OPTICAL COHERENCE TOMOGRAPHY: POSTERIOR SEGMENT APPLICATIONS

Texas Optometric Association
Austin, Texas • February, 2014

Nancy N. Wong, OD, PhD, FAAO
VA Western New York Health Care System
Montrose, NY

Disclosure Statement: No Financial Disclosures & No Conflicts of Interest

Transmission

Optical Scattering

Absorption

Optical Scattering

- Property of heterogeneous media
- Microscopic spatial variations of the refractive index within tissues from subcellular structures (e.g., nuclei, cytoplasm, cell membranes, smaller structures, nerve fibers, or axons)
- Optical scattering causes incident light to be redirected in multiple directions
  - Back-scattered light – incident light completely reverses direction when scattered
  - Back-reflection – incident light falls at boundary between 2 homogenous materials that have different indices of refraction

- Removed from incident beam: Absorption arises due to tissue chromophores (absorption spectrum approximates that of incident light)

- Hemorrhages
- Hypertrophy of the RPE
- Choroidal Nevus

- Tissue Chromophores (Hemoglobin & Melanin)

Normal Tissue

Abnormal Tissue

- Nerve fiber layer – NFL
- Outer plexiform layer or Henle’s fiber layer – OPL
- Boundary between photoreceptor inner segment (IS) & outer segment (OS)
- Highly reflective due to the highly organized outer segment
- Rich in rhodopsin visual pigment
- Choroidal and chorio-capillaris

- Ganglion cell layer – GCL
- Inner nuclear layer – INL
- Outer nuclear layer – ONL
Vitreo-Retinal Interface

- High optical transmission
- Typically, not visualized on OCT

Posterior hyaloid
- Minimally distinguishable from retinal surface
- The posterior hyaloid is visible in PVD

Asteroid Hyalosis
- Minimal reflective opacities

Abnormal Vitreo-Retinal Interface

- **PVD**
  - Collagen fibrils of the posterior vitreal cortex are adherent to the macular ILM
  - Adhesion facilitated by proteoglycans
    - Laminin
    - Fibronectin
  - In PVD, vitreal liquefication and weakening of adhesions occur

- Abnormal attachments between the vitreous and retina may result in alterations in retinal anatomy
  - Single or multiple retinal adhesions
  - Alteration of the retinal profile

Vitreo-Retinal Adhesions

- Vitreo-macular adhesions (VMA)
  - Adhesion of posterior hyaloid cortex involving the macular region
- Vitreo-macular traction (VMT)
  - Incomplete separation of the posterior vitreous
  - Persistent macular attachment
  - Incomplete posterior vitreous detachment

Abnormal attachments between the vitreous and retina may result in alterations in retinal anatomy

Vitreo-Macular Tractional Syndrome (VMTS)

- **VMTS** – clinically subtle
- OCT – increased recognition and diagnosis
  - Persistent vitreo-retinal adhesions (single or multiple)
  - Hyper-reflective bands
  - Altered retinal contour
  - Increased retinal thickness with possible intra-retinal edema

Epi-retinal Membrane (ERM)

- Layer of abnormal tissue proliferation on retinal surface
- **Etiology**
  - Trauma
  - Post-surgical
  - Idiopathic – Typically following posterior vitreous detachment

- **VMTS** – clinically subtle
Epiretinal Membrane

- OCT demonstrates:
  - Hyper-reflective band adherent to the internal limited membrane (ILM)
  - No retinal separation
  - Progression may result in:
    - Loss of foveal depression
    - Macular edema

OCT Definition of ERM

- ERM globally adherent on the ILM
- Represents majority of epiretinal membranes
- Better ERM surgical peel prognosis
- ERM demonstrates focal adhesions
- Less common

Pseudo-hole

- OCT distinguishes between pseudo-holes and true holes
- Pseudo-holes
  - Deep & widened foveal pit contour
  - Foveal pit becomes steepened
  - Retinal tissue remains at the base of the pit

Macular Lesions

- Macular cyst
  - Clear, signal-free area within the retina/fovea
- Lamellar hole
  - Partial thickness loss or separation of retinal tissue with a thin layer of persistent outer retina above the RPE
- Full-thickness macular hole
  - Complete loss of retinal tissue in the fovea extending to the RPE layer

Macular Cyst

- Clear, signal-free area within the retina/fovea

Lamellar Hole

- Partial thickness holes
- Reduction in foveal thickness corresponding to loss of internal retinal layers
- External retinal layers remain intact → preserving vision
  - External nuclear layer
  - External limiting membrane
  - Junction between the internal & external photoreceptor segments
**Lamellar Hole**

- Abnormal foveal contour with a reverse anvil configuration
- Separation of inner retinal layer
- Partial thickness loss or separation of retinal tissue with a thin layer of persistent outer retina above the RPE

