Advances in Choroidal Imaging With EDI-OCT

Choroidal thickening or thinning may be important diagnostic clues for several retinal pathologies.

BY GLENN YIU, MD, PHD

Enhanced depth imaging optical coherence tomography (EDI-OCT) is a novel imaging modality that has helped retina specialists learn more about the choroid's role in the eye since its description several years ago.[1] A large number of studies employing EDI-OCT have been published in recent years, and are beyond the scope of this discussion. Instead, this article aims to highlight some of the important ways that EDI-OCT has informed and changed our conceptions of the choroid.

EDI-OCT is an imaging technique that takes advantage of the increased depth of field from the inverted image obtained by placing a spectral-domain OCT device close to the eye. This allows better visualization of the choroid and choroid-scleral junction (CSJ) than could previously be obtained with conventional spectral-domain OCT imaging.[1] These improved images of the choroid allow the anatomy and thickness of the choroid to be evaluated.

Most clinicians assume that the normal thickness of the choroid should be approximately the same as the thickness of the overlying retina. However, there are several caveats to this generalization:

- The choroid becomes thinner with age. In a pilot study of EDI-OCT in normal eyes, Margolis and Spaide showed that choroidal thickness decreases with age by approximately 15 µm with every decade of life.[2]
- There is significant variability in choroidal thickness between individuals of similar age. This is not unexpected since, unlike the retina, which is neural tissue, the choroid is a vascular structure.
- Choroidal thickness varies with location in the macula; the choroid is thickest beneath the central macula and becomes thinner in all directions, especially nasally.[2]
- Choroidal thickness varies with axial length and refractive error.[3] The choroid is thinner in longer and more myopic eyes.
- Choroidal thickness varies with the time of day; it is generally thicker in the morning and thinner in the evening.[4]

In studying the peripapillary topography of the choroid with EDI-OCT, Ouyang and colleagues noted that the choroid is thinnest inferonasal to the optic nerve.[5] This thinning corresponds to the optic fissure during development, suggesting that all individuals may have some degree of a coloboma-like structure in this region of the eye.

DEFINING THE CSJ

Another important source of variability in choroidal thickness measurements involves the variable appearance of the CSJ. In some patients the CSJ is a distinct boundary, while in others it appears as a broad hyporeflective band. Comparing EDI-OCT images of the CSJ with histologic tissues, we found that the hyporeflective band corresponds to the lamina fusca, the histological correlate of the so-called suprachoroidal layer (SCL).[6]

Earlier this year, my colleagues and I reviewed EDI-OCT images from 74 healthy eyes, and found that a hyporeflective SCL is visible in 44.6% of subjects. We hypothesized that this appearance of the SCL on

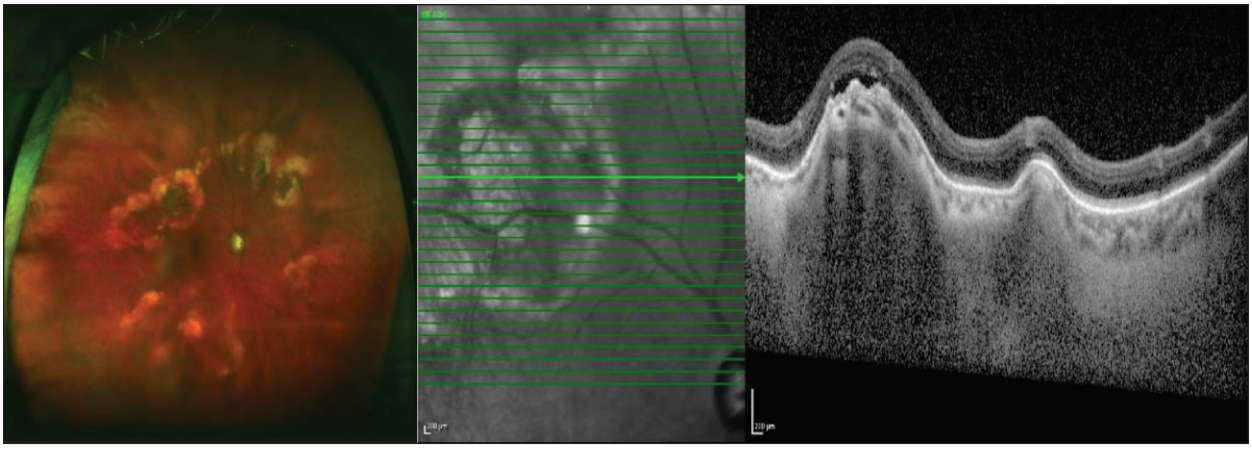

Figure 1. In some cases, EDI-OCT can help clarify a diagnosis, as in this patient referred to our clinic for possible choroidal metastases. Enhanced depth imaging, however, revealed that the mutifocal lesions arose from the sclera, thus supporting a diagonosis of sclerochoroidal calcification.

