Swept Source OCT

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Disclosure

Consulting Fee: Allergan; Carl Zeiss Meditec; Genentech; Optos; Regeneron
What is swept source OCT?

- Swept Source OCT
  - Another Fourier domain OCT technology
  - 5-10X faster than existing SD-OCT instruments
  - Also better sensitivity with less roll-off

From Potsaid et al, *Optics Express* 2010; 18: 20029.
Improved Speed

- **Swept Source OCT**
  - At these speeds, fixation/motion is less of an issue
  - Large areas can be scanned quickly and with extensive averaging

From Potsaid et al, *Optics Express* 2010; 18: 20029.
Large field OCT Imaging

12 mm B-scans are easy to obtain

Zeiss SS-OCT prototype (investigational device, not FDA cleared)
Large field OCT Imaging

Choroid and laminar portions of the optic nerve are well seen

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12 x 9 mm volume scans are also easy

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Produce OCT projection maps that truly resemble fundus images

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Large field OCT Imaging

12 mm B-scans – visualize ON and Macula

*Geographic atrophy*

Zeiss SS-OCT prototype (investigational device, not FDA cleared)
Higher Sensitivity

• Very little sensitivity loss with depth with swept source OCT
  - Better signal-to-noise ratio
• Enhances visualization of outer retinal structures

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Higher Sensitivity

• Very little sensitivity loss with depth with swept source OCT
  – Better signal-to-noise ratio
• Enhances visualization of outer retinal structures, and deep pathologies

Zeiss SS-OCT prototype (investigational device, not FDA cleared)
Combine high sensitivity with optimized averaging

- **Swept Source OCT**
  - Extensive averaging allows fine structures to be seen

*From Potsaid et al, Optics Express 2010; 18: 20029.*
A note about image quality...

• Though swept source devices feature better sensitivity than spectral domain devices:
  - devices do vary in the quality of their optics and other components
  - faster scan rates can be associated with degraded quality

• Averaged B-scans can hide these quality differences

• Advisable to look at the un-averaged native images when comparing between devices
A note about image quality…

- **Un-averaged native single B-scan image on patient with media opacity and myopia**

Even without averaging, despite scan rates > 100K/sec, outer retinal bands are well seen.

Note, no apparent sensitivity loss from anterior to posterior regions of retina in this eye with a deep staphyloma from pathologic myopia.

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A note about image quality...

- Underlying high quality B-scan data yields high quality OCT fundus images

Pathologic myopia with tilted nerve and PPA

High resolution “Megapixel”

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Long Wavelength Imaging

• Most Swept Source OCT devices features a light source with a 1050nm center wavelength

Most SD-OCT devices
OCT and wavelength

• Two “Windows of Opportunity” for retinal OCT imaging

**OCT Imaging Windows**

1. Visible to near infrared (950nm) -- BROAD
2. 1000nm – 1100nm -- NARROWER BANDWIDTH (restricted to 100 nm) and still more absorption than at shorter wavelengths
Choroidal Visibility: 1050 vs 840

Comparison Study at Doheny of 1050nm vs 840nm

Results:

- Even when the choroid was fully-visible at 840nm, considerable additional detail was visible at 1050nm

(both spectral domain)
Retinitis Pigmentosa

Orbital Fat
1.7mm Choroidal Melanoma
Choroidal imaging with SSOCT

ILM to choroid-sclera

ISOS to BM

Choroid
1/3 of choroid
2/3 of choroid

Zeiss Swept Source OCT (prototype, not yet FDA cleared)
En face imaging through retina and choroid

Zeiss SS-OCT prototype (investigational device, not FDA cleared)
Serous PED

Zeiss SS-OCT prototype (investigational device, not FDA cleared)
En face imaging through CNV

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En face imaging through CNV

Zeiss SS-OCT prototype (investigational device, not FDA cleared)
En face imaging through Geographic Atrophy

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En face imaging through Geographic Atrophy

Zeiss SS-OCT prototype (investigational device, not FDA cleared)
High-resolution en face OCT

En face slabs can be extracted from any layer of interest

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Non-proliferative Diabetic Retinopathy

• Microaneurysms visible on en face images

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Clinical Applications of Swept Source OCT

• Everything!
  - There is really no advantage of spectral domain over swept source OCT
  - Slightly better axial resolution at 840nm vs 1050nm is outweighed by many other advantages
Clinical Applications of Swept Source OCT

• But why will SS-OCT be a game changer?

