Could OCT be a Game Maker OCT in Optometric Practice: A Hands-On Guide

Murray Fingeret, OD
Nick Rumney, MSCOptom

Fourier Domain (Spectral) OCT

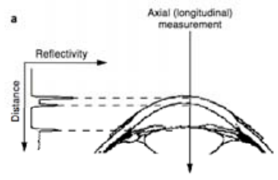
- New imaging method greatly improves resolution and speed of OCT
- High resolution allows more detailed images and layer by layer assessment
- High speed allows more data to be collected (3-D) and helps diminish eye motion artifacts
- Progression
  - allows registration of images
- Comprehensive assessment
  - Cup, Rim, RNFL, ganglion cell complex (macula region)
- Fundus imaging
- Anterior Chamber imaging

OCT: HISTORY

- OCT was developed in the early 1990s at MIT
- First studies showed ***ex vivo*** images of the retina and atherosclerotic plaques[2]
- ***In vivo* imaging was demonstrated in 1993[1], after the development of systems with improved image acquisition times (and, thus, reduced motion artifacts)[3]**

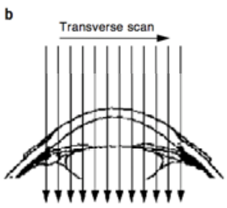
THE TECHNOLOGY BEHIND OCT

- OCT is analogous to ultrasound, but uses light instead of sound
- A beam of light is directed at the retina, and the echo time delay and magnitude of back-reflected and back-scattered light is measured (similar to A scan)[1]



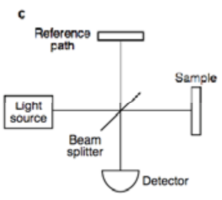
THE TECHNOLOGY BEHIND OCT

- The light beam then scans the tissue in the transverse direction to form a cross-sectional image (similar to B scan)[1]

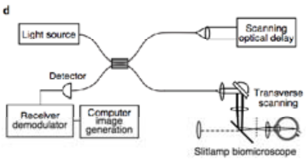


THE TECHNOLOGY BEHIND OCT

- The velocity of light is too high to measure optical echoes directly
- Instead, the light that is reflected back from inside the sample is measured indirectly, by correlating it with light that has traveled a known reference path
- This technique is called low coherence

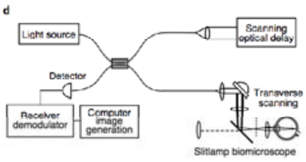


OCT TECHNOLOGY: TIME DOMAIN



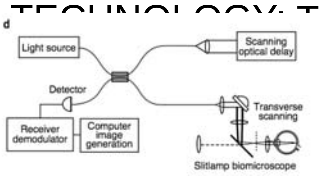
- The interferometer contains two arms:
- One arm contains a probe that focuses and scans the light onto the sample
- The other arm is a reference path with a translating (movable) mirror[1]

OCT TECHNOLOGY: TIME DOMAIN



- The combination of reflected light from the sample arm and from the reference arm gives rise to an interference pattern.
- This interference pattern is detected, and the info is processed to produce measurements of magnitude and echo delay time.[1]

OCT TECHNOLOGY: TIME



•In time-domain OCT, individual A-scans are acquired by varying the length of the reference arm, so that the scanned length of the reference arm corresponds to the A-scan length. This is accomplished by moving the translating mirror[4]. The resulting interference patterns are combined into a reflectivity profile. Areas of the sample that reflect back a lot of light will create greater interference than areas that do not.

•This data is then processed and displayed as a 2-D

OCT TECHNOLOGY: SPECTRAL DOMAIN

- Spectral domain OCT (also called Fourier-domain or high-definition OCT) was FDA approved in 2006[5]
- Spectral domain OCT uses a stationary reference arm and eliminates the need for a moving mirror; it does so by using a spectrometer as a detector.[4]

OCT TECHNOLOGY: SPECTRAL DOMAIN

•The spectrometer can measure numerous frequency components of reflected light, all at once; thus, entire A-scans can be acquired in one instance.[6]

•The spectrum that is measured is converted to depth information by Fourier-transform calculations, and this info is processed into images.[4]

OCT TECHNOLOGY: SPECTRAL DOMAIN

- The elimination of the need for movable parts and the use of the more efficient spectrometer allows for greatly increased sensitivity (150-fold)
- Increased sensitivity, in turn, allows for detection of weaker signals and faster data acquisition, which leads to Increased <u>resolution</u> and imaging <u>speed</u>[4]

SD OCT: ADVANTAGES

Resolution:
- TD OCT can achieve an axial resolution of 8-10 microns
- Most commercially available SD OCT devices achieve 5-8 microns
- Thus, SD OCT enhances one's ability to observe fine ocular pathologic features

SD OCT: ADVANTAGES

Speed:
- TD OCT has a maximum image acquisition speed of approximately 400 A-scans per second
- SD OCT devices can perform 18,000 to 50,000 A-scans per second (with a potential for up to 300,000)[7]
- ~ 50 - 100 times faster!

