Understanding and Interpreting OCT

The Swiss Army Pocket Knife of Eye Care

Mark T. Dunbar, O.D., F.A.A.O.
Bascom Palmer Eye Institute
University of Miami, School of Medicine

Mark Dunbar: Disclosure

◆ Consultant for Allergan
◆ Optometry Advisory Board and Speaker bureau for:
  ◆ Allergan
  ◆ Carl Zeiss Meditec
  ◆ Artic Dx
  ◆ Sucampo

Mark Dunbar does not own stock in any of the above companies

Optical Coherence Tomography (OCT)

◆ Non-contact, non-invasive imaging device
◆ Produces high-resolution images of the posterior segment
  ◆ Optical biopsy
◆ Quickly emerged as the standard of care for imaging in retina and glaucoma
◆ Revolutionized ocular disease management in all of eye care

The Origins of the OCT

1995 OCT1 debuted at 100 axial scans per second with a resolution of 20 µ

2002 The Stratus OCT was introduced
◆ Quadrupled the speed at 500 axial scans per second
◆ Resolution to 10 µ
◆ Stratus became the standard for the diagnosis of many retinal diseases and glaucoma

Main Clinical Utilities of OCT

◆ High resolution evaluation of retinal anatomy
◆ Diagnosis of macular conditions difficult to establish with biomicroscopy
◆ Quantitative assessment of retinal and vitreoretinal anatomic alterations
◆ Objective means for monitoring disease progression and/or therapeutic response
2007 Spectral-Domain OCT (Fourier Domain OCT)

- Speed of 27,000 – 40,000 axial scans per sec
- Analyzes data using a spectrometer
  - Allows the ability to determine various depths simultaneously – Time domain OCT does this serially
- Does not use a mirror
- Very fast acquisition speed -> 65 X > acquisition speed (1.28 for current vs milliseconds)
- Very high resolution – 3.5 to 6 µ
- 3-D imaging

Time Domain OCT

- Sequential
- 1 pixel at a time
- 1024 pixels per A-scan
- .0025 seconds per A-scan
- Slower than eye movements

Fourier Domain OCT

- Simultaneous
- Entire A-scan at once
- 1024 pixels per A-scan
- .00000385 sec per A-scan
- Faster than eye movements

Spectral Domain OCT

- Carl Zeiss: Cirrus
- OptiVue: Rtvue and the iVue
- Heidelberg: Spectralis
- Topcon
- Optos
- SOCT Copernicus (Reichert)
  - Now owned by Cannon

SD-OCT Differences

- Hardware is relatively similar
  - Tracking capabilities
  - Ancillary image capabilities
- Device should be easy to use and patient friendly
- Should be competitively priced
- It’s all about the software!

Advances in SD-OCT

- Improving software
- Noise reduction technology that provides higher resolution imaging
- Improvements in 3D rendering
- Enhanced depth imaging – imaging choroid
- Automatic Fovea Finding
- Progression analysis software
- Expanded normative data bases
Central Serous and Neurosensory Retinal Detachment
65 y/o White Female
↓ VA RE X 6 Wks, ↓ VA LE X > 1 Yr

20/100 20/400

64 y/o White Female
Blurred VA X 10 days
Seen 2 mo ago: normal exam

VA: 20/40
When is a hole... a hole?

Lamellar Macular Hole in the Era of OCT

- Witkin et al reported on 19 eyes of 18 patients with lamellar holes imaged with ultra-high resolution OCT
- All the lamellar holes shared some common features
  - An irregular foveal contour
  - A break in the inner fovea
  - Separation of the inner from the outer foveal layers, leading to an intraretinal split
  - Absence of a full thickness defect with intact photoreceptors posterior to the area of foveal dehiscence.

VMT:
Vitreomacular Traction

Vitreomacular Traction
Impending Macular Hole

Macular Edema

BRVO with Mac Edema
20/80

Decreased VA X 3 mo
Was 20/20 the year before
Outer Retinal Tubules

Brad Sutton, OD Case

Is this Histoplasmata Capsulatum?

