GETTING A BETTER LOOK AT GLAUCOMA

These three imaging techniques are brimming with potential for use in patients with glaucoma.

BY KONSTANTINA G. KALAS, OD; AND BRETT J. KING, OD, FAAO

The evolution of glaucoma imaging has been integral in helping clinicians diagnose glaucoma in its earliest stages and treat patients with confidence to arrest the disease. Advances in imaging technologies have enhanced our capability to document glaucomatous damage. (See the article by Greg Caldwell, OD, FAAO, on page 26 of this issue to read about the role of OCT angiography imaging in glaucoma.)

In this article, we discuss the importance of several other emerging imaging modalities for the future of glaucoma management: en face imaging, enhanced-depth imaging (EDI), and adaptive optics (AO) of the lamina cribrosa (LC).

WHAT IS EN FACE IMAGING?

En face, meaning *facing forward* in French, is an imaging technique that allows clinicians to closely examine each layer of the retina in a coronal orientation (C-scan instead of the traditional B-scan). An en face algorithm is available on most OCT platforms and modalities (ie, time-domain, spectral-domain, and swept-source), each of which offers its own advantages and disadvantages.

Regardless of modality, en face imaging provides key information to aid in the diagnosis and management of glaucoma, as it offers high resolution for visualizing early retinal nerve fiber layer (RNFL) abnormalities.[1]

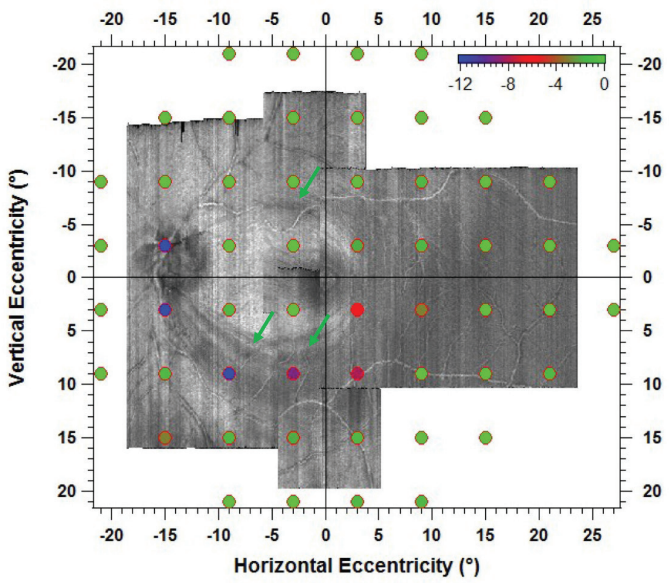


Image courtesy of Muhammed S. Alluwimi, BSc(Optom), MS, PhD, and William H. Swanson, PhD, of Indiana University.

Figure 1. Superior and inferior RNFL defects are noted (green arrows). Standard visual field locations are overlaid with depth of defect noted as color deviations from green. Notice the superior RNFL defect is between most of the visual field locations.

En Face Imaging in Glaucoma Management

RNFL loss is a proven indicator of structural glaucomatous damage. Traditional OCT scans allow us to

measure RNFL thickness to track these structural changes. In contrast, en face imaging measures RNFL reflectance. Hood et al showed that asymmetry in reflectance may be a better metric for detecting early changes than information from traditional scans.[2]

En face imaging allows the clinician to view the RNFL across a large area of the posterior pole, enabling him or her to evaluate variations in reflectance across the retina (Figure 1).[2,3] The large area view also appears to be less affected by artifacts, including segmentation errors and deviations due to axial length, than are other modalities.[4]

Although this technique provides myriad information, it has limitations. En face imaging fails to identify diffuse RNFL damage, unlike a traditional scan, due to its confined axial depth parameters.[1] Yet clinical application of en face imaging shows great promise once further work with regard to specificity and sensitivity is done.

It is recommended that this imaging technique be used in conjunction with traditional OCT scans and printouts. En face imaging is commercially available as an update on the Spectralis OCT (Heidelberg Engineering), the Topcon DRI OCT Triton (Topcon), Cirrus (Carl Zeiss Meditec), and Optovue products.

