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Quantitative shear wave elastography assessment of tibial nerve in diagnosis of diabetic peripheral neuropathy

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Abstract

Background: Diabetic peripheral neuropathy (DPN) is one of the most common complications of diabetes mellitus. Diagnosis of DPN is very important in the prognosis of disease and treatment as early treatment of DPN decreases both short-term and long-term morbidities. SWE elastography is a noninvasive and reproducible method for the precise evaluation of nerve stiffness.

Results: Tibial nerve stiffness is notably high at SWE in diabetic patients with DPN (mean shear wave elastography value of RT tibial SWE 75.3 ± 15.1 kPa) compared to patients without DPN (mean shear wave elastography value of RT tibial SWE 37.8 ± 11.6 kPa) and nerve stiffness in healthy control subjects (mean shear wave elastography value of RT tibial SWE 24.9 ± 6.3 kPa). There is a significant increase in the cross-sectional area (CSA) among diabetic patients with DPN (mean cross-sectional area of the right tibial nerve of 17 ± 1.9 mm^2) and without DPN (mean cross-sectional area of the right tibial nerve of 14.5 ± 3.8 mm^2) in comparison with control subjects (mean cross-sectional area of the right tibial nerve of 13.2 ± 3.1 mm^2) in the right side. Borderline significance of the CSA parameters of the tibial nerve study on the left side in different groups. The cutoff point to determine DPN among diabetic patients in the right lower limb is more than 63.8 kPa. With 89% sensitivity and 100% specificity in the detection of DPN on the right side, the SWE has 100% PPV and 95.5% NPV in the detection of DPN on the right side.

Conclusion: SWE is an effective assistant method in the diagnosis of DPN and is useful when a suspected neuropathy is not detectable by electrophysiology.

Keywords: Diabetic peripheral neuropathy, Ultrasound, Shear wave, Cross-sectional area

Background

Diabetic peripheral neuropathy (DPN) is considered currently the most common comorbidity of diabetes mellitus; its diagnosis mainly depends on the patient's symptoms and is confirmed by a nerve conduction study (NCS). Yet nerve conduction study is considered a complex method and has pitfalls and limitations and sometimes cannot be evoked in patients with advanced DPN and may be normal in patients with subclinical DPN [1, 2].

On B-mode ultrasound, the posterior tibial nerve exerts a slightly hyperechoic and heterogeneous echo compared to the adjacent muscles with small echogenic spots on the transverse axis [3, 4].

On the longitudinal axis, the posterior tibial nerve showed a heterogeneous road-like appearance, which consists of hyperechoic (myelin and connective tissue) and hypoechoic (nerve fibers). It looks like nearby tendons, but the echogenicity is slightly higher [5].

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The sonographic technique to reach the posterior tibial nerve is approximately along the cephalad border of the bony prominence of the medial malleolus and is closely related to the posterior tibial vessels. To prevent high branching of the nerve, the transverse US of the tibial nerve should be about 4 cm proximal to the cephalad border of the bony prominence of the medial malleolus [6].

High-resolution ultrasound has a good role in the diagnosis of DPN, which revealed increased cross-sectional area (CSA) of the tibial nerve [7].

Shear wave elastography (SWE) is a promising technique recently applied to different studies and many organs such as the breast, thyroid, and liver. It has a quantitative method to assess the stiffness of the tissue; the harder the tissue, the faster the shear wave travels. So the quantitative parameters of SWE could improve the diagnostic performance of US [8].

Using two-dimensional shear wave elastography (2D-SWE) to assess the tibial nerve stiffness revealed that the tibial nerve stiffness in diabetic patients with DPN is much higher than in diabetic patients without DPN as well as the healthy individuals [9].

So, SWE-based stiffness measurement of the tibial nerve can be used as another effective assistant method in the diagnosis of DPN; the study aims to evaluate the high-resolution sonographic cross-sectional area of the tibial nerve as well as the quantitative parameters of shear wave elastography in the diagnosis of DPN. Correlation between diabetic patients and control healthy persons determines the cutoff point of shear wave elastography value to determine DPN.

Methods

Fifty participants were included in the study from outpatient clinics and inpatient clinics during the period from September 2020 to March 2021 in the ultrasound and Doppler unit at the radiology department.

The study was designed as a case–control analytical observational study; we studied 30 cases with diabetes mellitus and 20 healthy adults served as a control group.

Patients included are the diabetic patients with no specific age-group and divided into two subgroups according to the clinical concern of diabetic peripheral neuropathy and electrodiagnostic studies (diabetics with peripheral neuropathy and diabetics without peripheral neuropathy). DPN was defined as a tibial motor nerve conduction velocity of more than 40 m/s as a gold standard.

Patients excluded were patients with other causes of peripheral neuropathy.

