Ophthalmic Imaging and the Emergence of SD OCT

Clinical experience with the Spectralis HRA+OCT.

BY JEFFREY S. HEIER, MD

Ophthalmic imaging has been evolving to keep pace with the burgeoning field. Today's technology is capable of identifying at-risk patients, measuring therapeutic responses, and probing potential treatment combinations. Optical coherence tomography (OCT) has specifically redefined the way we manage neovascularization and edema as they relate to a variety of retinal diseases. Next in line is spectral-domain (SD) OCT, the higher resolution and reduced motion artifact companion to the well-known time-domain (TD) OCT, for which we are seeing widespread adoption.

HISTORY OF RETINAL IMAGING

Diagnostic imaging was not always an integral part of the ophthalmologist's armamentarium. When flash fundus photography initially paired cameras with ophthalmoscopes in the 1920s, it was the first time clinicians were able to document their empirical observations and share them with students; however, this technique was limited in its practical applications due to its inability to reproduce illuminated, quality images of eye pathology.

It was not until the invention of the laser in 1960 that two critical barriers in eye imaging could be successfully surmounted: being able to direct an optimum amount of light into the eye to capture a well-defined representation, and achieving real-time images without the characteristic blurring from eye movement. This technology was later adapted for ophthalmic purposes and realized as confocal scanning laser ophthalmoscopy (cSLO), with the first systems originating from Heidelberg Engineering in Germany in 1991. Traditional fundus photography served ophthalmologists well, despite yielding pictures with scattered light. Advancements in cSLO offered a better alternative with the ability to create crisp retinal images and movies by scanning high-speed, transverse depictions of the retina.

The demonstrated utility of fluorescein angiography (FA), born out by Donald Gass' landmark atlas,[1] further complemented the benefits of cSLO, and the two were first adapted for binary use in 1996. When the laser emits the appropriate wavelength for fluorescein, vivid motion pictures capture the dye as it courses through the vasculature and enable the clinician to more accurately assess choroidal neovascularization (CNV). Indocyanine green angiography (ICGA), introduced soon afterward, works in much the same way as FA, including requiring a single injection during imaging.

The discovery of autofluorescence has since made it possible to detect certain disease processes without the injection of a dye. Lipofuscin present in retinal pigment epithelium (RPE) cells naturally fluoresces when exposed to an excitation filter of 488 nm, the illumination of which enables clinicians to differentiate between those diseases where lipofuscin accumulates in the cells and those in which it does not.[2,3] The appearance of autofluorescence often is indicative of impaired metabolism at the level of the RPE, and increased or absent autofluorescence each have significance regarding the health of the retina.[4] Paired with cSLO, this principle has been particularly useful in monitoring geographic atrophy (GA) in dry age-related macular degeneration (AMD).

FIRST COMMERCIAL OCT

Around the time that cSLO and FA began appearing together in diagnostic imaging systems, Carl Zeiss (Jena,

