

Pitfalls to Consider When Using Spectral-domain OCT

BY SRINIVAS R. SADDA, MD; AND PEARSE KEANE, MD



Retina Pearls is a column that appears regularly in Retina Today. The purpose of the column is to provide a forum for retinal specialists to share informative and exciting tips or pearls with regard to specific vitreoretinal surgical techniques, diagnostics, or therapeutics. This installment of Retina Pearls addresses spectral-domain (SD) optical coherence tomography (OCT). Srinivas R. Sadda, MD, and Pearse Keane, MD, relate that, while the new SD OCT systems are a vast improvement in imaging technology, we must be aware of the variables among the different technologies and how the SD OCT images are interpreted.



We extend an invitation to readers to submit surgical pearls for publication in Retina Today. Please send submissions for consideration to Dean Elliott (deliott@doheny.org) or Ingrid U. Scott, MD, MPH (iscott@psu.edu). We're looking forward to hearing from you.

-Dean Elliott, MD; and Ingrid U. Scott, MD, MPH

In recent years, optical coherence tomography (OCT) has become an essential tool for the diagnosis and management of vitreoretinal disorders. In conventional OCT systems, light reflected from the tissue of interest (ie, the neurosensory retina) is assessed as a function of time, and, hence, these systems are often referred to as time-domain (TD) OCT. Stratus OCT (Carl Zeiss Meditec, Dublin, CA), the most commonly used OCT system worldwide, is based on TD technology. Although Stratus OCT is capable of providing relatively high-resolution images (axial: 8 μm to 10 μm), the requirement for a mobile reference mirror limits its image acquisition speed to 400 A-scans per second, and thus, only sparse coverage of the macular area is possible.

Recently, many of the problems associated with TD OCT have been overcome, at least in part, by the release of the next generation of commercial OCT systems. These systems include: Cirrus HD-OCT (Carl Zeiss Meditec), 3D OCT-1000 (Topcon Medical Systems, Paramus, NJ), Spectralis HRA+OCT (Heidelberg Engineering, Heidelberg, Germany), RTVue-100

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(Optovue Corporation, Fremont, CA), Spectral OCT SLO (Opko Instrumentation, Miami, FL), SOCT Copernicus HR (Optopol Technology, Zawiercie, Poland), and 3D SDOCT (Bioptigen, Triangle Park, NC). These systems, termed spectral-domain (SD) or Fourier-domain OCT, are based on the assessment of light reflected from the retina as a function of frequency rather than of time. Using these devices, A-scans can be acquired 50 to 100 times more quickly than with TD technology. In addition to their increased image acquisition speed, these instruments offer improvements in sensitivity and image resolution (axial: 5 μm to 7 μm). Although many problems associated with TD OCT have been ameliorated with SD OCT systems, caution is still

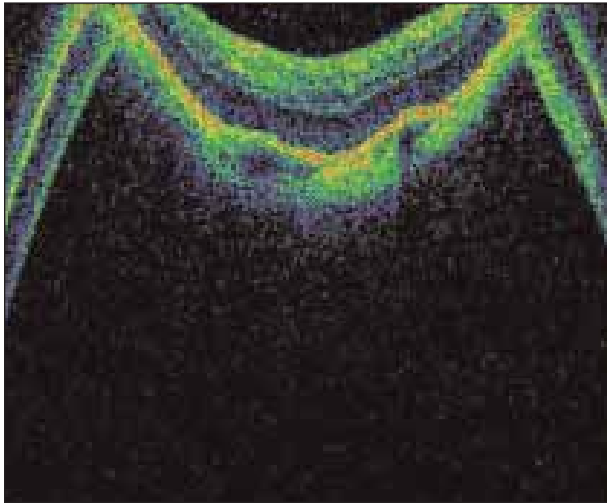


Figure 1. SD OCT B-scan of a patient with high myopia and long axial length. The image window is not able to fully contain the retina due to the staphylomatous elongation. Note the reflected retinal layers at both edges of B-scan which represents anterior portions of the conjugate image.

required as we become increasingly aware of image interpretation pitfalls specific to SD OCT. A few of these potential pitfalls are discussed below.

