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THE ROLE OF OPTICAL COHERENCE TOMOGRAPHY IN THE EARLY DETECTION OF GLAUCOMA AND AGE-RELATED MACULAR DEGENERATION

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Abstract

Optical coherence tomography (OCT) is a modern, non-invasive diagnostic modality in ophthalmology that enables high-resolution cross-sectional imaging of ocular tissues. This article provides a comprehensive analysis of the role of OCT in the early detection of glaucoma and age-related macular degeneration (AMD), highlighting its capabilities, advantages, and clinical significance.

Glaucoma is a chronic optic neuropathy characterized by the progressive loss of retinal ganglion cells, leading to characteristic structural changes in the optic nerve head and the retinal nerve fiber layer (RNFL). Age-related macular degeneration, on the other hand, is a degenerative disease affecting the macular region and is a leading cause of gradual central vision loss.

OCT allows precise assessment of key structural parameters in glaucoma, including optic nerve head metrics (disc area, rim area, and cup-to-disc ratio), peripapillary RNFL thickness, and the macular ganglion cell complex. In AMD, OCT enables high-resolution visualization of pathological features such as drusen, geographic atrophy, and choroidal neovascularization.

Advancements in spectral-domain OCT (SD-OCT) and swept-source OCT (SS-OCT) technologies have significantly enhanced diagnostic capabilities. Furthermore, OCT angiography (OCTA) provides additional insights into retinal and choroidal microvascular networks without the need for dye injection.

This article discusses the diagnostic value of OCT in the early detection of glaucoma and AMD, as well as the future prospects of its integration with artificial intelligence technologies.

Keywords: Optical coherence tomography, glaucoma, age-related macular degeneration, retinal nerve fiber layer, ganglion cell complex, macula, early diagnosis, OCT angiography.

Introduction

Diseases of the visual system are among the leading causes of disability and reduced quality of life worldwide. According to data from the Global Burden of Disease study, more than 80 million people were affected by glaucoma globally

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in 2020, and this number is projected to exceed 100 million by 2040 [1]. Age-related macular degeneration (AMD) is the leading cause of blindness among individuals over 50 years of age in developed countries [2]. Both conditions are characterized by an asymptomatic course in their early stages, while in advanced stages they lead to irreversible vision loss. Therefore, early diagnosis and timely initiation of treatment are crucial for improving prognosis.

Glaucoma is a chronic optic neuropathy characterized by the progressive loss of retinal ganglion cells (RGCs) and their axons, resulting in characteristic structural changes in the optic nerve head (ONH) and the retinal nerve fiber layer (RNFL), along with corresponding visual field defects [3]. Major risk factors include elevated intraocular pressure (IOP), age, myopia, genetic predisposition, and vascular dysfunction [4,5]. The two principal types of glaucoma are primary open-angle glaucoma (POAG) and angle-closure glaucoma (ACG), each with distinct pathogenetic mechanisms [6].

Age-related macular degeneration is a progressive degenerative disorder affecting the macular region, leading to gradual loss of central vision. AMD is broadly classified into two main forms: dry (atrophic) and wet (neovascular) [2]. The dry form is characterized by the presence of drusen and geographic atrophy, whereas the wet form involves choroidal neovascularization (CNV) accompanied by the accumulation of blood and fluid in the macular region [7].

Optical coherence tomography (OCT) has revolutionized ophthalmic diagnostics over the past two decades. It is a non-invasive imaging modality that provides high-resolution (1–15 μm) cross-sectional images of biological tissues [8]. OCT operates on principles analogous to ultrasound imaging; however, it utilizes light interference instead of sound waves, enabling significantly higher resolution [9]. The evolution of OCT technology from time-domain OCT (TD-OCT) to spectral-domain OCT (SD-OCT), and more recently to swept-source OCT (SS-OCT), has markedly improved imaging speed and diagnostic accuracy [10].

At present, OCT is not only a key diagnostic tool for glaucoma and AMD, but also plays a central role in the diagnosis and monitoring of numerous other ophthalmic conditions, including diabetic retinopathy, retinal vascular occlusions, macular holes, epiretinal membranes, and other retinal disorders [11].

