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Diagnostic Value of Shear Wave Elastography Combined with the Toronto Clinical Scoring System in Detecting Diabetic Peripheral Neuropathy

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Abstract

Background: Diabetic peripheral neuropathy (DPN) is a common microvascular complication of type 2 diabetes mellitus (T2DM) and a leading cause of foot morbidity. Nerve conduction studies (NCS) remain the reference standard but are time-consuming and assess predominantly large fibers. Shear wave elastography (SWE) enables non-invasive quantitative assessment of nerve stiffness. This study evaluated the diagnostic performance of tibial nerve SWE alone and in combination with the Toronto Clinical Scoring System (TCSS) in detecting DPN.

Methods: In this prospective observational study, 60 patients with T2DM were enrolled over one year. Participants were categorized into DPN and non-DPN groups based on NCS findings. All subjects underwent TCSS evaluation, conventional ultrasonography for tibial nerve cross-sectional area (CSA), and SWE to obtain Emean, Emin, and Emax values bilaterally. Group comparisons, correlation analysis, and receiver operating characteristic (ROC) analysis were performed.

Results: Tibial nerve stiffness parameters were significantly higher in the DPN group compared to the non-DPN group ($p < 0.01$). Mean right tibial nerve stiffness (Emean RT) demonstrated excellent diagnostic performance (AUC = 0.932; 95% CI: 0.872–0.993). SWE parameters showed strong positive correlation with TCSS scores ($r \approx 0.79$, $p < 0.01$). Combining SWE with TCSS improved diagnostic sensitivity and specificity compared with either modality alone.

Conclusion: Tibial nerve SWE is a reliable non-invasive imaging biomarker for DPN. When combined with TCSS, diagnostic accuracy improves significantly. SWE may serve as a practical adjunct screening tool in patients with T2DM.

Keywords: Diabetic peripheral neuropathy; Shear wave elastography; Tibial nerve; Toronto Clinical Scoring System; Type 2 diabetes mellitus

Introduction

Diabetes mellitus is a major global health concern, with rapidly rising prevalence worldwide[1]. Diabetic peripheral neuropathy (DPN) is one of the most common chronic complications, affecting nearly half of patients with long-standing type 2 diabetes mellitus (T2DM)[2]. DPN significantly increases the risk of foot ulceration, infection, and lower limb amputation[3].

Early diagnosis of DPN is essential to prevent irreversible complications. Nerve conduction studies (NCS) are considered the reference standard for diagnosis[4]. However, NCS are time-consuming, uncomfortable for patients, and primarily assess large myelinated fibers[5]. Subclinical neuropathy and small-fiber involvement may not be adequately detected in early stages[6].

Ultrasonography has emerged as a useful adjunct tool in peripheral nerve assessment[7]. Shear wave elastography (SWE) is an advanced ultrasound technique that quantitatively measures tissue stiffness based on shear wave propagation velocity[8]. In diabetic neuropathy, structural changes such as axonal degeneration, fibrosis, and endoneurial thickening may increase nerve stiffness[9].

Recent studies have demonstrated increased tibial nerve stiffness in patients with DPN[10],[11]. The Toronto Clinical Scoring System (TCSS) is a validated clinical tool for grading neuropathy severity[12]. However, it remains subjective and examiner-dependent.

This study aimed to evaluate tibial nerve stiffness using SWE in T2DM patients, assess its correlation with TCSS, determine its diagnostic accuracy, and evaluate whether combining SWE with TCSS improves detection of DPN.

Materials and Methods

Study Design and Population

This prospective observational study was conducted over one year in a tertiary care center. Sixty patients diagnosed with T2DM were enrolled after obtaining institutional ethics approval and informed consent.

Inclusion Criteria

· Age 20–65 years
· HbA1c ≥ 6.5%
· Fasting blood glucose ≥ 126 mg/dL or random blood glucose ≥ 200 mg/dL

Exclusion Criteria

· Type 1 diabetes mellitus
· Neuropathy of other etiologies
· Prior ankle/leg surgery or trauma
· Refusal to participate

Participants were divided into:
· **DPN group** (confirmed by NCS)
· **Non-DPN group**

NCS was performed according to established diagnostic criteria[4].

Clinical Assessment

All patients were evaluated using TCSS, which includes symptom score, reflex assessment, and sensory testing. Scores were categorized as[12]:
· 0–5: No neuropathy
· 6–8: Mild
· 9–11: Moderate
· ≥12: Severe

Ultrasonography and Shear Wave Elastography

A high-frequency linear transducer (4–15 MHz) was used. The tibial nerve was evaluated bilaterally at the level of the medial malleolus.
· Cross-sectional area (CSA) was measured by tracing inside the hyperechoic epineurial rim[13].
· SWE was performed with minimal transducer pressure.
· Quantitative parameters recorded:
o Emean
o Emin
o Emax

Three measurements were obtained and averaged.

