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The role of medial plantar nerve conduction studies in the diagnosis of diabetic polyneuropathy: A comparative analysis with sural nerve

Gülçin Koç Yamanyar[1], Hüsniye Aslan[2]

[1]Department of Neurology, Bursa City Hospital, Bursa, Türkiye; [2]Department of Neurology, Health Sciences University, Istanbul Training and Research Hospital, İstanbul, Türkiye

ABSTRACT

Objectives: Diabetic neuropathy, significantly impacts patients' quality of life and may lead to severe morbidity in the long term. Early detection of diabetic neuropathy is crucial in preventing or delaying irreversible damage. In this study, we aimed to evaluate the role of medial plantar nerve conduction studies in the early diagnosis of diabetic polyneuropathy and to determine which of the examined nerve conduction studies demonstrates higher sensitivity.

Methods: Sixty patients with suspected diabetic polyneuropathy and 30 healthy controls were included. Diabetic neuropathy symptoms were assessed using the Diabetic Neuropathy Symptom (DNS) score. Sensory and motor nerve conduction studies, including median, ulnar, posterior tibial, medial plantar, and sural nerves, were performed.

Results: Sensory response amplitudes of both medial plantar and sural nerves were significantly lower in patients compared to controls. Abnormal sensory responses were detected in 23 (38.33%) patients for the sural nerve and 39 (65%) for the medial plantar nerve.

Conclusions: Both nerve conduction studies are valuable in diagnosing diabetic polyneuropathy, but medial plantar nerve conduction studies demonstrated higher sensitivity. Including medial plantar nerve assessments in routine evaluations may improve diagnostic accuracy.

Keywords: Diabetic polyneuropathy, medial plantar nerve, sural nerve

Diabetic neuropathy, a common and chronic complication of Diabetes Mellitus (DM), can significantly impact patients' quality of life and lead to serious long-term morbidity. Detecting diabetic neuropathy at an early stage is crucial to prevent or delay irreversible damage [1].

Patients with diabetic neuropathy may experience dysesthetic and paresthetic symptoms, along with sensory, motor, and autonomic deficits. Beyond clinical symptoms and findings, electrophysiological studies play a key role in diagnosing diabetic neuropathy. In polyneuropathy (PNP), sensory nerves in the feet are frequently affected in the early stages [2, 3].

However, routine nerve conduction studies, which assess the sural and superficial peroneal nerves, do not effectively evaluate the distal regions of the foot [4].

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Corresponding author: Gülçin Koç Yamanyar, MD., Phone: +90 224 975 00 00, E-mail: dr.gulcinkoc@hotmail.com

Since the medial plantar nerve is one of the most distally located nerves in the foot, it may be affected in the early stages of PNP. In studies comparing medial plantar and sural nerve conduction studies, it has been shown that in some patients clinically suspected of neuropathy, sural nerve conduction findings may remain within normal limits, while medial plantar sensory response amplitudes are reduced or unrecordable during electrophysiological assessment. These findings highlight that medial plantar nerve conduction studies may represent a more sensitive method for the electrophysiological diagnosis of neuropathy [5, 6].

In this study, we aimed to evaluate the role of medial plantar nerve conduction studies in the early diagnosis of diabetic PNP in patients with clinically suspected diabetic PNP and to determine which of the examined nerve conduction studies—sural or medial plantar—demonstrates higher sensitivity.

METHODS

Between September and November 2011, a total of 60 patients who visited the Neurology outpatient clinics at Istanbul Training and Research Hospital and were referred to the Electrophysiology Laboratory with a suspected diagnosis of diabetic PNP were included in the study. The control group consisted of 30 healthy volunteers with no history of diabetes or neuropathic symptoms. Ethical approval for the study was obtained from the Medical Resaerch Ethics Committee of Istanbul Training and Research Hospital upon its dated June 15th, 2012, No: 148. Informed consent forms were obtained from all patients and healthy volunteers.

The study included patients aged 18 to 70 who had been clinically diagnosed with diabetes for at least six months and had a diabetic neuropathy symptom score of 1 or higher. Those with conditions, medications, or substance use that could cause neuropathy as well as pregnant women and individuals with entrapment neuropathy, were excluded.

