

Fourier-Domain OCT for the Anterior Chamber

Investigators are using a prototypic device to obtain high-resolution images of the drainage angle.

BY SANJAY G. ASRANI, MD

For some time, imaging modalities for the anterior segment have been limited to ultrasound biomicroscopy (UBM) and time-domain anterior-segment optical coherence tomography (OCT) (Visante OCT [Carl Zeiss Meditec, Inc., Dublin, CA], SL-OCT [Heidelberg Engineering, GmbH, Dossenheim, Germany]). Compared with UBM, OCT is more convenient, because it does not require contact with the patient's eye and it can be performed while the patient is upright. Unlike UBM, however, OCT does not provide the same depth of imaging and does not provide information about the ciliary body. Neither UBM nor time-domain anterior-segment OCT can image Schlemm's canal or provide detailed views of the trabecular meshwork.

The recent development of Fourier-domain OCT has revolutionized ocular imaging. Fourier-domain OCT has a scanning rate that is 100 times faster than that of traditional time-domain OCT, a difference that substantially increases the quality and quantity of data obtained from the eye. Even Fourier-domain systems have difficulty obtaining clear images of the anterior chamber (which typically exceeds 3 mm in depth), however, because the device induces a symmetric overlapping artifact that obscures important physiological details. Recent improvements in software have enabled doubling of the imaging depth, thus permitting views of the ciliary body and the full depth of the anterior chamber.

At the Duke University Biomedical Engineering Department in Durham, North Carolina, we incorporated this advanced software into a prototypic Fourier-domain OCT device and mounted the resulting instrument onto a modified slit-lamp biomicroscope. This configuration allows us to align the device with patients' eyes

"The slit-lamp-mounted Fourier-domain OCT device permitted us to visualize Schlemm's canal and the trabecular meshwork."

in just a few seconds. Our early experience suggests that this imaging technology may be a useful noninvasive method for evaluating individual structures in the drainage angle.¹

TECHNICAL SPECIFICATIONS

To date, my colleagues and I have used our prototypic Fourier-domain OCT system to image the eyes of approximately 150 healthy subjects and patients diagnosed with various types of glaucoma. The system has an estimated resolution of 9 μm axially and 19 μm laterally. To visualize structures inside the eye, the system captures high-resolution, two-dimensional B-scans (each of which comprises 800 A-scans) at the rate of 6.7 frames per second and displays the images on a monitor in real time. We used a horizontal line scan while imaging the anterior segment of patients' eyes to prevent interference from their eyelids.

We found that our slit-lamp-mounted Fourier-domain OCT device not only allowed us to image the drainage angle and the iris, but it also permitted us to visualize Schlemm's canal and the trabecular meshwork. In addition, we obtained two-dimensional and volumetric cross-sectional images of the anterior chamber.

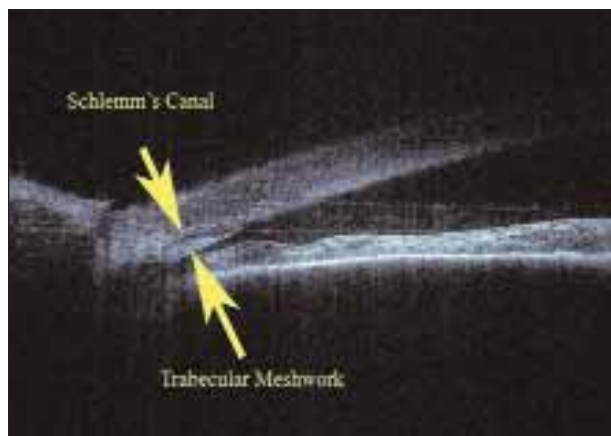


Figure 1. A Fourier-domain OCT image obtained with the author's prototypic slit-lamp-mounted device clearly shows Schlemm's canal and the trabecular meshwork in an eye with suspected narrowing of the angle.

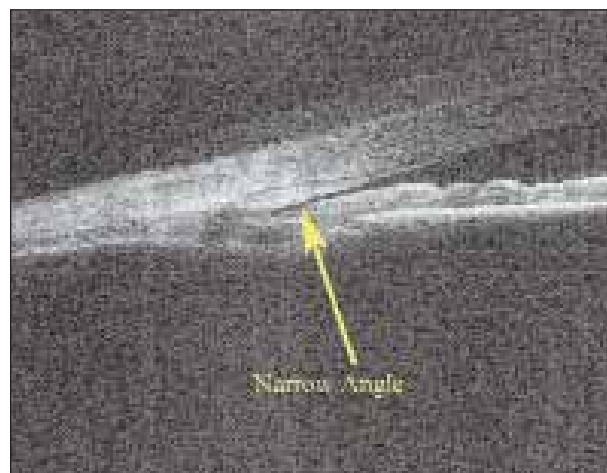


Figure 2. Fourier-domain OCT detected extreme narrowing of the angle in a patient who had no visible structures with gonioscopy.

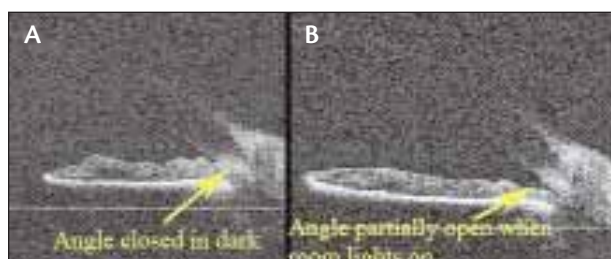


Figure 3. Fourier-domain OCT images of the same eye obtained under dark (A) and normal ambient (B) lighting conditions.