The study sample was divided into three groups: group A (which includes the diabetic patients with peripheral neuropathy), group B (which includes the diabetic patients without peripheral neuropathy), and group C (control persons).

Detailed history taking was obtained including duration of diabetes mellitus, type of treatment, and symptoms of diabetic peripheral neuropathy such as numbness, tingling, weakness, foot pain, or ataxia.

The referred physician was asked about the clinical examination and signs indicative of the presence or absence of peripheral symmetrical neuropathy (like abnormal knee/ankle reflexes, light touch examination, or test for vibration sensation).

Electrodiagnostic studies were performed by using conventional procedures. The routine nerve parameters recorded are the median, ulnar, peroneal, and tibial nerve motor distal latencies, compound muscle action potential amplitudes, and conduction velocities as well as the median, ulnar and sural sensory nerve amplitudes, distal latencies, and sensory conduction velocities for the upper and bilateral lower limbs.

Machine Ultrasound shear wave elastography and cross-sectional area of both posterior tibial nerves were done using Toshiba Aplio 500 with the linear probe of 7–14 MHz frequency.

Patient positioning All US examinations were performed while the patient is comfortable in the supine position on the examination table. Both ankles are slightly plantar-flexed and rotated externally with the rest of the lower limbs positioned in a neutral position. This position is fixed for all patients allowing proper comparison between different patients and limiting the bias like ankle movement that increased ankle soft tissue pressure. Patients were instructed not to move during the examination.

Cross section area measurements to reach the posterior tibial nerve is approximately along the cephalad border of the bony prominence of the medial malleolus and closely related to the posterior tibial vessels. To prevent high branching of the nerve, transverse US examination of the tibial nerve should be about 4 cm proximal to the cephalad border of the bony prominence of the medial malleolus.

Two sonographic measurements were performed for the cross-sectional area of the nerve, such as an indirect method that uses the ellipsoid formula and a direct one that uses a tracing cursor on the sonar machine. The indirect method formula is as follows: maximum diameter × minor diameter × π × 1/4 (square millimeters).

Shear wave elastography measurements Elastographic examinations were performed with the probe placed onto the skin surface with light contact using gel, keeping the sonar probe stationary during the examination of different acquisitions. The posterior tibial nerve is approximately along the cephalad border of the bony

prominence of the medial malleolus and is closely related to the posterior tibial vessels about 4 cm proximal to the upper border of the medial malleolus. Use the landmarks like tendons (flexor digitorum longus and flexor hallucis longus tendons) and vessels, namely posterior tibial vessels, to confirm the location of the nerve in the longitudinal plane.

Stiffness of the tibial nerve as evaluated with two-dimensional shear wave elastography (2D-SWE) and three different SWE elasticity indices ($E_{\text{-Mean,}}$ $E_{\text{-Min}}$, and E_{Max}) to diagnose DPN are obtained.

The measurements were obtained three times, and the average values are calculated; usually, there were not many differences in measurements of the same site.

Statistical analysis

The data were coded and entered using the software SPSS (Statistical Package for the Social Sciences) version 28. Data were summarized using frequency (count) and relative frequency (percentage) for categorical data. Standard diagnostic indices including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic efficacy were calculated. For comparing categorical data, the chi-square (χ^2) test was performed. An exact test was used instead of this method when frequency is needed to compare two independant percentages.

Comparisons between quantitative variables were made using the nonparametric Mann–Whitney test. For comparison of serial measurements within each patient, the nonparametric Wilcoxon signed-rank test was used [10]. For comparing categorical data, the chi-square (χ^2) test was performed. The exact test was used instead when the expected frequency is less than 5 [10]. *P* values less than 0.05 were considered statistically significant.

The receiver operating characteristic curve (ROC curve) was used to determine the best cutoff point, sensitivity, specificity, and area under the curve for shear wave elastography (SWE). The accuracy of the test depends on how well the test separates the group being tested into those with and without peripheral neuropathy. Accuracy is measured by the area under the ROC curve.

Results

There were 30 diabetic patients (19 females and 11 males) having a mean age of 52 years; the range of duration of diabetes is between 10 and 28 years and 20 healthy adults (11 females and 9 males) had a mean age of 40 years.

Calculated cross-sectional area (CSA) among those diabetics and controls showed a significant increase in the CSA among diabetic patients in comparison with healthy control subjects. There was a significant increase in both right and left posterior tibial nerve elasticity among diabetic patients in comparison with healthy control subjects (Table 1). There is no significant difference in the CSA or nerve elasticity in SWE between the right and the left posterior tibial nerves in either the diabetic or the control subjects.