CONJUGATE IMAGES

SD OCT relies on a combination of spectral interferometry and Fourier transformation. Fourier transformation is a mathematical function that is described as “Hermitian” (ie, it results in the production of two mirror images, one real and one inverted, which are symmetrical around a fixed point). SD OCT instruments generally display only one of the two possible images, typically the one in which the inner retina is uppermost. This has the unfortunate effect of limiting the distance over which OCT images can be obtained. For example, if a structure spans a large axial distance, such as in eyes with increased axial length due to pathologic myopia, portions of the conjugate image may extend onto the displayed image and be superimposed (Figure 1). Structures in the vitreous may also be reflected onto or beneath the retina—this may often result in the hyaloid face and/or asteroid bodies appearing both within and underneath the retina (Figure 2).

SEGMENTATION ERRORS

Stratus OCT uses image processing techniques to automatically detect the inner and outer retinal boundaries on OCT B-scans (segmentation) and thus provide measurements of retinal thickness. Using these techniques, it is possible to measure retinal thickness at

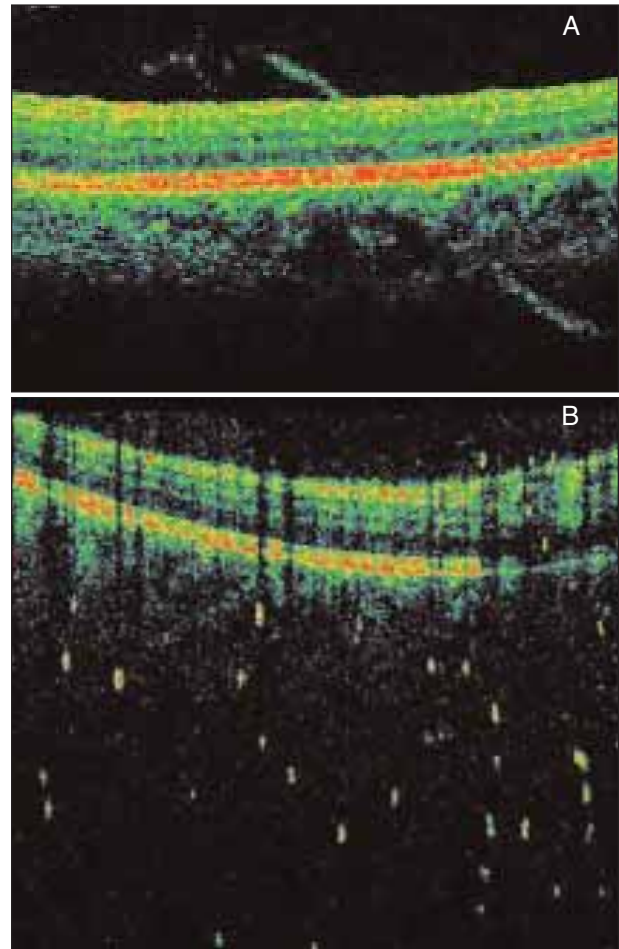


Figure 2. SD OCT B-scans showing artifacts reflected from the conjugate image: a band of the posterior hyaloid (A) and asteroid hyalosis appearing below the retina (B).

multiple locations and to construct retinal thickness maps. Caution is required in the use of this quantitative information, as errors in retinal segmentation are known to occur, and these errors are often severe. SD OCT systems also utilize automated image analysis software that provides retinal thickness measurements. In theory, the greater axial resolution, speed, and sensitivity of SD OCT should increase the accuracy of these quantitative assessments. Improvements in computer-image processing techniques and segmentation algorithms should also result in a reduced OCT error rate. Care is still required, however, as the quality of image segmentation varies between different SD OCT systems, and severe segmentation errors still occur, resulting in erroneous retinal thickness measurements. These errors commonly occur in the setting of epiretinal membranes or vitreoretinal traction, where the internal limiting membrane is misidentified. Errors also frequently occur

