

Spectral-domain OCT Reveals Details of Intraretinal and Choroidal Vasculature

The Advanced Visualization software on the Cirrus OCT provide useful anatomic information that other units cannot.

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Optical coherence tomography (OCT), first introduced in the 1990s and now a mainstay of diagnostic imaging for retinal specialists, provides micron-level resolution for views of the macula and optic nerve head. OCT helps the diagnostician determine why a patient does not see normally; the images it creates provide clues to whether the pathology is in the retina or further along the visual pathway in the optic nerve.

Used together, OCT and angiography can help refine the diagnosis. Fluorescein and indocyanine green angiography (FA and ICGA) serve to define the dynamic vascular complexities of a given region or lesion, its size, location, and perfusion status; to differentiate classic vs occult neovascularization, and so forth. On the other hand, OCT is used to directly measure neurosensory retinal tissue and fluid. OCT can be used to study vitreous adhesions and retinal lesion depths and their relationships with the retinal pigment epithelium (RPE) and choroid.

OCT imaging provides invaluable qualitative data about medical and surgical problems of the retina. It is useful in determining the timing and choice of clinical interventions for a wide range of indications. It has also proven to be excellent to follow and document the anatomic success of interventions. OCT is less useful, however, for assessing the visual success of therapy, as this is dependent on the viability of the photoreceptors.

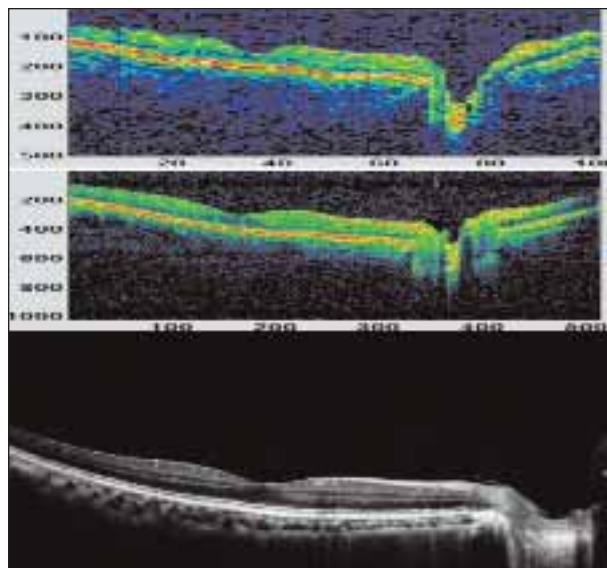


Figure 1. Improvement of resolution from first-generation OCT (top) to the second-generation (middle) to the Cirrus HD-OCT (bottom).

Only a weak correlation (0.52 correlation coefficient) was found between central retinal thickness and measured visual acuity in a study by the Diabetic Retinopathy Clinical Research Network.¹

In short, the experience and knowledge gained

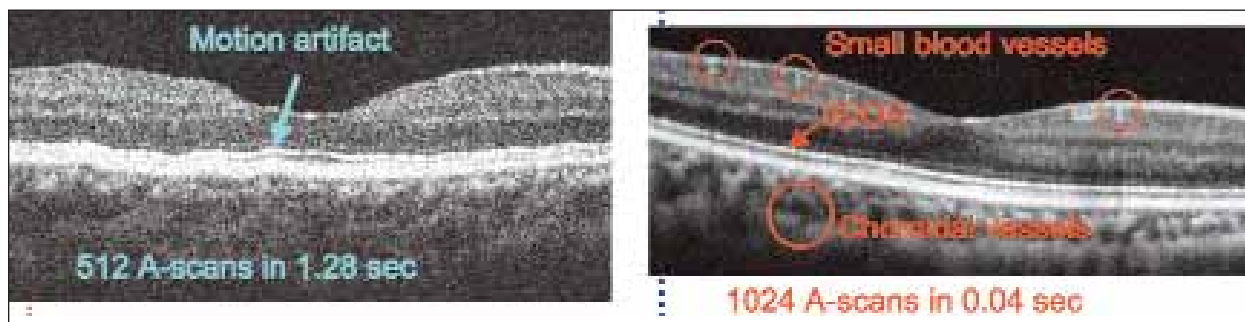


Figure 2. With SD imaging (right), details such as small blood vessels and the photoreceptor inner and outer segment boundary become clearly visible. There is no motion artifact that is commonly seen in conventional OCT images (left). Even deep choroidal vessels can be visible in normal eyes.

