OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY OF THE RETINA AND OPTIC NERVE

Lindsay B. Howse, OD

drlindsayhowse@gmail.com

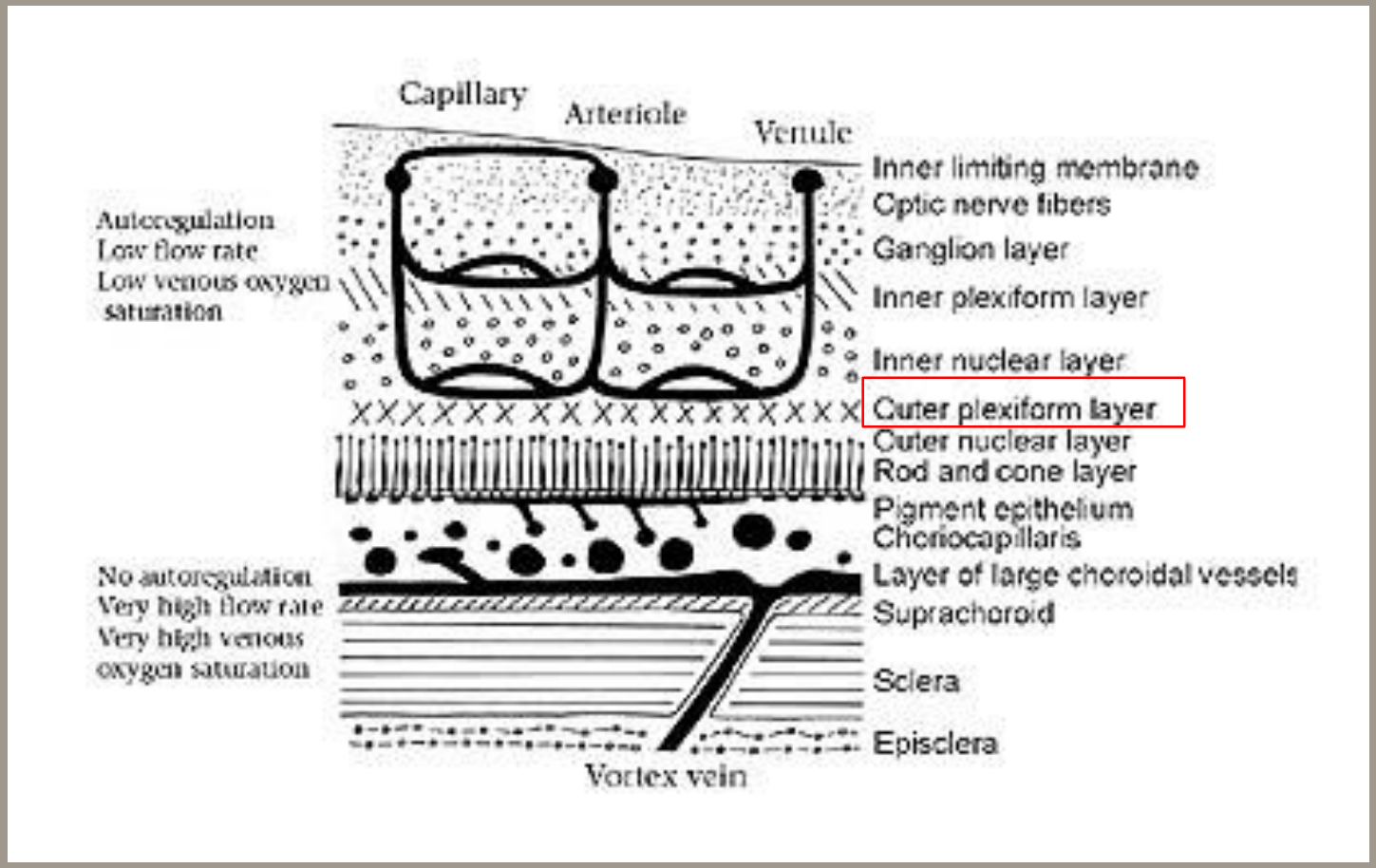
FINANCIAL DISCLOSURES

- None.

OUTLINE

- Introduction/How OCTA works
- OCTA Analysis
- Advantages and Disadvantages of OCTA
- Applications of OCTA
  - Diabetic retinopathy
  - Choroidal Diseases
  - Vascular occlusions and Macular Telantagiectasias
  - Retinitis Pigmentosa
  - Optic Neuropathies and Glaucoma

RETINAL AND CHOROIDAL BLOOD SUPPLY

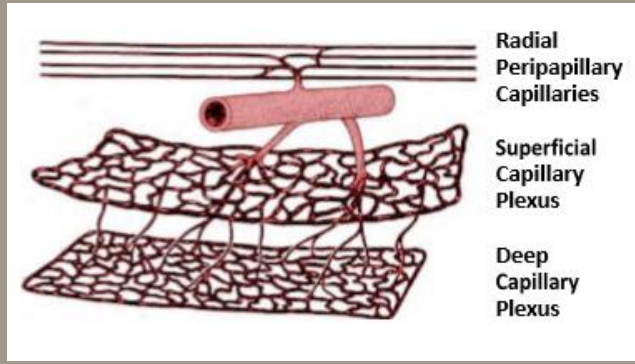


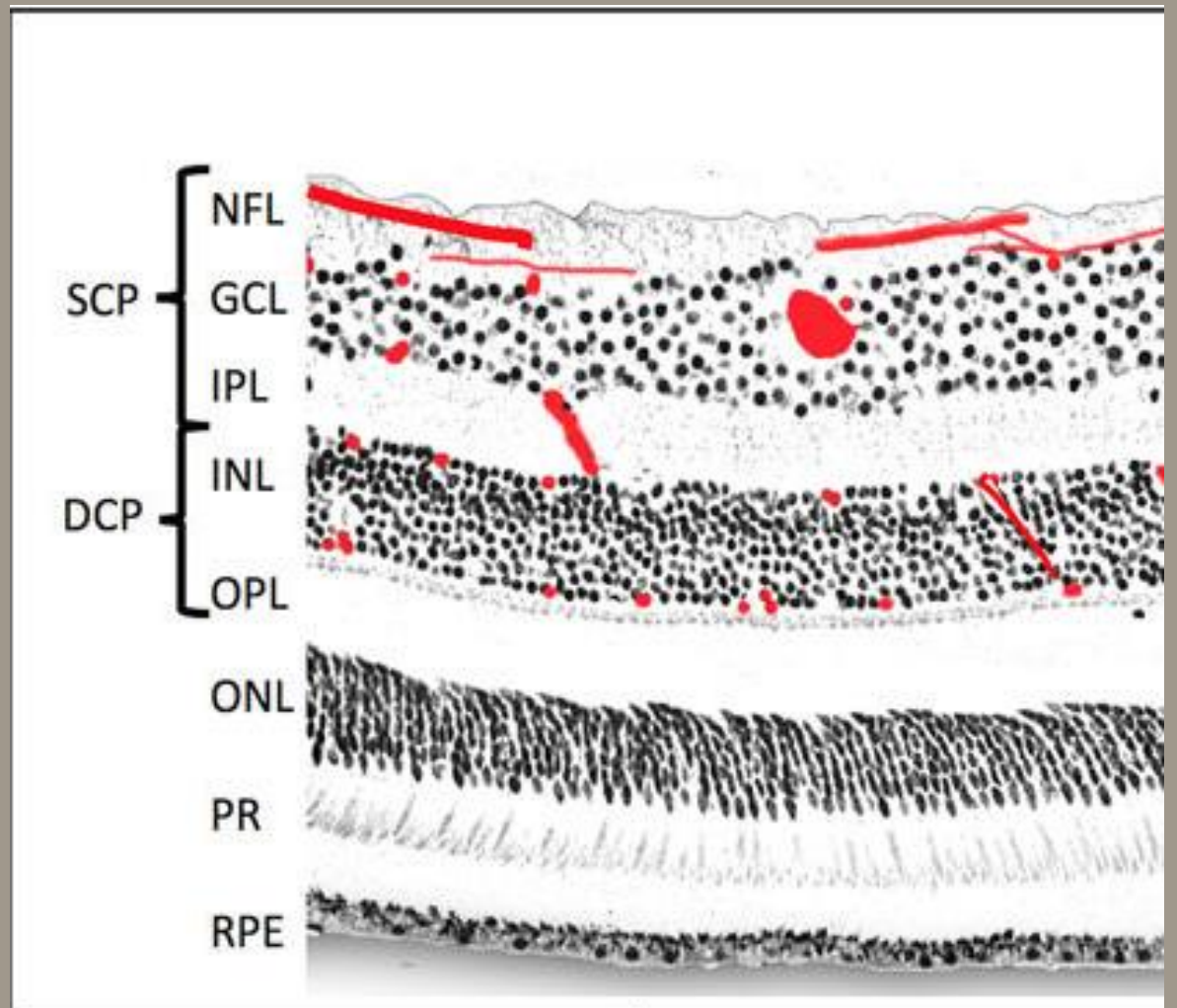
Central Retinal Artery (direct)

Choroid (diffusion)

