What's Up With OCTA?

A Brief Review of Optical Coherence Tomography Angiography

By understanding the mechanisms of a new imaging tool, retina specialists may further appreciate its potential.

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Optical coherence tomography angiography (OCTA) is an emerging imaging technique that employs motion contrast extracted from high-speed OCT images to generate high-resolution en face angiographic images noninvasively, rapidly, and without a dye injection. Initial clinical experience with OCTA has been promising, suggesting that OCTA can provide fine microvascular detail at least equivalent to that of fluorescein angiography (FA). There is also potential for using it to visualize abnormal blood flow in patients with ophthalmic diseases such as neovascular age-related macular degeneration (AMD), diabetic retinopathy (DR), and retinal vascular disease.

OCTA works by creating a decorrelation signal. The device compares the differences in the backscattered OCT signal intensity between sequential OCT b-scans obtained at a given cross-section (decorrelation signal) and uses this information to create a depth-resolved, en face map of the retinal and choroidal blood flow. Once axial bulk motion due to patient movement between sequential OCT b-scans is factored out, differences between repeated OCT b-scans are assumed to represent erythrocyte movement and, therefore, blood

At a Glance

- OCTA calculates differences in OCT b-scans to indicate erythrocyte movement.
- Software for OCTA is undergoing clinical testing on SD-OCT devices.
- OCTA could someday be used for monitoring CNV, DR, vascular occlusive disease, and macular telangiectasia.

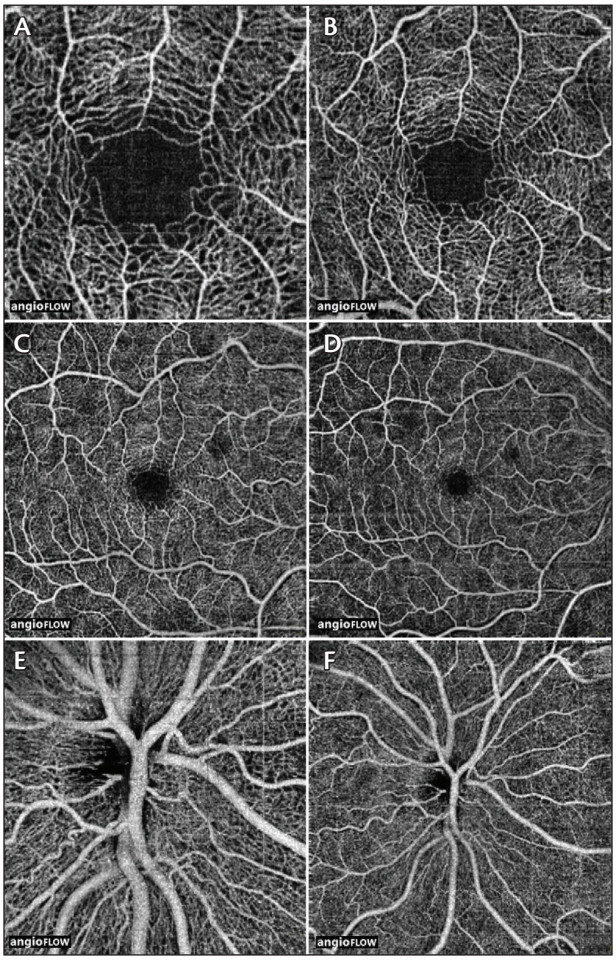

Figure 1. OCTA centered at the fovea and the optic nerve in an eye with no known disease. This image shows 2.0 x 2.0 mm (A), 3.0 x 3.0 mm (B), 6.0 x 6.0 mm (C), and 8.0 x 8.0 mm (D) images at the fovea, and 3.0 x 3.0 mm (E) and 6.0 x 6.0 mm (F) images at the optic nerve.

