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Shear wave elastography of the tibial nerve in healthy subjects

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Abstract

The purpose of this study is to investigate sonoelastographic features of the tibial nerve.

The study included 72 tibial nerves in 36 healthy subjects. High resolution ultrasound and Shear wave elastography were used to evaluate the tibial nerve. Cross sectional area and stiffness were measured.

The mean cross sectional area of the tibial nerve was 13.4 mm^2. The mean shear elastic modulus of the tibial nerve in the short axis was 23.3 kPa. The mean shear elastic modulus of the tibial nerve in long axis was 26.1 kPa. The tibial nerve elastic modulus also showed no correlation with cross sectional area neither in the long axis nor short axis. Age, height, weight, and body mass index showed no correlation with tibial nerve elastic modulus in short or long axes.

The elastic modulus of the tibial nerve has been determined in healthy subjects and can serve as a reference for future assessment of polyneuropathy.

Abbreviations: BMI = body mass index, CSA = cross sectional area, LA = long axis, SA = short axis, SWE = shear wave elastography.

Keywords: elastography, nerve, neuropathy, shear wave, Tibial, ultrasound

1. Introduction

Peripheral nerve disorders pathologies are commonly encountered in clinical practice. Electrodiagnostic studies have been the main diagnostic modality used for the diagnosis of peripheral nerve disorders especially neuropathies. However, these studies are invasive and time consuming. Over the last twenty years, conventional ultrasound gained popularity as a complimentary tool for the diagnosis for different peripheral nerve disorders. In addition to shorter acquisition time and less discomfort, advantages of ultrasound include wide availability, cheap price, and non-invasive nature.[1–3] Conventional ultrasound can quantify cross sectional area (CSA) of the peripheral nerves and can also detect some morphological changes like alteration in the nerve echogenicity.[1,4] Conventional ultrasound was reported to be of great benefit in the diagnosis of different acquired and hereditary neuropathies. In cases of peripheral neuropathy, there is associated increase of the intraneural pressure, nerve edema, and micro-vascular compromise. This could end with demyelination and functional deterioration of the nerve.[1] These histological changes are not detected by conventional ultrasound. Elastography was described in the early 1990s to provide information about tissue stiffness. Elastography was reported to provide more detailed information about biomechanical and elastic properties of peripheral nerves. Recent literature reported that nerve stiffness tend to increase in the setting of peripheral neuropathy.[1,2] In spiteof this, still elastography is not highly indicated in clinical practice for evaluation of the peripheral nerves. Two types of elastography are present at the moment. The first is strain elastography, where tissue displacement is evaluated by mild compression by the probe to estimate the tissue stiffness, resulting in color scaled qualitative and semi quantitative evaluation of elasticity. The other type is shear wave elastography (SWE), where a probe-induced pulse propagates through the tissue of interest waves in a shear manner and presented in kilopascals (kPa, Young modulus). One important advantage of SWE is

quantitative results. The other advantage is reproducibility and being less operator-dependent than strain type. SWE is now widely used in evaluating liver fibrosis, breast and thyroid masses. There is now special interest to use SWE for evaluation of the neuromuscular system.[5–10] Several studies were conducted to evaluate common types of neuropathies by SWE. Most of the studies performed on carpal tunnel syndrome (CTS) used the median nerve for elastographic evaluation. In diabetic poly-neuropathy, the median nerve and the tibial nerves are used for ease of accessibility and standard imaging technique.[11–14] The tibial nerve originates from L4-S3 spinal nerve roots and provides sensory and motor innervation to most of the posterior aspect of the leg and foot. It is the larger distal extension of the sciatic nerve, the largest nerve of the body. A significant degree of anatomical variation can be seen with the sciatic nerve which may lead to many relevant clinical considerations. It arises in the popliteal fossa and then continues down the leg posterior to the tibia. At the foot, it passes postero-inferior to the medial malleoulus through the tarsal tunnel, and terminates by dividing into the sensory branches. The main branches of the tibial nerve include the medial calcaneal nerve, the medial sural cutaneous nerve, the lateral and medial plantar nerves. The tibial nerve is involved in different types of neuropathies. Knowledge of the anatomical details together with biomechanical properties will help in the assessment and management of such disorders. Tibial nerve blockade is also important for surgeries around the knee like arthroplasty and could help in managing postoperative pain and recovery. [15,16] The aim of this work is to study the sonoelastographic features of the tibial nerve at the popliteal fossa.

