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REVIEW ARTICLE

The role of optical coherence tomography angiography in diseases of the posterior segment of the eye

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Summary

Optical coherence tomography angiography (OCTA) is a non-invasive, quantitative tool for imaging the retina and choroid that can visualize the microvasculature in three dimensions. It is widely used for diagnosing and monitoring treatment response for various diseases of the anterior and posterior segments of the eye. A systematic search of the relevant literature was conducted, focusing on the period of the most intensive development and clinical application of OCT angiography. This paper aims to summarize current knowledge of OCTA applications in the diagnosis and monitoring of posterior segment retinal pathologies and to discuss its advantages over traditional imaging techniques.

Keywords: optical coherence tomography angiography, posterior segment diseases, retinal vasculature, retinal vascular diseases

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INTRODUCTION

Optical coherence tomography angiography (OCTA) is a non-invasive imaging modality for visualizing the choroid and retina and imaging the microvasculature in three dimensions. It is widely used for diagnosing and following treatment response for various ophthalmological diseases (1, 2). Its use in assessing systemic conditions, such as cardiovascular, endocrine, respiratory, and neurological diseases, is also important (2, 3). The application of OCTA to systemic conditions improves understanding of disease pathogenesis and may identify potential biomarkers crucial for diagnosis, treatment, and prognosis (2).

By analyzing repeated sections of the same retinal area, it is possible to distinguish signal changes caused by moving molecules, such as red blood cells, from other sources, i.e., eye movements, in the OCT signal. This is the basis for creating a contrast image that highlights blood vessels against static surrounding tissues (1). Fluorescein angiography (FA), which required intravenous injection of dye, provided two-dimensional pictures of the back of the eye, with a larger field of view. The advantage of OCTA lies in its ability to visualize both the structure and blood flow within the vitreous, retina, and choroid, and to examine different depths of capillary networks. However, optical coherence tomography angiography has certain limitations, such as reduced light penetration into deeper layers due to the opacity of the optical media or image artifacts caused by patient non-cooperation or eye movements (1). Invasive methods such as FA and indocyanine green angiography can monitor phenomena such as leakage, dye accumulation, and staining that OCTA cannot, because the dynamics of blood cell movement are not included (4). Retinal pathology may be masked by leakage or hemorrhage, in which case OCTA is particularly useful because it can provide high-contrast, well-defined images of the microvasculature beneath the area (4). OCTA is a diagnostic adjunct for numerous ophthalmologic diseases (1, 4).

This paper aims to summarize current knowledge of OCTA applications in the diagnosis and monitoring of posterior segment retinal pathologies and to discuss its advantages over traditional imaging techniques.

MATERIALS AND METHODS

For this review paper, a systematic literature review was conducted in PubMed. The search included works published from January 2016 to January 2026, a period representing the decade of the most intensive development and clinical application of OCT angiography. As a criterion for literature selection, English-language keywords were used: optical coherence tomography angiography, OCTA, posterior segment diseases, retinal vasculature, retinal vascular diseases, retinal vein occlusion, diabetic retinopathy, age-related macular degeneration, AMD, wet form AMD, dry form AMD, chloroquine maculopathy, retinal dystrophy, macular dystrophy, ocular trauma.

The clinical importance of OCTA in the evaluation of diseases of the retina and choroid

Hydroxychloroquine retinopathy

Hydroxychloroquine (HCQ) is a safer metabolite of chloroquine, commonly used to treat various autoimmune diseases (5). A serious ocular side effect of this drug is retinal toxicity. HCQ is thought to bind to melanin within retinal pigment epithelium (RPE) cells, leading to damage of photoreceptors and the outer nuclear layer of the retina (6). This toxicity is irreversible and can cause blindness. Screening and early detection before RPE damage occurs can help preserve vision (6). According to the latest recommendations from the American Academy of Ophthalmology (AAO) published in November 2025, the primary risk factors for hydroxychloroquine retinopathy include exceeding the reference daily dosage, use for more than 5 years, kidney disease, tamoxifen use, and older age (7). The AAO recommends that all patients undergo annual screening after 5 years of continuous use of these drugs, while those at high risk should be examined more frequently (7). Diagnostic methods for HCQ retinal toxicity include, according to the latest guidelines, spectral domain OCT (SDOCT), fundus autofluorescence (FAF), automated perimetry (threshold 24-2C), and multifocal electroretinogram (7). Most European patients initially show RPE damage in a classic parafoveal pattern, while most Asian patients show extramacular damage near the arcades (7). Screening is essential during antimalarial therapy because if HCQ-induced damage remains undetected, irreversible vision loss can occur (7). The role of OCTA in the diagnosis of HCQ toxicity has become increasingly prominent in recent years. Some authors report that patients treated with HCQ for more than 5 years exhibit significant loss of vessel density (VD) in the parafoveal and perifoveal regions, while the foveolar avascular zone (FAZ) area is significantly larger than in low-risk patients (less than 5 years of use) and controls (6).