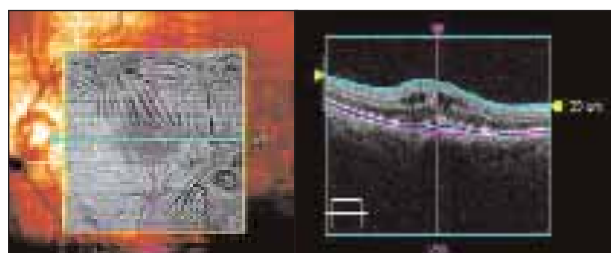


Figure 3. Slab lines can be applied with Advanced Visualization software for enhanced views of surface retinal pathology for surgical planning.

through clinical studies and in clinical practice have led to acceptance of OCT as the standard of care in retinal practices for many ophthalmic conditions.

EVOLUTION OF OCT

The concept of OCT was developed at Massachusetts Institute of Technology in the early 1990s, and the first commercial version of OCT was made available by Carl Zeiss (Jena, Germany) in 1996. Image acquisition required pupil dilation and lasted for 1 second. This first-generation instrument was followed by the OCT2 in 1999.

The third-generation Stratus OCT and the most recently introduced spectral-domain (SD) Cirrus HD-OCT (both Carl Zeiss Meditec, Dublin, CA) have subsequently decreased image acquisition times and improved image resolution (10 and 5 μm , respectively). The Stratus OCT is a time-domain (TD) instrument with a longer image acquisition time, and the Cirrus OCT is a SD (also known as Fourier-domain [FD]) instrument with a faster image acquisition time to create B-scan images of ocular structures.

Figure 1 shows the improvement of the resolution in OCT images from the first-generation OCT to the Cirrus HD-OCT.

Briefly, OCT works on the principle of interferometry. A broadband near-infrared light beam is split, with one beam



Figure 4. Shadowbox image of distorted intraretinal vessels underlying an epiretinal membrane with Advanced Visualization software.

of light traveling into the eye while the other goes to a reference mirror. The light beams from both paths are reflected back to a detector, where they are compared and used to construct a cross-sectional image of the retinal anatomy.²

Images can be obtained with resolutions of 10 μm axially from the surface of the retina to the choroid and 20 μm transversely across the retina.

In TD OCT, a mirror in the reference arm of the interferometer moves during each scan cycle to match the delay in various layers of the sample. The need for this mechanical movement limits the speed of image acquisition. In FD OCT, the reference mirror is stationary, and the interference between the sample and reference reflections is split into a spectrum (hence, "spectral" domain) and captured by a camera. This spectral interferogram is transformed using

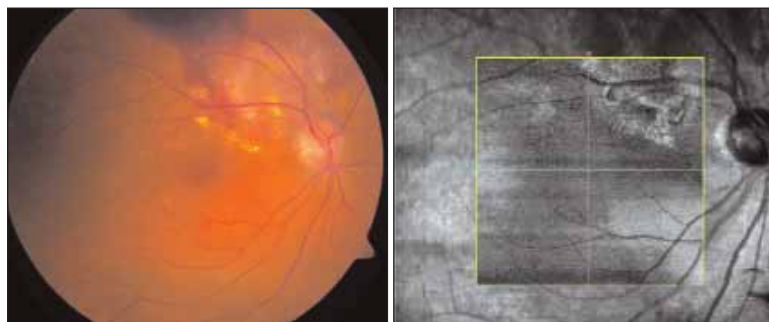


Figure 5. This case demonstrates idiopathic polypoidal choroidopathy, and the slab lines can be used to visualize the shadowgram of the polypoidal lesions within the choroid without having to perform indocyanine green angiography.

