

Advances in the Use of OCTA Techniques in Selected Central Nervous System Diseases

Shaojin Zhu, Zhongcen Pan, Duwei Cui, Yan Yu, Chi Xie*

The First Affiliated Hospital of Anhui University of Science and Technology, Huainan 232000, China

*Corresponding email: xiechi1970317@126.com

Abstract

Optical coherence tomography angiography (OCTA) is a non-invasive, convenient and non-contact fundus imaging technique, which can not only clearly present the microvascular and anatomical structure of the retina and choroid, but also quantitatively analyze them. The retina is considered the window to the brain, and some patients with central nervous system (CNS) diseases show characteristic changes in the retina that often precede the main symptoms of the CNS. In this review, we summarize the fundus changes observed in CNS diseases such as Alzheimer's disease, stroke, Parkinson's disease and multiple sclerosis by OCTA. Retinal biomarkers have the potential to serve as important tools for early diagnosis and monitoring of CNS disease progression. Moreover, OCTA provides a unique, non-invasive perspective for establishing an eye-brain axis evaluation system. However, current findings remain inconsistent due to variations in study protocols, sample sizes, and imaging platforms. Future large-scale, standardized multicenter studies are needed to validate the clinical utility of OCTA-derived metrics and to facilitate their integration into routine diagnostic workflows for CNS disorders.

Keywords

Optical coherence tomography angiography, Stroke, Alzheimer's disease, Parkinson's disease, Multiple sclerosis

Introduction

Due to their developmental and anatomical particularities, the retina and optic nerve extend from the diencephalon, and the retina is considered part of the central nervous system (CNS). Consequently, the retina shares many physiological characteristics with the brain. For instance, retinal ganglion cells exhibit partial properties of CNS neurons, and the blood-retinal barrier closely resembles the blood-brain barrier, maintaining direct synaptic connections throughout the lifespan [1]. In many CNS diseases such as Alzheimer's disease (AD), stroke, Parkinson's disease (PD), and multiple sclerosis (MS), characteristic retinal changes often occur earlier than clinical symptoms of CNS diseases. Therefore, fundus imaging can serve as a critical approach for early diagnosis of these disorders. While non-invasive observation of cerebral structures and vascular changes remains challenging, the retina - acting as a "window to the brain" - enables direct visualization of retinal structural and vascular alterations, providing a means to

assess the onset and progression of CNS diseases.

Optical coherence tomography angiography (OCTA) is a rapid, non-invasive retinal vascular imaging technology [2]. This technique employs repeated cross-sectional scans to detect moving red blood cells, comparing structural images pixel-by-pixel to identify signal changes caused by erythrocyte movement. Using split-spectrum amplitude-decorrelation angiography algorithms and motion correction techniques, OCTA enhances blood flow detection capability while eliminating motion artifacts, thereby generating retinal perfusion maps [3]. The built-in OCTA software divides the retina into four layers: the superficial capillary plexus layer, deep capillary plexus layer, outer retinal layer, and choriocapillary layer. It also enables quantitative analysis by automatically extracting parameters such as vessel density, foveal avascular zone (FAZ) area, perimeter, acircularity index, retinal thickness, and retinal nerve fiber layer (RNFL) thickness [4,5].

Currently, OCTA has been widely applied in ophthalmology and CNS research. Most studies utilize OCTA to observe retinal changes for predicting cerebral microvascular alterations, establishing an eye-brain axis evaluation system to assist in disease diagnosis and severity assessment [6]. This review focuses on the applications of OCTA in detecting retinal changes associated with various CNS diseases, aiming to identify retinal biomarkers and provide novel strategies for early diagnosis and disease progression monitoring of CNS disorders.

