

# Retinal OCT Interpretation

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The diagram shows the layers of the retina: Nerve fiber layer, Ganglion cell layer, Inner plexiform layer, Outer plexiform layer, Outer nuclear layer, Inner nuclear layer, and Outer retina. The fundus image shows the optic disc and macula, with an OCT scan overlaid on the macula.

# Objectives

- ▶ Overview and introduction to OCT technology
  - ▶ The goal is to help novices and experts alike to better understand OCT's capabilities in clinical practice.
- ▶ Specific OCT macula, pathological conditions and cases will be reviewed.

The series of OCT images shows various macular conditions: Figure 1a: Normal macula; Figure 1b: Macula with retinal detachment; Figure 1c: Macula with subretinal fluid; Figure 1d: Macula with subretinal fluid and drusen; Figure 1e: Macula with drusen; Figure 1f: Macula with drusen and subretinal fluid; Figure 1g: Macula with drusen and subretinal fluid; Figure 1h: Macula with drusen and subretinal fluid; Figure 1i: Macula with drusen and subretinal fluid.

Which eye?

A. OD  
B. OS

The OCT image shows a macula with a question mark, indicating a diagnostic challenge. The image is a cross-section of the retina, showing the layers and the macula.

# Intro/History: Optical Coherence Tomography

- ▶ OCT was first introduced in 1991
- ▶ Due to the transparency of the eye (i.e. the retina can be viewed through the pupil), OCT is an invaluable ophthalmic diagnostic tool.
- ▶ Time domain to Spectral/Fourier Domain

# Time vs Spectral Domain OCT

Comparison of OCT Images

OCT 1/2 (Time Domain)		1996
Status OCT (Time Domain)		2002
RTVue (Fourier Domain)		2006

# Time vs Fourier domain OCT

Time domain OCT	Fourier domain OCT
<ul style="list-style-type: none"> <li>• A scan generated sequentially, one pixel at a time of 1.6 seconds</li> </ul>	<ul style="list-style-type: none"> <li>• Entire A scan is generated at once based on Fourier transformation of spectrometer analysis</li> </ul>
<ul style="list-style-type: none"> <li>• Moving reference mirror</li> <li>• 400 scans/sec</li> <li>• Resolution - 10 micron</li> <li>• Slower than eye movement</li> </ul>	<ul style="list-style-type: none"> <li>• Stationary reference mirror</li> <li>• 26,000 scans/sec</li> <li>• Resolution - 5 micron</li> <li>• Faster than eye movement</li> </ul>

The comparison shows two OCT images side-by-side. The left image is a Time domain OCT image, and the right image is a Fourier domain OCT image. The Fourier domain image shows a much higher resolution and faster acquisition time.

### Epiretinal Membrane With Pseudohole: Time Domain vs. Spectral Domain OCT

**Time domain OCT**  
Very difficult to determine presence/absence of ERM. All views with similar show similar images.

**Spectral domain OCT**  
ERM is clearly visible.

Labels in images: Epiretinal membrane, Retinal surface.

### Time vs Spectral Domain OCT

**Time Domain (TD-OCT)**

- Advantage**
  - Intensity information is acquired in time domain
  - 10 microns resolution
- Disadvantage**
  - Limited acquisition rate due to moving reference mirror

### Spectral/Fourier Domain (SD-OCT)

- Advantages:**
  - Higher sensitivity than TD-OCT
  - No moving reference mirror required
  - High scanning speed
  - Single axial resolution through the tissue by evaluating frequency spectrum of the interference between the reflected light and a stationary reference mirror.
  - Up to 5 microns of resolution, 3 microns in newer devices
  - Increased resolution can decrease motion artifacts
  - Repeatability for tracking progression
- Disadvantages**
  - Noticeable signal drop off with depth

### SD-OCT

- Four commercially available spectral-domain (SD) OCT models
  - Spectralis SD-OCT (Heidelberg Engineering)
  - 3D OCT-2000 (Topcon Medical Systems)
  - Avanti RTVue XR (Optovue)
  - Cirrus HD SD-OCT 5000 (Carl Zeiss Meditec)

### Figures E-H. Macular Thickness Analysis By Manufacturer

**E. Avanti RTVue XR.** Normal macular thickness horizontal cross line scans with intact foveal pit contours and good scan alignment to OS.

**F. Spectralis SD-OCT.** Horizontal line scans OU showing RPE disruption OS greater than OD and drusen deposition OS. Mild vitreal macular traction is noted nasal to the macula OS.

**H. Cirrus HD OCT 5000.** macular cube scan OS with color and red free fundus images and horizontal B-scan with normal macular anatomy.

**3D OCT-2000.** macular thickness cube scan OS with color and red free fundus images and horizontal B-scan with normal macular anatomy.

**Vertical tomogram**  
ETDRS grid with thickness measurements, displayed in each macular sector.

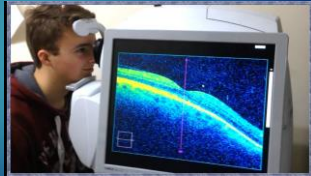
**Horizontal tomogram**  
3D surface map representing the LM through the RPE as well as individual layer assessment.

**H. HD-OCT 5000.** macular cube scan OS with intact RPE and mild sector macular thinning compared to normative data.

**Color-coded summary of central subfield thickness, cube volume and average cube thickness compared to normative data.**

## Advantages of OCT

1. Non-invasive
2. Non-contact
3. Painless
4. Fast
5. Reliable
6. Sensitive
7. Radiation-free

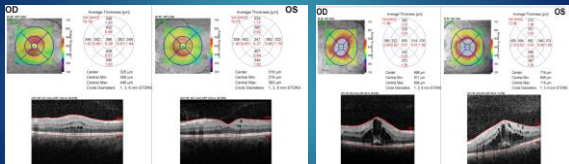


## Indications

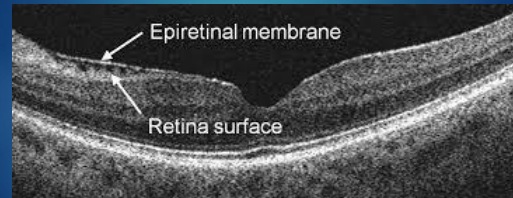
1. Examination of retinal layers
2. Monitor progression
3. Treatment planning
4. Monitor Response to therapy



