Optic Nerve & RNFL Imaging

Jorge L. Fernandez Bahamonde, MD.
Basics

- Glaucoma is a large group of disorders that share:
  - Progressive deterioration of the optic nerve and the visual field.
  - As much as 50% of the optic nerve fibers are lost before typical visual fields defects are detected\(^1\).
    - NFL changes will occur before VF or cupping changes are evident.

Early detection in glaucoma.

- **FDT.**
  - activity of a subset of magnocellular retinal ganglion cells.
- **SWAP.**
  - Blue (440 nm) on Yellow background.
    - Blue ganglion cell early affected.
  - Difficult.
    - Patient.
    - Interpretation.
Early detection & fup in glaucoma

- Imaging.
  - CSLO.
    - HRT-3
  - SLP.
    - GDX
  - OCT.
  - Optic nerve photography.
Confocal Scanning Laser Ophthalmoscopy CSLO.

- SLO. Acquire and analyze 3D images of the posterior segment.
  - HRT-3.
    - Qualitative and Quantitative information of the optic disk & macula.
    - FA
    - Blood Flow.
  - Optos, retinal camera that uses SLO.
  - SLP: GDx
CSLO-Basics.

- Laser scanning tomography.
  - Confocal pinhole + laser light:
    - High optical resolution.
    - “Optical sections” of a 3D object at each focal plane.
  - Light source HRT-3
    - Diode 670 nM.
    - Time 1.6 sec.
HRT-3.

Summation of images lead to 3 D

32 images total “depth” 2.5 mm (80 microns between images)
Darker images are anterior and posterior to focus.
For each focal plane the intensity of light reflected will be a function of depth.
- Color code topography.
  - Darker = Prominent.
  - Bright = Depressed
are needed to see this picture.
HRT-3

- **Pros.**
  - Non-dilated pupils.
  - Possible with media opacities.
  - Fast.
  - Comparison possible.

- **Cons.**
  - Inability to process with significant astigmatism.
  - Trouble with:
    - Myopic & Hyperopic discs.
    - Tilted discs.
    - Optic nerve drusen.
    - Physiologic excavation.
HRT-3

- Cons.
  - Analysis depends on
    - Manual disk demarcation.
    - Reference plane.
      - Changes with IOP (20-25 mm Hg)
      - Edema.
      - Cardiac cycle.
        - Decrease variability only if pulse synchronized.
Qualitative Assessment

- Horizontal Cross Section of the optic nerve.
  - Normal eye.
    - Low (smooth) slope for the temporal side.
    - Higher (sharp) slope nasal.
  - Glaucoma.
    - High temporal slope.
    - Deep Cup, wide and flat bottom.
Horizontal Cross Section

Normal Eye

Glaucoma
Height of the peripapillary retinal surface

- Normal eye.
  - Double hump.
    - Increase thickness of the superior and inferior nerve fiber layer.

- Glaucoma.
  - Variable loss of the hump.
    - Eventually flat line
Peripapillary retinal surface

Normal eye
Glaucoma
Parameters.

- **Neuroretinal Rim Area (RA).**
  - Most important predictor of CPSD and MD.
    - For High or Normal Tension Glaucoma.

- **Cup Shape Measure.**
  - Second most important predictor of MD.
    - Less negative, steeper more glaucomatous cup.
    - Independent of the reference plane.
    - Valuable for High or Normal Tension Glaucoma.
Moorfields Analysis.
- Data on Caucasians.
  - 80 normals, 51 POAG
  - Refractive error < 6 diopters.
- Graphic representation for sectors.
  - ✓ Normal. % of Neuroretinal rim (rim/disc area) falls between 95% limit of “normality”
  - ? Borderline. % is between 95 and 99% of normality.
  - ❌ Abnormal. % rim is outside the 99% limit.
HRT-II “Normal”
HRT-II “Borderline” progression to “Abnormal”
HRT II- Progression.

Examination: Date: May/20/2001
Scan: Focus: 1.0 dpt Depth: 3.75 mm

Comments:

Classification: Outside normal limits (*)

Date: May/20/2001 Signature:

Examination: Baseline May/20/2001 FollowUp: May/23/2003 Time elapsed: 23 months
Scan: Focus: 1.0 dpt Depth: 4.00 mm Operator: Maribel

Comments:

Classification: Outside normal limits (*)

Date: May/22/2003 Signature:

(*) Multivariate regression classification (Ophthalmology 1598:105-1057-1058).
Classification based on evidence. Diagnoses are physician's responsibility.
HRT-3, upgrade.

- Moorfields Rim/Disc size
- GPS. Glaucoma Probability Score
- Topographic Change Analysis (TCA)
## Limitations

- For Moorfields Regression Analysis and all 3 methods of Linear Discriminant Function.
  - Sensitivity decrease to 50% when specificity is raised to 95%.

