PENNSYLVANIA
OPTOMETRIC
ASSOCIATION

ALL THINGS OCT

COPE #56471-PD

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FINANCIAL DISCLOSURES

- Honoraria
  - Review of Optometry
  - Optometric Management
- Paid Scientific Advisory Board Member
  - Zeiss
  - Eye Promise/Zeavision
  - Genentech
- Consulting Fees
  - Zeiss
  - Eye Promise/Zeavision

FINANCIAL DISCLOSURES

- Proprietary Interests
  - None
- Stockholder: Zeavision
- CE Companies
  - AllThingsOCT.com   Park City

FREE E-NEWSLETTER

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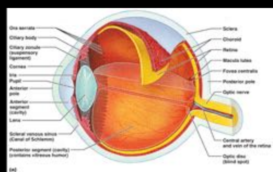
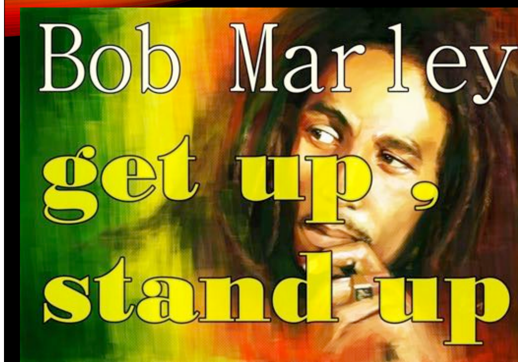
CHECK OUT OUR E-NEWSLETTER





COURSE GOAL

- To provide a broad overview of OCT and its use in clinical practice.
  - What is OCT?
  - How does it work?
  - Interpretation and clinical applications

Questions and Comments?

WHAT IS OCT?

WHAT IS OCT?

An optical imaging modality that performs high-resolution, cross-sectional tomographic imaging of the internal microstructure in materials and biologic systems by measuring back-scattered or back-reflected light. OCT images are two-dimensional data sets which represent the optical backscattering in a cross-sectional plane through the tissue.

-Fujimoto (2000)

WHAT IS OCT?

A noninvasive high resolution optical imaging technology based on interference between a signal from an object under investigation and a local reference signal. OCT can produce in real time a cross-section image of the object, i.e. a two-dimensional image in the space with a lateral coordinate, axial coordinate.

- Podoleanu (2000)

WHAT IS OCT?

OPTICAL

OCT is an imaging technology that is based on principles of physics, specifically optics.

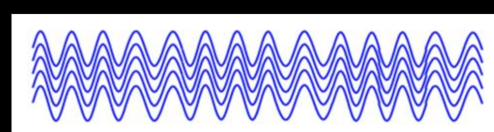
WHAT IS OCT?

COHERENCE

Coherent light is used in OCT imaging.

COHERENT LIGHT (OR, FUN WITH PHOTONS)

- Light in which the photons are all in step.
  - The change of phase within the beam occurs for all the photons at the same time.
  - There are no abrupt phase changes within the beam.
  - Light produced by lasers is both coherent and monochromatic (of one color).

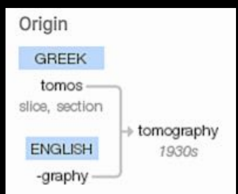


WHAT IS OCT?

TOMOGRAPHY

A technique used for displaying a representation of a cross section through a human body or a tissue.

EXAMPLES OF TOMOGRAPHY



- Computed Tomography
  - CT Scan
- Ultrasonography
  - AKA Echography
  - A-scan: 1-dimensional
  - B-mode: 2-dimensional

LET'S TRY THIS AGAIN

WHAT IS OCT?

Optical coherence tomography is a technology that uses coherent light to produce cross-sectional images.

-Pizzimenti (2018)

"Most major advances in the understanding of retinal diseases have been preceded by advances in imaging."

Richard Spaide, MD
NY Retina Consultants

Milestones in Retinal Imaging

▪Fundus Photography	1920s
▪Fluorescein Angiography	1950s
▪B-Scan Ultrasound	1970s
▪ICG Angiography (Digital)	1980s
▪CSLO (HRT), SLP (GDX)	1990s
▪OCT first demonstrated	1991
▪High-res Time Domain OCT	2001
▪Fourier (Spectral) Domain OCT	2006
▪ OCT Angiography	2015

Invasive

- Fluorescein angiography (FA)
- Indocyanine green angiography (ICGA)

Non-invasive

- Optical coherence tomography (OCT/OCTA)
- A/B scan ultrasonography
- Fundus photography
- Fundus autofluorescence (FAF)
- Wide field fundus imaging
- Multispectral imaging (MSI)
- Multi-color (multichannel) imaging

Benefits of Advanced Imaging Technologies in Optometric Practice

Benefits of Imaging

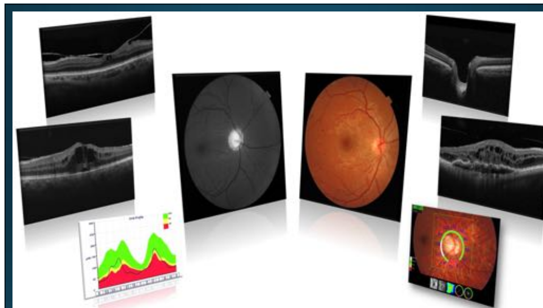
- Provide a higher level of care
  - Less referrals to sub-specialists (Dry AMD, CSC, Nevus)
  - Keep care in-house, keep revenues in house
- Use new technology as a marketing tool to attract new patients: A/B-scan, OCT, FAF, wide field fundus imaging
- I get referrals from many local ODs. You can too.
  - Become a recognized expert by reading and using the right tools. (And by attending this conference !)

OCT:

The Big Dog in Post Seg Imaging

OCT ADVANTAGES

- This non-invasive, hi res imaging can be rapidly performed *in vivo.*
- *Optical biopsy*
- AMD, DR, glaucoma, and other conditions can now be analyzed and correlated in real time to the symptomatology and prognosis.



Correlation of OCT results with history and other findings

OCT ADVANTAGES

CAPABILITIES OF SD-OCT

In our experience, spectral domain optical coherence tomography (SD-OCT) offers the following advantages:

- Simple, with a short learning curve
- Fast (2.4 seconds or less)
- Reliable
- Sensitive (resolution of 5 microns)
- Reproducible
- Noninvasive, noncontact and safe

OCT PERFORMS MANY FUNCTIONS

- Measures retinal thickness
- Measures the retinal nerve fiber layer (RNFL)
- Measures the volume of the retina
- Creates retinal thickness maps
- Isolates and creates maps of the internal limiting membrane (ILM) and the retinal pigment epithelium (RPE)
- Measures various parameters of the optic disc
- Displays three-dimensional views
- Provides classic C-scan (*en face*) analyses, creating horizontal tissue sections

OCT ADVANTAGES

With SD-OCT, clinicians can:

- Detect disease
- Evaluate treatment efficacy over time
- Quantify lesion thickness and volume
- Track disease progression
- Evaluate postoperative status
- Study 3-D views

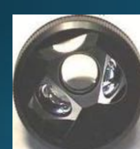
CAUTION!

OCT does

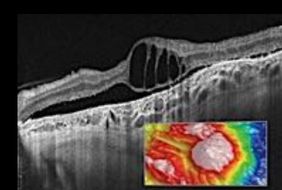
not

replace a dilated retinal examination.

Fundus Biomicroscopy and BIO



QUESTIONS AND COMMENTS?



