New Advances in OCT Imaging for Glaucoma

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Disclosures

- Consultant:
  - Reichert, Carl Zeiss Meditec,

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Why OCT?

OCT typically shows loss prior to VFs

@ earliest VF defect — mean RNFL was 75.09µ for glaucomatous eyes
  - vs. 90.68µ for controls/ normals

At 95% specificity, 35% of eyes had abnormal mean RNFL 4 years before VF changes.

19% of eyes had abnormal results 8 years before field loss

However, OCT can Never be used alone.

- Threshold Visual Fields are a defined Standard of Care
  - VFs often are better at showing disease progression, especially for middle to late stage glaucoma

- Disc Photos are also essential
  - Shows Disc Hemorrhages and PPA not seen on OCT
    * stereo is preferred but hard to obtain; high quality, true color mono is fine

- Evaluating OCT against ALL other risk factors is a must do
  - IOP, CCT, Corneal Hysteresis, Age, Race, etc.
New Advances in OCT Imaging for Glaucoma

Current 2nd Gen. = Spectral Domain OCT

Next Gen = "Swept Source OCT" faster with even higher resolution and deeper penetration.

Segmentation: Automated Algorithm

Must have High Quality Image, High Resolution, No Artifacts!

Cirrus HD-OCT

Example of a b/w image of the disc and fundus and single, high resolution B-scan of the optic nerve head.

Spectralis OCT: Optic Nerve

Edge of Optic Nerve and RNFL

Spectral Domain OCT: Many Options

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Spectral Domain OCT: Many Options

- There are many similarities and some differences
- Each instrument offers unique features
- There is no evidence that one instrument is clearly superior to the others
  - Each has its own Pros and Cons, find one that “fits” your practice
- Most OCT owner/users only use a small portion of the imaging “power” of their instrument, many are confused (that’s normal)
- It’s time to take a deeper dive into Interpretation

Cirrus OCT

- Glaucoma Applications:
  - RNFL
  - Optic Disc
  - Ganglion Cell Analysis
  - Not shown here

How to “Read” a Printout

1. FIRST!: Signal Strength
   - A key indicator of image quality
   - Should be 7/10 or higher on Cirrus
   - Do not interpret poor quality scan as “red” disease
2. Well centered image
3. No evidence of movement artifact
4. Review Plots and Displays
   - Thickness Map and Deviation Map
   - Quadrant and Sector Plots
   - TSNIT and Optic Nerve B-Scan Tomograms

R + L Tomograms = single B-Scan Images
use for image quality assessment

Most Important:
**Eye Movement Artifact:**
Repeat Scan or very cautious interpretation

**Cirrus: Optic Disc and cpRNFL Scans**
- **OPTIC DISC CUBE SCAN**
  - The 6mm x 6mm cube is captured with 200 B-scan lines top to bottom
  - This creates the Color Thickness Map

**CALCULATION CIRCLE to form “TSNIT.”**
- AutoCenter™ function automatically centers the 1.73mm radius peripapillary calculation circle around the disc for precise placement and repeatable registration.

**Glaucoma – cp RNFL Thickness Analysis**
- The RNFL color thickness map shows the patterns and thickness of the nerve fiber layer within the 6mm x 6mm cube
- The RNFL deviation map is overlaid on the OCT fundus image to illustrate precisely where RNFL thickness deviates from a normal range
- Thus: highlights the abnormal region(s)

**Limited ONH Analysis**
- **TSNIT (temporal-superior-nasal-inferior-temporal) circle, with a radius of 1.73mm, is established around the disc**
- The red/purple circle indicates the location of the RNFL TSNIT circle
- The circle is “broken” open on the temporal side, forming a “line” that can be laid out.
- By traditional convention order is TSNIT

- RNFL thickness is displayed in graphic format and compared to age-matched normative data
- Portions falling in “Red” are likely abnormal

**TSNIT line – cp RNFL Thickness Analysis**
- Temp/Sup/Inf/Temp
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Distribution of Normals

The Distribution of Normals color scheme is used for both the RNFL and the Optic Nerve Head analysis parameters. The table clarifies how the color scheme is used for each of the parameters.

General, Average RNFL Thickness Grouping

"Average Guidelines" (50 yo patient, No Disease)

- Green: ~75 microns to 110 (~100)
- Yellow: 70-75 microns
- Red: < 70 microns

NOTE!!!!