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In particular, OCT is indispensable for the early detection and longitudinal monitoring of chronic, progressive diseases such as glaucoma and AMD.

The aim of this article is to comprehensively analyze the role of optical coherence tomography in the early detection of glaucoma and age-related macular degeneration, as well as to evaluate its modern capabilities, principal diagnostic parameters, and clinical significance in ophthalmology.

Physical and Technical Principles and Types of Optical Coherence Tomography

History and Fundamental Principles of OCT

Optical coherence tomography was first introduced in 1991 by Huang et al. at the Massachusetts Institute of Technology [8]. The technique is derived from optical coherence reflectometry, which was initially used for detecting defects in fiber-optic cables. OCT operates in a manner analogous to ultrasound imaging; however, instead of sound waves, it employs low-coherence light [9]. Based on the principle of interferometry, this technology analyzes the interference between reflected and backscattered light signals from biological tissues to generate high-resolution cross-sectional images.

The principal advantages of OCT include its non-invasive nature, high spatial resolution (1–15 μm), rapid acquisition time, reproducibility, and the absence of a requirement for contrast agents [9,10].

Generations of OCT

Time-domain OCT (TD-OCT) represents the first generation of OCT devices, operating at a speed of approximately 400 A-scans per second [10]. In these systems, the depth information of reflected light signals is obtained through mechanical movement of a reference mirror. The main limitations of TD-OCT include low scanning speed and the ability to produce only two-dimensional images, which increases susceptibility to motion artifacts and reduces image resolution.

Spectral-domain OCT (SD-OCT), the second generation of OCT technology, belongs to the Fourier-domain OCT (FD-OCT) category. SD-OCT utilizes a light

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source with a wavelength of approximately 850 nm and operates at speeds of 100,000 A-scans per second or higher [11]. Unlike TD-OCT, SD-OCT does not require mechanical movement of the reference mirror; instead, the entire A-scan profile is acquired simultaneously. This significantly reduces acquisition time and enhances image quality. SD-OCT is widely regarded as the gold standard for the diagnosis of glaucoma and macular diseases.

Swept-source OCT (SS-OCT) represents the third generation of OCT technology and is also a type of FD-OCT. SS-OCT employs a tunable laser source with a wavelength of approximately 1050 nm and operates at speeds exceeding 200,000 A-scans per second [12]. Its main advantages include improved visualization of deeper structures such as the choroid and lamina cribrosa, reduced signal attenuation, and the ability to perform wide-field imaging [12,13]. This technology has opened new possibilities for studying lamina cribrosa changes in glaucoma and choroidal blood flow alterations in AMD.

OCT angiography (OCTA) is a non-invasive, dye-free imaging modality that visualizes blood flow based on motion contrast generated by erythrocytes [14]. OCTA enables layer-by-layer assessment of retinal and choroidal microvascular networks, including radial peripapillary capillaries, as well as superficial, intermediate, and deep capillary plexuses [14,15]. OCTA plays a crucial role in the early detection of microvascular alterations in both glaucoma and AMD.

OCT-Based Anatomical Foundations of the Retina and Optic Nerve

Accurate interpretation of OCT images requires a thorough understanding of the anatomy of the retina and the optic nerve (ON).

Retinal Layers

The retina consists of ten distinct layers, several of which can be clearly delineated using OCT [16]:

1.**Retinal nerve fiber layer (RNFL)** – the innermost layer, composed of axons of retinal ganglion cells; it is one of the most critical parameters in glaucoma diagnostics.

2.**Ganglion cell layer (GCL)** – consists of the cell bodies of ganglion cells.

