Choroidal Imaging Offers a New Window on Disease Management

The technology is already in use for diagnosis and management of some conditions.

BY PETER K. KAISER, MD

The choroid, the vascular layer of the eye, plays important roles in ocular anatomy and function, providing nutrition and support to the retina. It also plays a role in the pathophysiology of many posterior segment diseases. Our ability to visualize the choroid has historically been limited because of its location deep in the eye, behind the pigmented tissues of the retina. Traditional imaging modes for visualizing this anatomic layer have included ultrasound, with its limited resolution, and vascular-based modalities such as indocyanine green (ICG) angiography. Although optical coherence tomography (OCT) revolutionized the imaging of the retina during the preceding decade,[1] the choroid remained for the most part out of range for this technology as conventionally applied.

Beginning in 2008, Richard F. Spaide, MD, and colleagues[2,3] opened a new window on the choroid and its pathologies with their description of enhanced depth imaging (EDI) OCT. By positioning a spectral domain (SD) OCT device (Spectralis, Heidelberg Engineering) closer to the eye than is done in normal practice, they obtained an inverted image with the most tightly focused illumination at the level of the choroid or inner sclera.[2] In their investigations, Spaide and colleagues obtained inverted images of sections composed of 100 averaged scans from a rectangle focused over the fovea or other area of interest. This group has used EDI-OCT to measure the mean choroidal thickness in healthy volunteers[2] and in myopic eyes,[4] and to evaluate the association of choroidal thickness with age.[3] The investigators have also used this technology to assess the condition of the choroid in numerous pathologies, including retinal pigment epithelial detachment in age-related macular degeneration (AMD),[5] central serous chorioretinopathy (CSC),[6,7] dome-shaped macula,[8] and a newly described clinical entity, age-related choroidal atrophy (Figures 1-5).[9]

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MORE ACCESSIBLE

Many other centers have since published their own observations using EDI, and the bibliography for this new technology is lengthening almost daily as clinicians explore its implications. Manufacturers of

All figures appear courtesy of Lihteh Wu, MD.

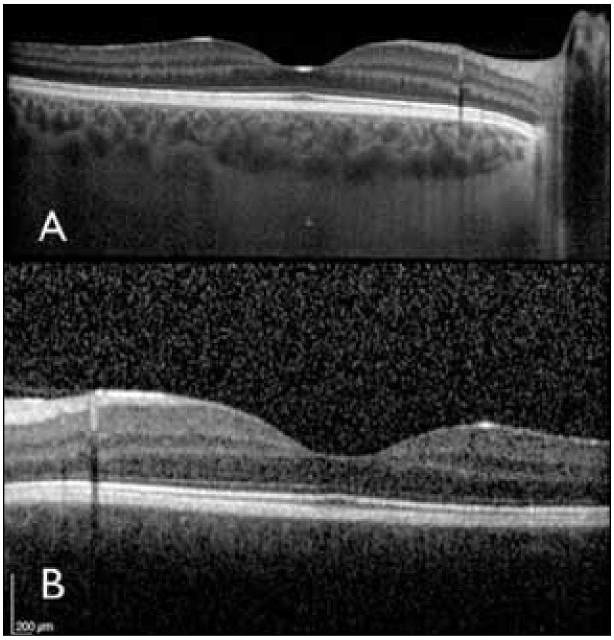

Figure 1. Comparison between EDI OCT scanning and conventional Spectralis OCT scanning of the same patient. EDI OCT (inverted mirror image) shows choroidal details and the choroidoscleral interface (A). Conventional OCT scanning showing no choroidal details (B).