Evaluation of Cases

Clinical assessment tests, patient history, physical examination findings, age, gender, disease duration, and medications used were recorded.

Patient symptoms were evaluated using the Diabetic Neuropathy Symptom (DNS) Score, a four-variable symptom scoring system. Each symptom is assigned one point, and a score of one or higher is considered indicative of diabetic PNP [7].

The control group consisted of healthy volunteers with no history of diabetes, neuropathic symptoms, medication use, or exposure to toxic substances. Their

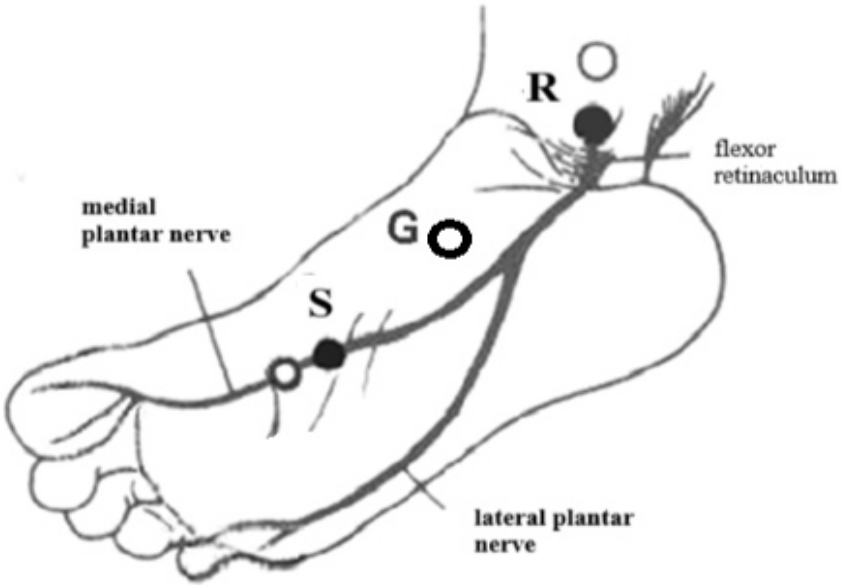

Fig. 1. Medial plantar nerve conduction technique (S=stimulating electrode, R=recording electrode, G=ground electrode (*Adapted with modifications from: Oh SJ. Clinical Electromyography: Nerve Conduction Studies. 2nd ed. Baltimore: Williams & Wilkins; 1993; p. 245.* [8]).

neurological examinations were completely normal. The control group underwent the same nerve conduction studies as the patient group.

Nerve Conduction Studies

Electrophysiological examinations were performed using a Dantec Keypoint Portable EMG device. Throughout the nerve conduction studies, the room temperature was maintained between 22-24°C. Before the examination, the skin was cleansed with alcohol in all cases to minimize skin resistance. Bipolar surface and ring electrodes were used for stimulation and recording during the nerve conduction studies.

In both the patient and control groups, motor and sensory responses of the median and ulnar nerves, posterior tibial motor response, and bilateral medial plantar and sural sensory responses were recorded. The orthodromic method was preferred for sensory nerve conduction studies.

For medial plantar nerve conduction studies, the recording electrode was placed over the flexor retinaculum, while the stimulation electrode was positioned medially on the sole of the foot, between the metatarsal bones. The nerve was stimulated at this site, and responses were recorded over the flexor retinaculum. Distal latency, amplitude, and conduction velocity of the nerve were measured (Fig. 1).

For sural nerve conduction studies, the recording electrode was placed behind the lateral malleolus. The nerve was stimulated 12-15 cm proximally, and responses were recorded. Distal latency, amplitude, and conduction velocity of the nerve were measured (Fig. 2).

Statistical Analysis

Statistical analyses were conducted using the NCSS 2007 & PASS 2008 Statistical Software. In addition to descriptive statistical methods (mean, standard deviation, median, frequency, and ratio), different tests were applied based on the data distribution. For normally distributed parameters, one-way ANOVA was used for comparisons between groups, and Tukey HSD was applied to identify the source of significant differences. For non-normally distributed parameters, Kruskal-Wallis test was used for group comparisons, and Mann-Whitney U test was applied to determine which group caused the difference. For categorical variables, the Yates-corrected Chi-square test was used. A P-value <0.05 was considered statistically significant.