SWE among those diabetics with PN (group A), without PN patients (group B), and controls (group C) revealed a significant increase in the posterior tibial nerve elasticity in diabetic patients with DPN in comparison with diabetic patients without DPN. Also, there is a significant increase in the posterior tibial nerve elasticity in diabetic patients with DPN in comparison with control subjects as well as a significant increase in the posterior tibial nerve elasticity in diabetic patients without DPN in comparison with control subjects (Table 2).

There is a significant increase in the CSA among diabetic patients with DPN and without DPN in comparison with control subjects on the right side with borderline significance on the left side (Table 2).

Table 1 Shear wave elastography (SWE) quantitative parameter (kilopascals) and cross-sectional area (CSA) in millimeter square among diabetic patients and control healthy persons

Factors	Diabetic patients Median (range)	Control healthy persons Median (range)	*P* value
Right posterior tibial SWE (kPa)	40.9(24.4–94.4)	23.4(15–35)	< 0.001
Left posterior tibial SWE	46.1(23.4–89.8)	25.8(16.4–36.2)	< 0.001
P value	0.616	0.589	
Factors	**Mean ± SD**	**Mean ± SD**	***P* value**
Right CSA (mm^2)	15.2 ± 3.5	13.2 ± 3.1	0.044
Left CSA (mm^2)	14.8 ± 3.1	12.9 ± 2.6	0.025
P value	0.524	0.497	

CSA cross-sectional area, *mm^2* millimeter square, *kPa* kilopascals, *SD* standard deviation, *SWE* shear wave elastography

Table 2 Shear wave elastography (SWE) quantitative parameter (kilopascals) and cross-sectional area (CSA) in millimeter square among those diabetics with peripheral neuropathy (DPN), diabetic without peripheral neuropathy (no DPN), and control persons

Factors	DPN (A) Mean ± SD	No DPN (B) Mean ± SD	Control (C) Mean ± SD	*P* value
Right posterior tibial SWE (kPa)	75.3 ± 15.1	37.8 ± 11.6	24.9 ± 6.3	< 0.001*
Left posterior tibial SWE	66.1 ± 16.8	38.6 ± 12.6	25.7 ± 6.9	< 0.001**
P value	0.242	0.603	0.589	
Factors	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	***P* value**
Right CSA (mm^2)	17 ± 1.9	14.5 ± 3.8	13.2 ± 3.1	0.020*
Left CSA (mm^2)	15.4 ± 3.9	14.5 ± 2.7	12.9 ± 2.6	0.085
P value	0.660	0.714	0.0.497	

CSA cross-sectional area, *DPN* diabetic peripheral neuropathy, mm^2 millimeter square, *kPa* kilopascals, *SD* standard deviation, *SWE* shear wave elastography

* *P* value is considred significant if ≤ 0.05

ROC curves (Fig. 1) to determine cutoff points of shear wave elastography value on the right and left tibial nerves to discriminate between diabetics with and without peripheral neuropathy revealed that the cutoff point to determine DPN among diabetic patients in the right lower limb is more than 63.8 kPa and in the left lower limb is more than 44.6 kPa. It has 89% sensitivity and 100% specificity with the SWE being 100% positive predictive value (PPV) and 95.5% negative predictive value (NPV) in the detection of DPN on the right side.

Discussion

Diabetes mellitus is one of the most serious healthcare chronic problems in the current century. Diabetic peripheral neuropathy (DPN) is the most common diabetic complication and the leading cause of disability and significantly lowers the quality of life and increases health costs associated with diabetes [2].

DPN diagnosis mainly depends on the patient's symptoms and is confirmed by a nerve conduction study (NCS) which is considered the most accurate method for the diagnosis; yet it showed some limitations like being relatively invasive, discomforting, and expensive [9].

High-resolution ultrasound in the neuromuscular application shows current expansion and provides information on nerve cross-sectional area (CSA), as well as its inner structure, and thus can reflect different degrees of DPN (Fig. 4) [11].

Shear wave elastography (SWE) is a promising technique that can reflect the state of nerve stiffness by assessing the velocity of shear wave propagation. The