On the other hand, results from other studies on the role of OCTA in diagnosing HCQ toxicity differ among investigators, leading to conflicting outcomes. Although OCTA has revolutionized the diagnosis of many retinal diseases, it is still not included in the latest AAO guidelines for screening for HCQ toxicity. Several factors could explain this exclusion. HCQ toxicity primarily targets the RPE and photoreceptor layers. While OCTA measures blood flow and vascular density, SDOCT and FAF directly visualize these specific layers. In addition, large, longitudinal studies showing that OCTA changes consistently precede the structural changes seen on SD-OCT are lacking. One of the main barriers to incorporating OCTA into official guidelines is the lack of a normative database and device interoperability. Although consensus has not yet been reached among researchers, OCTA remains a valuable, highly accurate, and reproducible method for monitoring patients on HCQ therapy, helping to assess when to discontinue the drug based on observed changes in parameters (6).

Diabetic retinopathy

Diabetic retinopathy (DR) is a microangiopathy that affects the small blood vessels of the retina (8). OCTA can identify early DR changes and provide a quantitative assessment of disease progression and possible complications across all retinal layers (8). Diabetic retinopathy may affect different layers of the retina, and OCTA could be useful for analyzing current and future treatments (9). It is known that the earliest clinical features of DR include microaneurysms, changes in venous blood vessels, intraretinal microvascular abnormalities, and, later, hard exudates and retinal hemorrhages (8). Progression to proliferative diabetic retinopathy is characterized by retinal neovascularization (10). OCTA can detect the earliest signs of microvascular changes in several studies (11-14) and identify capillary loss before lesions become clinically apparent (13, 15, 16). However, microaneurysms and vascular leakage are more effectively detected by fluorescein angiography (7). A key parameter of OCTA is the measurement of the FAZ size and total retinal ischemia, which helps minimize segmentation errors and account for confounding factors such as central involvement in diabetic macular edema (7). Given that the variability in FAZ size among healthy individuals is considerable, using FAZ area alone is of limited value (17, 18). The inclusion of additional parameters such as para-FAZ vessel density and FAZ circularity could improve the accuracy of assessing severity (19, 20).

The authors concluded that a reduction in VD in certain regions of the superficial and deep capillary plexus may indicate progression of diabetic retinopathy from the subclinical to the clinical phase and serve as a screening marker in people with diabetes without clinically detected retinopathy (21). Others analyzed differences in OCTA parameters between type 1 patients without diabetic retinopathy who received different treatment modalities (multiple daily insulin injections vs. continuous subcutaneous insulin infusion). They found a significantly lower parafoveal and perifoveal deep VD in the multiple daily insulin injections group. They concluded that continuous subcutaneous insulin infusion might be a better option than multiple daily insulin injections for preventing retinal complications, as it provides greater protection against retinal microvascular damage in the stages before the onset of DR (22).

As OCTA continues to develop and improve, it will reveal anatomical and vascular details with much greater precision, along with the identification of sensitive biomarkers (7).

