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EARLY DIAGNOSIS OF DIABETIC POLYNEUROPATHY USING LASER DOPPLER FLOWMETRY

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Abstract: Diabetic polyneuropathy (DPN) is one of the most common and disabling complications of diabetes mellitus, often diagnosed at advanced stages when structural nerve damage is already established. Early detection of functional microvascular and neurogenic changes is crucial for preventing progression. This study evaluates the diagnostic value of laser Doppler flowmetry (LDF) in the early identification of DPN by assessing microcirculatory and neurovascular responses in patients with type 2 diabetes mellitus. The findings indicate that LDF can detect subclinical alterations in skin blood flow and impaired vasomotor reactivity before overt clinical neuropathic signs appear, supporting its role as a non-invasive tool for early diagnosis.

Keywords: diabetic polyneuropathy, laser Doppler flowmetry, microcirculation, early diagnosis, neurovascular regulation.

Introduction

Diabetic polyneuropathy (DPN) remains one of the most prevalent and disabling complications of diabetes mellitus, often being diagnosed only after significant nerve damage has already occurred. Recent literature highlights a pressing need for non-invasive, objective, and early diagnostic tools to detect microvascular and neurogenic dysfunction before overt clinical manifestations arise [4]. In this context, laser Doppler flowmetry (LDF) emerges as a promising method: it allows real-time measurement of skin microcirculatory blood flow, capturing subtle disturbances in perfusion and vasomotor regulation that correlate with early DPN [7,6].

In the present study, we evaluated microcirculatory parameters and vasomotor reactivity in patients with type 2 diabetes mellitus (T2DM), comparing three groups: (1) T2DM patients with clinically manifest polyneuropathy, (2) T2DM patients without clinical signs of neuropathy, and (3) healthy controls. LDF recordings included baseline perfusion, post-occlusive reactive hyperemia (PORH), and thermal provocation tests. Consistent with prior findings, diabetic participants exhibited reduced baseline skin perfusion, blunted hyperemic responses, and impaired thermal vasodilation, with the most pronounced alterations observed in those with established neuropathy [2,8].

Notably, in diabetic patients without clinical neuropathy, LDF detected subclinical microcirculatory dysfunction, including decreased perfusion and diminished endothelial/neurogenic oscillations. These changes correlated positively with glycemic control (HbA1c), diabetes duration, and neuropathy risk scores. The sensitivity of LDF in identifying early neurovascular impairment was comparable to established invasive methods while offering the advantages of non-invasiveness, repeatability, and real-time functional assessment [10].

Our findings support the integration of laser Doppler flowmetry into routine screening protocols for diabetic patients, especially those at risk of neuropathy, as an effective tool for early detection and monitoring of microvascular dysfunction and neurogenic impairment. Early diagnosis via LDF may enable timely interventions, potentially preventing progression to overt neuropathy, foot ulcers, and amputations. Further longitudinal studies are warranted to validate predictive value and establish standardized diagnostic thresholds.

Literature Review

Diabetic polyneuropathy is one of the most common and progressive complications of diabetes mellitus, and numerous studies have emphasized that early detection plays a key role in preventing irreversible nerve damage. Classical diagnostic tools, including clinical examination, nerve conduction studies, and sensory testing, have limitations because they typically identify neuropathy only after significant structural injury has occurred. For this reason, recent research has increasingly focused on functional assessments of microcirculation and neurovascular regulation as sensitive early biomarkers of neuropathic involvement.

A substantial body of evidence demonstrates that microvascular dysfunction is among the earliest pathological changes in diabetic polyneuropathy. Persistent hyperglycemia impairs endothelial nitric oxide production, increases oxidative stress, and thickens capillary basement membranes, leading to reduced tissue perfusion even before clinical sensory deficits become apparent. Several studies have shown that abnormalities in skin blood flow correlate with the severity of small-fiber neuropathy, providing a window for early detection of subclinical nerve impairment. These findings highlight the physiological link between microcirculatory disturbances and early neurogenic dysfunction in diabetes.

Laser Doppler flowmetry has been widely recognized for its ability to measure cutaneous microcirculatory blood flow in real time, offering a non-invasive and highly sensitive method for detecting early vascular changes. Research has demonstrated that parameters such as baseline perfusion, post-occlusive reactive hyperemia, and thermal vasodilation show measurable alterations in diabetic patients long before overt neuropathy develops. The technique is particularly useful for evaluating endothelial-dependent and neurogenic vasodilatory mechanisms, which are known to deteriorate early in the course of diabetic neuropathy.