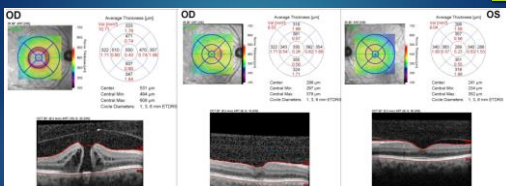
## Monitor progression



## Treatment planning



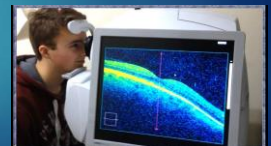
## Monitor response to therapy



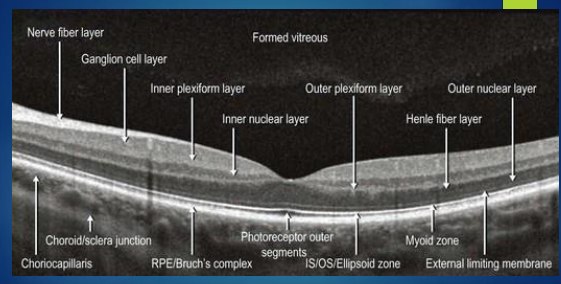
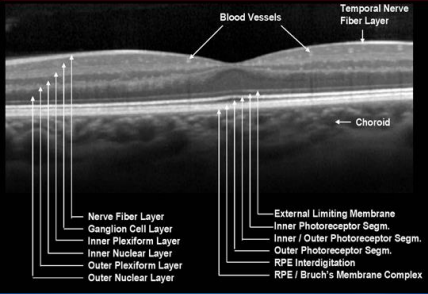
- ▶ Macular hole of right eye s/p PPV, ILM peel, S6 Gas 10/15/20
- ▶ Vision at baseline 20/100, improved to 20/50-2

## Limitations

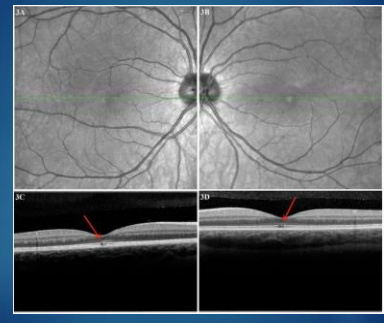
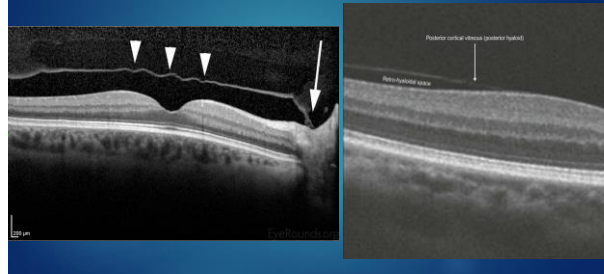
1. Good lacrimal layer needed
2. Transparent media needed
3. Dilation may be necessary
4. Limited to posterior pole



### Retinal Labeled Layers (Image zoomed to ~15°)

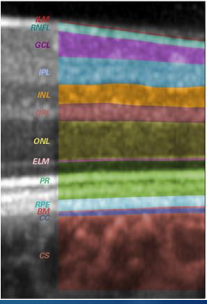


### Vitreous

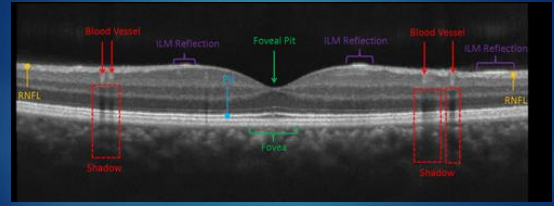


### Retinal Layers

Abbr.	Name
ILM	Internal Limiting Membrane
RNFL	Retinal Nerve Fibre 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
PR	Photoreceptor Layers
RPE	Retinal Pigment Epithelium
BM	Bruch's Membrane
CC	Choriocapillaris
CS	Choroidal Stroma

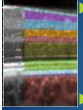


### PIL / Ellipsoid Zone / IS-OS Junction

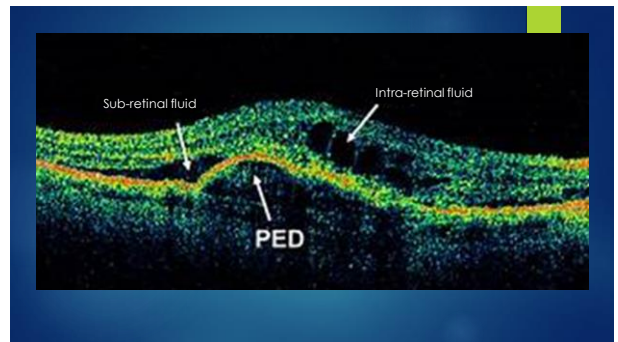
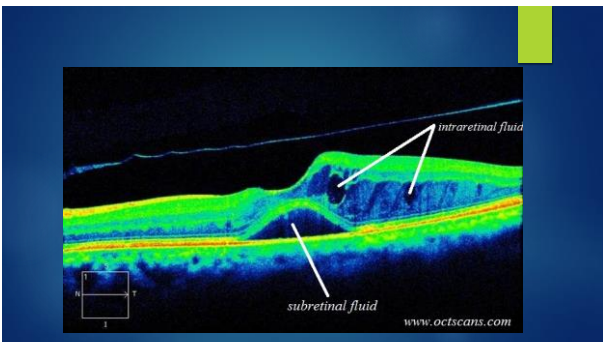
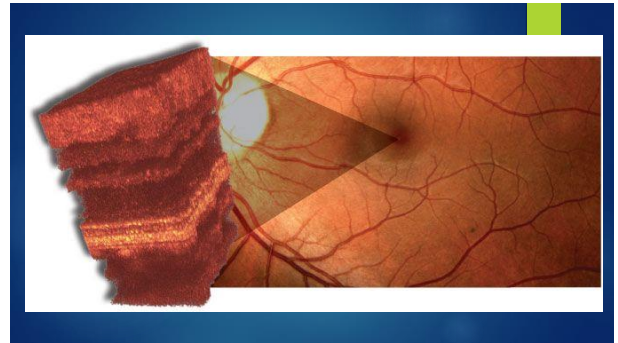
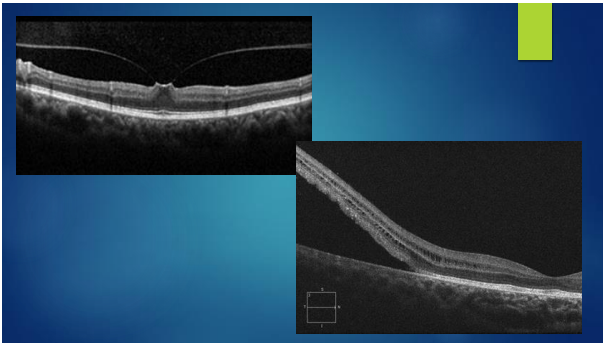
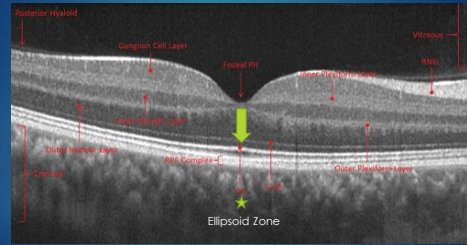