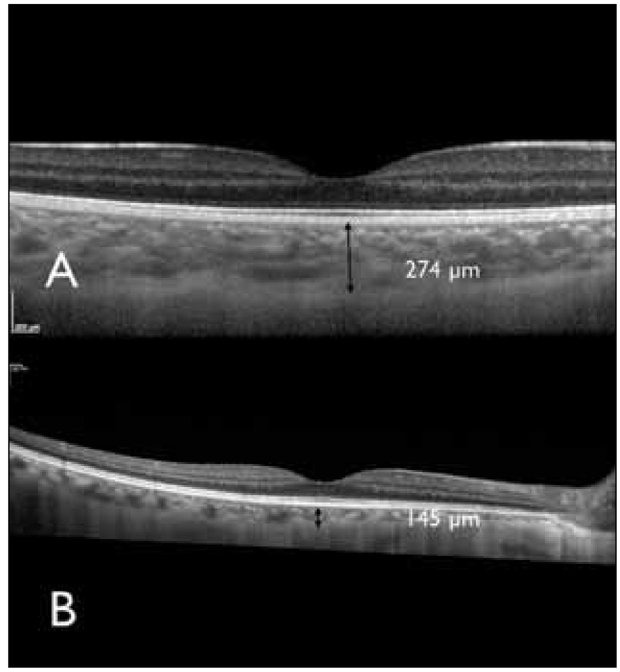

Figure 2. Comparison between EDI OCT scanning in two patients of different ages. A 10-year-old boy with a subfoveal choroidal thickness of 274 μm (A) and a 75-year-old man with subfoveal choroidal thickness of 145 μm (B).

SD-OCT equipment quickly realized the implications of EDI for their customers and have introduced features to allow clinicians to take advantage of its capabilities more easily.

One of the first things manufacturers did to improve the use of EDI was to allow users to flip the images. A result of moving the OCT unit closer to the eye, and thus the choroid closer to the zero-delay line, is that the resulting image is flipped—it appears upside-down compared to the way we have become accustomed to seeing OCT images. When EDI-OCT was first described, we simply looked at the images upside down. But the companies soon introduced software to re-flip the images so that we can view them as we normally would.

Another change has been the introduction of signal averaging by more manufacturers. The Heidelberg Spectralis has always included signal-averaging capabilities, but other companies have added signal averaging capabilities to their software. This is a relatively easy feature to add because signal averaging is simply a mathematic subtraction, a photographic principle.

The combination of image flipping and signal averaging (these features are given various names by different manufacturers) now provides devices that were not originally designed for EDI the ability to perform it. The newer software makes it easier for the average photographer to do EDI, and as a result this imaging modality is rapidly becoming more accessible.

The Ophthalmic Imaging Center at the Cole Eye Institute is investigating the use of EDI-OCT for a number of applications, and clinicians here and elsewhere are using the technology to manage diseases in ways we never could before.

SEEING CSC

Perhaps the greatest utility to date for EDI-OCT from a clinical standpoint is in the diagnosis and management of CSC. In this past, we would have used ICG imaging to diagnose and follow CSC, but now we are able to use EDI.

EDI has proven to be helpful in a number of patients we have seen lately for second opinions regarding anti-VEGF therapy. Say, for example, a 60-year-old woman presents for a second opinion with subretinal fluid, a pigment epithelial detachment, and drusen visible on standard SD-OCT. She is being treated with anti-VEGF therapy but has not experienced improvement in her visual acuity. On EDI-OCT we see a grossly thickened choroid, consistent with CSC. In AMD, EDI investigations have shown, the choroid is not thickened, but rather significantly thinner compared with age- and refraction-matched controls.[10]