SD OCT: ADVANTAGES

This increase in speed means:
- Motion artifacts are minimized
- Noise level of image is reduced, meaning the image better represents the true topography of the retina
- Multiple images can be acquired rapidly in different locations and orientations, allowing for greater coverage of the retina.
- Three-dimensional OCT data can be acquired[9]

SD OCT: ADVANTAGES

Ability to acquire 3-dimensional data:
- 3-D raster data sets (or 3-D data cubes) give enhanced visualization
- Such a continuous scan over a given area may reveal small or subtle focal changes that would be skipped over by other (radial 2-D) scans
- The info contained in the 3-D data cube can be used to create an OCT fundus image[9]

SD OCT: ADVANTAGES

OCT fundus images:
- Allow the operator to evaluate ocular motion that occurred during a scan[6]
- The cross-sectional (2-D) images that make up the 3-D data cube can be registered precisely to the fundus image, enabling direct comparison of OCT findings with those from clinical examination

SD OCT: ADVANTAGES

Image registration
- OCT fundus images can also be used to register OCT data taken in the same patient at different times
- This could enhance longitudinal evaluation of patients and enable the tracking of change over time[9]

SD OCT: LIMITATIONS

- Cost: Ranges between $40,000 and $120,000 (and can be higher, depending on service options, software packages, and maintenance plans)[10]
- Young technology
- At this time, available clinical data is still somewhat limited (literature that attests to the utility of SD OCT devices in diagnosis and management, and to the superiority of SD over TD OCT, remains sparse)[6, 10]
- Further optimization of image registration, acquisition, and processing is needed (e.g. motion artifacts can still be substantial)[6]

SD OCT: LIMITATIONS

- Lack of normative databases
- Devices are currently FDA-approved to aid in the detection and management of ocular diseases; they are not approved for quantification of any posterior segment structure or finding (though some have received approval for anterior segment measurement)[10]

SD OCT: CLINICAL APPLICATIONS

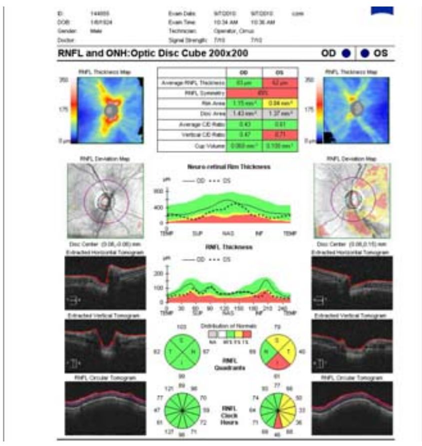
- SD OCT is useful for obtaining improved visualization of morphologic and pathologic features of the retina, optic nerve, and anterior segment
- SD OCT devices also enable the measurement of these structures

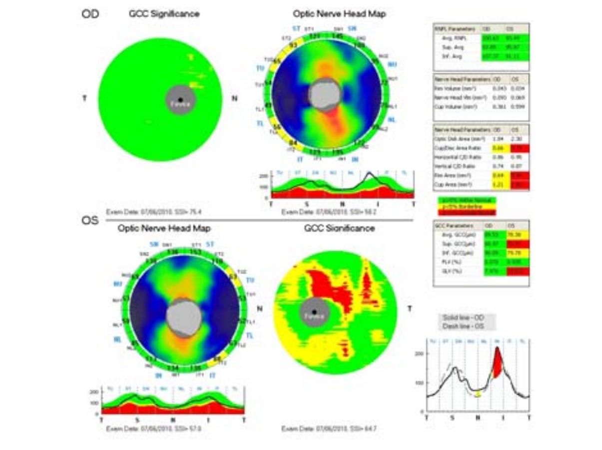
SD OCT: CLINICAL APPLICATIONS

- Keep in mind: OCT images do not depict true histology. Rather, they are based on changes in reflectivity.
- When the refractive indices of two adjacent structures are large, more light is reflected = stronger signal = red/bright
- Less light reflected = weaker signal = blue/dim
- No light reflected = black
- So it is possible for multiple layers to appear on an OCT image that are actually a part of the same cell layer histologically.

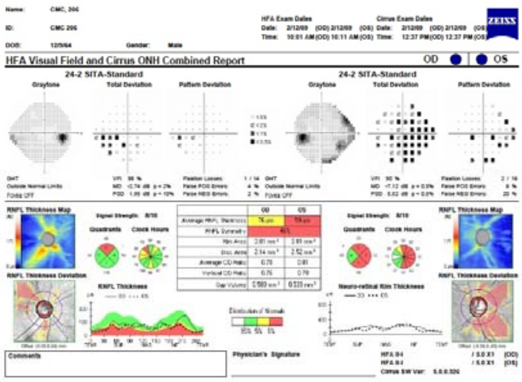
Spectral OCT's

- Topcon 3D OCT
- RTVue Optovue
- Heidelberg Sprectalis
- Zeiss Cirrus
- Others
  - Optigen
  - Biogen
  - OTI
  - OPtopol





Combined Imaging-Field Printout



Steps in Assessment

- Image quality
  - Focus, centration, Quality score, Illumination
- RNFL
  - Sector, Quadrants, TSNIT curve
- Optic Disc
  - Disc area, C/D, rim area, cup volume
- Macula

NEW INSTRUMENT

Novel Software Strategy for Glaucoma Diagnosis

Asymmetry Analysis of Retinal Thickness

The benefits of high-speed, detailed retinal thickness measurement by spectral-domain optical coherence tomography in glaucoma diagnosis have not been fully realized. We have modified the software protocols for such measurement and applied it for diagnosis at different stages of glaucoma. Using the Spectralis SD-OCT (Heidelberg Engineering, Carlsbad, California), we have customized the retinal thickness protocol to acquire detailed retinal thickness measurements of the central 20° of the posterior pole. These custom maps are displayed in a compressed color scale that reveals small losses in retinal thickness. A novel asymmetry analysis protocol was created to highlight differences between the eyes and the 2 hemispheres within each eye. We present case examples illustrating the ability of this strategy to detect glaucomatous defects, showing the promise of the protocol in the diagnosis and management of glaucoma.

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