

What Is the Role of Imaging in Glaucoma Care?

This technology enhances physicians' ability to diagnose disease and its progression, but clinical acumen is still essential.

BY IAN CONNER, MD, PhD, AND JOEL S. SCHUMAN, MD

Imaging is playing an increasingly critical role in the management of glaucoma. Although most practicing ophthalmologists were taught the art of carefully observing the optic nerve head and its correlation with perimetric changes, the recent advent of advanced, objective imaging technologies promises to elevate even the least proficient observer to an expert level. Optical coherence tomography (OCT), confocal scanning laser ophthalmoscopy (CSLO), and scanning laser polarimetry (SLP) are enhancing clinicians' confidence in their ability to make challenging treatment decisions. It is important, however, that practitioners have a working knowledge of these technologies' limitations and realistic expectations for their clinical application.

THE PREVIOUS PARADIGM

The diagnosis of glaucoma is clinical and has always required some element of subjectivity. This is unlikely to change, although newer imaging tools aim to reduce subjectivity. Traditionally, glaucoma has been defined as a characteristic optic neuropathy involving a recognizable pattern of neural damage and visual field loss, often associated with elevated IOP. The etiology can be multifactorial (eg, primary open-angle, pigmentary, pseudoexfoliative, angle-closure, trauma-related, uveitic, and many other glaucomas), but the final common pathway of retinal ganglion cell (RGC) loss appears to be the same. For that reason, physicians and researchers have a keen interest in reproducibly measuring the structure and function

"The diagnosis of glaucoma is clinical and has always required some element of subjectivity. This is unlikely to change, although newer imaging tools aim to reduce subjectivity."

of the RGC layer and retinal nerve fiber layer (RNFL) as well as the optic nerve head itself (Figure).

Historically, the mainstay of these efforts has been description, illustration, and later, photography of the optic nerve head. Unfortunately, different expert observers can provide discrepant assessments of the optic nerve head, and even single observers can have inadequate internal consistency.¹ This problem is perhaps compounded when one considers that the primary correlating measurements of function—perimetry derived from the patient's subjective responses—would be expected to have even less consistency among measurements. Despite this obvious shortcoming, all previous efforts to objectively supplant the gold standard of perimetry (eg, multifocal and pattern electroretinogram/visual evoked potential) have failed to reach even its level of validity.²

Despite the inherent uncertainties, clinicians have been required to make recommendations regarding the