2. Methods

2.1. Participants

72 tibial nerves were evaluated in 36 healthy adult subjects. After institutional review board approval, participants of the study were recruited between September 2019 and October 2019, and written consent was obtained. Only those without peripheral neuropathy, no history of numbness or limb pain, weakness, or paresthesias, in the lower limbs were included. For each participant, data including sex, age, weight, body mass index (BMI) and height were recorded. Subjects enrolled in this study were free from any diseases related to neuromuscular system, as indicated by and clinical examination and electrophysiologic methods.

2.1.1. Technique.
Ultrasound examinations were performed by using an 18 to 5 MHz linear-array transducer (Aixplorer; Mach 30, Aix enProvence, France). A radiologist (M.B, 19 years of experience) performed all examinations, images were reviewed by neurologist (A.E. 10 years' experience). All the participants were examined with hip abducted and externally rotated, with the knee in semi-flexed position. The tibial nerve was first identified in short axis (SA) in the popliteal fossa in relation to the popliteal vessels, and then the CSA was measured in mm². For the SWE measurements, each subject was scanned 3 times with removal of the probe from the skin between measurements. To increase the reliability of the reported stiffness values, a confidence map was used to mask areas below a specific confidence level. Large amount of gel was used with light touch of the probe to decrease pressure effect on the skin. First the tibial

nerve was identified in SA and SWE measurements were taken, then the probe was rotated 90 degrees to acquire longitudinal SWE measurements. In each exam, and after identifying the nerve, the probe was held stationary for 3 to 4 seconds and a 2 mm diameter region of interest (ROI) circle was placed within the hyperechoic epineurium. Real time shear wave images were recorded with color coding. The readings consisted of minimum elasticity (min), maximum elasticity (max), and mean elasticity (mean) with standard deviation (SD) and were reported in kPa. The spectrum of scale colors range from blue for softer tissues through red for stiffer tissues (Figs. 1 and 2)

2.2. Electrophysiologic methods

Nerve conduction studies were performed with Nihon-Cohden Neuropack device. All studies were performed under standard room temperature of 25°C. Hand temperature was maintained at ≥32°C. Electrodiagnostic studies were performed on both hands and feet in all subjects by an expert neurologist.

2.3. Statistical analysis

Statistical analysis was performed using Statistical Package for the Social Sciences version 21 software (SPSS Inc., Chicago, IL). Data were presented as mean ± standard deviation and range. Intra-observer variability was measured using Kohen's Kappatest. Independent sample test was used to assess the differences between mean elasticity of the right and left tibial nerves. The correlations between the mean elasticity bilaterally and age, weight, height, and BMI were calculated by Pearson correlation coefficient test.

3. Results

The study included 72 tibial nerves in 36 healthy adult subjects, with a mean age of 33.2 ± 6.5 [range 20–46], mean height 160.8 cm ± 10.1 [range 149–193], mean weight 64.1 kg ± 14.6 [range 45–125], mean BMI 24.9 ± 3.7 [range 17.3 -33.6]. The mean cross sectional area of the tibial nerve was 13.4 mm² [range 7–32 ± 4.9]. The mean shear elastic modulus of the tibial nerve in the SA was 23.3 kPa [range 9.2- 39.6 ± 7.2]. The mean shear elastic modulus of the tibial nerve in long axis (LA) was 26.1 kPa [range 12–50.3 ± 6.4]. Table 1 shows the demographic characteristics of study participants. Table 2 shows the CSA and stiffness values of the tibial nerve. The intra-observer reliability calculations resulted in an overall intra-class correlation coefficient of 0.78. No statistical differences were noted between the right and left sides regarding the CSA (P=.707), shear wave elastic modulus of the tibial nerve in SA (P=.054), and shear wave elastic modulus of the tibial nerve in the LA (P=.101).