"Floor" = approx. 50µ

NOTE!!!!

"Green" does NOT always mean no disease

Example Normative Data:

Optic Disc and VF of Previous Patient
**Example Normative Data:**

- RNFL Quadrant and Clock-Hour Plots often inaccurate due to "averaging" of thickness values over an area.
- Small, narrow RNFL defects are masked in a quadrant plot.
- We do not rely on them clinically.
- TSNIT is more accurate.

**Optic Nerve Head Analysis**

- The disc edge is determined by the termination of Bruch's membrane.
- This is validated in the literature.
- 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.

**Zeiss: Cirrus OCT Reports (2)**

**Optic Disc Analysis and Disc Area**

- Inner Cup Margin
- Disc Margin

**Focal Loss OD**

- Average RNFL Thickness
- RNFL Samples
- Disc Area: 2.23 mm²
- RNFL C/D Ratio: 0.77
- Vertical GCC Ratio: 0.74
Can you have glaucoma in the macula?

- Macula or Ganglion Scan Patterns for Glaucoma Suspects

Cirrus OCT: Ganglion Cell Analysis

- Second scan after scan of the optic nerve cpRNFL
- Measures thickness of the ganglion cell layer and inner plexiform layer (GCL + IPL layers)

Cirrus: GCA Report

The analysis contains:
- Data for both eyes (OU)
- Thickness Map – shows thickness measurements of the GCL + IPL in the 6mm by 6mm cube
- Deviation Maps – shows a comparison of GCL + IPL thickness to normative data.
- Thickness table – shows average and minimum thickness within the elliptical annulus.

Put it all together:

Macular/Ganglion Cell Analysis for Glaucoma: Key Points

- Is a “complement” to traditional RNFL scans
- Has a large number of false positives.
- Should NEVER be used as the sole basis of a diagnosis for glaucoma.
- Not proven to make an earlier diagnosis.

What are practitioners’ most common misunderstandings of imaging technology?

“‘The thought that these devices can diagnose glaucoma in the absence of corroborating clinical evidence is, in my opinion, the most common (and potentially dangerous) misunderstanding. The limited normative databases against which scans are compared can never cover the remarkably varied appearance and structure of the optic nerve we encounter in normal individuals.’

James Brandt, MD
Red Disease!

Common Forms of OCT Image Artifact

1. De‐centration (28% of scans)
2. Error associated with posterior vitreous detachment (14%)
3. Posterior RNFL misidentification (8%)
4. Poor signal (5%)
5. High Myopia (2%)
6. Peripapillary atrophy associated error (12%)
7. Posterior RNFL misidentification (8%)
8. Motion artifact (<1%)

• All have the potential of being misread by you as true disease, the so called "red disease"
• As any artifact is categorized as being outside the normative database, thus automatically depicted in red on the report
• Then leading to an erroneous diagnosis and possibly unnecessary treatment

Artifact from poor quality scan.

High Myopia

• Up to 50% will have abnormal scans
• RNFL thickness decreases with higher axial length
• Normative database excluded patients with refractive error of >+8 D and ‐12 D
• OCT for over ‐12D is NOT useful and should not be ordered
• Temporal shift of the ST and IT RNFL bundles
• Focus on changes in Ganglion Cell Maps, sometimes they are more reliable

Summary Thoughts

• OCT is a tool but cannot diagnose
  – Only a clinician can make a diagnosis
• Clinical judgement and expertise is necessary
  – Risk factors, IOP, disc size, refractive error, visual field patterns, etc
• Structure-Function correlation is very important
  – But only when it works as there are exceptions.
• Glaucoma diagnosis and management is still an art!
• Practice and Review. Practice and Review. Practice and Review.
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EXAMPLES and CASES
Not Included in Handout for Size and Length

Heidelberg Spectralis OCT

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OCT for Glaucoma: Key Anatomical Aspects

Recognized Challenge: Highly Variable ONH

Bruch's Membrane Opening (BMO)
ideal, objective landmark to remove ambiguity of NRR, CD, etc.