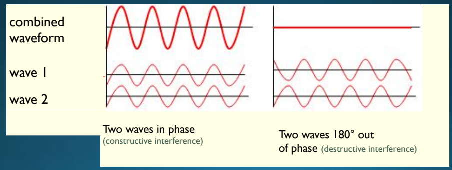
Massachusetts Institute of Technology

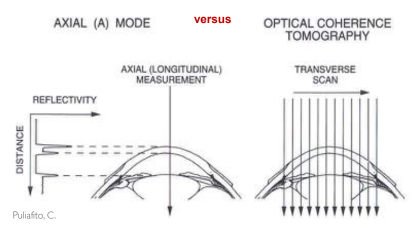
Milestones in OCT Imaging

- OCT was first demonstrated in 1991.
  - Huang D, Swanson EA, Lin CP, Schuman JS, Stinson WG, Chang W, Hee MR, Flotte T, Gregory K, Puliafito CA, Fujimoto JG. Optical coherence tomography. Science. 1991;254:1178–1181.
- The first *in vivo* tomograms of the human optic disc and macula were demonstrated in 1993.
  - Swanson EA, Izatt JA, Hee MR, Huang D, Lin CP, Schuman JS, Puliafito CA, Fujimoto JG. *In vivo*retinal imaging by optical coherence tomography. Opt Lett. 1993;18:1864–1866.
- Original research instrument 400 A-scans / second.
- Current SD-OCT instruments have imaging speeds up to 85,000 A-scans / second.

Principles of OCT

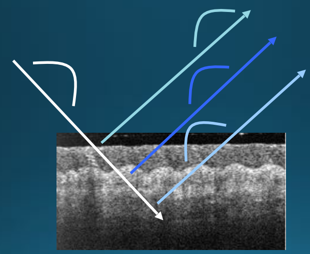
- How does it work?
- Low-coherence interferometry
- 2 waves that coincide with the same phase amplify each other
- 2 waves that have opposite phases will cancel out

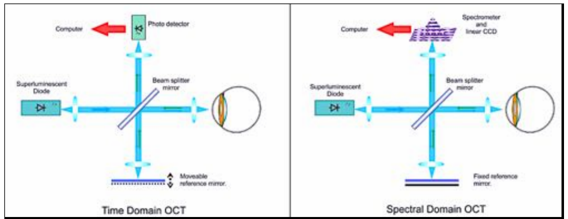




- A scan of the reflectivity of a sample tissue as a function of depth is referred to as an A-scan.
- A cross-sectional tomograph is achieved by laterally combining a series of A-scans.
- Two-dimensional data sets are digitized by a computer and presented as a gray-scale or false-color image.

OCT is analogous to B-scan ultrasound.





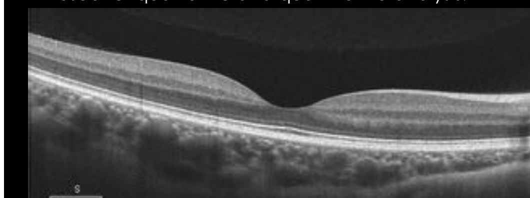
- In time domain, reference mirror is moving, slowing down the scanning rate.
- In spectral domain, reference mirror is stationary, which speeds up the scanning process.
- The information that was provided by the moving reference mirror in TD is replaced by employing a spectrometer on the detector side in SD.

Fourier Domain (Spectral) OCT

- Temporal (time) domain OCT measures light echo from a given time delay.
- Spectral/Fourier detection can measure all of the light echoes from all time delays simultaneously.
- Spectral/Fourier detects light echoes by using:
  - Interferometer
  - Spectrometer
  - High speed CCD camera
- The interference spectrum of the light is detected and digitally processed to construct the Fourier transform.

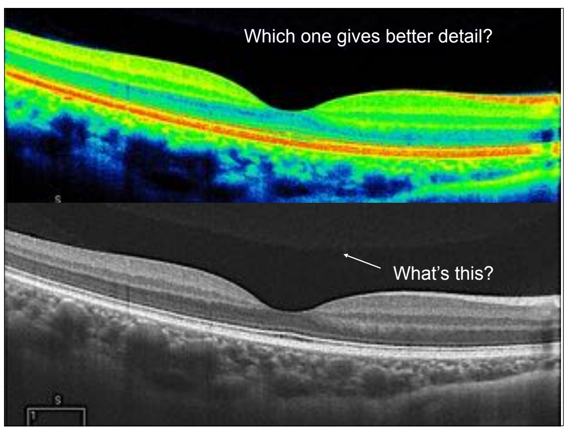
THE OCT B-SCAN

- Two-dimensional, cross-sectional.
- Used for qualitative and quantitative analysis.



SCAN STRATEGIES

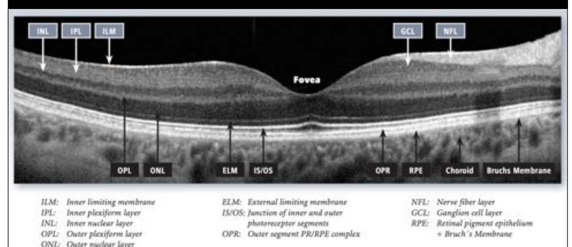
- Common Scan Options
  - Raster Line Scans
    - Cross-sectional image (2-D image)
    - Extremely fast acquisition
    - Highest resolution (HD)
    - Enhanced depth imaging (EDI)
  - Cube Scans
    - Volumetric images
    - Used for "en face" and 3-D visualization
    - Slower acquisition time (2.4 sec)
    - More prone to motion artifacts, blinks, etc
    - ON Cube
    - Macula Cube



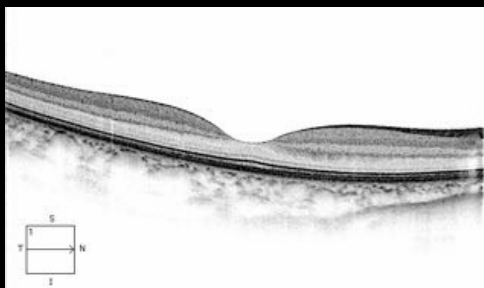
REFLECTIVITY

- In general, anatomical structures perpendicular to the signal beam, such as nerve fibers and plexiform (synaptic) layers, are more reflective (brighter).
- Structures parallel to the signal (such as nuclear layers) are less reflective so not as bright.

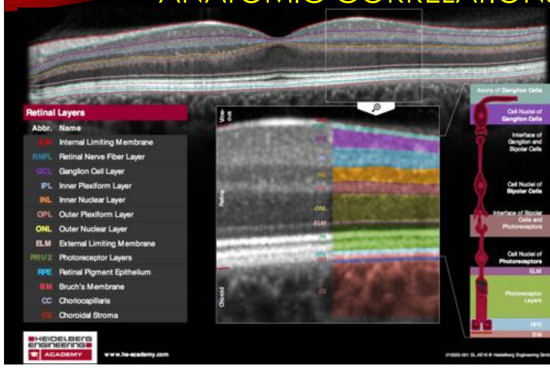
Layers on Cirrus HD OCT

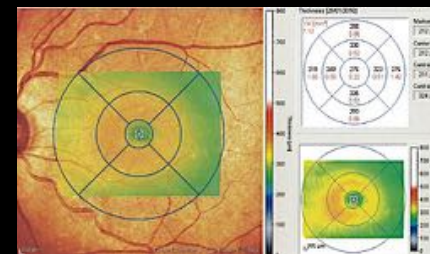


"Negative" OCT scan - Dark/light regions reversed.
E.g. Vitreous is white rather than black



ANATOMIC CORRELATIONS



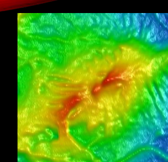


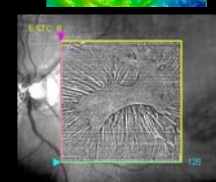
The 9-zone ETDRS Macular Grid

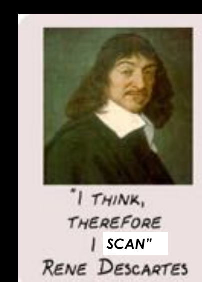
OCT INTERPRETATION

- Involves analysis and synthesis of info.
- René Descartes, 17th-century French philosopher, elucidated the principles of analysis and synthesis in "Le Discours de la Mèthode" in 1637.
- To replace the apparent chaos of data with an ordered and rationally constructed system,
- There can only be one true method, which consists of separating what is already simple and clear in order to understand that which is complex and obscure.

ERM IN 3-D



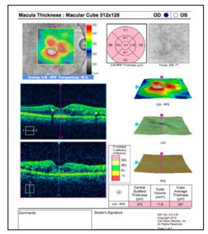


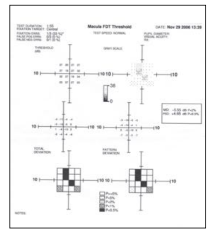


OCT INTERPRETATION

- In a logical process, the analysis of each of the elements is first performed.
- Then after this phase, the synthesis of all these elements is performed, and the results of these flow into the conclusions.