RESULTS

The average age of the patients in the study group was 54.25±8.53 years, while it was 52.93±8.09 years in the control group. There was no significant difference between the two groups in terms of age and gender. Among the patients in the study group, 30% (n=18)

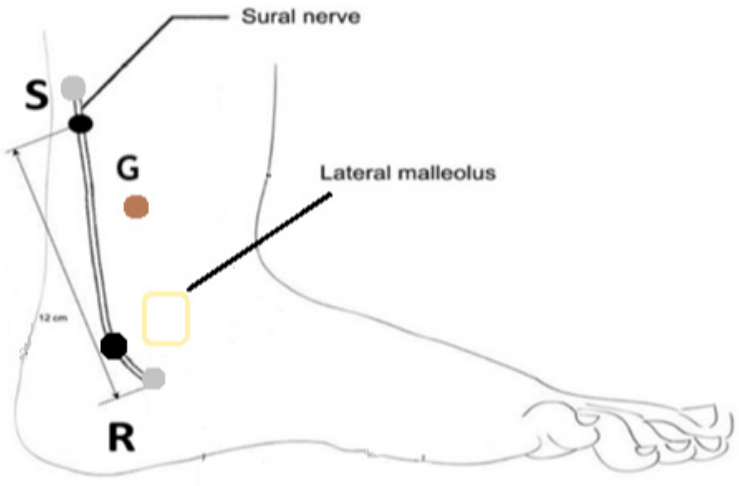

Fig. 2. Sural nerve conduction technique (S=stimulating electrode, R=recording electrode, G=ground electrode) (*Adapted with modifications from: Ricciardi D, Galiero R, Todisco V, et al. Neurophysiological assessment of peripheral neuropathy through whole plantar nerve conduction in type 2 diabetes mellitus and healthy control subjects. Metab Target Organ Damage. 2024;4:24. doi:10.20517/mtod.2024.20.* [9]).

Table 1. Demographic and clinical characteristics of participants

	Patient group (n=60)	Control group (n=30)	P value
Age (years)	54.25±8.53	52.93±8.09	0.484
Sex			
Male	24 (40%)	12 (40%)	
Female	36 (60%)	18 (60%)	
Duration of DM (years)			
<5	18 (30%)		
5-9	14 (23.30%)		
≥10	28 (46.70%)		

Data are shown as mean±standard deviation or n (%). DM=Diabetes Mellitus.
Student t Test, [a]Yates test

had been living with diabetes for less than 5 years, 23.3% (n=14) for 5-9 years, and 46.7% (n=28) for 10 years or more (Table 1).

In sural nerve conduction studies, sensory nerve action potentials could not be recorded in 9 patients. In patients with measurable sural responses, sural nerve distal latency was found to be significantly longer compared to the control group (P<0.01). Additionally, there was a notable decrease in sural nerve sensory response amplitude and conduction velocity (P<0.01) (Table 2).

In medial plantar nerve conduction studies, sensory nerve action potentials could not be recorded in 35 patients. In the 25 patients for whom medial plantar nerve sensory action potentials could be recorded, sensory nerve amplitudes were found to be significantly lower compared to the control group. (P<0.01). However, no significant difference was found in conduction velocity and distal latency measurements (Table 3).

In the nerve conduction studies conducted on healthy controls, bilateral sural nerve and medial plantar sensory responses were successfully recorded in all individuals.