## PIL / Ellipsoid Zone / IS-OS Junction

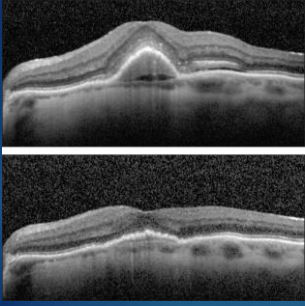
- ▶ Biomarker of photoreceptor integrity
- ▶ Junction between the inner & outer segments
- ▶ Can be considered an artifact due to difference in index of refraction of inner & outer segments
  - ▶ Prominent & very useful on OCT scans, barely visible in histological sections
- ▶ PIL is continuous throughout entire OCT scan in normal eyes



## OCT of normal eye



### Pigment Epithelial Detachment

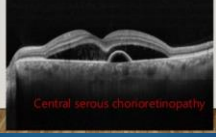


▶ A patient with a new occult CNV with PED and subretinal fluid (top) was treated with two monthly intravitreal injections of ranibizumab with flattening of the PED and resolution of the SRF (bottom).

### PED / Hypo-reflectivity

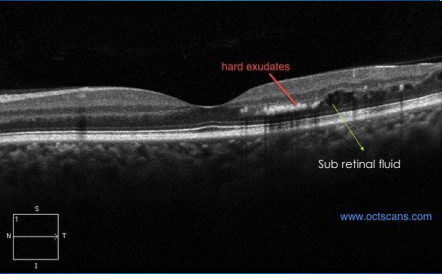
Retinal pigment epithelial detachment appears as

- a well defined, dome shaped hypo-reflective elevation of the RPE with cystic hypo-reflectivity.
- Such detachments may be present within the area of serous detachment or in an adjacent area



Central serous chorioretinopathy

### Exudates

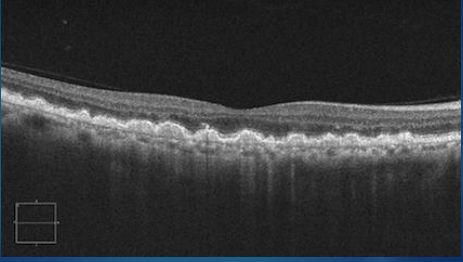


hard exudates

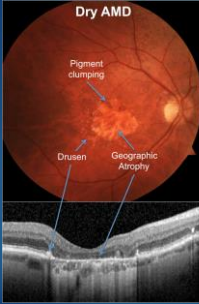
Sub retinal fluid

www.octscans.com

### Drusen



#### Dry AMD




Pigment clumping

Drusen

Geographic Atrophy

#### Wet AMD



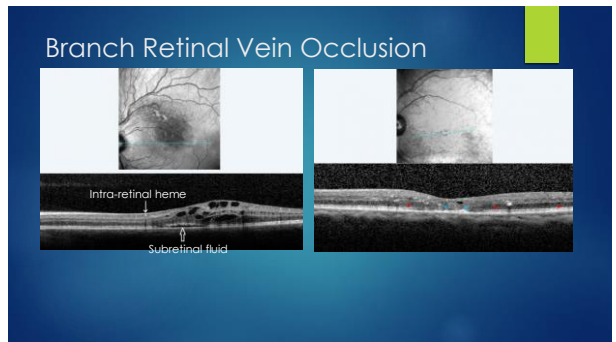
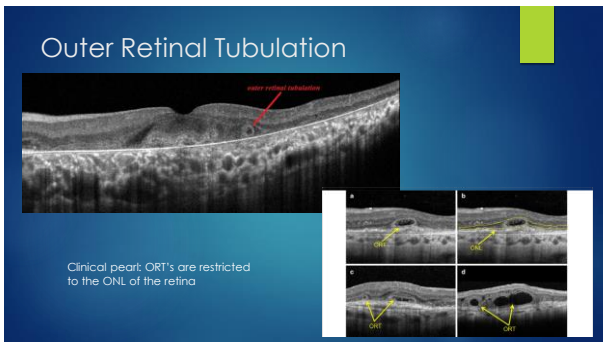
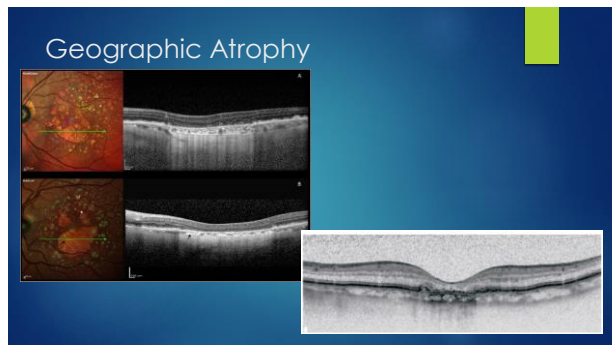
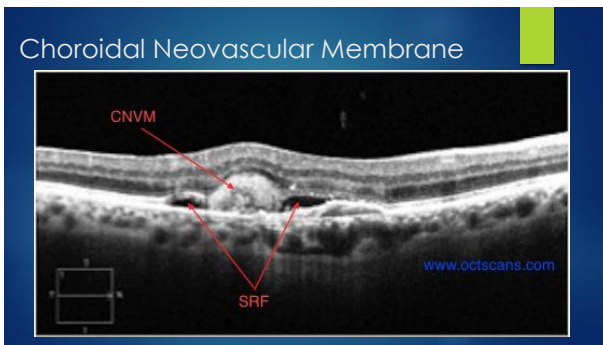
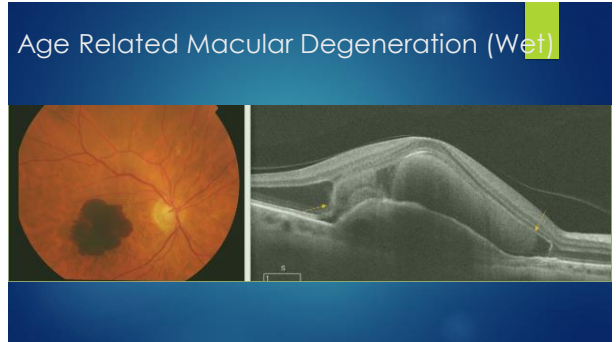
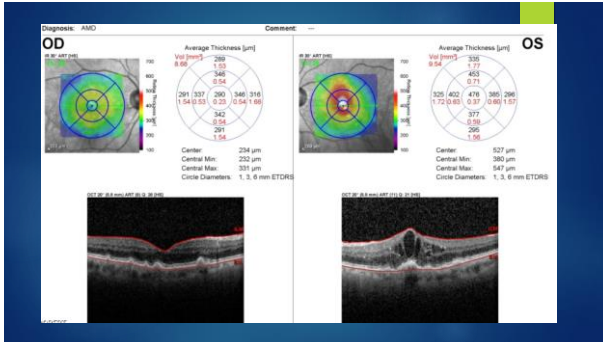
Subretinal Hemorrhage