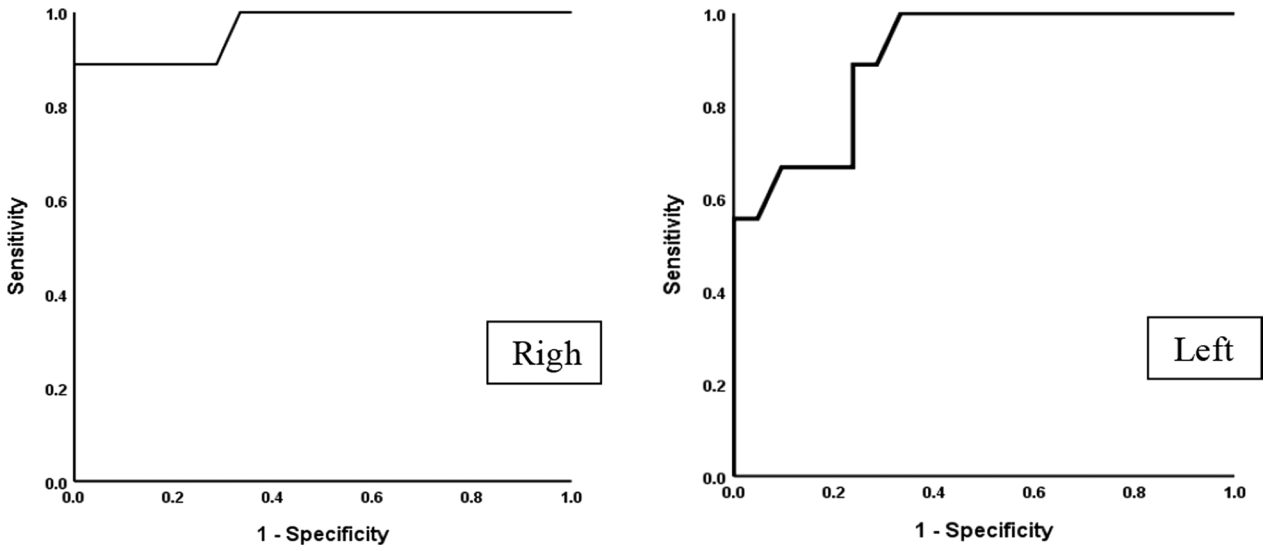

Fig. 1 ROC curve analysis to explore the discriminant ability of SWE to determine DPN in the right and left lower limbs

harder the tissue, the faster the shear wave travels. SWE may provide a more quantitative evaluation of tissue [11].

Determining the elasticity of the tibial nerve in diabetic patients could reveal early biomechanical changes that were likely caused by thickened fibrous sheaths of peripheral nerves, and might be a novel tool for characterizing diabetic neuropathy [12].

The study was carried out on 30 cases with diabetes mellitus having a mean age of 52 years, and 20 healthy adults had a mean age of 40 years.

The study found that there was a significant increase in the CSA among diabetic patients in comparison with healthy control subjects (Fig. 2). Also, there is a significant increase in the CSA among diabetic patients with DPN and without DPN in comparison with control