The CSA of the tibial nerve correlated positively with weight (P<.011), BMI (P<.001), and age (P<.002). No correlation was noted between CSA and height in our study. No statistical relation could be noted between elasticity measurements in long and short axes. The tibial nerve elastic modulus also showed no correlation with CSA neither in the LA nor SA. Age, height, weight, and BMI showed no correlation with tibial nerve elastic modulus in short or long axes. Table 3 shows the correlation between the CSA, stiffness, and demographic characteristics in our study.
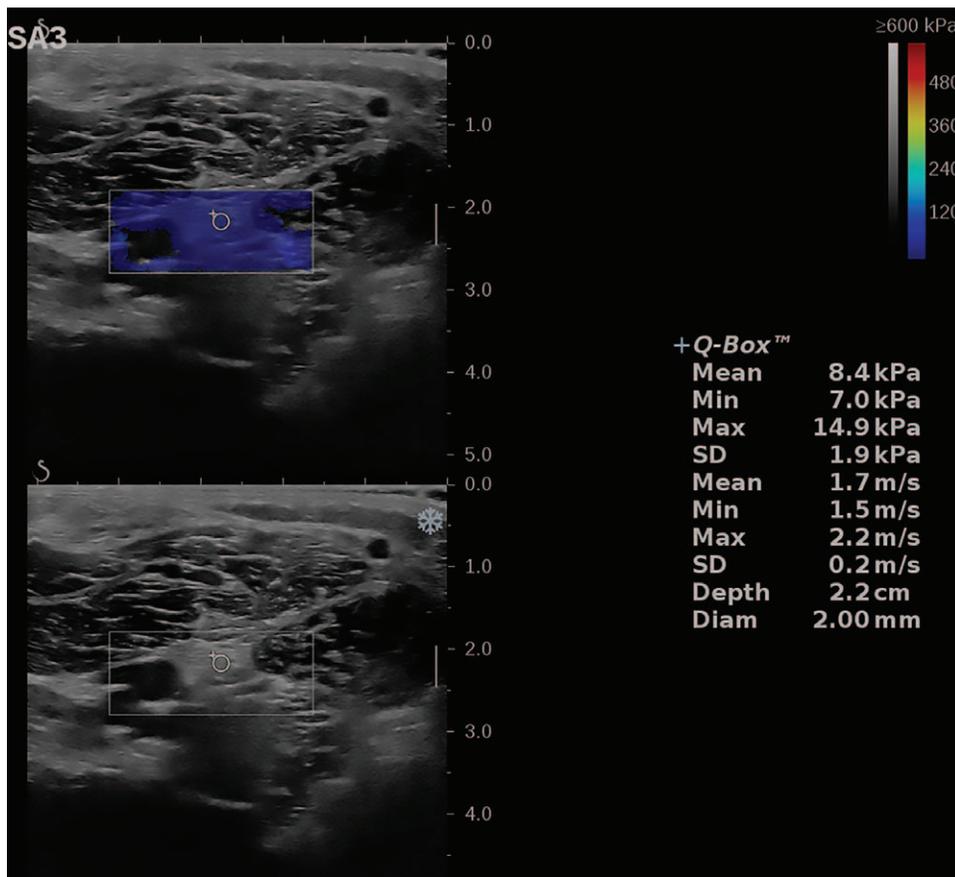
Figure 1. Short-axis view shear wave elastography of the tibial nerve, with color map, minimum, maximum, and mean stiffness in kPa.
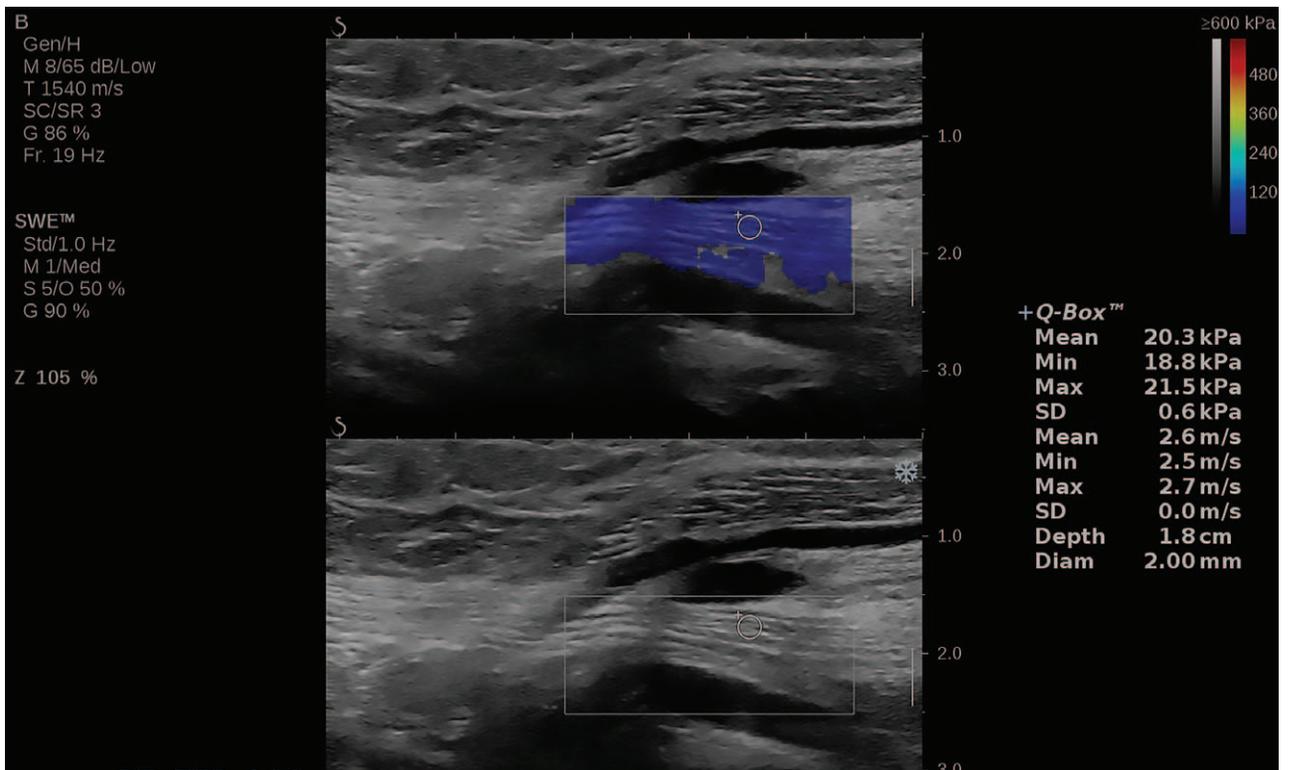