Retinal vascular diseases

OCTA allows the characterization of a wide range of retinal vascular diseases, including macroaneurysms, capillary remodeling, neovascularization, macular telangiectasias, retinal nonperfusion, and venous malformations (23, 24, 25, 26, 27). The application of OCTA has provided new insights into the anatomy and pathological processes of these conditions, contributing to easier, faster diagnosis, disease monitoring, and treatment, and to improved patient outcomes (26). Although current OCTA devices cannot assess vascular permeability or blood-retinal barrier integrity, they can generate high-contrast images of the microvasculature approaching the tissue-level resolution of blood vessels (28). In retinal vascular disorders, it is essential to establish the extent of ischemia or non-perfusion, vascular changes, tortuosity, dilation, non-perfusion areas, collateral vessel development, or neovascularization (29). The degree of capillary non-perfusion helps differentiate ischemic from non-ischemic retinal vein occlusion (RVO) and estimate the potential risk of neovascularization (30). Quantitative assessments using OCTA include measurement of the density, size, and extent of the FAZ. Evidence suggests that there is a reduced vascular density in the foveal and parafoveal capillary plexuses in RVO (31, 32). Also, in RVO, the deep plexus capillaries are usually more severely affected than the superficial ones (33, 34), most often as a consequence of the direct communication of the deep venous plexus with the main veins and the absence of vascular smooth muscle in the superficial plexus (34). In addition, FAZ enlargement in the deep capillary plexus is a common finding in the retinal venous plexus (35, 29). OCTA may be of great value in non-invasive retinal vascular imaging, facilitating prognostic assessment, monitoring therapy, and establishing thresholds and reference values that could be key predictors of treatment outcome in RVO (29).

Age-related macular degeneration

Age-related macular degeneration (AMD) is the leading cause of central vision loss worldwide. It has two forms: dry and wet. The advanced stage of dry AMD is characterized by geographic atrophy (GA), whereas in wet AMD, choroidal neovascularization is present. OCTA enables detailed analysis of the retinal and choriocapillary vascular networks, helping to understand the disease itself and identify characteristics indicating risk of disease progression (36). In addition to choriocapillary flow and vascular density, OCTA can also monitor the accumulation of sub-RPE deposits (37, 38). The presence of retinal drusenoid deposits may indicate outer retinal hypoxia. Changes in flow often precede RPE atrophy, and flow impairment at GA margins may predict the evolution patterns (36). Yet, OCTA limitations, such as image quality issues caused by structural changes in the RPE with drusen, difficulty measuring choroidal layer thickness, shadowing, and signal loss under the RPE or drusen, can lead to misinterpretation of perfusion status (39). In wet AMD, advances in OCTA improve the illustration of the choriocapillaris and deepen the understanding of this form of the disease. Diagnostic classifications of wet AMD have also evolved. It is now known that macular neovascularization (MNV) can originate from different sources, so the new classification includes three MNV subtypes according to the origin of MNV: Type 1-vessels from choriocapillaris into sub-RPE space; Type 2-vessels from choroid into subretinal space; and Type 3-vessels growing from retinal network toward outer retina (35). Accurate diagnosis and monitoring of therapeutic effect rely on OCTA detection of specific features, such as vascular branching, vascular loops, and peripheral anastomotic arcades, which may indicate impaired flow or localized atrophy (40). Growth patterns, such as neovascular lesions at the inner and outer edges and the presence of fluid, which may be intraretinal, subretinal, or sub-RPE, can also be analyzed. Non-absorbable subretinal fluid during vascular endothelial growth factor (VEGF) inhibitor treatment is often due to RPE drainage issues rather than disease activity, which may influence whether further treatment is needed. Fluid in the sub-RPE space may signal active or recurrent disease. Detection of fluid in any of these spaces indicates the need for continued or repeated anti-VEGF therapy (41). OCTA helps visualize the microcirculation of the retina and choroid, identify signs of recurrence, and thus prevent further morphological damage (42).

Retinal dystrophies

Hereditary retinal dystrophies are relatively rare compared with other retinal disorders, such as age-related macular degeneration. However, they cause significant visual acuity loss due to progressive degeneration of the photoreceptor-RPE complex (43, 44), especially in the age group between 21 and 60 years (43). This group of diseases is clinically and genetically heterogeneous, so early detection is essential for diagnosis and prognosis (43). Retinitis pigmentosa, the most common retinal dystrophy, is associated with mutations in approximately 100 genes. It often begins with night blindness, followed by progressive visual field loss, and in advanced stages may also involve the macula (45). Macular dystrophies show great clinical variability. Symptoms such as photophobia, color vision deficits, reading difficulties, and loss of visual acuity tend to develop early and usually precede visual field defects (46). The most common macular dystrophies are Stargardt disease, vitelliform macular dystrophy, and North Carolina macular dystrophy. Understanding of changes in retinal vascular structures in inherited retinal dystrophies is limited, but OCTA is considered a useful diagnostic tool for analyzing and identifying retinal changes (43, 47). Retinitis pigmentosa is characterized by narrowing of the retinal blood vessels, whereas in macular dystrophies, the blood vessels appear normal (45). The FAZ serves as a key indicator of central vision health, with its size and shape analyzed to assess macular condition (43). Various studies have shown that in macular dystrophies, the size and area of the FAZ do not change significantly (46, 47). In patients with retinitis pigmentosa and macular edema, the FAZ in the superficial vascular plexus is reduced in both the vertical and horizontal dimensions.