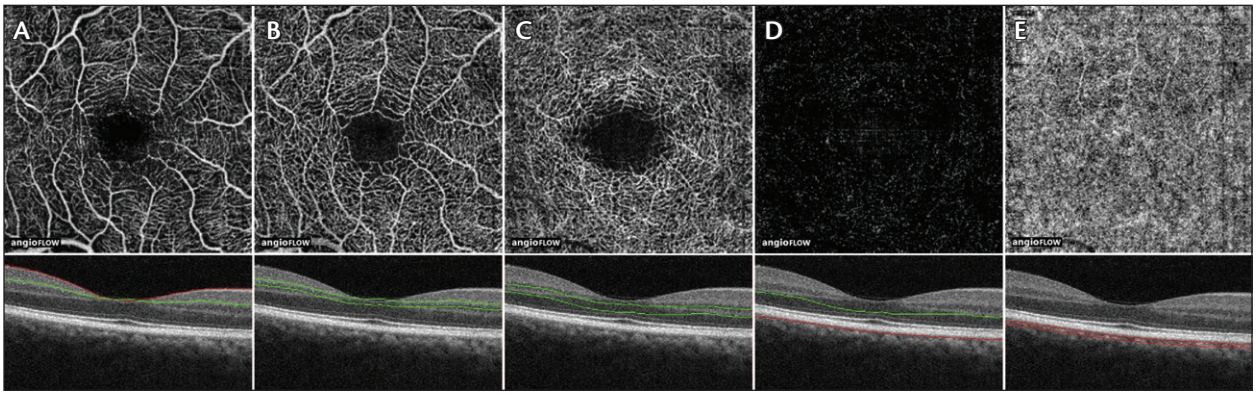

Figure 2. Segmentation of different vascular layers using OCTA: superficial plexus (A), intermediate plexus (B), and deep plexus (C) of the inner retina. Also shown are the outer retina (D) and choriocapillaris (E).

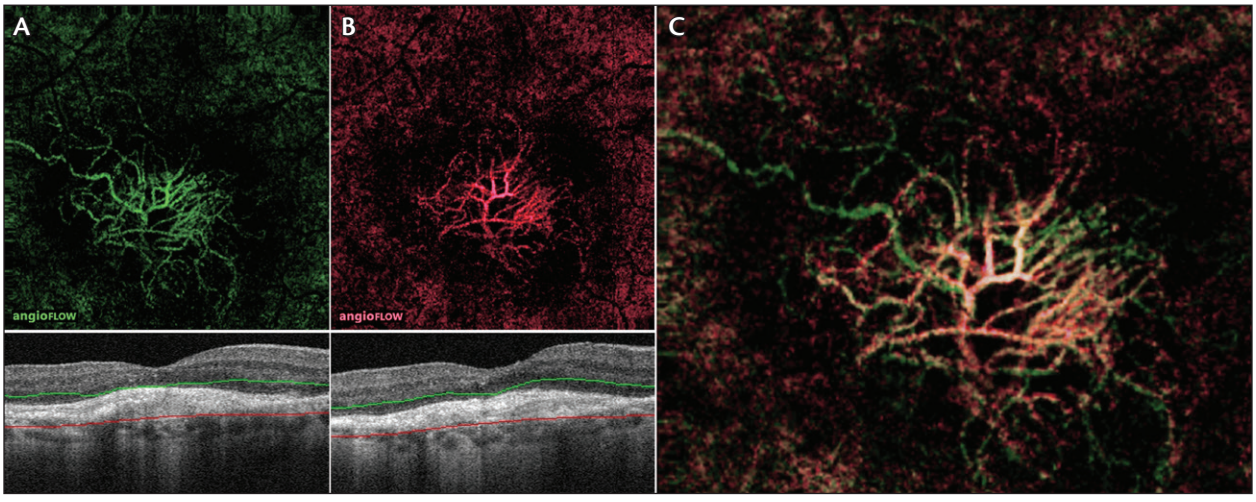

Figure 3. OCTA of CNV before (A) and 2 months after (B) treatment with anti-VEGF injection. Overlay of the images in A and B show that the CNV appears to have regressed and become less dense (C).

flow.[1-5] The OCTA technology coregisters the en face angiographic maps (OCT angiograms) with the corresponding cross-sectional OCT b-scans. Therefore, by scrolling through the OCT angiogram in a similar way as one might with a standard OCT cube scan, blood flow and structural information can be evaluated in tandem. The axial resolutions of the corresponding OCT b-scans are similar to the resolution of individual b-scans within a standard volumetric cube scan.

