OPEN ACCESS Freely available online

ISSN: 2684-1622
Journal of Eye Diseases and Disorders

Opinion Article

Retinal Microvascular Alterations as Predictors of Neurodegenerative Disorders

Natalia Herrera*

Department of Ophthalmology, University Hospital of Seville, Seville, Spain

DESCRIPTION

The human eye has long been described as a "window to the soul," but in the context of modern medicine, it has become the "window to the brain." The retina, an extension of the Central Nervous System (CNS), provides a unique, non-invasive opportunity to study neurovascular and neurodegenerative changes that mirror those occurring in the brain. With the advent of high-resolution imaging modalities such as Optical Coherence Tomography (OCT) and OCT Angiography (OCTA), subtle retinal microvascular alterations are increasingly being recognized as early biomarkers of systemic and neurological diseases, including Alzheimer's disease, Parkinson's disease, and multiple sclerosis [1]. This commentary explores how retinal microvasculature serves as a promising frontier for early diagnosis and disease monitoring in neurodegenerative disorders, with potential to revolutionize both ophthalmic and neurological clinical practice.

Embryologically, the retina originates as an outpouching of the diencephalon, making it an integral component of the CNS. It shares structural, vascular, and physiological similarities with the brain, including the presence of the blood-retinal barrier, glial cells, and complex synaptic networks. Unlike the brain, however, the retina can be visualized directly and non-invasively [2]. This accessibility makes retinal imaging a valuable diagnostic window for evaluating microvascular and neurodegenerative processes.

In recent years, retinal imaging has transitioned from being a tool for ocular diseases such as diabetic retinopathy or glaucoma to one that provides systemic insights. Changes in retinal microvasculature, such as reduced capillary density, vessel tortuosity, and thinning of retinal nerve fiber layers, are now associated with early neurodegenerative changes in the brain [3].

Accumulating evidence suggests that the retina mirrors amyloid-β deposition and neurofibrillary tangle formation found in the AD brain. OCT studies have revealed thinning of the Retinal Nerve Fiber Layer (RNFL) and Ganglion Cell-Inner Plexiform Layer (GCIPL), correlating with cognitive decline and hippocampal atrophy. OCTA further demonstrates reduced vessel density and perfusion in the superficial and deep capillary plexus of AD patients. These findings indicate that retinal imaging could serve as a surrogate marker for cerebral pathology long before clinical symptoms manifest [4,5].

In PD, retinal dopaminergic amacrine cells are affected similarly to brain dopaminergic neurons. OCT studies show thinning of the inner retinal layers, particularly the ganglion cell layer, reflecting dopaminergic neurodegeneration. OCTA has revealed reduced vessel density, suggesting a link between microvascular dysfunction and neurodegeneration in PD. These retinal changes could potentially be used as non-invasive biomarkers for disease progression and therapeutic response monitoring [6].

MS is characterized by demyelination and axonal loss, which are also observable in the retina. Thinning of the RNFL and GCIPL, particularly after optic neuritis, correlates with brain lesion load and disability scores. Retinal imaging, therefore, serves as a reliable marker of neuroaxonal damage, offering insight into disease activity and prognosis without the need for invasive procedures [7].

Optical Coherence Tomography (OCT) revolutionized retinal imaging by providing high-resolution cross-sectional images of retinal layers, allowing quantification of structural changes. The evolution of OCT Angiography (OCTA) further enabled visualization of retinal microvasculature without the need for dye injection, unlike traditional fluorescein angiography.

OCTA quantifies parameters such as vessel density, perfusion index, and foveal avascular zone area all of which are sensitive to subtle vascular alterations. Such parameters have been linked with systemic vascular dysfunction in hypertension, diabetes, and chronic kidney disease, suggesting that the retina can serve as a biomarker for systemic endothelial health [8].

