Neuro Retinal Imaging: GDx and OCT

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Presentation Overview

• Challenges in glaucoma diagnosis and management
• GDx: Theory and application
• OCT: Theory and application
Glaucoma Statistics

• High percent of undiagnosed cases
  – Over 50% of open-angle glaucoma cases in the USA
  – Many undiagnosed patients have undergone prior eye exams
  – Worsening problem as the proportion of older Americans increases
Challenges of Glaucoma

• Risk factors are not widely known among patients
  – Many do not know it runs in families or is more common in African and Hispanic ancestry
• The structural changes in early glaucoma can be difficult to distinguish
  – Wide variation of optic disc size in both normal and glaucoma patients
• Patients can’t tell that they have it
  – Most do not notice loss of function until they are nearly blind
It is Important to Understand the Structural / Functional Relationship in Glaucoma as the Disease Progresses

• Visual Field changes occur late in the disease
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- The Optic disc often changes before visual fields
It is Important to Understand the Structural / Functional Relationship in Glaucoma as the Disease Progresses

- Visual Field changes occur late in the disease
- The Optic disc often changes before visual fields
- The RNFL usually changes before both the visual fields and optic disc
Structural and Functional Exams in Glaucoma Management

• To identify:
  • those who are at risk for glaucoma
  • those who have glaucoma

• To determine:
  • whether it is at a mild, moderate or severe stage
  • whether the patient is getting worse over time
Clinical Exam of the Optic Nerve Head
Utility and Limitations

- Disc exam at the first visit – normal or abnormal?
  - Disc exams are subjective, or at best semi-quantitative
  - The wide variety of disc appearances requires long experience and expert judgment to separate normal from abnormal
  - Disc diameter must be taken into account

- Disc exam to assess change
  - Unless stereoscopic photographs are taken and compared over time, the ability of a clinician to judge change is very limited (chronology is important!)
Case Optic Nerves

OD

OS
Case

72 year old glaucoma suspect
Cup-to-disc ratio asymmetry
Highest untreated IOP 24 mm Hg OU
Anterior chamber angles open OU
Clear visual fields

- Central corneal thickness
  - 533 microns OD
  - 545 microns OS
- No prior ocular history or surgery
- No family history of glaucoma
- Good general health except for elevated cholesterol
Automated Nerve Fiber Layer Examination

- Benefits
- Quantitative measurement of NFL
- Comparison to normative database
- Often performed without pupil dilation
- Immediate data available
- Does not require “reference plane” as in automated disc analysis
- May be less dependent upon disc diameter
GDxVCC and GDXPRO
The amount of retardation from the RNFL is directly proportional to the RNFL thickness\(^1\).
GDx: Basic Principles

- Thicker RNFL increases retardation of polarized light
- RNFL measurements are HIGHLY reproducible (within 2-4 microns)
- Highly correlated with threshold perimetry
- Useful in differentiating normal vs glaucoma patients
GDxVCC vs GDxPRO (ECC)

- Other structures in the eye have same lamellar structure as RNFL and retard polarized light (eg cornea and lens)
- VCC (variable corneal compensator) corrects for inter-patient variability by performing a macular scan 1st to eliminate corneal birefringence
- GDxPro has ECC (enhanced corneal compensation)
  - In eyes with poor signal-to-noise ratio, ECC images are less susceptible to measurement noise than VCC images.
  - ECC improves the measurement sensitivity in eyes with advanced glaucoma, potentially extending the dynamic range of GDxVCC system for tracking the disease.
GDxPro Enhancements

- Software enhancement that is backward compatible with the last generation of GDx
- Intuitive touch Screen or mouse-driven operation
- Auto Focus optimizes imaging position
- Live fundus View ensures proper patient fixation prior to scan acquisition
- Simple-Touch Automatic Pupil Alignment and Touch Screen acquisition
- Restart alignment quickly returns the alignment back to the default setting
- Low Vision Target accommodates patients with compromised central vision
- Iris Image check to rule out alignment issues after the scan
GDx Printout

Normal

Glaucoma

Parameters

Thickness Map

Deviation Map

TSNIT Graph
GDxPRO Printout
Fundus Image is useful for image quality
• Is the image focused?
• Is it adequately illuminated?
• Is the ellipse centered on the ONH?
The Deviation Map

• Compares each individual’s entire Retinal Nerve Fiber Layer scan to the normative database
• Reveals the location and magnitude of Retinal Nerve Fiber Layer thinning
• Defects are color-coded based on probability of normality
• Simplifies interpretation (similar to the visual field pattern deviation)
Deviation Map, Thickness Map and Visual Field Pattern Deviation Correlations

Examples from normal to advanced glaucoma

A normal eye with normal thickness and deviation maps and normal visual field
Examples from normal to advanced glaucoma

An eye with focal Retinal Nerve Fiber Layer loss prior to visual field loss
Deviation Map, Thickness Map and Visual Field Pattern Deviation Correlations