### Case

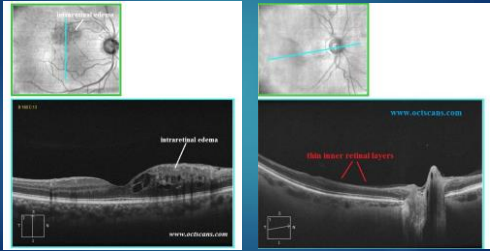
- ▶ 87 y/o Caucasian Male
- ▶ Visual Acuity (Snellen - Linear)
 

	Right	Left
▶ Dist sc	20/50 -2	20/400
▶ Dist ph sc	20/40 -1	20/150 -1
▶ Near cc	20/30	20/200
- ▶ Tonometry (Applanation, 4:05 PM)
 

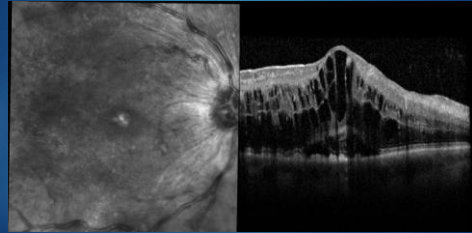
	Right	Left
▶ Pressure	12	13



## Branch Retinal Vein Occlusion

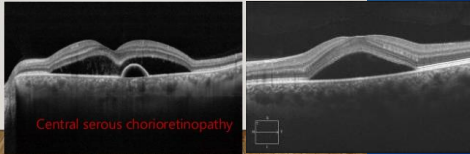


## Central Retinal Vein Occlusion

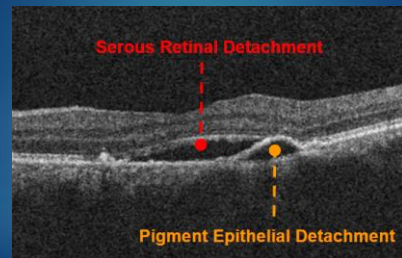


## CSCR

- Retinal pigment epithelial detachment appears as
- a well defined, dome shaped hypo-reflective elevation of the RPE with cystic hypo-reflectivity.
  - Such detachments may be present within the area of serous detachment or in an adjacent area



## CSCR



## Case History

### ► Patient

- 49 year-old Caucasian male

### ► Chief complaint (7/16/12)

- Vision was variable around the time of renal transplant in 2004 and 2011. Patient reported that vision has stabilized since after the transplant. No other visual complaints at present visit in 7/2012.

#### Medical Hx

- Chronic Kidney Disease, Stage 3; (Status-post renal two renal transplants, both at Dartmouth Hitchcock Medical Center in 2004 and 2011). Patient had been on dialysis prior to each transplant. On long term oral Prednisone. Also on dual immunosuppression with Prograf and Cellcept.

- Anemia of Chronic Kidney Disease

- Hypertension

- Secondary Hyperparathyroidism


#### Medications

- Diltiazem
- Tacrolimus
- Mycophenolate
- Metoprolol
- Simvastatin
- Calcitriol
- Sildenafil

## Clinical Findings

- **VA:** OD 20/20-2 and OS 20/40
- **Rx:** OD: plano-0.25X20 and OS: -0.25-0.50X105; +1.75 add
- **Pupils:** PERRL (-) APD
- **EOM:** smooth and full without diplopia or pain OU
- **Confrontation visual fields:** full to finger counting OU
- **Amsler Grid:** within normal limits OD, mild central metamorphopsia OS
- **Slit lamp exam:** within normal limits
- **IOP:** 14 OD and 14 OS at 2:00 PM by Applanation
- **Lens:** trace nuclear sclerotic cataracts OU.
- **Vitreous:** clear OU
- **CDR:** 0.20 round OD and OS
- **Rims:** pink and healthy
- **Margins:** distinct OU
- **Macula:**
  - **OD:** one circular area of pigment hyperplasia superior nasal to the macula and one less pigmented area of hyperplasia inferior nasal to the macula with mild retinal pigment epithelium mottling
  - **OS:** two circular areas of pigment hyperplasia adjacent to each other and moderate mottling
- **Vessels:** mild tortuosity OU
- **Posterior Pole:** clear OD, one spot of hyperpigmentation in the inferior temporal arcade OS
- **Periphery:** flat, No holes, tears or detachments OU





