New Advances in OCT Imaging for Glaucoma

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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.

Spectral Domain OCT: Many Options

• There 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
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

Glucoma – cp RNFL Thickness Analysis

- A 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 TNSIT circle

The circle is "broken" open on the temporal side, forming a "line" that can be laid out.
By traditional convention order is TSNIT

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. 50-55µ
- NOTE!!!!
  "Green" does NOT always mean no disease

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.

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)

GCA Analysis 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 annula.
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

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 (1%)
7. Incomplete segmentation (1%)
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

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

Green Disease

Patient with Glaucoma Damage OS only, RNFL has decreased from 100 to 80 microns
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.

EXAMPLES and CASES

Not Included in Handout for Size and Length

Heidelberg Spectralis OCT

Scan patterns:
1. ONH
2. BMO-MRW
3. RNFL
4. Posterior Pole

Cup-to-Disc Ratio Using OCT

- Optic disc “cup” is still a somewhat arbitrary entity using OCT – “empty space” within disc boundary
- The difference between the ILM and a reference plane based on BMO/RPE
- Empty space is defined as: BMO-derived disc area – neuroretinal rim area
- OCT-defined “cup-to-disc” ratio is a more consistent measure of such a parameter compared with the clinical definition BUT it is a derived measure rather than a direct measure, such as rim area
- OCT technology should be used to complement the clinical ophthalmic examination rather than confirm it
  - cup-to-disc ratio is a clinically-defined parameter

ONH Analysis

- BMO-MRW analysis using 48 equidistant data points
- BMO identified and BMO-MRW calculated using automated segmentation algorithm with possibility for manual override
- BMO-MRW thickness analysis adjusted for BMO area and age
- Garway-Heath BMO-MRW sector analysis for better structure/function correlation

Objective Landmark of Inner Edge of Rim

- The most anterior part of ONH contains the optic nerve fibers which make up the neuroretinal rim
- It is separated from the vitreous by the inner limiting membrane of Elsching (ILM)
- ILM is an objective inner boundary of neuroretinal rim tissue that is consistently detected by SD-OCT
Accurate SD-OCT Neuroretinal Rim Measurements

- BMO minimum rim width (BMO-MRW): BMO is used as landmark and rim width is quantified as the minimum distance between BMO and internal limiting membrane (ILM).

- Quantification of neuroretinal tissue made perpendicular to the axis at which nerve fibers exit the eye via the ONH.

- BMO-MRW overcomes limitation of overestimating rim tissue when using an arbitrary horizontal reference plane (BMO-HRW).

BMO-MRW Analysis

- 48 equidistant BMO-MRW data points are used to create a thickness profile around the ONH.
- These values are plotted on reference database profile (just like previous RNFL analysis).
- The reference data range that BMO-MRW thickness values are compared to are adjusted according the BMO area.
- For small BMO area, the thickness profile graph is shifted upward (thicker).
- For large BMO area, the thickness profile graph is shifted downward (thinner).

RNFL Analysis

- Three circle scans of 3.5mm, 4.1mm, and 4.7mm are automatically centered around BMO centroid.
  - 768 data points analyzed.
- RNFL thickness analysis adjusted for BMO area and age on all three scans.
  - Range of BMO area: 1.0 mm² - 3.4 mm².
- Garway-Heath sector analysis for better structure/function correlation.

Spectralis Report Interpretation

- Follow same guidelines as for any other OCT.

What’s Really New in OCT? “Swept Source Technology”

- DRI OCT TRITON PLUS
  - Swept Source OCT
  - 1050 nm light source
  - Normative database
  - 5 MP Non Mydriatic color fundus camera.
New Advances in OCT Imaging for Glaucoma

Swept Source OCT with 1050 nm wavelength light source

- Allows deeper penetration into choroid and sclera
- Less light scattering, improves results in eyes with cataracts and other media opacities
- Superior visualization of vitreous and choroid in the same scan
- Allows for scanning of highly myopic patients and patients whose pathology cannot be captured with conventional SD OCT
- Invisible OCT scanning light and high imaging speed of 100,000 A Scans/sec reduce effect of eye movements and allows more data to be collected per scan

Detecting OCT Progression

For patients diagnosed or at risk of glaucoma
- Stage disease if present
- Assess risk for progression
- IOP level, severity of damage, bilateral loss, disc hemorrhage, family history
- Treatment plan
- Surveillance
  - Establish adequate baseline
  - Photographs if available
  - Assessing photographs for change over time difficult due to subjective nature
  - Visual Field
  - Imaging