EDI-OCT corresponds to a subclinical suprachoroidal effusion that occurs in a proportion of healthy people. Interestingly, the presence and thickness of this layer is associated with more hyperopic refractive error. Our results suggest that the suprachoroidal effusion in some healthy eyes may be caused by the same osmotic forces that occur in conditions associated with hyperopia, like nanophthalmia or idiopathic uveal effusion syndrome.

An improved understanding of the CSJ also allows a more refined measurement of choroidal thickness. In our study, we measured choroidal thickness using 3 different posterior boundaries: the inner border of the large choroidal vessels (vascular choroidal thickness); the inner border of the SCL (stromal choroidal thickness); and the inner border of the sclera (total choroidal thickness). These different posterior boundary definitions resulted in significant differences in choroidal thickness measurements. Hence, future studies evaluating the thickness of the choroid on EDI-OCT should clearly define the posterior boundary employed.

PATHOLOGY RELATED TO CHOROIDAL THICKNESS

With the availability of EDI-OCT, several ocular pathologic conditions have been shown to demonstrate changes in choroidal thickness, with either abnormal thinning or abnormal thickening.

Abnormal Thinning

One of the first conditions characterized using EDI-OCT was age-related choroidal atrophy (ARCA), a condition described by Spaide in which the choroid becomes extremely thin in a small population of aged individuals, but the overlying retinal pigment epithelium is intact.[7]

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This condition is distinguished from geographic atrophy in age-related macular degeneration (AMD), where the retinal pigment epithelium overlying the choroid is also damaged. The diagnosis of ARCA is difficult to make, however, because the choroid becomes thinner with age even in normal eyes. Patients with ARCA have a relatively good visual prognosis compared with AMD, although they have a slightly higher risk for glaucoma.

Another condition in which the choroid can become very thin is high myopia.[3] Axial length is inversely correlated with choroidal thickness, so high myopes with long eyes often have extremely thin choroids. Interestingly, many of these patients retain very good corrected vision. Thus, as in the case of ARCA, choroidal thinning does not necessarily denote poor visual function and should not be considered as a biomarker for visual function.

Dome-shaped macula is another condition in which EDI-OCT has helped our understanding.[8] This finding occurs more commonly in highly myopic eyes, appearing as a convex protrusion in the posterior pole, often within a staphyloma. The phenomenon was previously hypothesized to result from a collapse of the sclera at

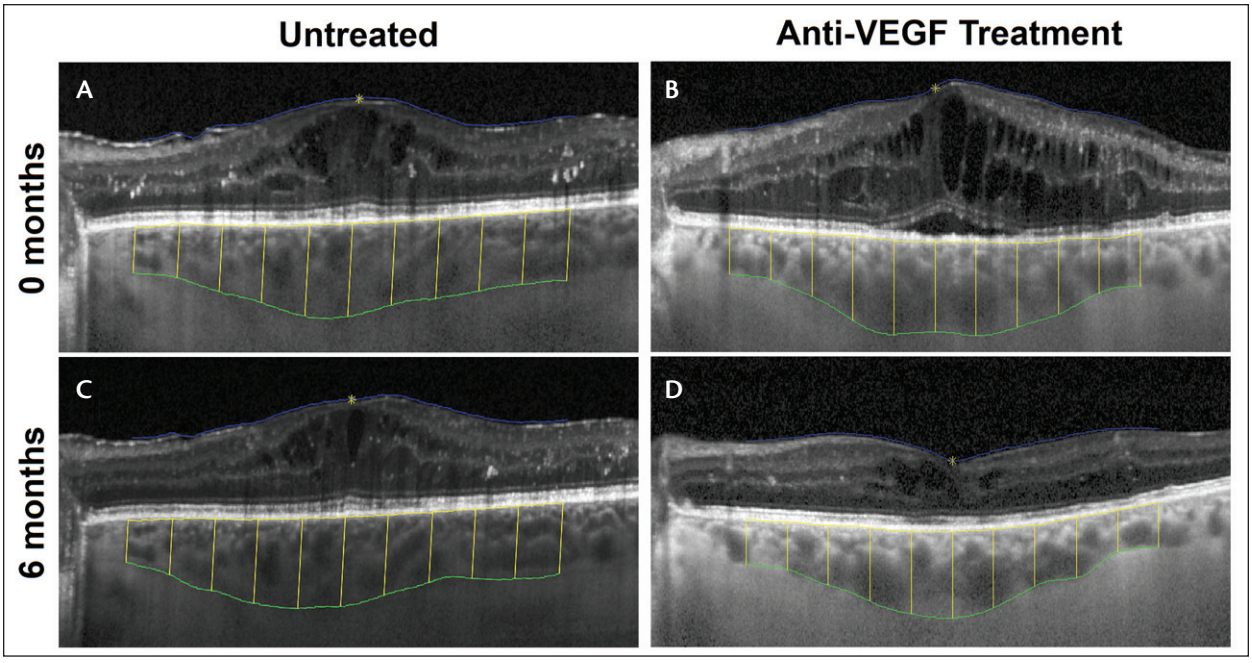

Figure 2. EDI-OCT images of patients with diabetic macular edema treated with or without anti-VEGF therapy from a study of 59 treatment-naïve eyes. There was significant thinning of the choroid over the macula among treated patients compared to untreated eyes. Although this finding has been seen in some case reports, the clinical significance is unknown.