Among the 60 patients in the study group, 23

Table 2. Results of sural nerve conduction studies

Sural nerve	Patient group (n=60)	Control group (n=30)	P value
Right			
Latency (msec)	2.33±0.49	2.03±0.28	**0.001****
Amplitude (µV) (median)	11.56±6.81 (11)	18.13±6.40 (16)	**0.001[a],****
Velocity (m/s)	53.27±7.95	60.15±5.55	**0.001****
Left			
Latency (msec)	2.27±0.41	2.09±0.28	**0.034***
Amplitude (µV) (median)	10.68±5.77 (11)	16.90±5.61 (14.5)	**0.00[a],****
Velocity (m/s)	53.44±7.56	59.52±4.27	**0.001****
Number of no response	9	0	

Data are shown as mean±standard deviation or median
Student-t test, [a]Mann Whitney U Test, *P<0.05, **P<0.01

Table 3. Results of medial plantar nerve conduction studies

Medial plantar nerve	Patient group (n=60)	Control group (n=30)	P value
Right			
Latency (msec)	2.08±0.37	2.16±0.35	0.451
Amplitude (µV) (median)	3.45±1.27 (3.50)	11.09±6.10 (8.25)	0.001[a,]**
Velocity (m/s)	60.08±6.26	58.72±6.95	0.456
Left			
Latency (msec)	2.03±0.33	2.05±0.28	0.754
Amplitude (µV) (median)	3.37±1.27 (3.00)	10.71±5.02 (8.70)	0.001[a,]**
Velocity (m/s)	59.88±6.40	59.87±6.51	0.996
Number of no response	35	0	

Data are shown as mean±standard deviation or median
Student-t test, [a]Mann Whitney U Test, *P<0.05, **P<0.01

(38.33%) had abnormal sural nerve sensory responses, while 39 (65%) had abnormal medial plantar nerve sensory responses (Table 4).

When comparing diabetes duration with nerve conduction findings, a statistically significant relationship was found between diabetes duration and motor and sensory responses of the median nerve, as well as motor responses of the posterior tibial nerve.

However, no significant correlation was found between sural and medial plantar sensory responses and disease duration.

DISCUSSION

In this study, we aimed to investigate the role of medial plantar nerve sensory conduction studies in the early detection of diabetic PNP by comparing sural nerve and medial plantar nerve sensory conduction measurements in patients clinically suspected of having diabetic PNP.

We found that the amplitudes of both the medial plantar and sural nerves were significantly lower in diabetic patients compared to healthy controls. While sural responses were absent in 9 patients, medial plantar sensory responses could not be recorded in 35 patients. In contrast, all healthy controls exhibited normal sensory responses in both the sural and medial plantar nerves.

A study by An *et al*. [8] reported that medial plantar nerve sensory response amplitudes and conduction velocities were significantly lower in diabetic patients compared to healthy controls [10].

In a study conducted by Altun *et al*. [11], medial plantar responses were absent in 19 out of 40 diabetic patients. Notably, in 10 out of 19 of these patients,

Table 4. Sensitivity of bilateral assessment of medial plantar and sural nerves

	Abnormal NCS (n=60)	Sensitivity
Medial plantar nerve	39	65%
Sural nerve	23	38.3%

NCS=nerve conduction studies

sural nerve conduction studies were found to be normal. Among the remaining patients, sural responses were absent in 7, while reduced sural sensory amplitudes were observed in 2 [11].

Similarly, Uluc *et al*. [12] found that among 30 diabetic patients, 9 had absent medial plantar nerve responses, while 11 had absent sural sensory responses. However, in cases where responses were recordable, they observed a significant reduction in medial plantar sensory response amplitudes, consistent with our findings [12].

It is well known that sensory nerve action potentials in the lower extremities tend to diminish and may become unrecordable in individuals over 60 years of age, making it difficult to distinguish between age-related changes and neuropathy in elderly diabetic patients [13]. However, several studies have shown that medial plantar sensory responses remain recordable in healthy controls under the age of 70 [14, 15]. Similarly, in a study by Keskin *et al*. [16] evaluating the reliability of medial plantar nerve conduction studies in healthy elderly individuals over the age of 65, medial plantar responses could not be recorded in only 2 cases, both over the age of 72, among a total of 81 participants. These results emphasize that medial plantar nerve conduction studies are reliable in healthy elderly individuals under the age of 72 [16].

In our study, the oldest patient was 66 years old, and the absence of sensory responses in some patients was attributed to the severity of diabetic PNP rather than aging. Further studies with larger patient cohorts are needed to better understand the impact of age, but it is important to note that age affects nerve conduction studies in both diabetic and healthy individuals. In our study, all healthy controls exhibited normal medial plantar and sural sensory responses, supporting this perspective.

