Spectral-domain OCT in Latin America

Wide adoption of SD technology may be slow due to cost-benefit issues.

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Time-domain (TD) optical coherence tomography (OCT) (Stratus OCT; Carl Zeiss Meditec Inc., Dublin, CA; Figure 1) is a commercially available computer-assisted precision optical instrument that generates cross sectional images (tomograms) of ocular structures with close to 10-µm axial resolution.[1] This technology is evolving, and its axial resolution has been reported to be as high as 3 µm in laboratory settings (Ultrahigh-resolution OCT).[2] OCT is analogous to B-mode ultrasound, except that it uses light rather than sound. Unlike ultrasound, OCT does not require contact with the tissue examined.

The technology relies on low-coherence interferometry to generate the images.[1] A low-coherence near-infrared light beam (820 nm) is directed toward the target tissue. The magnitude and relative location of the backscattered light from the tissue's microstructures are interpreted by the OCT to generate an image. The image generated is based on the optical properties of the microstructures present in the tissue imaged. The use of a near infrared, low-coherence light source allows good tissue penetration and the registration of reflections from a narrow region of the retina and the anterior segment of the eye. To be able do this, the light beam generated by a superluminescent diode is split and simultaneously directed onto the imaged tissue and onto an internal reference mirror. When the backscattered lightbeams from both sources are combined, a phenomenon known as interference occurs. A photodetector receives the combined signal and measures the interference. The relative location of the light backscattered from the imaged tissue is then determined based on the information obtained from the controlled internal reference mirror (Figure 2). This technology allows real-time imaging and examination of epiretinal, intraretinal, and subretinal morphology and can document subtle retinal disease that is often undetectable with conventional clinical examination alone.

Figure 1. Third-generation OCT (Stratus OCT Model 3000; Zeiss-Humphrey Inc., with software application version 4.0).

The vast majority of retinal specialists have access to TD OCT systems, and in combination with clinical evaluation and fluorescein angiography these systems are effective at determining anatomic response to treatment. Very few retina specialists in Latin America have access to spectral-domain (SD) OCT, which repre-

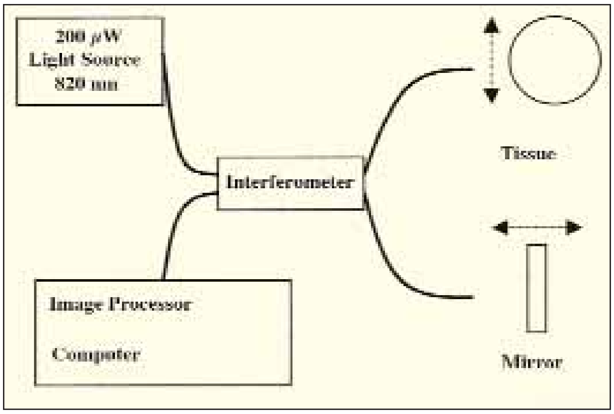
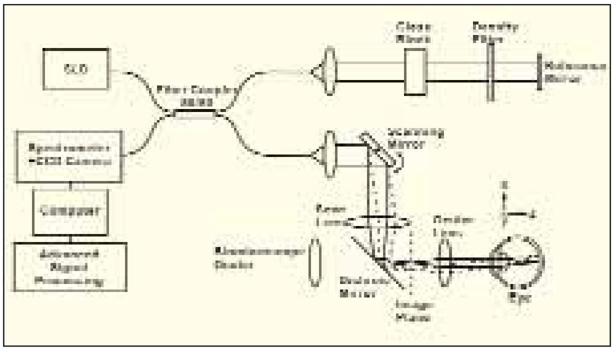


Figure 2. OCT uses an interferometer to resolve retinal structures by measuring the echo delay time of light that is reflected and backscattered from different microstructural features in the retina. The OCT projects a broad-bandwidth near-infrared light beam (820 nm) onto the retina from a superluminescent diode. It then compares the echo time delays of light reflected from the retina with the echo time delays of the same light beam reflected from a reference mirror at known distances. When the OCT interferometer combines the reflected light pulses from the retina and reference mirror, a phenomenon known as interference occurs. A photodetector detects and measures interference. Although the light reflected from the retina consists of multiple echoes, the distance traveled by various echoes is determined by varying the distance to the reference mirror.

sents the newest generation of OCT technology. SD OCT, also known as Fourier-domain (FD) OCT, represents a recent advance in OCT technology that enables imaging speeds of more than 25,000 axial scans per second, or ~50 times faster than TD detection.[3-5] SD or FD OCT is so named because the interference spectrum of echo time delays of light are measured by a spectrometer and high-speed charge-coupled device (CCD) camera. Because the interference spectrum is composed of oscillations whose frequencies are proportional to the echo time delay, axial scan measurements can be obtained by calculating the Fourier transform (ie, a mathematical operation that extracts the frequency content of a signal). In contrast to TD detection, SD detection measures all echoes of light simultaneously, and the position of the reference arm does not need to be adjusted (Figure 3). The result is a significant improvement over TD OCT in sensitivity and image acquisition speed with a reduction in motion artifacts (Figure 4).