- Large discs.
  - Low specificity, high sensitivity.
    - Increase false positives.

- Small discs.
  - High specificity, low sensitivity.
    - Increase false negatives.
HRT-II Follow ups.

- Follow ups comparison.
  - Stereo metric.
    - Check if parameters change more than 5-9% expected variation in glaucomatous eyes.
  - Topographic.
    - Use color code comparison provided by software.
HRT-II Follow ups.

- Topographic change.
  - One Baseline, 2 or 3 follow ups.
    - Independent of contour line.
      - Green significant elevation.
      - Red significant depression.
Scanning Laser Polarimeter, SLP

- **CSLO.**
  - Infrared diode laser
    - (780 nm).
    - 15° grid centered at the disk.
      - 128 x 128 pixels
      - 4 µm reproducibility¹.
  - Birefringence.
    - Polarized light changes as it passed through RNFL.
    - RNFL Thickness ≈ Retardation.

¹Blumenthal and Frenkel. IOVS, suppl. 2003
Retardation of the signal represents birefringence of anterior segment + RNFL thickness.

Compensator needed to eliminate anterior segment contribution.

- Evolution in compensation.
  - Less “Odd scans”.
- VCC. Obtains uniform birefringence.

The pattern in this circle is caused by anterior segment birefringence.
GDx VCC

- Test takes seconds.
  - Undilated pupils.
  - No reference plane.
    - Not affected by IOP.
- Edge of disk marked by tech.
- Instrument test a peripheral circle around this edge.
  - “Tech independent”.

![Image of GDx VCC test](image)
GDx VCC.

- RNFL thickness compared to database for normal and glaucoma patients.
  - Probability of damage for sector.
    - TSNIT.
    - NFI.
      - “Grade for damage”

3 Patella VM. Zeiss Meditec, Dublin, CA (unpublished data), 2003
GDx VCC Printouts.

- Symmetry analysis.
- Fundus image.
  - Check for image quality.
    - Eye examined.
    - Date
  - 15° of retina.
Printouts. *Symmetry Analysis*

- **Thickness map.**
  - Thinner-Thick.
    - Blue-green-yellow-red.
    - Superior & Inferior RNFL extends to borders of map.
      - Hourglass.
      - Symmetry.

- **Deviation map.**
  - Comparison to database.
  - Probability of RNFL loss.
    - Color coded.
    - Red, loss most likely.
Printouts. Symmetry Analysis

- Parameters.
  - Thickness in microns.
    - Color coded to reflect deviation from normal database.
    - Symmetry.
    - NFI.

- TSNIT graph.
  - Pattern should be within range (database)
    - Modulation “humps”.
    - Symmetry.
Printouts. Symmetry Analysis

- **NFI.**
  - Indicator of the likelihood of glaucoma.
    - < 30  Normal.
    - 30-50  Suspect.
    - >50  Glaucoma.
Serial Analysis.

Thickness Map

Deviation Map

Deviation

TSNIT Parameters

TSNIT Comparison
Odd Scans.

- Mostly resolved by variable corneal compensation.
  - Henle’s layer should show uniform birefringence.
- Modulation should not be affected by still not compensated anterior segment effect.
  - VCC should narrow the normal thickness range.
Odd Scans.

- Evaluated fundus view.
  - Centration.
  - Quality.
- TSNIT graphs.
  - Weird modulation.
  - Out of range.
GDx pre and post lasik.

With Fixed Compensation

VCC
Physiologic vs. pathologic excavation

Similar cups

Different TSNIT
VF and GDx correlation.
Early detection OD.

Courtesy of Dr. Naoya Fujimoto Chiba University, Japan
Early detection, FDT correlation.

Courtesy of Dr. Naoya Fujimoto Chiba University, Japan
61 year old white male, initial IOP, 20/24. CCT. 515/512. IOP has drop only to 15/16 on Cosopt OU and Alphagan OS. (green iris).
Correlation with VFs, GDx HRT-II

- 71 year old female, initial IOP 21/20 on Lumigan and Alphagan. (late 01)
  - CCT 516/516.
  - IOP dropped to 15-16 range after
    - SLT, and addition of Trusopt.
GDx

- Lack of hourglass pattern.
- Deviation from normals.
- Flattening of curve.
- Poor numbers, high NFI
### HRT-II 02

**Examination:**
Baseline: Jan/17/2002  
Follow-Up: Dec/17/2002  
Time elapsed: 11 months

**Scan:**
Focus: 2.00 dpt  
Depth: 3.25 mm  
Operator: Maria de Lourde

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#### OD

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<th>Change</th>
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<tr>
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**Comments:**

Classification: Outside normal limits (*)

Date: Dec/17/2002  
Signature: [Signature]

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#### OS

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**Comments:**

Classification: Outside normal limits (*)

Date: Dec/17/2002  
Signature: [Signature]

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Classification based on statistics. Diagnosis is physician's responsibility.