Clinical Case of Patient RW: Integrating Structure and Function



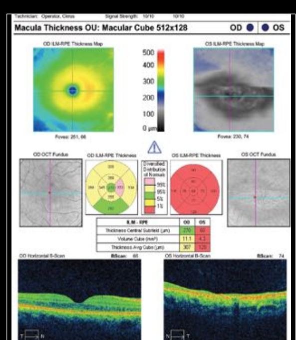


FDT Macula Threshold Testing

OCT Interpretation

- Reading an OCT report involves:
  - Reliability and image quality analysis
  - Qualitative analysis
    - 2-D, and 3-D images and maps
  - Quantitative analysis
    - retinal thickness, retinal map, volumetric data
  - Synthesis of all history and examination findings
    - retinal thickness
    - morphological alterations
    - hyper- and hypo-reflectivity
    - anomalous structures apparent with angiography
- Using this organized approach, we can usually reach a diagnosis

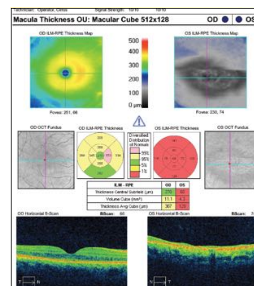
THE OCT REPORT



DUSN OS

INTERPRETATION

- Reflectivity
  - Increased or decreased reflectivity (brightness), shadowing
- Errors and artifacts
  - Signal-to-noise, alignment, blinks, image quality
- Quantitative analysis
  - Thickness and volume calculations, advanced visualization analysis
- Qualitative analysis of morphology
  - Morphologic alterations, anomalous structures



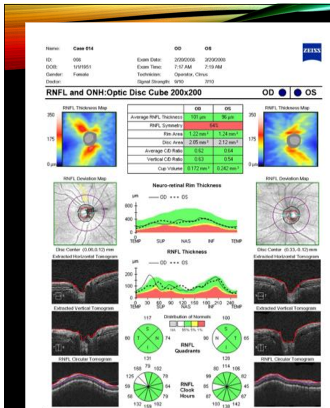
INTERPRETATION

DUSN OS

HIGH-QUALITY, RELIABLE OCT MACULAR CUBE SCAN SHOWS NORMAL FOVEAL CONTOUR AND SLIGHTLY HIGH RETINAL THICKNESS OD, WITH DIFFUSE MACULAR THINNING OS.

QUANTITATIVE ANALYSIS

- Segmentation
  - OCT software uses an algorithm to identify **tissue boundaries** (eg, vitreoretinal interface, RPE, etc). It is then able to calculate the **thickness and volume** of the various structures
  - Color maps display retinal thickness data in a visual format
- 3-D visualization
  - By combining numerous B-scans together, the software is able to create a 3-dimensional representation tissue structure
- Coronal ("*en face*") visualization
  - The combination of segmentation and 3-D analysis yields the ability to view coronal (frontal, transverse) sections of the tissue at any chosen depth within the retina, ON, choroid, etc.

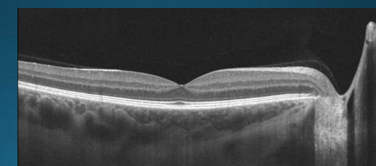


Segmentation analysis of the OCT signal separates the NFL from the rest of the retina, permitting the measurement of **NFL thickness**.

NFL thickness and analysis by OCT is critical in the evaluation of glaucoma.

Posterior Segment Applications

- Vitreous/Vitreoretinal Interface
- Neurosensory retina, RPE/Bruch's
- Choriocapillaris/Deeper Choroid
- Optic Nerve/NFLA



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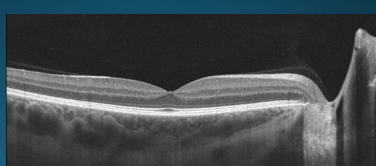
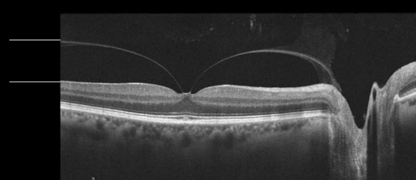


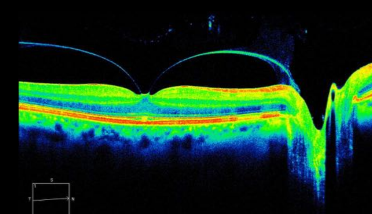
Posterior Segment Applications

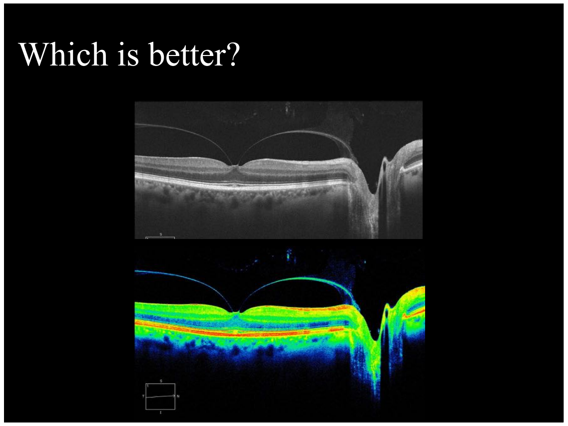
- Vitreous/Vitreoretinal Interface
  - VMA/T

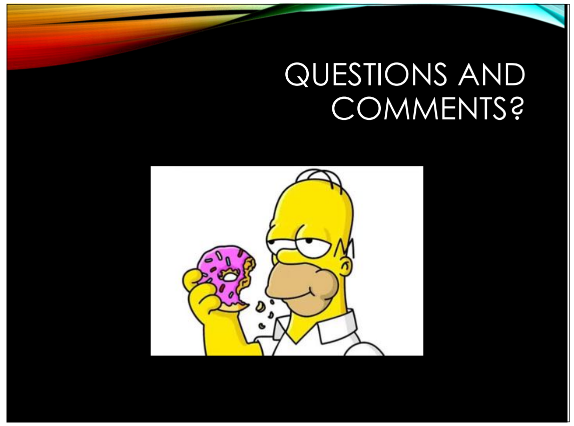


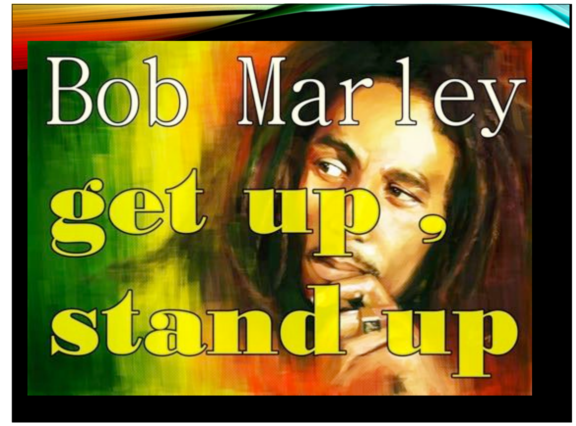
Posterior Segment Applications

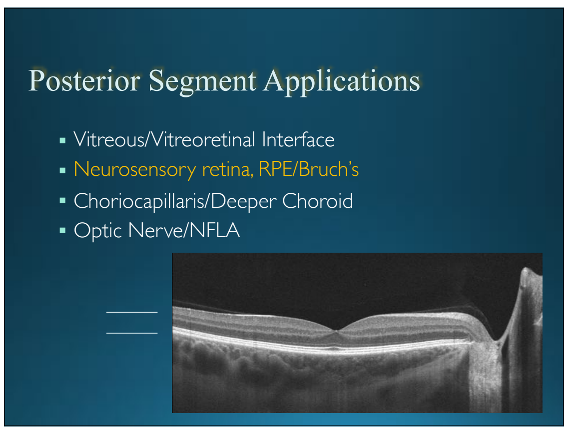
- Vitreous/Vitreoretinal Interface




Which is better?


QUESTIONS AND
COMMENTS?


