Journal of Medical Ultrasonics (2019) 46:45–49
https://doi.org/10.1007/s10396-018-0907-9

ORIGINAL ARTICLE

Virtual touch IQ elastography in evaluation of Achilles tendon in patients with chronic renal failure

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Received: 16 March 2018 / Accepted: 12 September 2018 / Published online: 5 October 2018

Abstract

Purpose To evaluate the sonoelastographic changes in the Achilles tendon in patients with chronic renal failure (CRF) using virtual touch imaging quantification (VTIQ) elastography.

Methods Twenty-six patients undergoing three hemodialysis sessions per week and 26 subjects admitted to our institution between January 2016 and April 2016 were included in this prospective study. The characteristics and body mass index of the patients were noted. Ultrasonography was performed parallel to the long axis of the bilateral Achilles tendons during relaxation of the legs using the Siemens Acuson S3000™ ultrasound device (Siemens HealthCare, Erlangen, Germany). Tendon thickness was reviewed, and tissue stiffness was quantitatively assessed using VTIQ elastography. Independent samples *t* test and Mann–Whitney *U* test were used for statistical analyses.

Results The median values of shear wave velocities of the Achilles tendon in patients with CRF were 7.19 m/s (4.23–9.77 m/s) on the right and 6.98 m/s (4.00–9.82 m/s) on the left, while they were 5.11 m/s (4.09–8.82 m/s) on the right and 5.36 m/s (4.05–8.80 m/s) on the left in controls. The stiffness of the Achilles tendons in patients with CRF was found to be higher than that in controls (right: $P<0.001$, left: $P=0.004$). There was no statistically significant difference in tendon thickness between the CRF and control groups ($P>0.05$).

Conclusion The thickness and stiffness of tendon can be effectively evaluated with sonoelastography. The thickness of the Achilles tendon did not significantly differ between the patients with CRF and healthy subjects. However, the stiffness of the Achilles tendon measured with VTIQ elastography was demonstrated to be increased in the patients with CRF.

Keywords Achilles tendon · Elastography · Hemodialysis · VTIQ

Introduction

Chronic renal failure (CRF) is one of the most common health problems worldwide [1]. The average life expectancy of patients with CRF has been prolonged by the development of diagnostic methods and dialysis. One of the musculoskeletal complications in patients undergoing hemodialysis is spontaneous tendon rupture [2–4]. The Achilles tendon, the largest tendon of the body, is the most commonly ruptured tendon. Spontaneous rupture of the Achilles tendon in patients with CRF is relatively rare [5–7]. However, it should be considered that this complication may result in disability if not treated or missed. Changes in the thickness and stiffness of the Achilles tendon may be associated with the risk of tendon rupture.

Ultrasonography is a radiation-free, easy, fast, and low-cost imaging method, and thus, it has become a preferred method in the evaluation of tendon rupture [8]. Ultrasonography is currently used not only as an imaging method but also as a method that provides functional data. Elastography, a relatively new method [9], can be used in the evaluation of tendon stiffness, which makes it advantageous over magnetic resonance imaging in this field. The elasticity of

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tissue can be assessed by two different methods: real-time elastography performed with manual compression and shear wave elastography (SWE) performed with an acoustic beam. Thus, SWE is a less user-dependent elastography technique compared to real-time elastography. Acoustic radiation force impulse (ARFI), a technique of SWE, uses mechanical excitation of tissue and produces shear waves. Three techniques, i.e., virtual touch imaging (VTI), virtual touch quantification (VTQ), and virtual touch imaging quantification (VTIQ), are defined as ARFI. VTI, known as conventional ARFI, provides a qualitative elastogram and demonstrates stiffness relative to the surrounding tissue. However, VTQ and VTIQ directly measure tissue stiffness and provide a quantitative elastogram, making these techniques more reliable than the conventional ARFI. Unlike VTQ, VTIQ combines relative and quantitative stiffness imaging using a shear wave map [10]. With the advantages of multiple-point measurement and providing a smaller region of interest (ROI) than that in VTQ, VTIQ shows a better diagnostic performance than VTQ [11]. Our aim is to evaluate sonoelastographic changes in the Achilles tendon in patients with CRF using VTIQ elastography.

Materials and methods

Study population

Twenty-six patients with CRF, who were on dialysis 3 days per week, and twenty-six control subjects admitted to our institution between January and April 2016 were included in this observational study. The patients with Achilles tear or history of tear, systemic inflammatory disease, and history of orthopedic surgery or peripheral artery disease were excluded from the study. In both groups, weights and heights of the participants were noted, and body mass index (BMI) was calculated by dividing the body weight (in kilograms) by the square of the height (in meters, kg/m^2). The study was approved by our institution's human research ethics committee. Informed consent was obtained from all individuals.