AT A GLANCE

- Because it has higher resolution in visualizing early retinal nerve fiber layer abnormalities, en face imaging provides key information to aid in the diagnosis and management of glaucoma.
- Enhanced depth imaging's application in imaging the lamina cribrosa highlights glaucoma's effects on lamina cribrosa thickness and position.
- Adaptive optics imaging eliminates monochromatic aberrations of the eye and allows for microscopic imaging of the retina to quantify blood flow, capillary density, and nerve fiber bundles.

WHAT IS EDI?

The LC is a mesh-like structure that provides mechanical support within the optic nerve. Because the neuroretinal rim is considered the primary site at which to observe the axonal damage in glaucoma,[5] it is important to investigate the relationship between the LC and the bowing that occurs with glaucoma.

Until recently, imaging deep structures such as the LC had been challenging. EDI is a specific mode of spectral-domain OCT that achieves deeper signal penetration by using longer wavelengths[6] or by inverting the image to allow deeper tissues to be in focus. Imaging the LC in glaucoma highlights the disease's effects on LC thickness and position (Figure 2).

EDI in Glaucoma Management

LC imaging can elucidate crucial differences among glaucoma subtypes. Studies have found that measurement of LC thickness with EDI revealed overall thinning in both primary open-angle glaucoma and normal-tension glaucoma, with significantly greater thinning in normal-tension glaucoma. Those with normal-tension glaucoma and a Drance hemorrhage had the highest rate of progression.[5-7] Thickness of the LC is also directly correlated with its position. When the LC is thinner, it tends to be displaced posteriorly.[6-8] These findings may explain why glaucoma continues to progress despite patients' strict compliance with IOP-lowering medication regimens.

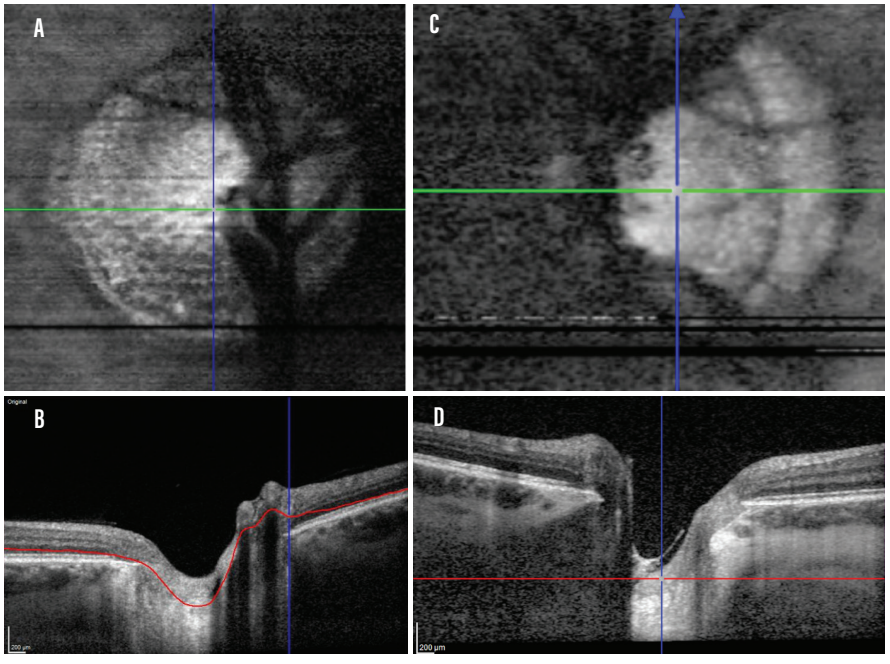
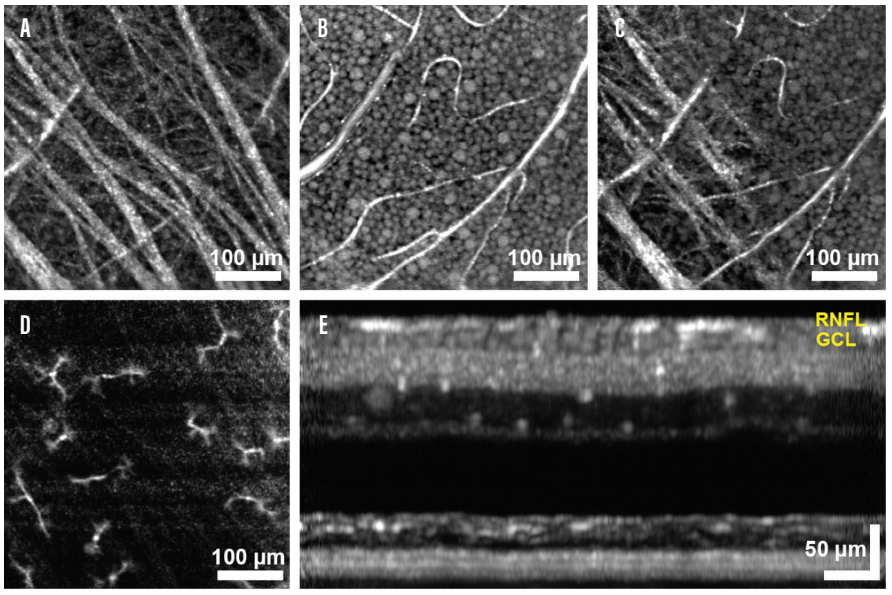