**Full-Thickness Macular Holes**

- OCT provides quantitative information
  - Base and minimum hole diameters
  - Retinal edge thickness
- Macular holes <400µm in diameter have higher rate of surgical success than larger holes

**Gass Classification of Macular Holes**

- **Stage 1**
  - Loss of foveal depression
  - Foveal cyst
  - Posterior hyaloidal tangential traction
- **Stage 2**
  - Intra-retinal cyst
  - Partially adherent operculum
- **Stage 3**
  - Full-thickness hole
  - Cystoid edema
  - Hole margins rounded
  - No PVD
- **Stage 4**
  - Full-thickness hole
  - Cystoid edema
  - Hole margin rounded
  - PVD

**Treatment**

- Enzymatic Vitreolysis with Ocriplasmin (28D S/P Injection – 125µg)
  - Ocriplasmin (n=464)
  - Placebo (n=188)
  - Sig
    - VMA Resolution
      - 26.5% vs. 10.1%
      - P<0.001
    - Total PVD
      - 13.4% vs. 3.7%
      - P<0.001
    - Non-surgical closure of macula hole
      - 40.6% vs. 10.6%
      - P<0.001

- Microplasmin for Intravitreal Injection – Traction Release without Surgical Treatment (MIVI-TRUST)

**Ocriplasmin (Jetrea®)**

- IV ocriplasmin (Jetrea®)
  - Truncated serine protease plasmin
  - Proteolytic activity against fibronectin and laminin
  - Non-surgical vitreolysis
    - Induces vitreous liquefaction
    - Separation of adhesions from retina


**Drusen**
- Irregularity and/or disruption of the contour of hyper-reflective band representing RPE / Bruch's membrane / chorio-capillaris complex
- Focal elevation of highly reflective RPE band
- Altered foveal contour

**Neovascular AMD**
- Irregular foveal contour
- Decreased reflectivity beneath neuro-sensory retina due to subretinal fluid accumulation from CNVM
- Thickened and/or irregular highly reflective external band

**Geographic Atrophy**
- Highly reflective signal from choroid in area corresponding to geographic atrophy
  - Enhanced penetration and reflection of signal from choroid due to attenuation of RPE / Bruch's membrane / chorio-capillaris complex
  - Overlying retina thinned with loss of layered structure of retina

**Clinical Applications of OCT in AMD**
- Characterizing CNVM, especially early CNVM
- Response to therapy
  - Qualitative
  - Quantitative
- Detecting an early recurrence of CNVM
- Assessment of fluid-free zone with anti-VEGF treatment

**Pigment Epithelium Detachments (PED)**
- Serous Detachment
- Drusenoid Detachment
- Vascular Detachment
- Fibrovascular Detachment
Fundus Autofluorescence

- FAF utilizes short-medium wavelength of light to detect lipofuscin accumulation
- Lipofuscin → Byproduct of phagocytized outer segment of photoreceptors
- Lipofuscin accumulates in RPE
- Lipofuscin represents a biomarker of
  - Normal aging
  - Chronic retinal disease
- Lipofuscin deposition in RPE may precede clinical / visual manifestations

FAF → Normal

- Fundus with normal RPE & normal level of lipofuscin → Mildly hyperfluorescent
- ONH without RPE → hypofluorescent
- Fovea & vessels exhibit signal absorption → hypofluorescent

FAF → Abnormal

<table>
<thead>
<tr>
<th>Hypofluorescent</th>
<th>Hyperfluorescent</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Dark)</td>
<td>(Bright)</td>
</tr>
</tbody>
</table>

- RPE atrophy
- Retinal hemorrhages
- Exudation
- Pigmentation
- Hard drusen
- Increased Lipofuscin
  - Best
  - Stargardt
- Old hemorrhages
- Soft drusen

Plaquenil®

2002 AOA Guidelines

- Dilated fundus exam
- Automated VF 10-2
- Color vision
- Optional
  - mERG
  - FA

2011 AOA Revised Guidelines

- Dilated fundus exam
- Automated VF 10-2
- 1 of the following
  - SD-OCT
  - mERG
  - FAF

Fundus Autofluorescence

- Geographic atrophy → Atrophic AMD
  - Atrophic retina has absence of RPE and lipofuscin
  - Atrophic area demonstrates hypo-fluorescence (decreased intensity) with high contrast to surrounding non-atrophic retina

Plaquenil®

- FAF
  - Mottled areas of increased FAF corresponding to injured RPE cells
  - Progression to areas of decreased FAF and atrophy, with a typical bull’s-eye configuration
**Fundus Autofluorescence**

- Geographic atrophy in non-neovascular AMD
  - Hypofluorescent (Dark)
  - Hyperfluorescent junctional zone (Bright banded surround)
    - Compromised RPE (prior to cell death)
    - Impaired RPE not supportive of photoreceptor outer segment
    - Junctional zone indicative of geographic atrophy progression
- Fundus Autofluorescence in Age-Related Macular Degeneration (FAM) Study
  - Clinical fundus appearance may NOT correlate with FAF imaging
  - FAF may be indicative of disease progression not clinically visible