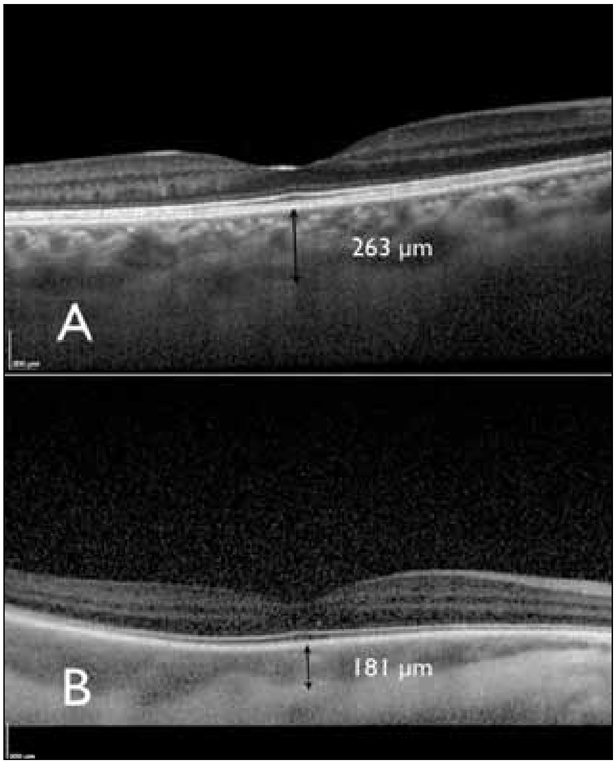

Figure 3. Comparison of EDI OCT scanning according to refractive status. A 43-year-old woman with no refractive error and a subfoveal choroidal thickness of 263 µm (A) and a 45-year-old woman with 8 D of myopia and a subfoveal choroidal thickness of 181 µm (B).

In this case, therefore, anti-VEGF therapy is not beneficial. For this patient, if her vision is good, we would observe, or if the vision is poor we might perform photodynamic therapy, a more appropriate treatment for CSC. In this case EDI helped us change a misdiagnosis to the correct diagnosis.

OTHER CONDITIONS, AND QUESTIONS

We have found EDI helpful in following a number of pathologic conditions. For instance the uveitides; EDI is useful in patients with uveitic pathologies, such as Vogt-Koyanagi-Harada syndrome, to assess whether the inflammation is responding to steroid or immunomodulatory therapy.

In a number of pathologies the choroid is thinned, but the reasons for and implications of the thinning are so far poorly understood. Thinning of the choroid is seen in eyes with AMD, glaucoma, and diabetic retinopathy,[10] as well as in retinitis pigmentosa and other hereditary retinal degenerations.[11] It has also been observed that the choroid thins with anti-VEGF therapy for AMD.[12]

The implications of these findings are not clear. Is the anti-VEGF therapy related to decreased choroidal blood flow; is that what is thinning the choroid? Is the thinning we see in the hereditary conditions a function of the retinal degeneration, or is it the other way around; is the choroidal thinning somehow causative of the retinal degeneration? These questions remain to be answered.

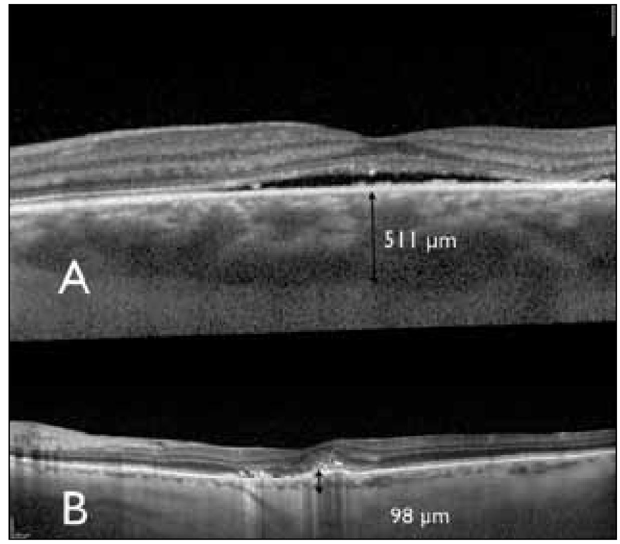

Figure 4. Differentiation between AMD and CSC using choroidal thickness. A 65-year-old man with active CSC with subfoveal choroidal thickness of 511 µm (A) and a 66-year-old man with exudative AMD and a subfoveal choroidal thickness of 98 µm (B).

