Optical Coherence Tomography Primer and Advanced Interpretation

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RETINAL ANATOMY

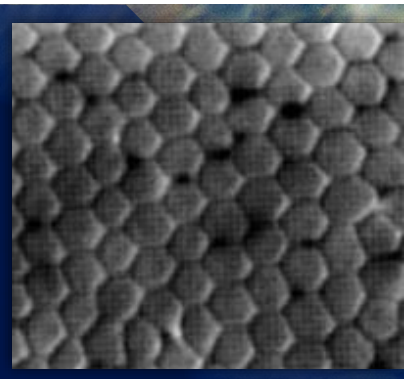
Approximately 100-120 million rods
Peak density of 100,000/mm²

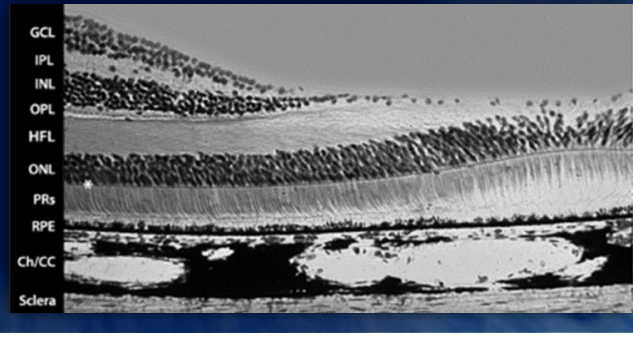
Approximately 4-5 million cones
Peak density of 200,000/mm²

Macula
5.5mm diameter

Fovea
1.5mm diameter

Foveola
0.3mm diameter





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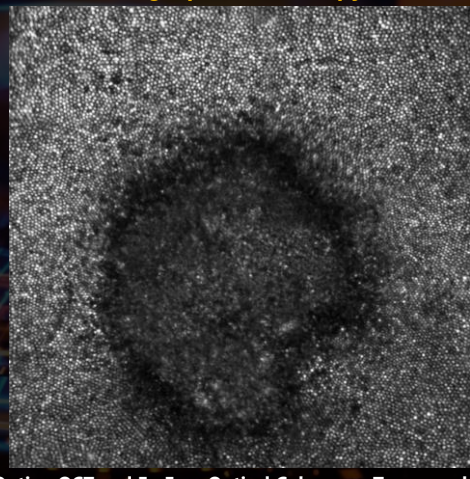
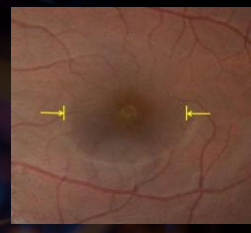
Clinical Retinal Imaging

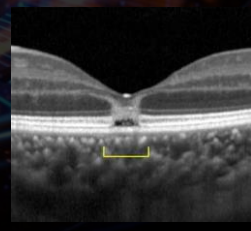
Solar Retinopathy viewed through Adaptive Optics

Photographic Image of Solar Eclipse

AO Scanning Ophthalmoscopy







Acute Solar Retinopathy Imaged With Adaptive Optics, OCT and En Face Optical Coherence Tomography
JAMA Ophthal (2017)

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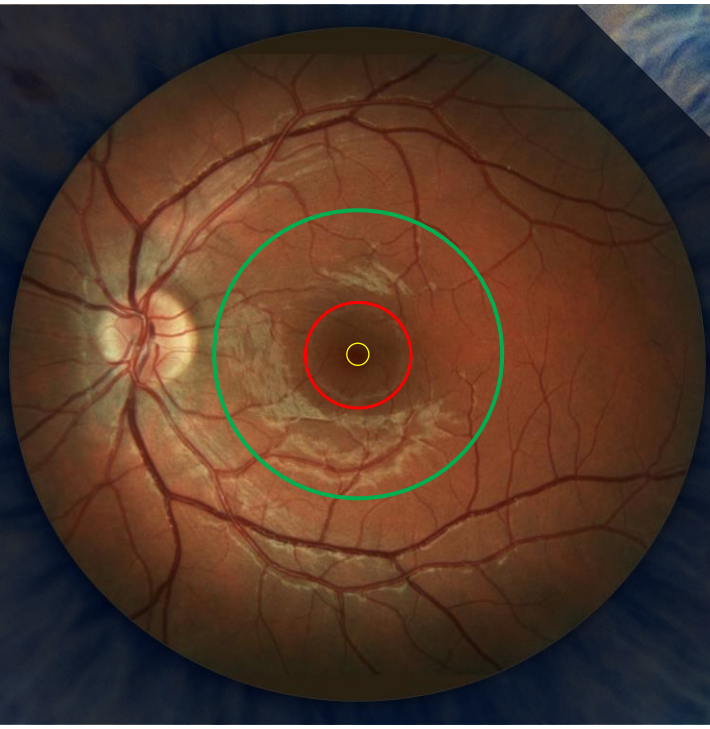
MACULAR REGION

Macula
5.5mm diameter

Fovea
1.5mm diameter

Foveola
0.3mm diameter



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Optical Coherence Tomography Primer

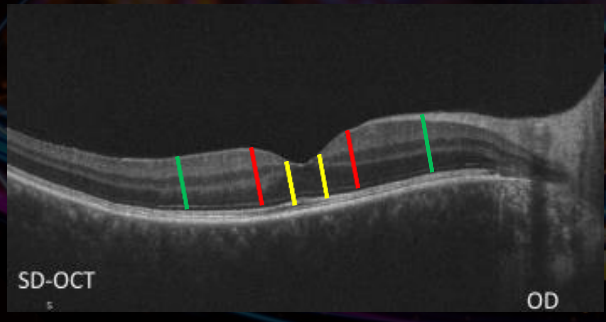
Spectral Domain vs. Swept Source

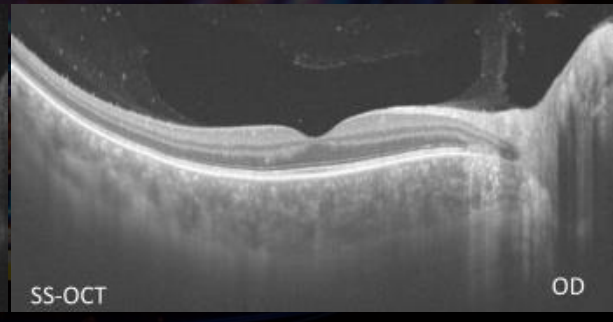
Spectral Domain

λ: 840nm
Charge-coupled device (CCD)
Resolution limits: 3-5µm
A-scan speed: ~50K/sec
B-scan field: 6mm
Resolution depth: RPE

Swept Source

λ: 1050nm
Photodetector
Resolution limits: 1-3µm
A-scan speed: ~100K/sec
B-scan field: 12mm
Resolution depth: choriocapillaris to scleral boundary





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Optical Coherence Tomography Primer

Spectral Domain vs. Swept Source

Model (Manufacturer)	Cirrus HD-OCT 5000 (Carl Zeiss Meditec)[1]	Plex Elite (Carl Zeiss Meditec)[1]	3D OCT-1 Maestro2 (Topcon)[2]	Triton (Topcon)[2]	Spectralis 2nd and 3rd Generation (Heidelberg)[3]	Spectralis OCT-A (Heidelberg)[3]	iVue80 Optovue (VIsionix)[4]	Optovue Avanti with Angiovue (Visionix)[4]
SD-OCT or SS-OCT?	SD-OCT	SS-OCT	SD-OCT	SS-OCT	SD-OCT	SD-OCT***	SD-OCT	SD-OCT
Scanning Speed (A-scans per second)	27,000-68,000*	100,000-200,000	50,000	100,000	85,000**	85,000	80,000	70,000
Axial Resolution (µm in tissue)	5	6.3	6	8	Optical: 7 Digital: 3.9	3.9	5	5
Imaging Modes	SD-OCT, cSLO	SS-OCT, OCT-A, LSO, CCD camera	SD-OCT widefield, color fundus, red-free fundus, IR fundus, enhanced IR fundus and external eye photography	SS-OCT, color fundus, red-free fundus, IR fundus	SD-OCT, cSLO	OCT-A	SD-OCT wide-field	SD-OCT widefield, OCT-A, enhanced-depth imaging
SD-OCT Normative Database: *Number of subjects*	284 RNFL study 282 macula, ganglion cell, ONH study		399		201 (RNFL thickness)		480	
SD-OCT Normative Database: *Ethnicity*	43% Caucasian 24% Asian 18% African American 12% Hispanic 1% Indian 2% Mixed ethnicity		59% Caucasian 20% African American 18% Hispanic/Latino 3% Other		European descent		47% Caucasian 19% Asian 10% African 15% Hispanics 8% Indian 1% Other	

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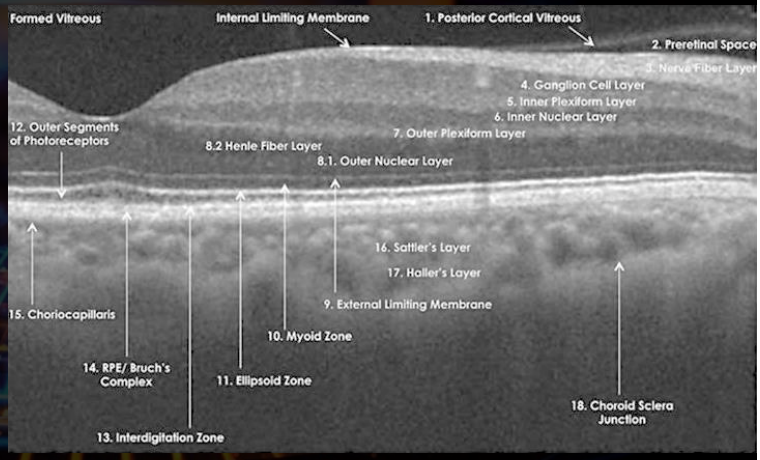
Optical Coherence Tomography Primer

Anatomic and Histologic Landmarks

2014 International OCT (INOCT) Panel

- Bands, Zones and Layers
- **Inner retina = ILM through INL**
  - ***Hyper-reflective bands = Interface junctions***
    - ***Posterior cortical vitreous***
    - ***ILM***
    - ***RNFL***
    - ***IPL***
  - ***Hypo-reflective bands = Nuclear layers***
    - ***GCL***
    - ***INL***
- **Outer retina = OPL through RPE**
  - ***Hyper-reflective bands = Interface junctions***
    - ***OPL***
    - ***ELM (Muller cells + PR inner segments)***
    - ***EZ (PR axons)***
    - ***Interdigitation***
    - ***RPE***
  - ***Hypo-reflective bands = Nuclear layers***
    - ***Henle fiber layer***
    - ***ONL***
    - ***PR outer segments***



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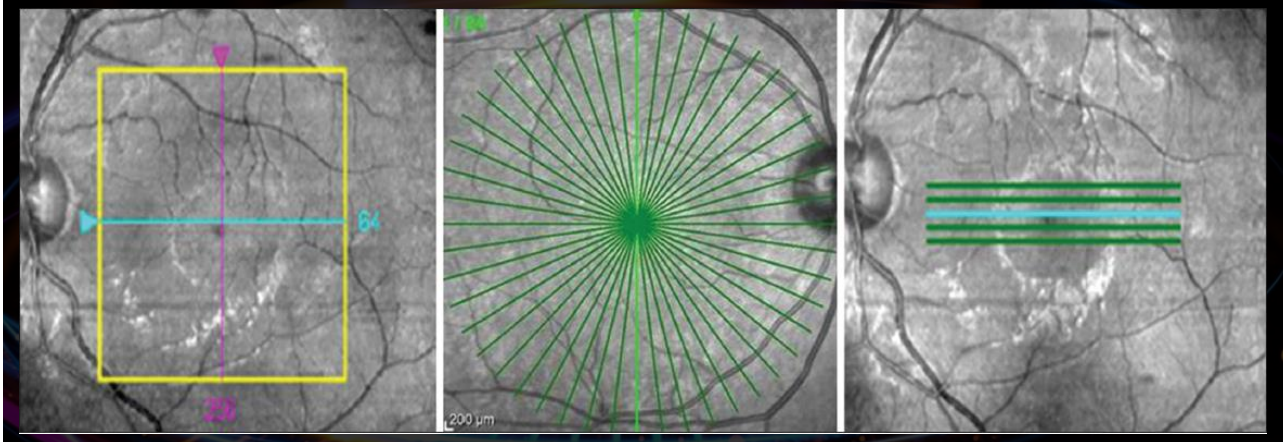
Optical Coherence Tomography Primer

Common OCT Measurement Protocols



Macular Cube | Radial Line Scan | Raster Scan

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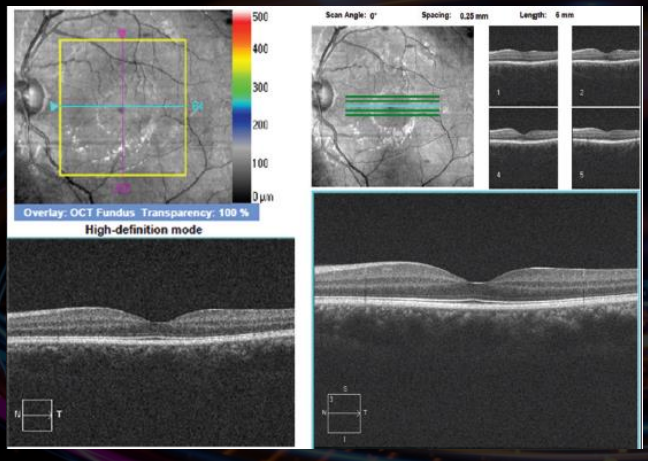
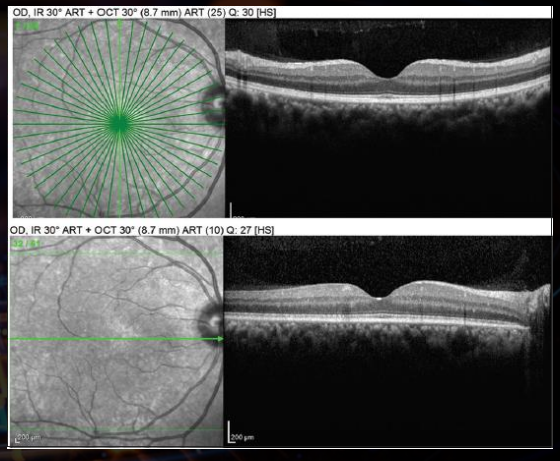
Optical Coherence Tomography Primer

Common OCT Measurement Protocols





Macular Cube | 5-line Raster

Zeiss Cirrus

24-line Radial Scan (TOP)
61-line Horizontal Scan (BOTTOM)
Heidelberg Spectralis

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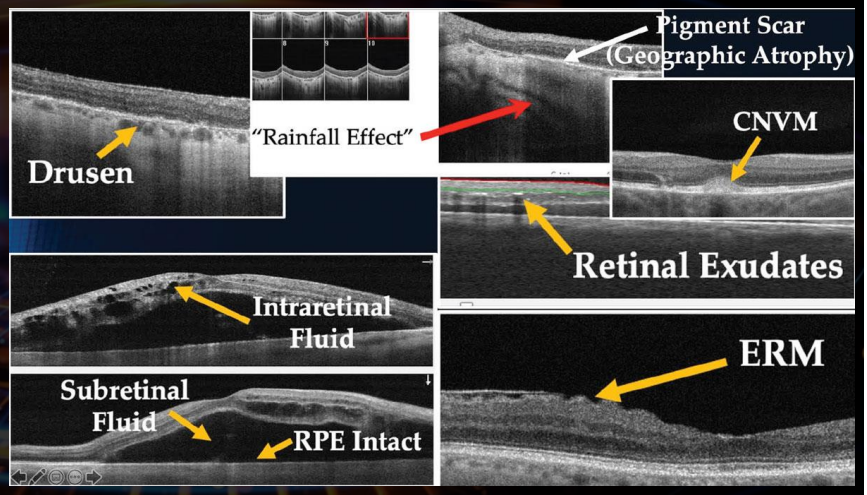
Optical Coherence Tomography Primer

Common Causes of Abnormal Reflectivity

Reduced Reflectivity
- **Fluid**
  - ***Retinal edema***
  - ***Subretinal fluid***
  - ***Sub-RPE fluid***

Increased Reflectivity
- **Hard exudates**
- **Calcification**
- **Hemorrhages**
- **Fibrosis**
- **Epiretinal/vitreous membrane**
- **CNV**
- **Hyperplasia**
- **RPE atrophy**
  - ***Sub-RPE Hyper-reflectivity***



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Optical Coherence Tomography Primer