Examples from normal to advanced glaucoma

A moderate glaucoma eye with superior RNFL loss and inferior visual field loss
Deviation Map, Thickness Map and Visual Field Pattern Deviation Correlations

Examples from normal to advanced glaucoma

An advanced glaucoma eye with advanced RNFL and visual field loss
Nerve Fiber Indicator (NFI)

- Based on both focal and diffuse Retinal Nerve Fiber Layer loss
- Utilizes a neural network, trained to discriminate normal from glaucoma
- Is the most sensitive parameter for discriminating normal from glaucoma
- Classification

<table>
<thead>
<tr>
<th>Normal</th>
<th>Borderline</th>
<th>Abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>31 50</td>
</tr>
<tr>
<td></td>
<td>51 100</td>
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</table>

<table>
<thead>
<tr>
<th>TSNIT Parameters</th>
<th>OD Actual Val.</th>
<th>OS Actual Val.</th>
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</thead>
<tbody>
<tr>
<td>TSNIT Average</td>
<td>48.08</td>
<td>33.27</td>
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<tr>
<td>Superior Average</td>
<td>54.39</td>
<td>46.23</td>
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<tr>
<td>Inferior Average</td>
<td>62.33</td>
<td>28.06</td>
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<tr>
<td>TSNIT Std. Dev.</td>
<td>22.36</td>
<td>14.83</td>
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<tr>
<td>Inter-Eye Symmetry</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>NFI</td>
<td>25</td>
<td>63</td>
</tr>
</tbody>
</table>
Clinical Interpretation of TSNIT Parameters

Parameters:

- Summary measures based on the calculation circle.
- Values outside normal are color-coded based on probability of normality.
Clinical Interpretation of TSNIT Graph

Temporal – Superior – Nasal – Inferior - Temporal

• Displays the thickness values along the Calculation Circle
  – Normal values are within the shaded area
  – Abnormal values fall below shaded area
TSNIT Parameters

**TSNIT Standard Deviation**

- The standard deviation of the thickness values contained within the Calculation Circle
- Captures the modulation (peak to trough difference) of the “double-hump” pattern

**High modulation** = high value

**Low modulation** = low value

High modulation corresponds to a high value in the graph, whereas low modulation corresponds to a low value.
Inter-Eye Symmetry

- Values near 1 represent good symmetry
- Values near 0 represent poor symmetry
• Cup-to-disc asymmetry in this case is due to asymmetry in disc size.

• GDx shows there is no loss of nerve tissue.
Stratus OCT/Cirrus HD-OCT

Cirrus HD-OCT

Stratus OCT
Cirrus HD-OCT vs. Stratus OCT

Cirrus

Stratus
Retina Pathology Visualization

Healthy RNFL  Glaucomatous Loss
Stratus OCT
## Stratus OCT Scan Patterns

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RNFL Thickness</strong></td>
<td>Three 3.4mm diameter circle scans centered on the cup</td>
</tr>
<tr>
<td><strong>Optic Nerve Head Map</strong></td>
<td>Six 4mm radial line scans centered on the cup</td>
</tr>
<tr>
<td><strong>Macular Thickness Map</strong></td>
<td>Six 6mm radial line scans centered on fovea</td>
</tr>
</tbody>
</table>
Stratus OCT Printout Options: RNFL Thickness Average Analysis

- Early detection of retinal nerve fiber layer loss
- RNFL thickness assessment and comparison of both eyes
- RNFL thickness measurement
- Graphed in a TSNIT orientation
- Compared to aged matched normative data
• 95% of normal population falls in or below green band
• 90% falls within green band
• 5% of normal population falls within or below yellow band
• 4% falls within the yellow band
• 1% falls within red band
• considered outside normal limits
Stratus OCT Printout Options: Retinal Thickness Tabular Output Analysis

Provides evaluation of the retinal condition:

- Increased retinal thickness
  ~ underlying pathology

- Retinal thinning

- Atrophy or glaucomatous changes

Patient data are compared to normative database

Results are displayed in thickness maps, sector maps and tabular data.
Clinical Examples with the Stratus OCT
OU Normal

Patient data (black line) corresponds closely with normal range (green band).

OU analysis demonstrates RNFL symmetry.

Inferior Average and Average Thickness for each eye are in the 95th percentile. Superior average is in the 90th percentile.
OD Normal OS Glaucoma

Healthy RNFL, OD

Flattened RNFL, OS

OU comparison shows asymmetry

RNFL outside of normal limits, OS
Glaucoma – RNFL Thickness Analysis
Identifying and Monitoring RNFL Loss

OPTIC DISC CUBE SCAN
The 6mm x 6mm cube is captured with 200 A-scans per B-scan, 200 B-scans.

CALCULATION CIRCLE
AutoCenter™ function automatically centers the calculation circle around the disc for precise placement and repeatable registration.

The placement of the circle is not operator dependent.