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3.**Inner plexiform layer (IPL)** – a synaptic zone between dendrites of ganglion cells and axons of bipolar cells.
4.**Inner nuclear layer (INL)** – composed of the cell bodies of bipolar, horizontal, and amacrine cells.
5.**Outer plexiform layer (OPL)** – synaptic region between photoreceptors and bipolar cells.
6.**Outer nuclear layer (ONL)** – contains the nuclei of photoreceptors.
7.**Photoreceptor layer** – consists of rod and cone segments.
8.**Retinal pigment epithelium (RPE)** – a monolayer of pigmented cells.
9.**Bruch's membrane** – a basal membrane located between the RPE and the choroid.
10.**Choroid** – a highly vascularized layer supplying the outer retina.
The ganglion cell complex (GCC) comprises the RNFL, GCL, and IPL layers and is among the earliest structures affected in glaucoma [17,18].

Optic Nerve Head (ONH) Parameters
OCT enables quantitative assessment of key ONH parameters [19,20]:
-Disc area
-Neuroretinal rim area
-Cup-to-disc ratio (vertical and horizontal)
-Cup volume
-Bruch's membrane opening–minimum rim width (BMO-MRW)

Lamina Cribrosa
Using swept-source OCT (SS-OCT), it is possible to visualize the depth, curvature, thickness, and focal defects of the lamina cribrosa [20]. The lamina cribrosa is considered a primary site of mechanical stress in the pathogenesis of glaucoma.

Macula
The macula is responsible for central vision and contains a high density of photoreceptors. OCT allows detailed measurement of the thickness of macular

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RNFL, GCL, IPL, INL, ONL, RPE, and choroid [18]. The foveal avascular zone (FAZ) can be effectively visualized using OCT angiography (OCTA) [14].

Glaucoma: General Characteristics and Diagnostic Challenges

Definition and Classification of Glaucoma

Glaucoma is a heterogeneous group of diseases characterized by progressive loss of retinal ganglion cells, resulting in characteristic optic nerve head cupping (excavation), thinning of the neuroretinal rim, and corresponding visual field defects [3].

The main types of glaucoma include [3,6]:

1.Primary open-angle glaucoma (POAG) – the most common form (70–90% of cases).

2.Angle-closure glaucoma (ACG) – less common but typically more severe.

3.Normal-tension glaucoma (NTG) – characterized by glaucomatous damage despite normal intraocular pressure.

4.Primary glaucoma – associated with genetic predisposition and age-related changes.

5.Secondary glaucoma – resulting from other conditions (e.g., diabetes, uveitis, trauma) or medications (e.g., corticosteroids).

Epidemiology

In 2020, approximately 80 million individuals worldwide were affected by glaucoma, and this number is projected to reach 111.8 million by 2040 [1]. In Europe, the prevalence of glaucoma among individuals aged 40–80 years is estimated at 2.93%, with 2.51% attributed to POAG [1]. The highest prevalence rates are observed in African and Asian populations.

Clinical Diagnostic Challenges

The diagnosis of glaucoma is based on a combination of clinical and instrumental methods [3,4,21]:

Ophthalmoscopy – evaluation of the optic nerve head (cup-to-disc ratio >0.5, focal or diffuse thinning of the neuroretinal rim).

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Tonometry – measurement of intraocular pressure (normal range: 10–21 mmHg).
Gonioscopy – assessment of the anterior chamber angle.
Perimetry – evaluation of the visual field using standard automated perimetry (SAP).
OCT – quantitative assessment of structural parameters.

Major Diagnostic Challenges [21,22]

1.Late diagnosis – visual field defects are not detectable until approximately 40–50% of retinal ganglion cells (RGCs) are lost, a stage referred to as "preperimetric glaucoma."
2.Subjectivity – perimetric results depend on the patient's attention and level of cooperation.
3.Interobserver variability – ophthalmoscopic findings may vary depending on the clinician's experience.
4.Diagnostic difficulty in myopic eyes – due to optic disc tilt, peripapillary atrophy, and posterior staphyloma.
5."Green disease" – presence of glaucoma despite OCT parameters remaining within the normal range [22].
6."Red disease" – false-positive OCT findings suggesting pathology in non-glaucomatous myopic eyes [22].