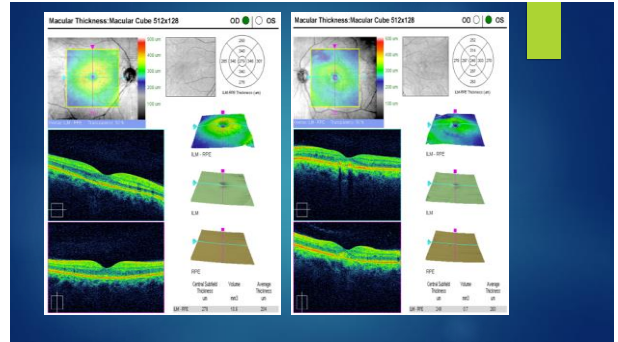
▶ OD: One circular area of pigment hyperplasia superior nasal to the macula & one less pigmented area of hyperplasia inferior nasal to the macula with mild retinal pigment epithelium mottling

▶ OS: Two circular areas of pigment hyperplasia adjacent to each other with moderate mottling

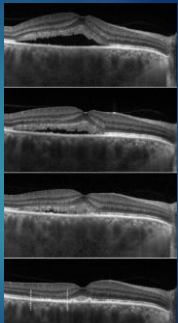
**(Assessment // Plan)**

1. Macular defect OS, longstanding since acute renal failure in 2000  
DFE in 4-6 months
2. Essential Emmetropia with Presbyopia OU  
Near prescription given

▶ No history of eye surgery or eye injury



### CSCR progression

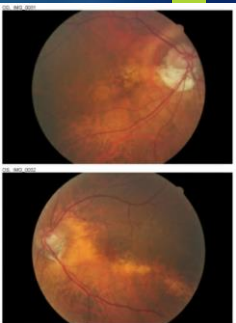
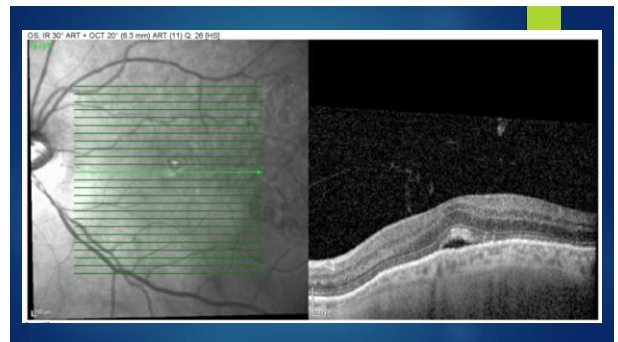
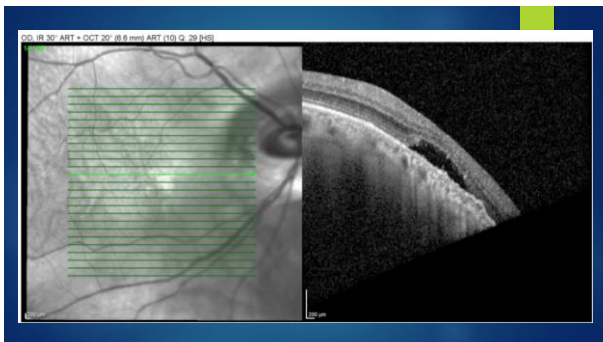


### Myopic Degeneration

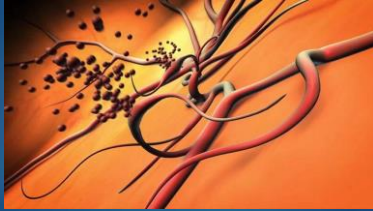
Fuchs spot is an area of RPE hyperplasia suspected to be the response of the RPE to previous regressed CNV

Myopic CNV is reported in 5% to 10% of cases of pathologic myopia.

Staphyloma development, characterized by outpouching of scleral tissue, typically involving the optic disc or the macula associated with lacquer cracks, RPE attenuation, epiretinal membrane and macular or foveal schisis

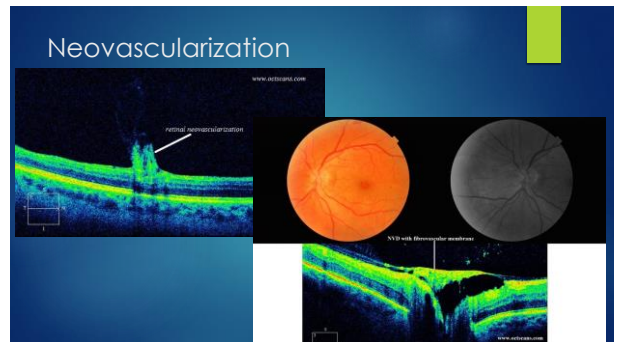
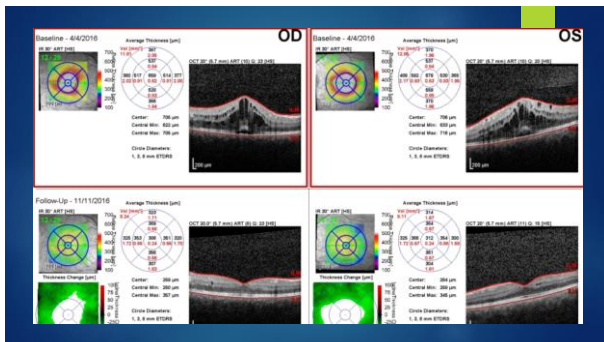
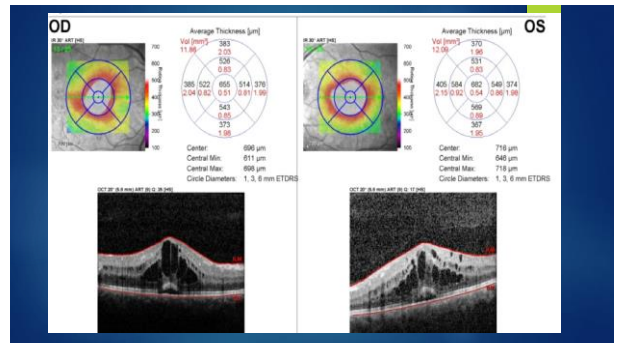
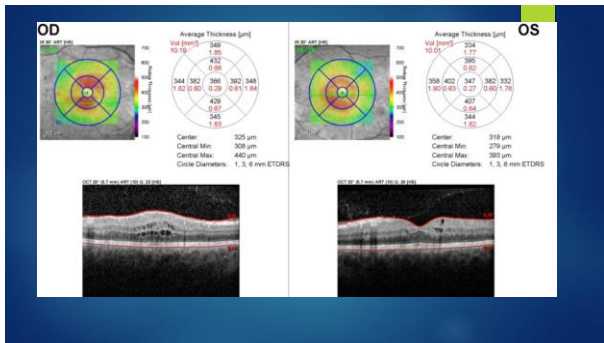



