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Optical Coherence Tomography Angiography Algorithms

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Optical coherence tomography (OCT)[1-3] is the most commonly used imaging modality in ophthalmology. Improvements in sensitivity, acquisition speed, and resolution[4-7] have enabled volumetric imaging of the anterior segment, retina, and optic nerve head with micrometer-scale depth resolution. Although conventional structural OCT aids the clinician in visualizing the anatomic changes that affect vision, it provides no direct information regarding retinal or choroidal vasculatures. As a result, structural OCT cannot identify vascular changes such as capillary dropout or pathologic new vessel growth in age-related macular degeneration and diabetic retinopathy that can lead to vision loss.

To visualize vascular changes, the most commonly used angiographic techniques in clinical practice are fluorescein angiography (FA) or indocyanine green angiography. FA is typically used to visualize retinal vasculature, while indocyanine green angiography is used for choroidal vasculature. While extremely useful, they require intravenous dye injection, which is time consuming and can have side effects.[8,9] In addition, dye leakage or staining may confuse the boundaries of capillary dropout or neovascularization. Finally, these techniques provide little depth information because of the two-dimensional nature of the acquired images.

In order to develop a no-injection, dye-free method for visualizing ocular vasculature, functional extensions of OCT have been explored. These techniques aim to contrast vasculature from static tissue by assessing the change in the OCT signal caused by flowing red blood cells in blood vessels. Although the specific methodology for OCT angiography (OCTA) has changed over the years, the concept remains the same. They can be broadly classified as techniques that rely on Doppler shift or speckle variance/decorrelation. This chapter provides a historical overview of OCTA techniques for *en face* blood vessel and microvasculature visualization. Because Doppler OCT is now mainly used for quantifying blood flow in larger vessels and not angiography, it is only briefly mentioned. For more information on Doppler OCT, please refer to a 2014 comprehensive review.[10]

Label-Free Angiography

For more than half a century, scientists, engineers, and clinicians have collaborated to devise technologies to visualize and quantify changes in the retinal and choroidal vascular networks that supply the eye. Techniques such as color Doppler imaging, laser Doppler velocimetry, laser speckle assessment, and blue field entopic technique have provided valuable insights into retinal physiology, but have not seen wide clinical use.[11] The limitations of these approaches include difficulty of use, poor reproducibility, large population variation in blood flow parameters, or limited availability of complex instrumentation. Because OCT systems are widely used in ophthalmology, its application to blood flow visualization and measurement could make clinical use more practical.

Since the early days of time-domain OCT, Doppler OCT has been explored as a tool for blood flow imaging. Doppler OCT uses the blood flow-induced phase difference between

Huang D, Lumbroso B, Jia Y, Waheed NK, eds.
Optical Coherence Tomography Angiography of the Eye (pp 13-18).