http://www.arn.org/docs/odesign/od192/invertedretina192.htm

CENTRAL RETINAL ARTERY

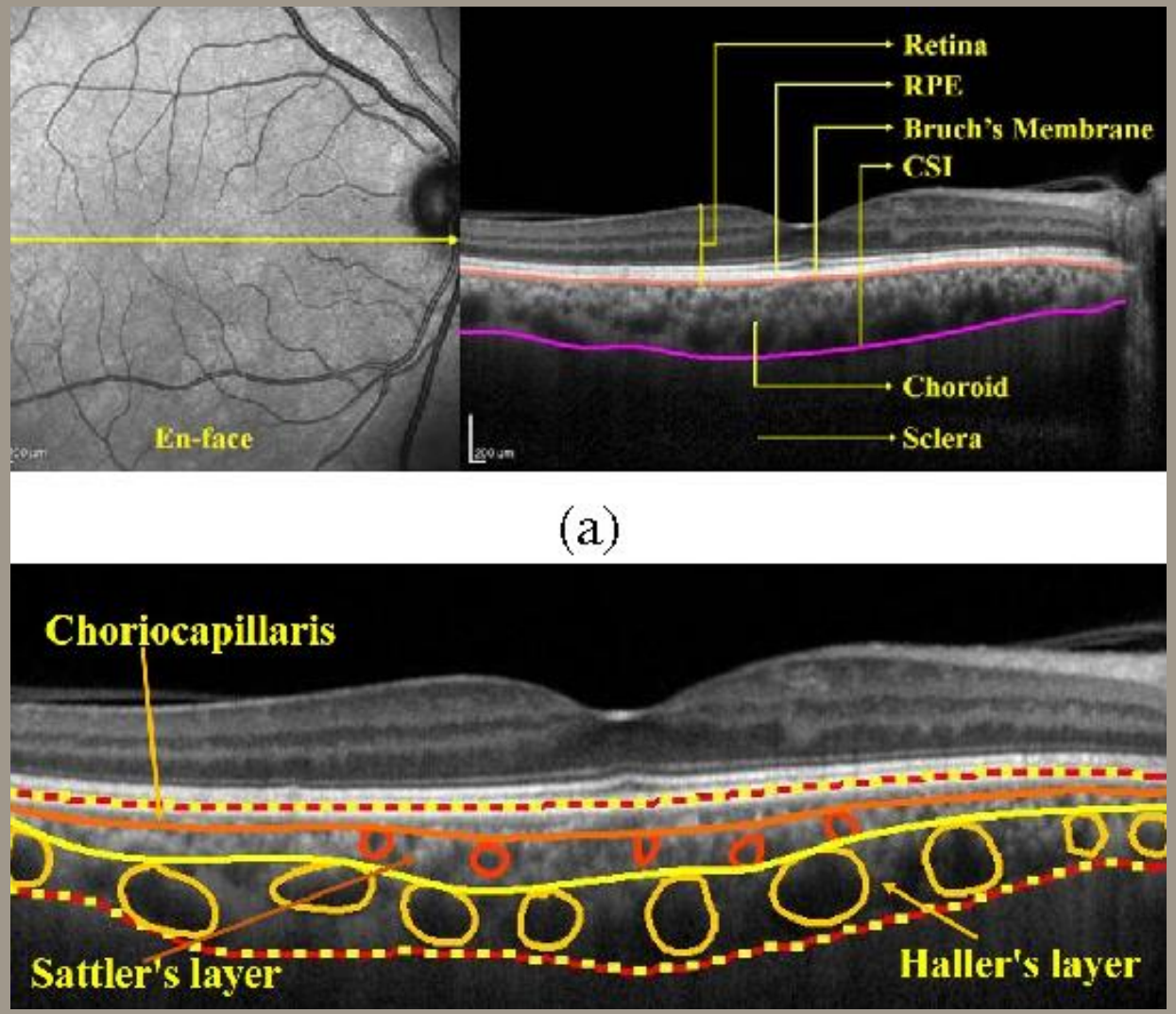




Current OCTA Nomenclature	Anatomic Layers
SCP	NFL
	GCL
	IPL
DCP	INL
	OPL

Campbell et al 2017

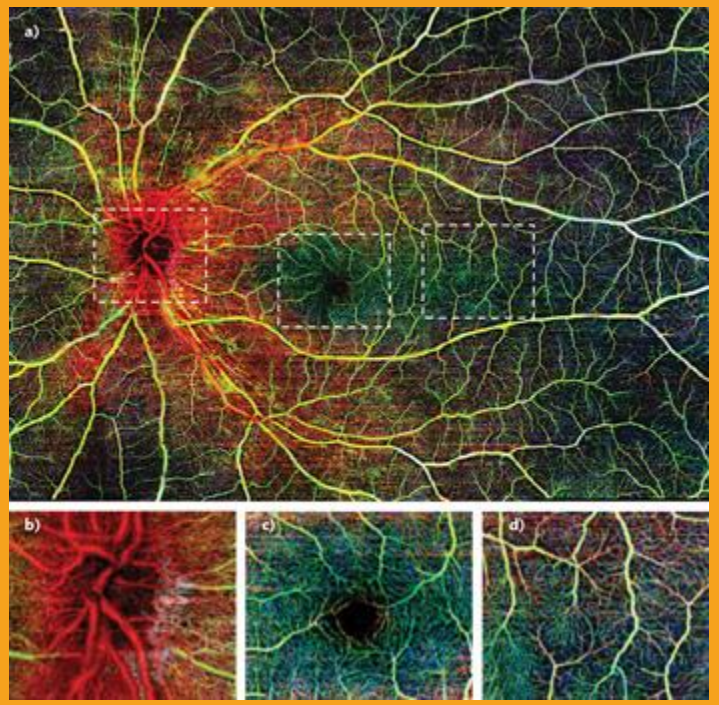
CHOROIDAL VASCULATURE



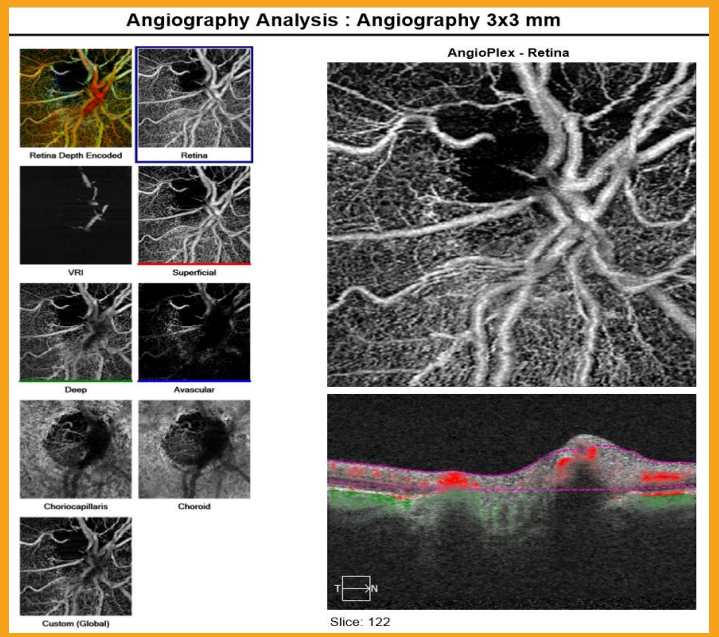
Ibrahim, M.N., Agarwal, S., Vupparaboina, K.K., Chhablani, J., Richhariya, A., & Jana, S. (2017). Segmenting and Labeling blood vessels in choroidal Haller's layer: A multiple target tracking approach. *2017 IEEE EMBS International Conference on Biomedical & Health Informatics (BHI)*, 113-116.

OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY (OCTA)

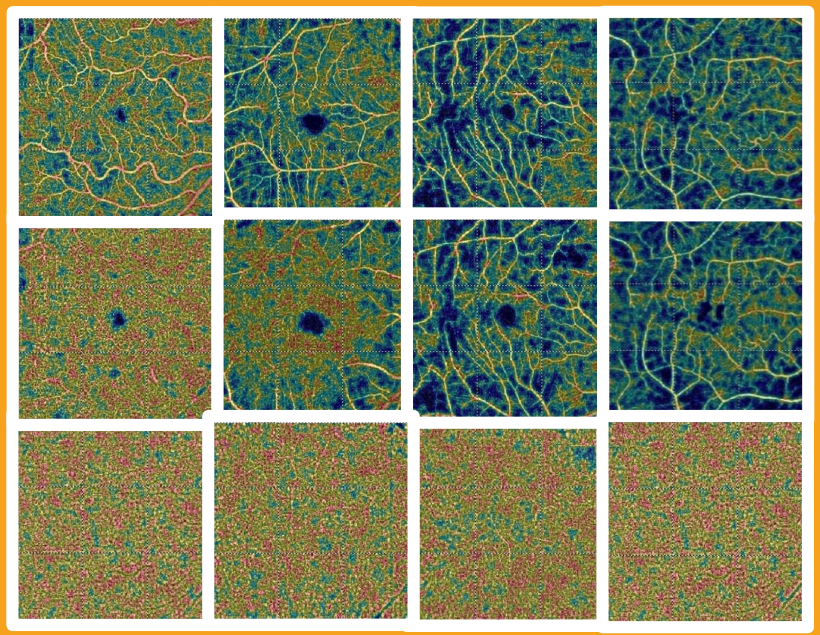
Non-invasive imaging technology that allows in vivo visualization of the retinal and choroidal vasculatures, including the peripapillary network.



Retina



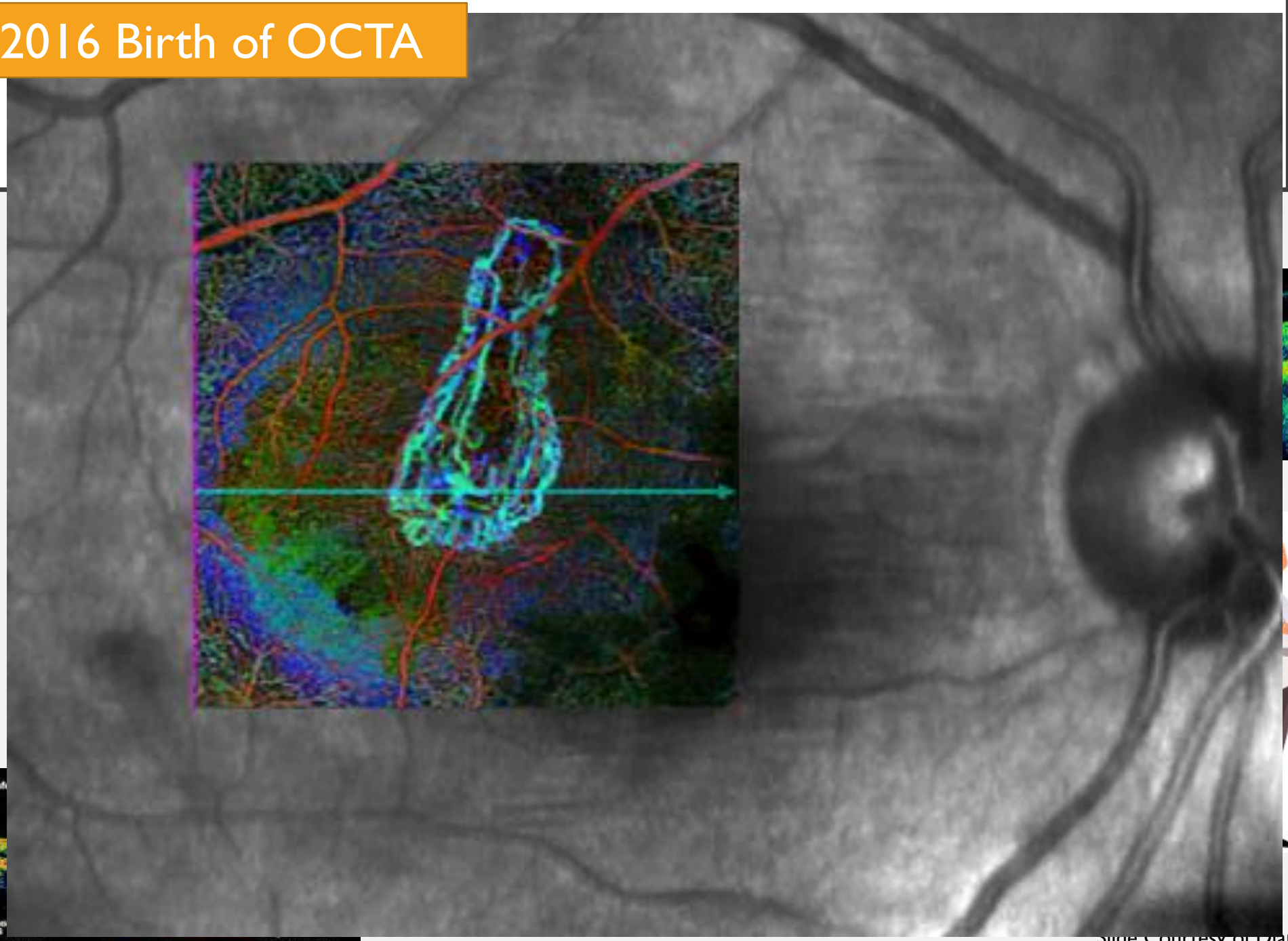
Optic Nerve



Density Maps

Q. Zhang et al., *J. Biomed. Opt.*, 20, 066008 (2015).

2016 Birth of OCTA



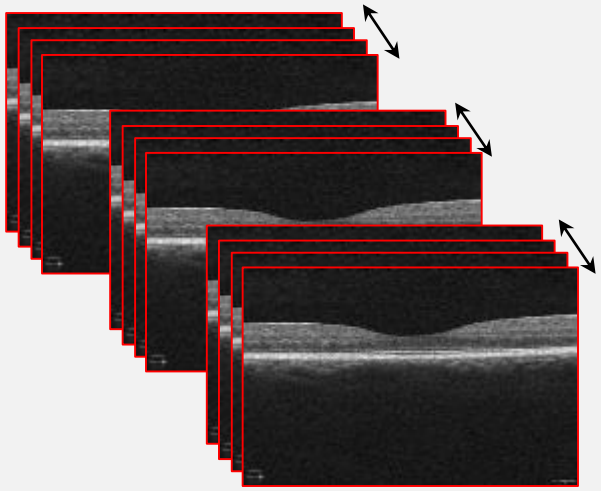
Slide Courtesy of Diana Shechtman, OD

OCTA

Dual modality- en face flow information + cross sec structure info simultaneously & depth coded