Bob Marley
get up,
stand up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Vitreous/Vitreoretinal Interface
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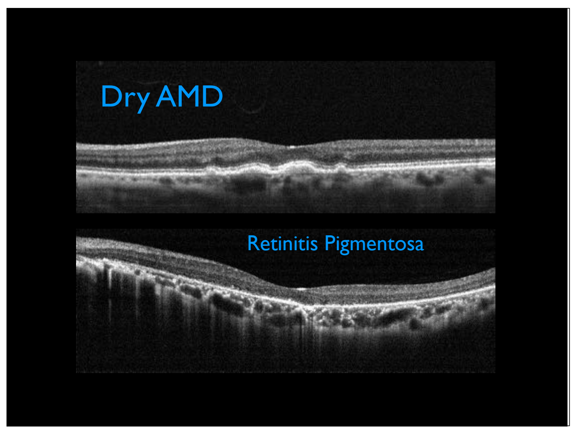
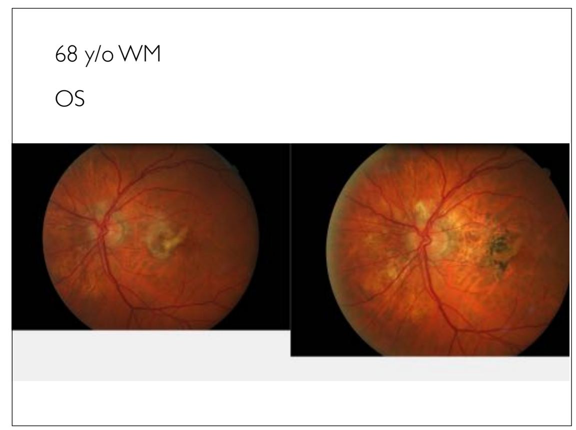
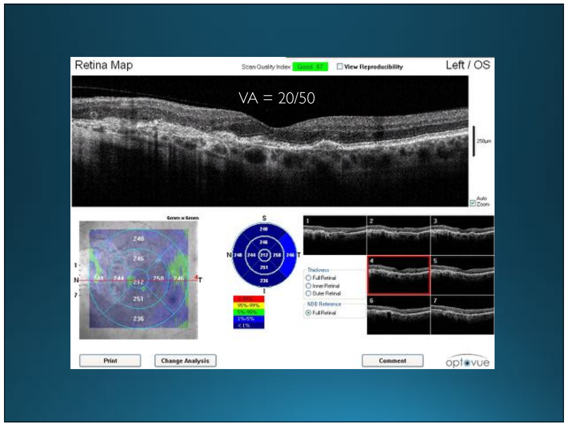
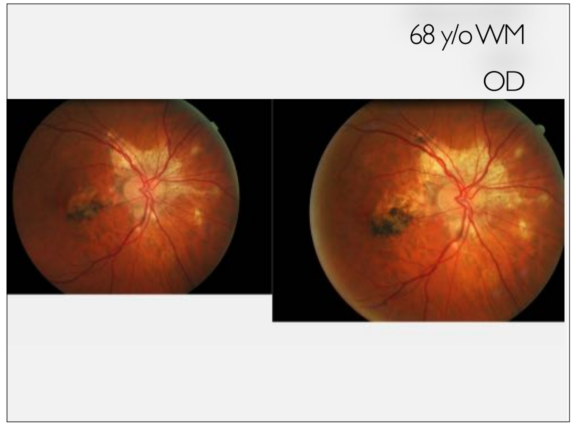
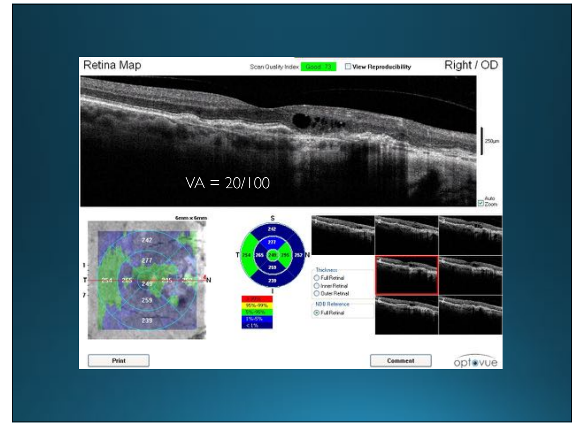
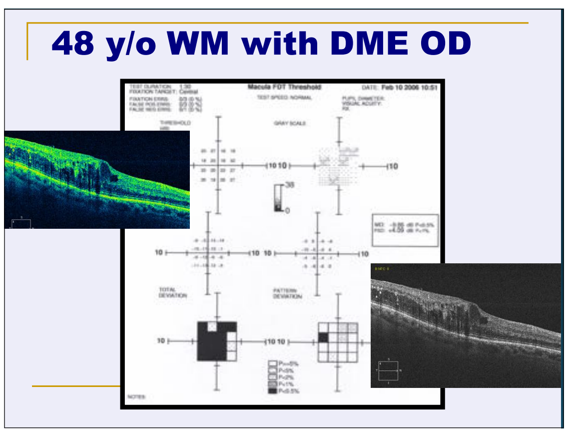

Dry AMD
Retinitis Pigmentosa

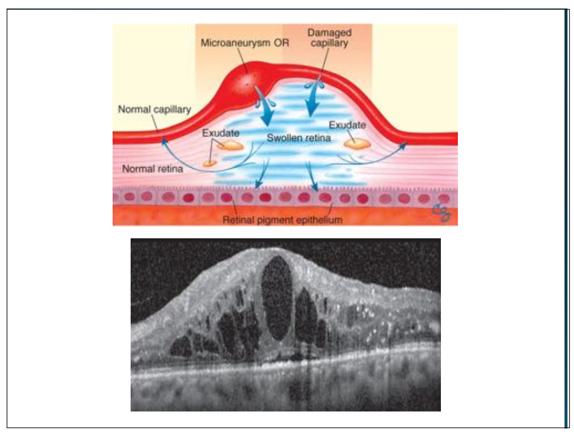

68 y/o WM
OS

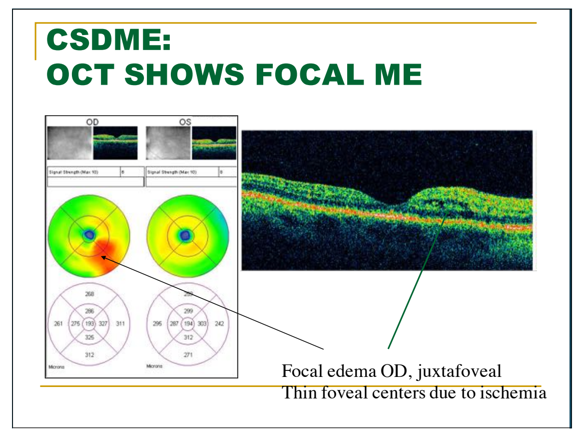

Retina Map
Left / OS
VA = 20/50
Print
Change Analysis
Comment
optovue


68 y/o WM
OD

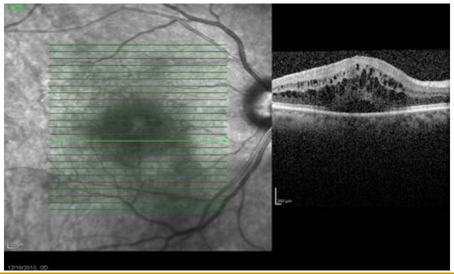

Retina Map
Right / OD
VA = 20/100
Print
Comment
optovue

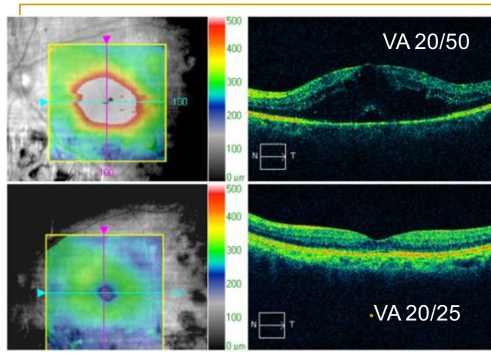

48 y/o WM with DME OD
Macula FDT Threshold


Microaneurysm OR
Damaged capillary
Normal capillary
Exudate
Swollen retina
Exudate
Normal retina
Retinal pigment epithelium