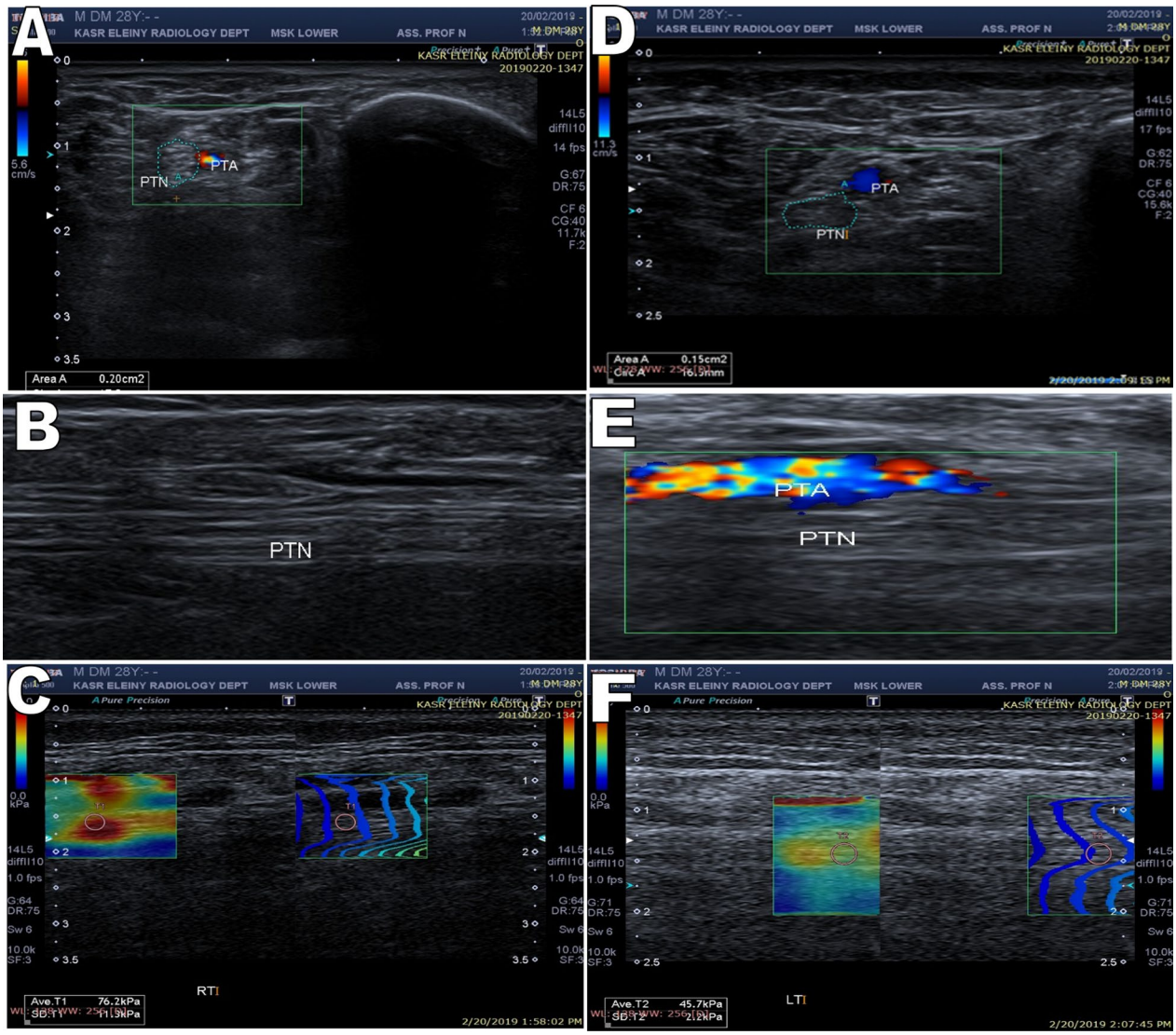

Fig. 2 A 63-year-old male patient diabetic for 28 years on insulin treatment with uncontrolled blood sugar and elevated Hb A1c, presented with bilateral lower limb numbness, tingling, and burning sensation as well as axonal neuropathy on nerve conduction study. High-resolution ultrasound **A** shows the right PTN in relation to the PTA with its CSA measuring 20 mm^2. **B** B-mode image shows the longitudinal axis of the right PTN. **C** The right image is the B-mode, and the left image measures the elasticity of the PTN (76.2 kPa) with a color-coded box, circular ROI (T1) for quantitative measurements and a color code scale at the top side of the image. **D** demonstrates the left PTN in relation to the PTA with its CSA measuring 15 mm^2. **E** B-mode image shows the longitudinal axis of the left PTN. **F** The elasticity of the PTN (45.7 kPa) with a color-coded box, circular ROI (T2) for quantitative measurements, and a color code scale at the top side of the image. There is an increase in the CSA and stiffness of both posterior tibial nerves

subjects on the right side with borderline significance on the left side. This matched Dikici et al. [6] and He et al. [11] studies.

Unlikely, He et al. [11] showed that regarding the tibial nerve CSA, the DM group was not significantly different from the control group, but he found, like our study, that it was significantly different from the DPN group.

There is a significant increase in the CSA among diabetic patients with DPN in comparison with control subjects on the right side ($P < 0.016$) matching the Ishibashi et al. [12] study which also noticed that the CSA became larger in proportion to the severity of neuropathy and Kang et al. [13] study that correlates the CSA of sural nerve with HbA_{1c} levels.

The study revealed that there is a significant increase in both the right and the left posterior tibial nerves elasticity in diabetic patients with DPN in comparison with diabetic patients without DPN and healthy control subjects ($P < 0.05$) and there is a significant increase in