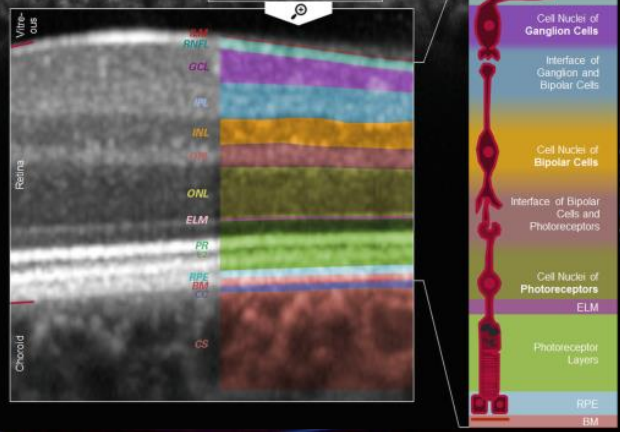
SD-OCT Cross-sections Based on Retinal Anatomy

Ganglion Cell Complex (GCC)

Henle Fiber Layer (PR axons)

AMD Ground Zero

Retinal Layers	
Abbr.	Name
ILM	Internal Limiting Membrane
RNFL	Retinal Nerve Fiber Layer
GCL	Ganglion Cell Layer
IPL	Inner Plexiform Layer
INL	Inner Nuclear Layer
OPL	Outer Plexiform Layer
ONL	Outer Nuclear Layer
ELM	External Limiting Membrane
PR1/2	Photoreceptor Layers
RPE	Retinal Pigment Epithelium
BM	Bruch's Membrane
CC	Choriocapillaris
CS	Choroidal Stroma



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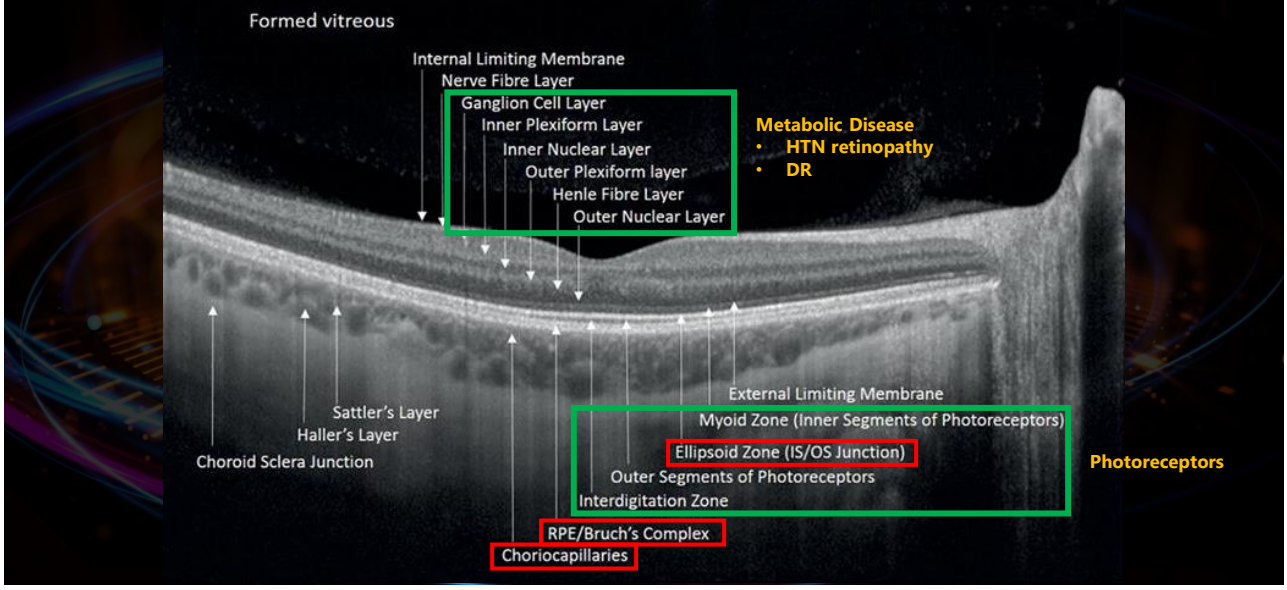
Optical Coherence Tomography Primer

SD-OCT Cross-sections Based on Retinal Anatomy



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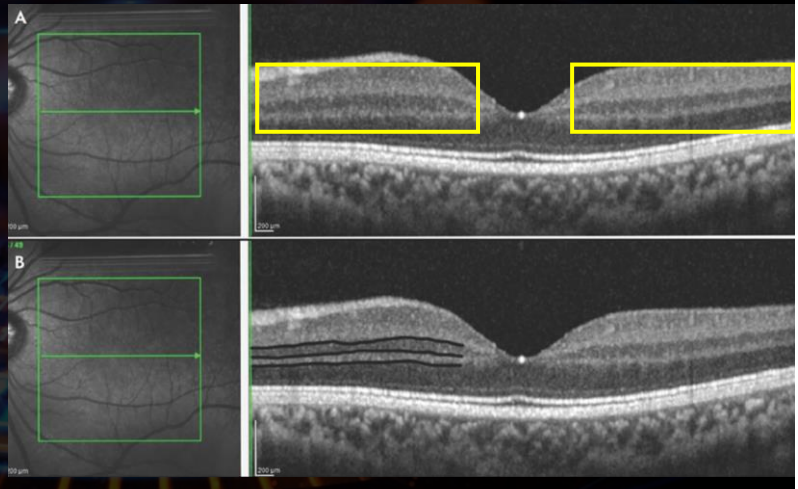
Optical Coherence Tomography Primer

SD-OCT Disorganization of Retinal Inner Layers (DRIL)

- **Healthy retinal tissue has an orderly, laminated structure highlighted by varying reflectivity patterns on SD-OCT**
- ***Loss of inner retinal laminations and boundaries between the layers***
  - ***Boundaries of the INL, OPL, and GCL-IPL complex within central 1,000-3,000µm***
- **Recent studies have compared areas of DRIL to OCTA imaging**
  - ***Associated with areas of ischemic damage correlated to areas of absent superficial, middle and deep capillary plexus flow***
- **Correlation has also been made between DRIL and other OCT findings**
  - ***Enlargement of FAZ***
  - ***Disruption of the EZ and ELM***



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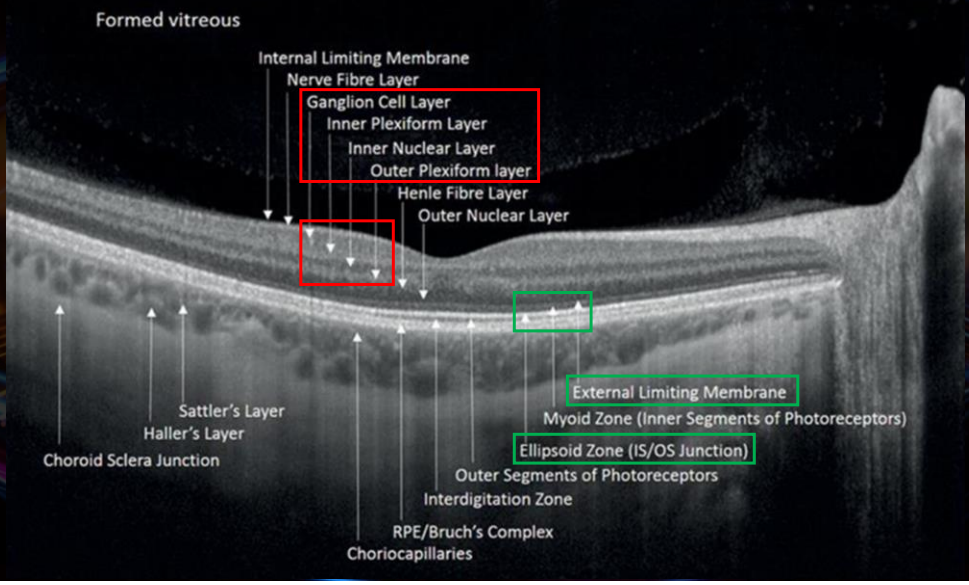
Optical Coherence Tomography Primer

SD-OCT Disorganization of Retinal Inner Layers (DRIL)



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SD-OCT Findings Related to Retinal Pathology

- ***Age-Related Macular Degeneration***
- Diabetic Retinopathy
- Retinal Vein Occlusions
- Central Serous Chorioretinopathy
- Macular Hole
  - FTH
  - LMH
- Autoimmune Retinopathy
  - Paraneoplastic syndromes

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Age Related Macular Degeneration

AREDS Criterion

***Drusen or GA within 2DD of fovea**

****Pigment abnormalities within 1DD of fovea**

*****Advanced AMD**
1) GA involving fovea
2) CNVM development

FIRST EYE (Must have VA >20/32, no advanced AMD and no disqualifying lesions)				SECOND EYE
AMD Category	Drusen Size*	Drusen Area*	Pigment Abnormalities**	
1	None or <63um	<125um diameter	None	Same as 1st
2	<63um **Or** >63um, <125um None if pigment abnormalities	>125um diameter **Or** >1 druse	Absent or Present **WITHOUT** GA	Same as 1st or Category 1
3a	>63um, <125um **Or** >125um None if GA present	>360um diameter (if soft drusen present) >656um diameter (if soft drusen absent) **Or** At least 1 druse	Absent or Present **WITHOUT central** GA	Same as 1st or Category 1,2
4a	Category 1,2 or 3			Advanced AMD***

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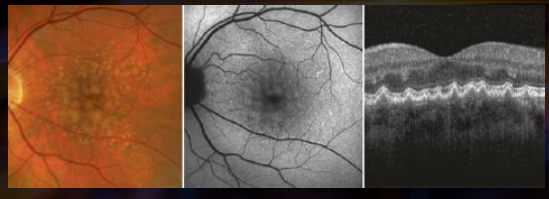
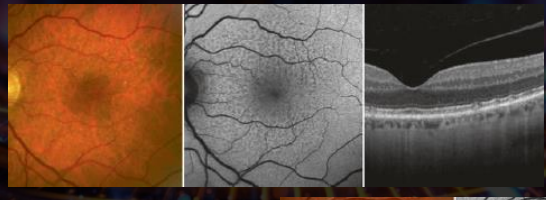
Optical Coherence Tomography Primer

Early AMD Comparative Imaging

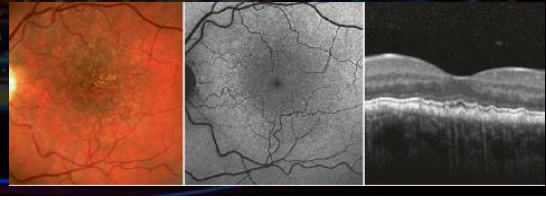
Soft Drusen



Reticular Pseudodrusen



Cuticular



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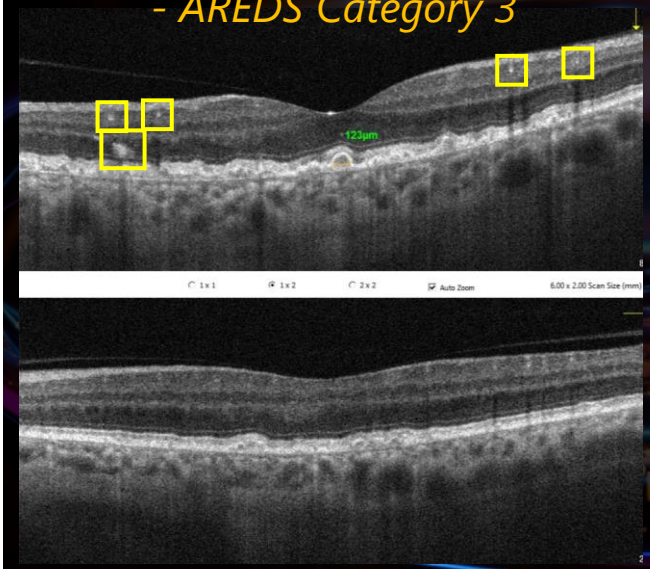
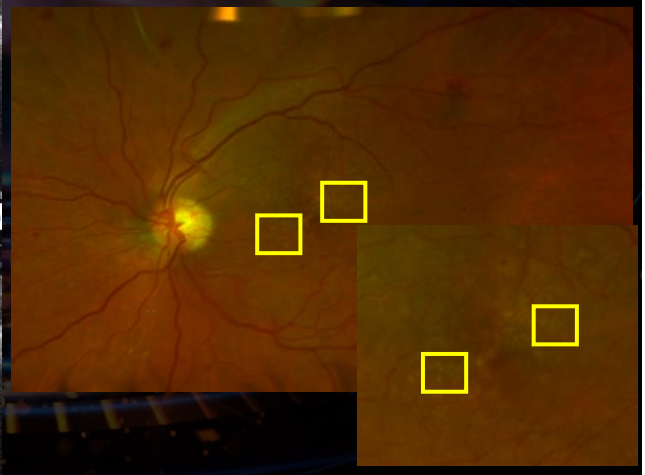
Subclinical AMD Diagnosis

SD-OCT Drusen Identification and Measurement

- AREDS Category 3





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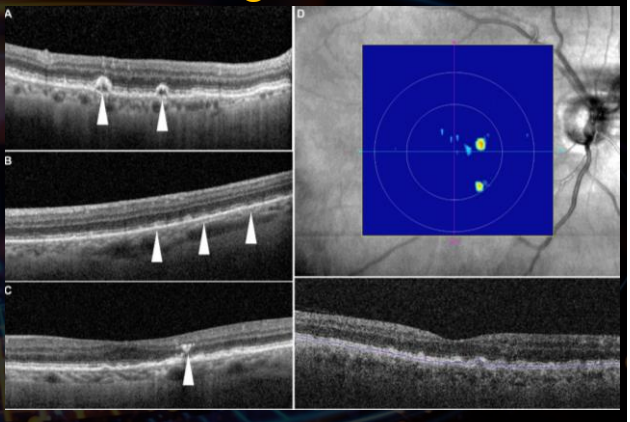
Subclinical AMD Diagnosis

Clinical Predictors of Advanced AMD Progression

- Visual loss (BCVA and CS)
- Reticular pseudodrusen
- ***Drusen load***
- ***Hyper-reflective foci***
- ***RPE hypo-reflectance***
  - ***Nascent geographic atrophy***
- ***Sub-RPE hyper-reflective columns***



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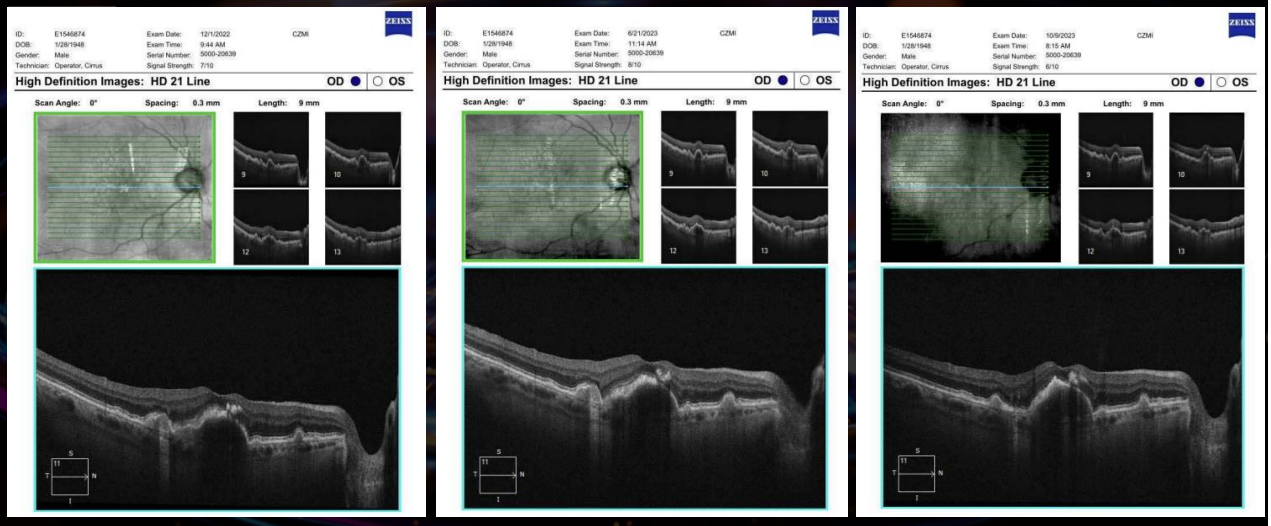
Subclinical AMD Diagnosis

Rapid Conversion of Advanced AMD to Geographic Atrophy

Dec2022 BCVA 20/30- **Jun2023 BCVA 20/30-** **Oct2023 BCVA 20/30-**



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Optical Coherence Tomography Primer

Intermediate AMD Comparative Imaging

Relationship between the distribution of intra-retinal hyper-reflective foci and iAMD progression

Arch Clin Exp Ophthal (2023) 261(12):3437-3447

Methods

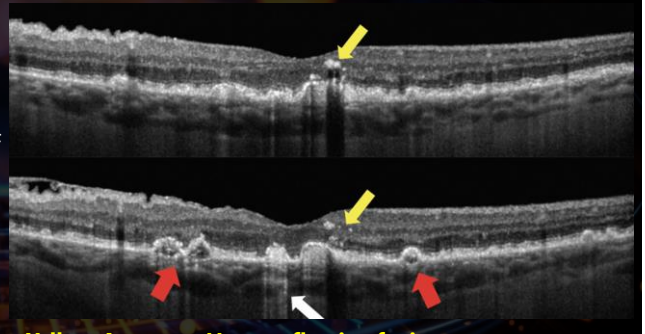
- Macular SD-OCTs of subjects with 2 years of follow-up were evaluated for the presence of iAMD and IHRF at baseline
- Number of IHRF in each slab at baseline and change in IHRF from baseline to year 2 were correlated with progression to late AMD at 2 years.