Figure 2. Imaging of the LC in a healthy control (A and B). Note the visualization of the laminar beams (A). Frames C and D show the LC of a patient with glaucoma with significant bending of the lamina. A glial separation can be seen (D).



Images courtesy of HaeWon Jung, Kazuhiro Kurokawa, PhD, and Donald T. Miller, PhD, of Indiana University.

Figure 3. En face imaging of the ganglion cell layer with AO-enhanced OCT and B-scan. RNFL bundles are shown, with thick bundles anteriorly and smaller fibers deep (A). Ganglion cell somas can be seen in the en face image (B). A transition in layers is noted as focus shifts from the RNFL to the ganglion cell layer (C). Presumed macrophages appear in the inner retina (D). An AO-enhanced OCT B-scan illustrates a thin RNFL with cell somas stacked in the ganglion cell layer (E).

Although LC imaging with EDI appears to be promising, its role in glaucoma management requires further research. Advances in image clarity using AO technology (see next section) in conjunction with EDI may also help to determine the importance of axonal bundles, glial cells, and small capillaries within the LC in eyes with glaucoma.[5]

WHAT IS AO?

Monochromatic aberrations in the eye are a significant limiting factor in acquiring high-resolution images. AO is designed to eliminate these aberrations in real time using wavefront sensors and deformable mirrors. In theory, AO can be built into current imaging modalities such as scanning laser ophthalmoscopy and OCT. The addition of AO would allow microscopic imaging of the retina to quantify blood flow and capillary density and to detect nerve fiber bundles.[9] Although this technology is still investigational and has limited clinical application today, its capabilities show exciting potential for future use in diagnosing and treating glaucoma.

AO Use in Glaucoma Management

According to Dong et al, AO has illuminated early RNFL defects by detecting individual RNFL bundles that are not seen in traditional OCT scans.[9] With unrivaled image clarity, detailed microscopic imaging may equip clinicians to detect glaucomatous changes at the cellular level, but normative databases have yet to be generated.[9,10]

AO imaging sacrifices field of view and depth of focus to achieve this superior image quality.[9] As a result, users must compile images from multiple scans to view large areas. Recent investigations have used AO to look at alterations in the RNFL, ganglion cell density, beams of the LC, and capillary density. Using AO-enhanced OCT, Liu et al proved the ability to image individual ganglion cell somas and to determine ganglion cell densities in individuals (Figure 3).[11] Those authors also demonstrated fine projections from the ganglion cell layer up to individual bundles of the RNFL.[11]

Further investigation with this technology of the relationship of structure and function may enhance understanding of and efforts to manage this disease.

PROGRESS IS ONGOING

Early diagnosis and treatment are essential to delay the irreversible effects of glaucoma; hence, it is of paramount importance to continue to push the boundaries of glaucoma imaging. Current imaging technologies offer good diagnostic accuracy and reproducibility, but the ongoing advances in en face imaging, AO, and EDI will continue to improve recognition of early glaucomatous damage. We await integration of these technologies into new clinical diagnostic tools. But, in the meantime, they are already aiding our understanding of glaucoma's pathophysiology and progression. ■

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