculty of Medicine, Baskent University, Istanbul, Turkey, from October 2015 to January 2016, and comprised bilateral Achilles tendons of patients with intermittent claudication and healthy individuals. Patients were evaluated with ARFI elastography performed on their bilateral AT and Doppler ultrasound on their posterior tibial artery. The sample size was calculated using the following formula.[8]

Sample size (n) =Z2 p (100 - p) N

d2 (N-1) +Z2 p(100-p)

Where,

Z2 =value of Z at 99% level of confidence, i.e. = 6.6564

P =the prevalence of intermittent claudication disease in PAD that is 33,3%.[9]

d2 =the margin of error = 5 % = 5 x 5 = 25

N =Normal SWV value of healthy Achilles tendon

Patients having diabetes, rheumatism, systemic inflammatory disorders and prolonged use of the Achilles tendon were excluded.

An equal number of controls were also enrolled in the study. Approval was obtained from the institutional ethics committee. Informed consent was taken from all participants.

Radiological evaluation of the changes in the heels of the study and the control group was fulfilled. The patients and control subjects underwent an ARFI elastography examination using a commercial scanner (Siemens Acuson S3000™ (9-L4) probe, Siemens Medical Solutions USA, Inc., Mountain View, California, United States), which was performed by a US physician with three months of experience in ARFI elastography. Linear probe was used for coloured Doppler ultrasonography and ARFI elastography. According to a previous study,[10] the AT was assessed by three parts: the proximal (muscle-tendinous junction), middle (2-4 cm above the insertion on the calcaneus) and distal (placing the calcaneus) sections. In this study, we assessed the middle part of the tendon. Achilles tendons were evaluated by radiologists with patients being in a prone position and the foot hanging over the edge of the examination bed in a relaxed position. Longitudinal images of each tendon were obtained by Ultrasound and ARFI elastography. ARFI elastography imaging technology includes virtual touch tissue imaging and virtual touch tissue quantification (VTQ).[6,7] VTQ was produced of microscopic tissue displacements (1-10 µm) with short-duration mechanical stimulation acoustic pulses in an area of interest (ROI) selected by the examiner.[11,12]

The probe was held at a right angle to prevent anisotropy.[13,14] ROI was determined by a predefined size (5x5 mm) provided by the system. To perform SWV measurements, sites that were approximately 2-4 cm above the insertion on the calcaneus were selected as ROI.

The combination of gray scale imaging with Doppler sonography was used in assessing occlusive arterial disease. Colour flow imaging makes it possible to evaluate the full length of the arterial segments of the lower limb and identify the absence of flow signals, sites of increased velocity, flow pattern, evaluate the cross-sectional examination of the artery and estimate relative stenosis. On the other hand, pulsed Doppler sonography was used to obtain the peak systolic velocity with a Doppler gate placed at sites of aliasing and then 2-4 cm proximal to the suspected lesion and then the velocity ratio was calculated so that by both colour imaging and duplex ultrasonography were recorded.

SPSS 16 was used for statistical analysis. Mann-Whitney U test and independent sample t-test were used where appropriate. $P<0.05$ was considered statistically significant.

Results

Of the 84 participants, 42(50%) were patients and

Table-1: SWV values in Achilles tendon at patient and control groups.

	n	SWV Mean	SD
Patient	84	5,2412	0,45667
Control	84	2,8363	0,56384
Total	168	4,0388	1,31003

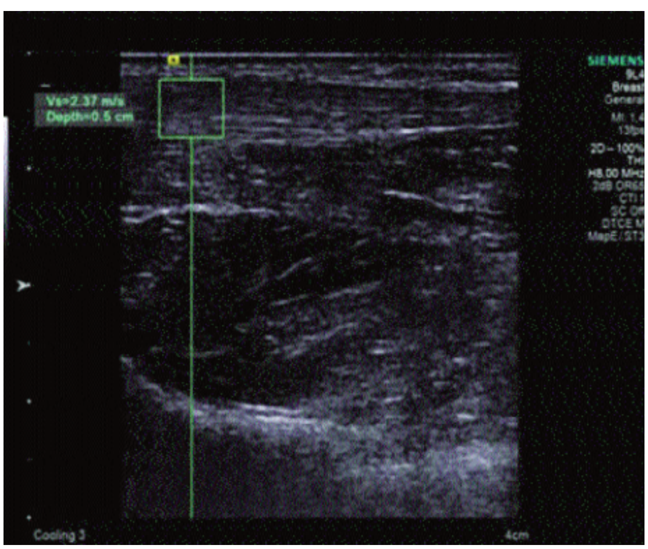
p<0.05
SWV: Shear Wave Velocity.
SD: Standard Deviation.

Table-2: SWV values in Achilles tendon at patient groups.

	Posterior tibial artery (n)	AT SWV Values (Mean)	AT SWV Values (SD)
Monophasic flow (-)	23	4,9409	0,40637
Monophasic flow (+)	61	5,3544	0,42466
Total	84	5,2412	0,45667

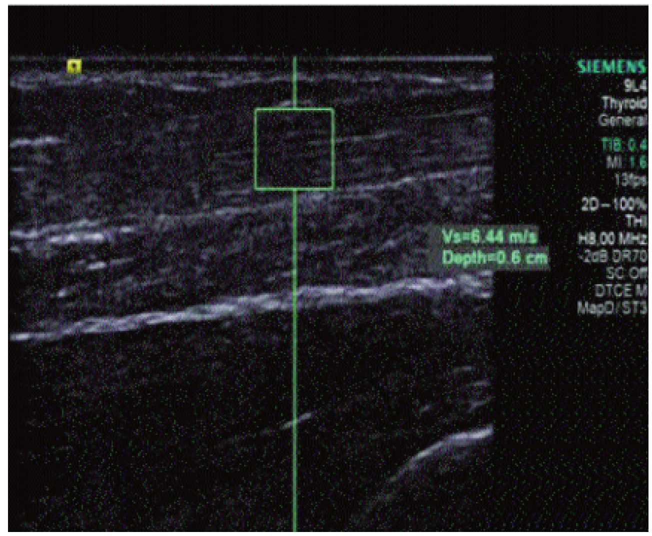
p<0.01
AT: Achilles Tendon
SWV: Shear Wave Velocity
SD: Standard Deviation.