Managing glaucoma over time

- For patients diagnosed with glaucoma or are glaucoma suspects due to large cupping or unusual optic discs (myopic, tilted), detecting change is important
- This is a difficult task requiring periodic tests (photos, imaging, visual fields) to be performed over time watching for change
- Change can occur at any time
- Change does not occur at the same rate over the patient’s lifetime
- Due to test variability, just because a test is different from the previous one does not mean the person got worse
  - Need to confirm that change has occurred

Glaucoma Progression

- Ability to discriminate true change, over and beyond measurement variability, is a central requirement for any progression technique
- Perimetry or Imaging
- Progression may be measured by
  - Structural changes at the optic nerve head, retinal nerve fiber layer and macula using OCT
  - Functional changes noted as deterioration in the visual field
- Past progression is the best guide to future progression rate
New Advances in OCT Imaging for Glaucoma 2020

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**Glaucoma Progression**
- Historically progression determined by:
  - Evaluating optic nerve in real time and comparing with old photographs:
    - Decide if most recent picture indicates change
  - OR
  - Evaluating visual field printouts, either single field or overview, by inspection to see if more points flagged on most recent field

**Glaucoma Progression**
- New developments in assessing for change:
  - Better understanding of who and when progression occurs
  - Imaging instruments have improved
  - OCTs have < 5um resolution
  - Clinical structural change occurs before functional loss
  - Use central field tests such as 24-2C
  - Computerization and software have improved
  - Introduction of OCT GCC GPA
  - Visual field and imaging instruments allow quantification of data to recognize change using sophisticated mathematical principles
  - Single points and global indices

**Glaucoma Progression**
- Glaucoma progresses slowly with high variability
- Change is often non-linear
- Perimetry and OCT are complimentary methods to detect change
- Stereo photography and 2-D photography may detect early change but difficult and tedious to use
- Difficult to see cup/disc ratio change unless it is large
- Imaging provides quantitative measurements that may improve ability to detect progression

**Glaucoma Progression**
- Tools
  - Structural - Optic Disc and RNFL and Macula
  - Photographs
  - Imaging - OCT
  - RNFL and C/D ratio
  - RNFL and Macula GCC Guided Progression Analysis (GPA)
  - OCTA - The Future
  - Functional
  - Perimetry
  - Glaucoma Progression Analysis (GPA)
  - Overview printouts

**Glaucoma Progression**
- The best method to detect progression varies depending upon the stage of disease:
  - Mild to Moderate – OCT
  - Floor effect at approximately 55-60um
  - Moderate to Advanced – Visual Fields

**Risk factors for Progression**
- Extent of damage at time of diagnosis
- IOP
- Bilateral loss
- Disc hemorrhage
- Central visual field loss
- Cornea hysteresis
- Family history of progression
- Pseudoxfoliation glaucoma
Detecting Structural Progression of Glaucoma with the OCT

- What tools do we have currently?
- How are they used?
- What is the evidence to support the use?
- How can changes resulting from aging be differentiated from true progression?
- Better than Visual Fields?

OCT “Trend” Analysis

Four Parameters:
- Average, Superior, Inferior RNFL thickness
- Average C/D Ratio

A Regression Line is drawn to determine rate of change for all the data that has been collected over time.

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

What Change is Significant?

- For avg RNFL, short-term change = ~ 4 µm is considered significant
- For superior/inferior RNFL = ~ 7 µm
- For Macula GCL-IPL = ~ 4 µm

First. Obtain good OCT Images

A number of things can undermine the accuracy of an OCT scan. To avoid basing a medical decision on poor data, be mindful of these five factors:

Factors Affecting OCT Accuracy:
1. Signal Strength and quality. Movement and blinking artifacts
2. Scan alignment.
3. Scan centration.
4. Opacities.
5. Segmentation errors.

RNFL Age Related Change is also Important:

When glaucoma patients show 2-3 times this or more, they will eventually show significant VF loss

What tools do we have currently?

Helpful Strategies

- Look at the entire report, not just 1 or 2 sections.
- Always consider Artifact vs. True Disease or Progression
- Look for focal change (Event), not just overall change Trend)
  - a new RNFL defect
  - widening of an existing defect
  - deepening of an existing RNFL defect without widening
  - Correlate with Visual Fields and other findings.

Limitations to OCT Progression

- 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

Things to Think About

- 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?

Natural History of Structural Change

- Normals = ~ 2 to 5 microns/decade
  - 0.2 to 0.5 per year

- Glaucoma is Variable
  - Dependent upon
  - Stage of the disease
  - Quadrant
  - Increased rate of loss in patients with a higher baseline RNFLT

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 (\(\mu m/\text{year}\))
    - Normal: -0.52 to -0.60
    - POAG: -0.82 to -2.12

- Significant Progression Event:
  - \(\geq 4-5 \mu m\) repeatable reduction in global RNFL

- Significant Rate of Progression:
  - reduction of \(\geq 3 \mu m\) per year

EXAMPLES and CASES