The application of OCTA in AD

The progression of AD is a continuous process, evolving from an asymptomatic preclinical stage to mild cognitive impairment and eventually severe dementia [7]. AD ranks as the fifth leading cause of death among individuals aged 65 and older in the United States. By 2030, the U.S. population aged 65 and older is projected to reach 74.0 million, with approximately 8.5 million affected by AD [8]. Classic pathological hallmarks of AD include intracellular neurofibrillary tangles, neuronal loss, and β -amyloid deposition in the brain, which activates microglia to release inflammatory mediators, triggering neurotoxicity and exacerbating disease progression [9]. Clinical manifestations include memory impairment, language deficits, and visuospatial perception abnormalities. However, the preclinical stage often lacks obvious symptoms, making early diagnosis challenging. Current diagnostic tools such as magnetic resonance imaging (MRI) and positron emission tomography (PET) are costly, non-portable, and unsuitable for large-scale screening. As an extension of the brain with shared developmental origins, the retina may reflect cerebral β -amyloid pathology, positioning retinal structural changes as potential biomarkers for preclinical AD diagnosis [10].

An increasing number of studies have applied quantitative measurements - such as retinal thickness, vessel density, and retinal nerve fiber layer thickness - to characterize retinal alterations in early-stage Alzheimer's disease. Evidence suggests that even at the preclinical stage, the foveal avascular zone (FAZ) may be enlarged and retinal thickness reduced, potentially preceding overt clinical symptoms [11]. Longitudinal

observations further indicate that FAZ enlargement can progress over time despite relatively stable cognitive scores, implying that retinal imaging metrics may support preclinical AD screening, risk stratification, and earlier intervention [12]. In parallel, other reports describe decreases in retinal thickness and vessel density in early AD, with changes most pronounced in the macular region, possibly related to β -amyloid-associated microvascular constriction and impaired perfusion [13]. However, findings remain inconsistent: Some studies have reported increased vessel density in β -amyloid-positive individuals and no detectable FAZ changes. These discrepancies may reflect inter-individual differences in retinal metabolic demand, compensatory vascular remodeling or neovascular responses, and heterogeneity in disease stage and study inclusion criteria.

As AD progresses, retinal ganglion cells and optic nerve axons degenerate, leading to peripapillary RNFL thinning. Paradoxically, some studies reported increased RNFL thickness in AD patients, possibly reflecting pre-degenerative neuroinflammation and gliosis [14]. In late-stage AD, worsening cognitive decline correlates with further reductions in retinal vessel density, choroidal thinning, and FAZ enlargement [15]. Dynamic changes in retinal parameters throughout AD progression underscore their potential as reliable biomarkers for diagnosis and monitoring. Although OCTA-based studies on early retinal changes in AD are expanding, inconsistent conclusions persist. Further validation and identification of additional retinal biomarkers to predict AD onset and track its progression remain critical challenges.

The application of OCTA in stroke

Stroke, a prevalent cerebrovascular disease, remains a leading global cause of death and disability. China bears the highest stroke-related mortality worldwide. Although China's stroke incidence has declined from 222 to 201 per 100,000 between 2005 and 2019, ischemic stroke rates continue to rise. The overall prevalence is increasing, with a younger-onset trend. This imposes substantial economic burdens on individuals, families, and society [16]. Retinal structural and microvascular alterations reflect cerebral

microvascular and neuronal damage. Retinal and cerebral vasculature share developmental origins, with 75% of ischemic strokes attributed to internal carotid artery stenosis, which concurrently affects both vascular systems [17].

Earlier studies based on fundus photography reported that retinal vascular features are independently associated with stroke, and that retinal abnormalities may vary across different stages of the disease. Nonetheless, the diagnostic value of these observations has been constrained by the largely qualitative nature of fundus imaging and the limited availability of reproducible quantitative metrics. OCTA overcomes these limitations by precisely visualizing retinal microvascular changes in stroke patients, enabling layer-specific, quantitative assessment of perfusion and capillary integrity [18]. Comparative evaluations of large-artery atherosclerotic versus small-artery occlusive stroke have shown that both subtypes commonly exhibit reduced deep capillary plexus vessel density (DVD), whereas alterations in the superficial capillary plexus are often subtle. This pattern supports the idea that DVD may provide higher sensitivity as a retinal biomarker of ischemic stroke, potentially because the dense and complex deep capillary network is particularly susceptible to ischemic injury. In addition, peripapillary RNFL thickness has been found to differ between stroke subtypes, with more pronounced superior RNFL thinning in large-artery atherosclerotic stroke, suggesting that RNFL-derived measures may contribute to stroke subtype classification.

