Clinical Utility of OCT for Retinal Diseases

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Optical Coherence Tomography (OCT)

• Based upon Michelson interferometry
  – light passes through eye $\rightarrow$ different reflections from different layers
  – Interference pattern produced from reflections and from reference mirror

• Resolutions of OCT Machines
  – Time domain: 10-15 um
  – Fourier / Spectral domain: 5um
  – Ultrahigh resolution (UHR-OCT): 2-3 um
OCT

• Invented in 1990 at MIT and Harvard Medical School by James Fujimoto, PhD & David Huang, MD PhD who built an interferometer to measure the thickness of the cornea and retina (2012 Champalimaud Awardees)


• OCT became commercially available in 2002
OCT 3 (Stratus): Time Domain

- “State of the art” in 2007
- Two forms of data output
  - 6 linear scans through area of interest (usually the fovea)
OCT 3: Time Domain

• Two forms of data output
  – 6 linear scans through area of interest (usually the fovea)
  – Macular topography mapping
    • Software interpolates between scans
FD OCT
Simultaneous
2048 pixels at a time

Small blood vessels
IS/OS

1024 A-scans in 0.04 sec
Higher speed, higher definition and higher signal.

TD OCT
Sequential
1 pixel at a time

Motion artifact

512 A-scans in 1.28 sec
Benefits of Spectral Domain OCT

- Speed of Acquisition
- Eye Tracking (Heidelberg)
- Exact Registration
- Reliable and Reproducible
- Software analysis
  - Heidelberg
  - Optovue
Normal Retina OCT Structures

- NFL and ganglion cell layers are bright
- Densely packed nuclear layers are dark
- Horizontal plexiform layers are bright
- Photoreceptors are hypo-reflective
- Ellipsoid (formerly IS/OS junction) is bright
- RPE, inner choroid are hyper-reflective

Nasal = thicker NFL
Current Applications of SD OCT

• Unexplained visual acuity loss or evidence of toxicity
  • Cellular explanation of symptoms
    – Volumetric scan show subtle findings
• Determination for need of therapy
• Tracking response to therapy
• Patient Education
• Operating Room – Tissue Dissection
• Research
  – Detection of early toxicity or early degeneration
  – Clinical trials outcome
  – Analysis of retinal layers
Unexplained Vision Loss

- Pay attention to ellipsoid layer
Case Study: Unexplained visual loss

• 17 y/o man with beta-thalassemia on oral desferasirox
• Painless loss of vision with central scotomas and dyschromatopsia
• Fundus exam, FA, ERG normal
• 20/25 OU
Case Study: Unexplained visual loss

- 17 y/o man with beta-thalassemia on oral desferasirox
- Fundus Normal

Image Courtesy of Dr. Amani Fawzi
Case Study: Unexplained visual loss

• 17 y/o man with beta-thalassemia on oral desferasirox
• FA normal
Case Study: Unexplained visual loss

- 17 y/o man with beta-thalassemia on oral desferasirox
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Image Courtesy of Dr. Amani Fawzi
Case Study: Unexplained visual loss

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- 20/25 OU

Infra-red image: Outer retinal damage

Image Courtesy of Dr. Amani Fawzi
Benefit of SDOCT:
Diagnosis of unsuspected disease
BRVO c/o Scotoma
Focal Retinal Atrophy
BRVO c/o Scotoma
Focal Retinal Atrophy
Case Study: Possible Screening Tool
Detection of Early toxicity

Perifoveal abnormalities: baseline (left) then 18 months later (loss of ellipsoid layer)
Juxtafoveal Telangiectasis

- Intraretinal “cavities”
- ILM drape
- Retina is not thickened
Reattachment after Chronic RD

VA is limited due to severe loss of ellipsoid layer
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Qualitative Use of OCT

- Baseline
- Anatomic findings
- Document change
- Aid in treatment decision
- Good educational tool for patients

- One month post treatment
OCT in Retinal Diseases

• Diagnosis:
  – Mechanical traction
  – Epiretinal membrane
  – Intraretinal edema
  – Subretinal fluid, lesions
  – Atrophy of structures
Vitreomacular Interface
Epiretinal Membrane
Partially Attached Vitreous
Vitreomacular Traction
Persistent diabetic macular edema (DME) despite seven sessions of focal laser therapy was imaged. OCT disclosed a point vitreous adhesion at the fovea with loss of the normal foveal contour, intraretinal fluid, and retinal thickening.