HOW IT WORKS

In order to obtain a densely sampled volume, OCTA requires higher imaging speeds than most currently available OCT machines provide. Slow scanning speeds result in an unacceptable tradeoff between limited field of view, increased image acquisition time, and decreased image resolution. Currently, prototype software (AngioVue, OptoVue) is under limited clinical testing across the United States on the commercially available RTVue XR Avanti spectral-domain OCT (SD-OCT) device (OptoVue). The device scans at 70 000 a-scans per second and obtains OCTA images of 304 x 304 a-scans in approximately 3.0 seconds, comparing two OCT b-scans at each given cross-section.[6] The same scanning density can be used to create a variety of OCTA image sizes: 2.0 x 2.0 mm, 3.0 x 3.0 mm, 6.0 x 6.0 mm, or 8.0 x 8.0 mm (Figure 1). This results in a tradeoff between image resolution and field of view, with 2.0 x 2.0 mm OCTA images having the highest resolution and the best microvascular detail, but 8.0 x 8.0 mm OCTA images having the largest field of view. The AngioVue software can be used to manually segment OCT angiograms into en face projections of the superficial, intermediate, and deep inner retinal vascular plexuses, outer retina, and choriocapillaris. The superficial inner retina segmentation (Figure 2A) shows vasculature in the retinal nerve fiber layer (RNFL) and ganglion cell layer (GCL). The vascular plexuses at the border of the inner plexiform layer

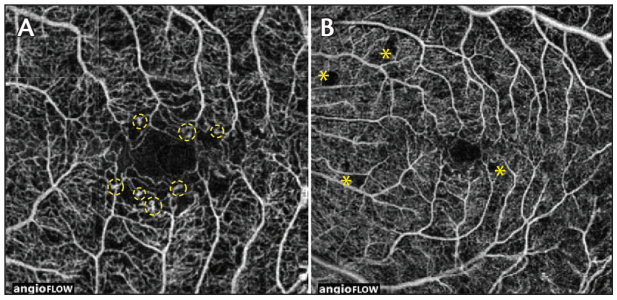

Figure 4. OCTA of an eye with nonproliferative DR. A 3.0 x 3.0 mm image provides better fine detail of the microvasculature such as microaneurysms, indicated by circles (A). A 6.0 x 6.0 mm image shows a wider field of view (B). Areas of capillary nonperfusion are indicated by an asterisk.

(IPL) and inner nuclear layer (INL) and the border of the INL and outer plexiform layer (OPL) are displayed by the intermediate and deep inner retina segmentations, respectively (Figure 2B-C). The outer retina segmentation (Figure 2D) in normal eyes should show no blood flow between the OPL and Bruch membrane. A 10-µm slice directly below Bruch membrane is shown by the choriocapillaris segmentation (Figure 2E). Faster imaging speeds would allow a denser OCTA scan with an increased field of view.

The fastest OCTA acquisition speed, 400 000 a-scans per second, was developed by the Massachusetts Institute of Technology and is being tested at the New England Eye Center in Boston. It employs a vertical cavity surface emitting laser with a swept-source OCT (SS-OCT) device. This ultrahigh-speed prototype obtains 500 x 500 a-scans in approximately 3.8 seconds, comparing five OCT b-scans at each cross-section to obtain four OCT angiograms that are merged to improve the signal-to-noise ratio. OCT angiograms up to 12.0 x 12.0 mm have been obtained. Manual segmentation of the OCT angiograms can be performed as described above. Additionally, the longer wavelength of the SS-OCT system (1060 nm) increases light penetration into pigmented tissues, thereby improving choroidal blood flow visualization compared with the shorter wavelength used in SD-OCT.[5,7]

WHAT IT CAN DO

Exploration of the clinical utility of OCTA in evaluating retinal diseases has just begun. Because OCTA can image the separate retinal layers, it can be used to easily visualize choroidal neovascularization (CNV) in the outer retina of eyes with neovascular AMD. This may prove useful for monitoring CNV size and adjacent fluid noninvasively over time (Figure 3).[6-8] OCTA is being used to elucidate pathologic changes in the retinal vasculature in diseases such as DR, vascular occlusive disease, and macular telangiectasia. The high resolution of OCTA provides information about areas of capillary nonperfusion, vessel dilation and attenuation, telangiectasias, microaneurysms, and vascular proliferation (Figure 4).[9-10] Further studies are needed to gain a better understanding of the technology, including its potential role in screening, monitoring, and guiding treatment decisions. ■

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