Optical Coherence Tomography

Optical: Light-based

Coherence: property of light waves in which the oscillations maintain a fixed relationship to each other

Tomography: Cross-sectional imagery

OCT Image Acquisition

“Cube of Data”

- Similar to ultrasound but uses light instead of sound to image tissue
- Beam of light is directed into tissue and reflections coming from different layers of the tissue are received by a detector

OCT Image Acquisition Table:

<table>
<thead>
<tr>
<th>OCT Version</th>
<th>Scans/sec</th>
<th>A-scans/Pixel</th>
<th>Image Density</th>
<th>RNFL Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCT1 1996</td>
<td>20</td>
<td>500</td>
<td>512 x 1024</td>
<td>5</td>
</tr>
<tr>
<td>OCT2 2000</td>
<td>20</td>
<td>500</td>
<td>512 x 1024</td>
<td>5</td>
</tr>
<tr>
<td>OCT3 2002</td>
<td>20</td>
<td>500</td>
<td>512 x 1024</td>
<td>5</td>
</tr>
<tr>
<td>Cirrus HD-OCT 2007</td>
<td>20</td>
<td>1024</td>
<td>1024 x 4096</td>
<td>20</td>
</tr>
</tbody>
</table>

At first, OCT was slow

- First OCT images taken by Huang and Schuman over night in James Fujimoto’s laboratory, MIT

OCT – Time Domain Stratus

Strengths:
- Provides Cross Sectional images
- Useful to calculate RNFL thickness
- Cross section scans useful for retinal pathologies
- Database comparisons

Weaknesses:
- Slow scan speed (500 A-scans/second)
- Limited data for glaucoma, 768 pixel (A-scan) ring for RNFL
- Limited data for retina, 6 radial lines with 128 A-scans (pixels) each
- Macula maps 97% interpolated
- No progression analysis
- Location of scan ring affects RNFL results
- Prone to motion artifacts because of slow scan speed
- Poor optic disc measurements
**Time Domain OCT susceptable to eye movements**

- 768 pixels (A-scans) captured in 1.92 seconds is slower than eye movements
- Stabilizing the retina reveals true scan path (white circles)

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**Stratus vs. SD-OCT**

- 10 micron axial
- 500 a-scans per sec.
- 512 A-Scans per B-Scan
- 1024 d-points e A-Scan
- 2 mm deep
- 131,072 total d-points
- Eye Tracking!!

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**Spectral Domain: Why??**

- Enhanced reproducibility and registration
- Objective quantitative data that supports standardization of care at an expert level.
- Pinpoint correlations in ocular structure and function, matching areas of abnormal tissue with attendant vision problems.
- Enhance sensitivity and specificity in disease detection and reduce uncertainty in glaucoma suspects.
- Improved software is available to help detect *disease progression*.

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**OCT Technology: Advantages**

- Has ushered in a whole new era of retinal care
  - Diagnosis
  - Response to treatment
- New diagnoses once only speculated
  - VMT
  - Macular Schisis
- Information once only available through histopathology or dissection
- Can replace FA in some cases
OCT Technology: Caveats

• DOES NOT take place of clinical exam!
• DOES NOT take place of careful history taking
• DOES NOT replace FA in some cases!
• DOES NOT REPLACE COMMON SENSE!

• ONE MORE PIECE OF CLINICAL PICTURE
  – Not the end all be all!!
  – Not to be taken in vacuum

Plaquenil Toxicity: How Prevalent?

Not Recommended for
Fundus photography Recommended for documentation, especially at baseline; but not sensitive for screening insufficient resolution for screening Insufficient resolution for screening insufficient resolution for screening Insufficient resolution for screening Insufficient resolution for screening Insufficient resolution for screening Insufficient resolution for screening Insufficient resolution for screening Insufficient resolution for screening

Time-Domain OCT Fundus photography
Phosphene angiography Use only if preclinical changes are needed
Full-field ERG Important for evaluation of established toxicity, but not for screening
Amsler grid Use only as anadjunct test
Color testing Easy Use only as anadjunct test
Quick (3-5)

EOG Questionable sensitivity

EOG = electro-oculogram; FAF = fundus autofluorescence; mfERG = multifocal electroretinogram; SD-OCT = spectral domain optical coherence tomography.