The Role of OCT in Glaucoma Diagnosis

Peripapillary RNFL Thickness

Peripapillary retinal nerve fiber layer (RNFL) thickness is one of the most important parameters assessed by OCT in glaucoma diagnostics [23,24]. RNFL thinning is often an early indicator of glaucoma and may be detected years before the onset of visual field defects [24].

Normative data. Spectral-domain OCT (SD-OCT) devices incorporate age-adjusted normative databases. RNFL thickness physiologically decreases with age at a rate of approximately −0.48 to −0.60 µm per year [23]. Normative classification is typically color-coded: green indicates normal (>99th percentile),

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yellow indicates borderline (95th–99th percentile), and red indicates abnormal (<5th percentile) [22,23].

Diagnostic accuracy. Average RNFL thickness and inferior sector RNFL thickness demonstrate the highest sensitivity and specificity for glaucoma detection (sensitivity: 60–98%, specificity: 80–95%) [23,24]. In preperimetric glaucoma, sensitivity ranges from 21% to 87% [23].

Asymmetry. An inter-eye difference in average RNFL thickness exceeding 9 µm significantly increases the likelihood of glaucoma [22,24].

Floor effect. Once RNFL thickness reaches its residual "floor" level (approximately 49–65 µm), further changes become difficult to detect, limiting its utility in monitoring advanced glaucoma [25].

Macular Ganglion Cell Complex

The macular region contains the highest density of RGCs (approximately 50% of the total RGC population). OCT enables measurement of the ganglion cell complex (GCC: RNFL + GCL + IPL) or ganglion cell–inner plexiform layer (GCIPL: GCL + IPL) thickness [17,18,26].

Diagnostic value. Macular GCIPL parameters demonstrate diagnostic accuracy comparable to, and in some studies superior to, RNFL measurements for detecting preperimetric and early-stage glaucoma [17,18,26]. Average and minimum GCIPL thickness are the most informative parameters.

Advantage in myopic eyes. In myopic eyes, optic nerve head tilt and peripapillary atrophy may compromise RNFL measurements. In contrast, macular GCIPL is less affected by axial length and provides higher specificity in glaucoma diagnosis [26].

Hemifield asymmetry along the horizontal raphe. Automated detection of asymmetry between superior and inferior hemifields along the horizontal raphe on GCIPL maps demonstrates high diagnostic accuracy for early glaucoma (AUROC: 0.97) [27].

Temporal raphe sign. The presence of a horizontal demarcation line along the temporal raphe on GCIPL maps is considered a pathognomonic feature of glaucoma and assists in differentiating it from other optic neuropathies [27].

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Optic Nerve Head Parameters

OCT-based three-dimensional volumetric scans enable detailed assessment of optic nerve head (ONH) parameters [19,20,28]:

Disc area (normal range: 1.5–2.5 mm^2)

Neuroretinal rim area (reduced in glaucoma)

Cup-to-disc ratio (typically >0.5–0.6 in glaucoma)

Cup volume (increased in glaucoma)

Bruch's membrane opening–minimum rim width (BMO-MRW). This parameter represents the minimum distance from the anatomical landmark of Bruch's membrane opening to the internal limiting membrane. Compared to the conventional cup-to-disc ratio, BMO-MRW is considered more sensitive and reproducible for glaucoma diagnosis [28].

Wide-Field OCT

Swept-source OCT (SS-OCT) enables simultaneous imaging of the optic nerve head and macular region within a single volumetric scan. Wide-field RNFL maps have demonstrated high diagnostic accuracy in detecting preperimetric and early-stage glaucoma [29,30].

Monitoring Glaucoma Progression

OCT provides two principal approaches for detecting glaucoma progression [31,32]:

1.Event-based analysis – for example, Guided Progression Analysis (GPA) in Cirrus OCT; progression is defined when a statistically significant change from baseline is detected.

2.Trend-based analysis – evaluates the rate of change of parameters over time (µm/year).

Rate of progression. A global reduction in average RNFL thickness of ≥5 µm or a sectoral RNFL reduction of ≥7–8 µm is suggestive of progression [31]. A

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decrease in GCIPL thickness exceeding 4 µm is also indicative of disease progression [32].