“…dead ringer for Histoplasmata Capsulatum cysts seen in the lung as shown in multiple images available on Google.”

Conclusions: Degenerating photoreceptors may become arranged in a circular or ovoid fashion during a process we propose to term outer retinal tubulation. These changes are apparently common in advanced diseases affecting the outer retina and retinal pigment epithelium. This observation has practical implications because these findings can be misinterpreted as intrafoveal or subfoveal fluid, possibly prompting unnecessary interventions.

Loss of the “PIL”
54 y/o Hisp Male

VA RE X 10 Yrs

Plaquenil Screening: Traditionally

- Baseline macula photos
- Color vision testing
- Amsler grid
- 10-2 Visual fields
- Yearly exams

Revised Recommendations on Screening for Plaquenil Toxicity

- Amsler grid testing removed as an acceptable screening technique
  - NOT equivalent to threshold VF testing
- Strongly advised that 10-2 VF screening be supplemented with sensitive objective tests such as:
  - Multifocal ERG
  - Spectral domain OCT
  - Fundus autofluorescence

Revised Recommendations on Screening for Plaquenil Toxicity

- Tests Not Recommended for Screening:
  - Fundus photography
  - Time domain OCT
  - Fluorescein angiography
  - Full-field ERG
  - Amsler grid
  - Color vision screening
  - EOG
Revised Recommendations on Screening for Plaquenil Toxicity

- SD-OCT can show localized thinning of the parafoveal retinal layers confirming toxicity
  - May be unable to see with TD-OCT
  - Changes maybe visible **prior to VF defects**
- FAF may reveal subtle RPE defects with reduced autofluorescence
- MF-ERG can objectively document localized paracentral ERG depression in early retinopathy

Leonardo
57 y/o Hispanic Male

- “Routine” exam
- Has had poor vision for ~ 25 yrs or so
- VA: 20/70 RE; 20/60 LE
- CVF: FTFC OU
- Pupils: ERRL – No APD
- SLE – Tr NS
when the neurosensory retina is detached, the angle is shallow, but when the RPE is detached, the angle is steep.

**Advances in SD-OCT**
- Improving software
- Noise reduction technology that provides higher resolution imaging
- Improvements in 3D rendering
- Enhanced depth imaging – imaging choroid
- Automatic Fovea Finding
- Progression analysis software
- Expanded normative data bases

**Advanced Visualization**
- With "Slab" analysis, user can image 2D en face representations of common retinal layers/disorders:
- Allows you to isolate and visualize a layer of the retina
- The thickness and placement of the layer are adjustable
- This provides a virtual dissection of the retina by extracting the layer of interest
Macular Change Analysis

Ongoing Dry AMD/Geographic Atrophy Studies

Documenting Progression in Dry/Atrophic AMD

Advanced RPE Analysis

- **RPE Elevations**: If the RPE is raised, a new proprietary algorithm for Cirrus maps and measures the area and volume of the elevations.

- **Sub-RPE Illumination**: If the RPE is absent or has lost integrity, a new proprietary algorithm for Cirrus can map and measure the affected area.

---

Advanced RPE Analysis

<table>
<thead>
<tr>
<th>Sponsor</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aresia/BRI</td>
<td>ACU-02</td>
</tr>
<tr>
<td>Alcon/SAGE</td>
<td>ALI2098</td>
</tr>
<tr>
<td>Allergan</td>
<td>Med BARP FA</td>
</tr>
<tr>
<td>Alesix/COMPLETE</td>
<td>Eculizumab</td>
</tr>
<tr>
<td>Neurecotech</td>
<td>NT-511</td>
</tr>
<tr>
<td>Ophthotech</td>
<td>Dry AMD therapies</td>
</tr>
<tr>
<td>Optiomed</td>
<td>Early-stage AMD therapies</td>
</tr>
<tr>
<td>Others/OMEGA</td>
<td>O7-551</td>
</tr>
<tr>
<td>Pfizer</td>
<td>RHEG</td>
</tr>
<tr>
<td>Quark/Pfizer</td>
<td>PF-04532655</td>
</tr>
<tr>
<td>Siron</td>
<td>Ferrocene</td>
</tr>
<tr>
<td>Oak Park Natl. Lab./TORPA</td>
<td>Photobiomodulation</td>
</tr>
<tr>
<td>NBI</td>
<td>Sirolium</td>
</tr>
<tr>
<td>NEVAREDS II</td>
<td>Antioxidants</td>
</tr>
<tr>
<td>NY Eye &amp; Ear</td>
<td>Copaline vaccinations</td>
</tr>
</tbody>
</table>