SAMPLE SCANS

Figure 1 shows a high-resolution, 5-mm scan obtained from a patient with suspected narrowing of the angle. Schlemm's canal was visible as a curvilinear lucent area external to the trabecular meshwork. The lucent area extended from the scleral spur to the anterior tip of the trabecular meshwork located at the end of Descemet's membrane.

The Fourier-domain OCT scan shown in Figure 2 was obtained from a patient whose eyes had narrow angles. The almost complete obliteration of space between the trabecular meshwork and the root of the iris was consistent with the absence of visible angle structures on gonioscopy.

A comparison of the angle's appearance with gonioscopy and Fourier-domain OCT provided important information about how different lighting levels affect the morphology of the anterior chamber. A patient who presented to our office with a complaint of experiencing headaches while watching TV in a dark room had a relatively open angle with a barely visible scleral spur for

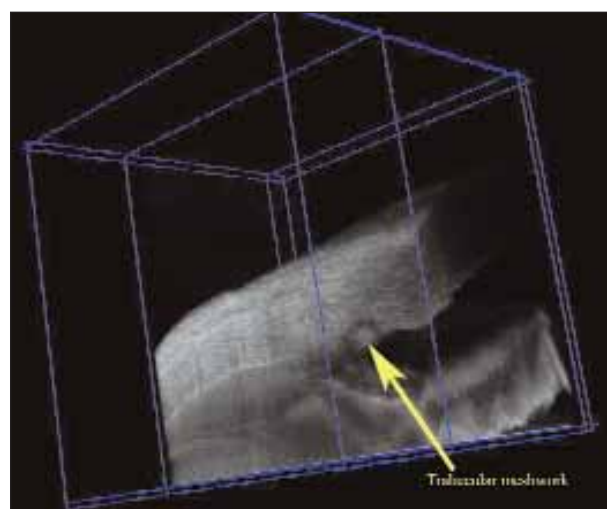


Figure 4. The trabecular meshwork is visible in a volumetric rendering of images obtained with Fourier-domain OCT.

360° on gonioscopy. Fourier-domain OCT images of the same patient obtained under dark conditions revealed that the angle was completely closed (Figure 3A). In images obtained when the room's lights were on, however, the angle appeared to open partially (Figure 3B). This case highlights the effect of ambient light on the pupillary diameter of certain individuals and demonstrates how using a slit lamp during gonioscopy can constrict the pupil and make the angle appear wider than it is.

My colleagues and I also obtained volumetric information about the anterior chamber with our prototypic device. Although we can learn a lot about the overall nature of the angle by visualizing it nasally and temporally along

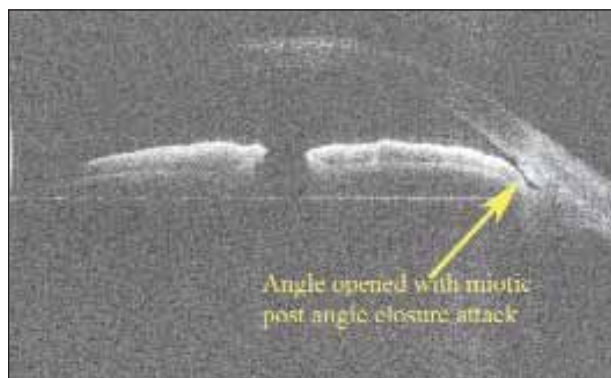


Figure 5. Scanning with Fourier-domain OCT demonstrated edema of the iris and trabecular meshwork in a patient recovering from an acute angle closure.

a line that horizontally crosses the pupil, this orientation only provides data across two points along the circumference. Volumetric or multiple-angled scans may be useful for imaging eyes that have unevenly configured angles as well as for visualizing certain pathologies.

The 3-D image shown in Figure 4 was acquired at a rate of 13.4 B-scans per second and consists of 60 frames acquired over 4.5 seconds. This technology allows the visualization of both Schlemm's canal and the trabecular meshwork.

Figure 5 shows an eye that was recovering from acute angle closure. Although pilocarpine had produced pupillary miosis, the iris and trabecular meshwork appeared to be swollen, presumably due to post-attack edema.

Fourier-domain OCT scanning can also help detect cyclodialysis clefts, a condition that is difficult to diagnose with gonioscopy in severely hypotonous eyes (Figure 6), as well as detachment of the ciliary body.

CLINICAL APPLICATIONS

Gonioscopy is a learned skill that, when performed carefully, allows physicians to identify landmarks in the drainage angle. This examination can be completed with and without compressing the cornea with the contact lens. Gonioscopy may not always provide optimal results, however, because physicians may have difficulty recognizing landmarks in eyes with minimally pigmented trabecular meshworks. In addition, a combination of inadvertent corneal indentation and exposure to light from the slit lamp may cause the angle to appear open when it is really narrow.

Because Fourier-domain OCT uses infrared versus ambient or incidental light and does not require corneal contact, it may help physicians identify angles that are truly narrow. This technology does not completely



Figure 6. Fourier-domain OCT demonstrated a cyclodialysis cleft.

replace gonioscopy, however, because the latter method is invaluable for detecting early posterior synechiae, identifying neovascularization, and studying the angle's configuration with and without corneal compression.

CONCLUSION

The frequency of angle-closure glaucoma is expected to increase in the next 20 years, especially in China and India, where the already high prevalence of the disease will be exacerbated by a rising life expectancy. Angle closure is also commonly missed in white and black populations, because many clinicians do not perform gonioscopy during routine eye examinations, and intermittent angle closure is one of the more difficult types of glaucoma to diagnose.

Anterior segment imaging with Fourier-domain OCT may improve the early diagnosis of narrow angles and allow physicians to demonstrate the dynamic anatomy of the angle in patients who are otherwise asymptomatic. Further studies will investigate this technology's utility for imaging different types of glaucoma and for evaluating the effect of medical, surgical, and laser treatments on structures in the angle. □

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