Ultrasound technique

The ultrasonography examinations of all participants were performed with a Siemens Acuson S3000™ ultrasound device (Siemens HealthCare, Erlangen, Germany) equipped with VTIQ software. The Achilles tendon was evaluated in a relaxed position while the subject was lying prone with the feet hanging freely down the side of the table. A 9-MHz transducer was used for B-mode imaging and elastography examinations. The probe was gently moved without any pressure, and was held vertical to the tendon while performing the examination to avoid anisotropy. The distal one-third of the Achilles tendon was evaluated on ultrasound. To standardize shear wave values, the part that was approximately 2 cm above the insertion on the calcaneus was selected as the ROI. The anteroposterior dimension of the tendon on B-mode imaging was regarded as tendon thickness. The size of the VTIQ-measuring box was adjusted to include the tendon with the surrounding tissue (Fig. 1). The size of the ROI was 1.5 × 1.5 mm, as specified by the manufacturer. For each tendon, three ROIs were identified, and the median value of them was recorded. The size of the VTIQ-measuring

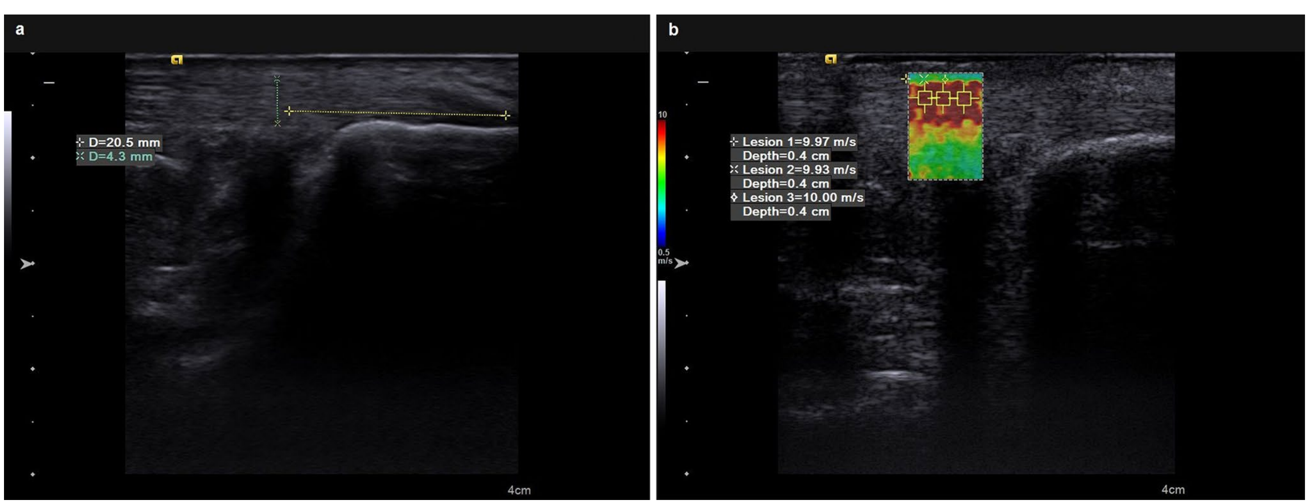

Fig. 1 Sonography images of the right Achilles tendon in a 60-year-old male patient with chronic renal failure. **a** On gray-scale images, the part that is approximately 2 cm above the insertion on the calcaneus was selected as the region of interest (ROI). **b** Size of the VTIQ-measuring box was adjusted to include the tendon with the surrounding tissue, and the shear wave velocities (SWVs) were determined with the VTIQ method

box and location of ROIs were adjusted by consensus of two radiologists, who had more than 5 years of experience in musculoskeletal radiology.

Statistical analysis

SPSS for Windows version 19 software package (SPSS Inc, Chicago, IL, USA) was used for statistical analyses. Descriptive variables were presented as median and range. Shapiro–Wilk test was used for testing normality. Independent samples *t* test was used for the comparison of two groups distributed normally, while Mann–Whitney *U* test was used for the comparison of two groups not distributed normally.

Results

There were 26 patients (10 female and 16 male patients) with CRF, and the mean age of the patients was 56 ± 8.39 years. The control group included 26 patients (12 female and 14 male patients) with a mean age of 52 ± 8.32 years. BMI values and age were not statistically significant between the CRF and control groups. The median duration of hemodialysis treatment was 31.9 months (range 6–180) for the patients with CRF, and it was not correlated with the elastography values. Tendon rupture was not demonstrated in our study.

On B-mode imaging, the median thickness of the right Achilles tendon in the control and CRF groups was found to be 5.10 (range 3.6–6.4) mm and 5.35 (range 4.0–7.0) mm, respectively. The median thickness of the left Achilles tendon in the control and CRF groups was found to be 4.90 (range 4.1–8.3) mm and 5.20 (range 4.0–6.5) mm, respectively. There was no statistically significant difference in tendon thickness between the CRF and control groups ($P > 0.05$).

The shear wave velocities (SWVs) of the Achilles tendon in CRF patients and the control group are presented in Table 1. The median SWVs of Achilles tendons in the patients with CRF were significantly higher than those in the control group (right: $P < 0.001$, left: $P = 0.004$).

