Optical Coherence Tomography (OCT) for Clinicians
Indiana University School of Medicine, Ophthalmology Department

Thomas Ciulla MD MBA
Poll Question 1

What is your position?
1. Ophthalmologist
2. Ophthalmologist-in-training (registrar/resident)
3. Nurse
4. Ophthalmic Technician/Allied Health
5. Medical Student
6. Mixed Group of Different Positions
OCT

non contact
non invasive
micron resolution
cross-sectional study of retina
correlates very well with the retinal histology
HISTORY OF OCT

• 1991 - first OCT paper - by Huang et al
• First in-vivo studies of human retina - 1993
Figure 1. The light path through a Michelson interferometer. The two light rays with a common source combine at the half-silvered mirror to reach the detector. They may either interfere constructively (strengthening in intensity) if their light waves arrive in phase, or interfere destructively (weakening in intensity) if they arrive out of phase, depending on the exact distances between the three mirrors.
Low-coherence interferometry in near infrared range (810 nm)

THE OCT SETUP

Broadband source → Fiber-optic beamsplitter → Detector → Amplifier → Bandpass filter → Computer

Tissue
Scanning reference mirror
Types of OCT

**TD – OCT** (time domain)
- Reference mirror moves
- Interference not detected by special interferogram
- No Fourier transformation
- 1 pixel at a time
- Slow
- Motion artifacts present
- Less sharp images

**FD - OCT / SD – OCT** (Fourier / spectral)
- Reference mirror stationary
- Interference detected by special interferogram
- Interference pattern Fourier transformed
- 2048 pixels at a time
- Rapid
- No motion artifacts
- Sharper and clear images
How does it work?

• 128 to 768 axial samples (A-scans) in a single "scan pass"
• Each A-scan has 1024 data points and is 2mm long (deep).
Resolution

- When all of the A-scans are combined into one image, the image has a resolving power of about 10 microns vertically and 20 microns horizontally
OCT

• System
  – Fundus viewing unit
  – Interferometric unit
  – Computer display
  – Control Panel
  – Color inkjet printer

• Procedure
  – Machine is activated
  – Patients pupils are dilated
  – Pt seated comfortably
  – Asked to look into the target light in the ocular lens
  – Discouraged to blink
  – Protocol selected as per case requirement
Scan Protocol Types

- Line
- Circle
- Radial Lines
The "line" scan simply scans in a single, straight line. The length of the line can be changed as well as the scan angle.
The "circle" scans in a circle instead of a line.
The "radial lines" scans 6 consecutive line scans in a star pattern
Other protocols

- The "fast" scan protocols - reduce the time needed for multiple scans
- Raster lines – multiple line scans in a rectangular region to cover the areas of pathology – eg: CNVM
- Repeat scan – repeats previously saved scans
- 3D scan- 3D volumetric analysis
RASTER SCAN
TYPES OF MACHINE SCANS

• POSTERIOR SEGMENT SCAN
  • Macular scan
  • Optic disc scan
  • Glaucoma RNFL Thickness Analysis Scan

• ANTERIOR SEGMENT SCAN
Macular Scan

The normal foveal profile is a slight depression in the surface of the retina
Retinal Anatomy Compared to OCT

- The vitreous - black space on the top of the image
- Fovea - normal depression
- Umbo - central hyper reflective dot within foveola
- The nerve fiber layer (NFL) and the retinal pigment epithelium (RPE) - highly reflective than the other layers of the retina (red – yellow)
- RNFL – thicker on nasal side of macula
- Areas of minimal signals (blue – black)
- ONL – thickest portion
Ellipsoid Zone/ELM
OCT and Fluorescein Angiography in retinal diagnosis

FAs provide excellent characterization of retinal blood flow over time, as well as size and extent information on the x and y axis (north-south, east-west)

The OCT gives us information in the z (depth) axis, telling us what layers of the retina are affected
Optic Disc Scan
RNFL thickness analysis scan

Protocols

• Circle scan
• Fast circle scan
• Proportional circles
• RNFL map
• Concentric 3 ring protocol
Optic Disc Scan Print Out
Clinical applications of posterior segment scan

**Vitreo-macular Disorders**
- Vitreo-macular traction
- Macular hole
- Macular pucker

**Intraretinal Disorders**
- Retinal vascular occlusions
- Macular edema
- Macular telangetasia

**Subretinal Disorders**
- Retinal detachment
- Central serous retinopathy
- Optic pit related

**Photoreceptor, Ellipsoid zone & RPE**
- Cone dystrophy
- Plaquenil toxicity
- Macular laser injury
- Solar Retinopathy

**RPE & Choroid**
- Choroidal folds
- Adult onset vitelliform
- Polypoidal choroidal vasculopathy
- AMD
Macular Hole
Time Domain versus Spectral Domain OCT
Macular Holes Cause by Vitreomacular Traction
Macular Holes Cause by Vitreomacular Traction
Macular Hole
Evolution through phases
Macular Hole