24 Radial Scans through center of ONH

This is for explanation of the BMO-MRNH only. These scans are not reviewed on most patients and are not on the final report.
Minimum Rim Width (MRW) identified at 48 points

Reference Database Plot of the MRW

Full Thickness Macular Region Scan

Ganglion Cell Layer Scan

cpRNFL and Radial Scan for MRW follow same guidelines as for Cirrus or any other OCT

Visual Fields of past example Examine for all structure/function correlation

Cirrus OCT as comparison:
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OCT 4 Years Prior. Lost to F/U. IOP = 16 OD/28 OS

Photos from 4 years prior.

Another Example and Additional Interpretation

iVue OCT: Brief Overview

iVue OCT: RNFL

iVue OCT: GCC
Case EG: mild OHTN with no other RFs

Cirrus RNFL and GCA

Visual Fields

iVue OCT

Photos

iVue:
In early to moderate glaucoma, progression thinning of RNFL thickness measured by SD-OCT is a very useful tool to judge progression of disease. At advanced stages however, SD-OCT is less clinically useful due to a “floor effect” of RNFL thickness.

With advanced loss, RNFL thickness levels off, rarely falling below 50 µm and almost never below 40 µm due to the assumed presence of residual glial or non-neural tissue including blood vessels.

At this level of disease, serial visual fields are more useful to judge progression.
Average RNFL Values for Cirrus OCT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal Range*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average RNFL Thickness</td>
<td>75.0 - 107.2</td>
</tr>
<tr>
<td>RNFL Symmetry</td>
<td>76% - 95%</td>
</tr>
<tr>
<td>Rim Area</td>
<td>1.03 - 1.69</td>
</tr>
<tr>
<td>Average C/D Ratio</td>
<td>0.64 - 0.21</td>
</tr>
<tr>
<td>Vertical C/D Ratio</td>
<td>0.62 - 0.21</td>
</tr>
<tr>
<td>Cup Volume</td>
<td>0.01 - 0.035</td>
</tr>
</tbody>
</table>

Cirrus OCT GPA Analysis

Floor Effect on OCT Leads to VF Progression
Avg RNFL = 52

Change from Baseline = Baseline - Event

Regression Lines = Trend

Baseline

Regression Lines = Trend

Change from Baseline = Baseline - Event

Regression Lines = Trend

Change from Baseline = Baseline - Event
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Two baseline exams are required

Yellow Coded: Change greater than test-retest variability.

Red: Confirmed on follow up.

GPA “Event” Analysis = Thickness + Deviation Maps

Cirrus RNFL/ONH Trend Analysis

Three Parameters: Average, Superior, Inferior RNFL

Cirrus GPA: TSNIT Analysis

TSNIT values from baseline and current exams are plotted.

Areas of statistically significant change are color-coded yellow when first noted and then red when the change is sustained over consecutive visits.

Progression is less frequently noted on this plot.
**Legend** summarizes GPA analyses and indicates with a check mark if there is possible or likely loss of RNFL:

- RNFL Thickness Map Progression (best for focal change)
- RNFL Thickness Profiles Progression (best for broader focal change)
- Average RNFL Thickness Progression (best for diffuse change)

**Age Related RNFL and Macular Thinning:**
- Is not accounted for in the analysis
- \(-0.52 \mu m/\text{year}\)
- thus, not all negative slope is disease related and may not be related to glaucoma progression
- Review all clinical findings
- do not base management decisions on OCT alone

**Rate of change**
- Severity of the disease
- Patient demographics: age/anticipated life span/family history etc.
- Is the patient at risk for loss of vision-related quality of life?

**Age Related Rate of RNFL Progression**
- RNFL thickness decreases with age in normal, healthy individuals. Based on a longitudinal study, the age-related rate of reduction in RNFL thickness has been estimated to be:
  - \(-0.52 \mu m/\text{year}\) for average RNFL
  - \(-1.35 \mu m/\text{year}\), superior RNFL
  - \(-1.25 \mu m/\text{year}\), inferior RNFL
- When glaucoma patients show 2-3 times this or more, they will eventually show significant VF loss
Age-related RNFL Changes and Progression

- Longitudinal Studies
  - Mean loss of average RNFL thickness (µm/year)
    - Normal: -0.52 to -0.60
    - POAG: -0.82 to -2.12

- Significant Progression Event:
  - ≥ 4-5 µm repeatable reduction in global RNFL

- Significant Rate of Progression:
  - Reduction of ≥ 3µm per year

EXAMPLES and CASES

Not Included in Handout for Size and Length