Predictors of progression. Lower baseline RNFL and GCIPL thickness, faster rates of structural decline, presence of optic disc hemorrhage, advanced age, and elevated intraocular pressure (IOP) are significant risk factors for more rapid progression [31,32].

Role of OCT Angiography in Glaucoma Diagnosis

OCT angiography (OCTA) is a non-invasive, dye-free imaging modality that enables visualization of blood flow and has provided new insights into the role of vascular dysfunction in glaucoma pathogenesis [14,15,33,34].

Key Parameters

Vessel density (VD) – the percentage area occupied by perfused vessels within a given region. Radial peripapillary capillary (RPC) density and macular superficial vessel density are the most extensively studied parameters [33,34].
Flow index (FI) – the average decorrelation value representing blood flow within a specific region.

Vessel Density in Glaucoma

Eyes with glaucoma demonstrate significantly reduced RPC density and macular superficial vessel density compared to healthy controls [33,34]. The diagnostic accuracy of VD is comparable to RNFL and GCIPL thickness (AUROC: 0.85–0.95).

Preperimetric glaucoma. Reduction in VD can be detected at the preperimetric stage, in some cases even before measurable RNFL changes [34].

Floor effect. The floor value of VD is lower than that of RNFL and GCIPL, making it more useful in monitoring advanced-stage glaucoma [35].

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Choroidal Microvascular Dropout (MvD)

MvD refers to a complete loss of choroidal microvasculature in the region of parapapillary atrophy, detectable in the deeper layers on OCTA [36,37]. It is particularly characteristic of glaucoma, especially normal-tension glaucoma, and is strongly associated with optic disc hemorrhage and lamina cribrosa defects [36,37]. The presence of MvD correlates with faster RNFL thinning and more rapid visual field progression [37].

Foveal Avascular Zone (FAZ)

In glaucomatous eyes, the FAZ area is enlarged, and this enlargement correlates with the rate of RNFL and GCIPL thinning [38]. A reduction in FAZ area has been observed following IOP-lowering surgical interventions, suggesting potential revascularization [38].

Age-Related Macular Degeneration: General Overview

Definition and Classification

Age-related macular degeneration (AMD) is a progressive degenerative disorder of the macula and a leading cause of blindness among individuals over 50 years of age [2,7]. AMD is classified into two major forms:

1.Dry (atrophic) AMD (85–90%) – characterized by drusen and geographic atrophy.

2.Wet (neovascular) AMD (10–15%) – characterized by choroidal neovascularization (CNV) and accumulation of fluid and blood in the macular region.

Drusen are extracellular deposits located between the retinal pigment epithelium (RPE) and Bruch's membrane, composed of lipofuscin and lipids. Based on size, drusen are classified as small (<63 μm), intermediate (63–125 μm), and large (>125 μm) [7].

Geographic atrophy is characterized by progressive loss of the RPE, photoreceptors, and choroid.

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Choroidal neovascularization (CNV) occurs due to disruption of Bruch's membrane, allowing abnormal blood vessels to grow from the choroid into the retina.

Epidemiology

In developed countries, signs of AMD are present in approximately 10–15% of individuals over the age of 50. Dry AMD accounts for 85–90% of cases, while wet AMD accounts for 10–15%; however, the latter is responsible for 80–90% of severe vision loss cases [2,7].

Clinical Diagnosis

The diagnosis of AMD is based on the following methods [2,7]:
Fundus examination – detection of drusen, RPE changes, geographic atrophy, and CNV
Fluorescein angiography (FA) – gold standard for detecting CNV
OCT – detailed visualization of macular layers
OCTA – non-invasive detection of CNV without dye injection

Role of OCT in AMD Diagnosis

Dry AMD
OCT provides the following capabilities in the diagnosis of dry AMD [2,7,39]:
Drusen visualization. On OCT, drusen appear as elevations of the RPE layer from Bruch's membrane. OCT allows quantitative assessment of drusen size, number, and distribution.
Geographic atrophy. Appears as areas of complete loss of the RPE and photoreceptors. OCT enables precise delineation of atrophic boundaries and monitoring over time.
Retinal layer thickness. Thinning of outer retinal layers (ONL, photoreceptors) and RPE is observed in dry AMD.
Choroidal thickness. A reduction in choroidal thickness (choroidal atrophy) is commonly observed.