## Questions?

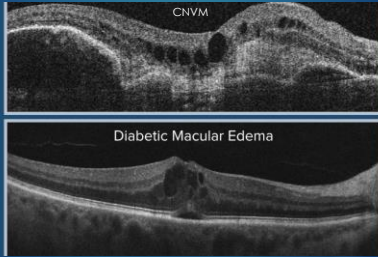


## Case

- ▶ 41 year old Caucasian male
- ▶ T2DM, HTN, obesity, OSA
- ▶ Diabetic, checks BG 2-4x per day.
- ▶ **Last BG 200, Last A1c 12+, BP 140/90**
- ▶ Chief complaint: blurred vision
  
- ▶ BCVA: 20/30 OD and OS
- ▶ Normal EOMs, Full CFF, PERRL (-) APD
- ▶ Normal slit lamp exam, IOP 14 OD, 13 OS
- ▶ Fundus exam remarkable for HMAS, CWS, exudates, no NVD, no NVE OU, macular thickening OU



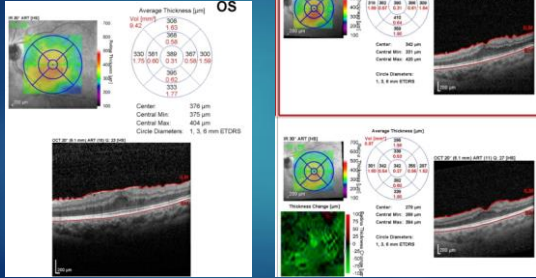
Re-cap / Clinical Pearl



Watzke Allen's sign



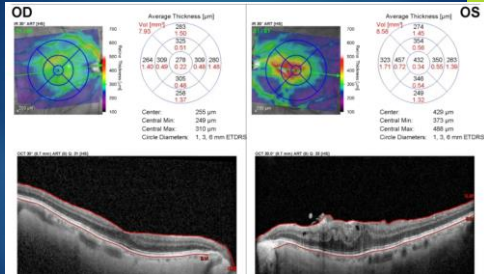
Epiretinal Membrane



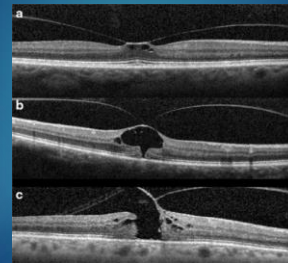
CLASSIFYING VMA

CLINICAL STAGES	ATTRIBUTES	COMMENTS
VMA	Vitreous adhesion to central macula with no demonstrable retinal morphologic changes.	Has been called stage 0 in the past when contralateral eye has FTMH, normal appearance on clinical examination, no symptoms.
VMT	Vitreous adhesion to central macula with demonstrable changes by OCT but no full-thickness tissue dehiscence; may include the following: tissue cavitation, cystoid changes in macula, loss of foveal contour, elevation of fovea above the RPE.	May or may not have yellow changes in central macula on examination; can be referred to as impending macular hole if FTMH is present in contralateral eye.
Small FTMH	Hole $\leq 250 \mu\text{m}$ ; may be round or have a flap adherent to vitreous; operculum may or may not be present.	Visual acuity may be relatively good; optimal size for successful repair by pharmacologic vitreolysis; very high probability of success with vitrectomy surgery.
Medium FTMH	Hole $> 250$ but $\leq 400 \mu\text{m}$ ; may be round or have a flap adherent to vitreous; operculum may or may not be present.	High probability of success with vitrectomy surgery.
Large FTMH	Hole $> 400 \mu\text{m}$ ; vitreous more likely to be fully separated from macula.	Slightly less probability of successful closure with vitrectomy surgery.

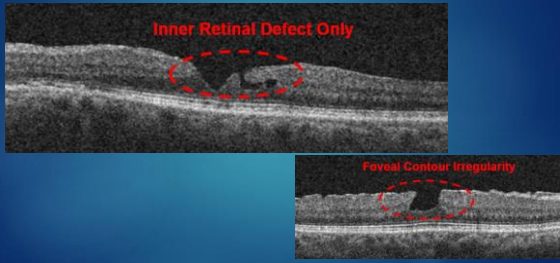
FTMH, full-thickness macular hole; OCT, optical coherence tomography; RPE, retinal pigment epithelium; VMA, vitreomacular adhesion; VMT, vitreomacular traction.  
SOURCE - Adapted from Duker JS et al. Ophthalmology. 2013;120(12):2611-2619.



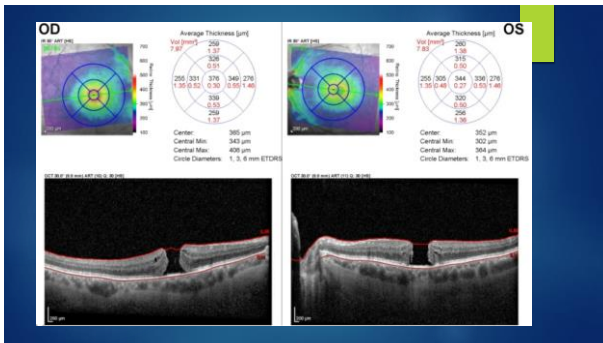
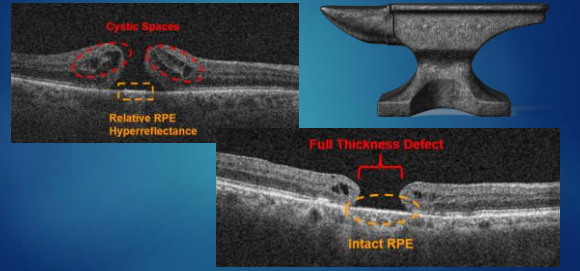
Vitreomacular Traction