CSDME:
OCT SHOWS FOCAL ME
OD
OS
Focal edema OD, juxtafoveal
Thin foveal centers due to ischemia

DIFFUSE CSDME





Six mon s/p IV Lucentis x 6

Posterior Segment Applications

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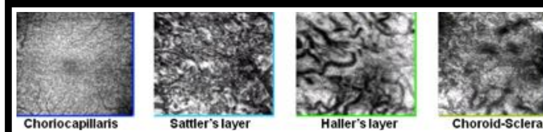
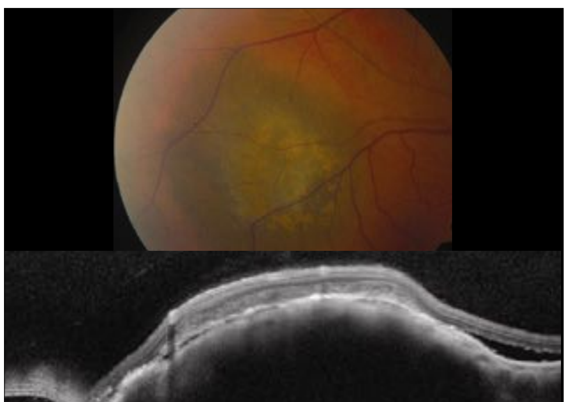
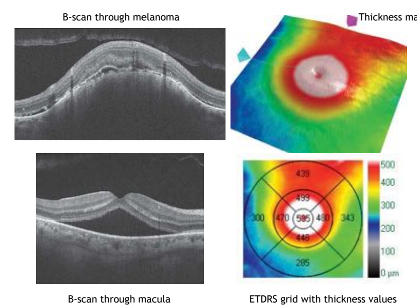
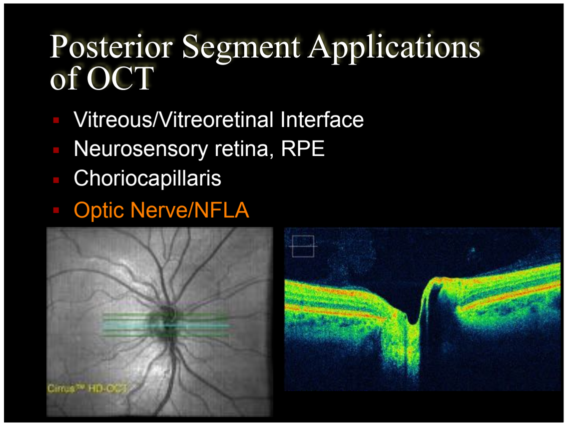
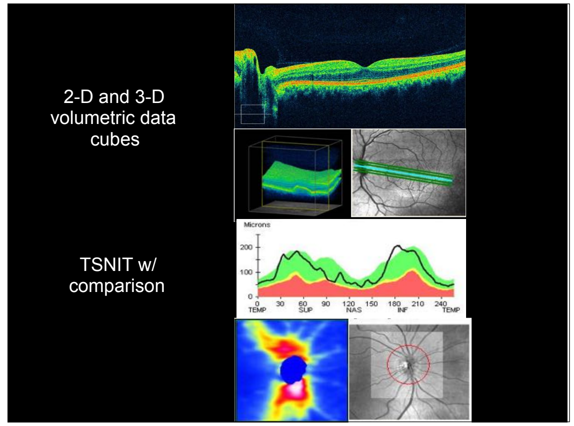
- Optic Nerve/NFLA

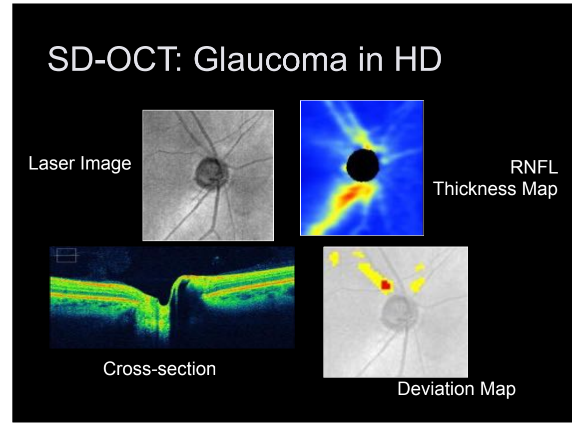


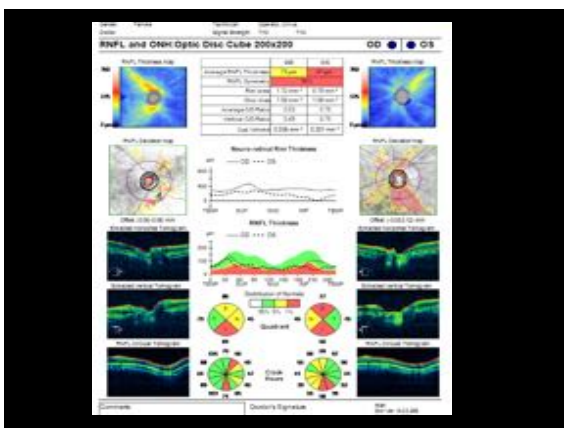


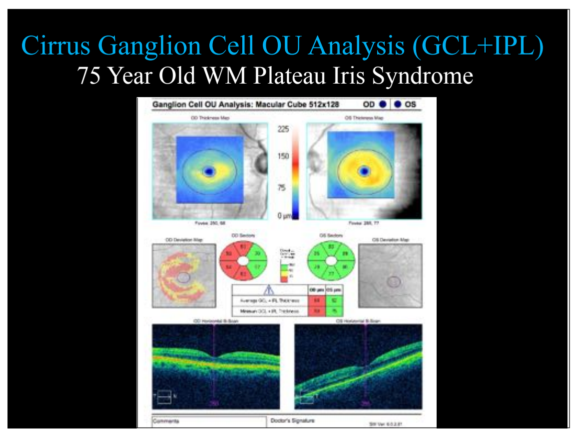


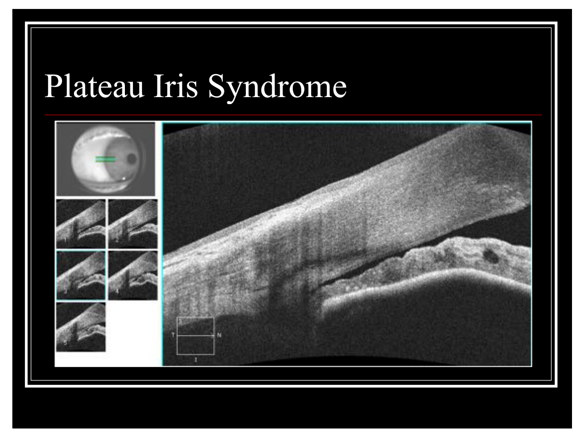

Posterior Segment Applications of OCT
Vitreous/Vitreoretinal Interface
Neurosensory retina, RPE
Choriocapillaris
Optic Nerve/NFLA
Cirrus™ HD-OCT

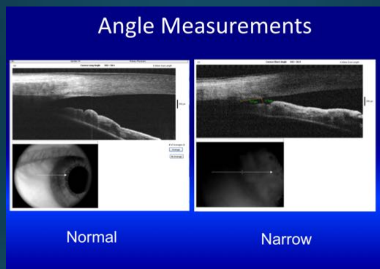

2-D and 3-D volumetric data cubes
TSNIT w/ comparison
Microns
200
100
0
0 30 60 90 120 150 180 210 240
TEMP SUP NAS INF TEMP


SD-OCT: Glaucoma in HD
Laser Image
RNFL Thickness Map
Cross-section
Deviation Map


RNFL and ONH:Optic Disc Cube 200x200
OD
OS

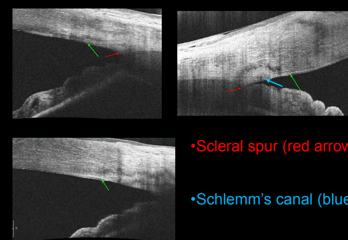

Cirrus Ganglion Cell OU Analysis (GCL+IPL)
75 Year Old WM Plateau Iris Syndrome
Ganglion Cell OU Analysis: Macular Cube 512x128
OD
OS


Plateau Iris Syndrome



Anterior Segment OCT

Anterior Segment Imaging
Angle Structures

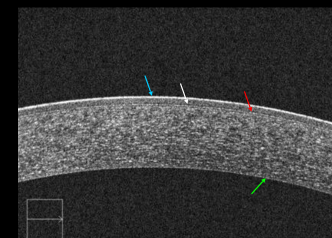


•Scleral spur (red arrow)

•Schlemm's canal (blue arrow)

•Schwalbe's line (green arrow)

Anterior Segment Imaging
Cornea/CCT



HD-OCT of normal cornea. Layers identified with colored arrows as follows: tear film (blue), epithelium (white), Bowman's layer (red), Descemet's/endothelium (green).