In stroke populations, OCTA commonly reveals a pattern of decreased retinal vessel density, a reduced foveal avascular zone (FAZ) area and perimeter, and an increased acircularity index. Multivariable models indicate that these OCTA-derived metrics remain independently associated with stroke risk even after adjustment for major vascular comorbidities such as diabetes and hypertension [19]. In ischemic stroke specifically, retinal neurodegeneration appears to be accelerated, manifested by faster thinning of the ganglion cell complex and concurrent tissue volume loss. Moreover, optic disc vessel density has been reported to correlate positively with RNFL thickness, supporting the

concept of coupled microvascular impairment and neural injury within the retina [20].

Impaired neurovascular unit (NVU) function represents a key stroke mechanism. Cerebral NVU damage during stroke activates neuroinflammatory pathways, disrupting microvascular integrity. Retinal NVU, sharing components with cerebral NVU, likely undergoes similar damage, reducing retinal perfusion. Reduced radial peripapillary capillary flow in superficial RNFL correlates with RNFL thinning [21,22]. Post-stroke retrograde trans-synaptic degeneration manifests as macular ganglion cell layer thinning and visual field defects, positioning this layer as an imaging biomarker for visual pathway damage [23].

As a metabolically active, oxygen-demanding tissue, the retina exhibits heightened sensitivity to hypoperfusion and hypoxia. OCTA-based retinal blood flow monitoring offers a rapid, cost-effective alternative to computed tomography (CT) and MRI for cerebral perfusion assessment, enabling large-scale stroke screening.

Application of OCTA in PD

Parkinson's disease (PD) is a progressive neurodegenerative disorder primarily characterized by motor symptoms such as resting tremor, rigidity, bradykinesia, and postural instability. In recent years, non-motor symptoms - including depression, anxiety, sleep disturbances, and cognitive impairment - have gained increasing recognition [24]. The degeneration of dopaminergic neurons in the CNS of PD patients is linked to misfolded protein aggregates. Notably, similar protein deposits have been identified in postmortem retinal cells, suggesting that retinal structural changes may underlie visual dysfunction in PD, such as altered visual acuity, reduced contrast sensitivity, photophobia, and hallucinations [25].

Growing evidence highlights significant retinal microvascular and RNFL thickness alterations in PD. Patients exhibit reduced FAZ area in both superficial and deep retinal layers, alongside decreased parafoveal perfusion density, skeleton density, and capillary loss. The superficial capillary plexus density in the parafoveal region correlates with ganglion cell-inner plexiform

layer (GC-IPL) thickness. PD patients with cognitive impairment show markedly thinner parafoveal GC-IPL compared to cognitively intact patients, indicating OCTA's potential for early PD diagnosis and clinical subtype differentiation [26].

Peripapillary RNFL thickness changes serve as valuable biomarkers for assessing motor and cognitive dysfunction severity in PD. Compared to healthy controls, mild-to-moderate PD patients demonstrate reduced average peripapillary RNFL thickness, particularly in the temporal and inferior quadrants, with more pronounced thinning in advanced motor dysfunction [27]. Progressive RNFL thinning correlates with worsening cognitive impairment, suggesting dopamine deficiency may drive RNFL alterations - a hypothesis requiring further validation [28]. In PD, OCTA often shows reduced superficial vessel density and perfusion, alongside choroidal remodeling (increased luminal area and a lower choroidal vascularity index). Combining these metrics with clinical findings may improve PD diagnosis [29].