Results

- Among 71 patients with iAMD, ***43% of had evidence of both iAMD and IHRF at baseline***
  - ***19% showed progression to late AMD after 2 years***
- ***Presence of IHRF in outer retina was independently associated with a significant risk of progression to late AMD***

Conclusions

- ***Risk of progression to late AMD appears to be significantly associated with the distribution and extent of IHRF in the outermost retinal layers***



Yellow Arrows = Hyperreflective foci
Red Arrows = Irregular drusen/non-uniform reflectivity
White Arrows = Hyperreflective columns

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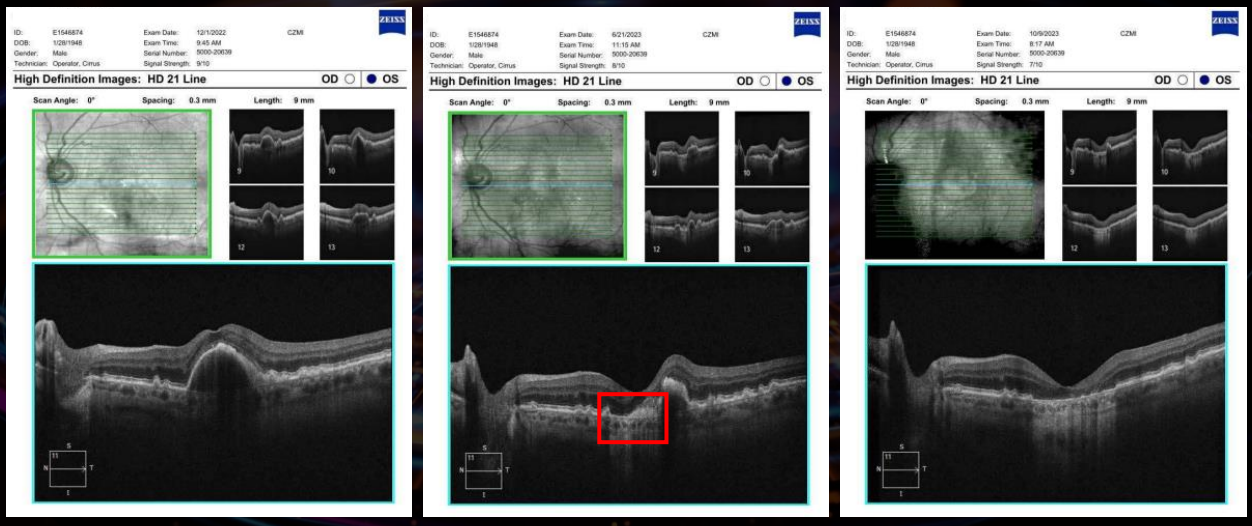
Subclinical AMD Diagnosis

Rapid Conversion of Advanced AMD to Geographic Atrophy

Dec2022 BCVA 20/30 **Jun2023 BCVA 20/200** **Oct2023 BCVA 20/100**



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Take Home Points

SD-OCT – AMD

- ~85% of AMD patients have atrophic AMD
- nvAMD is responsible for majority of severe VA loss
- Primary risk factors for advanced AMD:
  - Increasing age
  - Northern European ancestry
  - Genetic factors
    - ***Routine genetic testing not recommended at this time***
  - Cigarette smoking (modifiable)
  - AREDS2 supplementation should be considered in patients with intermediate or advanced AMD
    - ***(-) evidence to support use in < iAMD***
    - ***(-) evidence of any prophylactic value***
  - ***HOWEVER…***
    - ***Retinal carotenoid and polyphenol supplementation DOES show clinically-validated improvement in early AMD***
- FA, OCT and OCTA are useful diagnostic tests in detect of new or recurrent neovascular activity
- Early detection and prompt treatment improves the visual outcome
- Intravitreal anti-VEGF represents the first line treatment of nvAMD

Putnam Preferred Practice Pattern – AMD Worksheet

- FHx
  - 1st degree relative
  - Age of onset
- Systemic Review of concurrent inflammatory conditions
  - Collagen vascular disease (RA / SLE / sarcoid)
  - Thyroid condition
  - Vascular disease (DM / HTN / dyslipidemia)
- Laboratory testing
  - Lipid panel (HDL/LDL + total cholesterol + triglycerides)
  - Genetic Testing – Arctic Medical Labs
    - apoE / CFH / ARMS2
- B/P measured 3X
  - Mean Arterial Pressure (MAP) = [systolic + (2*diastolic)]/3
  - Mean Ophthalmic Perfusion Pressure = [(0.67*MAP) - IOP]
    - Difference between diurnal and nocturnal MAP is nocturnal hypotension
- BCVA
  - ETDRS
  - Pelli-Robson or PV 5%
- AdaptDx
  - 6.5min screener
    - 5-7 year precursor to clinical AMD
- Cone Contrast Testing (CCT) Threshold
- Baseline Imaging
  - Full color fundus
  - FAF (ultra-wide-field, if possible)
  - OCT 5-line Raster
    - Identification of changes @ Bruchs or drusen formation @ RPE
  - OCTA
    - Create baseline vascular appearance
    - Identify early neovascularization (deep plexus / choriocapillaris / Bruch's / intraretinal)
- Oral Supplementation
  - Lutein (20mg) and Zeaxanthin (5mg) and *meso*-zeaxanthin (10mg)
    - MacuHealth **[10/2/10]** / MacuShield **[AREDS+ 10/2/10]**
  - Ω-3 1000mg (DHA 650mg + EPA 350mg)
  - *Trans*-resveratrol 500mg QD
  - Curcumin 1000mg QD
  - CoQ_{10} 100-200mg QD

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SD-OCT Findings Related to Retinal Pathology

- Age-Related Macular Degeneration
- ***Diabetic Retinopathy***
- Retinal Vein Occlusions
- Central Serous Chorioretinopathy
- Macular Hole
  - FTH
  - LMH
- Autoimmune Retinopathy
  - Paraneoplastic syndromes

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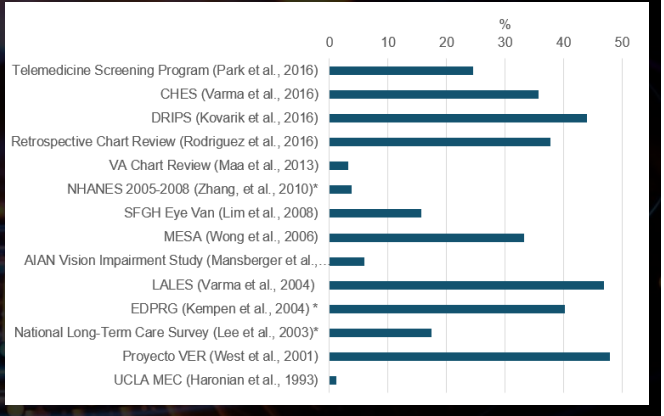
Diabetic Retinopathy
Epidemiology

Prevalence of DR in the US in 2021
JAMA Ophthalmol (2023) 141(8):747-754

Main Outcomes and Measures
- DR
  - Any retinopathy in the presence of diabetes, including NPDR (mild, moderate, or severe), PDR or macular edema
- VTDR
  - Severe NPDR retinopathy, PDR, PRP scars or macular edema

Results
- **Estimated 9.6 million people living with DR**
  - ***DR prevalence rate of 26%***
  - ***VTDR prevalence rate of 5%***
- Prevalence of DR and VTDR varied by demographic characteristics and geography.



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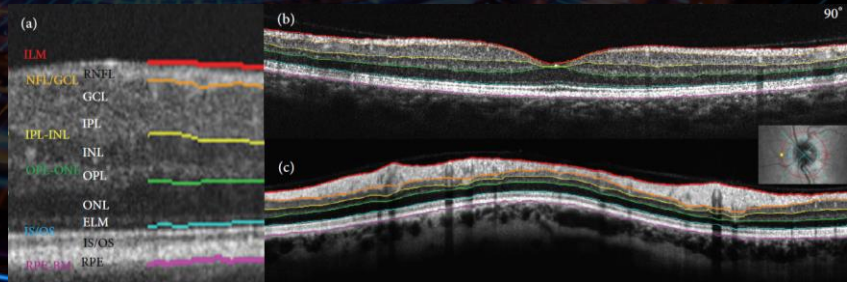
Optical Coherence Tomography Primer
Early Diabetic Retinopathy

Retinal Layers Changes in Human Preclinical and Early Clinical Diabetic Retinopathy Support Early Retinal Neuronal and Müller Cells Alterations
J Diab Res (2018) Article ID 905058

Methods
- 74 diabetics and 50 controls underwent stereoscopic fundus photography and SD-OCT. After automatic retinal segmentation into 5 layers, the thickness of each layer was calculated, and values compared among groups

Results
- ***Of 74 DM: 30 patients had (-)DR and 44 patients (+)NPDR***
  - ***Significant increase of IPL and INL found in DR eyes versus controls***
  - ***Significant decrease RNFL and macular RGC in DR***
  - ***Peripapillary area showed no differences between DR and controls***

Conclusion
- ***Decreased RNFL thickness with increased INL/OPL thickness in DM +/- DR suggest early alterations within inner retina***
- ***Outer retina appears unaffected in early stages of DM***



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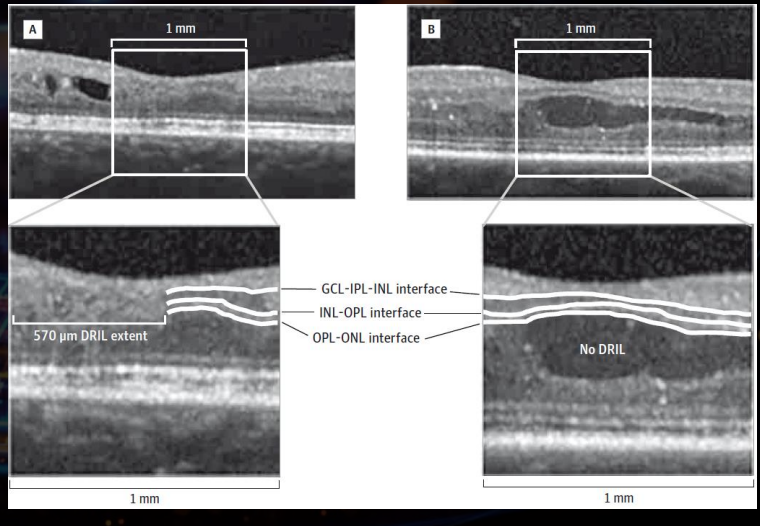
Optical Coherence Tomography Primer
Early Diabetic Retinopathy

Disorganization of the Retinal Inner Layers as a Predictor of BCVA in Eyes With Center-Involved DME
JAMA Ophthal (2016) 132(11): 1309-1316

Design, Setting, and Participants
- Demographics, VA, and SD-OCT images from 96 subjects with DM and baseline CI-DME
  - Baseline
  - 4-months
  - 8-months

Results
- ***Greater DRIL extent at baseline correlated with worse baseline VA***
- ***DRIL and ELM disruption was predictive of an 8-month VA change***
  - ***Each 300-µm DRIL increase within 4mos predicted 1-line VA decline***

Conclusions
- ***DRIL in 1-mm foveal area associated with VA***
- ***Change in DRIL predicts future change in VA***



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Optical Coherence Tomography Angiography Primer

Diabetic Retinopathy Management (2019 AAO PPP)

Diabetic Retinopathy (Management Recommendations)

Management Recommendations for Patients with Diabetes

Severity of Retinopathy	Presence of Macular Edema	Follow-up (Months)	Panretinal Photocoagulation (Scatter) Laser	Focal and/or Grid Laser*	Intravitreal Anti-VEGF Therapy
Normal or minimal NPDR	No	12	No	No	No
Mild NPDR	No	12	No	No	No
	ME	4–6	No	No	No
	CSME†	1*	No	Sometimes	Sometimes
Moderate NPDR	No	6–12	No	No	No
	ME	3–6	No	No	No
	CSME†	1*	No	Sometimes	Sometimes
Severe NPDR	No	4	Sometimes	No	No
	ME	2–4	Sometimes	No	No
	CSME†	1*	Sometimes	Sometimes	Sometimes
Non-high-risk PDR	No	4	Sometimes	No	No
	ME	4	Sometimes	No	No
	CSME†	1*	Sometimes	Sometimes	Sometimes
High-risk PDR	No	4	Recommended	No	Considered
	ME	4	Recommended	Sometimes	Usually
	CSME†	1*	Recommended	Sometimes	Usually

CSME

- Retinal thickening <500µm from foveal
- Exudates <500µm from fovea with adjacent retinal thickening
- 1DD of retinal thickening within 1DD of fovea

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Take Home Points

SD-OCT – DR

- DM I - annual screenings beginning 5 years after onset
- DM II – screening diagnosis and annually thereafter
- ***Glucose and B/P control lowers retinopathy risk***
- Women with DM who become pregnant should be examined early and closely in pregnancy course
  - ***Eye examination is not required when gestational diabetes occurs during pregnancy***
- ***CI-DME with vision loss = Intravitreal anti-VEGF***
- ***Non-CI DME = Laser photocoagulation surgery***
- ***PDR = PRP***

Putnam Preferred Practice Pattern – DR Worksheet

- **History**
  - Duration of DM diagnosis
  - Past glycemic control (*FBS* and *HbA1C*)
  - Medications
  - MHx (Obesity / renal disease / *HTN* / *dyslipidemia* / neuropathy)
  - OcHx (Trauma / Eye disease / Surgery or Injections)
- Laboratory testing
  - Fasting glucose (<110 mg/dL) and A1c (<6%)
  - Lipid panel (HDL/*LDL* + *total cholesterol* + triglycerides)
- B/P measured 3X
  - Mean Arterial Pressure (MAP) = [systolic + (2*diastolic)]/3
  - Mean Ophthalmic Perfusion Pressure = [(0.67*MAP) - IOP]
    - Difference between diurnal and nocturnal MAP is nocturnal hypotension
- BCVA
  - ETDRS
  - Pelli-Robson or PV 5%
- CCT Threshold
- Baseline Imaging
  - Full color fundus
    - (+/-) CSME - Retinal thickening within 500 µm of macular center
      - Hard exudates within 500 µm of macular center
      - Retinal thickening >1DD with any portion within 1DD of the macular center
    - (+/-) Signs of NPDR
    - (+/-) Center-involved
    - (+/-) ONH neovascularization
    - (+/-) Vitreous / pre-retinal hemorrhage
  - FAF (ultra-wide-field, if possible)
  - OCT 5-line Raster
    - Identification of changes foveal thinning of inner retinal layers
  - OCTA
    - Create baseline vascular appearance
    - Identify early neovascularization (deep plexus / choriocapillaris / Bruch's / intraretinal)
- Oral Supplementation
  - Lutein and Zeaxanthin and *meso*-zeaxanthin
    - MacuHealth **[10/2/10]**
  - Ω-3 1000mg (DHA 650mg + EPA 350mg)
  - *Trans*-resveratrol 500mg QD
  - Curcumin 500-1000mg QD

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SD-OCT Findings Related to Retinal Pathology

- Age-Related Macular Degeneration
- Diabetic Retinopathy
- ***Retinal Vein Occlusions***
- Central Serous Chorioretinopathy
- Macular Hole
  - FTH
  - LMH
- Autoimmune Retinopathy
  - Paraneoplastic syndromes

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Retinal Vein Occlusions

Epidemiology

Burden of disease of retinal vein occlusion: review of the literature
Eye (2021) 25(8): 981–988

- Population-based studies prevalence rates
  - ***BRVO: ~2%***
  - ***CRVO: ~0.2%***
- 15-year incidence rate is estimated at:
  - ***~1.8% for BRVO and 0.2% for CRVO***
- Primary risk factors:
  - Age in 10-year increments ***(OR: 1.93)***
  - Diastolic B/P in 10 mmHg increments ***(OR: 1.47)***
  - Hyperlipidemia
- Race, sex and glaucoma were not significant risk factors

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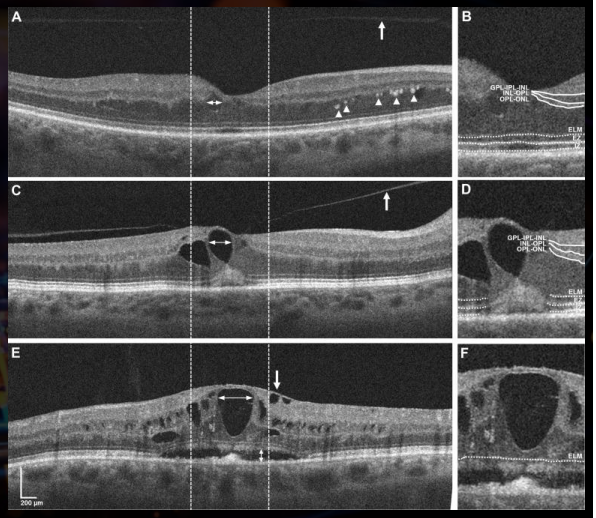
Optical Coherence Tomography Primer
Retinal Vein Occlusion

SD-OCT Predictors of Visual Outcomes after Ranibizumab Treatment for Macular Edema Resulting from RVO
Ophthal (2020) 4(1): 67-76

Methods
- Central subfield thickness (CST)
- Presence of VMT or ERM
- Presence, location, and amount of intraretinal fluid or SRF
- Presence, location, and amount of hyperreflective foci
- Disorganization of retinal inner layers (DRIL)
- Disruption of external limiting membrane (ELM), ellipsoid zone (EZ), and interdigitation zone (IZ).