• What are the key new applications that will expand the purview of OCT?
Penetrating through the sclera

- Imaging choroidal tumors may be an exciting new application
- Imaging the anterior orbit?? --- remains to be seen

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Vitreous imaging with SS-OCT

Better sensitivity means better visualization of subtle structures

- Better evaluation of vitreo-macular interface disease and normal vitreous dynamics
- Possibility of quantification of vitreous cell
Vitreous imaging with SS-OCT

Wide angle scans allow vitreous relationships between optic nerve and macula to be studied

Zeiss SS-OCT prototype (investigational device, not FDA cleared)
Evolution of Vitreomacular Detachment in Healthy Subjects

Published online August 22, 2013

Recent advancements in optical coherence tomography (OCT) have identified the key role that peripheral posterior vitreous detachment (PPVD) plays in the development of macular holes, 

Vitreomacular traction syndrome, and some aspects of diabetic macular edema. 

Before OCT was introduced, the anatomy of the posterior vitreous was hard to visualize during a biomicroscopic examination because of its transparency. The vitreous anatomy was verified histomorphologically in postmortem eyes. 

Several reports have suggested that anomalous PPVD causes vitreomacular traction syndrome, results in traction with macular pucker or macular holes, and contributes to some cases of diabetic macular edema. 

Wong et al. described perimacular, a liquefied area of the vitreous anterior to the macula, which was observed in tangential thick macula cuts of the macula in posterior vitreous detachment (PPVD) and macula holes. 

Methods: 

We performed SD-OCT with noise reduction (Cirrus OCT version 4.1, Carl Zeiss Meditec) in the right eye of 36 healthy individuals.

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Vitreous imaging with SS-OCT

With SS-OCT, both the vitreous and choroid can be imaged simultaneously with brilliant detail

Zeiss SS-OCT prototype (investigational device, not FDA cleared)
Anterior segment imaging with SS-OCT

Deep penetration (1050nm) and high sensitivity of SS-OCT allows visualization of full extent of lens/IOL and angle recess
Anterior segment imaging with SS-OCT

Imaging the Iris with Swept-Source Optical Coherence Tomography: Relationship between Iris Volume and Primary Angle Closure

Heather Mok, BS; Guohua Xu, BM, Christopher Kai-Shun Leung, MD, MB, C3R

Objective: To measure iris volume and anterior segment parameters using a swept-source anterior segment optical coherence tomography (OCT) and investigate factors associated with iris volume and iris volume change after pupil dilation in eyes with open angles and angle closure.

Design: Cross-sectional study.

Participants: A total of 88 eyes, including 31 eyes from 21 patients with primary angle closure (PAC) or PAC suspect, 31 eyes from 20 patients with primary open-angle glaucoma (POAG), and 24 eyes from 15 normal subjects, were included.

Methods: The anterior segment parameters and iris were imaged and measured by the Casia SS-1000 OCT (Tomey, Nagoya, Japan) in room light, dark, and after pharmacologic dilation. Linear mixed models were used to examine the association between iris volume and change in iris volume after dilation and each of the following: age, sex, anterior chamber volume (ACV), axial length, pupil diameter, and angle width.

Main Outcome Measures: Iris volume.

Results: The mean iris volume significantly decreased from light to dark and after pharmacologic dilation in angle closure (40.0±5.2, 38.8±5.4, and 32.5±4.5 mm³, respectively), POAG (40.0±5.3, 39.4±5.4, and 33.6±4.2 mm³, respectively), and normal eyes (40.1±4.2, 38.1±3.9, and 33.6±4.4 mm³, respectively). From room light to dark, the iris volume of 16.7% normal, 19.4% POAG, and 19.4% angle closure eyes increased iris volume (P < 0.005). After pharmacologic dilation, iris volume decreased in all eyes. Iris volume was negatively associated with ACV and positively associated with axial length (P < 0.001). The change in iris volume per millimeter change in pupil diameter was 2.11, 2.01, and 1.83 mm²/mm in the angle closure, POAG, and normal groups, respectively (P > 3.414). A smaller ACV (P = 0.049) and older age (P = 0.039) were associated with a smaller change in iris volume per millimeter change in pupil diameter. Larger iris volume, smaller ACV, and greater pupil diameter were significant determinants of a smaller angle width (all P < 0.003).