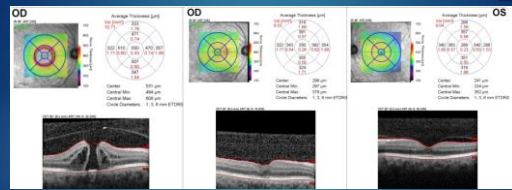
### Lamellar Hole



### Macular Hole

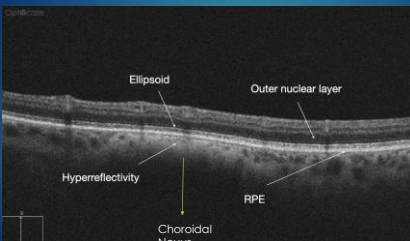


### Full Thickness Macular Hole



- ▶ Macular hole of right eye s/p PPV, ILM peel, SF6 Gas 10/15/20
- ▶ Vision at baseline 20/100, improved to 20/50-2

### Choroidal Nevus



- ▶ Deep to the RPE is a compression of the choriocapillaris (hyperreflective).
- ▶ Just below this, there is a Choroidal Nevus, a hyporefective lesion

### Choroidal Melanoma



Subretinal fluid temporal and nasal to the disc near the tumor

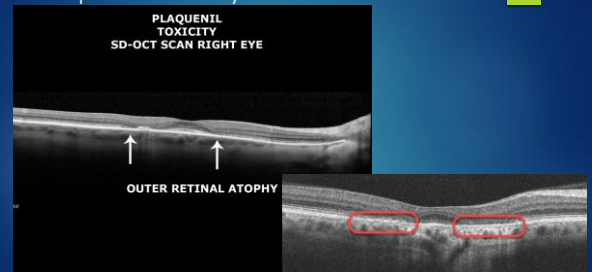
## Subretinal fluid – Choroidal Melanoma



## Antimalarial / Amiquinolines (Chloroquine & Hydroxychloroquine)

- ▶ Treatment for rheumatologic conditions
- ▶ Retinal toxicity often related to large cumulative lifetime doses over many years
- ▶ Increased risk with daily dose greater than 400 mg or (in underweight individuals, over 6.5 mg/kg ideal body weight) or total cumulative dose of more than 1000 grams, use of medication greater than 5 years, renal or liver disease, underlying maculopathy and age over 60 years

## Plaquenil Toxicity



## American Academy of Ophthalmology

- ▶ The risk of toxicity is dependent on daily dose and duration of use
- ▶ At recommended doses
  - ▶ the risk of toxicity up to 5 years is under 1%
  - ▶ up to 10 years is under 2%
  - ▶ rises to almost 20% after 20 years
  - ▶ However, even after 20 years, a patient without toxicity has only a 4% risk of converting in the subsequent year

## Case

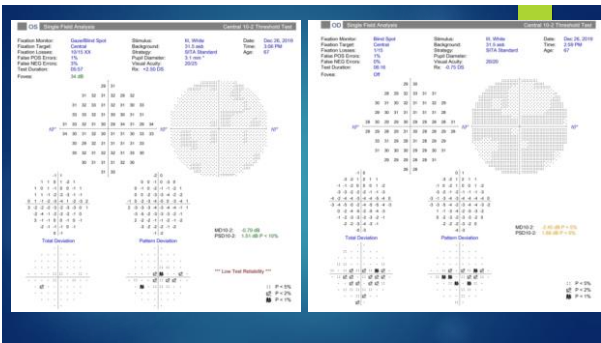
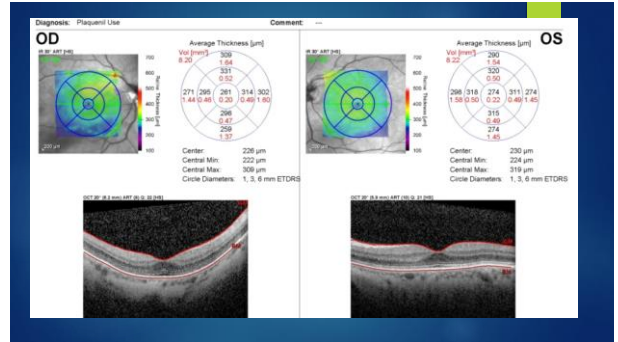
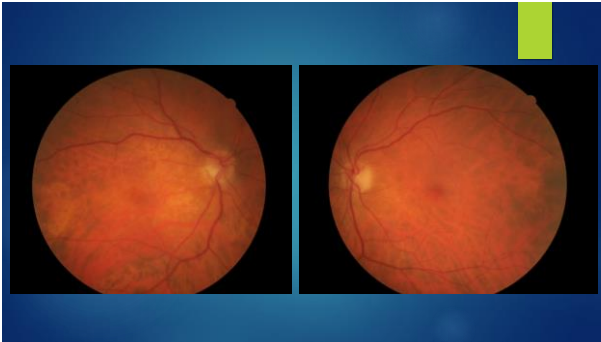
- ▶ 68 y/o Caucasian female on **Plaquenil for Rheumatoid Arthritis**
- ▶ On treatment since 2004. Has been taking 400mg/day. Body weight 178lbs = 80.7kg. Total use of 2190g

### Visual Acuity (Snellen - Linear)

	Right	Left
▶ Dist cc	20/20	20/20 -1
▶ Near sc	20/20	20/30 -
▶ V		
▶ Tonometry (Applanation, 2-45 PM)		
▶ Pressure	16	16

### Slit lamp / Fundus Exam

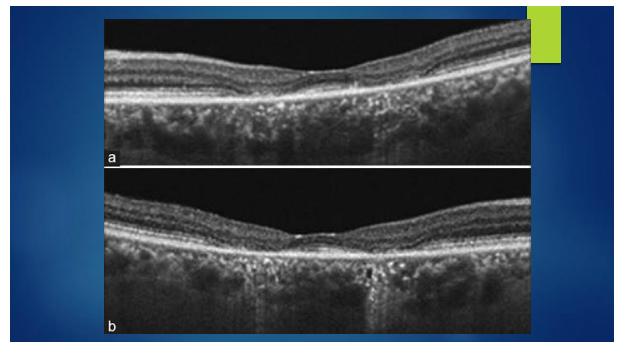
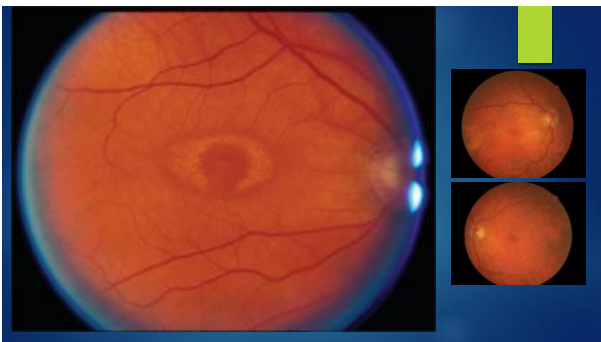
1+ NSC OU, PVD OU, ?mottling OD, otherwise unremarkable