Several SD OCT systems have become available during the past year or so, and common among all of them is that they are faster and provide better resolution



(Courtesy of Jay S. Duker, MD)

Figure 3. Schematic of SD OCT imaging system. In contrast to TD OCT systems, a spectrometer coupled to a CCD camera detects the entire interference spectrum, from which the Fourier transform is calculated. The position of the reference arm does not need to be adjusted.

than TD systems. The difficulties, however, to adopt this new technology in Latin America will be discussed in this article.

ADVANTAGES OF SD OCT

The speed and resolution of SD OCT are impressive. In addition, reproducibility is more accurate with SD OCT. There is no question that SD OCT will reveal information not seen on TD OCT. In addition, as technology improves, people tend to move to newer models because of speed, convenience, and improved capabilities. Academic practices that are eager to discover how much more information this new technology can provide about retinal anatomy in the face of advanced disease and treatment will adopt SD OCT faster. The SD OCT system enables the clinician to accurately compare a certain point in the macula and its response to treatment with the same point in the macula at a different point in time.

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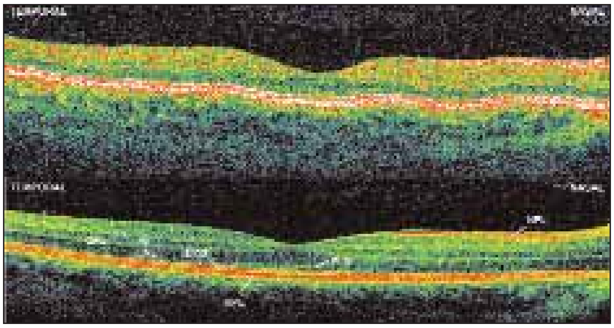
In Brazil, SD OCT technology (Spectralis OCT; Heidelberg Engineering Inc., Vista, CA) has been adopted. A huge leap forward in improving macular imaging was achieved with the advent of SD OCT devices. Remarks about the real relevance of this new OCT technology in the clinical scenario should be viewed with caution at the



(Courtesy of Jay S. Duker, MD)

Figure 4. Normal retina comparison of TD OCT image with 8- to 10-μm axial resolution and 512 axial scans taken in 1.3 seconds (above) and with SD OCT image with 5-μm axial resolution and 4096 axial scans taken in 0.039 seconds (below). Motion artifact manifests in the TD OCT image as a wavy retinal contour. The SD/FD domain OCT image does not have motion artifact and shows better discrimination of retinal layers. ELM = external limiting membrane; INL = inner nuclear layer; IPL = inner plexiform layer; IS/OS = photoreceptor inner segment/outer segment junction; NFL = nerve fiber layer; ONL = outer nuclear layer; OPL = outer plexiform layer; RPE = retinal pigment epithelium.

present moment, but it is definitely providing more information compared with TD OCT. Among the new imaging capabilities associated with SD OCT technology, four features deserve special consideration: (1) elimination of motion artifacts; (2) enhanced identification of the retinal layers and vitreomacular interface; (3) true angiotomographic correlation (angiography studies [fluorescein and indocyanine green] can be now performed simultaneously with OCT imaging), and; (4) real monitoring of macular changes ("eye-track" feature enables automatic imaging of the exact same macular area over time). For all these reasons, Colombia and Venezuela are near to adopting the technology and are waiting for the respective national importing licensing approval.

THE PROBLEM

Standard TD OCT can meet the needs of most retina practices. In addition, SD OCT may need more time to be interpreted than TD OCT as more details of the retina will be available to us. TD OCT is readily available throughout modern retina practices, and there might not be an overnight switch to these fourth-generation systems. The problem is that the vast majority of clinical decisions would not be changed in most practices with SD OCT rather than TD OCT. Furthermore, in a clinical trial there are issues about having different instruments in different clinics, and many centers in Latin America are involved in clinical trials. Which one of the several SD OCT systems now on the market should we buy? Looking at retinal thickening with different systems will give results that may not be comparable. Many of us who already have the Stratus OCT device favor adopting SD OCT by switching to the Cirrus HD-OCT (Carl Zeiss Meditec, Inc.) hoping that the "old" images may be translated to the new technology and that a better deal can be obtained by a "trade-in" program to make the adoption of SD OCT technology more cost effective. Nevertheless, countries such as Chile, the nations of Central America, and Puerto Rico are reluctant to trade the already very effective TD OCT for SD OCT at a higher cost, even with the reduced rate offered by the Carl Zeiss Meditec trade-in program. One may assume that they would be even more reluctant to choose a system from a different manufacturer.

Although retinal specialists in Latin America are all anxious to use SD OCT technology because it promises higher speed and resolution, as well as improved reproducibility, it will take some time to be widely adopted due to cost-benefit issues. ■

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