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Wet AMD

OCT is the primary imaging modality for the diagnosis of wet AMD [2,7,40]: Choroidal neovascularization (CNV). On OCT, CNV appears as a hyperreflective, irregular structure located beneath or within the RPE. OCT enables assessment of the location, size, and activity of CNV.

Intraretinal and Subretinal Fluid

On OCT, intraretinal fluid appears as hyporeflective spaces (cysts) within the retinal layers. Subretinal fluid, on the other hand, manifests as a hyporeflective area accumulated between the photoreceptors and the retinal pigment epithelium (RPE).

Pigment Epithelial Detachment (PED)

PED represents an area where the RPE is detached and elevated from Bruch's membrane. On OCT, it is visualized as a convex elevation of the RPE line.

Monitoring Treatment Efficacy

OCT serves as the primary tool for evaluating the efficacy of treatment in neovascular age-related macular degeneration (nAMD), particularly during anti-VEGF therapy [40]. Treatment response is assessed by observing reductions in intraretinal and subretinal fluid, changes in PED volume, and a decrease in central macular thickness.

Role of OCT Angiography in nAMD Diagnosis

OCT angiography (OCTA) provides additional diagnostic capabilities in nAMD [14,15,40]:

-Noninvasive visualization of CNV: OCTA offers a noninvasive alternative to fluorescein angiography, enabling the visualization of choroidal neovascularization (CNV). It allows assessment of CNV morphology, extent, and blood flow.

-Choroidal vascularity index (CVI): CVI, defined as the ratio of the choroidal luminal area to the total choroidal area, has been shown to decrease in nAMD.

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-Choriocapillaris fenestration disruption: OCTA can detect disruptions in the choriocapillaris fenestrations.

Differential Diagnosis

OCT plays a crucial role in differentiating glaucoma and nAMD from other ocular pathologies [21,39]:

Glaucoma differential diagnosis:

Ischemic optic neuropathy (ION): OCT shows typically sectoral thinning of the retinal nerve fiber layer (RNFL) (superior or inferior), sharply demarcated compared to glaucoma.

Hypotensive optic neuropathy: Diffuse RNFL thinning is observed.

Myoclonic epilepsy-related optic neuropathy: RNFL thinning is accompanied by macular changes.

Mitochondrial optic neuropathies (Leber hereditary optic neuropathy, autosomal dominant optic atrophy): Selective damage to the papillomacular bundle is observed.

Differential Diagnosis of nAMD:

Polypoidal choroidal vasculopathy (PCV): OCT shows polyp-like structures beneath the RPE.

Retinal arterial macroaneurysm (RAT): OCT reveals intraretinal fluid and macular edema.

Central serous chorioretinopathy (CSC): OCT demonstrates subretinal fluid with focal RPE detachment.

Myopia-associated choroidal neovascularization: OCT shows CNV accompanied by myopic posterior staphyloma.

Artificial Intelligence and OCT

In recent years, the integration of artificial intelligence (AI) and deep learning technologies with OCT has advanced the diagnosis of glaucoma and nAMD [41,42].