Accuracy, registration and reproducibility are assured.
RNFL Analysis

RNFL THICKNESS MAP shows the patterns and thickness of the nerve fiber layer within the full 6mm x 6mm area.

RNFL thickness and comparison to normative data is shown in circle, quadrants and clock hour display.

RNFL DEVIATION MAP, overlaid on the OCT fundus image, illustrates precisely where RNFL thickness deviates from the normal range. Data points that are not within normal limits are indicated in red and yellow.

RNFL thickness along the calculation circle is displayed in graphic format and compared to age-matched normative data.
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 colorized yellow or red
- Yellow denotes change from both baseline exams
- Red denotes change from 3 of 4 comparisons

**Summary Parameter Trend Analysis**
- Rate 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

- Legend summarizes GPA analyses and indicates with a check mark if there is possible or likely loss of RNFL
Macular Cube Scan

Name:
ID: 432
DOB: 02/28/1973
Gender: Male
Doctor:

Exam Date: 02/19/2000
Exam Time: 01:44 PM
Technician: Operator, Cirrus
Signal Strength: 10/10

Macula Thickness: Macular Cube 512x128

Overlay: ILM - RPE Transparency: 50%

ILM-RPE Thickness (μm)
Fovea, 253, 62

ILM - RPE

Distribution of Normal
- 99%
- 99%
- 5%
- 1%

Central Subfield Thickness (μm)
Cube Volume (mm³)
Cube Average Thickness (μm)

| ILM - RPE | 303 | 11.0 | 303 |

OD • OS
Automatic Fovea Finder™

Fovea center = 255, 71  
Scan center = 255, 64

Macula Thickness Analysis is aligned with fovea location (left)

Resulting analysis may differ from analysis aligned on scan center (right)
Macular Thickness Normative Data

Macular thickness is compared to an age-matched normative database as indicated by a stop-light color code.

<table>
<thead>
<tr>
<th>Central Subfield Thickness (um)</th>
<th>Volume (mm^3)</th>
<th>Average Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILM - RPE</td>
<td>272</td>
<td>274</td>
</tr>
<tr>
<td>ILM - RPEfit</td>
<td>275</td>
<td>279</td>
</tr>
<tr>
<td>RPE - RPEfit</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Macula Normative Distribution

Of the normal population:

- 1% fall within the light red band; considered outside the normal limit
- 4% fall within or above the light yellow band
- 90% fall within or below the green band
- 4% fall within or below the yellow band
- 1% fall within the red band; considered outside the normal limit
Macular Change Analysis

Provides visual and quantitative comparison of two exams. Post-acquisition registration and the unique Fovea Finder function allows the accuracy and precise repeatability of macular thickness measurements.
Clinical Examples with Cirrus OCT
RNFL Thickness Analysis: Normal
RNFL Thickness Analysis: Glaucoma OD
RNFL Thickness Analysis: Glaucoma OU
Quickie Case
Case History

• 55 black male coming complaining about decreased vision at near
• Positive medical history of hypertension for 10 years, currently medicated.
• Mother has glaucoma
Entrance Skills

- Va’s: 20/20 OD, OS
- Pupils: PERRL
- EOM’s: FROM
- CVF: full to finger count
- IOP’s: 16, 16 OD, OS
  - Pachy: 540, 550 OD, OS
  - Fundus eval: see photos
    - OD: c/d 0.45/0.45
    - OS: c/d 0.6/0.6
    - HVF: see photos
What we did.

• We discussed with the patient that it appeared he had early glaucomatous changes (early nasal step OS, reduced NFL OS) and with a positive family history we recommended he be treated.

• We also educated patient that we could monitor him very closely every 3 months and watch for further change, and then begin treatment at that time.
Treatment

- Patient chose to begin treatment
- We started him on Travatan Z qhs in the left eye.
- We felt this would be the best medication for lowering his eye pressure without significant side effects related to his hypertension and to potential allergy affects of other prostaglandin analogs.
Follow up

• Patient returned in 2 weeks for a follow up and his IOP had decreased from 16 to 12 in the left eye.

• Patient asked whether there was potential to have glaucoma in his right eye. We said it was possible and he decided he wanted to initiate treatment in his right eye as well.
Case

• 60 yo WM
  – Type 2 DM: 4 years
  – Hypertension: 4 years
  – Bilateral PK’s secondary to keratoconus (has running suture OD)
  – Has history of steroid injections for lower back stenosis (with history of increased IOP up to 40 after injections)
  – VA(RGP): 20/25, 20/20-
  – IOP: OD: range 20-24, OS: range 17-20
OCT Retinal Images
Pigment Epithelial Detachment
Cystoid Macular Edema
AMD with Subretinal Fluid
CNV: Choroidal Neovascularization
Vitreomacular Traction
Full Thickness Macular Hole with Operculum
Central Serous Chorioretinopathy
Diabetic Macular Edema
Epiretinal Membrane