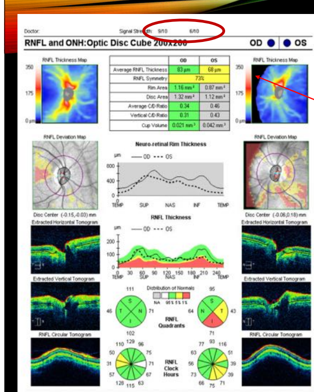
IMAGE QUALITY

Conditions that can affect the quality of OCT scans include:

- Transparency of the optic media
- Poor corneal condition or lacrimal film

ERRORS AND ARTIFACTS

- Signal-to-Noise
  - A large number of factors may contribute to low signal strength (poor media clarity, misalignment, eye movements)
    - Poor signal quality **interferes with segmentation analysis** and results in errors in quantitative analysis
    - A low signal strength **(≤6)** should prompt the examiner to discard the scan or use it with caution
- Alignment errors and blinks
  - **Vignetting and black zones** within the scan can be caused by misalignment, inadequate optimization, and patient movement or blinking during capture



VIGNETTING DUE TO MISALIGNMENT

- The black crescent on the left edge of the scan of the OS is an artifact due to poor alignment of the patient with the instrument.
- Note the signal strength in this eye is also low (6/10 OS compared to 9/10 OD).
- Poor quality scans may lead to misinterpretation and contribute to misdiagnosis.
- **Any scan with a signal strength of 6 or less should be repeated.**

QUESTIONS AND COMMENTS?

POST SEG IMAGING

MULTIMODAL
WIDE FIELD
ENHANCED DEPTH

CAUTION!

WIDE FIELD AND ENHANCED DEPTH IMAGING DOES

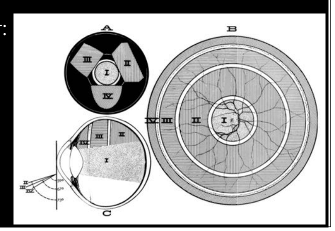
NOT

REPLACE A DILATED RETINAL EXAMINATION.

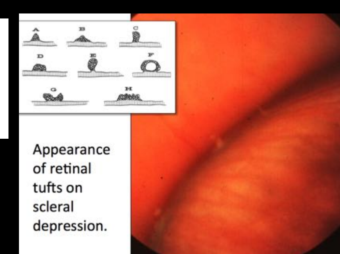
FUNDUS BIOMICROSCOPY AND BIO

GOLDMANN 3-MIRROR LENS

- Mirror use
  - Small (thumbnail, IV) mirror: Gonioscopy, Far periphery (ora to pars plana)
  - Middle (square, III) mirror: Peripheral retina (equator to ora)
  - Large (wide, II) mirror: Mid-periphery (arcades to equator)
  - Central (I) lens: Posterior pole

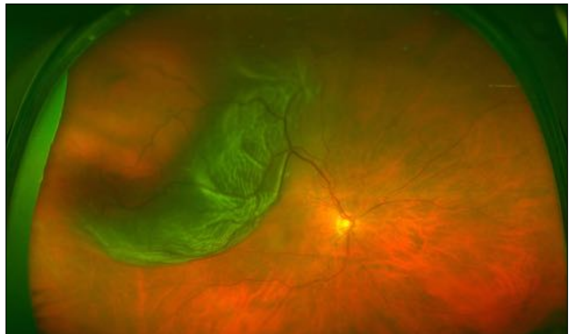


SCLERAL INDENTATION



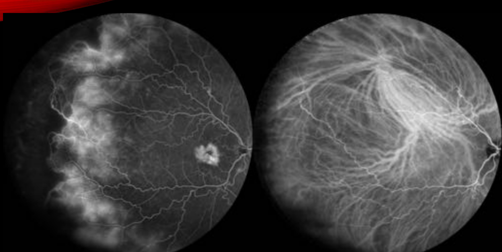
MILESTONES IN IMAGING

- Wide field SLO 2000
- Other Wide Field Imaging 2000-2015
  - Confocal Scanner
  - Multi-color/channel/spectral Imaging
  - Fundus Autofluorescence (FAF)
- Wide field OCT/OCTA 2018



A full color Optomap scan of an RD is accomplished by combining images produced by three lasers (red, green and blue)

CALIFORNIA WIDE-FIELD ANGIOGRAPHY



PDR w/periph ischemia, CME on FA (left) and ICGA on HRA

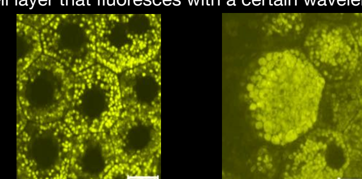
FUNDUS AUTOFLUORESCENCE

While Angiography images BRB integrity, FAF captures **metabolic activity.**

Imaging Technologies: FAF

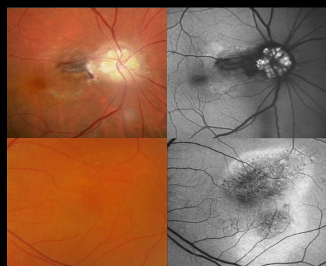
What is autofluorescence in the retina?

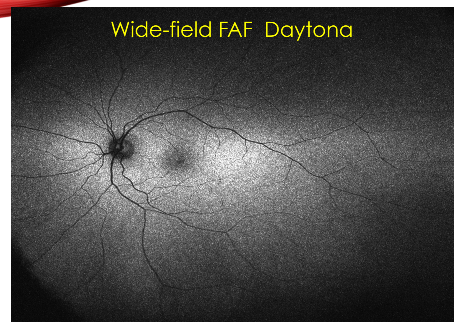
- FAF is the fluorescence of the lipofuscin molecule within the RPE cell layer that fluoresces with a certain wavelength.



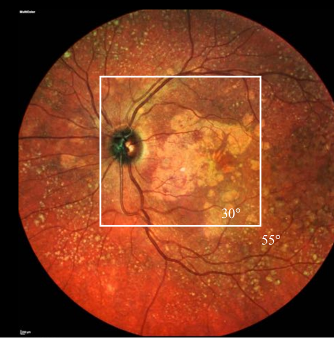
AUTOFLUORESCENCE (FAF)

- Early ID of disease.
  - ON drusen
  - CSC
- Predictive marker
  - increased FAF signal precedes dry AMD progression.
- Monitor Dx.
- Functional correlation.

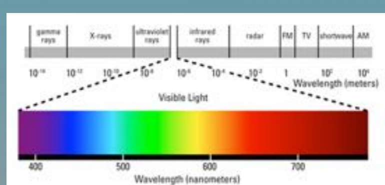




WIDE FIELD MULTICOLOR IMAGING W/SPECTRALIS

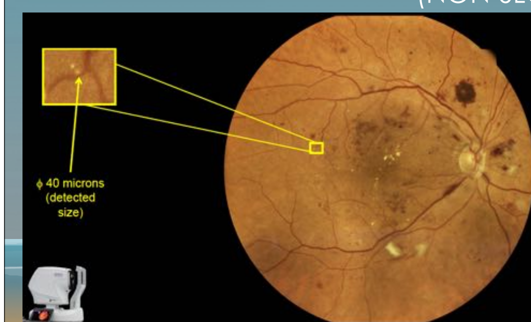


HOW DOES MCI WORK?