Combined optical coherence tomography (OCT) and OCTA outperform standalone modalities in sensitivity and diagnostic power, offering novel biomarkers for tracking PD progression [30]. Despite occasional conflicting findings, OCTA demonstrates exceptional utility in PD diagnosis and severity assessment. Retinal imaging via OCTA may emerge as a groundbreaking tool for PD detection, though further studies are needed to validate its clinical value. Future integration of OCTA with functional MRI could deepen insights into retina-brain structural and functional connectivity, advancing PD diagnosis and therapeutic strategies.

The application of OCTA in MS

Multiple sclerosis (MS) is a degenerative inflammatory disorder of the central nervous system (CNS), often leading to neurodegenerative changes. It represents the leading cause of non-traumatic neurological disability in young adults and remains incurable [31]. MS manifests with diverse clinical symptoms, including vision loss from optic neuritis, limb weakness or sensory deficits from transverse myelitis, diplopia due to brainstem dysfunction, and ataxia from cerebellar damage. Current diagnosis relies on MRI and cerebrospinal fluid analysis,

while pharmacological and immunotherapeutic interventions offer limited efficacy and high relapse rates, driving research into complementary therapies [32,33].

Both the CNS and retina exhibit abnormalities in MS patients. The afferent visual pathway - spanning the retina to the visual cortex - is among the most affected systems, highlighting its potential as a biomarker. Inflammation, demyelination, and axonal degeneration within this pathway underlie MS-related visual impairments. Studies reveal significantly reduced parafoveal superficial vessel density (SVD) in MS patients, with progressive declines over disease duration, though these microvascular changes appear independent of optic neuritis history [34]. In multiple sclerosis (MS), OCTA studies often report a marked reduction in superficial vessel density (SVD) with relatively preserved DVD. SVD loss appears more closely linked to ganglion cell complex and RNFL atrophy, whereas DVD alterations may relate to thinning of ganglion cell and inner nuclear layers [35].

Prospective observations in demyelinating multiple sclerosis (MS) suggest that retinal vessel density can remain relatively stable initially but may decline over time, particularly evident by the second year, whereas choriocapillaris density may stay unchanged [36]. This pattern supports vascular involvement alongside neurodegeneration and neuroinflammation, paralleling progressive CNS pathology. In addition, peripapillary vessel density is reduced in both newly diagnosed and relapsing-remitting MS, with greater impairment in relapsing cases. Collectively, retinal capillary loss may signal early vascular pathology or subclinical white-matter damage, highlighting OCTA metrics as valuable biomarkers for tracking inflammatory and neurodegenerative progression and informing earlier intervention [37].

Furthermore, peripapillary RNFL thickness not only aids MS diagnosis but also tracks therapeutic responses in progressive MS, informing clinical decision-making for treatment selection [38].

Conclusion

With the intensification of population aging, the burden

of central nervous system (CNS) diseases continues to rise. Current research aims to identify novel biomarkers in ocular tissues to advance diagnostic windows, improve clinical detection rates, and provide scientific, targeted guidance for CNS disease management, thereby alleviating disease-related burdens. As a non-invasive, radiation-free imaging modality, optical coherence tomography angiography (OCTA) enables direct visualization of retinal microvascular changes and quantitative analysis of structural parameters, offering unprecedented insights into CNS pathology. This positions OCTA-derived metrics as promising biomarkers for diagnosing and monitoring CNS diseases. Growing evidence confirms that retinal alterations in CNS diseases are not coincidental but reflect intrinsic pathophysiological connections, though detailed mechanisms require further elucidation. Advances in retinal imaging technology now allow rapid, high-resolution visualization of broader and deeper retinal structures, accelerating the discovery of novel biomarkers for early CNS disease detection. However, discrepancies persist across studies due to limited sample sizes, heterogeneous imaging device parameters, and inconsistent software algorithms. Future efforts should prioritize large-scale multicenter studies to standardize imaging tools and protocols, establish correlations among OCTA, CT, MRI, and clinical manifestations, and validate retinal biomarkers.