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AI in Glaucoma Diagnostics:
Automated glaucoma detection based on OCT images (AUROC 0.93–0.97).
Visual field prediction using OCT data.
Automatic clustering of glaucoma phenotypes.
Early prediction of disease progression.
AI in nAMD Diagnostics:
Automated detection and segmentation of drusen, geographic atrophy, and CNV.
Predicting the risk of progression from dry to neovascular nAMD.
Predicting response to anti-VEGF therapy.
Segmentation-Free Deep Learning:
Traditional OCT analysis requires precise layer segmentation, which may be error-prone in myopic eyes or in the presence of pathology. Segmentation-free deep learning models analyze entire OCT volumes, eliminating segmentation errors and improving diagnostic accuracy [42].
Clinical Recommendations for OCT Use:
Glaucoma OCT Protocol [21,22,23]:
Peripapillary RNFL scan (200×200 or 512×128).
Macular GCIPL/GCC scan.
3D optic nerve head volume scan.
OCTA (if available) – RPC density and FAZ assessment.
nAMD OCT Protocol [7,39,40]:
Macular volume scan (512×128 or 1024×128).
High-resolution linear scans (HR-lines).
OCTA – for CNV detection.
Follow-Up Intervals [31,32,40]:
Glaucoma: every 6–12 months (depending on progression risk).
Dry nAMD: every 6–12 months.
Neovascular nAMD: every 1–3 months (depending on treatment stage).

Comparative Analysis of OCT Technologies
Time-Domain OCT (TD-OCT) has a scanning speed of 400 A-scans per second, a wavelength of 820 nm, and a resolution of 10–15 µm. Its visualization depth is

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limited. Choroid and lamina cribrosa visualization are poor, and motion artifacts are frequent. Diagnostic accuracy for glaucoma and nAMD is moderate.
Spectral-Domain OCT (SD-OCT) achieves a scanning speed of over 100,000 A-scans per second, using a wavelength of 840–870 nm with a resolution of 5–7 µm. It provides moderate visualization depth, with choroid and lamina cribrosa visualization being average or limited. Motion artifacts are reduced compared to TD-OCT. Glaucoma and nAMD diagnostics are highly accurate.
Swept-Source OCT (SS-OCT) operates at more than 200,000 A-scans per second with a wavelength of 1050 nm and resolution of 5–8 µm. It allows deep visualization, excellent choroid and lamina cribrosa imaging, and minimal motion artifacts. Diagnostic accuracy for both glaucoma and nAMD is very high.

Conclusion

Optical coherence tomography (OCT) has revolutionized the early detection, differential diagnosis, and monitoring of glaucoma and age-related macular degeneration (AMD) in ophthalmology.

Key Conclusions:

1.OCT in Glaucoma Diagnosis:

Peripapillary retinal nerve fiber layer (RNFL) thickness, macular ganglion cell-inner plexiform layer (GCIPL), and optic nerve head (ONH) parameters allow the detection of structural changes even in the preperimetric stage of glaucoma. GCIPL and GCC measurements are particularly valuable in myopic eyes and early glaucoma. Reduced vascular density detected by OCT angiography (OCTA) provides novel insights into the role of vascular dysfunction in glaucoma pathogenesis. Visualization of the lamina cribrosa using swept-source OCT (SS-OCT) is critical for understanding glaucoma mechanisms.

2.OCT in AMD Diagnosis:

OCT enables quantitative assessment of drusen and geographic atrophy in dry AMD, and detection of choroidal neovascularization (CNV), intraretinal, and subretinal fluid in neovascular AMD, allowing monitoring of treatment efficacy.

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OCTA facilitates noninvasive visualization of CNV and evaluation of choroidal blood flow.

3.Advances in OCT Technologies:

Spectral-domain OCT (SD-OCT) is currently regarded as the "gold standard." Swept-source OCT (SS-OCT) offers superior visualization of the lamina cribrosa and choroid, along with wide-field imaging capabilities. OCTA provides dye-free assessment of blood flow.

4.Integration of Artificial Intelligence:

Deep learning models automatically analyze OCT images, improving diagnostic accuracy, reducing segmentation errors, predicting disease progression, and clustering phenotypes.

5.Clinical Significance:

OCT facilitates early diagnosis, helping to prevent irreversible vision loss, objectively evaluate treatment response, and detect disease progression in a timely manner.

Future developments in OCT technology, including adaptive optics OCT, visible-light OCT, wide-field OCTA, broader clinical implementation of AI models, and telemedicine integration, are expected to open new avenues in glaucoma and AMD diagnosis and management.

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