Statistical Analysis

Data were analyzed using SPSS version 22. Continuous variables were expressed as mean ± SD. Independent t-test was used for group comparison. Pearson correlation analysis assessed association between SWE parameters and TCSS. ROC curve analysis determined diagnostic accuracy. A p-value < 0.05 was considered statistically significant.

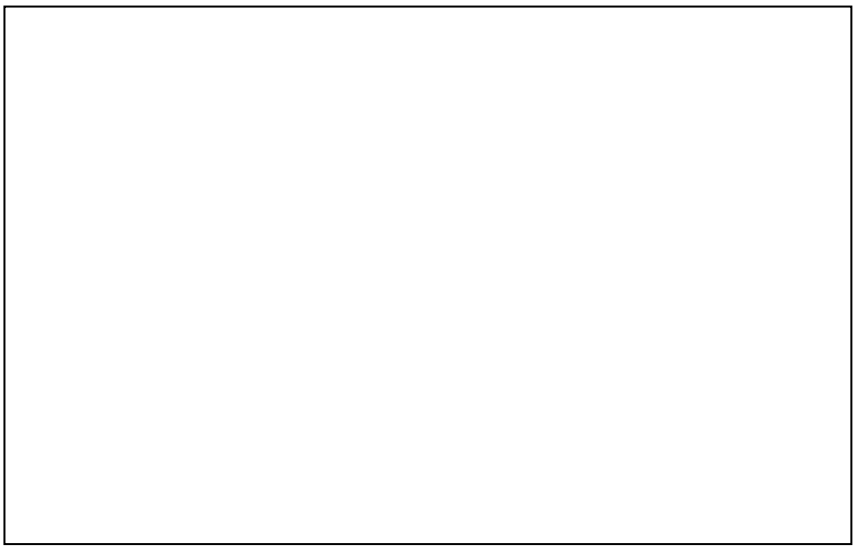
Results

Baseline Characteristics

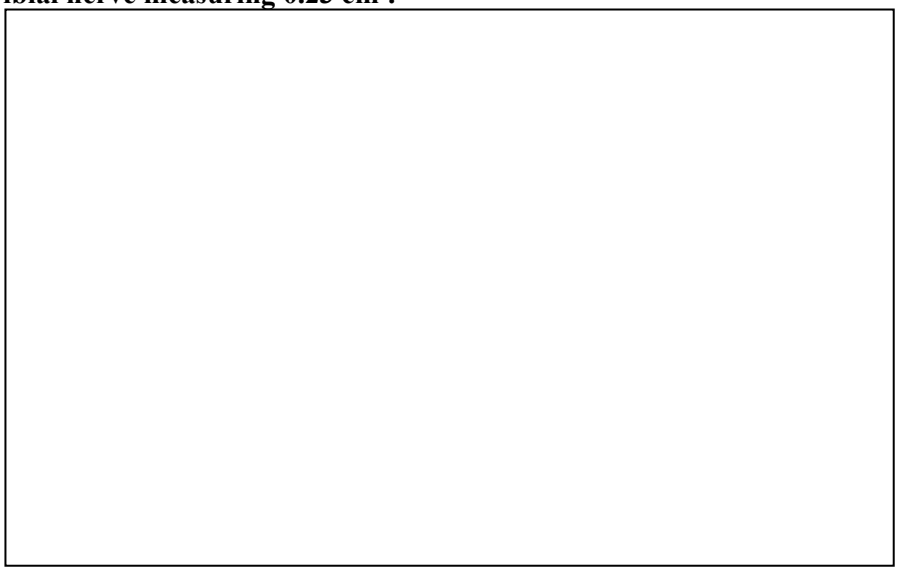
The mean age was 48.05 ± 9.43 years. HbA1c levels were significantly higher in the DPN group ($p = 0.03$). No significant differences were observed in BMI, duration of diabetes, fasting glucose, or LDL levels.

Tibial Nerve Cross-Sectional Area

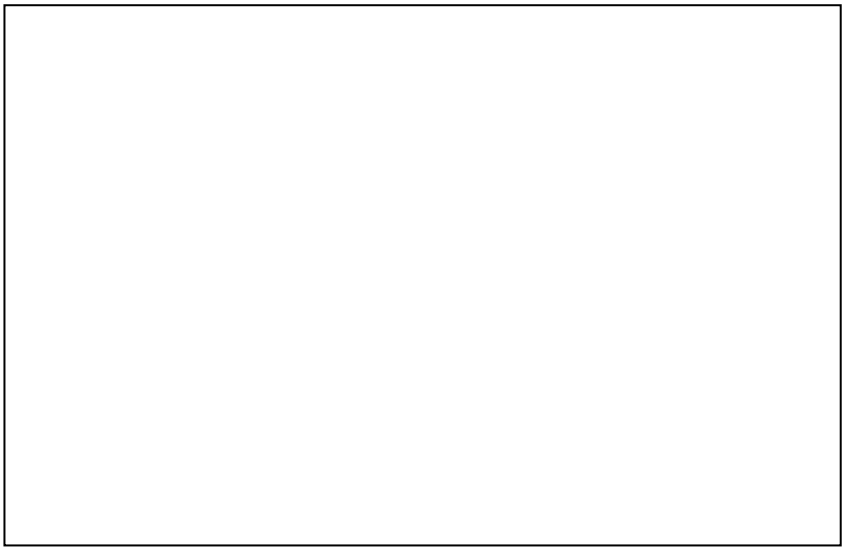
Right tibial nerve CSA was significantly higher in the DPN group ($p = 0.02$), whereas left CSA did not reach statistical significance.