Results
- Worse baseline BCVA was associated with
  - ***ERM presence***
  - ***Higher SRF***
  - ***Larger intraretinal cysts***
  - ***Higher percentage of DRIL***
  - ***Higher percentage of EZ and IZ disruption***

Conclusions
- Although SD-OCT features may be associated with presenting vision in eyes with ME and RVO, ***most eyes treated with ranibizumab achieve substantial vision gains***
- ***Only older age and better baseline BCVA limited visual improvements***



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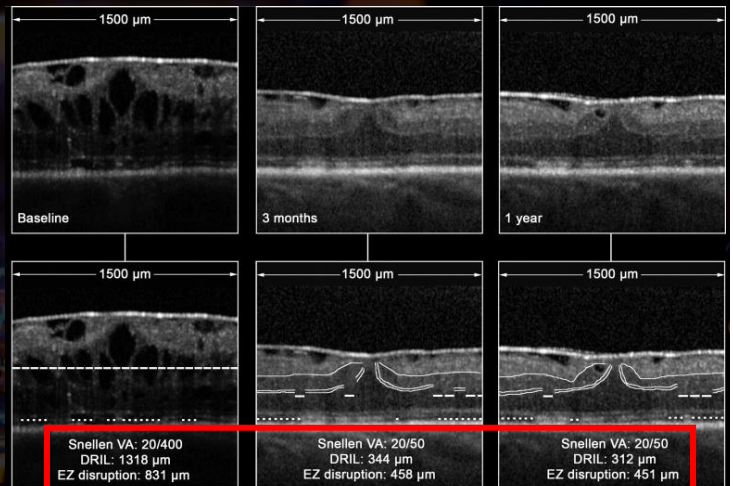
Optical Coherence Tomography Primer
Retinal Vein Occlusion

Disorganization of Retinal Inner Layers and Ellipsoid Zone Disruption Predict Visual Outcomes in Central Retinal Vein Occlusion
Ophthal Retina (2019) 3(1): 83-92

Methods
- VA and SD-OCT images from baseline, 3mos and 12mos were reviewed
- Morphologic features in ***1500-µm foveal zone*** were analyzed by masked graders for DRIL, EZ and ELM disruption, cone outer segment tip (COST) visibility, cysts, subretinal and intraretinal fluid and ERM

Results
- Worsening VA over 1-year was associated with DRIL and EZ disruption and decreased COST visibility
- ***3-month increase in DRIL and EZ disruption were the only factors predicting VA worsening over 1 year, accounting for 86% of variability***

Conclusions
- ***Early recovery over 3 months in both DRIL and EZ parameters are key drivers of 1-year VA outcomes***



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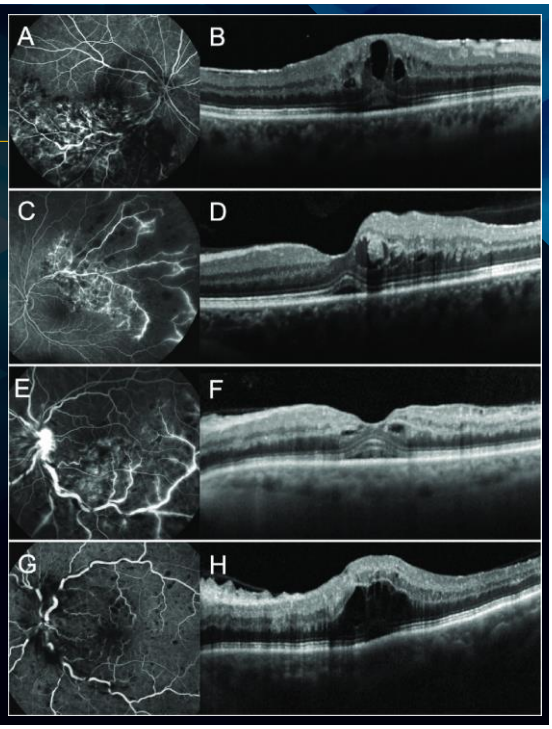
Take Home Points
SD-OCT – RVO

- ***RVO prognosis of varies according to the site of the occlusion and the type of occlusion***
  - ***Ischemic or Non-ischemic***
- ***Distal RVOs with less occlusion have a better prognosis than more proximal RVOs with greater ischemia***
- CRVOs and hemi-CRVOs have clinically similar courses
  - Associated with anterior segment neovascularization and neovascular glaucoma
- BRVOs and hemiretinal vein occlusions have a visible A/V crossing where the occlusion occurs
- ME may complicate both CRVOs and BRVOs
  - ***First line treatment for associated ME is anti-VEGFs***
  - Laser photocoagulation surgery in BRVO has a potential role in treatment
- ***Optimizing control of HTN, DM and serum lipid levels and are important in the management of systemic risk***



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SD-OCT Findings Related to Retinal Pathology

- Age-Related Macular Degeneration
- Diabetic Retinopathy
- Retinal Vein Occlusions
- ***Central Serous Chorioretinopathy***
- Macular Hole
  - FTH
  - LMH
- Autoimmune Retinopathy
  - Paraneoplastic syndromes

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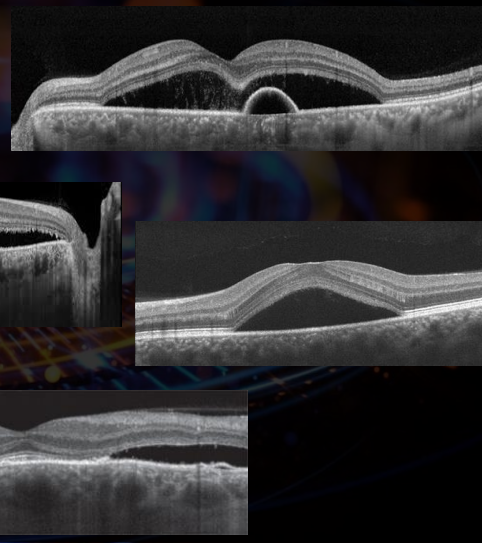
Central Serous Chorioretinopathy

Epidemiology

Central Serous Chorioretinopathy Review

Clin Exp Ophthal (2023) 51(3):243-270

- Most commonly affects males aged between 20-50 years
  - Patients >50 tend to present with bilateral findings, retinal pigment epitheliopathy and secondary choroidal neovascularization
- Reported male : female ratio range 2:1 to 6:1
  - Described in patients as young as 8 years, and as old as 83 years
  - ***4th most common non-surgical, fluid-leakage retinopathy***
    - ***AMD***
    - ***DR***
    - ***RVO***
- Age-adjusted incidence
  - ***23.4 per 100,000 men*****
  - ***9.6 per 100,000 women***



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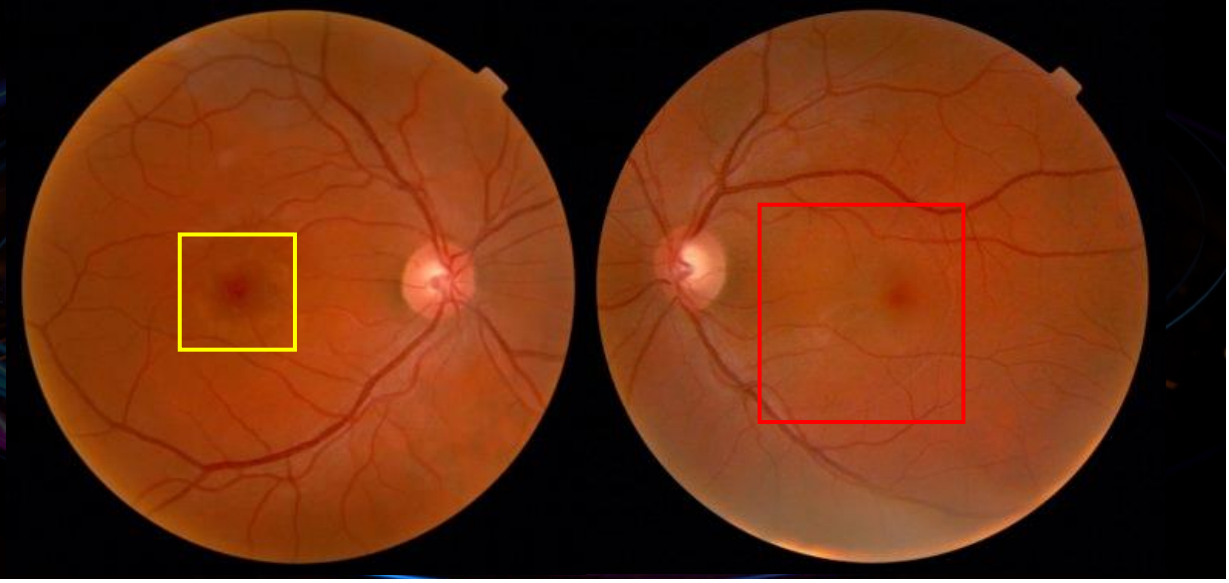
Optical Coherence Tomography Primer - Case #1

Central Serous Chorioretinopathy – Day 1



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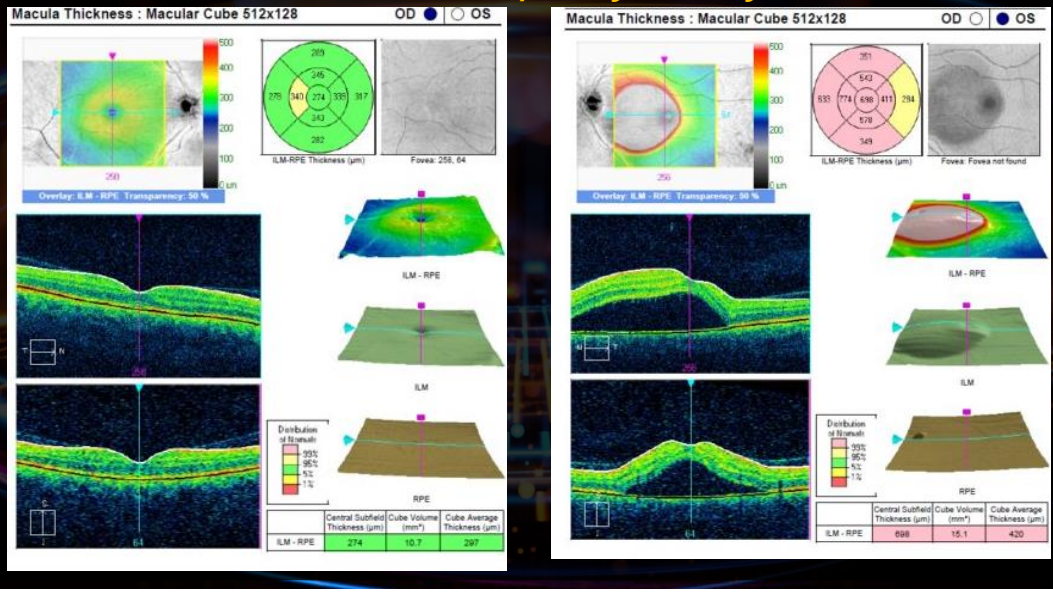
Optical Coherence Tomography Primer – Case #1

Central Serous Chorioretinopathy – Day 1



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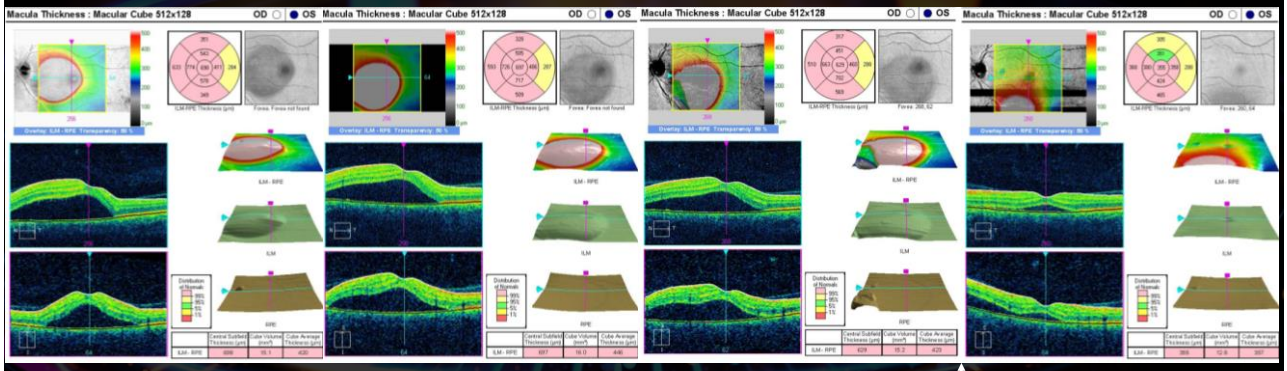
Optical Coherence Tomography Primer – Case #1

Central Serous Chorioretinopathy – Day 1 through 21



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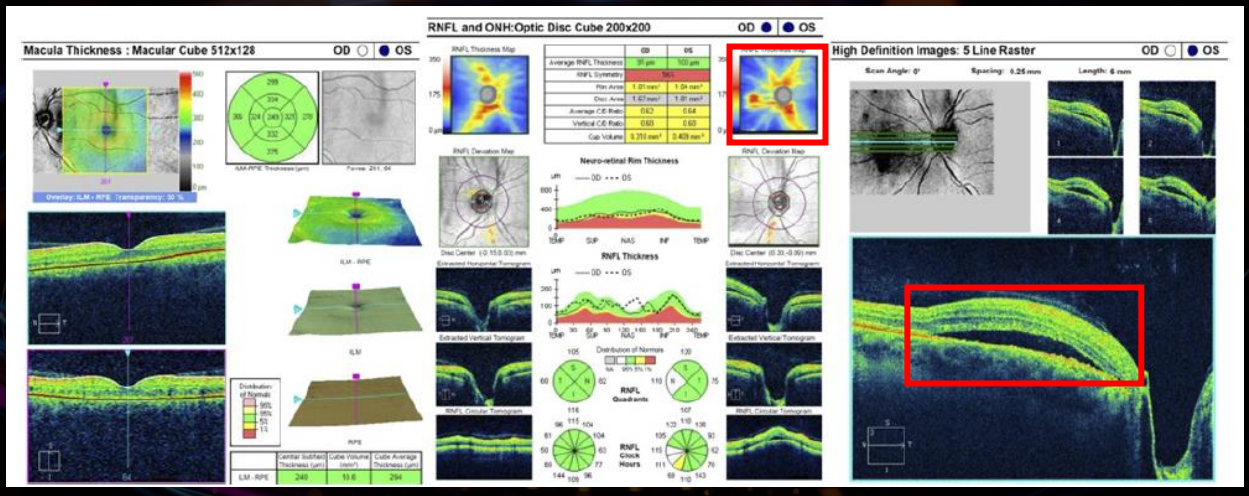
Optical Coherence Tomography Primer – Case #1