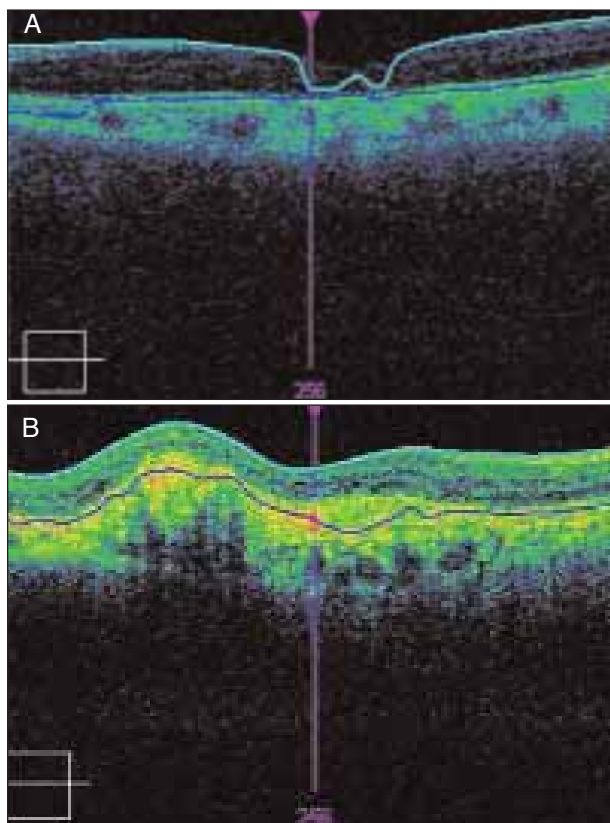


Figure 3. Segmentation errors in the identification of retinal boundaries in the setting of: low signal strength (A) and complex pathology with choroidal neovascular tissue in the sub-retinal space (B).

in scans with low signal strength and in patients with complex morphologic features such as concurrent sub-retinal fluid, subretinal tissue, and pigment epithelium detachment (PED) (Figure 3).

MOTION ARTIFACTS

Due to the slow speed of TD OCT, accurate acquisition of OCT B-scans is hindered by the presence of motion artifacts; these artifacts often manifest as undulations in the neurosensory retina that may make recognition of certain morphologic features more difficult (eg, PEDs). The image analysis software of Stratus OCT performs automatic alignment of A-scans using image-processing techniques to compensate for these motion artifacts. This function is not required in SD OCT systems as the high speed scanning of these instruments prevents the problem of A-scan misalignment within OCT B-scans. Motion artifacts (eg, vertical microsaccades), however, remain a problem for SD OCT when high sampling density is required; for example, when generating large 3-D data stacks. This may result in inac-

