



AI-BASED - BIOMARKERS FOR EARLY DIAGNOSIS OF DIABETIC
PERIPHERAL NEUROPATHY: EMERGING ROLE OF MACHINE
LEARNING AND DIGITAL DIAGNOSTICS

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Annotation: *Diabetic peripheral neuropathy (DPN) is one of the most common and disabling complications of diabetes mellitus. Early diagnosis remains difficult because clinical symptoms frequently appear only after irreversible nerve damage has already developed. Recent advances in artificial intelligence (AI), machine learning, and digital diagnostic technologies have created new opportunities for earlier detection of DPN. AI-based biomarkers derived from retinal imaging, corneal confocal microscopy, wearable technologies, and laboratory parameters may improve diagnostic precision and predictive accuracy. This review summarizes current evidence regarding the role of AI technologies in the early diagnosis of diabetic neuropathy and discusses the future potential of machine learning in preventive neurology and personalized medicine.*

Keywords: *Diabetic peripheral neuropathy; artificial intelligence; machine learning; digital biomarkers; early diagnosis*

Introduction

Diabetes mellitus is a rapidly increasing global health problem associated with multiple chronic complications, including diabetic peripheral neuropathy



(DPN). DPN affects sensory, motor, and autonomic nerves and significantly reduces patients' quality of life. Common clinical manifestations include numbness, burning pain, paresthesia, impaired balance, and muscle weakness. In advanced stages, diabetic neuropathy may lead to diabetic foot ulcers, infections, and lower limb amputation. Despite significant advances in diabetes management, early diagnosis of diabetic neuropathy remains challenging. Traditional diagnostic approaches such as neurological examination and nerve conduction studies often detect neuropathy only after considerable neuronal injury has already occurred. Consequently, researchers are increasingly investigating modern technologies capable of identifying subtle pathological changes during the earliest stages of disease progression. Artificial intelligence has emerged as one of the most promising innovations in modern medicine. Machine learning algorithms are capable of analyzing large volumes of clinical, imaging, and laboratory data with remarkable precision. These technologies may improve diagnostic accuracy, reduce human error, and enable earlier intervention before severe neurological complications develop. This review aims to summarize current evidence regarding AI-based biomarkers used in the early diagnosis of diabetic peripheral neuropathy while also discussing future perspectives and clinical applications of machine learning technologies.

Methods

This review article was prepared using scientific literature obtained from PubMed, Google Scholar, ScienceDirect, and PMC databases. Scientific articles published between 2015 and 2026 related to diabetic neuropathy, artificial intelligence, machine learning, retinal imaging, corneal confocal microscopy, and digital biomarkers were analyzed. Keywords used during literature search included "diabetic peripheral neuropathy," "artificial intelligence," "machine learning," "digital diagnostics," "retinal imaging," and "AI biomarkers." Review articles, meta-analyses, clinical studies, and experimental research papers written in English were included in the review.



Results and Discussion

Artificial Intelligence in Diabetic Neuropathy Diagnosis

Artificial intelligence refers to computer systems capable of performing tasks that normally require human cognitive abilities. In recent years, AI technologies have increasingly been integrated into medical diagnostics because of their ability to process complex datasets and identify hidden pathological patterns. Machine learning algorithms can analyze demographic data, laboratory findings, imaging results, and neurological assessments simultaneously. Several studies have demonstrated that AI-assisted systems may predict diabetic neuropathy progression more accurately than traditional diagnostic methods. These technologies may therefore contribute significantly to earlier diagnosis and more personalized patient management.

Retinal Imaging as an AI-Based Biomarker

Retinal imaging has emerged as one of the most promising non-invasive biomarkers for diabetic neuropathy. Since retinal microvascular abnormalities often reflect systemic vascular and neurological damage, retinal analysis may provide valuable information regarding early neuropathic changes. Deep learning algorithms are capable of analyzing retinal photographs and detecting subtle vascular abnormalities associated with diabetic neuropathy. AI-assisted retinal imaging provides a rapid and non-invasive screening approach while also improving diagnostic accuracy and reducing the possibility of human error during clinical evaluation. Recent investigations suggest that retinal vessel abnormalities strongly correlate with neuropathy severity and disease progression.

Corneal Confocal Microscopy and Machine Learning

Corneal confocal microscopy (CCM) has become an important diagnostic tool for detecting small fiber neuropathy during early disease stages. This non-invasive imaging technique allows visualization of corneal nerve fibers with high resolution. Machine learning systems can automatically



evaluate corneal nerve fiber density, nerve branch density, and nerve fiber length. Automated AI-assisted analysis improves diagnostic consistency and may identify neuropathic changes before severe clinical symptoms develop. Consequently, CCM combined with machine learning may become an important component of future diabetic neuropathy screening programs.

Wearable Technologies and Digital Biomarkers

Recent advances in wearable technologies have created new opportunities for continuous monitoring of diabetic patients. Smart sensors and wearable health devices are capable of collecting real-time physiological and biomechanical data. Artificial intelligence systems can analyze gait abnormalities, plantar pressure distribution, balance disturbances, and physical activity patterns in diabetic patients. Continuous monitoring through wearable technologies may facilitate early identification of neuropathy progression and improve preventive interventions. In addition, remote monitoring systems may reduce healthcare costs while increasing patient accessibility to diagnostic services.

Predictive Models and Personalized Medicine

Modern machine learning algorithms can integrate multiple clinical and laboratory parameters into predictive diagnostic models. Several predictive systems combine HbA1c levels, inflammatory cytokines, oxidative stress markers, lipid profile abnormalities, and imaging findings to identify patients at high risk for diabetic neuropathy progression. These predictive technologies may support personalized medicine by enabling clinicians to design individualized prevention and treatment strategies according to each patient's risk profile. Early risk prediction may significantly reduce severe neurological complications and improve long-term patient outcomes.

Limitations and Ethical Considerations

Although artificial intelligence demonstrates significant potential in diabetic neuropathy diagnosis, several limitations remain. Many AI-based





models still require validation using larger and more diverse patient populations before they can be fully integrated into routine clinical practice. Ethical concerns regarding data privacy, algorithm transparency, and potential diagnostic bias also require careful consideration. Furthermore, healthcare professionals need appropriate training to effectively utilize AI technologies in clinical settings.

Conclusion

Artificial intelligence and machine learning technologies represent promising tools for the early diagnosis of diabetic peripheral neuropathy. AI-based biomarkers derived from retinal imaging, corneal confocal microscopy, wearable technologies, and laboratory parameters may significantly improve diagnostic accuracy and predictive capability. Future research should focus on validating integrated biomarker models, improving algorithm reliability, and developing personalized diagnostic systems capable of identifying neuropathy during its earliest stages. The integration of AI technologies into diabetic care may transform preventive neurology and substantially improve patient outcomes in the future.

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