Central Serous Chorioretinopathy – Day 56



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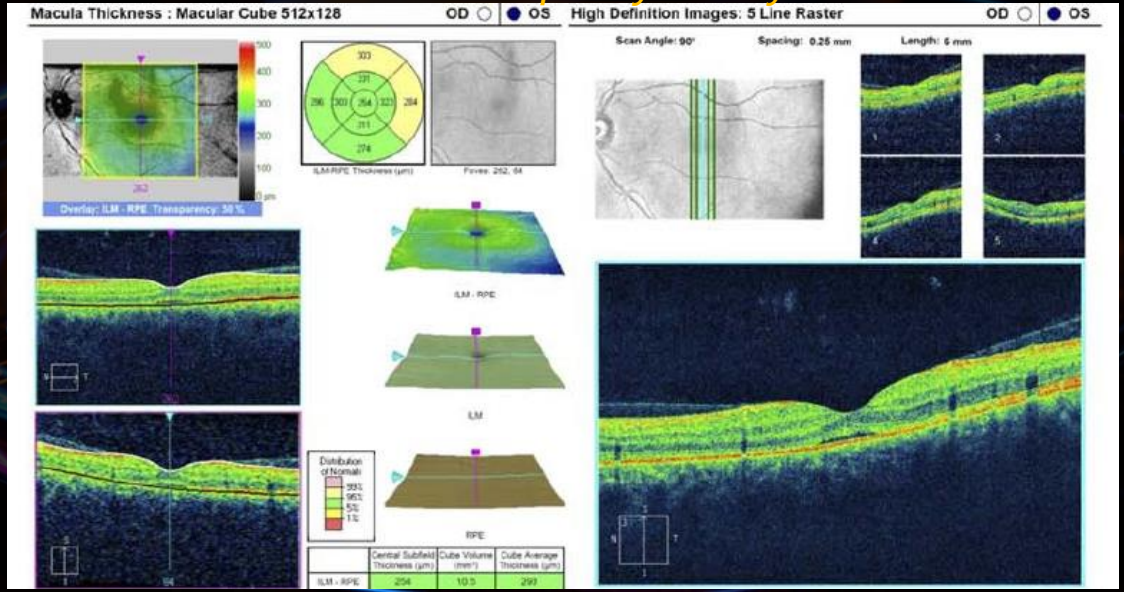
Optical Coherence Tomography Primer – Case #1

Central Serous Chorioretinopathy – Day 105



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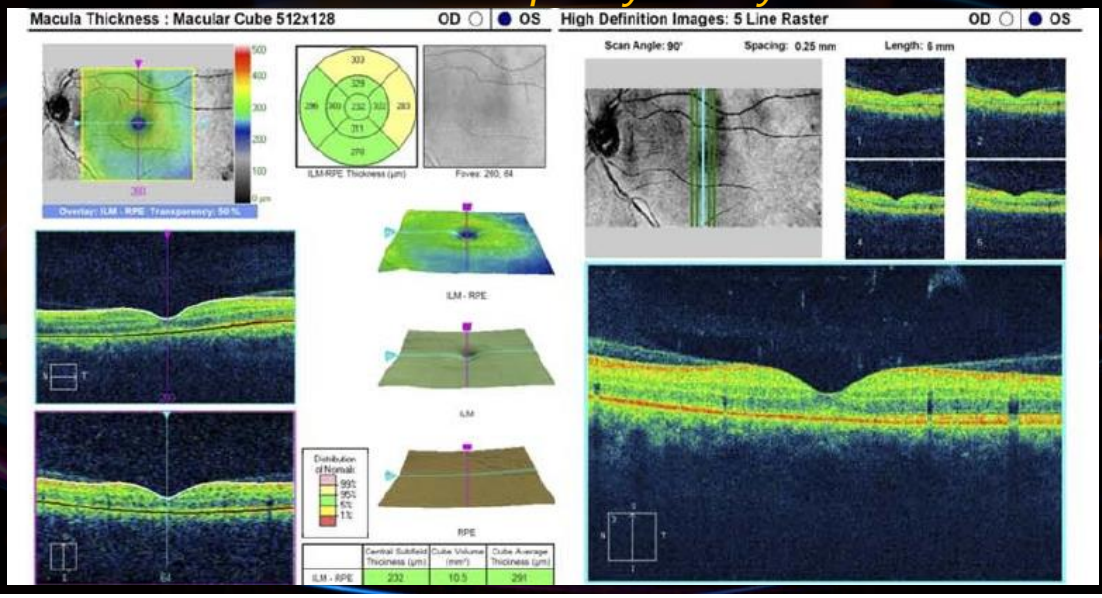
Optical Coherence Tomography Primer – Case #1

Central Serous Chorioretinopathy – Day 112



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Optical Coherence Tomography Primer – Case #1

Central Serous Chorioretinopathy

Cirrus OCT Macular Cube 512x128 OS

Date	Central subfield thickness	Cube volume	Cube mean thickness
Initial	698	15.1	420
1 wk F/U	697	16.0	446
2 wk F/U	629	15.2	423
3 wk F/U	355	12.8	357
4 wk F/U	333	11.8	328
5 wk F/U	281	11.1	308
6 wk F/U	Retinal specialist evaluation		
7 wk F/U	243	10.7	298
8 wk F/U	249	10.6	294
9 wk F/U	253	10.6	296
10 wk F/U	260	11.2	310
11 wk F/U	350	13.6	377
12 wk F/U	704	17.1	474
13 wk F/U	Retinal specialist evaluation		
14 wk F/U	314	11.1	309
15 wk F/U	254	10.5	292
16 wk F/U	232	10.5	291

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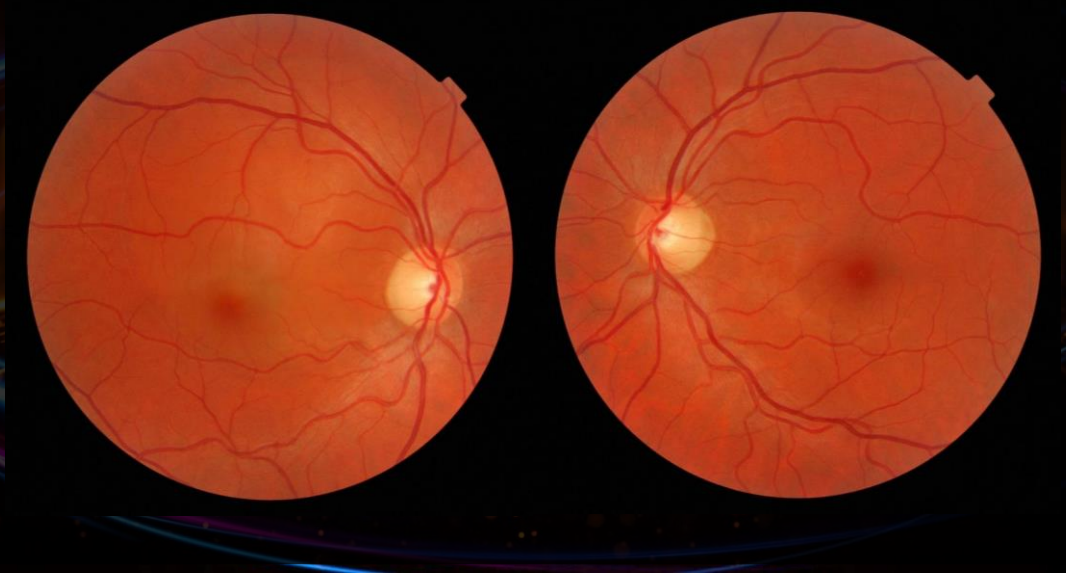
Optical Coherence Tomography Primer – Case #2

Central Serous Chorioretinopathy – Day 1



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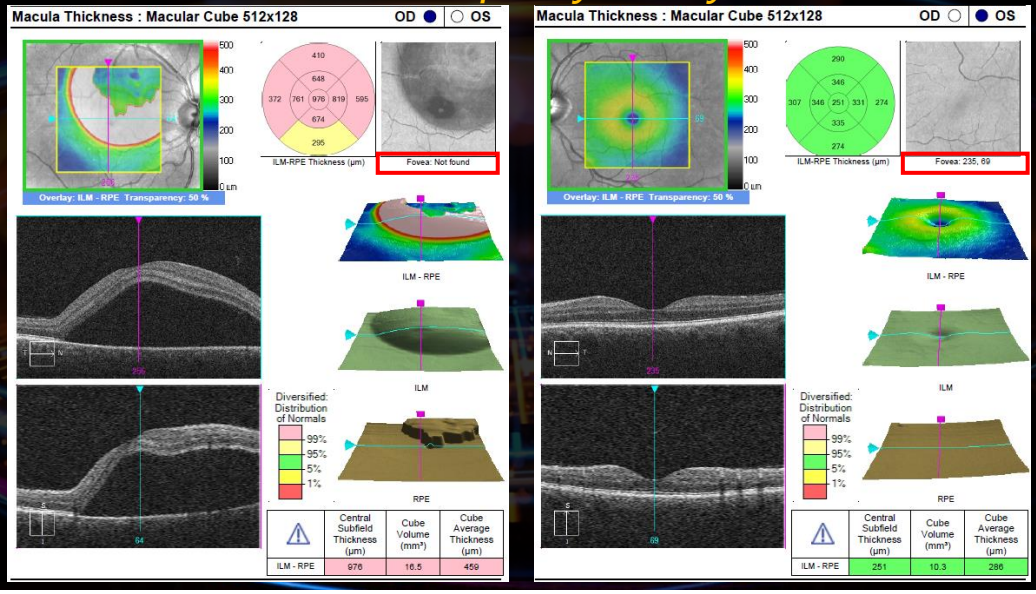
Optical Coherence Tomography Primer – Case #2

Central Serous Chorioretinopathy – Day 1



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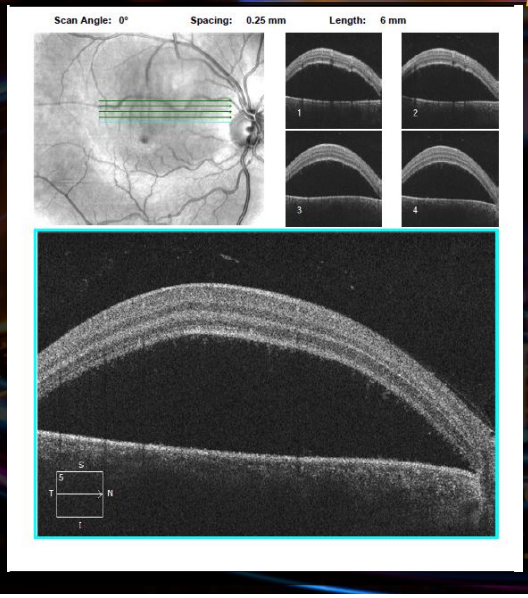
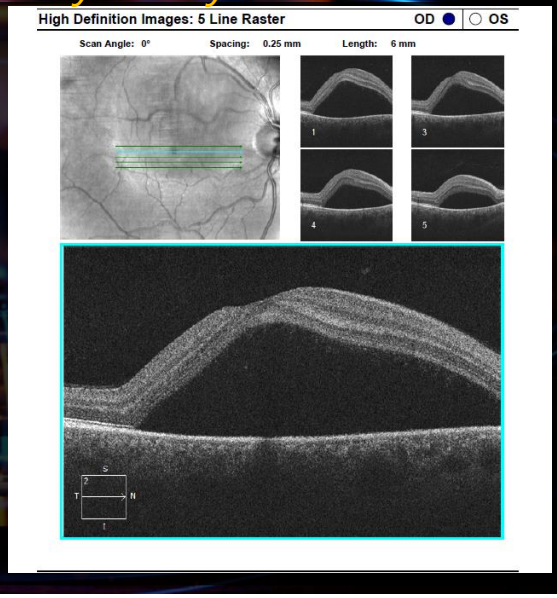
Optical Coherence Tomography Primer – Case #2

Central Serous Chorioretinopathy – Day 1





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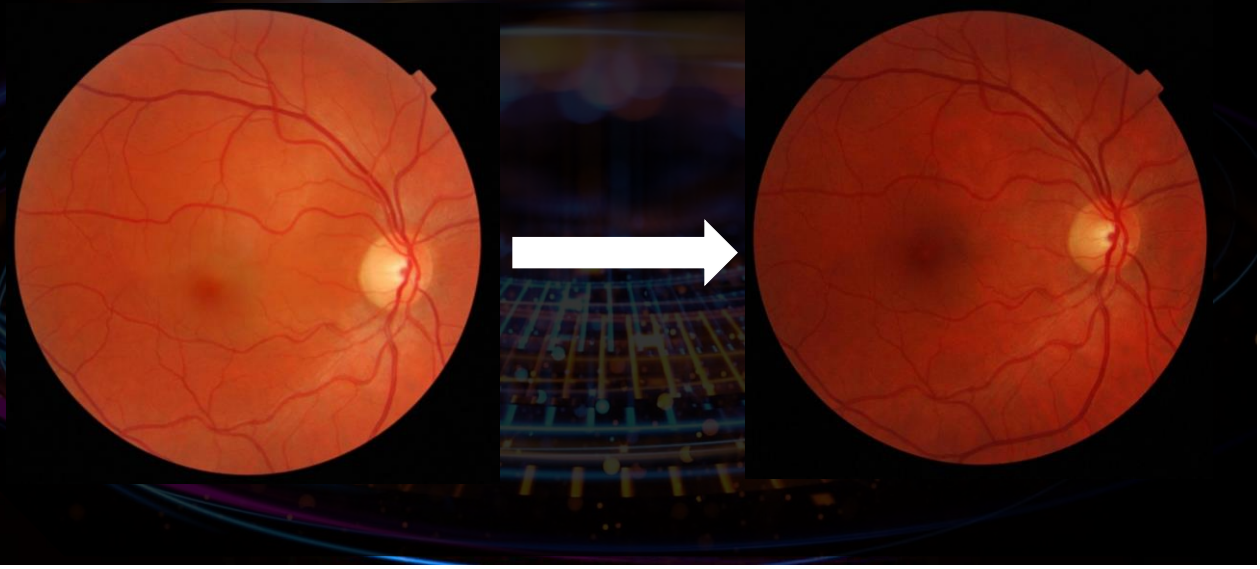
Optical Coherence Tomography Primer – Case #2

Central Serous Chorioretinopathy – Day 30



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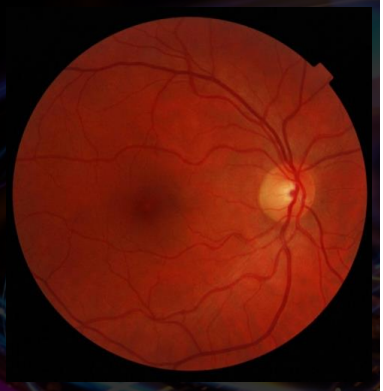
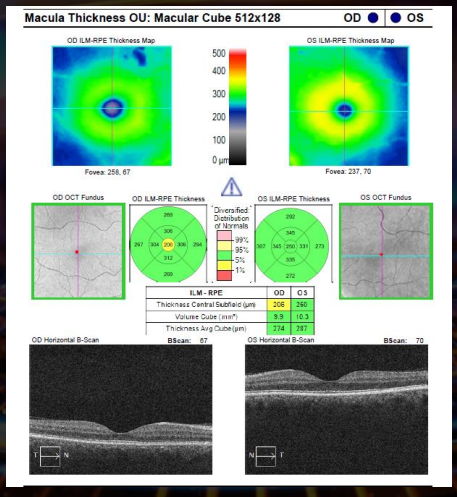
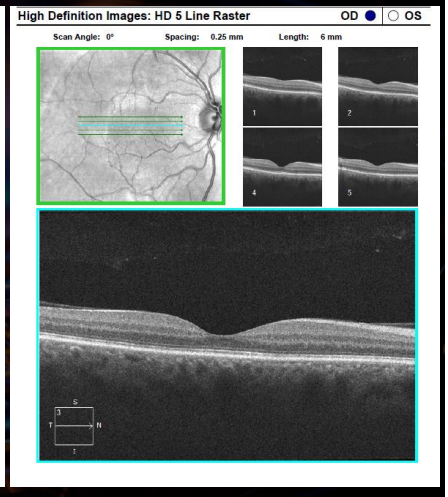
Optical Coherence Tomography Primer – Case #2

Central Serous Chorioretinopathy – Day 30







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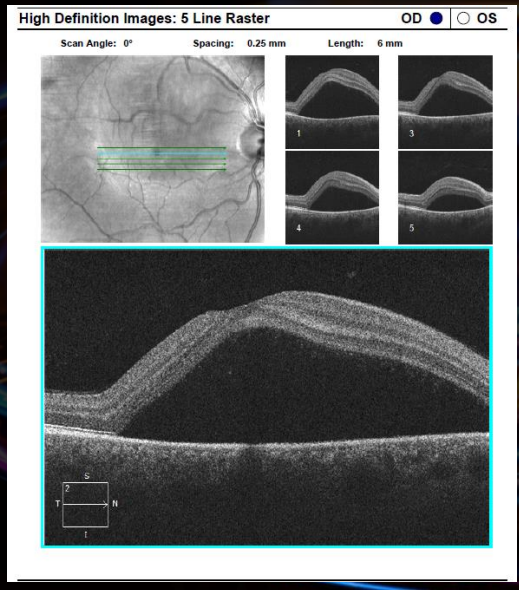
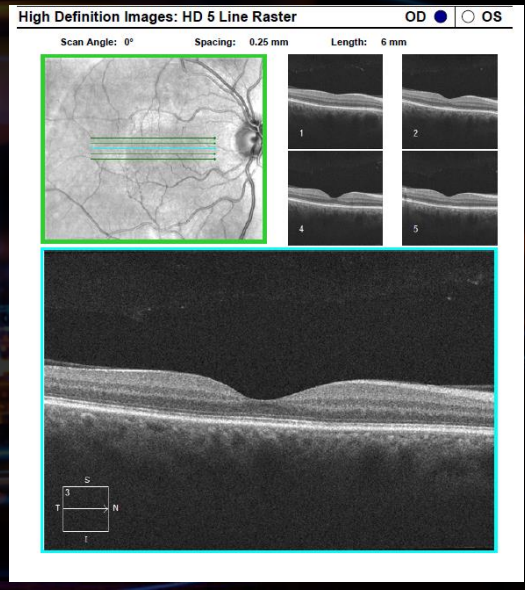
Optical Coherence Tomography Primer – Case #2