42(50%) were controls. The number of bilateral Achilles tendons was 168, i.e. 84(50%) of patients and 84(50%) of controls. Among patients, 19(45.2%) were females and 23(54.8%) were males. In the control group, 20(47.6%) were females and 22(52.4%) males. The overall mean age of patients was 58.4±11.83 years and that of controls was 58.50±8.59 years.



ARFI: Acoustic Radiation Force Impulse
SWV: Shear Wave Velocity

Figure-1: ARFI elastography of the Achilles tendons in a state of relaxation in healthy men at ages of 60 years (SWV = 2,37 m/s).



ARFI: Acoustic Radiation Force Impulse
SWV: Shear-Wave Velocity.

Figure-2: ARFI elastography of the Achilles tendons in a state of relaxation in patient men at ages of 62 years (SWV = 6,44 m/s).

SWVs of the Achilles tendon were different between the two groups (p<0.05).

SWV was 5.24±0.45 m/s in the relaxed state in the patient group (Figure-1).

SWV was 2.83±0.56 m/s in the relaxed state in control group (Figure-2) (Table-1).

In the patient group, no monophasic flow pattern was observed in 23(27.4%) posterior tibial arteries, and mean SWV was 4.94± 0.40 m/s in the relaxed state AT. In contrast, monophasic flow pattern was observed in 61(72.6%) posterior tibial arteries, and mean SWV was 5.35±0.42 m/s in the relaxed state AT (Table-2).

SWV values were higher in monophasic flow patterns in the posterior tibial artery than in those without monophasic flow patterns at patient groups and it was the statistically significant difference in SWV mean values (p<0.01).

Discussion

AT is echogenic and exhibits a characteristic fibrillar structure on the longitudinal scan. The tendon is surrounded by a paratenon which is a dense connective tissue structure that appears as echogenic borders surrounding the tendon.[13,14] AT is a relatively large superficial structure, easily imaged by ultrasound which can be helpful in distinguishing between Achilles tendinitis, paratenonitis, and retrocalcaneal bursitis.

Many previous studies reported the enthesopathic changes of the AT and the value of ultrasound in evaluating these changes.[15,16] AT does not have a true synovial sheath, but instead has a paratenon. The paratenon is a connective tissue sheath that surrounds the entire tendon and is able to stretch 2 to 3 cm with movement, which allows maximal gliding action. Running produces forces up to eight times the body's weight, placing significant repetitive stress on the tendon for prolonged periods.[17] Tendonitis in athletes is usually caused by training errors or wearing improperly fitting shoes. Also, could be due to abnormal biomechanics and friction from extrinsic or external pressure. To our knowledge, there has been no reported association of limb ischaemia with Achilles tendinopathic changes demonstrated with ultrasound. So far, there has only been one case of a patient with spontaneous bilateral rupture of AT secondary to lower limb ischaemia.[18] We have examined the tendinopathic changes of AT by ultrasound in patients complaining of intermittent claudication due to limb ischaemia. Ultrasonographically, the homogeneous thickness, uniform fibrillar echotexture, and sharply defined echogenic margins of the tendon are considered as the main features of normal appearance of the tendon.[15] Loss of the fibrillar echotexture is always an abnormal finding and it can range from a diffuse blurring of the tendon texture to focal aspects of fibrillar interruptions. Maffulli reported that a diffuse thickening of the tendon is a common condition in persons older than 35 years.[19]

The arterial flow pattern is the triphasic flow in healthy individuals. According to the degree of arterial occlusion, the pattern can change into to monophasic pattern. Tendinophatic changes in tendon begin with dysregulation of blood flow. Aging, vascular compromise or a combination of these factors may result in increased predisposition to injury and microtears within the tendon. SWV measurement using ARFI elastography imaging provides quantitative and reproducible information about the tendon stiffness in real-time. We selected the middle portion of the tendon for ARFI elastography measurement because it is a common site of rupture.[20] This may correspond closely to a significant reduction in the number of blood vessels observed in the middle part of the tendon.[21]

We found that AT tendon stiffness increased in the patient group. Since there is no similar study in literature, no comparison can be made with the results.

In this study, there are some technical concerns with ARFI elastography measurement of the Achilles tendon. Due to the standard size (5x5 mm) of the ROI, the coverage of a portion of the tissue around the tendon may negatively affect the measurement. However, due to the existence of individual differences in the thickness of the Achilles tendon, ROI sometimes includes not only tendon tissue, but also some adjacent soft tissues, which may introduce error. In order to reduce this error, ROI is held in the center of the tendon.

Conclusion

The elasticity of healthy tendon decreased with intermittent claudication in patients. It is useful to take protective measures to prevent tendon rupture. This study included only 42 patients with intermittent claudication. More studies are needed to confirm the value of this new method of assessing the ARFI elastography of the tendon.

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Conflict of Interest: None.

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