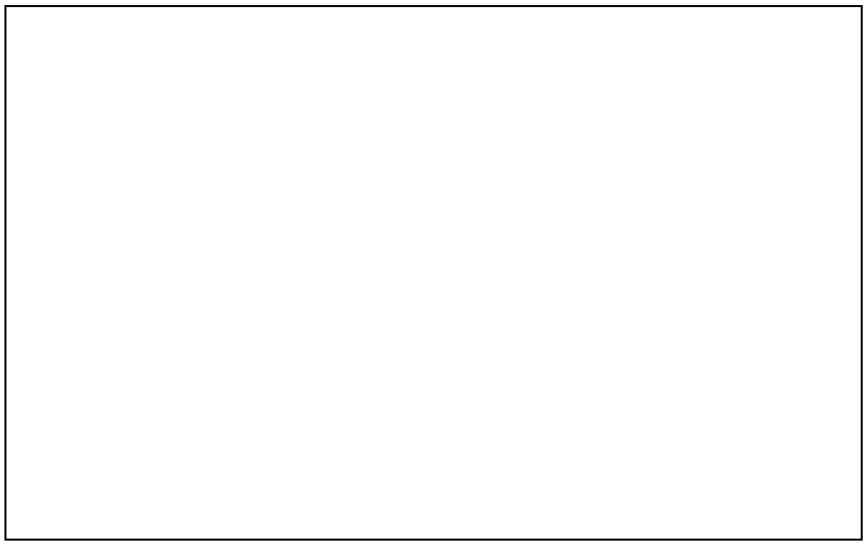
CSA of Right Tibial nerve measuring 0.23 cm².



SWE measurements of Right Tibial nerve shows increased stiffness E Mean (86.92 kpa) and Emax (114.82kpa).



CSA of Right Tibial nerve measuring 0.04 cm².



SWE measurements of Right Tibial nerve shows normal stiffness Emin (18.49 Kpa), E Mean (27.08 kpa) and E Max(33.07 kpa).

SWE Findings
All SWE parameters (Emean, Emin, Emax) were significantly elevated in the DPN group bilaterally ($p < 0.01$). The most discriminative parameter was Emean of the right tibial nerve.

Correlation Analysis
SWE parameters showed strong positive correlation with TCSS:
· Emean RT vs TCSS: $r = 0.791$ ($p < 0.01$)
· Emean LT vs TCSS: $r = 0.795$ ($p < 0.01$)

Diagnostic Accuracy
ROC analysis demonstrated excellent diagnostic performance:
· Emean RT AUC = 0.932 (95% CI: 0.872–0.993)
Combining SWE parameters with TCSS improved sensitivity and specificity compared with either modality alone.

Discussion
This study demonstrates that tibial nerve stiffness measured by SWE is significantly increased in patients with DPN. These findings are consistent with previous studies reporting increased tibial nerve stiffness in diabetic neuropathy[10],[11].
The high AUC (0.932) observed in our study indicates excellent diagnostic performance. Meta-analytic evidence supports the diagnostic utility of SWE in DPN[14]. Unlike CSA measurements, which reflect structural enlargement, SWE directly assesses mechanical properties of the nerve and showed stronger correlation with TCSS severity.
The strong correlation between SWE and TCSS suggests that nerve stiffness may reflect clinical neuropathy severity. Combining imaging biomarkers with clinical scoring enhances diagnostic confidence.
Clinically, SWE may serve as:
· A non-invasive screening tool in diabetic clinics
· An adjunct in settings where NCS is unavailable
· A potential monitoring tool for neuropathy progression

Limitations
· Single-center study
· Moderate sample size
· Lack of longitudinal follow-up
· Absence of small-fiber specific testing

Conclusion

Tibial nerve stiffness assessed by shear wave elastography is significantly elevated in diabetic peripheral neuropathy and demonstrates excellent diagnostic accuracy. Strong correlation with TCSS supports its clinical relevance. Combining SWE with TCSS enhances diagnostic performance and may serve as a valuable non-invasive screening strategy in patients with type 2 diabetes mellitus.

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