Central Serous Chorioretinopathy [Day 1]

[Day 30]





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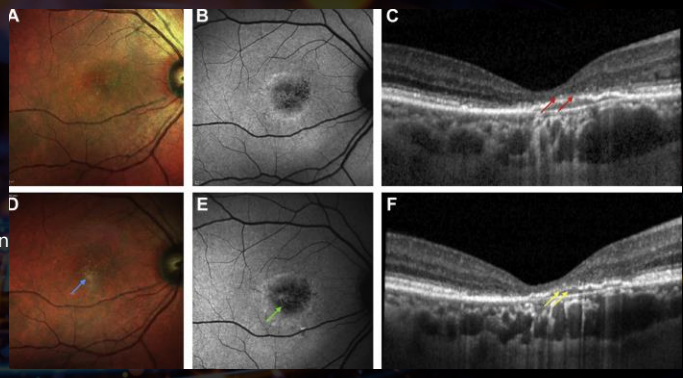
Optical Coherence Tomography Primer

Central Serous Chorioretinopathy

OCT Risk Factors for 3-Year Development of Macular Complications in Eyes With "Resolved" Chronic CSC

Am J Ophthal (2021) 223: 129-139



Methods

- 71 eyes with "resolved" chronic CSC at baseline and 36 months of regular follow-up examinations

Results

- ***20 eyes (28.2%) developed macular complications***
  - 9 eyes (12.7%) displayed CNV
  - 9 eyes (12.7%) had large areas of RPE atrophy
  - 2 eyes (2.8%) developed cystoid macular degeneration
- ***Increased risk of development of CNV***
  - ***Intraretinal hyper-reflective foci [HR: 11.58]***
  - ***Inner choroidal attenuation [HR: 9.66]***
  - ***Macular complications in fellow eye [HR: 20.17]***
- ***Development of RPE atrophy***
  - ***ONL thinning [HR: 13.47]***
  - ***Inner choroidal attenuation [HR: 13.20]***
  - ***Dome-shaped PED [HR: 21.40]***

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Take Home Points

SD-OCT – CSC

Preferred practice pattern in central serous chorioretinopathy

Br J Ophthal (2018) 101(5):587-590

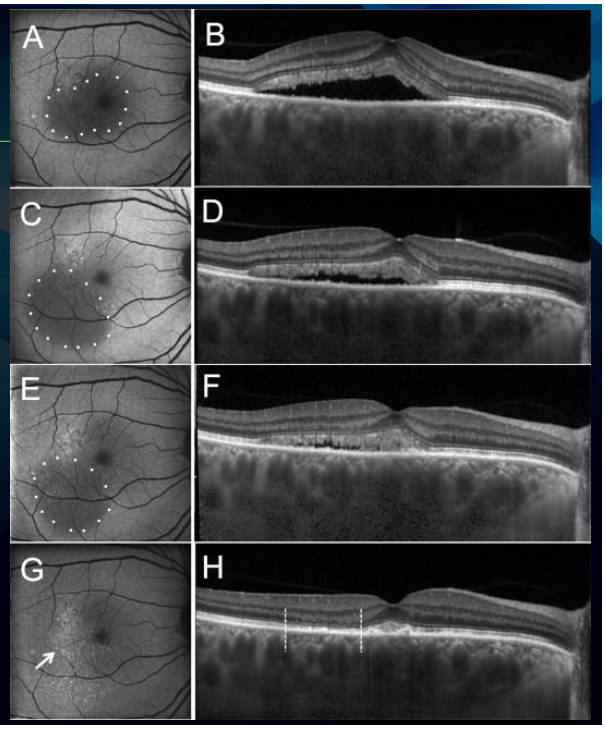
- CSC management lacks well-defined guidelines given the variable natural history of this disease and the lack of prospective trials
  - Online preferred physician practice survey to track trends and variations management

Results

- ***Chronic cases***
  - ***67% offered PDT as first line treatment***
    - ***Full dose and half-fluence (61%)***
- Chronic cases with intraretinal cystic changes
  - 43.1% opted for observation
  - EDI-OCT: 60%
  - ICG: 38%

Conclusions

- While there are common practice patterns for CSC, there are ***variations in regional and individual practice patterns***



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SD-OCT Findings Related to Retinal Pathology

- Age-Related Macular Degeneration
- Diabetic Retinopathy
- Retinal Vein Occlusions
- Central Serous Chorioretinopathy
- ***Macular Hole***
  - ***FTMH***
  - ***LMH***
- Autoimmune Retinopathy
  - Paraneoplastic syndromes

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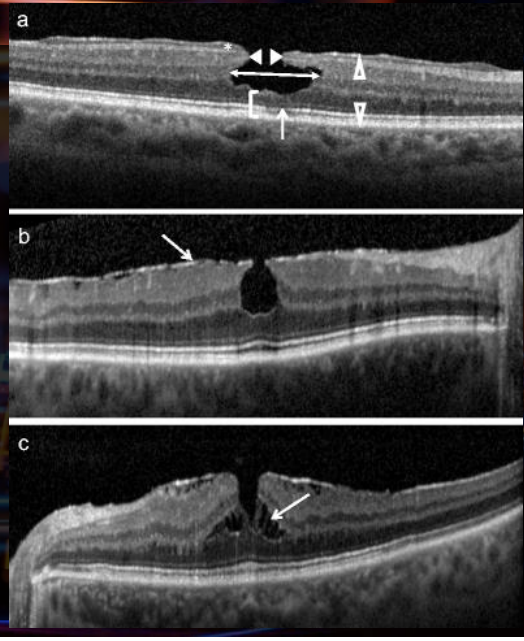
Lamellar and Full-Thickness Macular Holes

Epidemiology

Risk factors for the development of idiopathic macular hole: population-based cohort study

Scientific Reports (2022) 12(1): 21778

- Idiopathic presentation is typically unilateral
  - Bilateral involvement varies widely from 2-28% with no definitive systemic association
- Females are more commonly involved (3:1) in sixth or seventh decade of life
  - Myopic and traumatic macular hole can present at any age
- ***Prevalence ~3.3 per 1000***
- ***Incidence ~7.8 per 100,000***
- Etiology primarily idiopathic or related to VMT
  - Intraocular surgical intervention / laser
  - Epiretinal membrane
  - Hypertensive retinopathy
  - Diabetic retinopathy (DR)
  - Vitelliform dystrophy



Lamellar Hole

Macular Pseudohole + ERM

Macular Pseudohole + Cleaved Edges

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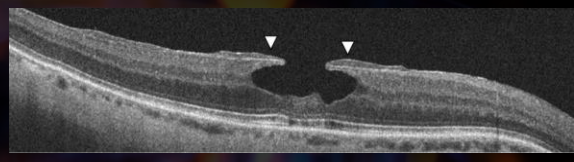
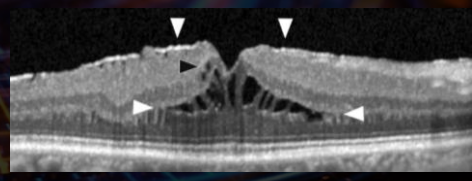
Optical Coherence Tomography Primer
Lamellar and Full-Thickness Macular Holes

OCT-based consensus definition for lamellar macular hole
Br J Ophthal (2019) 104(12)

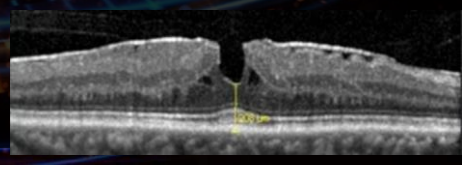
- **LMH**
  - Irregular foveal contour
  - Foveal cavity with undermined edges
  - Loss of foveal tissue with EZ disruption



- **ERM foveoschisis**
  - ***ERM***
  - Schisis at Henle fiber layer
  - INL microcystoid spaces with retinal thickness increase



- **Macular pseudohole**
  - ***Foveal sparing ERM***
  - Steepened foveal profile and an increased central retinal thickness
  - Microcystoid spaces



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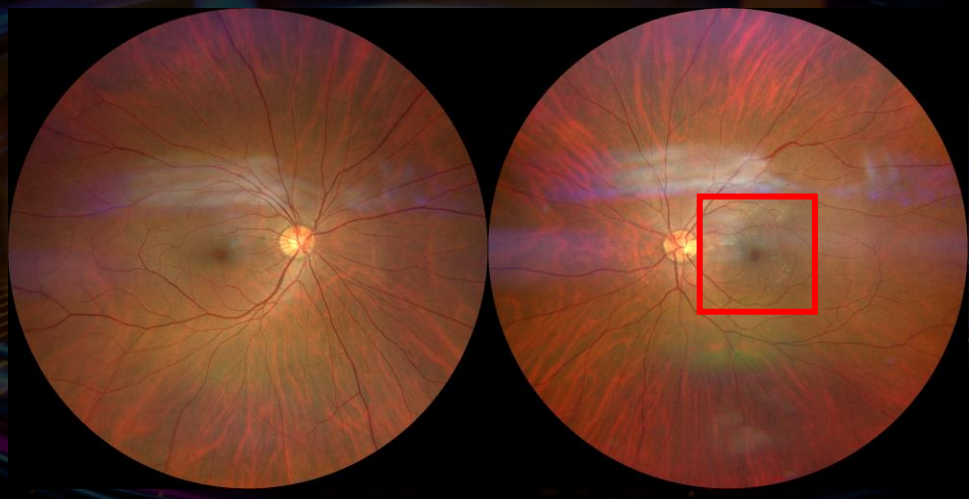
Optical Coherence Tomography Primer – Case #1
Lamellar and Full-Thickness Macular Holes



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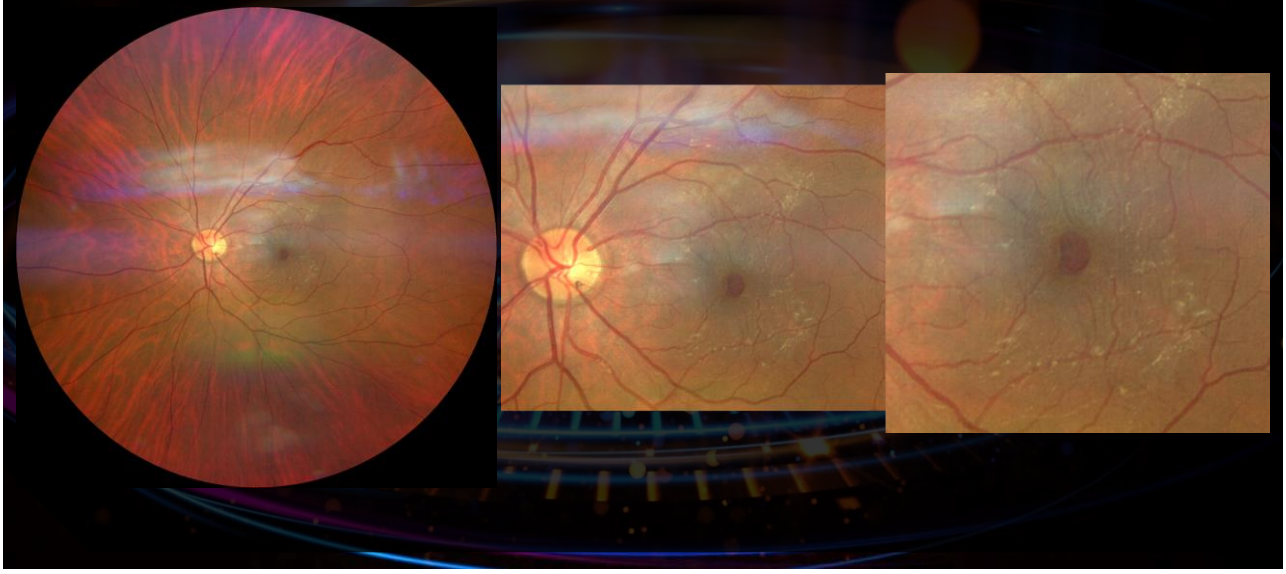
Optical Coherence Tomography Primer – Case #1

Lamellar and Full-Thickness Macular Holes



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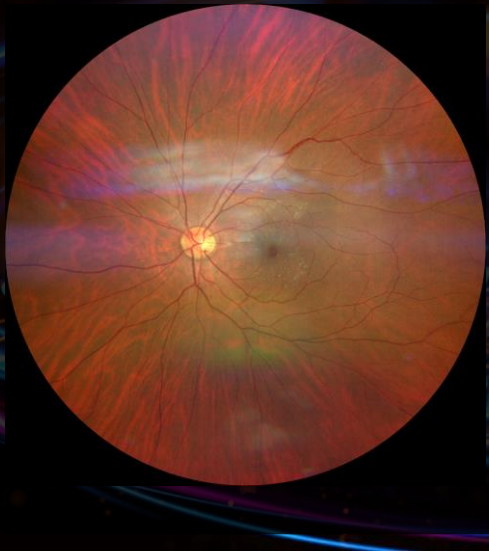
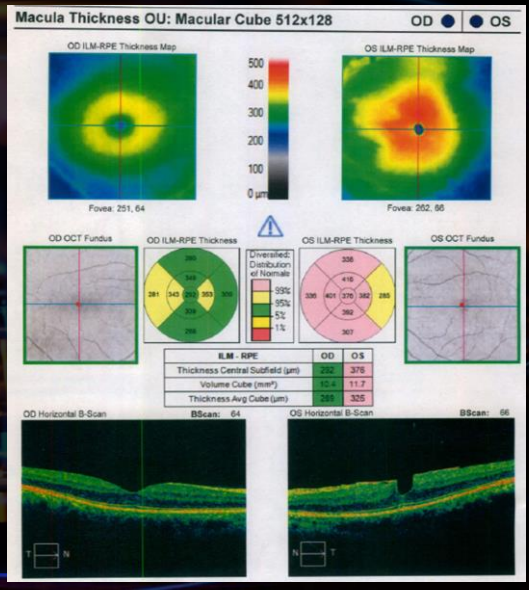
Optical Coherence Tomography Primer – Case #1

Lamellar and Full-Thickness Macular Holes





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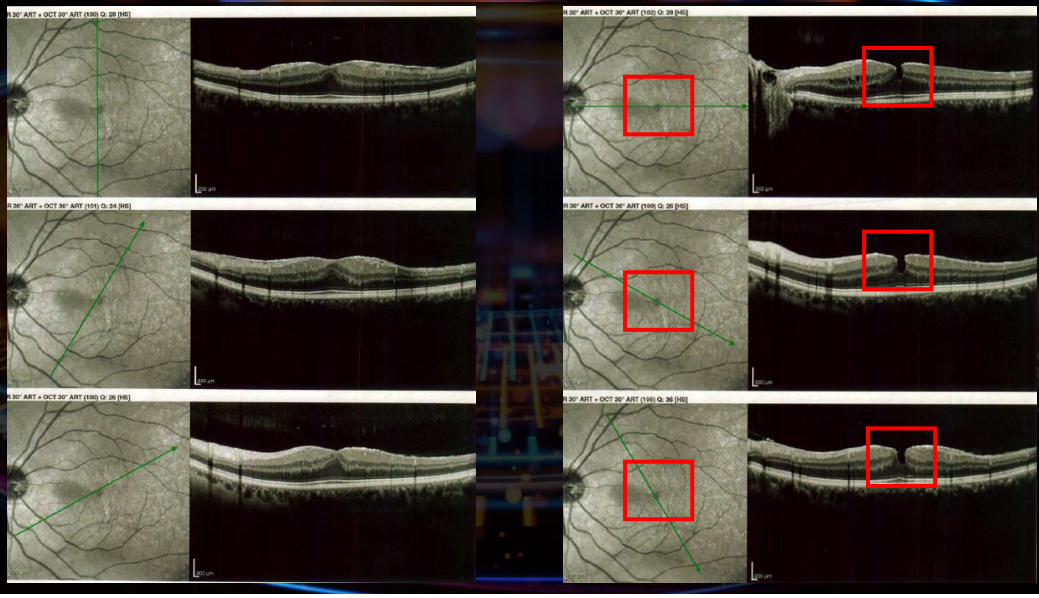
Optical Coherence Tomography Primer