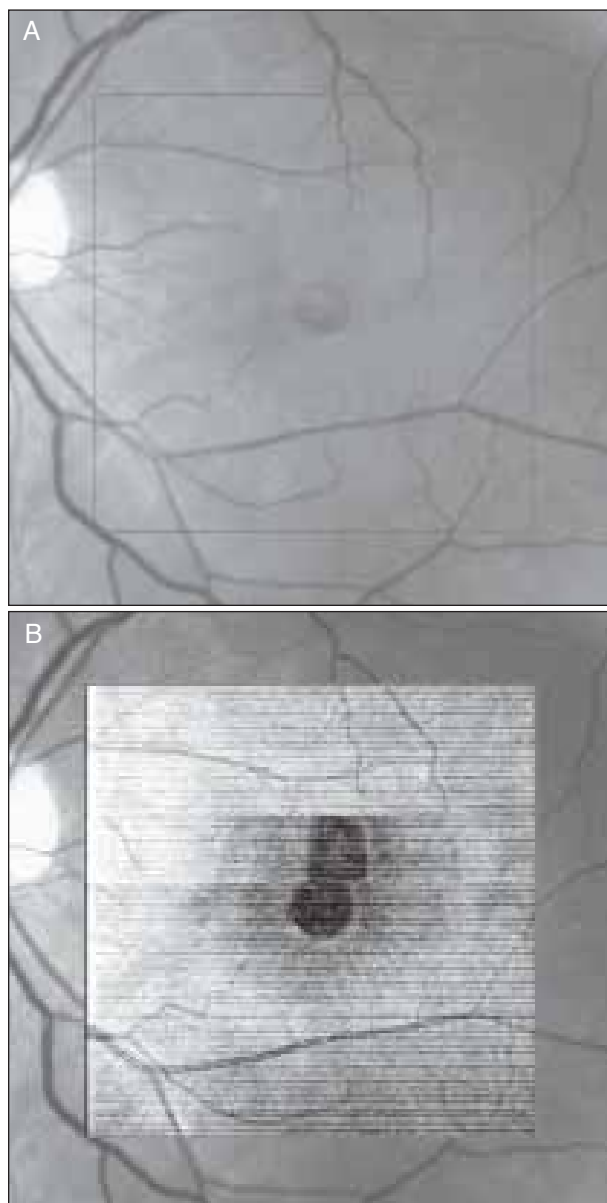


Figure 4. Infrared image (A) and SD OCT fundus image superimposed on infrared image (B) of a patient with a full-thickness macular hole. OCT fundus image appears to show two macular holes due to fixation artifact induced by a vertical saccade.

curate retinal thickness measurements and the generation of unrepresentative abnormal features on retinal thickness maps (Figure 4). For example, at an acquisition speed of 25,000 A-scans per second, a raster scan (which consists of a rectangular pattern of horizontal line scans that run in parallel across the macula) of the macula consisting of 512 x 512 A-scans (so-called isotropic sampling) would require more than 10 sec-

onds to be obtained. Many SD OCT systems address this problem by sacrificing sampling density along one axis of the raster scan; however, some commercially available OCT instruments, such as the Spectralis, also provide real-time eye motion tracking that theoretically enables longer acquisition times and higher density data sets. Eye tracking in patients with poor fixation, however, may also increase the time required to obtain a dense 3-D set and ultimately reduce the density of B-scans that can be practically obtained.

It is important for retina specialists to recognize some of the potential pitfalls associated with the use of these (SD OCT) instruments.

RASTER SCAN DENSITY

The limited A-scan acquisition speed of Stratus OCT restricts both the number of A-scans that can be used to construct each OCT B-scan, and the number of OCT B-scans that can be acquired in succession. The high speed of SD OCT facilitates significantly greater sampling of the macular area via the use of raster-scanning protocols. SD OCT systems commonly use raster-scan protocols that consist of 128 B-scans, with each B-scan consisting of 512 A-scans (raster scans). The greater retinal sampling density of SD raster scans may facilitate early detection of morphologic changes in disease states and allow these changes to be followed over time more accurately. SD OCT scanning protocols are still evolving, however, and the optimal scan density for maximum clinical applicability remains unknown. The physician must also be aware that significant differences in retinal scanning protocols exist between OCT systems. For example, the Spectralis utilizes multiple B-scan averaging to produce extremely high quality retinal images; however, this improvement in image quality may come at the expense of retinal scanning density.

OCT FUNDUS IMAGES

Another important feature of SD OCT is the ability to generate OCT fundus images. These images are generated from the raster scan (3-D) OCT data by summing the intensity of pixels in the axial direction, resulting in a pixel brightness value for each axial scan position. OCT fundus images show a direct view of the macula in which the retinal vascular arcades may be clearly visible and spatially consistent with the vasculature on color photographic or angiographic images. OCT fundus

images are useful in the clinical setting as they may facilitate registration of any point on an OCT image with a corresponding point on the retinal surface. OCT fundus images also permit the acquisition of images in the same location over time. The interpretation of OCT fundus images, however, requires caution. Although these images mimic those of standard fundus photography, many features seen on color photographs may not be seen on OCT fundus images. In addition, eye motion artifacts may create abnormal features (Figure 4) and may reduce the accuracy of registration in SD OCT systems that depend on the OCT fundus image for B-scan alignment (ie, systems without eye tracking).

CONCLUSION

SD OCT systems are likely to supplant TD OCT systems as the standard of care for retina specialists in the near future. In the early stages of adoption, however, it is important for retina specialists to recognize some of the potential pitfalls associated with the use of these instruments. ■

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