Spectral Domain: Many Options

• Ease of use
• Customer support
• Integration of other technology
  – FAF
  – Color
  – MSI
• Reputation of company

Table 2. Chloroquine and Hydroxychloroquine Screening Procedures

<table>
<thead>
<tr>
<th>Timeline</th>
<th>Baseline examination within first year of use; Annual screening after 1 year of use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended Screening Procedures</td>
<td>Onset examination (dilated retinal examinations are important for detection of associated retinal disorders, but should not be relied on for screening low sensitivity, e.g., macular edema)</td>
</tr>
<tr>
<td>Automated visual field</td>
<td>White S-2 threshold testing. Interpret with a low threshold for abnormality, and then if abnormalities appear</td>
</tr>
</tbody>
</table>

In addition, if available, perform one or more of the following objective tests:

- SD-OCT: Rigor test that can be done routinely can show abnormalities very early, even before field loss.
- mfERG: Valuable for evaluation of superior or nasal visual field loss, may show damage in areas than visual field testing.
- FAF: May validate other measures of toxicity; can show abnormalities earlier than field loss.
How to “Read” a Printout

• **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

• Well centered image
• No evidence of movement artifact
• Review Plots and Displays
  – Thickness Map and Deviation Map

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Basic Interpretation of OCT B-Scans: What can we see?

- **Retinal Contour:** Normal/Abnormal
- **Thickness:** Thick or thin?

- **Artifacts**
  - Motion Blur
  - Shadows/Blocking
  - Breaks/Blinks
  - Algorithm Failure: Thickness Error/Artifact/Straight-Line Error
  - Technician Error

- **Pathology**
  - Pre Retina: PVD/Floaters/Asteroids/Vit. Attachments/Traction/ERM-PMF
  - Cystoid/Diffuse Edema/Retinal Holes/Papilledema/Optic: Pit
  - Drusen/ONH Drusen/RPE/Geographic Atrophy
  - Neovascularization: Choroidal/Neovascularization, Tumor, Nerve
  - Outer Retina/Choroidal/RPE/LE

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Macular Thickness Normative Data

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

- **Normal Distribution:**
  - 1% of the normal population
  - 3% of the normal population
  - 3% of the normal population
  - 5% of the normal population
  - 10% of the normal population

- **Stop-light color code:**
  - Green: within ±2 SD of the mean
  - Yellow: within ±3 SD of the mean
  - Red: outside ±3 SD of the mean

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Macular Cube Scan

With resolution of 5µm and repeatability of 2.5µm, Cirrus HD-OCT captures a dense cube of scan data in just 2.4 seconds. Proprietary algorithms provide 2-D and 3-D images, layer segmentation and optical biopsies for assessment of the retinal condition and precise registration allows identification and evaluation of change.

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Cirrus HD-OCT Healthy Macula

- **NFL:** Nerve Fiber Layer
- **IS/OS:** Inner/Outer Segmental Boundary
- **OPL:** Outer Plexiform Layer
- **IS/OS:** Inner/Outer Segmental Boundary
- **RPE:** Retinal Pigment Epithelium

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13 Retinal Layers!
Macular Hole

- Full thickness macular hole OS
- Consult with retinal specialist
  - Felt that due to duration of situation, unlikely that any surgery would have meaningful benefit on vision
  - RTC q 6 mos
  - Monocular precautions including polycarbonate RX

Macular Hole

- Present as a circular to oval depression of varying degrees in the avascular area of the macula
  - May have surrounding cuff of edema
- Most common cause is idiopathic
  - Other causes include blunt trauma, severe myopia, solar retinopathy, CME
- Highest incidence in 7th decade of life
- Women 2x as often as men