Lamellar and Full-Thickness Macular Holes



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Optical Coherence Tomography Primer

Lamellar and Full-Thickness Macular Holes

Percentage of Fellow Eyes That Develop Full-Thickness Macular Hole in Patients With Unilateral Macular Hole

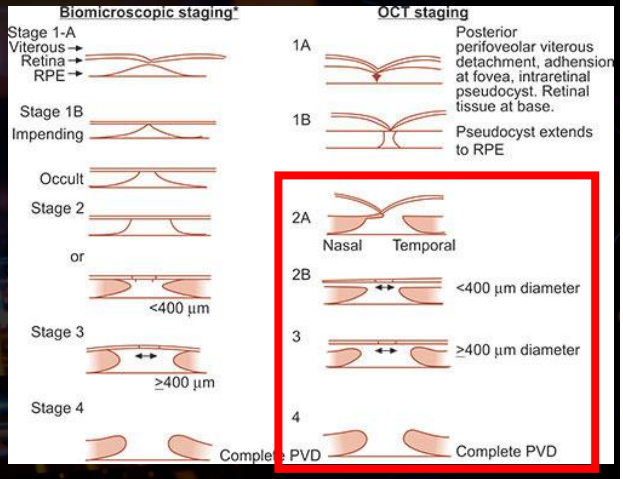
Arch Ophthalmol (2012) 130(3):393-394

Results

- 394 men and 688 women in the study with mean age at initial surgery of 64.2±8.2 years with F/U period of 5.9±3.8 years
- 960 (88%) remained a unilateral MH and 122 patients (12%) developed an MH in the fellow eye
- Gender, age at onset and axial length were not significantly different between the unilateral and bilateral groups
- Risk of the fellow eye developing an MH
  - ***11.6% at 5 years***
  - ***16.7% at 10 years***
  - ***21.9% at 20 years***
  - ***24.5% at 30 years***

Conclusion

- ***Appearance of the vitreoretinal interface in SD-OCT images is associated with the risk of developing an MH in the fellow eye***



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Take Home Points

SD-OCT – LMT + FTMH

- More common in females than in males
  - Usually occur after age 55
- 15% rate of MH formation in fellow eye within 5-year period after first eye
- ***Patients with VMT and (-) macular hole (stage 1-A or 1-B) should be observed without treatment as they often remain stable or even improve***
  - ***No evidence that treatment improves the prognosis***
- Most patients with stage 2 to 4 macular holes will have a poor prognosis without treatment
  - Visual prognosis is good following successful macular hole closure
- ***Studies report ~90% of recent MH <400µm can be closed with vitrectomy surgery***
- Early detection of a macular hole is associated with both a higher closure rate after vitrectomy surgery as well as better postoperative visual acuity

TABLE 1 Clinical Stages and Characteristics of Macular Holes

Stage*	Characteristics
1-A (impending)	• Loss of the foveal depression and a yellowish foveal spot (100–200 µm in diameter) • Localized shallow detachment of the perifoveal vitreous cortex with persistent adherence to the foveola • Vitreofoveolar traction may horizontally separate (split) the retina at the fovea (pseudocyst) that corresponds to the yellow spot[21] • Epiretinal membranes are uncommon • Visual acuity ranges from 20/25 to 20/80 • Surgical intervention is not recommended
1-B (impending)	• Yellow ring 200–350 µm in diameter • Posterior extension of the pseudocyst with disruption of the outer retinal layer[21-23] • The retinal roof remains intact with persistent adherence of the posterior hyaloid to the retina[21,23] • Epiretinal membranes are uncommon • Visual acuity ranges from 20/25 to 20/80 • Surgical intervention is not recommended
2	• Small full-thickness (<400 µm in diameter) retinal defect, often eccentric • Epiretinal membranes are uncommon • Visual symptoms include metamorphopsia and decreased vision • Visual acuity 20/25 to 20/80
3	• Full-thickness hole ≥400 µm in diameter • The posterior hyaloid is separated from the macula but may remain attached at the optic disc and be attached more peripherally[21] • An operculum or a flap is present on the posterior hyaloid over the hole and is visible clinically or by means of optical coherence tomography • A cuff of subretinal fluid may be detected along with intraretinal edema and cysts • Drusen-like deposits** may be occasionally seen in the base of the hole • A rim of retinal pigment epithelium hyper/hypopigmentation is often present at the junction between edematous or detached retina and normal-appearing attached retina in long-standing cases[24] • Epiretinal membranes may be present • Visual acuity usually ranges from 20/100 to 20/400[17,24]
4	• A full-thickness hole with a diameter usually larger than stage 3 (>400 µm in diameter) • A complete posterior vitreous detachment with a Weiss ring[20,23] • A cuff of subretinal fluid, intraretinal edema, and cystoid changes are usually present • Drusen-like deposits* may be occasionally seen in the base of the hole • Epiretinal membranes are more frequent[25] • Visual acuity is more profoundly affected to 20/100 to 20/400[17,24]

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SD-OCT Findings Related to Retinal Pathology

- Age-Related Macular Degeneration
- Diabetic Retinopathy
- Retinal Vein Occlusions
- Central Serous Chorioretinopathy
- Macular Hole
  - FTMH
  - LMH
- ***Autoimmune Retinopathy***
  - ***Paraneoplastic syndromes***

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Autoimmune Retinopathy
Epidemiology

Update on autoimmune retinopathy
J Ophthal 2020 68(9):1829-1837

- Female in 6th-7th decade with (-) FHx of RP or other inherited retinal dystrophies
- Divided into 2 groups
  - Paraneoplastic
    - Cancer-associated retinopathy (CAR)
    - Melanoma-associated retinopathy (MAR)
  - Non-paraneoplastic (more common and younger)
    - ***Typically diagnosis of exclusion***
    - ***Acute zonal outer occult retinopathy (AZOOR)***
      - Bilateral, asymmetric
    - ***Multiple Evanescent White Dot Syndrome (MEWDS)***
      - Unilateral
- If testing is consistent AIR:
  - ***Perform ARA testing.***
    - ***(+) ARA: Refer for systemic malignancy evaluation***
    - (-) ARA or (-) malignancy: tentative nPAIR diagnosis

Table 1: Characteristic Features of AIR Subtypes

	CAR	MAR	nPAIR
Presentation	• Associated with malignancy (may present before or after cancer diagnosis) • 2:1 ratio female:male • > 45 years old • Bilateral, slowly progressive vision loss • Rod and cone dysfunction	• Associated with melanoma • May present years after diagnosis • More prevalent in men • Vitelliform retinopathy (rare)	• History of autoimmune disease • Younger patients • More prevalent in women • Bilateral, subacute vision loss • Diffuse retinal atrophy
Associated antibodies	• Recoverin • Alpha-enolase • Tubby-like protein 1 • Heat shock cognate protein 70 • Glyceraldehyde 3-phosphate dehydrogenase • Carbonic anhydrase II	• Transducin • Arrestin • Bestrophin • Anti-aldolase A and C • Rhodopsin • Carbonic anhydrase II • Myelin basic protein • Interphotoreceptor retinoid-binding protein	• Recoverin • Alpha-enolase • Carbonic anhydrase II • Transducin-alpha • Müller cell–associated antigen
Diagnostic studies	• ffERG: a- and b-wave abnormalities • OCT: loss of the ellipsoid layer, external limiting membrane, and outer nuclear layer; cystic spaces	• ffERG: reduced b-wave, normal dark-adapted a-wave • IHC: staining of ARAs in bipolar layer	• ffERG: diffuse depression • OCT: thinning of outer layer, irregular ellipsoid layer
Treatment	• Steroids • IVIG • Immunosuppressive agents • Antioxidants	• Plasmapheresis • IVIG • Radiation therapy/surgery to reduce tumor burden	• Local/systemic steroids • Antimetabolites

SOURCE: Adapted from Grewal DS et al. *Retina*. 2014;34(5):827-845. **Abbreviations:** ARAs, antiretinal antibodies; ffERG, full-field electroretinogram; IHC, immunohistochemistry; IVIG, intravenous immunoglobulin; OCT, optical coherence tomography.

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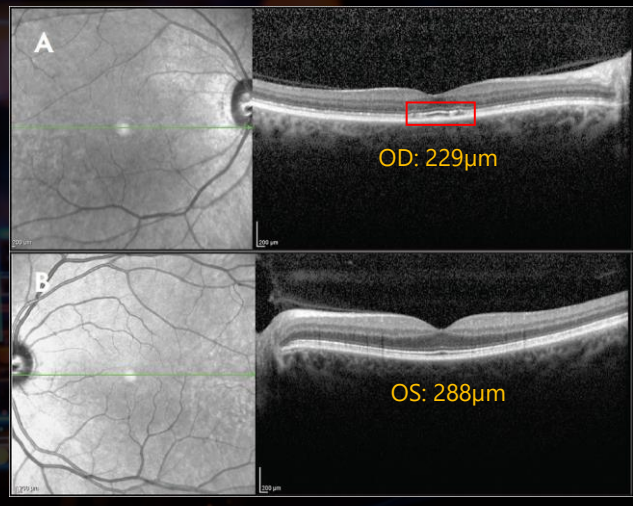
Optical Coherence Tomography Primer
Autoimmune Disease

Retinal Sublayer Analysis in Autoimmune Retinopathy and Identification of OCT Phenotypes
Ocular Immun Inflamm (2023) 10: 1-8

Methods
- 2007-2017 chart review performed evaluating AIR patients
- SD-OCT retinal sublayer analysis was performed, and paradoxical thickening phenotypes were reviewed.

Results
- 29 AIR patients with (+) anti-retinal antibodies identified
- ***Thinner retinal sublayers compared to controls***
  - ***12 patients (41.4%) had paradoxical thickening of OPL suggesting two distinct OCT phenotypes***
- ***No association was found between retinal sublayer thickness and specific antiretinal antibodies***

Conclusions
- Pathogenicity of antiretinal antibodies remains unclear
- OCT phenotypes observed underscore need to identify underlying disease processes



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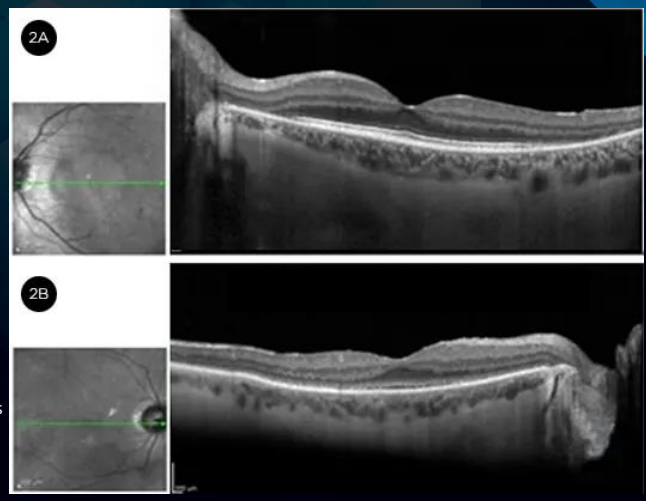
Take Home Points

SD-OCT – Autoimmune Retinopathy

- **Cancer-Associated Retinopathy (CAR)**
  - Observed in different tumor types including small cell lung carcinoma (most frequent), cervical cancer, endometrial carcinoma and uterine sarcoma
  - May present after or before cancer diagnosis
  - Generally, develops after the age of 45 (female > male)
  - ***Unilateral, slowly progressive vision related to both rod and cone dysfunction***
  - ***SD-OCT = Cystic spaces + loss of the EZ, ELM and ONL***
- **Melanoma-Associated Retinopathy (MAR)**
  - Melanoma has been diagnosed and has metastasized
  - Associated with cutaneous and uveal melanomas
  - More common in men than in women
  - ***May present with visual symptoms years after the diagnosis***
    - ***Photopsia, peripheral field loss and nyctalopia***
  - ***May show ON pallor, RPE abnormalities and vessel changes***
- **Non-Paraneoplastic Autoimmune Retinopathy (nPAIR)**
  - Most common subtype (e.g. AZOOR)
  - Patients tend to be younger and FHx of autoimmune disease
  - Presents bilaterally with photopsias, scotomas, color vision changes
  - ***Must R/O malignancy and RP***
  - ***SD-OCT = thinning of ONL with irregularity of the EZ***
  - Absence of retinal degeneration, fundus lesions, or intraocular inflammation



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Subclinical Retinopathy Diagnosis

- SD-OCT
- +
- ***OCTA***

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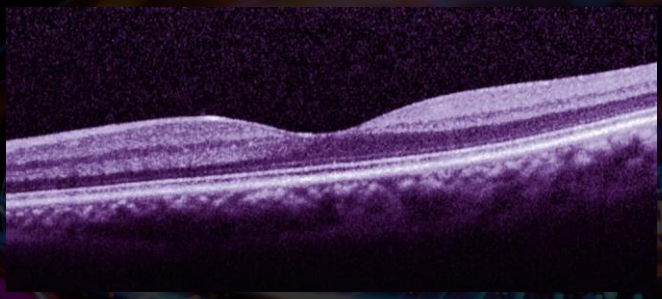
Clinical Retinal Imaging

Optical Coherence Tomography + Angiography



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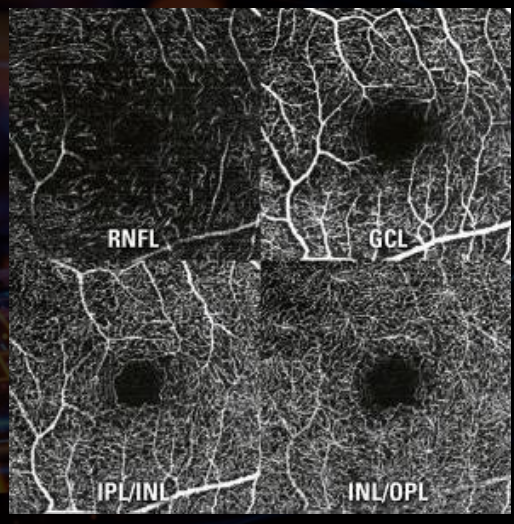

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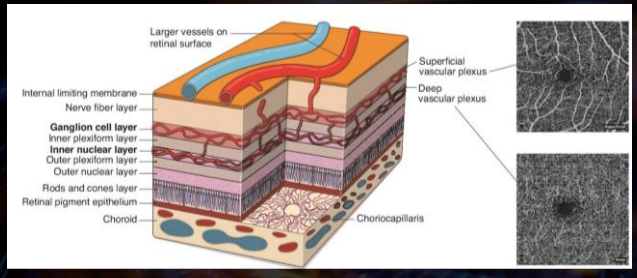
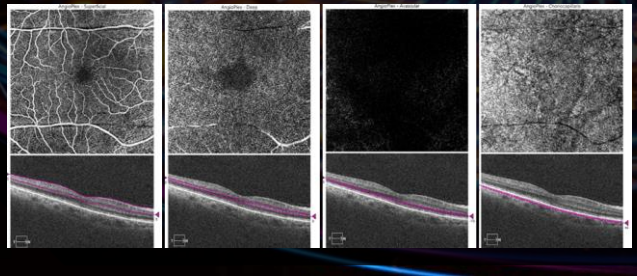
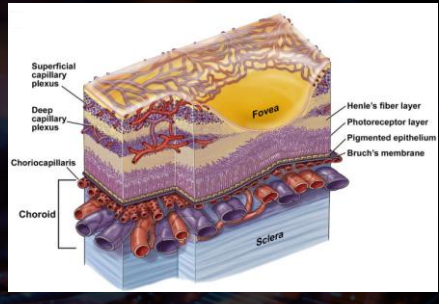
Optical Coherence Tomography Angiography Primer

Optical Coherence Tomography Angiography (OCTA)







Superficial capillary plexus (SCP)
Within NFL and GCL at the same level as the arterioles and major venules

Deep capillary plexus (DCP)
Between the INL and the OPL

Avascular outer retina
Comprises the ONL and PR nuclear layer and photoreceptors.
normally avascular where any apparent flow is a projection artifact or results from **pathology*

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Optical Coherence Tomography Primer

OCT relationship with OCTA - Intermediate AMD

Quantitative analysis of inner retinal structural and microvascular alterations in intermediate AMD: SS-OCTA study

Photodiag and Photodynamic Therapy (2020) 32:102030

Methods

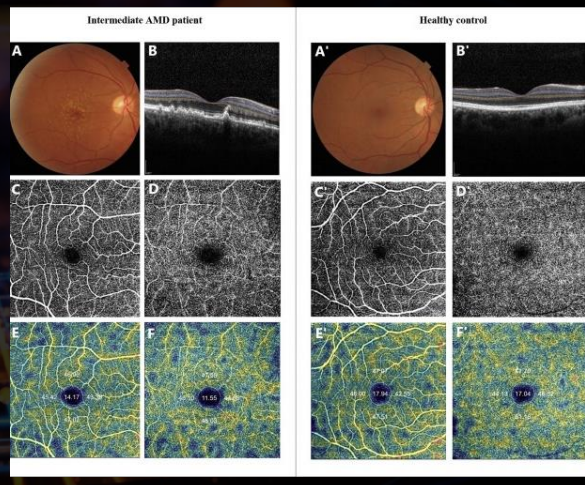
- 58 iAMD patients and 64 controls were enrolled
- RNFL, GCL, IPL, INL, OPL thicknesses analyzed in central and parafovea
- FAZ area and vessel density of the SCP and DCP in the fovea and parafoveal region were obtained