Detects motion of scattering particles such as **red-blood cells** within sequential OCT B-scan *Voxels* performed repeatedly at the same location of the retina – very fast

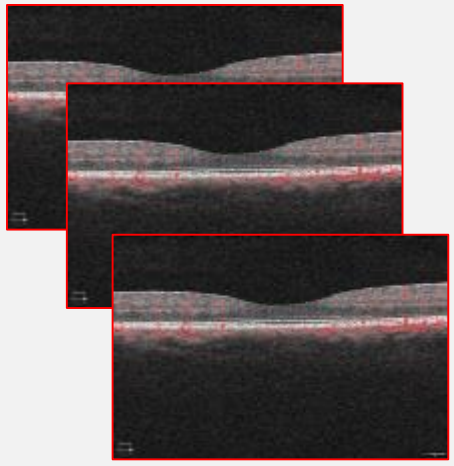
Acquisition with FastTrac



Clusters of OCT B-scans.
Each cluster b-scan acquired in the same position on the retina… anatomy doesn't't change

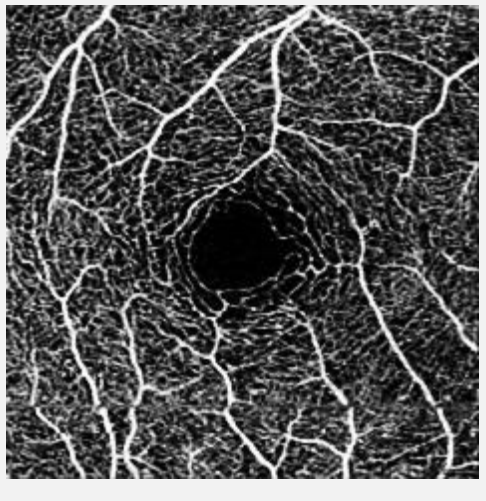
OCT=anatomy

Data Processing powered by OMAG^{C} (decorrelation)



Blood flow OCT B-scan.
Each cluster generates one Blood flow scan is the only change = movement

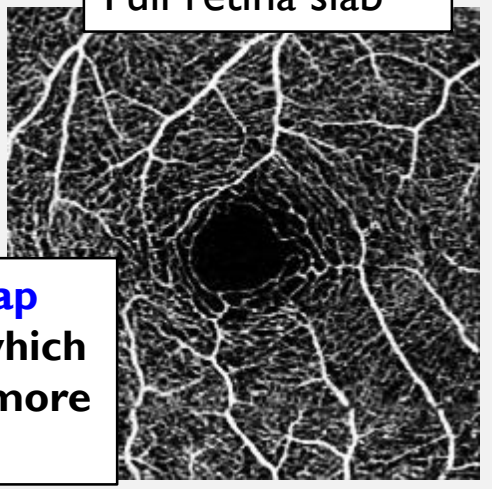
OCTA = vascular



AngioPlex Map. Process pixels
Reconstructed map of the perfused microvasculature within the retina and choroid.

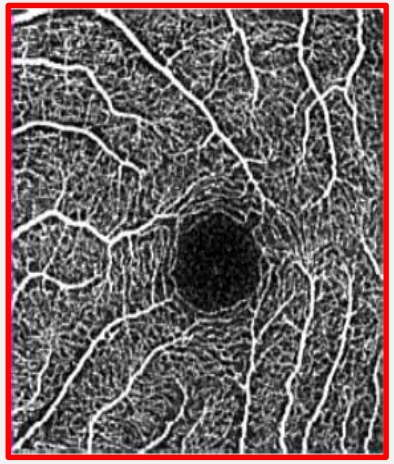
RETINAL SEGMENTATIONS

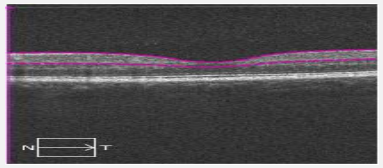
Full retina slab



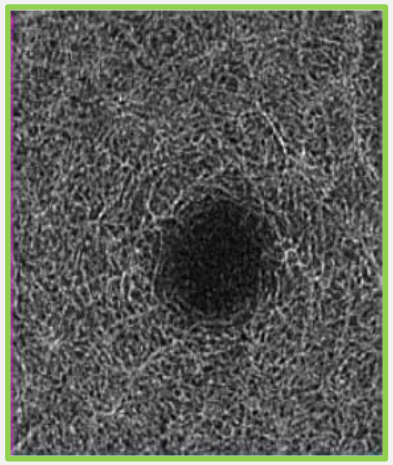
Color Depth Retinal Map can help you determine which section you need to look more carefully

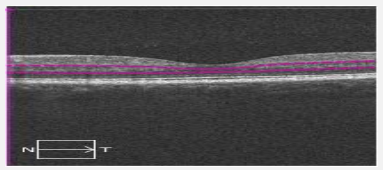
Superficial Retina (ILM to IPL)



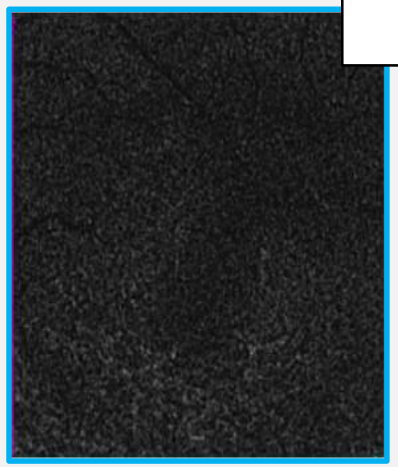


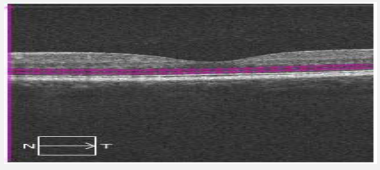
Deep Retina IPL to OPL



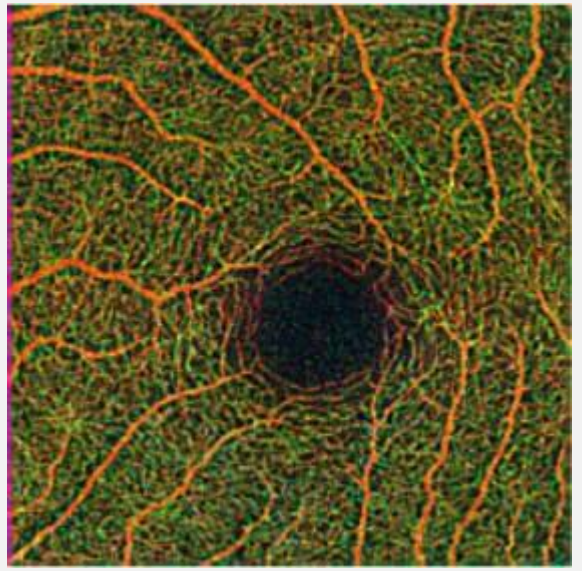


Avascular Retina Below OPL





combines superficial, deep and avascular maps ILM to RPE

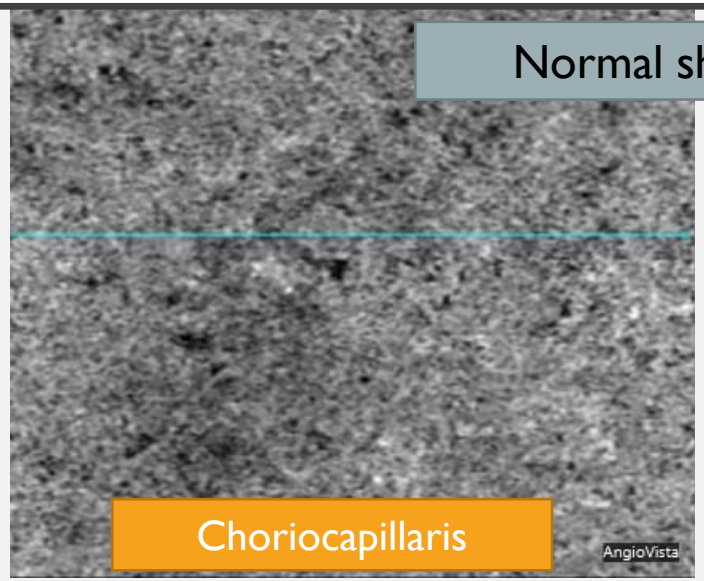


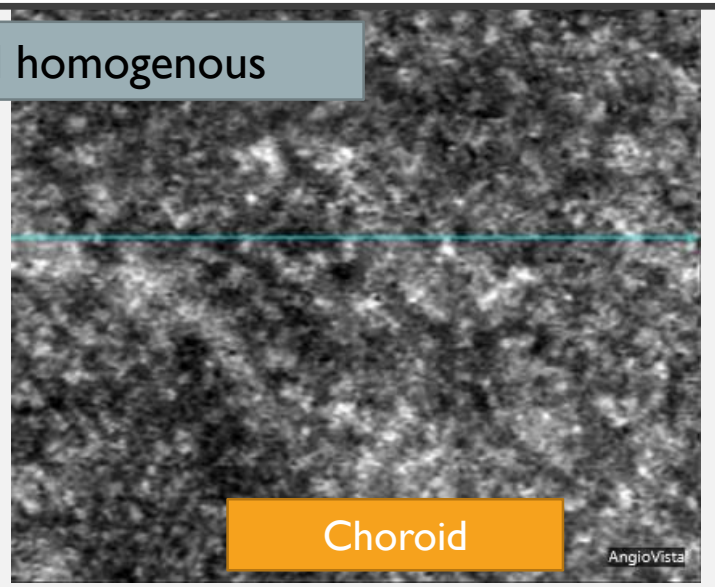
OCTA Maps are flattened 2D representations vasculature. Color Represents Depth in Tissue