Macular Hole
Lamellar Hole
Retinal Edema

- **BRVO**
  - Retina is thickened
  - Cystoid spaces

- **DME**
  - May be associated with subretinal fluid

- **CRVO**
  - Cannot know the etiology of edema just by OCT

- **DME/CME**
Central Serous Chorioretinopathy

NSD/SRF

PED
Exudative AMD
Geographic Atrophy

TD OCT. Retinal layers difficult to distinguish. GA = suggested by increased transmission.

FD OCT  Focal thinning of the outer nuclear layer overlying loss of photoreceptors; indicated by interruption of the ellipsoid junction and ELM is seen.

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OCT in Retinal Diseases

• Management
  – Objective measurement of response to treatment (ie resolution of macular edema)
  – Monitoring for recurrence of subretinal fluid
  – Documentation of mechanical change
PED with CNV s/p Bevacizumab x 2

VA 20/200
OCT 534

Vertical

VA 20/60
OCT 203

Horizontal

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CME s/p Rx

Vertical

Horizontal
Resolving NSD s/p steroids
Wet AMD with RPE Rip
Quantitative OCT Measures

- Retinal Thickness Measurements
- Topography Maps
- Analysis Programs
Case Study: AMD

Reference image
Quantitative OCT Measures

- Retinal Thickness Measurements
- Topography Maps
- Analysis Programs
Retina Analysis with the RTVue: Macula Maps (MM5)

Provides:
- Layer specific thickness maps
- Detailed B scans
- ETDRS thickness grid
- Data Captured: 19,496 A scans (pixels)
- Time: 750 msec
- Area covered: 5 mm x 5 mm (grid pattern)

Full retinal thickness
ILM to RPE

Inner retinal thickness
ILM to IPL

Outer retinal thickness
IPL to RPE

RPE/Choroid Elevation
RPE height

Surface Topography
ILM height
OCT

- Discuss OCT technology and machines
- Discuss clinical applications
- Discuss potential artifacts and interpretation
- Research Applications
Potential Artifacts

- Boundary line errors
- Sampling errors
- Motion artifact
- Low signal strength
Boundary Lines
Boundary Line Errors: Stratus OCT

OCT scan from a patient with a full-thickness macular hole. (A) Automated retinal boundary detection by the Stratus OCT version 4.0 software interpolates the inner retinal surface across the discontinuity (arrow), and the resultant retinal thickness map (B) does not demonstrate the retinal hole.

Alignment Software Errors: Stratus OCT

OCT scan of a patient with a fibrovascular pigment epithelial detachment associated with AMD. (A) Generation of a retinal thickness map by the Stratus OCT version 4.0 software requires "alignment" of the A-scans, which results in an artificial flattening of the FVPED. This does not accurately reflect the overall retinal surface topography (B) or the raw scan data (C). In addition, it fails to differentiate the subretinal fluid from the neurosensory retina.

Potential Artifacts

- Boundary line errors
- Sampling errors / Incomplete image acquisition
- Motion artifact
- Low signal strength
Decentration Error

Boundary line error  >10% standard deviation

Scan not centered on image window

Fovea not centered

Bow tie artifact
Incomplete Image Acquisition
Potential Artifacts

- Boundary line errors
- Sampling errors / Incomplete image acquisition
- Motion artifact
- Low signal strength
Motion Artifact
Motion Artifact

- Fine ERM is now seen
- RPE smooth
Potential Artifacts

- Boundary line errors
- Sampling errors
- Motion artifact
- Low signal strength:
  - Poor resolution limits image quality and findings detectable
  - Blurry image
Dense Cataract
Potential Artifacts: Low Signal Strength
OCT

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• Discuss potential artifacts and interpretation
• Research Applications
Benefit of SDOCT:
Useful for Research Applications

• Clinical trials – exact registration
• Evaluation of ultrastructural changes in diseases
Exact Registration:
Non-AMD Lucentis Trial

- 37 y/o
- 20/15

Image Courtesy of Jeff Heier
Benefit of SDOCT: Useful for Research Applications

- Clinical trials – exact registration
- Evaluation of ultrastructural changes in diseases
Research: Retinal Degeneration

- Retinitis Pigmentosa
- Cone Rod Dystrophy
- Stargardts Disease
Retinal Dystrophy

- Histopathology shows shortening of the outer segments of rods and cones occurs first even before symptoms. (Milam et al. Prog Retin Eye Res 1998;17:175-205.)