Results

- ***RNFL, GCL, and IPL were significantly thinner compared to controls***
- ***Parafoveal SCP vessel density significantly decreased compared to controls***
- ***GCC was significantly correlated with SCP vessel density measurements***

Conclusion

- ***Inner retina is affected in iAMD in terms of structural and microvascular components***
- ***Inner retinal thinning is significantly correlated with vessel density reduction suggesting a cause-and-effect relationship***



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Subclinical AMD Diagnosis

Optical Coherence Tomography Angiography

Retinal vessel density in exudative and nonexudative AMD on OCTA

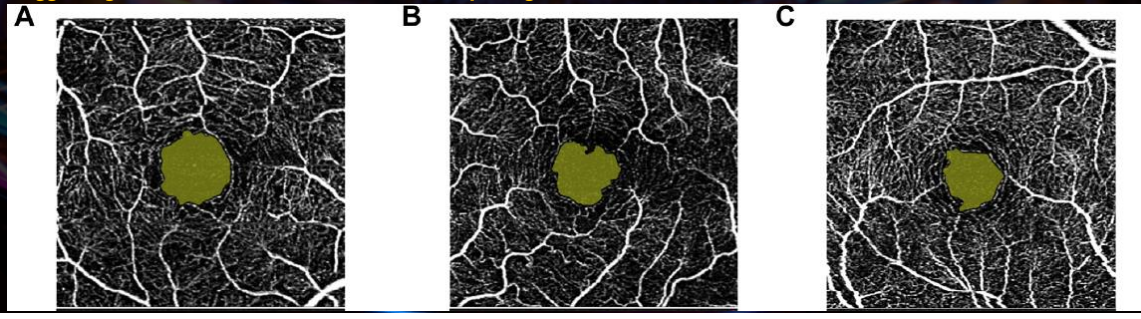
American Journal of Ophthalmology (2020) 212:7-16

Results

- In eyes with AMD, vessel density (VD) decreases with age in the foveal, parafoveal and full macular regions
- Exudative AMD demonstrated lower VD especially in the parafoveal (30%±6% vs 33%±6%) and full regions (28%±6% vs 31%±6%) compared with atrophic AMD

Conclusion

- ***Retinal VD is decreased in eyes with exudative AMD compared with atrophic AMD but is unaffected by anti-VEGF treatments suggesting a retinal vascular contribution to the pathogenesis of AMD.***



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Subclinical AMD Diagnosis

Choroidal Neovascularization (CNV)

- **Type 1 – Occult**
  - New vessels develop in the choroid located BELOW RPE and ABOVE Bruch's
- **Type 2- Classic**
  - New vessels develop in choroid located ABOVE RPE and ABOVE Bruch's
- **Type 3- RAP (Retinal Angiomatous Proliferation)**
- **Type 4- Mixed**

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Optical Coherence Tomography Primer

OCT relationship with OCTA - Diabetic Retinopathy

Evaluation of vessel density in DRIL after resolved DME using OCTA

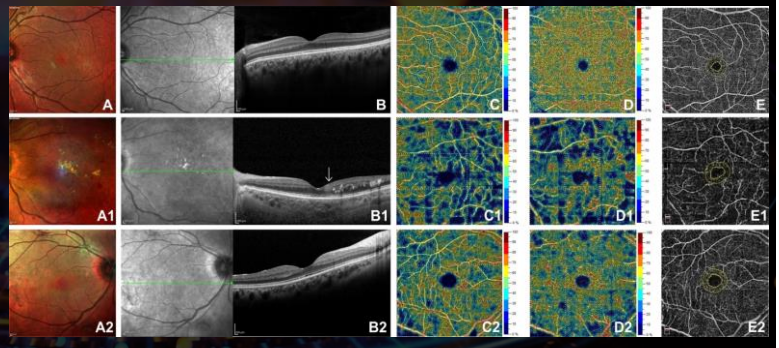
Plos ONE (2021) 16(1)

Methods

- 37 DRIL patients (63±14), 30 (+) DR, (-)DRIL patients and 35 controls were evaluated for VD in the macular region SCP, DCP and FAZ

Results

- DRIL and no DRIL groups showed decreased VD in SCP and DCP and larger FAZ compared to controls
  - ***DRIL shows statistically significant***
    - ***Reduction in VD***
    - ***Increased FAZ***
- Significant negative correlation between foveal SCP, DCP and BCVA in DRIL group



Conclusions

- ***Presence of DRIL significantly associated with:***
  - ***Decreased SCP and DCP vascular density***
  - ***Increase FAZ***
  - ***Decreased BCVA***

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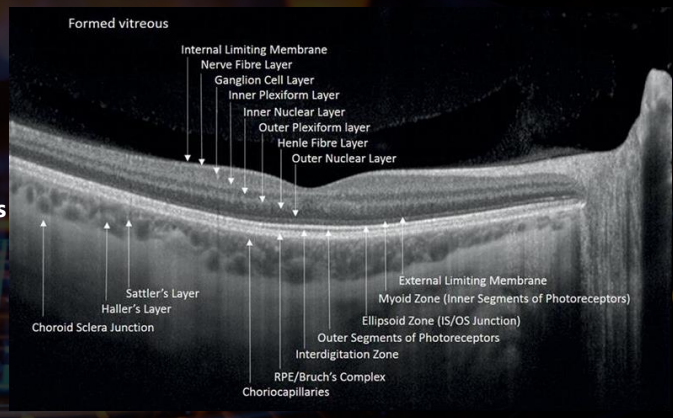
Take Home Points

- ***OCT has limited value in isolation***
  - **Clinical Signs**
    - **Amsler Chart 7**
    - **Photostress test**
    - **Watske-Allen**
  - **Color fundus photos**
  - **FAF photos**
- ***OCT has direct correlation to OCTA***
  - **DRIL and EZ disruption are manifestations of underlying SCP and DCP perfusion deficits**
- ***OCT is a medically reimbursable procedure***
  - **Ophthalmic conditions**
  - **Systemic conditions**
- ***Clinical pathology generally shows in:***
  - ***Vitreoretinal interface***
  - ***Inner retinal***
  - ***Outer retina***
  - ***Bruch's/RPE***
  - ***Choroid***



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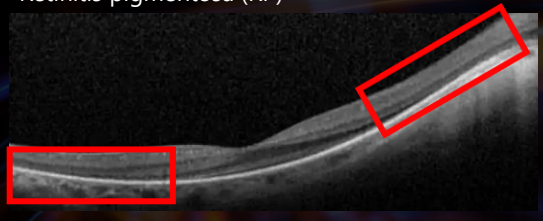
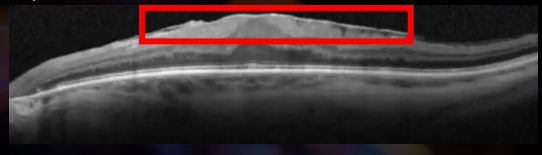
Take Home Points

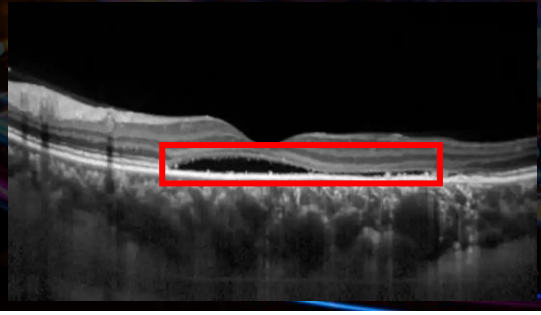
Retinitis pigmentosa (RP)



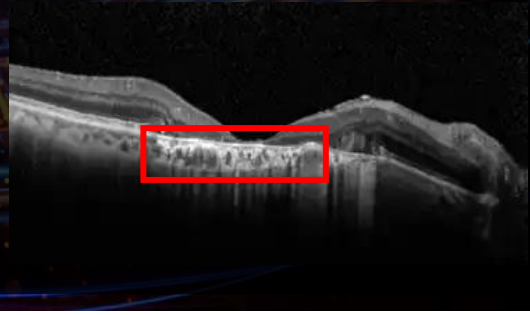
Epiretinal Membrane (ERM)



Central Serous Chorioretinopathy (CSC)



Geographic Atrophy



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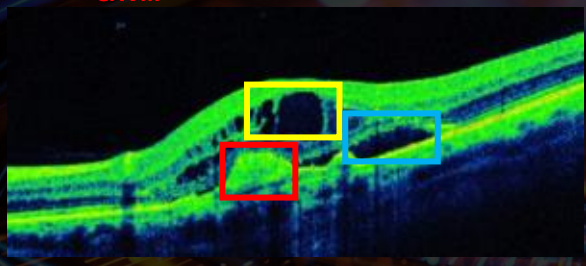
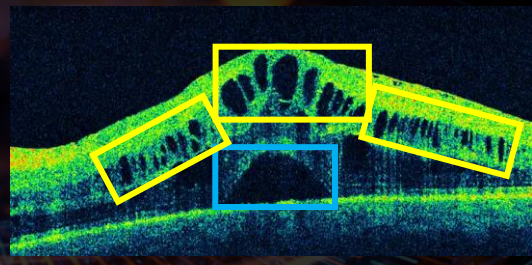
Take Home Points

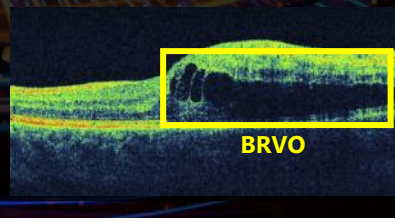
- **nvAMD**
  - **Intraretinal fluid**
  - **Subretinal fluid**
  - **CNVM**



- **Diabetic Macular Edema (DME)**
  - **Intraretinal fluid w/n OPL***
  - **Subretinal fluid**



- **Retinal Vein Occlusion (RVO)**
  - **Intraretinal fluid***



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Take Home Points

Clinical correlation required

- **Epiretinal membrane (ERM)**
  - Above ILM at vitreoretinal interface
  - Hyperreflective membrane causing traction on the inner retinal surface
  - ***Older patient, often with PVD describing central distortion***
- **Diabetic Macular Edema (DME)**
  - Within INL and OPL
  - Hypo-reflective cysts
  - ***H/O DM, central vision blurry, often with worsened DR***
- **Central serous retinopathy (CSC)**
  - Outer retina, sub-RPE
  - Hypo-reflective serous fluid
  - ***Younger male, Type A, steroid/hormone medication use***
- **Age-Related Macular Degeneration (AMD)**
  - Outer retina, Bruch's/RPE
  - Hyperreflective bumps
  - ***Usually older, fair-skinned patients, minimal symptoms***

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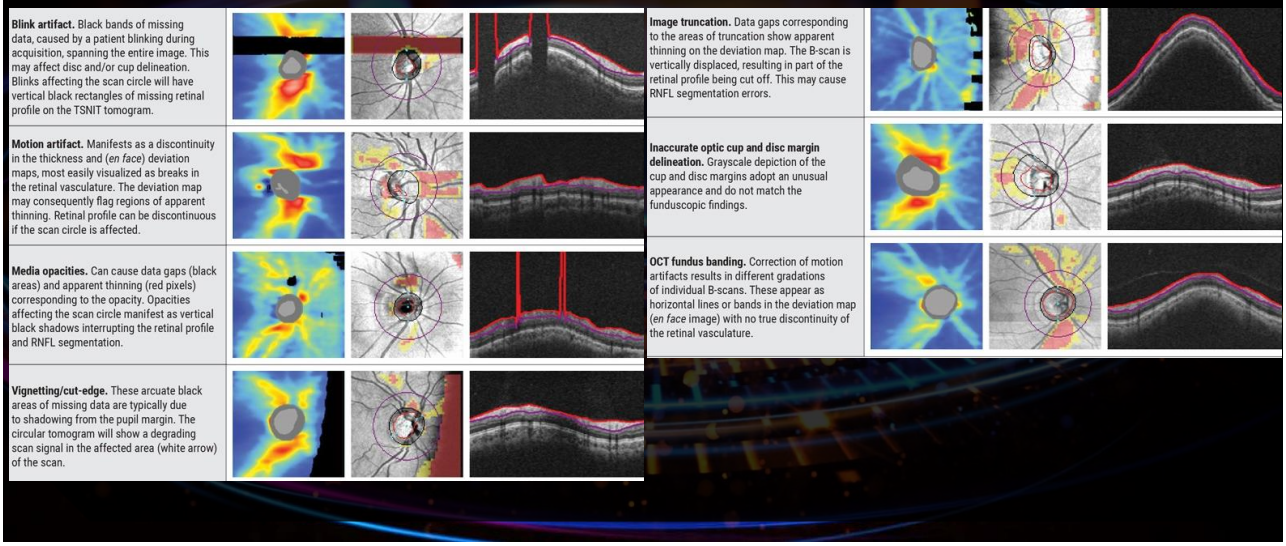
Take Home Points



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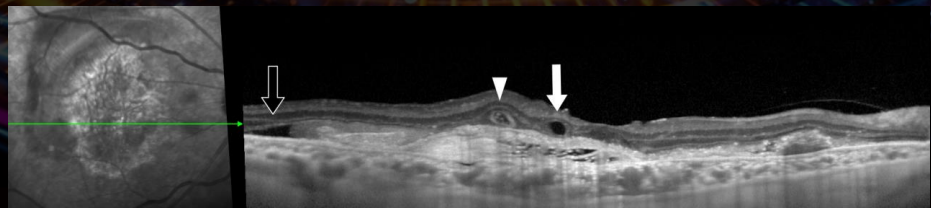
Take Home Points

Pro Tips

- **Within SD-OCT, sensitivity is not constant throughout the image**
  - As the tissue of interest moves further from the point of maximum sensitivity ***(zero delay line)***, image quality can decrease and noise can increase
  - ***Setting change can acquire images with either vitreous or choroid closer to zero delay line***
    - Default Setting: Most devices utilize maximal sensitivity on vitreous side
- **Consider review of layer segmentation lines if clinical correlation doesn't match**
  - Macular GCC = NFL + GCL + IPL ***(DEVICE DEPENDENT… NEXT SLIDE)***
    - ***Automated placement of layer segmentation may erroneously measure thickness***
- **Outer retina tubulations (ORT)**
  - ~2.5% of nvAMD patients show ORTs at time of diagnosis
    - ***~45% of nvAMD develop ORTs over 4 years***



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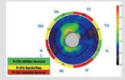
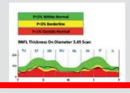
Take Home Points

Pro Tips

Table 1. OCT Devices the Authors Have Used to Analyze Progression

	Cirrus HD-OCT (Carl Zeiss Meditec)	Spectralis OCT (Heidelberg Engineering)	RTVue-100 (Optovue)
Axial resolution	5 µm	7 µm	5 µm
Scanning speed	27,000 A-scans/sec	40,000 A-scans/sec	26,000 A-scans/sec
Manufacturer signal index (MSI) recommended threshold	Signal strength = 6 or 7 (max=10)	Quality = 15 (max=40)	Signal strength index = 39 (max=100)
RNFL scanning protocol	6x6 mm³ cube centered on optic disc; RNFL thickness generated from 3.46-mm diameter circle	3.45 mm circle scan centered on optic disc	Radial and circular scans centered on optic disc; RNFL thickness generated from a 3.45-mm diameter circle
RNFL thickness map	OD 	OD	OS 
Normative database and reporting			
Macular scanning protocol	6-mm² grid measures the macular GCIPL thickness with an elliptical annulus around the fovea	30° x 25° volumetric scan of 8x8-mm² grid oriented on foveal-BMO axis	7-mm² area of macula, with center shifted 0.75 mm temporally
Retinal layers measured in the macula	GCIPL measures ganglion cell layer and inner plexiform layer	Full thickness macula	GCC measures RNFL, ganglion cell layer and inner plexiform layer
Macular thickness map	OS 	OS 	OD 

Abbreviations: RNFL= retinal nerve fiber layer thickness; GCIPL= ganglion cell inner plexiform layer; GCC= ganglion cell complex.

Average RNFL Thickness

	Zeiss	Spectralis
Healthy	94 ± 8µm	103 ± 10µm
Suspect	87 ± 10µm	92 ± 10µm
Glaucoma	70 ± 10µm	73 ±11µm
Normal RNFL Loss	-0.50 µm/yr	-0.60 µm/yr
OAG RNFL loss	-1.0 µm/yr	-2.0 µm/yr
RNFL floor values	***60µm****	***50µm****

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Questions?

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