The development of multimodal imaging diagnostic systems, eye-brain axis prediction models, and standardized databases, combined with AI-assisted diagnosis and treatment systems, will advance early diagnosis, prevention, and personalized management of CNS diseases. These innovations promise to transform the paradigm from reactive treatment to proactive, precision-based CNS healthcare.

Funding

This work was supported by The Tenth Batch of “50 Stars of Science and Technology” Innovative Projects in Huainan.

Acknowledgments

The authors would like to show sincere thanks to those techniques who have contributed to this research.

Conflicts of Interests

The authors declare no conflict of interest.

References

- [1] Zhou, L. Y., Liu, Z. G., Sun, Y. Q., Li, Y. Z., Teng, Z. Q., Liu, C. M. (2025) Preserving blood-retinal barrier integrity: a path to retinal ganglion cell protection in glaucoma and traumatic optic neuropathy. *Cell Regeneration*, 14(1), 13.
- [2] Mayor, M., Camafort, M., Estruch, R. (2024) Retinal microvasculature assessment: useful to refine cardiovascular risk. *European Heart Journal*, 45(33), 3086-3088.
- [3] Lin, Z., Zhang, Q., Lan, G., Xu, J., Qin, J., An, L., Huang, Y. (2024) Deep learning for motion artifact-suppressed octa image generation from both repeated and adjacent oct scans. *Mathematics*, 12(3), 446.
- [4] Veselinović, M., Trenkić, M., Čanadanović, V., Jovanović, P., Veselinović, A., Petrović, M., Kasumović Bećirović, A. (2025) The significance of OCTA in studying vessel density and retinal thickness in individuals with myopia. *Medicina*, 61(3), 532.
- [5] Pourbagherkhah, P., Shojaee, S., Farjami, M., Baghban Jaldian, H. (2025) A meta-analysis of retinal vascular density in different severities of myopia assessed by optical coherence tomography angiography. *Ophthalmic and Physiological Optics*, 45(6), 1534-1548.
- [6] Shen, Z., Zhang, S., Yu, W., Yue, M., Hong, C. (2024) Optical coherence tomography angiography: revolutionizing clinical diagnostics and treatment in central nervous system disease. *Aging and Disease*, 16(1), 77.
- [7] Rafii, M. S., Aisen, P. S. (2023) Detection and treatment of Alzheimer’s disease in its preclinical stage. *Nature Aging*, 3(5), 520-531.
- [8] Better, M. A. (2023) Alzheimer’s disease facts and figures. *Alzheimers Dement*, 19(4), 1598-1695.
- [9] Thakur, S., Dhapola, R., Sarma, P., Medhi, B., Reddy, D. H. (2023) Neuroinflammation in Alzheimer’s disease: current progress in molecular signaling and therapeutics. *Inflammation*, 46(1), 1-17.