• Stage 1 - Foveal Detachment
Macular Hole

- Stage 2- Eccentric Hole
Macular Hole

• Stage 3 - No PVD
Macular Pucker
Macular Pucker
Macular Pucker with retinoschisis
Macular Pucker with Pseudohole
Macular Pucker with Pseudohole
Macular Pucker & Vitreomacular Traction
Clinical applications of posterior segment scan

Vitreo-macular Disorders
- Vitreo-macular traction
- Macular hole
- Macular pucker

Intraretinal Disorders
- Retinal vascular occlusions
- Macular edema
- Macular telangetasia

Subretinal Disorders
- Retinal detachment
- Central serous retinopathy
- Optic pit related

Photoreceptor, Ellipsoid zone & RPE
- Cone dystrophy
- Plaquerenil toxicity
- Macular laser injury
- Solar Retinopathy

RPE & Choroid
- Choroidal folds
- Adult onset vitelliform
- Polypoidal choroidal vasculopathy
- AMD
BRAO with Retinal Ischemia
**Macular Edema**

- Intraretinal areas of decreased reflectivity and retinal thickening.

- Round, optically clear regions within the neurosensory retina are noted in cystoid macular edema.
Diabetic Macular Edema

intraretinal edema

panretinal photocoagulation laser scars
Macular Telangectasia Type 1
Clinical applications of posterior segment scan

Vitreo-macular Disorders
- Vitreo-macular traction
- Macular hole
- Macular pucker

Intraretinal Disorders
- Retinal vascular occlusions
- Macular edema
- Macular telangetasia

Subretinal Disorders
- Retinal detachment
- Central serous retinopathy
- Optic pit related

Photoreceptor, Ellipsoid zone & RPE
- Cone dystrophy
- Plaquerel toxicity
- Macular laser injury
- Solar Retinopathy

RPE & Choroid
- Choroidal folds
- Adult onset vitelliform
- Polypoidal choroidal vasculopathy
- AMD

AMD
Central Serous Retinopathy
Optic Pit Related Macular Detachment
<table>
<thead>
<tr>
<th>Clinical applications of posterior segment scan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vitreo-macular Disorders</strong></td>
</tr>
<tr>
<td>Vitreo-macular traction</td>
</tr>
<tr>
<td>Macular hole</td>
</tr>
<tr>
<td>Macular pucker</td>
</tr>
<tr>
<td><strong>Intraretinal Disorders</strong></td>
</tr>
<tr>
<td>Retinal vascular occlusions</td>
</tr>
<tr>
<td>Macular edema</td>
</tr>
<tr>
<td>Macular telangetasia</td>
</tr>
<tr>
<td><strong>Subretinal Disorders</strong></td>
</tr>
<tr>
<td>Retinal detachment</td>
</tr>
<tr>
<td>Central serous retinopathy</td>
</tr>
<tr>
<td>Optic pit related</td>
</tr>
<tr>
<td><strong>Photoreceptor, Ellipsoid zone &amp; RPE</strong></td>
</tr>
<tr>
<td><strong>RPE &amp; Choroid</strong></td>
</tr>
<tr>
<td>Choroidal folds</td>
</tr>
<tr>
<td>Adult onset vitelliform</td>
</tr>
<tr>
<td>Polypoidal choroidal vasculopathy</td>
</tr>
<tr>
<td>AMD</td>
</tr>
</tbody>
</table>
International Nomenclature for OCT Meeting
Consensus Normal OCT Terminology

- Henle’s-ONL junction (subtle)
- Formed Vitreous
- Posterior Cortical Vitreous
- Preretinal Space
- Nerve Fiber Layer
- Ganglion Cell Layer
- Inner Plexiform Layer
- Inner Nuclear Layer
- Outer Plexiform Layer (dendritic)
- Henle Fiber Layer (axon OPL)
- Outer Nuclear Layer
- Outer Segments
- Choriocapillaris
- RPE/Bruch’s Complex
- Interdigitation Zone
- Ellipsoid Zone
- External Limiting Membrane
- Myoid Zone
- Sattler’s Layer (inner Choroid)
- Haller’s Layer (Outer Choroid)
- Choroid Sclera Junction
Plaquenil Toxicity with Ellipsoid Zone Disruption, “Flying Saucer Sign”
Macular Laser Injury with Ellipsoid Zone Disruption & Improvement
Solar Retinopathy with Ellipsoid & Interdigitation Zone Disruption
Cone Dystrophy
Clinical applications of posterior segment scan