the base of a staphyloma, but EDI-OCT has since shown that it actually results from an abnormal thickening of the sclera underneath the choroid with compression of the overlying choroid. This configuration may cause congestion of the choroidal vessels, which could explain why some eyes with dome-shaped maculas can develop subretinal fluid (SRF) without the presence of choroidal neovascularization (CNV).

Abnormal Thickening

At the other end of the spectrum are conditions in which the choroid becomes abnormally thickened, such as central serous chorioretinopathy (CSC). The diagnosis and monitoring of CSC has evolved since the advent of EDI-OCT.[9] In addition to evaluating leakage on fluorescein or indocyanine green angiography, EDI-OCT allows the clinician to distinguish CSC from similar masquerading conditions by the increased thickness of the choroid. These images can also be used to guide management. After photodynamic therapy in CSC, for example, resolution of SRF may be associated with choroidal thinning over time.[10]

The choroid is also thickened in patients with Vogt-Koyanagi-Harada (VKH) syndrome, a uveitic condition in which EDI-OCT can again be valuable to help guide treatment. With steroid therapy, resolution of SRF has been shown to accompany a decrease in choroidal thickness.[10] Although EDI-OCT may be less invasive than conventional angiography in monitoring treatment response, reports of its use are limited or anecdotal. Thus, the interpretation of choroidal thickness data in CSC or VKH should be handled with caution, as its use as a disease biomarker has not yet been proven in a rigorous manner.

Another use of EDI-OCT is in the diagnosis of choroidal tumors.[11] This imaging modality allows the clinician to determine not only the thickness of small choroidal lesions, often more accurately than via ultrasonography, but also the anatomic features of the lesions. For example, hyporeflective spaces consistent with vascular channels can help establish a diagnosis of choroidal hemangioma. In contrast, tumors such as a nevus or melanoma usually have a more homogeneous appearance.

Finally, EDI-OCT can help distinguish choroidal lesions from those arising from the sclera. For example, a patient was referred to our clinic for evaluation of possible choroidal metastases. EDI-OCT clearly showed that the multifocal lesions actually arose from the sclera, supporting a diagnosis of sclerochoroidal calcification. (Figure 1).

THE CHOROID IN AMD

Despite numerous published studies,[12-20] there is no clear consensus on the association of choroidal thinning with AMD. There are several potential reasons for the lack of agreement. First, AMD is an age-related condi-

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tion, and, as noted previously, the choroid gets thinner with age. Therefore, it is difficult to parse out whether choroidal thinning in AMD may be related to natural aging. Second, the diagnosis of AMD is often used in similar conditions such as polypoidal choroidal vasculopathy (PCV),[18,21] where the choroid may be thicker. Although PCV occurs more frequently in patients of Mediterranean or Asian descent, it may be underdiagnosed in white populations. Patients with PCV also tend to be younger compared with AMD patients, and may therefore have a thicker choroid at baseline.

Another complicating factor in understanding the choroid's role in AMD is the advent of anti-VEGF therapy. Most patients with neovascular AMD today are undergoing anti-VEGF therapy, which has been associated with choroidal thinning in recent reports.[22,23] My colleagues and I recently looked at EDI-OCT images from patients with diabetic macular edema being treated with anti-VEGF agents.[24] Our cohort study included 59 treatment-naïve eyes: 26 were observed without treatment, while 33 underwent anti-VEGF therapy over 6 months. In contrast to untreated eyes, which showed no significant change in choroidal thickness, those that received anti-VEGF injections showed significant choroidal thinning in the central macula (Figure 2). The clinical relevance of this finding, however, remains unknown.

CONCLUSION

The ability to image the choroid with EDI-OCT has provided us much valuable insight into this vascular layer. Choroidal thickness generally decreases with age and axial length but is highly variable among individuals. The different appearance of the CSJ may contribute to this variability and should be carefully defined when choroidal thickness is measured. Choroidal thinning may occur in age-related choroidal atrophy, high myopia, and possibly as a consequence of anti-VEGF therapy, although the functional relevance of this thinning remains to be determined. Choroidal thickening can occur in CSC and VKH, and may potentially be used to monitor response to therapy. However, the role of the choroid in AMD is still a mystery, and whether choroidal thinning actually occurs in AMD remains a subject of debate. While EDI-OCT is a valuable imaging modality readily available to clinicians, future advances are necessary to better understand the choroid's role in health and disease. ■

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