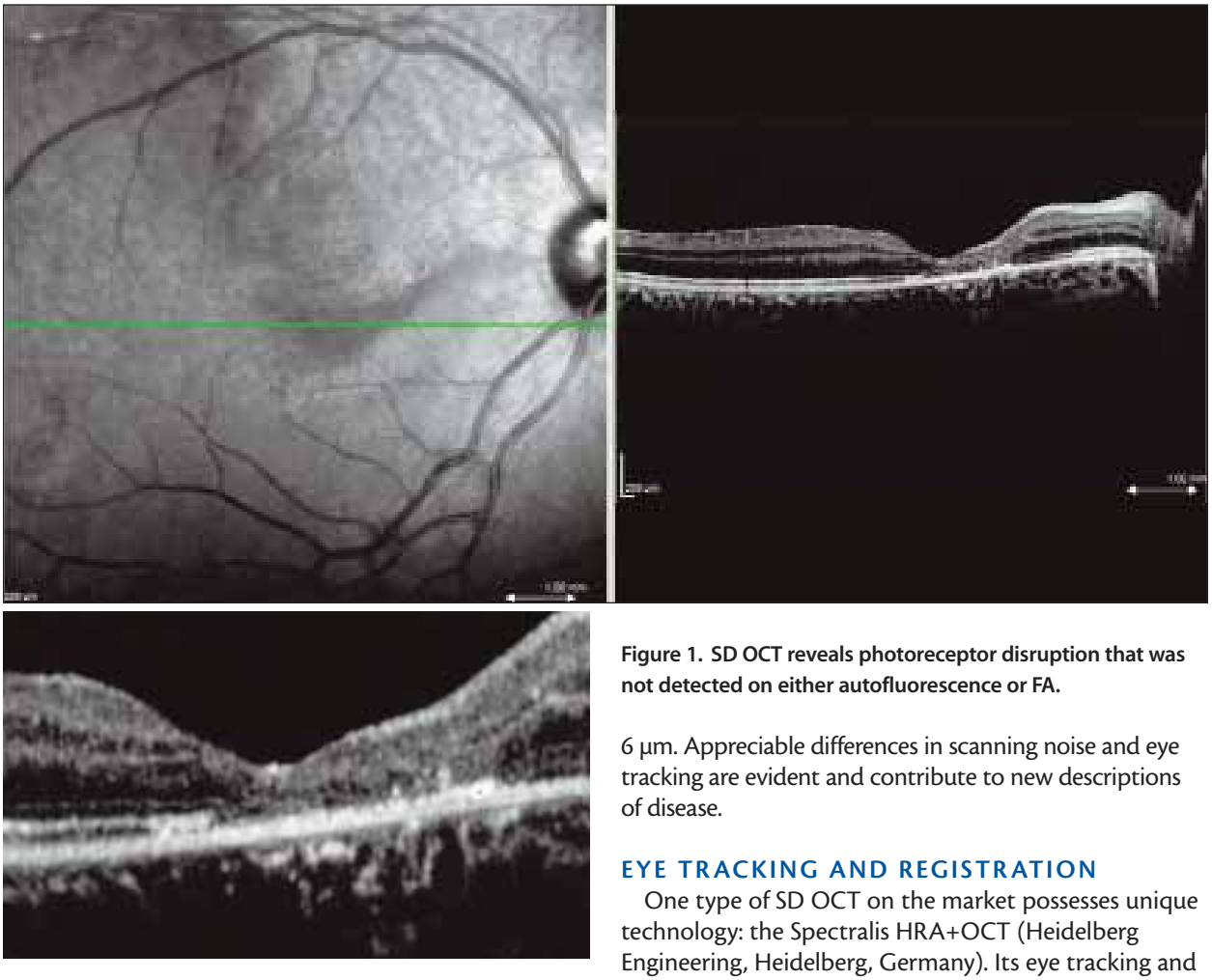

Figure 1. SD OCT reveals photoreceptor disruption that was not detected on either autofluorescence or FA.

Germany) introduced the first commercial product with TD OCT. This technology differed from cSLO in that it created cross-sectional reproductions of the retina as opposed to transverse images, thereby manifesting pathology through veritable retinal layers. Due to its much improved detail and enhanced accuracy, TD OCT has permitted the clear differentiation between intraretinal and subretinal fluid pockets, helped recognize response to treatment and disease recurrence, and otherwise elevated ophthalmic imaging to an indispensable tool in retinal diagnosis, management, and outcome assessment.

The limitations of TD OCT fueled continued progress in cross-sectional imaging, and SD OCT was introduced in 2006. Motion artifacts related to eye movement and operator errors were, for the most part, resolved with SD OCT, but although scanning speeds are 100 times faster, residual artifacts are still visible in 3-D images. The absolute resolution of these images when compared with TD OCT stills and movies is significant, however, especially given the small increase in true resolution from 10 to 6 µm. Appreciable differences in scanning noise and eye tracking are evident and contribute to new descriptions of disease.

EYE TRACKING AND REGISTRATION

One type of SD OCT on the market possesses unique technology: the Spectralis HRA+OCT (Heidelberg Engineering, Heidelberg, Germany). Its eye tracking and registration capabilities are able to improve image clarity by scanning the retina at 40 kHz, thereby both decreasing capture time and countering the distorting effects of eye movements.

The eye-tracking technology captures two scans simultaneously: a reference and a cross-sectional image. Alignment of these two images permits identification of reliable reference points and corrects for eye movement distortion. Because patients are typically followed over a period of time, the true registration feature enables clinicians to be absolutely sure that they are looking at the same spot on the retina every time.

In general, a technician acquires digital stills with Spectralis from SD OCT integrated with confocal laser angiography. High-resolution cross-sectional images of the retina can be combined with any of the following imaging complements: FA, ICGA, autofluorescence, red-free or infrared. Additionally, volume scans, or stacks of parallel B-scans, allow the clinician to selectively review potentially pathologic areas.