Currently, this technology is being used mostly to assess single-point subfoveal choroidal thickness, but hopefully in the future it will help us to differentiate, for example, the roles of choriocapillaris vs larger choroidal vessels in a particular pathophysiology. Other questions, too, such as whether thickness variations among patients have prognostic significance, require investigation.

LOOKING TO THE FUTURE

Because of Spaide and colleagues' innovation in optimizing the choroidal position relative to the zero delay line, as well as the higher speed capabilities of newer OCT devices that allow signal averaging, we now have a new window on the choroid. As we improve our use of EDI, our needs for other imaging modalities may diminish.

With increased vision, of course, has come the realization that the more we can see, the more questions we have. It is hoped that EDI will eventually help us to find the answers.

In addition, new technologies such as higher speeds and longer laser wavelengths will help us to further

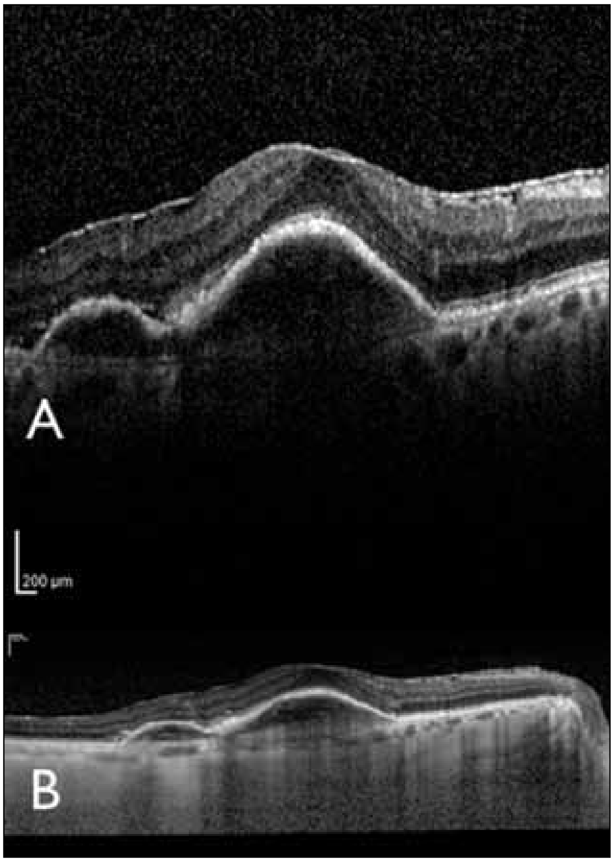

Figure 5. Comparison between conventional Spectralis OCT scanning and EDI OCT scanning of an eye with a pigment epithelial detachment (PED) associated with exudative AMD. In conventional Spectralis OCT scan, notice the hyporeflective area under the PED (A). In EDI OCT image of the same patient, notice that the area under the PED is no longer hyporeflective (B).

improve the visibility of the choroid. For example, Carl Zeiss Meditec has an experimental OCT device using a 1050-nm light source that allows even deeper penetration into the choroid. It peers so deep into the eye, in fact, that in some cases we can see the retrobulbar space. The images from this device are spectacular.

The next frontier currently being investigated at the Cole Eye Institute is choroidal area and choroidal volume. Just as we can use conventional SD-OCT to generate area and volume for the retina, with the right analysis software we can do the same for the choroid. Most investigators to date have been looking at single-point thickness of the choroid. Will it be advantageous to look at choroidal volume in a 6-by-6 area? Will these images correlate better with disease findings? These are all areas that the Ophthalmic Imaging Center at the Cole Eye Institute is working on.

The most exciting thing, however, is that we already can see things we never could before. Clinicians are using this technology routinely to diagnose and manage patients with CSC, uveitis, choroidal tumors, and other conditions. Considering that this imaging modality was described less than 5 years ago, we must assume that we are only on the tip of the iceberg regarding the potential for this technology. We look forward to probing deeper into the choroid with the aid of EDI-OCT. ■

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