In contrast, in patients without macular edema, the FAZ in the same plexus is reduced only vertically (45, 48). In patients with macular dystrophies, there is a significant decrease in flow within the superficial plexus and deep layers (outer retina, choriocapillaris) (47, 49). On the other hand, in patients with retinitis pigmentosa and edema, the most significant reduction in perfusion and flow occurs in the choriocapillaris (48, 49). All of this suggests that OCTA is a valuable tool for examining vascular changes, abnormalities, and potential biomarkers in patients with retinal dystrophies (43).

Blunt ocular trauma

Blunt trauma to the eye is the most common ocular injury that can cause monocular blindness (50). The possible complications after blunt ocular trauma are hyphema, retinal contusion, retinal tear, retinal detachment, retinal or vitreous hemorrhage, or traumatic optic neuropathy (50). OCTA, as a rapid, non-invasive, and detailed imaging technique, allows detailed visualization of the retinal and choriocapillary vascular networks (51). Studies show that changes in the FAZ are not significant in the first 24 hours after trauma (52). In contrast, after 2 weeks, changes can be detected in the superficial capillary plexus and, less frequently, in the deep capillary plexus (50). Early microcirculatory disturbances can also be observed, even in the absence of visible clinical lesions (52). Blunt trauma temporarily reduces retinal blood vessel density, impairing retinal blood flow. The resulting ischemia increases VEGF and oxygen transport, leading to changes in the capillary network and narrowing of the FAZ (53). The mechanisms underlying this OCTA finding may include stretching of the neurosensory retina due to mechanical force from blunt trauma, transferring the force to the retinal vascular plexus and inducing vasogenic responses, such as arterial spasm and changes in blood flow (50). The role of OCTA in detecting changes not visible on clinical examination is crucial for the diagnosis, appropriate therapy, and follow-up of traumatized patients (50).

CONCLUSION

In summary, OCTA provides detailed, non-invasive insight into the retinal vascular architecture that was previously unattainable without contrast agents. Its clinical utility is most evident in the early diagnosis of choroidal neovascularization and the quantification of macular ischemia. Despite challenges, OCTA represents a paradigm shift in retinal imaging, offering a safer, faster, and more precise approach to personalized patient care and could be the gold standard for longitudinal follow-up and clinical decision-making.

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Data Availability Statement: The datasets used and/or analyzed during the current study are available without restriction from the corresponding author. All relevant data are within the paper.

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ULOGA OPTIČKE KOHERENTNE TOMOGRAFIJE ANGIOGRAFIJE U BOLESTIMA ZADNJEG SEGMENTA OKA

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Sažetak

Optička koherentna tomografska angiografija (OCTA) je neinvazivna, kvantitativna alatka za snimanje mrežnjače i horoideje, sposobna da vizualizuje mikrovaskulaturu u tri dimenzije. Široko se koristi za dijagnostikovanje i praćenje odgovora na lečenje različitih bolesti prednjeg i zadnjeg segmenta oka. Sprovedena je sistematska pretraga relevantne literature, sa akcentom na period najintenzivnijeg razvoja i kliničke primene OCT angiografije. Cilj ovog rada jeste da sumira aktuelna saznanja o ulozi OCTA u dijagnostici i praćenju oboljenja zadnjeg segmenta retine, kao i da analizira njene prednosti u poređenju sa konvencionalnim tehnikama snimanja.

Ključne reči: optička koherentna tomografska angiografija, bolesti zadnjeg segmenta, vaskulatura mrežnjače, vaskularne bolesti mrežnjače

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