Discussion

Chronic kidney disease and hemodialysis are well-known risk factors for tendon disorders. Achilles tendon rupture in patients on regular hemodialysis treatment has been described in the literature [6, 7, 12]. Predisposing factors in these patients include long-term hemodialysis, secondary hyperparathyroidism, β-2 microglobulin-associated amyloidosis, fluoroquinolone use, corticosteroid use, malnutrition, chronic inflammation syndrome, and chronic acidosis [13, 14]. Secondary hyperparathyroidism has been suggested as the main reason for tendon ruptures in patients on chronic hemodialysis treatment [2, 15]. In this study, we demonstrated that VTIQ elastography values correlating with tendon stiffness significantly increased in patients with CRF undergoing hemodialysis.

Teber et al. [16] compared the elasticity of the quadriceps tendon between patients with CRF on a dialysis program and control subjects. They used a strain elastography technique based on mechanical compression of tissue and demonstrated that quadriceps tendons were significantly thinner in patients with CRF compared to the control group. They also reported decreased tendon stiffness in patients with CRF. In contrast to their study, we demonstrated increased tendon stiffness of the Achilles using VTIQ. We think that increased stiffness might be secondary to a possible effect of secondary hyperparathyroidism and hypercalcemia in tendons.

VTIQ, developed by fusing the advantages of imaging and quantification, is one of the more advanced elastography techniques. It is a color-coded display of relative SWV within the user-defined ROI superimposed on a conventional B-mode ultrasound image. VTIQ, a reproducible method, provides more accurate measurements of tissue stiffness in the ROI, and thus, it has the potential to technically overcome the limitations of former methods [10]. Several studies reported the application of VTIQ in breast tissue [17–20]. Zhang et al. [21] stated that the combination of ultrasonography and VTIQ could improve the specificity (32.7% vs. 87.3%, $P < 0.001$) with relatively high sensitivity (97.1% vs.

Table 1 SWVs and thickness of Achilles tendon in patients with CRF and control subjects

	CRF patients	Control subjects	*P* value
SWVs of right Achilles tendon (m/s)	7.19 (4.23–9.77)	5.11 (4.09–8.82)	$P < 0.001$
SWVs of left Achilles tendon (m/s)	6.98 (4.00–9.82)	5.36 (4.05–8.80)	$P = 0.004$
Right Achilles tendon thickness (mm)	5.35 (4.00–7.00)	5.10 (3.60–6.40)	$P > 0.05$
Left Achilles tendon thickness (mm)	4.90 (4.10–8.30)	5.20 (4.00–6.50)	$P > 0.05$

The parameters are presented as median and range

CRF chronic renal failure. *SWVs* shear wave velocities

85.3%, $P = 0.075$). In another study by Zhang et al. [22], they reported that tendon function was associated with the elasticity of the repaired Achilles tendon. Thus, they suggested that SWE can be used for predicting the function of the Achilles tendon.

Elastography can also be used to identify tendinopathy. The previous studies found that tendinopathies in different locations displayed different elasticities compared to tendons of healthy subjects [23–26]. Using SWE, Coombs et al. [27] reported lower elasticity of insertional Achilles tendon and higher elasticity of the patellar tendon in patients with tendinopathy compared to controls. Zhang et al. [28] demonstrated greater elasticity for the proximal patellar tendon in 13 athletes with unilateral patellar tendinopathy, compared to both the unaffected tendon of the patients and controls. In 38 participants with patellar tendinopathy, Dirrichs et al. [24] reported lower SWVs in symptomatic tendons compared to those in asymptomatic tendons.

The effect of secondary hyperparathyroidism on the tendon rupture mechanism is controversial [2, 15]. Some researchers have hypothesized that the cause of rupture is osteolytic bone resorption at the tendon insertion site and that change in the tendon structure does not occur [3, 4, 29]. However, Terai et al. [30] stated that there was an increase in vascular calcification in CRF patients with secondary hyperparathyroidism, and calcific deposition in tendons might also have occurred. In our study, 24 patients with CRF had secondary hyperparathyroidism, supporting this statement. In addition, CRF patients are less physically active than healthy sedentary adults [31, 32]. They may also have more muscle atrophy [33] and reduced exercise capacity [34–38]. In line with these studies, Turan et al. [39] reported age-related sonoelastography changes in the Achilles tendon. We think that tendon rupture may be associated with reduced tendon elasticity and increased tendon stiffness in elderly individuals.

This study has several limitations. First, it was a single-center study with a relatively small-study population. Second, oral interview was used to rule out concomitant diseases and metabolic disorders of volunteers. In addition, interobserver variability was not assessed in our study.

Conclusion

The thickness and stiffness of tendons can be effectively evaluated with sonoelastography. The thickness of the Achilles tendon did not significantly differ between the patients with CRF and healthy subjects. However, the stiffness of the Achilles tendon in patients with CRF increased on VTIQ elastography. Further studies are needed to better evaluate the effect of hemodialysis on tendon elasticity.

Compliance with ethical standards

Conflict of interest Emrah Caglar, Ibrahim Ilker Oz, Serkan Guneyli, Muammer Bilici, Sevil Uygun Ilıkhan, Fatih Yılmaz, and Ali Borazan declare that they have no conflicts of interest.

Ethical statement 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 1964 and later versions.

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