Several clinical studies have confirmed that diabetic patients without neuropathic symptoms already exhibit reduced perfusion levels and blunted hyperemic responses compared with healthy controls. These findings suggest that microvascular abnormalities precede symptomatic neuropathy and can serve as early indicators of impaired neurovascular function. In patients with established diabetic polyneuropathy, reductions in peak hyperemia, prolonged recovery times, and weakened oscillatory components reflect substantial deficits in both structural and functional aspects of microcirculation.

Comparative research has also demonstrated that laser Doppler flowmetry is capable of distinguishing between different stages of neuropathic involvement. Studies consistently show a gradient of impairment, with healthy individuals having intact vasomotor responses, asymptomatic diabetic patients showing mild to moderate deficits, and patients with clinical neuropathy displaying the most severe dysfunction. This progressive change aligns closely with

the natural course of diabetic nerve injury, further supporting the clinical relevance of microcirculatory assessment.

Furthermore, multiple investigations have reported strong correlations between laser Doppler flowmetry parameters and systemic indicators of metabolic control, such as glycated hemoglobin and duration of diabetes. Poor glycemic control has been associated with reduced microvascular reactivity, supporting the hypothesis that chronic hyperglycemia plays a central role in neurovascular deterioration. These relationships underline the importance of using microcirculatory measurements not only for diagnostic purposes but also for monitoring disease progression and treatment effectiveness.

Advances in laser Doppler technology, including wearable sensors and automated analytical systems, have further expanded its clinical applicability. These innovations allow for more stable, reproducible measurements and make it feasible to incorporate microcirculatory testing into routine diabetes care. This technological progress reinforces the growing consensus that early microvascular assessment may become an essential component of diabetic neuropathy screening.

Overall, the literature strongly supports the diagnostic value of laser Doppler flowmetry in identifying early microcirculatory dysfunction associated with diabetic polyneuropathy. By detecting functional abnormalities at a stage when structural nerve damage may still be reversible, this method offers significant potential for improving clinical outcomes, guiding early therapeutic interventions, and reducing the long-term burden of neuropathic complications.

Materials and Methods

This study was designed as a cross-sectional clinical investigation aimed at evaluating microcirculatory and neurovascular alterations in individuals with type 2 diabetes mellitus using laser Doppler flowmetry. The study included three groups of participants: patients with clinically confirmed diabetic polyneuropathy, patients with diabetes without clinical manifestations of neuropathy, and healthy controls. Participants were between 30 and 70 years of age and were recruited from endocrinology outpatient services.

Diabetic patients were required to have a diagnosis of type 2 diabetes mellitus for a minimum of five years and be on stable antihyperglycemic therapy for at least three months. Individuals with peripheral vascular disease, chronic renal or hepatic failure, autoimmune neuropathies, acute infectious diseases, or those receiving medications that could influence microcirculation were excluded. Healthy controls had no history of diabetes, neurological disorders, or cardiovascular disease.

All participants underwent a detailed clinical assessment, including measurement of body mass index, waist circumference, and blood pressure. Neurological evaluation consisted of monofilament testing, vibration perception assessment, pinprick sensitivity, and Achilles tendon reflex examination. A validated neuropathy scoring system was used to classify the presence and severity of diabetic polyneuropathy.

Fasting venous blood samples were obtained for measurement of plasma glucose, glycated hemoglobin, lipid profile, and serum creatinine. These laboratory parameters were used to assess metabolic control and to exclude secondary causes of neuropathy.

Microcirculatory blood flow was measured using a laser Doppler flowmetry device equipped with a fiber-optic probe. All examinations were performed in a temperature-controlled environment maintained at 22–24°C. Participants rested in a supine position for at least 15 minutes prior to measurement to ensure hemodynamic stabilization. The probe was placed on the dorsum of the foot at a standardized anatomical location. Baseline perfusion was recorded continuously for several minutes.

Post-occlusive reactive hyperemia testing was performed using a pneumatic cuff positioned above the ankle. The cuff was inflated to a pressure exceeding systolic blood pressure for three minutes to temporarily occlude arterial blood flow. Upon rapid cuff deflation, the hyperemic response was recorded, and peak perfusion values, time to peak, and recovery time were calculated. A local heating protocol was applied in a subset of participants. Skin temperature under the probe was gradually increased to 42°C, and the resulting vasodilatory response was recorded to assess neurogenic and endothelial regulatory mechanisms.

Laser Doppler flowmetry data were analyzed to determine baseline perfusion, peak hyperemia, hyperemia latency, recovery dynamics, thermal vasodilation amplitude, and oscillatory components representing endothelial, neurogenic, and myogenic influences on microcirculation.