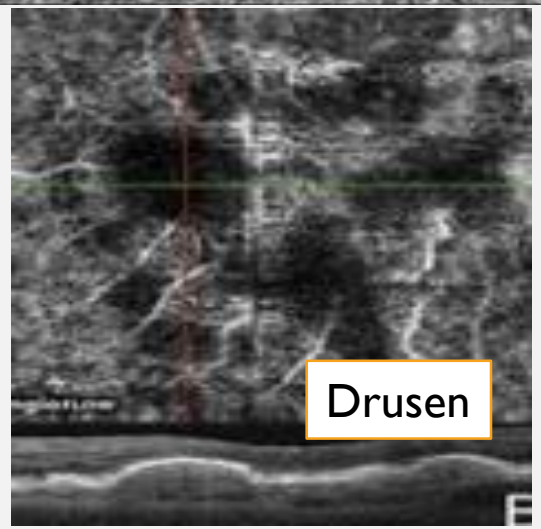
Slide Courtesy of Diana Shechtman, OD

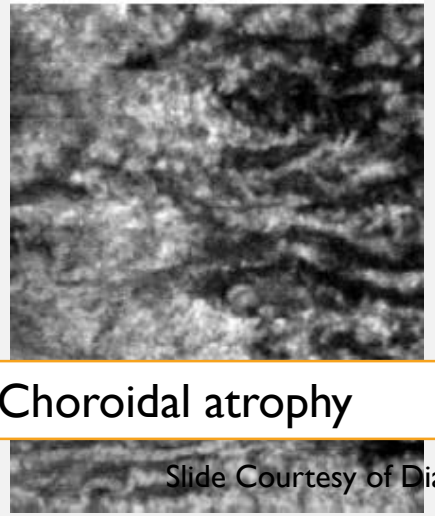
CHOROIDAL VASCULATURE

Normal should be dense and homogenous









Slide Courtesy of Diana Shechtman, OD

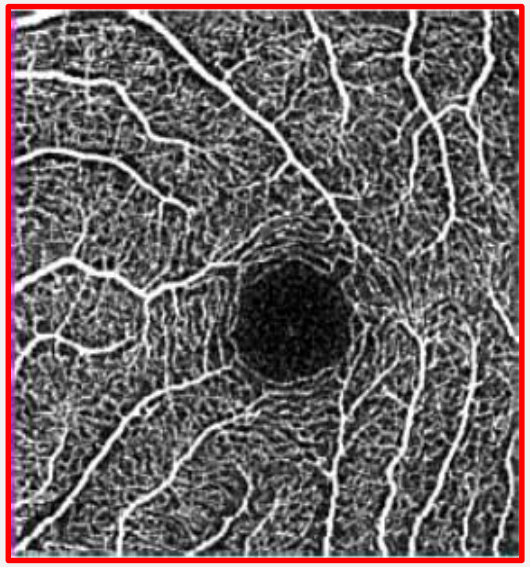
TECHNOLOGY

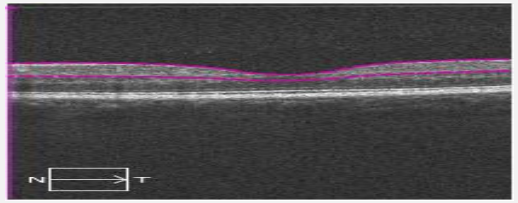
- AngioVue (Optovue)
- AngioPlex (Zeiss)
- Spectralis OCT Angiography (Heidelberg)

OCTA ANALYSIS

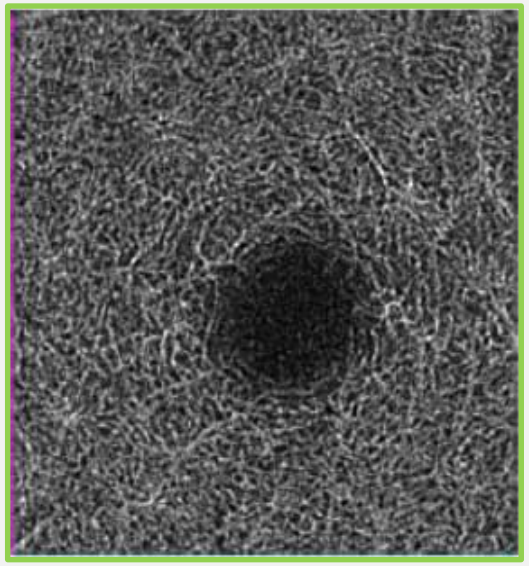
NORMAL OCTA

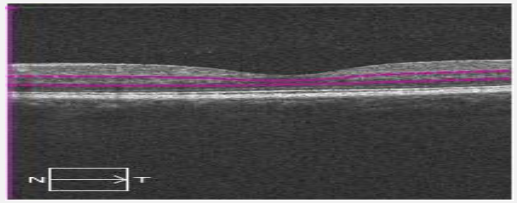
Superficial Retina
(ILM to IPL)



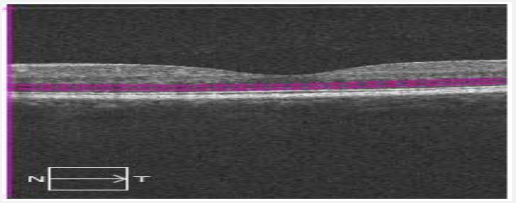


Deep Retina
IPL to OPL

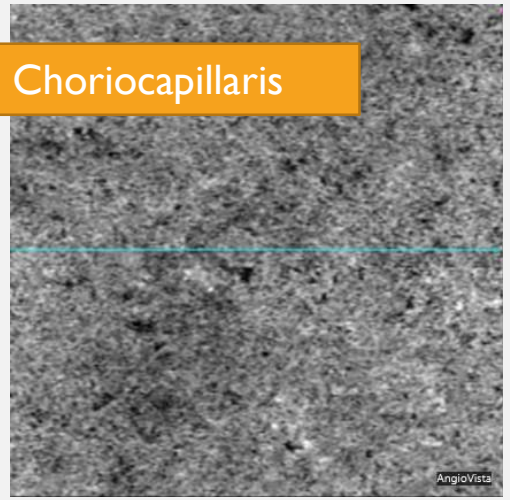




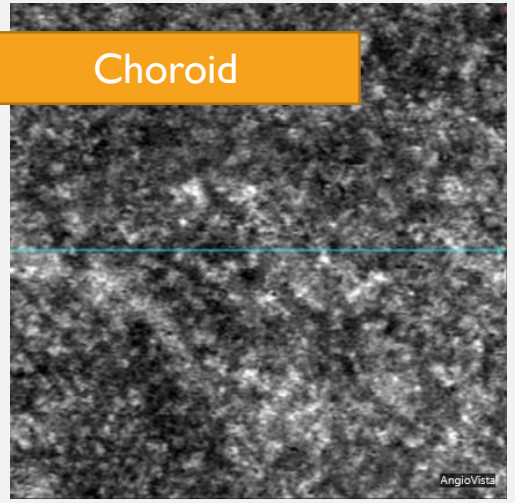
Avascular Retina
Below OPL



Choriocapillaris



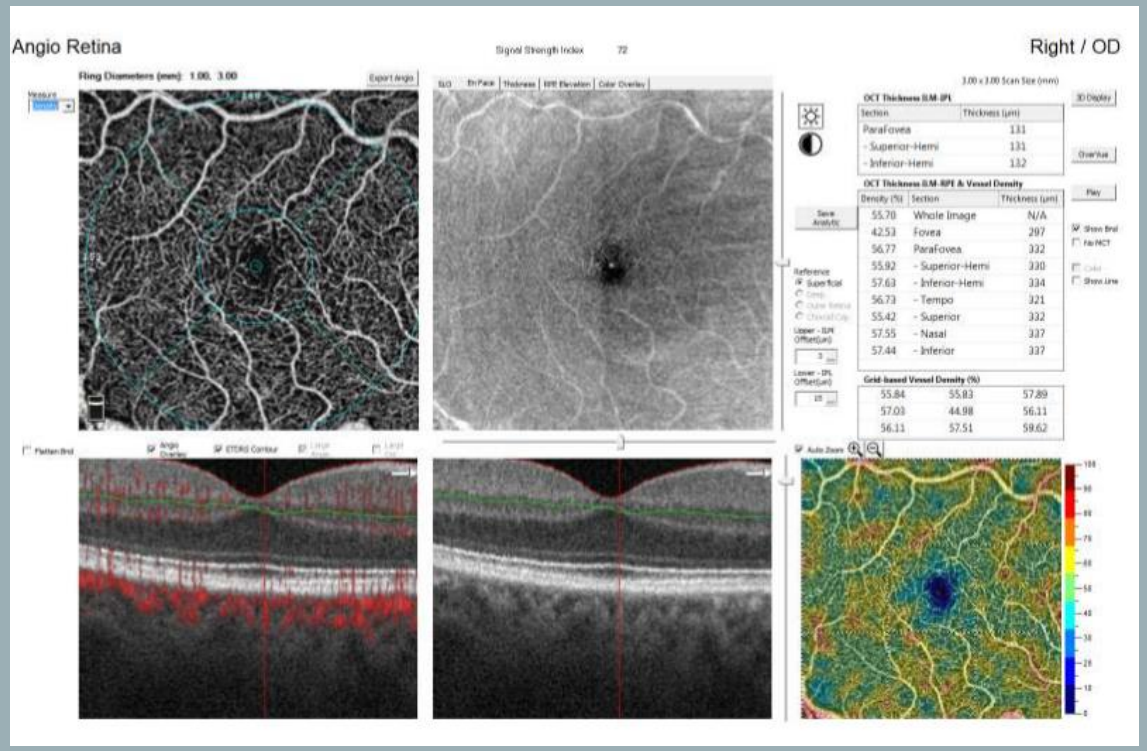
Choroid



Slide Courtesy of Diana Shechtman, OD

NORMAL OCTA

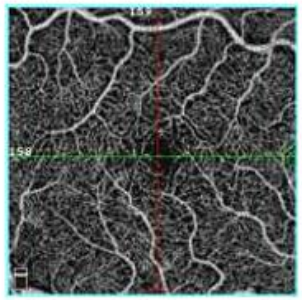
Capillary Density



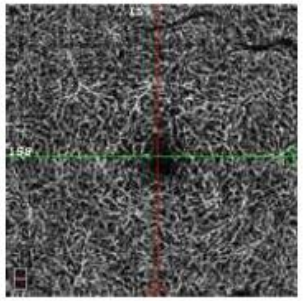
Retina OverVue **Right / OD**

Image Type: Angio

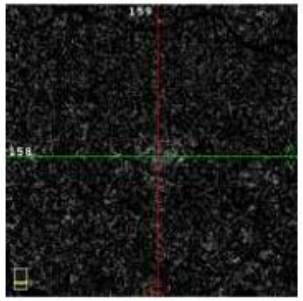
3.00 x 3.00 Scan Size (mm)