**CVO Macular Edema**

- Elevation / thickening of neuro-sensory retina due to fluid accumulation
- Edematous fluid accumulation results in:
  - Edema → optically transparent
  - Decreased reflectivity
- Superficial blood results in increased reflectivity

**DM Macular Edema**

- Clinical presentation
  - Vascular endothelial compromise
  - Breakdown of blood retinal barrier
  - Increased vaso-permeability
- OCT demonstrates
  - Focal edema
  - Diffuse edema
    - Thickened retina
    - Small irregular cavities

**OS Pseudophakic CME**

- CME (Irvine Gass Syndrome)
  - Retinal thickening
  - Intra-retinal cavities of reduced reflectivity
  - OCT may be equally effective as IV FA in establishing diagnosis OD CME but less invasive
  - Quantitative measurements of retinal thickness to evaluate therapeutic efficacy

**Optic Nerve**

**Progression of ONH Drusen**

- Hyaline bodies with calcific component located anterior to the lamellar cribrosa
- Pathogenesis
  - Abnormal axonal transport and metabolism
  - Accumulation of axoplasmic debris
  - Deformation of amorphous cellular material embedded in the optic nerve
  - Compress NFL
  - Visual Field Defect
  - Compress Vascular Supply
  - Disc Hemorrhage
  - Disrupt Juxta-Papillary Tissue
  - CNVM
Optic Disc Edema

- Bilateral + increased intra-cranial pressure → Papilledema
- Clinical findings
  - Optic disc swelling
  - Elevation primarily due to axonal swelling and degeneration
- OCT findings of papilledema
  - RNFL demonstrates thickening in sections on TSNIT scan
  - Smooth internal contour and a lazy V pattern on SD-OCT
  - Retinal hemorrhages and exudation may result in increased backscattering and shadowing of underlying structures

Optic Nerve Drusen vs. Edema

<table>
<thead>
<tr>
<th>Drusen</th>
<th>Edema</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevated optic nerve head</td>
<td>Elevated optic nerve head</td>
</tr>
<tr>
<td>Lumpy-bumpy appearance</td>
<td>Smooth internal contour and a lazy V pattern on TD-OCT</td>
</tr>
<tr>
<td>RNFL thinning nasally, thickening other sections</td>
<td>Diffuse RNFL thickening in all sections of nerve</td>
</tr>
</tbody>
</table>

Drusen

- Elevated optic nerve head
- Lumpy-bumpy appearance
- RNFL thinning nasally, thickening other sections
- Direct visualization of drusen on SD-OCT

Central Serous Choroidopathy

- Central serous choroidopathy
  - Isolated RPE leakage
  - Chronic diffuse retinal pigment epitheliopathy
- Clinical presentation
  - Choroidal fluid leakage
  - Compromise or disturbance to RPE
  - Serous retinal detachment
  - Serous RPE detachment
- OCT demonstrates
  - Serous retinal detachment
  - Serous PED
  - Defect in RPE

Choroidal Nevi

- Amelanotic
- Pigmented Nevus
- Increased pigment & choroidal reflectivity

Polypoidal Choroidal Vasculopathy (PCV)

- PCV characterized by collection of thin-walled, dilated vessels at the level of the inner choroid
  - Degenerative sub-RPE complex containing a native (non-neovascular) dilated aneurismal venule with degenerative arteriolaris
  - Choroidal vessels become hyalinized
  - Dilution of the venule
  - Polyp-like aneurismal dilatations
  - Intrachoroidal branching vascular networks terminating in polyp-like aneurismal dilatations
  - Choroidal neovascularization
- Progression may result in formation of choroidal vascular complexes, hemorrhagic/serous pigment epithelial detachments, retinal edema, neurosensory retinal detachments and/or subretinal hemorrhages
Focal Choroidal Excavation

- SD OCT Imaging
  - Excavation of the choroid
  - Retina from outer plexiform layer to RNFL remain undisturbed
  - Excavated region extends from outer retinal layer to the external limiting membrane
  - ELM and junction between IS/OS follow excavation contour but tissue remains intact

Conclusion

- Unprecedented ultra-structural visualization of
  - Vitreo-retinal interface
  - Retina
  - Optic Nerve
  - Choroid
- OCT permits
  - Quantification & Qualification
  - Diagnostic and serial management

Newest technologies
- Handheld OCT
- Intraoperative OCT
- Handheld Intraoperative OCT (Bioptigen System)
- Prospective intraoperative and perioperative OCT (PIONEER)
- Functional OCT
  - Doppler SD-OCT (structure and blood flow)
  - Polarization Sensitive (PS) SD-OCT (utilizes light depolarization properties of RPE to visualize RPE for AMD RPE degeneration & progression)
- No longer imagining, IMAGING!