- [10] Koronyo, Y., Rentsendorj, A., Mirzaei, N., Regis, G. C., Sheyn, J., Shi, H., Koronyo-Hamaoui, M. (2023) Retinal pathological features and proteome signatures of Alzheimer's disease. *Acta Neuropathologica*, 145(4), 409-438.
- [11] Duffy, B. V., Castellanos-Canales, D., Decker, N. L., Lee, H. J. A., Yamaguchi, T. C., Pearce, E., Fawzi, A. A. (2025) Foveal avascular zone enlargement correlates with visual acuity decline in patients with diabetic retinopathy. *Ophthalmology Retina*, 9(7), 667-676.
- [12] Kaštelan, S., Gverović Antunica, A., Puzović, V., Didović Pavičić, A., Čanović, S., Kovačević, P., Konjevoda, S. (2025) Non-invasive retinal biomarkers for early diagnosis of Alzheimer's disease. *Biomedicines*, 13(2), 283.
- [13] Min, Y., Zhou, H., Li, Z., Wang, Y. (2025) Retinal biomarkers in cognitive impairment and dementia: structural, functional, and molecular insights. *Alzheimer's & Dementia*, 21(9), e70672.
- [14] Arora, A., Chauhan, N., Ali, S. A. (2024) Molecular and immunological gene expression of neurological disorders. *Evidence-Based Neurological Disorders*, 181-227.
- [15] Vagiakis, I., Bakirtzis, C., Andravizou, A., Pirounides, D. (2024) Unlocking the potential of vessel density and the foveal avascular zone in optical coherence tomography angiography as biomarkers in Alzheimer's disease. *Healthcare*, 12(16), 1589.
- [16] Zhang, R., Liu, H., Pu, L., Zhao, T., Zhang, S., Han, K., Han, L. (2023) Global burden of ischemic stroke in young adults in 204 countries and territories. *Neurology*, 100(4), e422-e434.
- [17] Werring, D., Adams, M., Benjamin, L., Brown, M., Chandratheva, A., Cowley, P., Toma, A. (2024) Stroke and cerebrovascular diseases. *Neurology: A Queen Square Textbook*, 107-198.
- [18] Wang, L., Wang, J. Y., Chen, C., Kang, M., Xu, S. H., Wei, H., Shao, Y. (2024) OCTA evaluates changes in retinal microvasculature in renal hypertension patients. *Scientific Reports*, 14(1), 28910.
- [19] Colcombe, J., Solli, E., Kaiser, A., Ranadive, I., Bolneni, S., Berger, J., Modi, Y. (2025) The use of retinal imaging including funduscopy, OCT, and OCTA for cardiovascular risk stratification and the detection of subclinical atherosclerosis. *Current Atherosclerosis Reports*, 27(1), 23.
- [20] Donaldson, L., Chen, M., Margolin, E. (2023) Transsynaptic ganglion cell degeneration in adult patients after occipital lobe stroke. *Journal of Neuro-Ophthalmology*, 43(2), 243-247.
- [21] Rong, X., Sun, X., Hao, Y., Sun, X., Li, J., Nie, H. (2023) Assessment of peripapillary retinal nerve fiber layer thickness and vessel density in newly diagnosed SLE patients without ocular symptoms. *Graefes Archive for Clinical and Experimental Ophthalmology*, 261(12), 3599-3606.
- [22] Yang, T. Y., Zhang, T. Q., Xie, L. Q., Zhang, Y., Liu, S. M., Zeng, X. W., Xu, G. X. (2023) Quantitative study of peripapillary retinal nerve fiber layer thickness and peripapillary vessel density in patients with different stages of Parkinson's disease. *International Journal of Ophthalmology*, 16(5), 762.
- [23] Cheng, J., Paracha, S. S., Agrawal, S., Wu, Z., Sung, C. H. (2025) Recent advances in visual dysfunction and ocular biomarkers in neurological disorders. *Eye and Brain*, 49-67.
- [24] Mantovani, E., Zucchella, C., Argyriou, A. A., Tamburin, S. (2023) Treatment for cognitive and neuropsychiatric non-motor symptoms in Parkinson's disease: current evidence and future perspectives. *Expert Review of Neurotherapeutics*, 23(1), 25-43.
- [25] Casciano, F., Zauli, E., Celeghini, C., Caruso, L., Gonelli, A., Zauli, G., Pignatelli, A. (2024) Retinal alterations predict early prodromal signs of neurodegenerative disease. *International Journal of Molecular Sciences*, 25(3), 1689.
- [26] Singh, R., Singh, B., Hussain, A., Ranjan, R., Chandra, S., Joshi, D. (2025) Comparison of retinal nerve fiber layer (RNFL) and ganglion cell-inner plexiform layer (GC-IPL) thickness in low to moderate myopic patients using SD-OCT in the rural population of western Uttar Pradesh. *International Journal of Life Sciences*