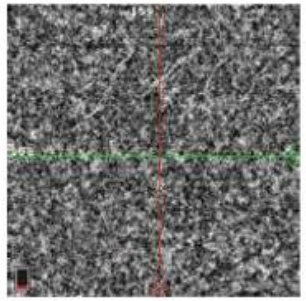
Angio - Superficial



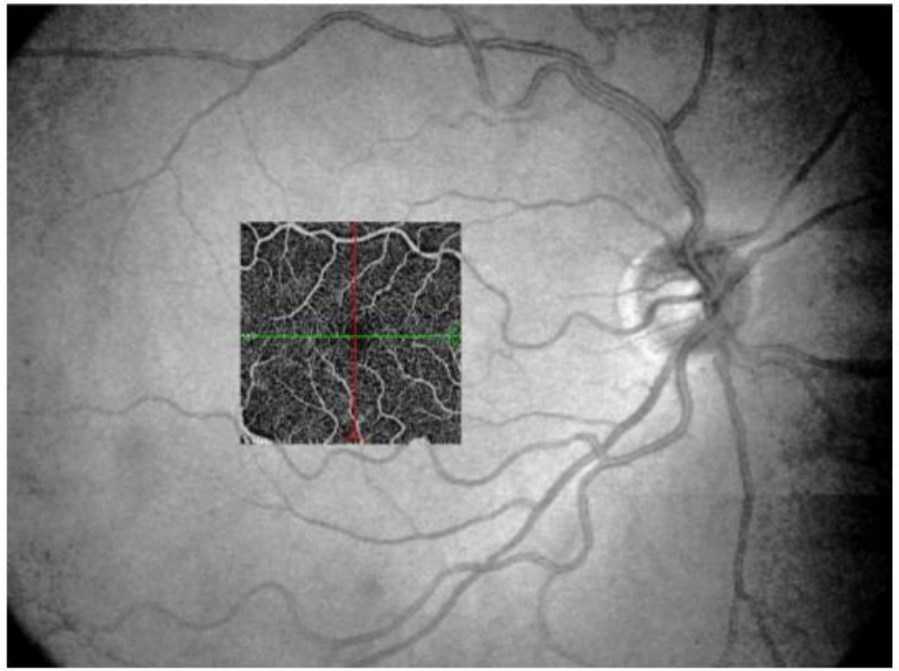
Angio - Deep



Angio - Outer Retina

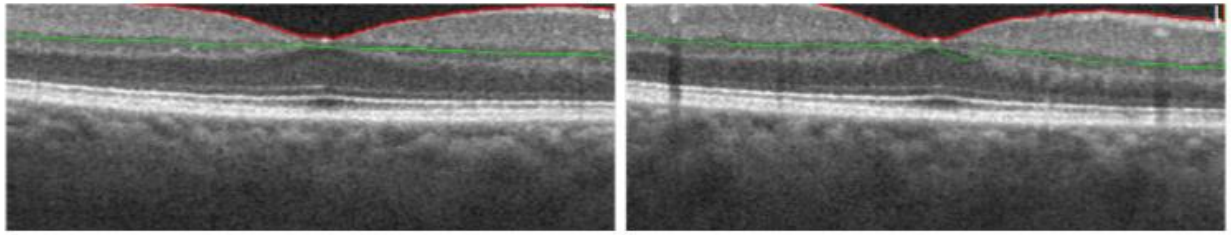


Angio - Choroid Capillary

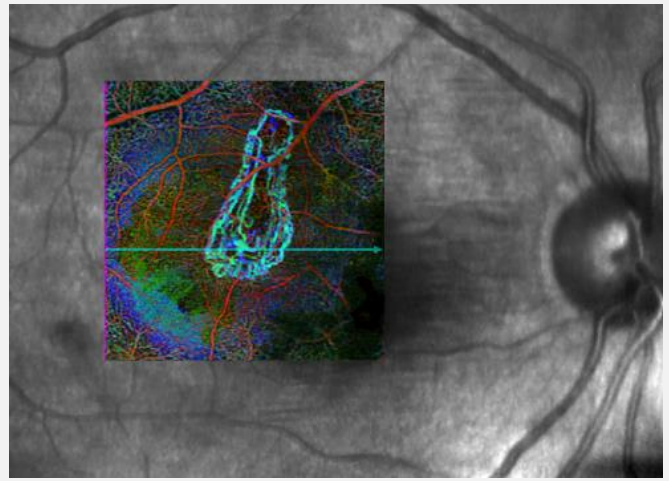


Reference image on 08/30/2016

Zoomed

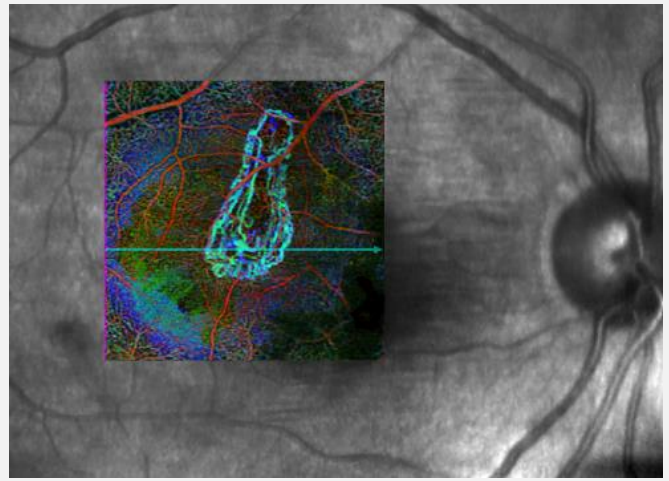


COMPARISON TO FLUORESCEIN ANGIOGRAPHY AND ICG



- Advantages of OCTA
  - Non-invasive imaging, no use of exogenous dye
  - No risk of adverse affect (from dye)
  - Fast! Takes 3-4 seconds compared to several minutes
  - Repeatability
  - Higher resolution – Able to visualize fine detail of vasculature at all retinal layers because not obscured by leaking dye
  - Provides more precise depth localization and delineation of lesions

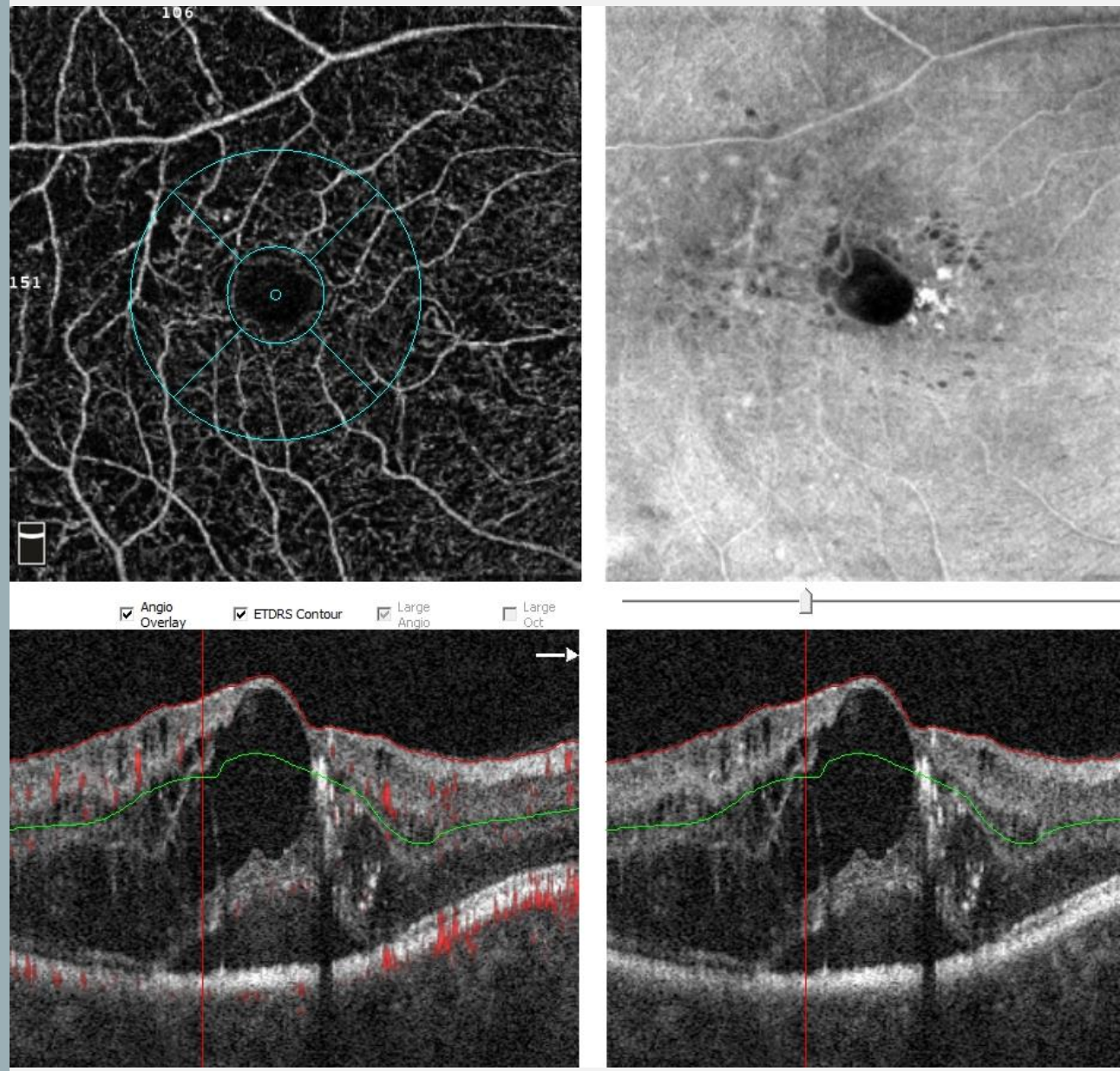
COMPARISON TO FLUORESCEIN ANGIOGRAPHY AND ICG



- Disadvantages of OCTA
  - Cannot visualize active leakage
  - Not able to visualize vessels that have no flow or slower flow than detection threshold of OCTA
  - Limited field of view… still developing widefield imaging
  - Susceptible to artifacts (motion, blink and shadowing)