Macular Hole

- Vision typically 20/80 to 20/200 with full-thickness hole
- If pt has macular hole in one eye, 28-44% chance of macular hole in other eye w/o a PVD
  - If PVD already, very little chance
- Watzke-Allen sign useful to differentiate true hole from similar appearance
- OCT very useful

VMT: Vitreomacular Traction

- VMT syndrome is characterized by a partial detachment of the posterior detachment with persistent adherence to the macula
  - Can lead to CME, ERM, and macular hole formation
- Once thought to be relatively rare, with advent of OCT now being seen more and more
  - In one study, 8% of pts were thought to have VMT by clinical observation only, but 30% by OCT

VMT

- More commonly encountered in older women
  - Can occur in either sex, and age, no apparent racial predilection
- Aphakia and pseudophakia are protective, as these patient typically have a complete PVD
- Pts may report decreased vision, metamorphopsia and photopsia
VMT
- Clinically, very hard to diagnose
  - PVD with adherence to macular area
  - Can present as macular surface wrinkling/striae, similar to ERM, or loss of foveal reflex
  - May also note a thickened posterior hyaloid membrane
  - Retinal blood vessel distortion straightening may be present
  - Retinal thickening/macular edema may be associated
- OCT IS THE KEY!!!!

VMT
- Natural progression of disease is rather variable
  - Slow progression possible with near normal acuity
  - Approx 10% will have spontaneous PVD and resolution
- Therefore, close monitoring may be advised for some patients

VMT
- In patients with poor vision, or symptomatic, a pars planar vitrectomy (PPV) may be considered
  - Duration, severity should also be considered
- Literature reports up to a 75% success rate and improvement of vision following PPV

Jetrea (Ocriplasmin)
- Intravitreal injection of thrombolytic agent that causes lysis of vitreous
  - Pharmacologic vitrectomy
  - FDA-approved October 2012 for treatment of symptomatic vitreomacular adhesion
  - Two phase 3 trails
    - 26.5% of pts had resolution of VMA vs. 10.1% with placebo
    - Minimal adverse effects
  - Available January 2013
  - Cost?

Expansile Gas injection
- 15 eyes, 14 pts with symptomatic VMT injected intravitreally with 0.3ml perfluoropropane (C_3F_8), expansile gas
  - At 1 mos, traction release in 40% of pts (6/14)
  - At 6 mos, traction release in 60% (9/14)
  - Foveal contour restored in 47% of eyes
  - No gain in VA
  - Only 33% of pts had to have PPV
  - Horiz diameter < 750um, foveal thickness < 500 um, and low vitreous face reflectivity were very responsive (100%)

Epi-retinal Membrane
- AKA macular pucker, cellophane maculopathy
- Can be secondary to peripheral retinal disease, such as detachment or tear; a retinal vascular disease such as BRVO; inflammation; trauma or idiopathic
- Idiopathic tend to be more mild and non-progressive vs. those after retinal tear
Epi-retinal Membrane

- VA can range from 20/20 to 20/200 or worse
  - Studies show > 5% have worse than 20/200
- Often metamorphopsia is only complaint with idiopathic ERM
- Fewer than 20% of cases are bilateral
- Surgical removal is considered if severe vision loss or distortion

Epi-retinal Membrane

- Consider surgery if:
  - VA 20/40 or worse
  - Symptomatic
  - Visual need of patient
- 30 minute procedure
- Face down compliance after surgery for up to 2 weeks
- Make sure you have an experienced surgeon!!