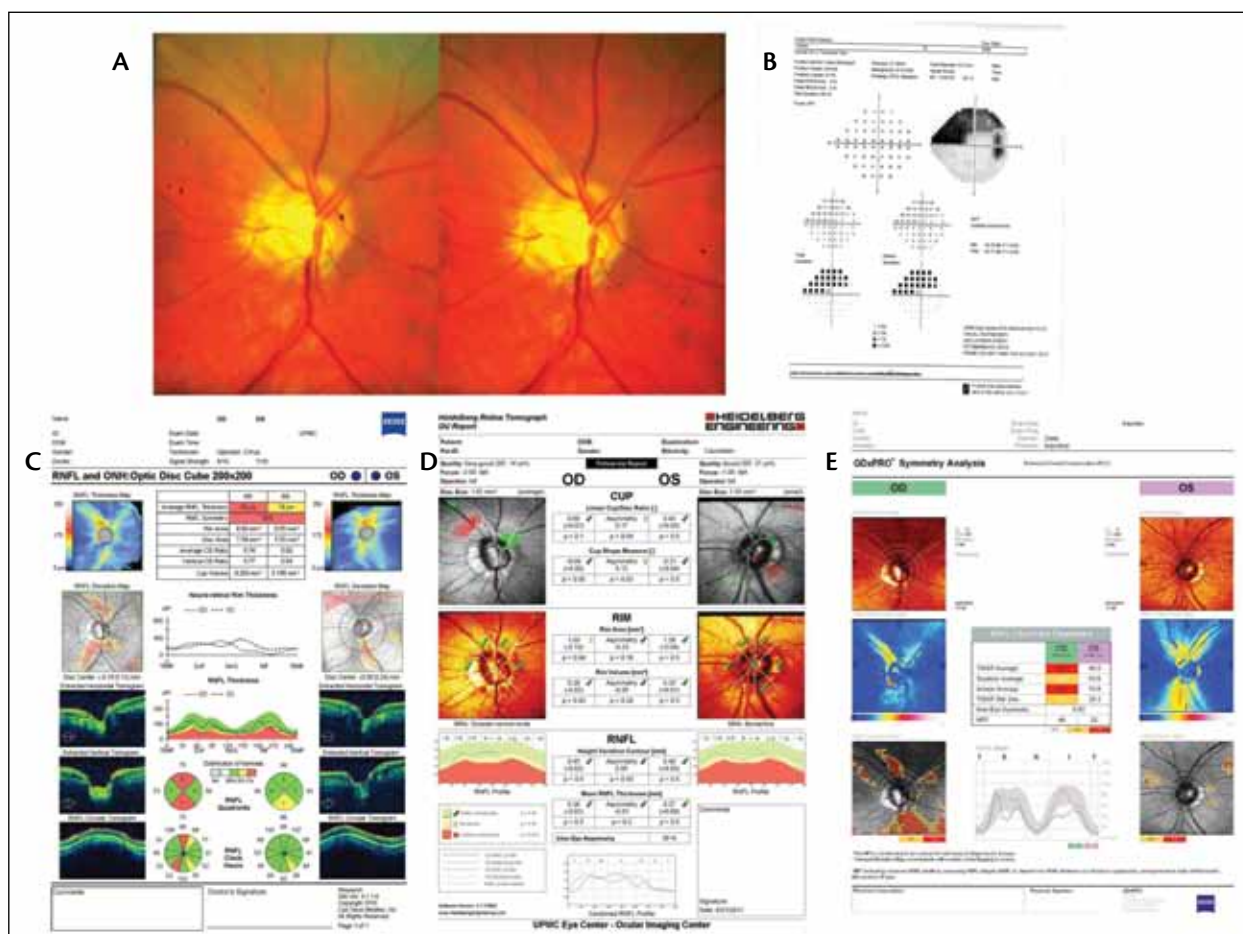


Figure. Advanced imaging in glaucoma correlates well with a traditional examination of the optic nerve head and automated perimetry. A stereo disc photograph demonstrates advanced cupping and an inferior notch in the right eye of this patient (A). Humphrey visual field test (Carl Zeiss Meditec, Inc.) with correlating superior Bjerrum scotoma (B). Imaging with the Cirrus HD-OCT (Carl Zeiss Meditec, Inc.) shows a thin inferior and superior RNFL in the right eye of the same patient (C). The Moorfields regression analysis display of the HRT (Heidelberg Engineering GmbH) CSLO device correlates well with the known neuroretinal rim and RNFL defect inferiorly in the patient's right eye (D). The GDxPRO SLP device (Carl Zeiss Meditec, Inc.) also shows a loss of RNFL integrity corresponding with the known defect in the patient's right eye (E).

use of costly medications with many known side effects, laser procedures, or fistulizing surgeries with the potential to dramatically worsen the patient's vision even if they achieve the goal of a lower IOP. It is no wonder, then, that there is tremendous enthusiasm behind efforts to objectively and reproducibly characterize the optic nerve head, RNFL, and RGC layer and to use this information to better guide the diagnosis and management of glaucoma.

THE CURRENT STATE OF IMAGING TECHNOLOGY

It is important to state at the outset that no imaging procedure is able to definitively diagnose glaucoma,

predict progression, or even detect very subtle progression. Instead, these tools provide an objective foundation on which the astute clinician may base his or her decision making. Each technology has now reached a level of maturity where not only are its measurements reproducible, but it also uses ever-expanding normative data sets and has the ability to statistically detect glaucomatous progression.³⁻¹² Manufacturers are continually refining and updating the software analyses to improve the usefulness of the acquired data.

It is beyond the scope of this article to adequately cover all of the nuanced advantages and disadvantages of each technology, but a brief overview is presented herein. CSLO works by mapping the surface topogra-

“No imaging procedure is able to definitively diagnose glaucoma, predict progression, or even detect very subtle progression.”

phy of the retinal tissue using a series of coronal images, but it is presently limited in axial resolution. CSLO discriminates well between glaucomatous and healthy eyes, and its progression analysis has been validated.¹³ SLP detects the birefringence of reflected light from the peripapillary retina to assess the status of the RNFL. SLP also provides a progression analysis.¹⁴ Finally, OCT utilizes interferometry to construct three-dimensional representations of retinal layers, including the macular and circumpapillary RNFL. The speed and anatomic resolution of current OCT technology even allow individual discrimination of macular nerve fiber, ganglion cell, and inner plexiform layers of the retina, thus pushing the envelope for detecting neurodegeneration quite proximally.^{15,16} Progression analysis on OCT is also validated and maturing, as with the other technologies.¹⁷

As promising as each of these developments seems, some lack of overlap remains in the detection of progression between techniques. This problem will be apparent to clinicians in settings where multiple technologies are available for each patient (eg, university-based practices), but it could create a misleading impression of progression in settings where only one technology is available. The data available from these impressive imaging machines must be taken as but a piece of the larger clinical picture. Close observation and repetitive measurements when the physician is clinically uncertain remain a cornerstone of glaucoma management.

CONCLUSION

Although imaging technology still requires quality assessment and accurate interpretation, the addition of objective data undoubtedly elevates the clinician's ability to detect and treat glaucoma and its progression at their earliest possible stages.¹⁸ It is well understood that earlier treatment has the potential to decrease the severity and impact of glaucoma-related blindness. In addition, the practitioner's enhanced certainty facilitates his or her decision making when the advancement of therapy is required, and this greater confidence helps to reduce the incidence of undertreatment. ■

Ian Conner, MD, PhD, is a fellow with the Glaucoma Service at the UPMC Eye Center of the University of Pittsburgh School of Medicine. He acknowledged no financial interest in the products or companies mentioned herein. Dr. Conner may be reached at connerip@upmc.edu.