APPLICATIONS OF OCTA

DIABETIC RETINOPATHY



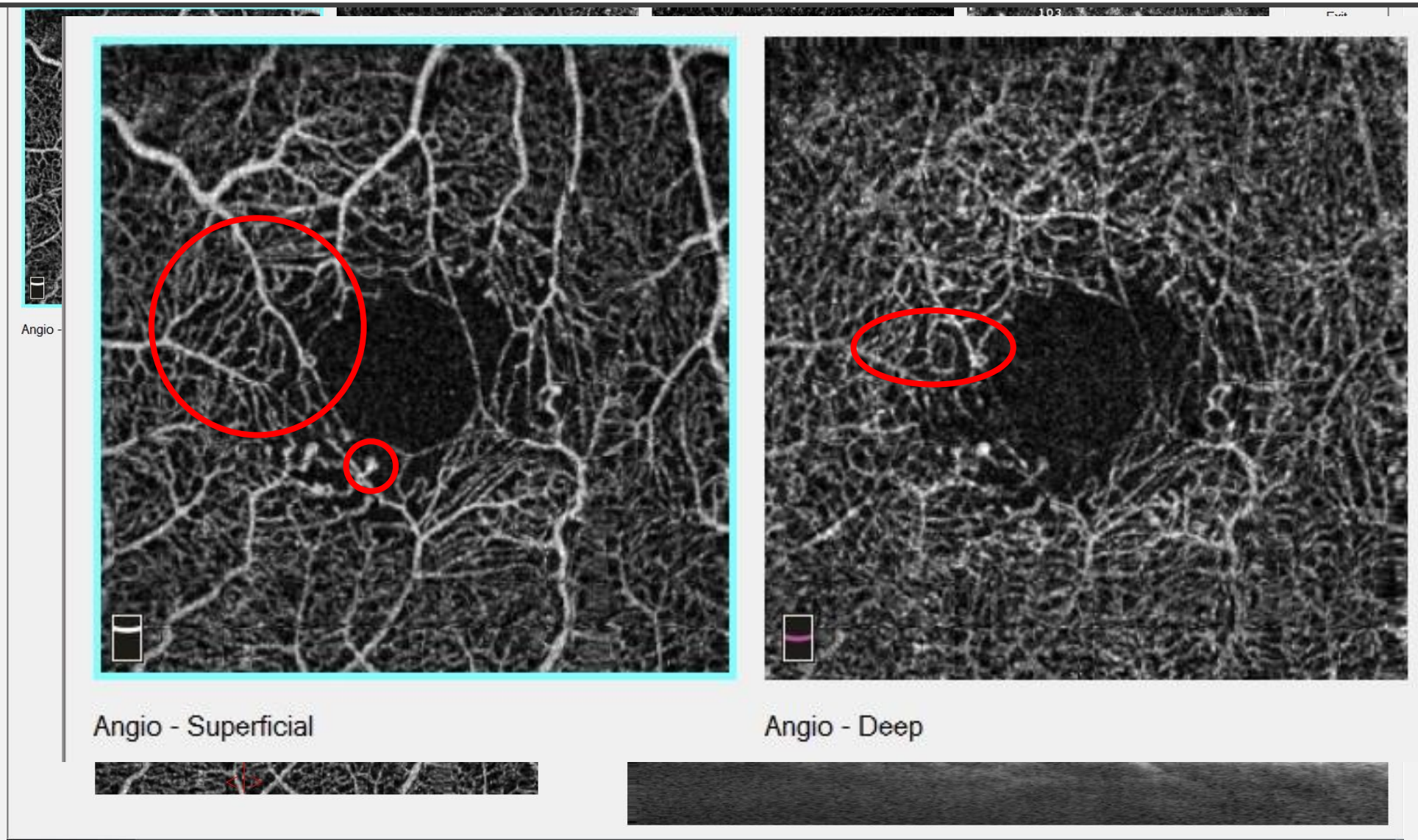
DIABETIC RETINOPATHY

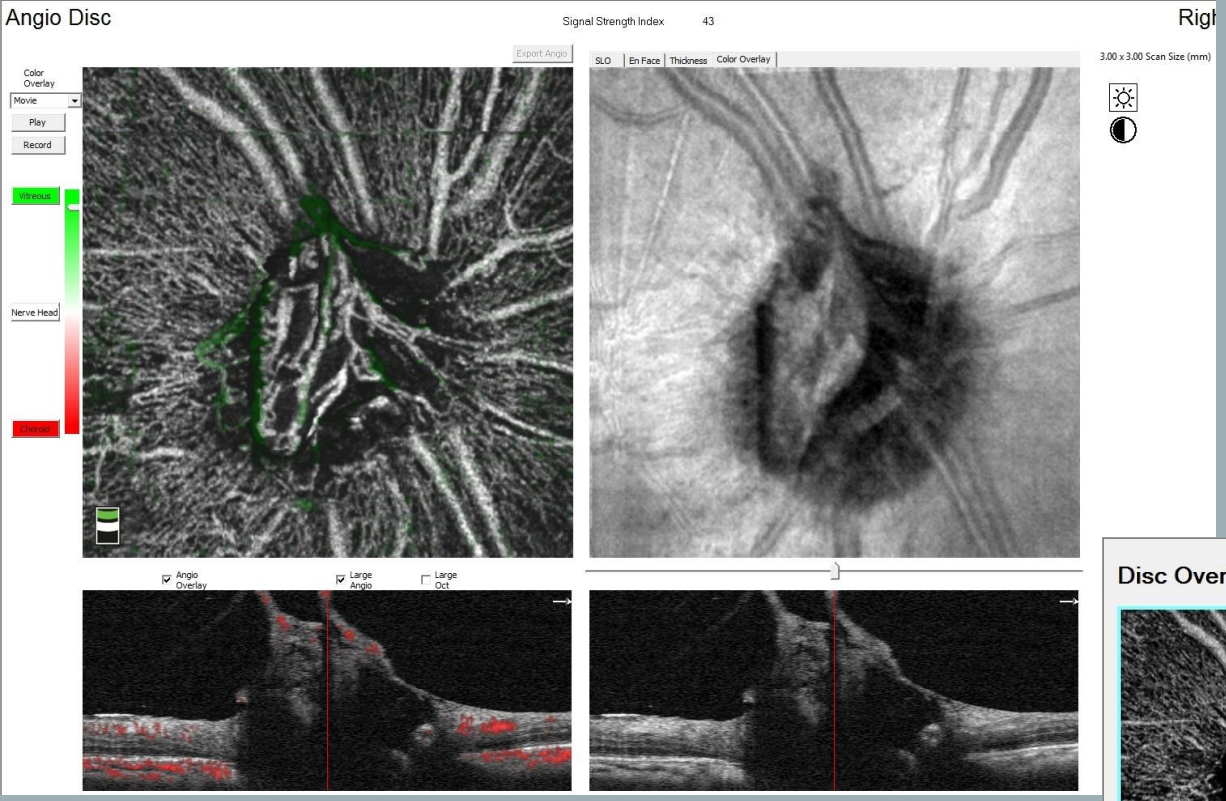
- Mostly affects the superficial capillary plexus (SCP)
- Easier to identify vascular anomalies associated with DR:
  - Microaneurysms
  - Retinal capillary dropout
  - Enlargement and distortion of foveal avascular zone
  - Vascular loops
  - Neovascularization

DIABETIC RETINOPATHY

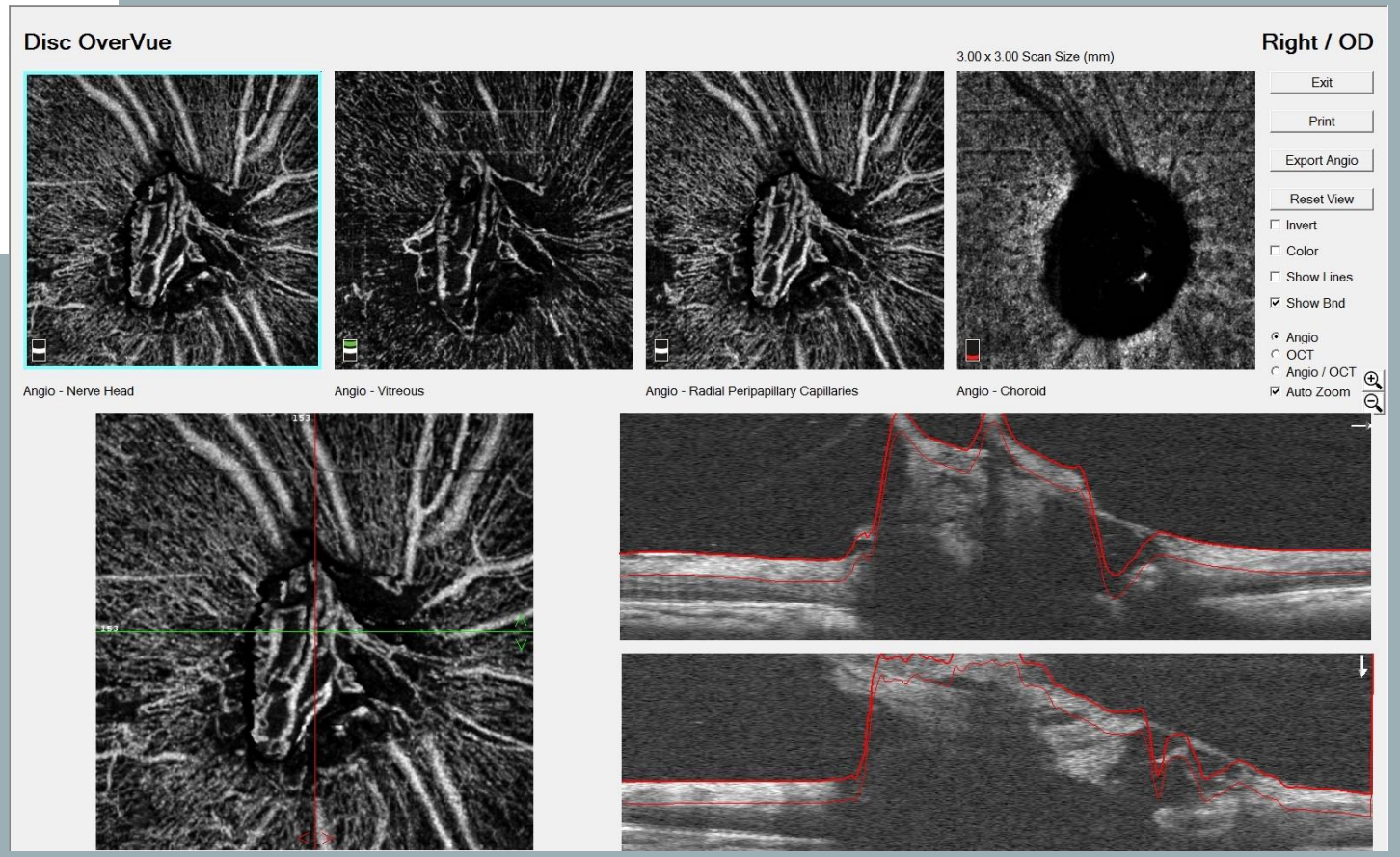
- Study by Carlos et al 2015
  - 61 eyes with DM with no DR and 28 control eyes of healthy subjects
  - OCTA able to image foveal microvascular changes not detected by clinical examination.
  - FAZ remodeling more in diabetic than in control eyes (36% vs 11%)
  - More capillary non profusion in diabetic eyes (21% vs 4%)
  - Conclusion: diabetic eyes showed statistically significant FAZ enlargement compared to healthy eyes, irrespective of presence of DR.