Central Serous Retinopathy

- Common disorder of unknown etiology which typically affects men between age 20 and 45
  - Males to females 10:1
- Serous detachment of neurosensory retina due to leakage from small defect in RPE

Central Serous Retinopathy

- Pt typically presents with fairly recent onset of blurred VA in one eye with a scotoma, micropsia, or metamorphopsia
  - VA typically 20/30-20/70
  - Often correctable with low hyperopic RX
  - Unilateral in 70% of cases

Central Serous Retinopathy

- Appears as a shallow round or oval elevation of the sensory retina often outlined by a glistening reflex
- FA is helpful in providing definitive diagnosis
  - Classic Smoke stack appearance (occasionally)
  - Ink-blot appearance
- OCT shows marked elevation

Central Serous Retinopathy

- Risk factors
  - Type A personality
  - Stress
  - Use of systemic cortico-steroids
  - Pregnancy
Central Serous Retinopathy

- 80-90% of pts will undergo spontaneous resolution and return to normal (or near normal) VA within 1-6 mos.
  - >60% resolve back to 20/20
  - Rare to have vision remain < 20/40
- Approx 40% will get recurrence
- CNVM is VERY rare occurrence, but possible

Central Serous Retinopathy

- No known medical therapy has been proven effective
  - Topical steroids, NSAIDs etc
- Localized photocoagulation may be of some benefit, but only if
  - Duration at least 4 months
  - VA in other eye is reduced from other attacks
  - Recurrent CSR has already reduced VA in that eye
  - Pt is intolerant of vision and willing to take risk
- PDT suggested in some cases
  - Avastin?
  - Behavior modification?

RPE Tears

- RPE tears most common following PEDs, especially those treated with anti-Vegf therapy
- Also associated with PDT, postoperative hypotony after glaucoma surgery, trauma, PED associated with CSR, and CNVM from angioid streaks, POHS and myopic degeneration
- Poor prognosis with final acuity typically 20/200 or worse

RPE Tears

- Clinically appear as a well-demarcated area of bare choroid immediately adjacent to hyperpigmented area, representing redundant, retracted RPE
  - Often accompanied by heme or exudates
  - Pts typically report with sudden and severe loss of vision
    - Median time 4 weeks after injection

RPE Tears

- Fluorescein Angiography
  - Sharply demarcated area of hyperfluorescent window defect (area of absent RPE) with adjacent area of blocking hypofluorescence (redundant RPE)
  - Alternating light and dark bands of the RPE can sometime be seen, representing folded or pleated RPE

RPE Tears

- OCT
  - Critical feature is a focal disruption of RPE layer
    - With PED, RPE retracts and forms a dome like, tent like or pleated shape
    - The redundant RPE may appear irregular in contour with a thicker hypereflective reflex
    - Retina appears intact over the tear
RPE Tears: Treatment
- Recent study evaluated role of Lucentis in patients with RPE tear
  - 21 eyes, 20 pts with RPE tears
    - 9 eyes spontaneous, 12 secondary to treatment
    - Treated for average of 12 mos with average of 7 injections
    - VA improved in 6 pts (28.57%)
    - VA remained stable in 12 pts (57.14%)
    - VA decreased in 3 pts (14.28%)
- Pts without foveal involvement did better

Solar Maculopathy
- Damage to the outer layers retina as shown on OCT
  - Outer segment of photoreceptors and RPE
- Clinical exam, small yellowish lesion
- Acuity typically 20/40 20/60
  - Little to no correlation with appearance and acuity
- Greater risk in younger individuals who are more likely to start at sun or eclipse
  - With clear lenses
  - Also, schizophrenic pts, pts on LSD, etc.

High Myopia
- 67 yo presents for annual exam. Wonders if glasses need update
- States never had great vision OS
- OD: -9.25-2.75x080 20/30-2
- OS: -11.00-1.75x103 20/20-

Macular Schisis
- Relatively new entity, ≈1999 by Takano and Kishi
  - Prior to this, misinterpreted as shallow RD or even edema
- With OCT, thought to be not uncommon in highly myopic individuals with posterior staphyloma
- Characterized by intraretinal splitting, in both inner and outer retina, with cystoid spaces

Macular Schisis
- Fairly stable with time, with mild fluctuations in vision
- Treatment (vitreectomy) generally only recommended if vitreal traction, as may lead to macula hole
- Consider OCT in high myopes with central vision problems

OCT: Final Thoughts
- Has ushered in a whole new understanding of retinal disease
- Fast becoming the standard of care
- Many models /makes available

• THANK YOU!!