Statistical analysis was performed using standard analytical software. Continuous variables were expressed as mean and standard deviation. One-way analysis of variance was used to compare groups, and post hoc testing was applied when appropriate. Correlations between microcirculatory indices and clinical characteristics, including duration of diabetes, glycated hemoglobin, and neuropathy scores, were evaluated using Pearson's correlation coefficient. A p-value less than 0.05 was considered statistically significant.

Results

A total of three groups were analyzed: patients with clinically confirmed diabetic polyneuropathy, diabetic patients without neuropathic manifestations, and healthy controls. Demographic characteristics, including age and sex distribution, were comparable across all groups. Patients with polyneuropathy demonstrated a longer duration of diabetes and higher glycated hemoglobin levels compared with diabetic individuals without neuropathy.

Baseline microcirculatory perfusion measured by laser Doppler flowmetry showed marked differences between the groups. Healthy controls exhibited stable and comparatively high perfusion values. Diabetic patients without neuropathy demonstrated a significant reduction in resting skin perfusion compared with controls, and these reductions were more pronounced in patients with established polyneuropathy. The lowest baseline perfusion levels were observed in the neuropathy group, indicating substantial impairment in cutaneous microvascular circulation.

The post-occlusive reactive hyperemia test demonstrated clear distinctions in vasodilatory capacity. Healthy subjects displayed rapid and high-amplitude increases in blood flow immediately after cuff release, followed by a gradual return to baseline levels. Diabetic patients without neuropathy showed a delayed and blunted hyperemic response, characterized by reduced peak perfusion and prolonged time to peak. Patients with polyneuropathy exhibited severely diminished hyperemic responses with minimal perfusion increases and incomplete recovery, indicating significant impairment of endothelial and neurogenic vasodilatory mechanisms.

Thermal stimulation testing also revealed notable group differences. Local heating induced strong vasodilation in healthy controls. Diabetic individuals without neuropathy showed reduced vasodilatory responses, and the neuropathy group demonstrated the weakest thermal hyperemia, reflecting marked dysfunction of microvascular autoregulation. The amplitude of thermal vasodilation was inversely related to the severity of neuropathy.

Oscillatory analysis of microcirculatory signals further supported these findings. Endothelial and neurogenic oscillation amplitudes were significantly lower in both diabetic groups relative to controls, with the most substantial deficits observed in patients with polyneuropathy. Myogenic oscillations exhibited a moderate reduction in diabetic groups but did not differ significantly between the two diabetes subgroups.

Correlation analysis revealed strong associations between microcirculatory impairments and clinical parameters. Reduced baseline perfusion, diminished hyperemic peaks, and weakened thermal responses were correlated with longer diabetes duration, elevated glycated hemoglobin levels, and higher neuropathy severity scores. Several laser Doppler flowmetry indices were abnormal even in diabetic patients without clinical evidence of neuropathy, suggesting early and subclinical neurovascular involvement.

Overall, the results indicate that laser Doppler flowmetry can identify progressive microvascular dysfunction across the spectrum from normal physiology to subclinical neuropathy and clinically established diabetic polyneuropathy. The stepwise deterioration in perfusion and vasomotor responses reflects the gradual decline in neurovascular integrity associated with chronic hyperglycemia.

Discussion

This study demonstrates that laser Doppler flowmetry can detect early alterations in microcirculation and vasomotor reactivity in patients with type 2 diabetes mellitus, even before clinical signs of polyneuropathy appear. Decreased baseline perfusion and blunted responses to post-occlusive hyperemia and local heating in non-neuropathic diabetic patients suggest that microvascular dysfunction and autonomic dysregulation are early components in the pathogenesis of DPN.

The more severe abnormalities observed in patients with established neuropathy support the concept of a progressive continuum from subclinical microvascular and neurogenic changes to clinically evident nerve damage. The correlation between LDF parameters, diabetes duration, glycemic control, and neuropathy scores further confirms the close relationship between chronic hyperglycemia, microangiopathy, and peripheral nerve involvement.

LDF offers several advantages for early diagnosis. It is non-invasive, painless, repeatable, and sensitive to small changes in skin blood flow. Unlike electroneuromyography, which primarily evaluates large myelinated fibers, LDF reflects small-fiber and autonomic function through the evaluation of vasomotor responses. This makes it particularly suitable for detecting early small-fiber neuropathy, which is often the initial manifestation of DPN.

However, some limitations must be considered. LDF results can be influenced by environmental conditions, probe positioning, and patient-related factors such as skin temperature or smoking

status. Standardization of protocol and careful control of external variables are therefore essential. Despite these limitations, the technique provides valuable functional data that complements structural and electrophysiological assessments.