DIABETIC RETINOPATHY: MICROANEURYSMS



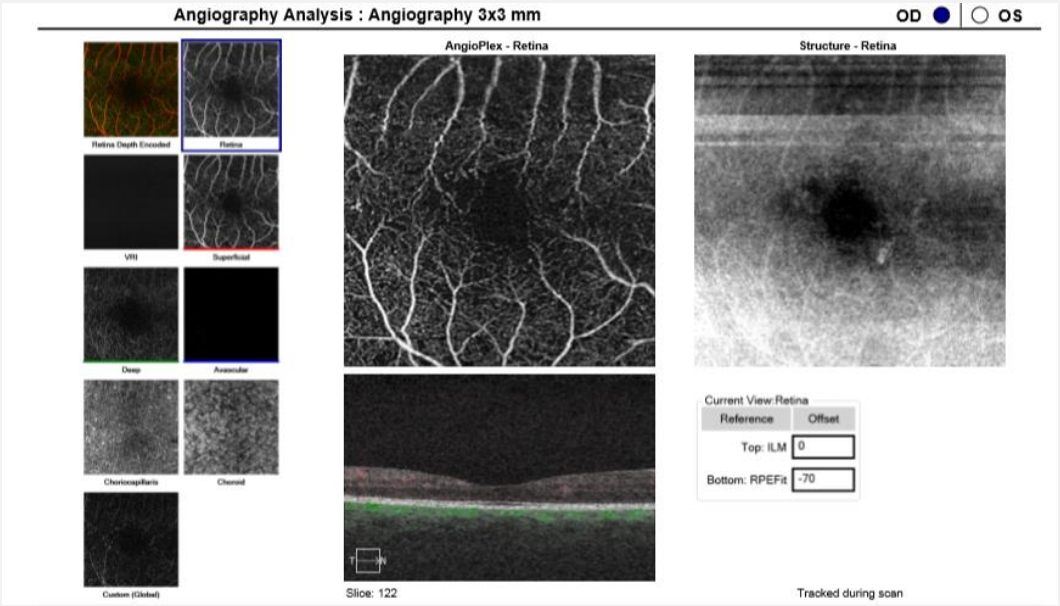

Angio Disc
Signal Strength Index 43
Color Overlay
Movie
Play
Record
Vitreous
Nerve Head
Choroid
Export Angio
SLO
En Face
Thickness
Color Overlay
3.00 x 3.00 Scan Size (mm)
Angio Overlay
Large Angio
Large Oct

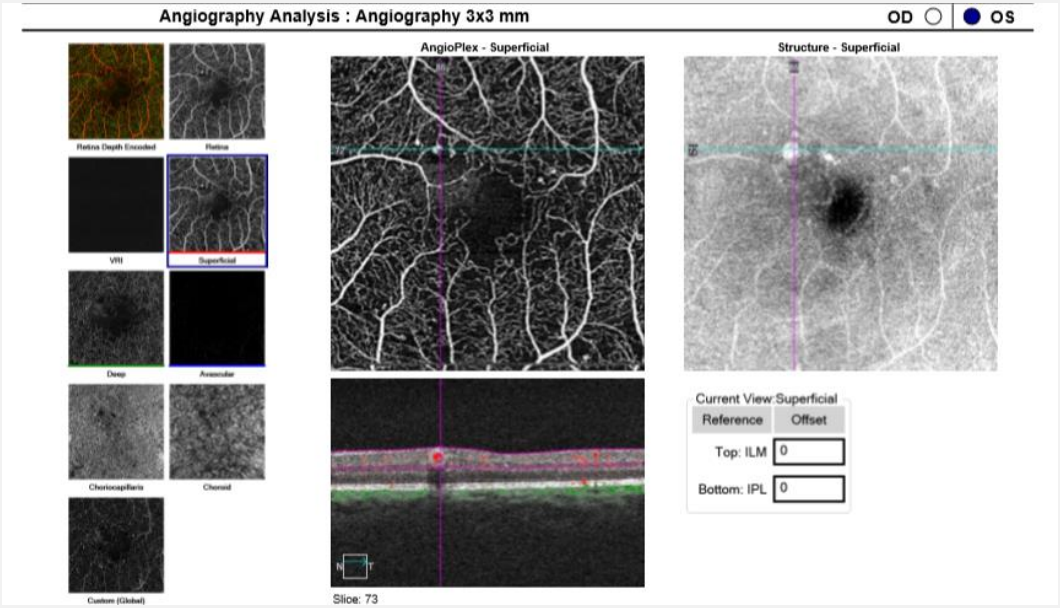
NVD


Disc OverVue
Right / OD
3.00 x 3.00 Scan Size (mm)
Exit
Print
Export Angio
Reset View
Invert
Color
Show Lines
Show Bnd
Angio
OCT
Angio / OCT
Auto Zoom
Angio - Nerve Head
Angio - Vitreous
Angio - Radial Peripapillary Capillaries
Angio - Choroid

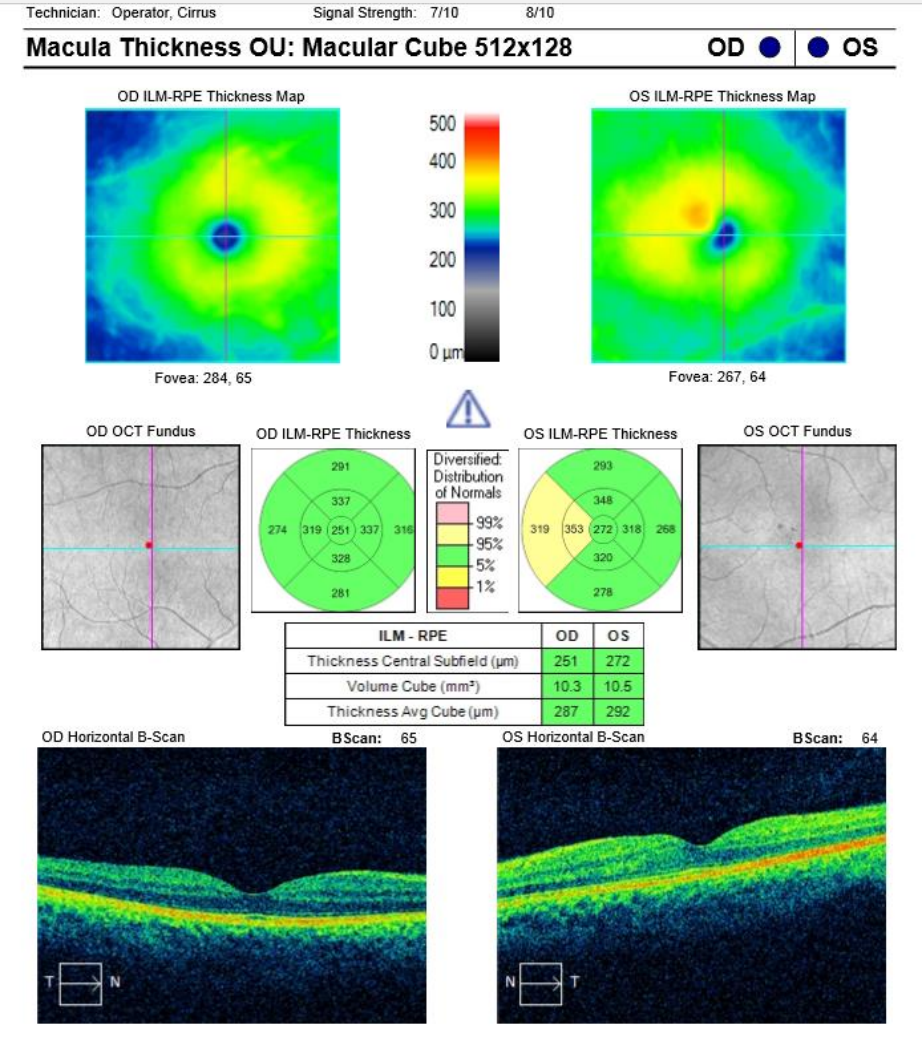
BUT MY PATIENT SEES 20/20….

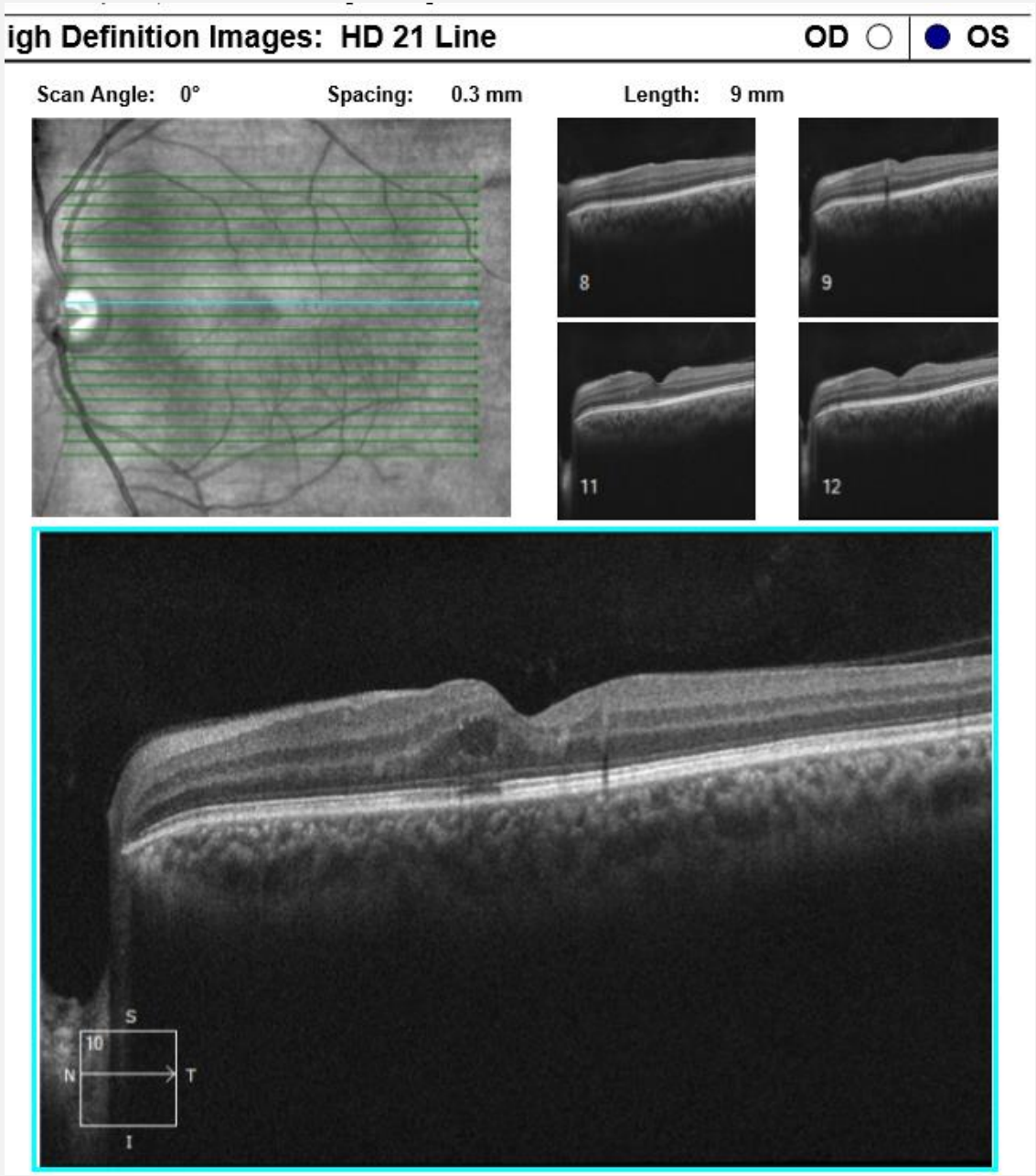
- 47 YO African American Male
- Type 2 DM x 10 years
- Best corrected vision 20/20 OD, OS