Software: HRT-07-3.2
IOP 16-18 last 3 yrs on Xalatan.
Unreliable fields, suspicious nerve

Age 87
IOP range 18-20
CCT 522/517
Xalatan prescribed OD.
Non-invasive cross sectional representation of posterior segment tissues.

“Similar” to a B-scan but,
- Light waves improve resolution from 150 microns to 8.
  - 850 nm low coherence near infrared.
- Qualitative and Quantitative output.
- Excellent detail in vitreoretinal interface disorders.
OCT-Basics.

- Continuous beam of light divided in two. (850 nM, diode laser)
  - Half travel to a reference mirror.
  - The other half into the eye.
- Interference pattern of the resultant wave correspond to the thickness and distance of the reflecting tissues.
OCT-Basics

- **Resolution.**
  - Axial 8 microns.
  - Transverse 13 microns.
- **Presentation.**
  - False colors that represent optical reflectivity
    - Optical properties not necessary histopathologic morphology.
  - Dimensions correspond to true anatomy.
  - Darker colors: min. or no reflectivity (-100 dB).
  - Bright colors: high reflectivity (-50 dB).
**OCT-Normal Retina**

- **RPE-choriocapillaris**: highly reflective posterior red layer.
  - 70 microns.
- **Photoreceptors**: darker and less reflective band.
- **Middle retina**.
- **NFL**: Red layer at the vitreo-retinal interface.
- **Vitreo-retinal interface**.

**Diagram:**
- NFL
- Middle retina
- RPE-choriocapillaris
- Photoreceptors
- Vitreo-retinal interface
Indications.

- Excellent for vitreoretinal interface disorders.
- Other uses:
  - NFL Glaucoma.
  - Macular diseases.
OCT-Basics

- Disadvantages.
  - Good fixation required.
  - Pupil dilation recommended.
  - Affected by media opacities.
    - Cataract.
    - Corneal Edema.
OCT for Glaucoma.

- Optic nerve analysis report.
  - Topographic view of the optic nerve head.
    - Looks similar to HRT-II
- RNFL thickness report.
  - Thickness of NFL around optic nerve.
    - Looks similar to a GDx.
Optic nerve analysis report

Individual Radial Scan Analysis
- Rim Area (Vert Cross Section): 0 mm²
- Avg Nerve Width @ Disk: 0.18 mm
- Disk Diameter: 0.0 mm
- Cup Diameter: 0.0 mm
- Rim Length (Horiz.): 0.0 mm
- Cup Offset (microns): 0

Optic Nerve Head Analysis Results
- Vert. Integrated Rim Area (Vol.): 0.326 mm³
- Horiz. Integrated Rim Width (Area): 1.756 mm²
- Disk Area: 2.32 mm²
- Cup Area: 0.514 mm²
- Rim Area: 1.966 mm²
- Cup/Disk Area Ratio: 0.202
- Cup/Disk Horiz. Ratio: 0.47
- Cup/Disk Vert. Ratio: 0.479

Non Standard Analysis. Less than 6 scans used.

Signature: ____________________________
Physician: Noel De Leon, M.D.

Optic Nerve Head Analysis Results
- Vert. Integrated Rim Area (Vol.): 0.007 mm³
- Horiz. Integrated Rim Width (Area): 0.16 mm
- Disk Diameter: 1.44 mm
- Cup Diameter: 1.3 mm
- Rim Length (Horiz.): 1.4 mm
- Cup Offset (microns): 0

Optic Nerve Head Analysis Results
- Vert. Integrated Rim Area (Vol.): 0.016 mm³
- Horiz. Integrated Rim Width (Area): 0.81 mm
- Disk Area: 1.631 mm²
- Cup Area: 1.179 mm²
- Rim Area: 0.852 mm²
- Cup/Disk Area Ratio: 0.729
- Cup/Disk Horiz. Ratio: 0.86
- Cup/Disk Vert. Ratio: 0.86

Non Standard Analysis. Less than 6 scans used.

Signature: ____________________________
Physician: Jorge L. Fernandez, M.D.
RNFL thickness report

DOB: 02/08/1921, ID: 134-22-9145, Female

Scan Date: 03/06/2004
Scan Length: 10.47

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<td>Max</td>
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<td>Avg.</td>
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<td>Avg. Th.</td>
<td>76.73</td>
<td>32.82</td>
<td>43.91</td>
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Signature: __________________________

Physician: Luis De Corral, M.D.
Conclusion.

- Modern imaging technology.
  - Probably too expensive for solo-practice.
  - Evident:
    - Moderate to severe damage.
    - “Super normals”
  - Confusion in the middle.
    - Analysis still in infancy stage.
    - Small control data for comparison.