Fourier equations to produce an axial scan. The absence of moving parts allows the image to be acquired rapidly—approximately 60 times faster than with TD OCT.

The Table shows a comparison of the characteristics of TD and FD OCT. FD OCT can capture more than 2,000 pixels simultaneously, whereas TD OCT captures one pixel at a time. In the time it takes TD OCT to form one axial scan, FD OCT can capture an entire image. The higher speed and higher resolution of FD OCT allows higher definition, or more pixels per image.

With higher resolution, more anatomic details can be seen, such as small blood vessels and the photoreceptor inner and outer segment boundary. With faster acquisition speed, the motion artifacts seen in conventional OCT images are eliminated. In addition, because of the efficiency of simultaneous signal acquisition, FD OCT actually has a higher signal, appearing brighter and cleaner than time-domain OCT. Even deep choroidal vessels can be visible in normal eyes (Figure 2). Improved light sources allow five times greater axial resolution (2 μ m resolutions).

ADVANCED VISUALIZATION

In addition to the enhanced resolution now available with Fourier-domain technology, the Cirrus offers the ability to create virtual views of different layers in the retina, known as “slab” or C-scan analysis. Using the

Advanced Visualization features on the Cirrus, the user can create “en-face” 2-D representations of anatomic layers including the vitreoretinal interface, the RPE and neurosensory retina, and the choroidal vasculature. Advanced Visualization can also create representations of disorders and conditions such as epiretinal membranes, intraretinal cysts or hemorrhages, choroidal neovascularization (CNV), and pigment epithelial detachments.

This can be accomplished because the Cirrus obtains up to 200 B-scans in a 6x6-mm cube, allowing the creation of a

true 3-D dynamic cube with minimal interpolation of data. With this density of information, 2-D images can be selected from anywhere in the cube.

For example, one can select an epiretinal membrane slab from a data cube and lay it over an infrared fundus image. Similarly, one can select a slab 20 to 90 μ m thick to examine “shadowgrams” of the intraretinal and choroidal vasculature. Slabs can be selected to show CNV or a pigment epithelial detachment, depending on the thickness of the lesion (Figures 3-5).

Visualization of this data in 3-D demonstrates subtle pathology not evident with conventional 2-D images. It can assist the surgeon by better defining epiretinal pathology before surgery. It can also facilitate evaluation of the retinal vasculature without having to perform FA and can help to define choroidal vascular pathology without ICGA.

OCT has established itself as essential to modern retinal practice. Recent advances in image acquisition and resolution with the Cirrus HD-OCT allow the creation of 3-D volumetric reconstructions and point-to-point correlation of OCT images with fundus images. Furthermore, the powerful new Advanced Visualization software provides the retinal specialist a useful new tool to better define retinal and RPE pathology and to directly visualize retinal and choroidal vasculature. ■

TABLE. CHARACTERISTICS OF TIME-DOMAIN AND FOURIER-DOMAIN OCT	
Time Domain	Fourier Domain
Sequential	Simultaneous
1 pixel at a time	Entire A-scan at once
400 pixels per A-scan	2048 pixels per A scan
0.25 sec per A scan	0.00000385 sec per A scan
512 A-scans in 1.28 sec	1024 A-scans in 0.04 sec
Slower than eye movements	Faster than eye movements

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1. The Diabetic Retinopathy Clinical Research Network. Relationship between optical coherence tomography-measured central retinal thickness and visual acuity in diabetic macular edema. *Ophthalmology*. 2007;114(3):525-536.
2. Bressler N, Ahmed I. *The Stratus OCT Primer: Essential OCT*. Jena, Germany; Carl Zeiss Meditec; 2006.