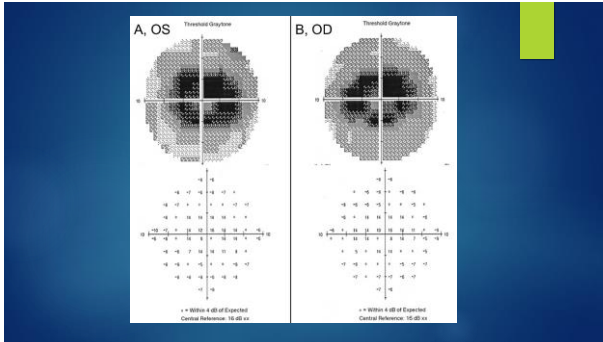


► The exam and multimodal imaging showed early signs of retinal toxicity

► Risk for toxicity is low if the total dose is <1000gr but increases thereafter. Based on this, recommended that the patient stop taking plaquenil.

► FAF monochromatic OU: normal





### Gilenya/Fingolimod – MS tx

- ▶ Treatment for multiple sclerosis
- ▶ Gilenya: **Fingolimod-associated macular edema (FAME)** is the most common
- ▶ retinal hemorrhages and retinal vein occlusion can occur

### Pentosan Polysulfate (Elmiron)

- ▶ Treatment for interstitial cystitis that millions of Americans take
- ▶ Type of pigmentary retinopathy
- ▶ First reported to cause maculopathy in 2018. In one of the papers the mean duration of treatment in the affected patients was ~18.3 years however this is likely under-reported given that this association was not known until recently.

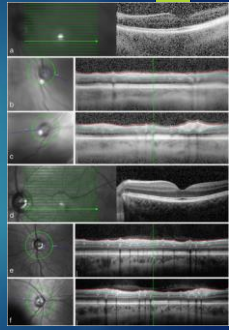
Figure 1: Representative images of a patient with PPS-associated maculopathy. A. Color fundus photography reveals paracentral hyperpigmented spots and yellowish subretinal deposits. The hyperpigmented spots appear to be an early manifestation of the condition; they are often absent in late, atrophic disease. B. Fundus autofluorescence imaging reveals striking AF abnormality, with a fairly well-circumscribed, central patch of hyper- and hypoautofluorescent spots. C. Optical coherence tomography imaging reveals focal nodules of hyperreflectance at the level of the RPE, found to co-localize with hyperpigmented spots.

### Radiation Retinopathy

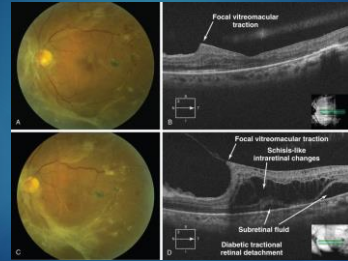
### Juxtafoveal Macular Telangiectasia

## Keratoconus

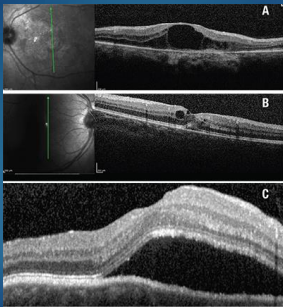
- ▶ **Optical imperfections of keratoconic corneas impaired the OCT signal to levels of diagnostic futility**
  - ▶ Neutralization of anterior irregularity of a keratoconic cornea with a fundal contact lens was sufficient to overcome the keratoconus-induced degradation of OCT signal.
- ▶ **Does Keratoconus Alter Macular Anatomy?**
  - ▶ Investigation using a fundal contact lens neutralizing the effect of the anterior corneal curvature may aid in determining the degree to which keratoconus is associated with altered macular anatomy.



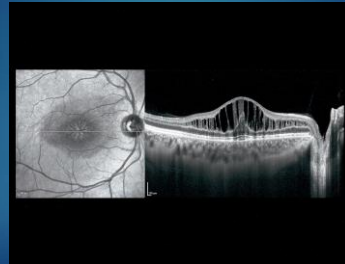
## Traction Retinal Detachment



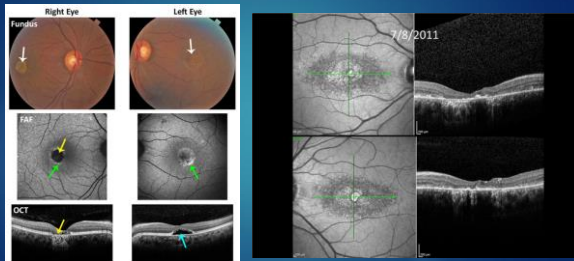
## Uveitis



## X-Linked Retinoschisis



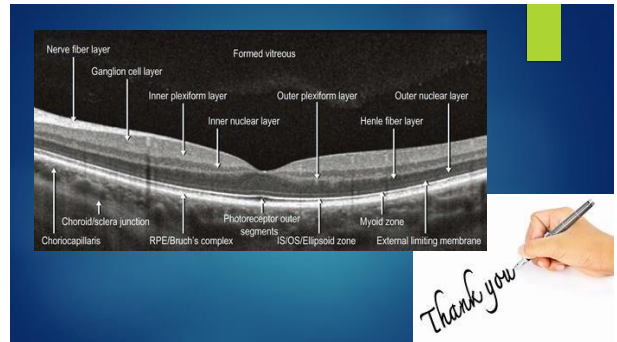
## Yolk Lesion in Best's Disease







- ▶ Understand OCT's capabilities in clinical practice
- ▶ Learn to meaningfully interpret the various lines, layers, contours and shapes in normal eyes.
- ▶ Transition to detecting variations in different retinal, choroidal and vitreal abnormalities
- ▶ With experience, estimate the VA based on appearance of the PIL/ellipsoid zone under the fovea



## References

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