- Biotechnology and Pharma Research*, 14(4), 1126-1133.
- [27] Moawad, E. M., Abd-ElHady, M. E., Fouda, B. H., Asran, A. S., Hashish, E. A. (2025) Structural and functional retinal and optic nerve changes in Parkinson's disease: an OCT-based study. *Suez Canal University Medical Journal*, 28(11), 33-43.
- [28] Casciano, F., Zauli, E., Celeghini, C., Caruso, L., Gonelli, A., Zauli, G., Pignatelli, A. (2024) Retinal alterations predict early prodromal signs of neurodegenerative disease. *International Journal of Molecular Sciences*, 25(3), 1689.
- [29] Di Maio, L. G., Cennamo, G., Montorio, D., De Michele, G., Palmieri, G. R., Baratto, L., De Rosa, A. (2024) Spectral domain and angiography optical coherence tomography in Parkinson's disease: structural and vascular changes in the retina correlate with disease severity and progression. *Acta Neurologica Scandinavica*, (1), 8555083.
- [30] Salehi, M. A., Rezaghali, F., Mohammadi, S., Zakavi, S. S., Jahanshahi, A., Gouravani, M., Singh, R. P. (2023) Optical coherence tomography angiography measurements in Parkinson's disease: a systematic review and meta-analysis. *Eye*, 37(15), 3145-3156.
- [31] Dighriri, I. M., Aldalbahi, A. A., Albeladi, F., Tahiri, A. A., Kinani, E. M., Almohsen, R. A., Altowairqi, F. (2023) An overview of the history, pathophysiology, and pharmacological interventions of multiple sclerosis. *Cureus*, 15(1), e33242.
- [32] Filippi, M., Preziosa, P., Arnold, D. L., Barkhof, F., Harrison, D. M., Maggi, P., Rocca, M. A. (2023) Present and future of the diagnostic work-up of multiple sclerosis: the imaging perspective. *Journal of Neurology*, 270(3), 1286-1299.
- [33] Tramacere, I., Virgili, G., Perduca, V., Lucenteforte, E., Benedetti, M. D., Capobussi, M., Filippini, G. (2023) Adverse effects of immunotherapies for multiple sclerosis: a network meta-analysis. *The Cochrane Database of Systematic Reviews*, (11), CD012186.
- [34] Liu, J., Song, S., Gu, X., Li, H., Yu, X. (2023) Microvascular impairments detected by optical coherence tomography angiography in multiple sclerosis patients: a systematic review and meta-analysis. *Frontiers in Neuroscience*, 16, 1121899.
- [35] Mohammadi, S., Gouravani, M., Salehi, M. A., Arevalo, J. F., Galetta, S. L., Harandi, H., Paul, F. (2023) Optical coherence tomography angiography measurements in multiple sclerosis: a systematic review and meta-analysis. *Journal of Neuroinflammation*, 20(1), 85.
- [36] Bostan, M., Li, C., Cheong, J. W., Wong, D. W. K., Tan, B., Ismail, M. B., Chua, J. (2025) Longitudinal analysis of retinal and choriocapillaris in patients with multiple sclerosis: a 3-year study. *Journal of Neurology*, 272(3), 237.
- [37] Vujosevic, S., Parra, M. M., Hartnett, M. E., O'Toole, L., Nuzzi, A., Limoli, C., Nucci, P. (2023) Optical coherence tomography as retinal imaging biomarker of neuroinflammation/neurodegeneration in systemic disorders in adults and children. *Eye*, 37(2), 203-219.
- [38] Elahi, R., Taremi, S., Najafi, A., Karimi, H., Asadollahzadeh, E., Sajedi, S. A., Sahraian, M. A. (2025) Advanced MRI methods for diagnosis and monitoring of multiple sclerosis (MS). *Journal of Magnetic Resonance Imaging*, 62(6), 1546-1578.