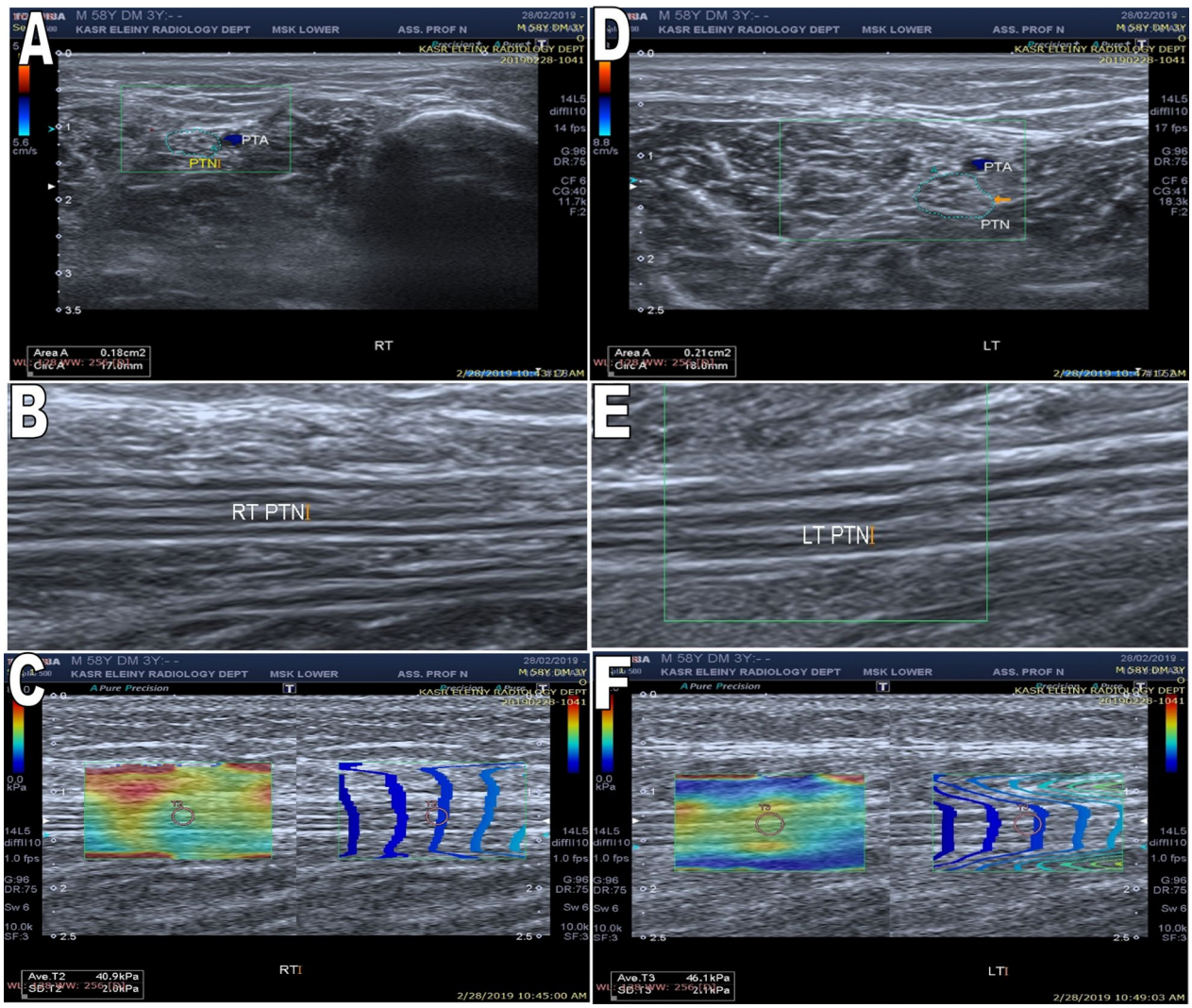

Fig. 3 A 58-year-old male patient diabetic for 2 years controlled on oral anti-glycemic drugs, with no signs or symptoms of DPN with normal nerve conduction study. **A** The right PTN in relation to the PTA with its CSA measuring 18 mm^2. **B** B-mode image shows the longitudinal axis of the right PTN. **C** The right image is the B-mode, the left image measures the elasticity of the PTN (40.9 kPa) with a color-coded box, circular ROI (T2) for quantitative measurements, and a color code scale at the top side of the image. **D** The left PTN in relation to the PTA with its CSA measuring 21 mm^2. **E** B-mode image shows the longitudinal axis of the left PTN. **F** The right image is the B-mode, the left image measures the elasticity of the PTN (46.1 kPa) with a color-coded box, circular ROI (T3) for quantitative measurements, and a color code scale at the top side of the image. There is a mild increase in the CSA and nerve stiffness of both tibial nerves; however, the patient has no clinical or neuro-electrical signs of DPN denoting that SWE can estimate the state of the neuropathy even whenever ever it is still subclinical