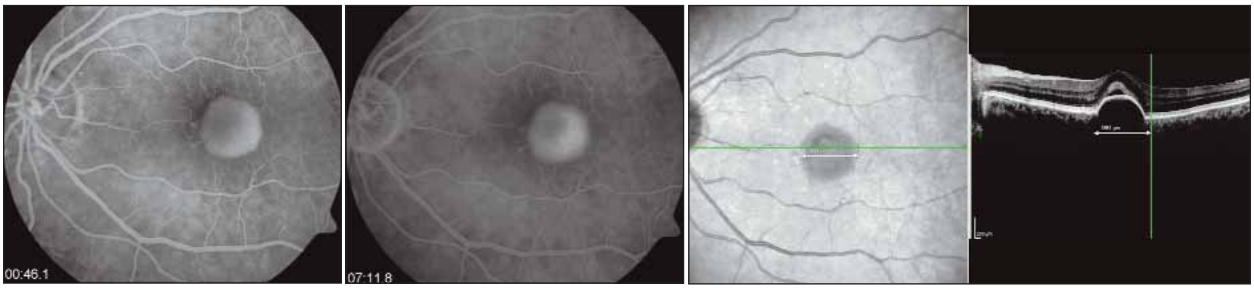

Figure 2. A patient with a PED without obvious leakage is found to have subtle subretinal fluid detected on an SD OCT volume scan.

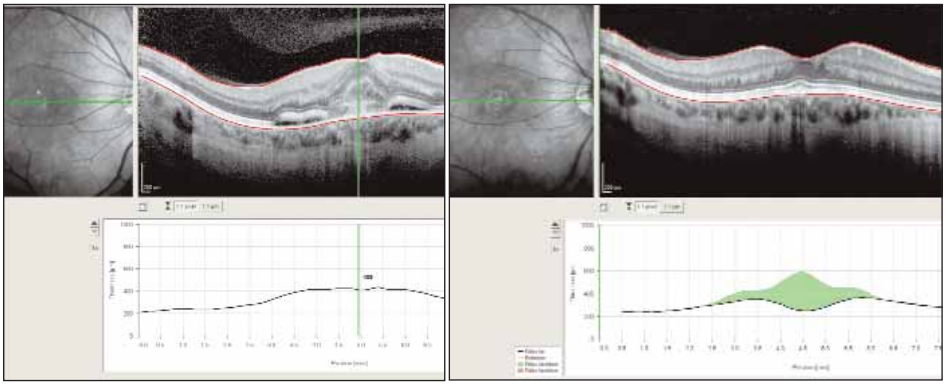

Figure 3. Marked regression of non-AMD CNV in a patient 37 years of age.

CASE IN POINT

In my practice, we use Spectralis for diagnostic imaging, and there have been several cases that have underscored the advantages of eye tracking and true registration. Diagnoses, treatments, and outcome measurements have all been affected by these innovations.

For instance, a 12-year-old boy who had suffered a soccer injury to the right eye came to us with 20/200 vision. Autofluorescence images and FA from a previous clinic revealed a healthy optic nerve and significant extrafoveal commotio retinae but no clear reason for the visual decline. Once we analyzed his fundus with SD OCT, we were able to detect the complete disruption of his photoreceptor layer, which accounted for the vision level reduction (Figure 1).

Patients with chronic CNV have similarly demonstrated the value of eye tracking. We have had two such cases where there did not appear to be any residual or recurrent fluid on FA. Upon conducting a volume scan with SD OCT, however, an area of leakage damage became evident (Figure 2). Understanding the extent of pathology begs the question whether patients like these should be treated with intravitreal injection, when perceptible improvements would be unlikely. Further evaluation will be likely to address questions such as these in the future.

Lastly, a 37-year-old medical researcher presented to us with a non-AMD lesion and 20/100 vision. After treatment with ranibizumab (Lucentis, Genentech), the patient exhibited 20/15 vision and showed a remarkable normalizing of anatomy with SD OCT scans (Figure 3). If I had not been certain that true registration was pinpointing the same area, I would have been doubtful that such resolution of pathology had indeed occurred.

CONCLUSION

Technological strides in diagnostic imaging have revolutionized the way in which retinal specialists diagnose, treat, and assess their patients. We have been able to discriminate the finest points of pathology with our Spectralis SD OCT and have turned our retinal scans from promising indicators into true decision-making tools. ■

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1. Gass JDM. *Stereoscopic Atlas of Macular Disease Diagnosis and Treatment,* Vol. 2. Mosby: St Louis, 1997.
2. Delori FC, Dorey CK, Staurenghi G, Arend O, Goger DG, Weiter JJ. In vivo fluorescence of the ocular fundus exhibits retinal pigment epithelium lipofuscin characteristics. *Invest Ophthalmol Vis Sci.* 1995;36(3):718–729.
3. Feeney-Burns L, Berman ER, Rothman H. Lipofuscin of human retinal pigment epithelium. *Am J Ophthalmol.* 1980;90(6):783–791.
4. Schütt F, Bergmann M, Holz FG, Kopitz J. Isolation of intact lysosomes from human RPE cells and effects of A2-E on the integrity of the lysosomal and other cellular membranes. *Graefes Arch Clin Exp Ophthalmol.* 2002;240(12):983–988.