Conclusions: The mean iris volume decreased after pupil dilation in open-angle and angle closure eyes, and the degree of reduction was less in eyes with a smaller ACV. Both iris volume and ACV were important determinants of the anterior chamber angle.

Financial Disclosures: The author(s) have no proprietary or commercial interest in any materials discussed in this article. Ophthalmology 2013;118:1-8 © 2013 by the American Academy of Ophthalmology.
Anterior segment imaging with SS-OCT

Iris imaging

Evaluation of the trabecular outflow system, Schlemm’s canal, and collector channels is an area of current interest
Choroidal imaging with SS-OCT

Zeiss SS-OCT prototype (investigational device, not FDA cleared)
Optic Nerve Head Imaging with SSOCT

Improved visualization of deep ocular structures in glaucoma using high penetration optical coherence tomography

Kaveh Mansouri and Robert N Weinreb

The introduction of optical coherence tomography (OCT) has revolutionized ophthalmology through the ability to noninvasively image the retina in vivo. Glaucoma is the leading cause of irreversible blindness worldwide. Despite major advances in imaging techniques, the pathogenesis of glaucoma remains poorly understood and is at present. The lamina cribrosa (LC) is the presumed site of axon injury in glaucoma. Its thinning and deformation have been suggested to contribute to glaucoma development and progression by impaired axoplasmic flow within the optic nerve fibers, leading to apoptosis of retinal ganglion cells. To visualize the deep ocular structures such as the choroid and the LC, OCT imaging has been used, particularly the enhanced depth imaging (EDI)-OCT modality of spectral domain (SD)-OCT. However, the posterior lamina surface especially is not seen clearly using this method. A new generation of OCTs, swept-source (SS)-OCT, is able to image the LC and the choroid in vivo. SS-OCT employs a shorter wavelength compared with conventional OCT, generally set at 1050 nm (instead of 840 nm). We review the knowledge of the LC and findings from trials that use SD-OCT and EDI-OCT, and experience with a prototype SS-OCT to quantify choroid changes and visualize the LC in its entirety.

Glaucoma is a leading cause of blindness worldwide [1]. It is defined as a group of progressive optic neuropathies with characteristic retinal ganglion cell damage at the optic disc and a compromised visual field. However, the mechanisms of the disease remain poorly understood. Many individuals remain undiagnosed or treated inadequately, and the public health impact of glaucoma will only increase as the world's population ages.

The zone of the retinal ganglion cells comprises the so-called rim of the optic disc before crossing the eye through the lamina cribrosa (LC), a neural structure at the optic nerve head that is characterized by sheets of porous connective tissue. The LC is presumed to provide mechanical support to those optic nerve fibers within the deep optic disc region. Structural thinning of the LC via deformation and compression, has been associated with glaucoma [2]. Changes in the LC's structure and shape also have been correlated with progression of the disease [3, 4]. Overall, deformation of the LC likely impairs axoplasmic flow disrupting transport of trophic factors important to survival of retinal ganglion cells [5]. Thus, structural changes in the LC may play a role in neuronal death characteristic of glaucoma. Also, from a biomechanical perspective, the LC is the spherical casing of the eye, which makes it more vulnerable to the toxins leading that may play a role in glaucoma [6]. Therefore, understanding the forces that affect the structure of the LC will further elucidate the mechanisms of glaucoma. Characterization of both...
Glaucomatous nerves with SSOCT

Drance hemorrhages are associated with tears in the lamina

Moderate to severe glaucoma

Zeiss SS-OCT prototype (investigational device, not FDA cleared)
Glucomatous nerves with SS-OCT

Early glaucoma

Zeiss SS-OCT prototype (investigational device, not FDA cleared)
Summary

• Swept source OCT represents the next evolution of OCT technology

• Its higher speed, higher sensitivity, and expected longer wavelength light source, offer important advantages over existing commercial SD-OCT devices

• SS-OCT will likely further expand the applications and importance of OCT
Thank you!