- OCT offers a “live biopsy” of these eyes

- OCT to Determine:
  1. Structural changes
  2. Prognosis
OCT and CME in Retinal Dystrophy

- 63 patients without CME on exam
- Mean age = 36 years (range 9-71 years)
- 20/63 had CME in at least one eye (32%)
- 11/63 had CME in both eyes (18%)
- Subclinical CME has implications for future management of disease
- Rate of CME exceeds that found in literature using FA


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OCT and Progression of Retinal Dystrophy

- Dimension of the Goldmann visual field (distance from the center point to isopter I4e) correlated with distance to highly reflective signal from the IS/OS ($r = 0.75$, $P < 0.0001$)

- The greater the distance in VF, the greater the distance measured in OCT.

- Further research warranted to determine whether this may be an objective marker of progression of retinal degeneration in RP.

OCT: Normal vs Dystrophy

The retinal thickness profile demonstrates mORL thinning despite the good central visual acuity. This mimics the histopathology in early disease, where thinning and loss of photoreceptors is seen early on without visual acuity being affected.

Rod Cone Dystrophy: Advanced

46 y/o, 20/100 OD, 20/400 OS

Horizontal OCT scan shows corresponding hyperreflectivity of the choroidal layer with overlying marked retinal and RPE thinning

Thinning involves foveal area

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Thank you!
Qualitative OCT Interpretation

Qualitative review

• Contour of retinal surface

• Dark areas
  – Cellular nuclei: GCL, INL, ONL
  – Shadowing beneath retinal blood vessels
  – Fluid, cystic spaces
  – Loss of tissue

• Bright areas
  – Interface changes: NFL, IPL, OPL, ELM
  – Ellipsoid layer (previously IS/ OS junction)
  – RPE
  – Lipid
Retinitis Pigmentosa/CME
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  - Lipid
Topography Map to Detect Abnormality

35 year old man, 20/20 OU, sickle SS disease
Value of Reproducibility for Analysis of Change: CME Comparative Analysis

Four months after baseline
Reproducibility/Registration
Current Applications of SD OCT

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Qualitative Use of OCT: Patient Education/Documentation
3-D Imaging

Courtesy of TOPCON
Cone Rod Dystrophy

52 y/o, CF OD and 20/200 OS. ERG cone-rod

Loss of choriocapillaris with marked retinal thinning with preserved RPE as compared to RP.

Note loss of the IS/OS and ORL boundaries. Horizontal ORL profile shows the dip in the central thickness of this patient compared with normal controls (grey band).

OCT in Retinal Dystrophy

- Determine presence of CME
- Monitor Rx response for CME
- Determine photoreceptor degeneration
- Determine Prognosis?
- Differentiate different subtypes of RP based on degree of rods/cones and RPE affected
Diagnosis: ERM and Drusen

Motion artifact (arrow). Ellipsoid line, ELM and RPE appear to merge over larger drusen, consistent with “shortening” of the photoreceptor IS/OS.

Note separation between ERM & retina and distinct drusen. Choroidal vessels visible (sinusoidal hyper-reflective lines surrounding optically empty cavities).
FD OCT. Subretinal component of CNV seen. Subretinal fluid (arrow), confirmed by the intact and uninterrupted ELM and ellipsoid line superior to the fluid.

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Case Study: Diagnosis

35 year old man, 20/20 OU, sickle SS disease
Case Study: Diagnosis

35 year old man

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Retinal OCT Interpretation

- Image orientation

Nasal  Temporal
Diagnosis: Vitreous traction

OCT image shows vitreomacular interface abnormalities and epiretinal membrane. Disruption of the normal foveal contour, intraretinal fluid with retinal thickening, and irregularities of the retinal surface are evident.

A. TD OCT. ELM and Bruch’s focally interrupted (arrow).

B. FD OCT. Entire length of the ELM is clearly visible, without interruption. Bruch’s membrane is visible as a highly reflective layer outside the RPE.

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CNV with Myopic Degeneration