Joel S. Schuman, MD, is the Eye and Ear Foundation professor and chairman of the Department of Ophthalmology at the University of Pittsburgh School of Medicine, and he is the director of the UPMC Eye Center. He is also a professor of bioengineering at the University of Pittsburgh School of Engineering and a professor at the Center for the Neural Basis of Cognition, Carnegie Mellon University and University of Pittsburgh. Dr. Schuman receives royalties from intellectual property licensed by M.I.T. and Mass Eye & Ear to Carl Zeiss Meditec, Inc. Dr. Schuman may be reached at (412) 647-2205; schumanjs@upmc.edu.



1. Lichter P. Variability of expert observers in evaluating the optic disc. *Trans Am Ophthalmol Soc.* 1976;74:532-572.
2. Korth M. The value of electrophysiological testing in glaucomatous diseases. *J Glaucoma.* 1997;6(5):331-343.
3. Kim JS, Ishikawa H, Sung KR, et al. Retinal nerve fibre layer thickness measurement reproducibility improved with spectral domain optical coherence tomography. *Br J Ophthalmol.* 2009;93(8):1057-1063.
4. Dreher AW, Tso PC, Weinreb RN. Reproducibility of topographic measurements of the normal and glaucomatous optic nerve head with the laser tomographic scanner. *Am J Ophthalmol.* 1991;111:221-229.
5. Mikelberg FS, Wijsman K, Schulzer M. Reproducibility of topographic parameters obtained with the Heidelberg Retina Tomograph. *J Glaucoma.* 1993;2:101-103.
6. Hoh ST, Ishikawa H, Greenfield DS, et al. Peripapillary nerve fiber layer thickness measurement reproducibility using scanning laser polarimetry. *J Glaucoma.* 1998;7:12-15.
7. Zangwill L, Berry CA, Garden VS, Weinreb RN. Reproducibility of retardation measurements with the Nerve Fiber Analyzer II. *J Glaucoma.* 1997;6:384-389.
8. Chauhan BC, McCormick TA, Nicoletta MT, LeBlanc RP. Optic disc and visual field changes in a prospective longitudinal study of patients with glaucoma: comparison of scanning laser tomography with conventional perimetry and optic disc photography. *Arch Ophthalmol.* 2001;119:1492-1499.
9. Kamal DS, Garway-Heath DF, Hitchings RA, Fiske FW. Use of sequential Heidelberg Retina Tomograph images to identify changes at the optic disc in ocular hypertensive patients at risk of developing glaucoma. *Br J Ophthalmol.* 2000;84:993-998.
10. Poinsoosawmy D, Tan JCH, Bunce C, et al. Longitudinal nerve fibre layer thickness change in normal-pressure glaucoma. *Graefes Arch Clin Exp Ophthalmol.* 2000;238:965-969.
11. Boehm MD, Nedrud C, Greenfield DS, Chen PP. Scanning laser polarimetry and detection of progression after optic disc hemorrhage in patients with glaucoma. *Arch Ophthalmol.* 2003;121:189-194.
12. Wollstein G, Schuman JS, Price LL, et al. Optical coherence tomography longitudinal evaluation of retinal nerve fiber layer thickness in glaucoma. *Arch Ophthalmol.* 2005;123:464-470.
13. Wollstein G, Garway-Heath DF, Fontana L, Hitchings RA. Identifying early glaucomatous changes: comparison between expert clinical assessment of optic disc photographs and confocal scanning ophthalmoscopy. *Ophthalmology.* 2000;107:2272-2277.
14. Alencar LM, Zangwill LM, Weinreb RN, et al. Agreement for detecting glaucoma progression with the GDx guided progression analysis, automated perimetry, and optic disc photography. *Ophthalmology.* 2010;117(3):462-470.
15. Ishikawa H, Stein DM, Wollstein G, et al. Macular segmentation with optical coherence tomography. *Invest Ophthalmol Vis Sci.* 2005;46:2012-2017.
16. Tan O, Chopra V, Lu AT, et al. Detection of macular ganglion cell loss in glaucoma by Fourier-domain optical coherence tomography. *Ophthalmology.* 2009;116:2305-2314.
17. Leung CK, Cheung CY, Weinreb RN, et al. Evaluation of retinal nerve fiber layer progression in glaucoma: a study on optical coherence tomography guided progression analysis. *Invest Ophthalmol Vis Sci.* 2010;51:217-222.
18. Vessani RM, Moritz R, Batis L, et al. Comparison of quantitative imaging devices and subjective optic nerve head assessment by general ophthalmologists to differentiate normal from glaucomatous eyes. *J Glaucoma.* 2009;18(3):253-261.