While there was a statistically significant difference between patient and control groups in terms of medial plantar sensory response amplitudes, there was no significant difference in distal latency and conduction velocity values. This could be explained by the predominant axonal degeneration in diabetic polyneuropathy, which primarily affects sensory amplitudes rather than conduction velocities. However, since medial plantar sensory responses were absent in 35 patients, statistical comparisons were only possible in the 25 patients with measurable responses. When considering the entire patient group, it is evident that medial plantar nerve conduction is significantly impaired.

In the patient group, isolated impairment of medial plantar nerve sensory conduction was observed in 15 patients, whereas 24 patients exhibited abnormalities in multiple nerve conduction studies. Without medial plantar nerve conduction studies, the rate of electrophysiologically detected neuropathy in the patient group would be 40%, but when medial plantar nerve conduction is included, this rate increases to 65%.

When comparing sural and medial plantar nerve conduction studies, sural sensory conduction abnormalities were observed in 23 (38.3%) out of 60 diabetic patients, whereas medial plantar nerve abnormalities were detected in 39 (65%) patients. Importantly, all patients with abnormal sural sensory responses also had abnormal medial plantar nerve responses. However, 15 patients with abnormal medial plantar responses had normal sural nerve conduction studies, suggesting that medial plantar nerve abnormalities may be an earlier indicator of diabetic polyneuropathy.

Similarly, a study by Løseth *et al*. [15] reported that 59% of diabetic patients had abnormal medial plantar nerve conduction studies, while only 24% exhibited sural nerve abnormalities. Another study by An *et al*. [10] found that 46.7% of symptomatic diabetic patients and 14.3% of asymptomatic patients had abnormal medial plantar sensory action potentials, highlighting the predominant axonal degeneration in the medial plantar nerve in diabetic PNP.

These findings suggest that medial plantar nerve conduction studies are more sensitive for the electrophysiological diagnosis of diabetic PNP. This increased sensitivity may be due to the early involvement of the medial plantar nerve, which can be affected even when other sensory nerves remain intact. The early vulnerability of this nerve might be explained by its distal localization.

In light of these findings, we believe that including medial plantar nerve conduction studies in routine nerve conduction assessments for diabetic PNP can significantly improve diagnostic sensitivity.

Limitations

This study has several limitations. First, it was con-

ducted in a single center, which may limit the generalizability of the findings to broader clinical settings. Second, the study was conducted on a relatively small patient group. Future studies involving larger cohorts may provide more robust statistical results and help validate our findings. Third, the findings were not confirmed with skin biopsy, which might have provided additional insight into small fiber involvement. Finally, the cross-sectional design of the study precludes any conclusions about the progression or longitudinal changes in nerve conduction in diabetic patients over time.

CONCLUSION

This study highlights the importance of medial plantar nerve conduction studies in the early diagnosis of diabetic PNP. Our findings indicate that medial plantar nerve conduction studies are more sensitive than sural nerve conduction studies in detecting early neuropathic changes in diabetic patients. While both tests are valuable in the electrophysiological assessment of diabetic PNP, the medial plantar nerve was found to be more frequently affected.

Given the increased sensitivity, integrating medial plantar nerve conduction studies into routine diagnostic protocols may enhance the detection of diabetic neuropathy, particularly in cases where standard assessments yield normal results.

Future studies with larger patient cohorts are needed to further validate these findings and explore potential age-related influences on nerve conduction studies. However, our results suggest that including medial plantar nerve conduction studies in standard evaluations can significantly improve diagnostic accuracy of diabetic PNP.

Ethical Statement

The study was approved by the Istanbul Training and Research Hospital Clinical Research Ethics Committee (Decision no.: 148 and date: 15.06.2012). Informed consent forms were obtained from all patients and healthy volunteers.

Authors' Contribution

Study Conception: GKY, HA; Study Design: GKY, HA; Supervision: HA; Funding: HA, GKY; Materials: HA, GKY; Data Collection and/or Processing: GKY; Statistical Analysis and/or Data Interpretation: GKY; Literature Review: GKY; Manuscript Preparation: GKY and Critical Review: GKY, HA.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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