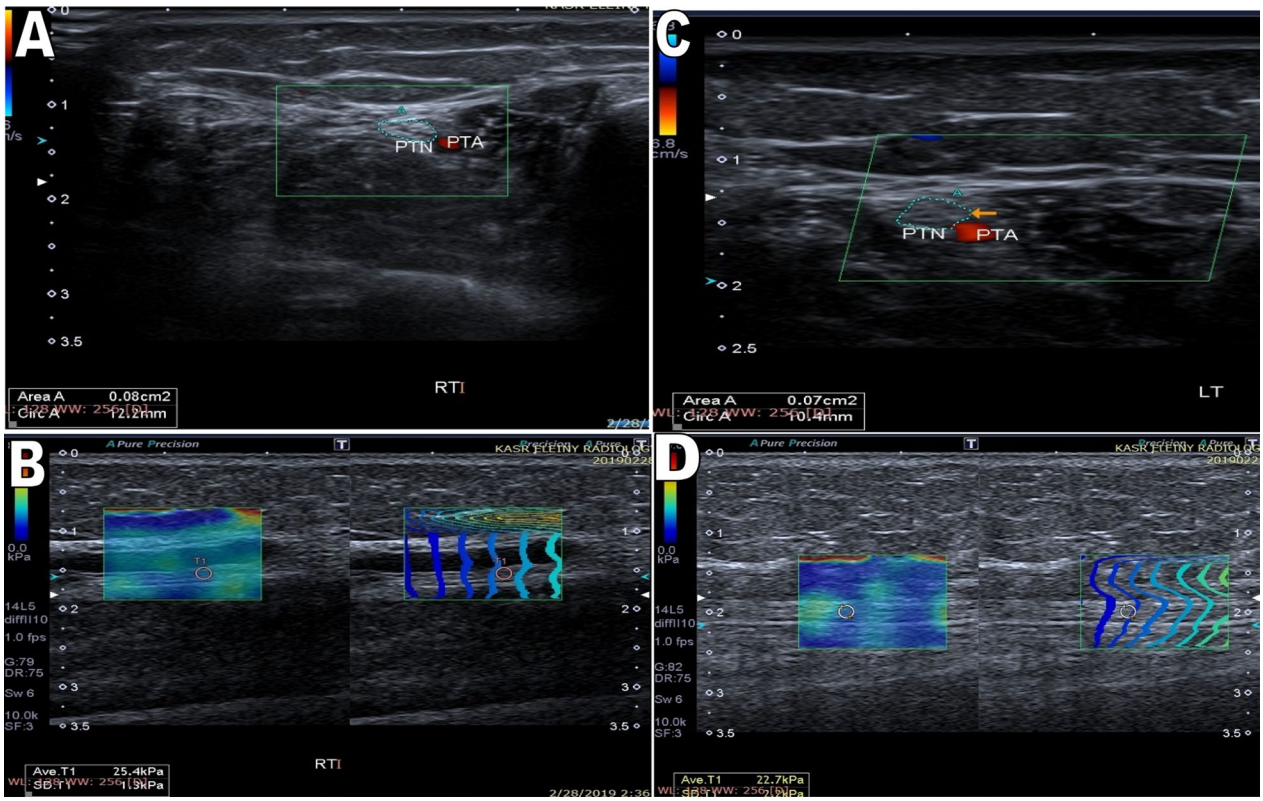

Fig. 4 A 30-year-old female patient not diabetic and not complaining of any chronic disease with normal nerve conductive study. **A** The right PTN in relation to the PTA with its CSA measuring 8 mm^2. **B** The right image is the B-mode, and the left image measures the elasticity of the PTN (25.4 kPa) with a color-coded box, circular ROI (T1) for quantitative measurements and a color code scale at the top side of the image. **C** The right PTN in relation to the PTA with its CSA measuring 7 mm^2. **D** The right image is the B-mode, the left image measures the elasticity of the PTN (22.7 kPa) with a color-coded box, circular ROI for quantitative measurements, and a color code scale at the top side of the image. Normal CSA and nerve stiffness matching the clinical and nerve conduction study

both the right and left posterior tibial nerves elasticity in diabetic patients without DPN in comparison with control subjects (Fig. 3). This is in accordance with Dikici et al. [6] and He et al. [11] studies (Fig. 4).

It also showed that there is no significant difference in posterior tibial nerve elasticity between the right and left limb in either patients with DPN, without DPN, or control subjects [11].

Jiang et al. [9] found that the $E_{\text{-Mean}}$, $E_{\text{-Min}}$, and E_{Max} of the tibial nerve were significantly larger in patients in diabetic patients with DPN than those in diabetic patients without DPN and normal control persons. As regards the nerve stiffness, there is no significant statistical difference between diabetics without DPN and control persons. Also, there is no significant difference between the stiffness of right and left tibial nerves among diabetics with and without DPN and control persons.

Ishibashi et al. [12] found that the elasticity of the tibial nerve in patients without neuropathy was reduced compared with control participants and decreased further after developing the neuropathy.

In the current study, we found that the cutoff point to determine DPN among diabetic patients in the right lower limb is more than 63.8 kPa and that the SWE has 89% sensitivity and 100% specificity in the detection of DPN on the right side [6]. The AUC has 95% CI of 0.90–0.99 on the right side and 95% CI of 0.79–0.99 on the left side [11].

Study limitations

There is no specific age-group, especially in the control group, yet it seems not to affect the study results. The CSA is calculated by the indirect method using the formula which could be relatively subjective.

Conclusion

Based on our results, tibial nerve stiffness is significantly increased at share wave elastography in diabetics who had clinical signs and electrophysiological study diagnosis of neuropathy. Patients without neuropathy also had significantly higher nerve stiffness compared to healthy control subjects. This finding might suggest the presence of subclinical neuropathy.

Diabetic patients with DPN and without DPN have a significant increase in CSA of the tibial nerve compared to control subjects on the right side with borderline significance on the left side.