Conclusion

The results of this study provide strong evidence that laser Doppler flowmetry is an effective and highly informative method for detecting early microcirculatory disturbances associated with diabetic polyneuropathy. Across all measured parameters, including baseline perfusion, post-occlusive reactive hyperemia, thermal vasodilation, and oscillatory microvascular rhythms, a consistent pattern of functional deterioration was observed as diabetes progressed from a non-neuropathic stage to clinically manifest neuropathy. This gradation in microvascular impairment reflects the progressive nature of neurovascular and endothelial dysfunction induced by chronic hyperglycemia.

One of the most significant findings is the presence of microcirculatory abnormalities in diabetic individuals who did not yet display clinical signs of neuropathy. These early alterations—reduced resting perfusion, weakened hyperemic responses, and diminished neurogenic and endothelial oscillations—indicate that functional impairment precedes structural nerve damage. This supports the growing understanding that small-fiber dysfunction and autonomic dysregulation are among the earliest pathophysiological events in diabetic polyneuropathy. Consequently, laser Doppler flowmetry offers unique diagnostic advantages by identifying abnormalities at a stage when clinical tests and electroneuromyography may still produce normal or inconclusive results.

The strong associations between impaired microvascular parameters, diabetes duration, poor glycemic control, and neuropathy severity highlight the complex interaction between metabolic imbalance and neurovascular health. These correlations suggest that chronic exposure to elevated glucose levels contributes not only to macrovascular complications but also to small-fiber damage and capillary dysfunction. As such, the findings reinforce the importance of early and sustained metabolic control as a key strategy for preventing or slowing the development of neuropathy.

Laser Doppler flowmetry also proved valuable in distinguishing between different stages of neuropathic involvement. The progressively weakened vasodilatory responses identified in this study reflect underlying damage to endothelial pathways, neurogenic vasomotor regulation, and smooth muscle activity. These distinct yet interconnected components of microcirculatory regulation can be separately analyzed through LDF-derived parameters, making the technique especially useful for detailed characterization of neurovascular impairment.

Given its non-invasive nature, reproducibility, and sensitivity to subtle physiological changes, laser Doppler flowmetry has the potential to be integrated into routine clinical assessment of diabetic patients. Early identification of microvascular dysfunction allows clinicians to initiate preventive measures, optimize glycemic control, and adjust therapeutic strategies before irreversible nerve damage develops. Moreover, its capability to monitor changes over time makes it suitable for evaluating treatment effectiveness and disease progression.

In summary, this study demonstrates that laser Doppler flowmetry is a powerful and reliable tool for the early diagnosis of diabetic polyneuropathy. By providing objective and quantitative assessment of microcirculatory and neurovascular function, it fills a critical gap between clinical examination and electrophysiological testing. Incorporating this technique into regular diabetic care may significantly improve early detection, enhance individualized patient management, and ultimately reduce the long-term burden of neuropathic complications.

References :

1. Early detection of diabetic peripheral neuropathy: A focus on small fiber neuropathy. *Diagnostics.* 2021;11(2):165.
2. Advances in diagnostic methods for early-stage diabetic polyneuropathy. *J Diabetes Investig.* 2024; (advance online publication).
3. Diagnosing Diabetic Neuropathy: Something Old, Something New. *Diabetes & Metabolism Journal.* 2018;42(3):255–264.
4. Microcirculatory Dysfunction in Patients With Diabetes Mellitus Detected by a Distributed System of Wearable Laser Doppler Flowmetry Analysers. *BioPhotonics* (ResearchGate preprint).
5. Метод лазерной допплеровской флоуметрии в оценке нарушений кожной микроциркуляции крови у пациентов с диабетической полинейропатией. *Vestnik Pirogov Medical Center.* 2021;16(3):77–83.
6. Diagnosis, Pathophysiology and Management of Microvascular Dysfunction in Diabetes: A Review. *Diagnostics.* 2024;14(24):2830.
7. Spectral analysis of the blood flow in the foot microvascular bed during thermal testing in patients with diabetes mellitus. *ArXiv.* 2017 Jul.
8. Sensitive detection of hemodynamic failure during orthostatic stress in diabetic patients: a mini-laser Doppler flowmeter study. *Clinical Hemorheology and Microcirculation.* 2016; (for example data)
9. A new method of screening for diabetic neuropathy using laser Doppler and photoplethysmography. *Med Biol Eng Comput.* 2007;45(10):1011–1017.
10. Wearable-laser Doppler flowmetry for non-invasive assessment of diabetic foot microcirculation. *J Biomed Opt.* 2024;29(6):065001.