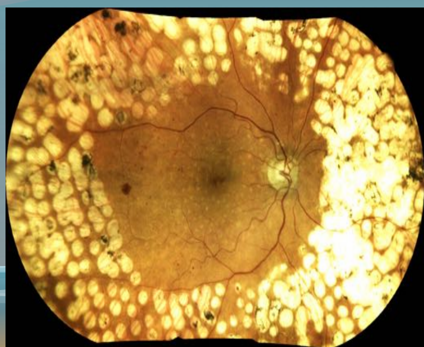
- MCI is achieved using the principle of confocal scanning laser ophthalmoscopy (cSLO).
- Multicolor images are illuminated with three select color wavelengths: infrared, green, and blue.

EIDON CONFOCAL SCANNER (NON-SLO)



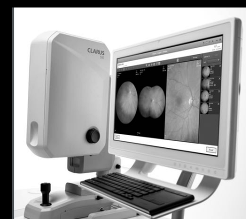
RED-FREE

100° mosaic image (up to 150° with manual mode)



CLARUS WIDE-FIELD IMAGING

- CLARUS 500 produces a 133° image with 7 μm resolution.
- HD ultra-widefield images are automatically merged to achieve 200° field of view.



Sub-retinal Heme Secondary to CNV

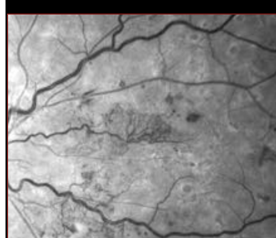
200° View

BROAD LINE FUNDUS IMAGING

- True color images are generated through sequential illumination by broad-spectrum red, green, and blue LEDs (light-emitting diodes).
- This yields gives a natural-looking fundus image, as it appears through direct observation.

Light Source	Wavelength
Red LED	585 – 640 nm
Green LED	500 – 585 nm
Blue LED	435 – 500 nm
IR Laser Diode	785 nm

RGB CHANNEL SEPARATION



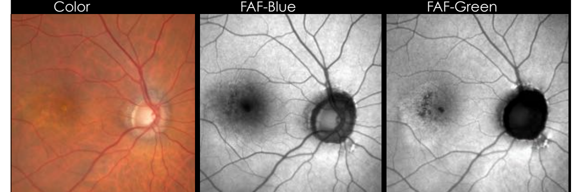
Green Channel--PDR

Blue Channel—Healthy RNFL

GEOGRAPHIC ATROPHY

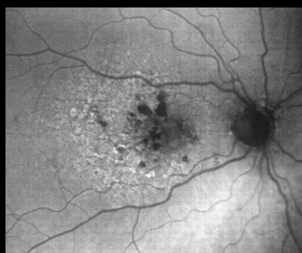
COURTESY OF JESSE JUNG, M.D.
EAST BAY RETINA CONSULTANTS

Color FAF-Blue FAF-Green



Green FAF (right) shows the borders of the GA more clearly because macular pigment does not absorb that wavelength.

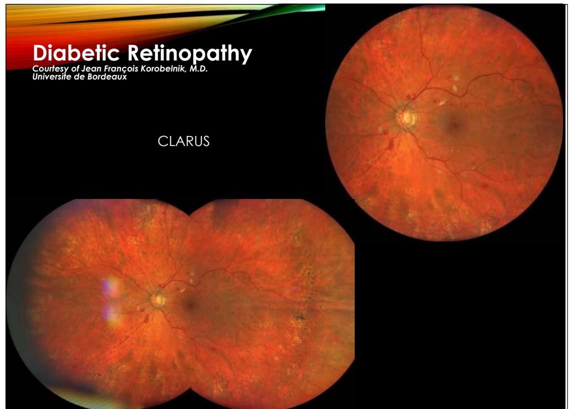
FAF OF DRY AMD ON CLARUS



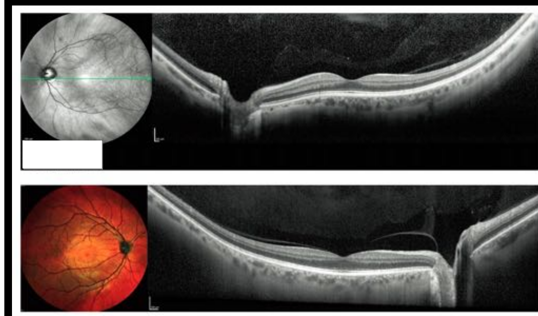
Diabetic Retinopathy

Courtesy of Jean François Korobelnik, M.D.
Université de Bordeaux

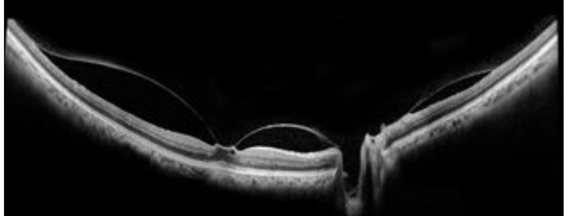
CLARUS



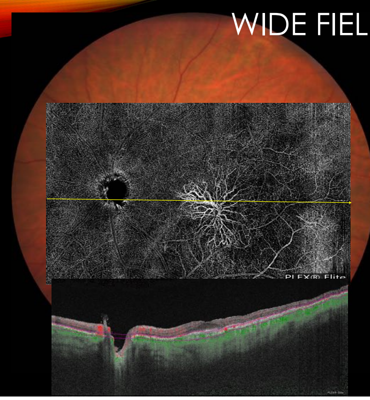
WIDE FIELD OCT HD RASTER--VMA



WIDE FIELD OCT HD RASTER--VMA



WIDE FIELD OCTA CNV

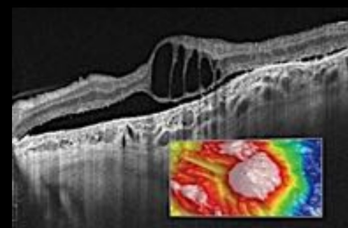


QUESTIONS AND COMMENTS?

WHAT IS ENHANCED DEPTH OCT IMAGING?

- EDI-OCT
- Enhanced-depth imaging (EDI) OCT modifies the standard technique of image acquisition to better reveal the structural details of the choroid.

EDI



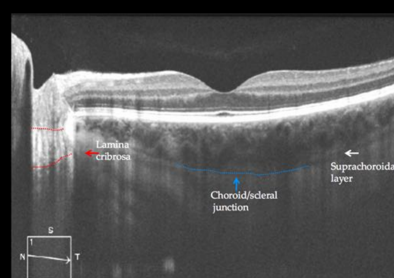
HOW IS EDI ACHIEVED?

- SD-OCT has a coherence gate of about 2 mm.
- Coherence gate is the tissue depth at which the interference image can be obtained.
- An interference signal can be obtained when the retinal tissue being examined enters the coherence gate.
- However, the signal intensity attenuates in the depth direction, from superficial to deep layers (choroid).
  - The deeper you go, the more attenuated the signal

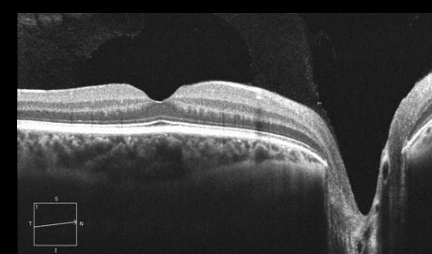
HOW IS EDI ACHIEVED?

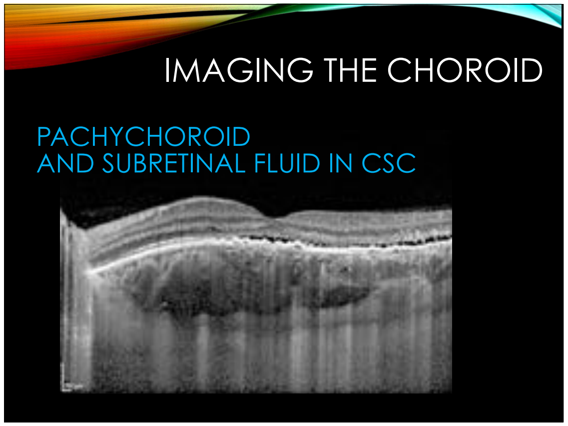
- Consequently, to obtain high-quality images in standard SD-OCT, it is important to bring the retinal tissue to the upper aspect of the imaging range.
- In contrast, EDI-OCT creates an inverted mirror image. The reference surface of the inverted mirror image surface is on the choroidal side.