Initial

3 Months

**Volume**: 0.212 mm³

**Volume**: 0.257 mm³
Advanced RPE Analysis

Screen 2

OCT in Glaucoma

Traditional Methods of Assessing Glaucoma

- IOP monitoring
  - Major risk factor
- Subjective evaluation of the optic nerve
- Visual field testing

There is a need for objective testing that can reliably detect those patients who may have glaucoma and/or are at risk of developing glaucoma

73 eyes with glaucoma vs. 146 age-matched normals
Peripapillary ONH parameters and RNFL thickness measured

Most sensitive:
- Vertical rim thickness (VRT): 0.963
- Rim area (RA): 0.962
- RNFL thickness at 7:00: 0.957
- RNFL thickness inferior quadrant 0.953
- Vertical CD ratio 0.951
- Average RNFL thickness were most sensitive 0.950

Normal vs. Mild Glaucoma

Most Sensitive:
- RNFL thickness at 7:00
- VRT
- Rim area
- RNFL thickness inferior quadrant
- Average RNFL thickness
- Vertical CD ratio
The disc edge is determined by the termination of Bruch’s membrane. The rim width around the circumference of the optic disc is then determined by measuring the amount of neuro-retinal tissue in the optic nerve. In this method, the disc and rim area measurements correspond to the anatomy in the same plane as the optic disc.

Tania: 44 y/o Hispanic Female
- Has been seen several times over the yrs for routine eye care
  - 1998: TA 20/22
  - 09/05: TA 18/20
  - 12/07: 19/20

Tania: 44 y/o Hispanic Female
- 12/08: TA: 25/21
  - Pach: 610/620 µ
  - OCT done 1/5/08 – for review
- 4/20/09: TA 23/24
- 4/19/10: TA 23/25
- 10/11/2010: TA 22/23

Tania
- Ocular HTN
  - No treatment
  - Is there a reason to justify treating her?
- What is her risk for developing glaucoma?
  - 5 yrs vs. lifetime?

Issues Relevant to Tania
- What is his risk of actually developing glaucoma?
- From OHTS:
  - Depends mostly on corneal thickness…?
    - IOP of 25.75 mmHg
      - Ave Corneal thickness < 556 µ: 36% Risk
      - Corneal thickness 565 to 588 µ: 13%
Tania: 47 y/o: Oct 25, 2011

- TA: 24/23

Cirrus HD-OCT GPA Analysis

Image Progression Map

- Two baseline exams are required
- Third exam is compared to the two baseline exams
- Sub pixel map demonstrates change from baseline. Yellow pixels denote change from both baseline exams
- Third and fourth exams are compared to both baselines. Change identified in three of the four comparisons is indicated by red pixels; yellow pixels denote change from both baselines

Change refers to statistically significant change, defined as change that exceeds the known variability of a given pixel based on population studies.

Cirrus HD-OCT GPA Analysis

TSNIT Progression Graph

- TSNIT values from each exam are shown
- Significant difference is colored yellow or red
- Yellow denotes change from both baseline exams
- Red denotes change from 3 of 4 comparisons

Legend summarizes GPA analyses and indicates with a check mark if there is possible or likely loss of RNFL.