The outcome conclusion suggests that SWE-based stiffness with quantitative assessment for the tibial nerve was relatively better than CSA and considered an effective method helping in the diagnosis of DPN, as well as early prediction of neuropathy in subclinical cases not detected by electrophysiology.

Abbreviations

AUC: Area under the curve; B-mode: Brightness mode; CI: Confidence interval; CMAP: Compound muscle action potential; CSA: Cross-sectional area; DM: Diabetes mellitus; DPN: Diabetic peripheral neuropathy; EMG: Electromyography; kPa: Kilo Pascal; NCS: Nerve conduction study; NCV: Nerve conduction velocity; NPV: Negative predictive value; PPV: Positive predictive value; PSSD: Pressure-specified sensory device; PTN: Posterior tibial nerve; ROI: Region of interest; SD: Standard deviation; SPN: Superficial peroneal nerve; SPSS: Statistical Package for Social Science; SWE: Shear wave elastography; TCNS: Toronto clinical neuropathy score; TN: Tibial nerve; TTS: Tarsal tunnel syndrome; US: Ultrasound; V: Vein.

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Author contributions

AAH and MMS put the idea of the study, edited the manuscript, and participated in the study design. HRN participated in the study design and performed the statistical analysis. ROK and ASK were involved in patients collection and clinical assessment. All authors read and approved the final manuscript.

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Availability of data and materials

All the datasets used and analyzed in this study are available with the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Written informed consent was signed by all patients before the examination. The study was approved by the research committee of faculty of medicine, Kasr Alainy Hospital, Cairo University 2020. No reference number is provided as the committee just say yes or no according to the system in our faculty of medicine at 2020 (date of starting of this research).

Consent for publication

All patients included in this research were fully conscious and gave written informed consent to publish the data contained within this study.

Competing interests

The authors declare that they have no competing interests.

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References

1. Ohana M, Moser T, Moussaouï A, Kremer S, Carlier RY, Liverneaux P et al (2014) Current and future imaging of the peripheral nervous system. Diagn Interv Imaging 95(1):17–26
2. Juster-Switlyk K, Smith AG (2016) Updates in diabetic peripheral neuropathy. F1000Research. 5
3. Watanabe T, Ito H, Sekine A, Katano Y, Nishimura T, Kato Y et al (2010) Sonographic evaluation of the peripheral nerve in diabetic patients. J Ultrasound Med 29(5):697–708
4. Lawande AD, Warrier SS, Joshi MS (2014) Role of ultrasound in the evaluation of peripheral nerves. Indian J Radiol Imaging 24(3):254
5. Aslan A, Aktan A, Aslan M, Gülseren Y, Kabaalioğlu A (2018) Shear wave and strain elastographic features of the brachial plexus in healthy adults: reliability of the findings—a pilot study. J Ultrasound Med 37(10):2353–2362
6. Dikici AS, Ustabasioglu FE, Delil S, Nalbantoglu M, Korkmaz B, Bakan S et al (2017) Evaluation of the tibial nerve with shear-wave elastography: a potential sonographic method for the diagnosis of diabetic peripheral neuropathy. Radiology 282(2):494–501
7. Brown MN, Pearce BS, Karl HW, Trescot AM (2016) Distal saphenous nerve entrapment. Peripheral Nerve Entrapments Clin Diagnosis Manag 1:645–654
8. Singh K, Gupta K, Kaur S (2017) High-resolution ultrasonography of the tibial nerve in diabetic peripheral neuropathy. J Ultrason 17(71):246
9. Jiang W, Huang S, Teng H, Wang P, Wu M, Zhou X et al (2019) Diagnostic performance of two-dimensional shear wave elastography for evaluating tibial nerve stiffness in patients with diabetic peripheral neuropathy. Eur Radiol 29(5):2167–2174
10. Chan YH (2003) Biostatistics 102: quantitative data-parametric & non-parametric tests. Singap Med J 44(8):391–396
11. He Y, Xiang X, Zhu BH, Qiu L (2019) Shear wave elastography evaluation of the median and tibial nerve in diabetic peripheral neuropathy. Quant Imaging Med Surg 9(2):273–282
12. Ishibashi F, Taniguchi M, Kojima R, Kawasaki A, Kosaka A, Uetake H (2016) Elasticity of the tibial nerve assessed by sonoelastography was reduced before the development of neuropathy and further deterioration associated with the severity of neuropathy in patients with type 2 diabetes. J Diabetes Investig 7(3):404–412
13. Kang S, Kim SH, Yang SN, Yoon JS (2016) Sonographic features of peripheral nerves at multiple sites in patients with diabetic polyneuropathy. J Diabetes Complicat 30(3):518–523

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