<table>
<thead>
<tr>
<th>Vitreo-macular Disorders</th>
<th>Subretinal Disorders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitreo-macular traction</td>
<td>Retinal detachment</td>
</tr>
<tr>
<td>Macular hole</td>
<td>Central serous retinopathy</td>
</tr>
<tr>
<td>Macular pucker</td>
<td>Optic pit related</td>
</tr>
<tr>
<td>Intraretinal Disorders</td>
<td>Photoreceptor, Ellipsoid zone &amp; RPE</td>
</tr>
<tr>
<td>Retinal vascular occlusions</td>
<td>Cone dystrophy</td>
</tr>
<tr>
<td>Macular edema</td>
<td>Plaquenil toxicity</td>
</tr>
<tr>
<td>Macular telangetasia</td>
<td>Macular laser injury</td>
</tr>
<tr>
<td></td>
<td>Solar Retinopathy</td>
</tr>
<tr>
<td>RPE &amp; Choroid</td>
<td></td>
</tr>
<tr>
<td>Choroidal folds</td>
<td></td>
</tr>
<tr>
<td>Adult onset vitelliform</td>
<td></td>
</tr>
<tr>
<td>Polypoidal choroidal vasculopathy</td>
<td></td>
</tr>
<tr>
<td>AMD</td>
<td></td>
</tr>
</tbody>
</table>
Choroidal Folds
Adult Onset Foveal Vitelliform Dystrophy
Polypoidal Choroidal Vasculopathy
Dry AMD: Drusen
Dry AMD: Geographic Atrophy

Figure 3. SD-OCT horizontal scan over the fovea in a patient with non-exudative AMD with geographic atrophy. There is loss of outer retinal layers including the RPE, EPIS line, COST line, ELM, and the outer nuclear layer. The Bruch’s membrane and choroidal capillaris is visible due to the overlying outer retinal atrophy.
Dry AMD: Geographic Atrophy with Pseudocyst

Figure 8: Pseudocysts in a patient with nonexudative age-related macular degeneration. The hyporeflective space does not indicate a CNVM but a degenerative process.

Pseudocysts can be seen on SD-OCT as a hyporeflective circular shaped lesion. This retinal finding is seen in retinal degenerative conditions and is common in atrophic age-related macular degeneration. Pseudocysts can be mistaken as intraretinal edema secondary to leakage from a choroidal neovascular membrane (CNVM). However, pseudocysts do not leak on fluorescein angiography. They are believed to correspond to Muller cell degeneration, as suspected in idiopathic juxtafoveal retinal telangiectasis type 2A.
Neovascular AMD: Fibrovascular PED
Neovascular AMD

Serous PED

Hemorrhagic PED
Neovascular AMD: Central PED with Overlying Subretinal Fluid
Neovascular AMD: RPE Tear
Neovascular AMD:
Subretinal & Intraretinal Fluid
Neovascular AMD:
Outer Retinal Tubulation
Neovascular AMD: Outer Retinal Tubulation
Neovascular AMD: Scar
Neovascular AMD: Scar
Scar associated with worse VA

- Would like to prevent
- Need to identify risk factors
Scar Risk factors

- Classic CNV
- Thick retina
- Thick SRF
- Thick subretinal tissue
Neoasascular AMD:
Fibrotic Scar Development

Scar in area of classic CNV
Neovascular AMD: SHRM
Subretinal Hyper-reflective Material

• Tissue external to photoreceptors and internal to RPE and/or Bruch’s membrane

• Thought to represent CNV components:
  – CNV
  – Blood
  – Fibrin
  – Fibrosis

• Correlates with Type 1 “Classic” CNV
Subretinal Hyperreflective Material in the Comparison of Age-Related Macular Degeneration Treatments Trials

- SHRM common
- Correlates with VA
- None: 74 letters, Foveal SHRM: 64 letters
- ELZ loss with foveal SHRM
- Scar associated with SHRM (70% vs 35%)
SHRM Thickness Measurements Correlate with Vision

VA worse: increasing SHRM height
VA worse: increasing SHRM width
Optical Coherence Tomography (OCT) for Clinicians
Indiana University School of Medicine, Ophthalmology Department

Thomas Ciulla MD MBA