Guided Progression Analysis - RNFL thickness over time

- 8 exam comparison
- Data registration
- Trend analysis
- Progression flags

RNFL thickness trend lines showing broad changes

Summary Parameter Trend Analysis

- Rates and significance of change shown in text
- RNFL thickness values for overall average, Superior Average, and Inferior Average are plotted for each exam.
- Yellow marker denotes change from both baseline exams
- Red marker denotes change from 3 of 4 comparisons
- Confidence intervals are shown as a gray band

RNFL thickness maps showing focal thickness changes

TSNIT thickness graph comparison to baseline showing semi-focal change

Progression Flags

Guided Progression Analysis

- RNFL thickness trend lines showing broad changes

GPA Optic Disc-Cube 200x200

- GPA flag: High, Moderate, and Low
- GPA flag: Significant change
- GPA flag: Change from baseline
- GPA flag: Change from previous exam
- GPA flag: Change from follow-up exam
- GPA flag: Change from excluded exam
Cirrus OCT Glaucoma Updates

- Advanced GPA for OCT
- Ganglion cell complex normative data base

Vesta: 61 y/o Hatian Female

- Has been followed with NTG since 2006
  - GL suspect 2001 – always with suspicious ON’s
- Meds: Alphagan bid OU, Latanoprost q hs OU
- Medical Hx: HTN, HIV (+) for > 15 yrs
- VA: 20/20
- TA for the past 3 or 4 yrs: 9-13 mmHg OU
  - Last 2 visits 9 mmHg – today 13
Ganglion Cell Analysis

- Measures thickness for the sum of the ganglion cell layer and IPL using data from the Macular 200 x 200 or 512 x 128 cube scan patterns.

- RNFL distribution in the macula depends on individual anatomy, while the GCL+IPL appears regular and elliptical for most normals. Thus, deviations from normal are more easily appreciated in the thickness map, and arcuate defects seen in the deviation map may be less likely to be due to anatomical variations.

Ganglion Cell Analysis

- Data for both eyes (OU)
- Thickness Map - shows thickness measurements of the GCL + IPL in the 6mm X 6mm cube, contains an elliptical annulus centered about the fovea.
- Deviation Maps - shows a comparison of GCL + IPL thickness to normative data.
- Thickness table - shows average and minimum thickness within the elliptical annulus.
- Sector maps - divides the elliptical annulus of the Thickness Map into 6 regions: 3 equally sized sectors in the superior region and 3 equally sized sectors in the inferior region. Values are compared to normative data.
- Horizontal and Vertical B-scans.
51 y/o Hispanic Female

- Reports shadow peripherally in her LE
- VA: 20/20 OU
- CVF: FTFC; Pupils: NO APD
- TA: 16-17 on 3 visits

Basic Glaucoma - Circle Scan Analysis
Heidelberg Spectralis

Spectralis: Samples 1536 A-Scans vs. 256 with Cirrus and Stratus
Normal Images and Thickness Map

RNFL fibers can be seen following the blood vessel arcades on the infrared image. The OCT scan shows a normal distribution of RNFL thickness around the ONH. Posterior Pole thickness map shows thicker areas (white and red) along the blood vessel arcades and around the macula. (The ganglion cell complex (GCC) is typically thicker around the macula.)

RTVue Glaucoma Package

Glaucoma Analysis with the RTVue: Nerve Head Map

Provides:
- Cup Area
- Rim Area
- RNFL Map

TSNIT graph

16 sector analysis compares sector values to normative database and color codes result based on probability values (p values)

Color shaded regions represent normative database ranges based on p values
Early Glaucoma

OS Normal

Borderline Sector results in Superior-temporal region

Abnormal parameters

TSNIT dips below normal

TSNIT shows significant Asymmetry

Summary: OCT and Glaucoma

- OCT is able to accurately detect early glaucoma with good reliability
- Also very good with already established glaucoma
- Determining same day reliability is critical
  - Corroborate your findings
  - To be able to accurately utilize serial analysis in future scans
- OCT is as good as other ON imaging devices