Figure 2. Long axis view shear wave elastography of the tibial nerve, with color map, minimum, maximum, and mean stiffness in kPa.

Table 1

The demographic characteristics of study participants (mean ± standard deviation).

	Mean	± SD	No	%
Age in year	33.2	6.5		
Gender				
Male			15	41.7
Female			21	58.3
Height (Cm)	160.8	10.1		
Weight (Kg)	64.1	14.6		
Body mass index	24.9	3.7		

SD = standard deviation.

4. Discussion

We studied the tibial nerve in healthy adult subjects by SWE. The relationship between elasticity and height, weight, body mass index, gender, were also studied. Conventional ultrasound is widely used in the diagnosis of peripheral nerve disorders, and can clearly depict the echotexture and the (CSA) of peripheral nerves. However, sometimes there is no statistical difference between the CSA in diseased nerves with neuropathy, and the control group.[12,17] With the addition of SWE assessment to CSA measurements great value was added in these cases and helped in the diagnosis and assessment of disease progression.[4,11–14] The stiffness of the tibial nerve was found to be higher patients with diabetes with and without diabetic polyneuropathy.[13] The CSA measurements of the tibial nerve obtained in our study (13.4 mm^2 ± 4.9) are comparable to most of published research except for Wei et al (28 mm^2 ± 0.04) and Cartwright et al (35.3 mm^2 ± 10.3) who obtained larger CSA measurements for the tibial nerve at the popliteal fossa.[11,18] The mean stiffness of the tibial nerve in the longitudinal axis in our study was (26.1 ± 6.4 kPa), which was slightly lower than Jiang et al (32.8 ± 7.1 kPa), Dikici et al (29.3 ± 7.1kPa), and He et al (3.64 ± 0.49 m/s).[4,12–14] Aslan et al showed lower mean stiffness values in the SA than our study (16.89 kPa) with a cutt-off value of (17.1 kPa).[4] In the LA Aslan et al showed a mean stiffness of (48.72 kPa) and a cut-off value of (91.86 kPa), which is significantly higher than our study and other reports by Dikici et al and He et al who suggested (50.52 kPa) as a reasonable cut-off value for the diagnosis of mild neuropathy. [12–14] Side to side analysis revealed no significant difference of nerve stiffness, coinciding with Dikici et al and He et al. Dikici et al also showed no difference between both sexes matching with our results. Age did not correlate with nerve stiffness in our study which is also compatible with Dikici et al. Most of the studies considering the tibial nerve SWE, used LA SWE measurements only, except for Aslan et al, who used both axes. Our study showed difference between short and long axes SWE measurements, however, this was not statistically significant. Aslan et al showed a statistically significant difference between both axes.[4,12–14] Several challenges

Table 2

CSA and stiffness values of the tibial nerve (mean ± standard deviation).

	Minimum	Maximum	Mean	± SD
Tibial CSA	7	32	13.4	4.9
Tibial SA	9.2	39.6	23.3	7.2
Tibial LA	12.2	50.3	26.1	6.4

CSA = Cross sectional area, LA = Long axis, SA = Short axis, SD = Standard deviation.

Table 3

Correlations between demographic factors, cross sectional area, and stiffness in the long and short axes.

	Tibial CSA	Tibial SA	Tibial LA
Age			
Pearson Correlation	.353*	.035	−.162
Sig. (2-tailed)	.002	.768	.173
N	72	72	72
Height			
Pearson Correlation	.045	−.052	.110
Sig. (2-tailed)	.707	.663	.357
N	72	72	72
Weight			
Pearson Correlation	.299†	.007	.177
Sig. (2-tailed)	.011	.956	.136
N	72	72	72
BMI			
Pearson Correlation	.374*	.055	.118
Sig. (2-tailed)	.001	.645	.323
N	72	72	72
Tibial CSA			
Pearson Correlation	1	.064	−.008
Sig. (2-tailed)		.595	.948
N	72	72	72
Tibial SA			
Pearson Correlation	.064	1	.093
Sig. (2-tailed)	.595		.437
N	72	72	72
Tibial LA			
Pearson Correlation	−.008	.093	1
Sig. (2-tailed)	.948	.437	
N	72	72	72

BMI = body mass index, CSA = cross sectional area, LA = long axis, SA = short axis, SD = standard deviation.

* Correlation is significant at the 0.01 level (2-tailed).

† Correlation is significant at the 0.05 level (2-tailed).

are faced when using SWE for assessment of the peripheral nerves. Nerve stiffness can vary substantially with different limb positions and different magnitudes in the lower limb.[19,20] Also repetitive compression of the nerve could occur due to close proximity to bone.[21] As described above, although LA SWE measurements are more appropriate and reproducible, however, examination in the LA SWE could be challenging in obese patients, and also in the brachial plexus.[22] This study has several limitations. Small sample size decreases the accuracy of elasticity measurements. In our study we measured the tibial nerve in the popliteal fossa explaining differences in the mean CSA measurements. Future studies on a large sample size, could help to increase the validity of measurements. These further studies should include studying the elasticity in patients with polyneuropathies and comparing them to the elasticity of the normal tibial nerve. We believe that in order to establish cut-off limits for discriminating normal healthy nerves from diseased ones, knowledge of the elasticity values is necessary. In conclusion, we believe that SWE of the tibial could be a useful future tool to aid in the studying change of the stiffness of the tibial nerve in different pathologies for diagnostic and therapeutic purposes.

Author contributions

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