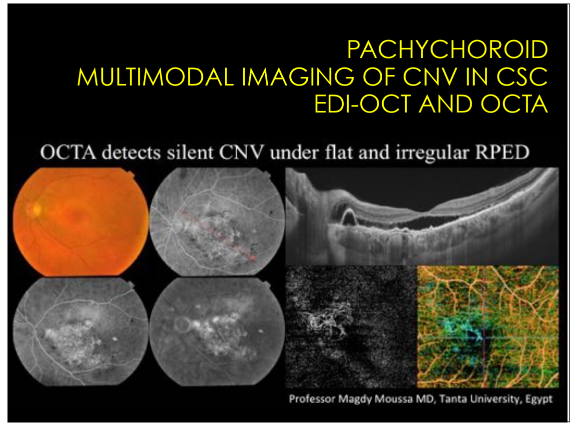
EDI SHOWS DEEPER INTRAORBITAL ON, LAMINA, C/S JXN

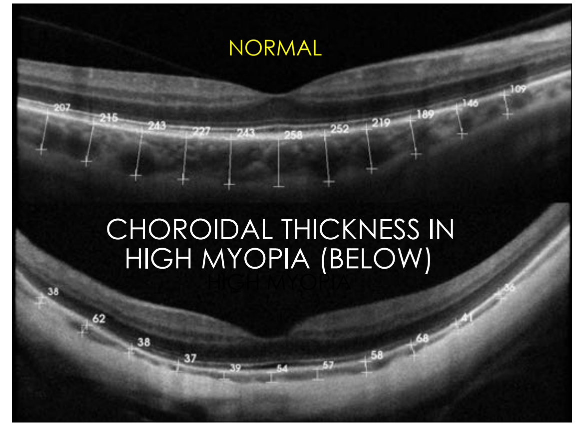


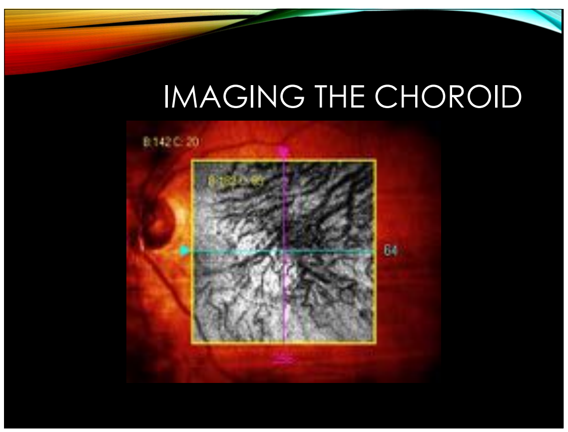
EDI

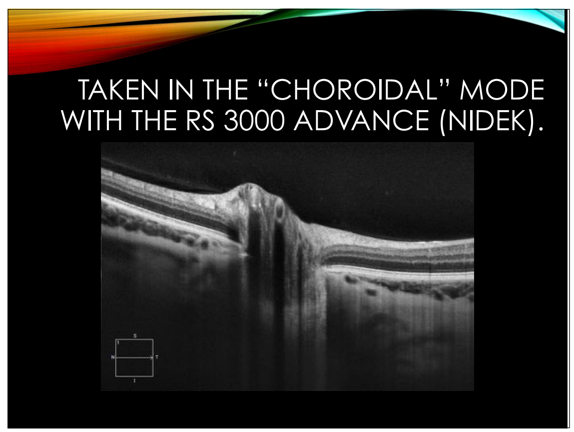


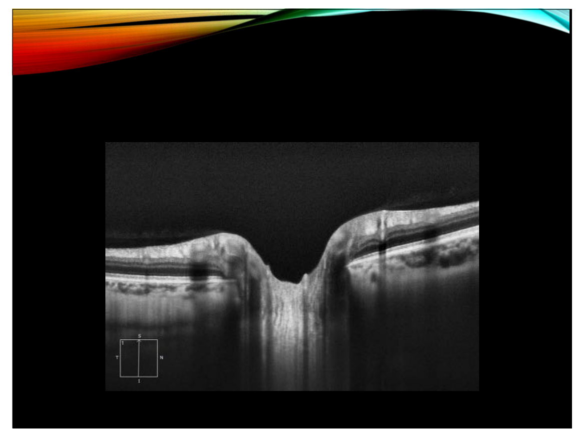

IMAGING THE CHOROID
PACHYCHOROID
AND SUBRETINAL FLUID IN CSC

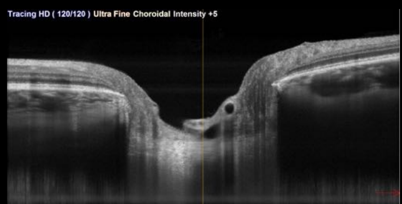

PACHYCHOROID
MULTIMODAL IMAGING OF CNV IN CSC
EDI-OCT AND OCTA
OCTA detects silent CNV under flat and irregular RPED
Professor Magdy Moussa MD, Tanta University, Egypt

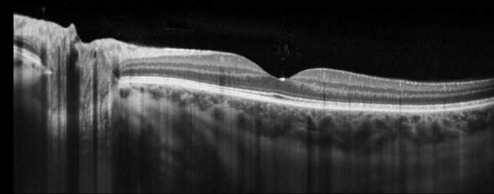

NORMAL
CHOROIDAL THICKNESS IN
HIGH MYOPIA (BELOW)


IMAGING THE CHOROID


TAKEN IN THE "CHOROIDAL" MODE
WITH THE RS 3000 ADVANCE (NIDEK).



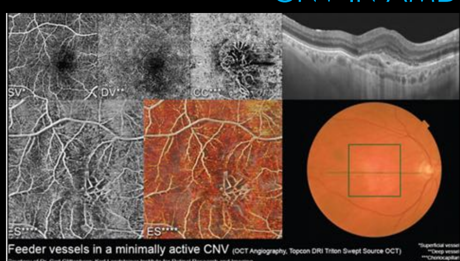




WHAT IS SWEPT SOURCE OCT?

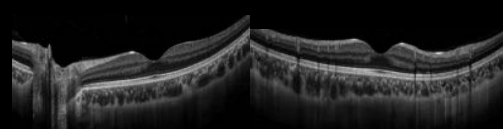
- A second type of Fourier Domain-based OCT.
  - The other FD-OCT is Specrtal Domain (SD-OCT)
- SS-OCT
  - Twice as fast (twice as many A-scans / second) as SD OCT
  - Allows for wide field imaging (12mm vs. 6-9 mm). Easily gets ONH and macula in the same scan
  - Uses a longer wavelength of light, so can image much more effectively through media opacities, and penetrate deeper into the choroid (2.6 mm depth vs. 2.3mm)

SS-OCT + OCTA SHOWS CNV IN AMD



SS-OCT combined with OCT angiography of feeder vessels in a minimally active CNVM

SWEPT SOURCE OCT



- 1,050nm wavelength
- 100,000-249,000 A-scans/sec!!
- Allows deeper imaging of choroid, sclera, intra-orbital ON, vasculature (SS-OCTA)

COMING SOON?

CONCLUSIONS

- Enhanced-depth OCT and wide field imaging provide information about tissue morphology, retinal/choroidal vasculature, and metabolic status (FAF).
- This information, combined with history, DFE and functional testing, enables clinicians to make more informed decisions about diagnosis, treatment & management, and when to obtain consultation.

TAKE-HOME

- OCT/OCTA is here to stay and will one day be as common in our offices as the slit lamp.
- Select an OCT instrument based on your practice needs with an eye toward future upgrades.
- OCT, along with traditional examination techniques, will continue to save vision.

THANK YOU!

- Joe
- allthingsoct@gmail.com