OPTICAL COHERENCE TOMOGRAPHY AND OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY IN OPHTHALMOLOGY

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Abstract: Optical coherence tomography is a non-invasive method of imagining the anterior and the posterior segment of the eye. It is commonly used in ophthalmic practice to diagnose and monitor various pathologies of the eyeball. Optical coherence tomography angiography (OCTA) is a useful tool to visualize the entire retinal and choroidal microvasculature, allowing the assessment of retinal perfusion without intravenous dye administration.

Keywords: OCT, OCTA, optical coherence tomography, optical coherence tomography angiography
INTRODUCTION

The first reports on optical coherence tomography appeared in 1990 from the laboratory of Professor James Fujimoto from Massachusetts Institute of Technology [6,7]. Optical coherence tomography (OCT) is a non-invasive imaging method based on optical scanning. It is an interferometric technique that uses near-infrared light. The principle of action of OCT is based on the interferometric measurement of the scattering or reflection of a light beam with low coherence from individual structures of the eyeball [22]. It allows the detailed assessment of the layered structure of the tissue; therefore, this method is called “in vivo optical biopsy” (see Fig. 1).

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In the following years, the OCT developed intensively and number of clinical publications appeared on the use of OCT in various pathologies of the anterior and posterior segment of the eye [1,3,10,12,15,17,18]. OCT is commonly used in everyday ophthalmic practice and is the most frequently ordered examination in the diagnosis of macular diseases such as age-related macular degeneration, central serous chorioretinopathy, epiretinal membrane and diabetic retinopathy (see Fig. 2 and Fig. 3).

Fig. 1. Normal macula in OCT B-scan.

Fig. 2. OCT- B scan shows thickening of the retina, large drusen, subretinal fluid in a patient with AMD.
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The “gold standard” in retinal vasculature assessment [16]. This method enables visualization of even slight vascular pathologies of the posterior pole and retinal periphery. The main limitation of this technique is the necessity of intravenous dye administration (see Fig. 5).

Optical coherence tomography angiography (OCTA) is a new, non-invasive tool that delivers highly detailed, three-dimensional images of the entire microvasculature of the retina and choroid, providing retinal perfusion assessment without intravenous dye injection [14,19].

Moreover, OCT is being commonly used to diagnose and monitor glaucoma patients. The examination provides assessment of the thickness of the peripapillary nerve fibers, optic disc parameters and thickness of retinal ganglion cells (see Fig. 4).

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Conventional OCT enables a detailed assessment of the structure of the retina but does not allow the assessment of the retinal circulation. Since the 1960s, fluorescein angiography (FA) has been

Fig. 3. OCT- B scan shows subretinal fluid in patient with central serous chorioretinopathy.

Fig. 4. OCT scan in a glaucoma patient.

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Foveal avascular zone (FAZ) is a round capillary-free area within the macula visualized in OCTA scans. The FAZ area in healthy eyes is measured to be about 0.26 mm² in the superficial plexus and 0.49 mm² in the deep vascular plexus. Measurements of the FAZ zone using OCTA have been used in patients with microcirculatory deficiency such as diabetic retinopathy. Studies revealed that the FAZ zone increase in diabetic patients (see Fig. 7).

The outer retina is avascular in the healthy eye; hence the layer is most often visible as a homogeneous, dark background (no flow). Vessels in this layer can be observed only in pathological conditions, such as the macular neovascularization (MNV) in wet age-related macular degeneration (AMD) [2]. The layer of normal choriocapillaris exposes appears as a greyish grainy background. In pathological condi-

Fig. 5.  Fluorescein angiography image showing normal flow in retinal vessels.
Fig. 6. OCTA assessment of the superficial retinal plexus, including detailed measurement and color map of macular vessel density.

Fig. 7. OCTA showing foveal avascular zone area.
Furthermore, OCTA can be used in diagnostics of optic nerve pathologies for example in glaucoma [4,5,11,13]. Pathological vessels have an irregular caliber and course, form waves, bends and loops, so the blood stream may be interrupted. There may be connections between the superficial and deep weaves - shunts, rarely seen in healthy people. The background of the avascular regions is dark and smooth or slightly grainy (see Fig. 9 and Fig. 10).
Fig. 9. OCTA image in a patient with branch retinal vein occlusion- dark areas of ischemia and irregular vessels are visible.

Fig. 10. OCTA image of the non-perfusion areas in superficial plexus and microaneurysms in deep vascular plexus in a diabetic patient. The OCT-B scans show thickening of the retina and intraretinal fluid.
Fig. 11. The optic disc flow disturbance maybe visible even in preperimetric glaucoma.

Fig. 12. Wide-field OCTA in a patient with diabetic retinopathy. (Courtesy of Prof. Hirano, MD. PhD. Shinshu Univ).
The possibility of assessing the flow in the vessels of the optic nerve, both the larger ones and the peripapillary capillaries, makes OCTA a technique more and more popular in the diagnosis of glaucoma [9] (see Fig. 11).

OCTA is a part of the routine OCT using Angio Retina scans (for macular flow assessment) or Angio Disc scans (to assess optic disc flow) and takes a few seconds.

OCTA is an irreplaceable tool used to visualize and analyze changes in capillaries and pathological vessels in retinal diseases, glaucoma and other optic nerve neuropathies.

The method limitations are the same as that of standard optical coherent tomography. These include optical media opacities, poor fixation, too narrow pupil or nystagmus.

Moreover, the limitation of typical OCTA macular scans is that it provides visualization only the area of the posterior pole. OCTA scans cannot assess leakages that are typically visualized in fluorescein angiography. Moreover, the method provides limited information about actual blood flow, imagining mainly the vascular structure. In the future we may commonly use wide-field OCTA imaging that shows peripheral vascular changes and provides a wider field of imagining [21] (see Fig. 12).

CONCLUSIONS

OCTA equals simultaneous angiography and high-resolution OCT. It enables early detection of pathologies within the vessels at different levels of the retina. OCTA as a non-invasive and repeatable test is commonly used in ophthalmology even in patients with worse cooperation.

AUTHORS’ DECLARATION:

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