Furthermore, the reproducibility and non-invasiveness of OCTA make it an ideal candidate for longitudinal monitoring, particularly in aging populations where neurodegenerative diseases are prevalent. Emerging studies indicate that chronic neuroinflammation plays a central role in both retinal and cerebral degeneration. Microglial activation in the retina can

Correspondence to: Natalia Herrera, Department of Ophthalmology, University Hospital of Seville, Seville, Spain, E-mail: nataliaherrera@uhs.es

Received: 01-Sep-2025, Manuscript No. JEDD-25-30118; **Editor assigned:** 03-Sep-2025, PreQC No. JEDD-25-30118 (PQ); **Reviewed:** 17-Sep-2025, QC No. JEDD-25-30118; **Revised:** 24-Sep-2025, Manuscript No. JEDD-25-30118 (R); **Published:** 01-Oct-2025, DOI: 10.35248/2684-1622.25.10.297

Citation: Herrera N (2025). Retinal Microvascular Alterations as Predictors of Neurodegenerative Disorders. J Eye Dis Disord. 10:297.

mirror that in the brain, with pro-inflammatory cytokines disrupting the blood-retinal barrier, leading to neuronal injury. Retinal vessel rarefaction and reduced perfusion may reflect similar microvascular pathology in the brain.

Therefore, identifying retinal biomarkers associated with inflammation, vascular leakage, and neural loss could provide a multidimensional approach to early diagnosis. The ability to detect these changes before irreversible brain damage occurs represents a transformative shift toward preventive neurology. The integration of retinal imaging into neurological evaluation could fundamentally alter diagnostic workflows [9]. A simple, non-invasive retinal scan may, in the future, complement or even precede more invasive tests such as cerebrospinal fluid analysis or Positron Emission Tomography (PET) scans.

For instance, incorporating OCT and OCTA screening into geriatric ophthalmic check-ups could enable early detection of patients at risk for cognitive decline. Artificial Intelligence (AI)-driven analysis of retinal images further enhances diagnostic precision, allowing automated recognition of disease-specific vascular or structural patterns. Beyond diagnostics, retinal biomarkers could play a pivotal role in evaluating the efficacy of neuroprotective and anti-inflammatory therapies. Monitoring retinal changes in real time could provide surrogate endpoints for clinical trials, reducing costs and improving patient outcomes [10].

CONCLUSION

Despite the growing body of evidence, several challenges remain. Standardization of imaging protocols, inter-device variability, and the establishment of normative databases across ethnic groups are critical for widespread clinical adoption. Additionally, large-scale, longitudinal studies are necessary to validate retinal biomarkers as reliable predictors of neurodegeneration. Integration of multimodal imaging combining OCT, OCTA, fundus autofluorescence, and hyperspectral imaging may provide deeper insights into the interplay between neuronal and vascular components of the retina. Future research should also explore molecular imaging techniques capable of visualizing amyloid or tau deposition directly *in vivo*.

REFERENCES

1. Jiang H, Wang J, Levin BE, Baumel BS, Camargo CJ, Signorile JF, et al. Retinal microvascular alterations as the biomarkers for Alzheimer disease: are we there yet?. J Neuroophthalmol. 2021; 41(2):251-260
2. Wang X, Chou Y, Zhu H, Xing B, Yao Y, Lu L, et al. Retinal microvascular alterations detected by optical coherence tomography angiography in nonfunctioning pituitary adenomas. Transl Vis Sci Technol. 2022;11(1):5
3. Robbins CB, Thompson AC, Bhullar PK, Koo HY, Agrawal R, Soundararajan S, et al. Characterization of retinal microvascular and choroidal structural changes in Parkinson disease. JAMA Ophthalmol. 2021;139(2):182-188.
4. Kaderli ST, Karalezli A, Sul S. Microvascular retinal alterations in rhegmatogenous retinal detachment after pneumatic retinopexy. Acta Ophthalmol. 2021;99(4):383-389
5. Nassan M, Videnovic A. Circadian rhythms in neurodegenerative disorders. Nat Rev Neurol. 2022;18(1):7-24
6. Brandebura AN, Paumier A, Onur TS, Allen NJ. Astrocyte contribution to dysfunction, risk and progression in neurodegenerative disorders. Nat Rev Neurosci. 2023;24(1):23-39.
7. Lamptey RN, Chaulagain B, Trivedi R, Gothwal A, Layek B, Singh J. A review of the common neurodegenerative disorders: current therapeutic approaches and the potential role of nanotherapeutics. Int J Mol Sci. 2022;23(3):1851
8. Malhotra RK. Neurodegenerative disorders and sleep. Sleep Med Clin. 2018;17(2):307-314
9. Phillips MC, Picard M. Neurodegenerative disorders, metabolic icebergs, and mitohormesis. Transl Neurodegener. 2024;13(1):46.
10. Javed A, Khanna A, Palmer E, Wilde C, Zaman A, Orr G, et al. Optical coherence tomography angiography: a review of the current literature. J Int Med Res. 2023;51(7):3000605231187933.