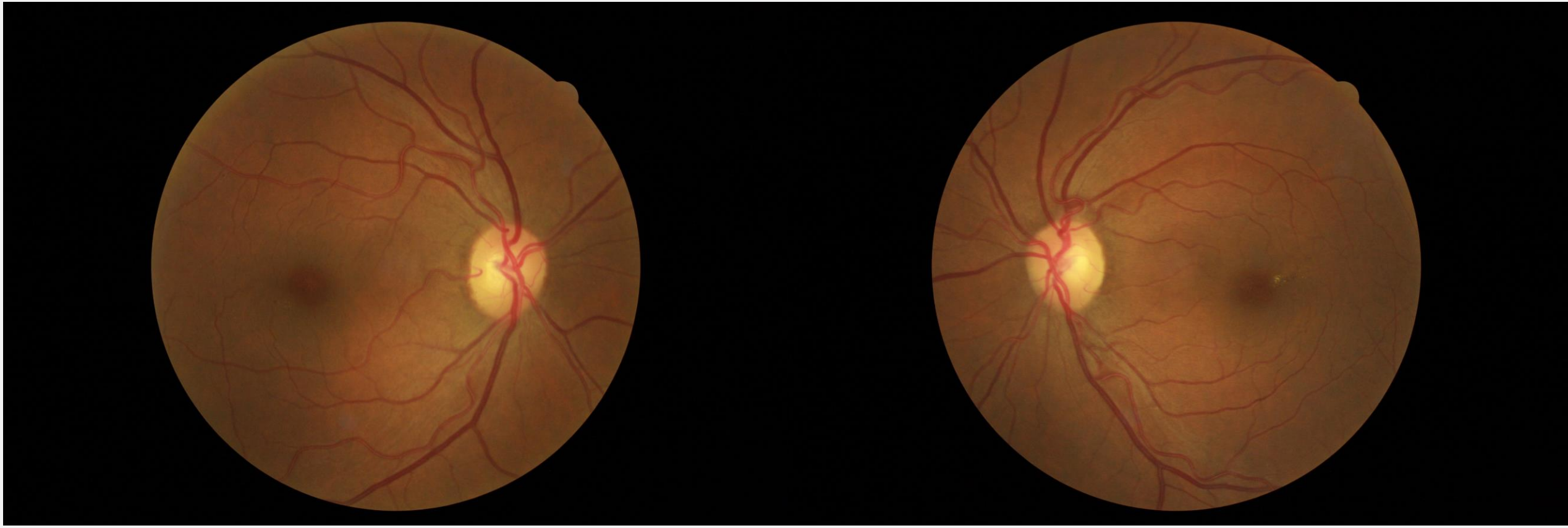


BUT MY PATIENT SEES 20/20….

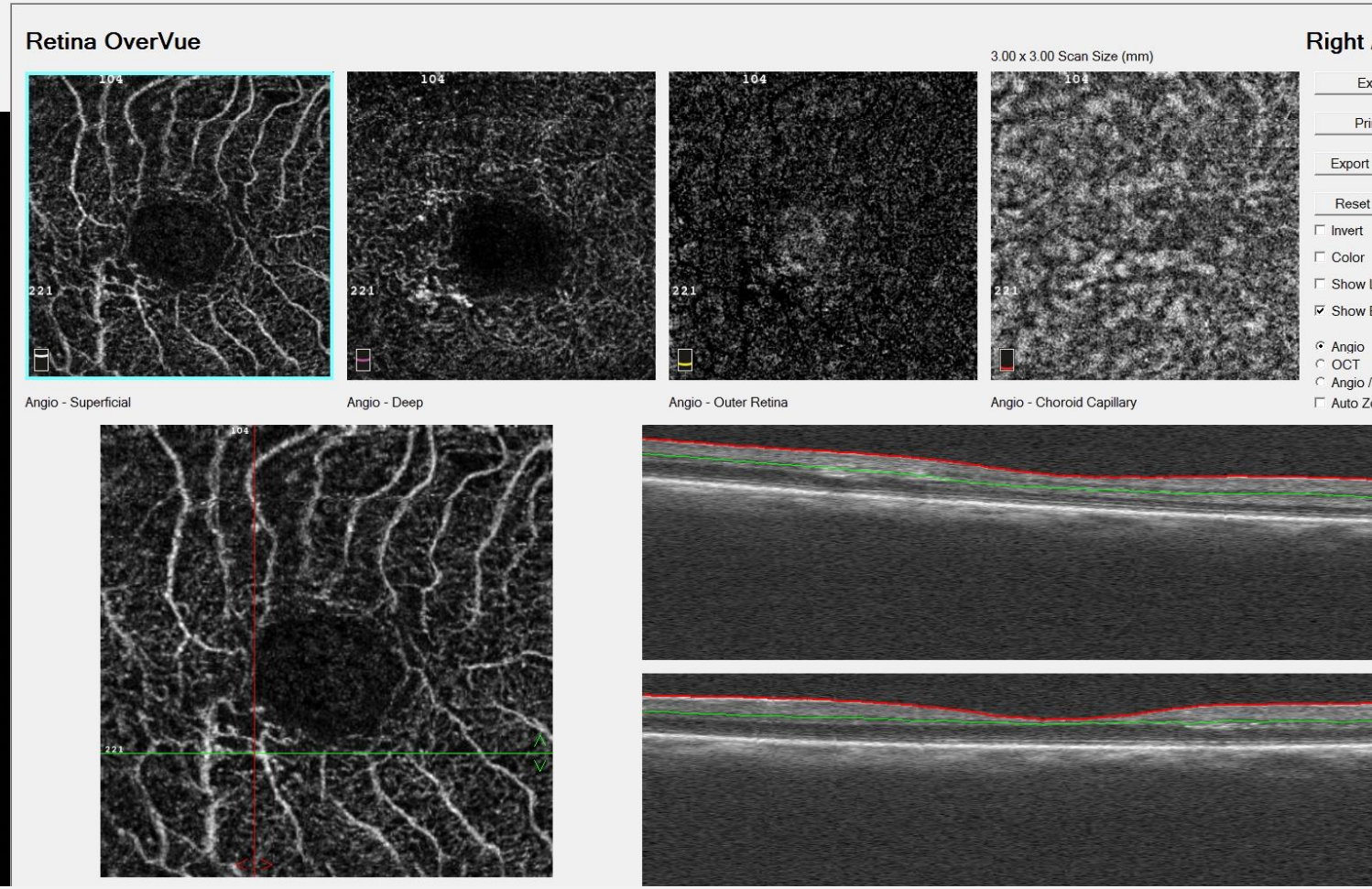




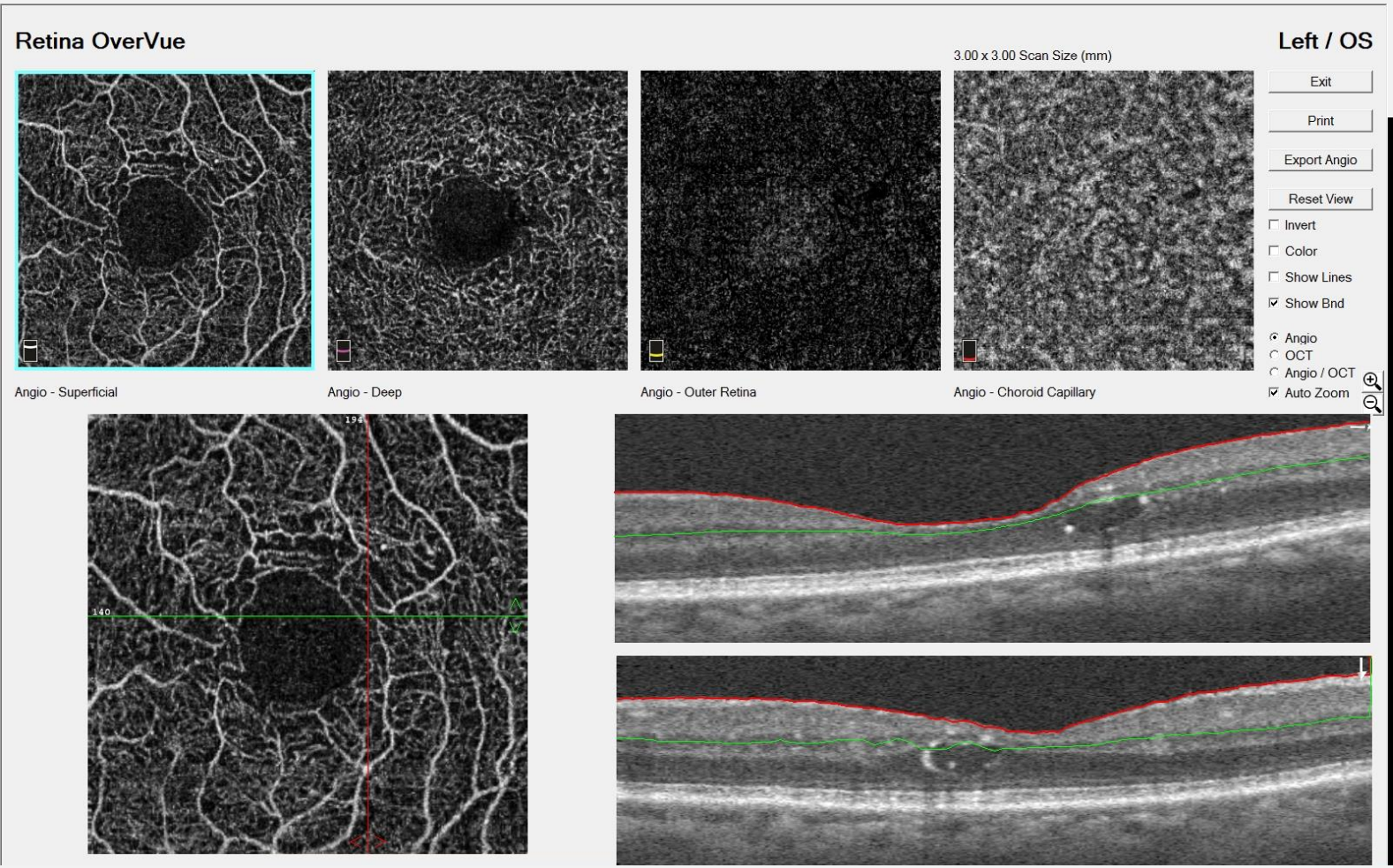
OCTA DETECTION OF MICROVASCULAR CHANGES IN DM



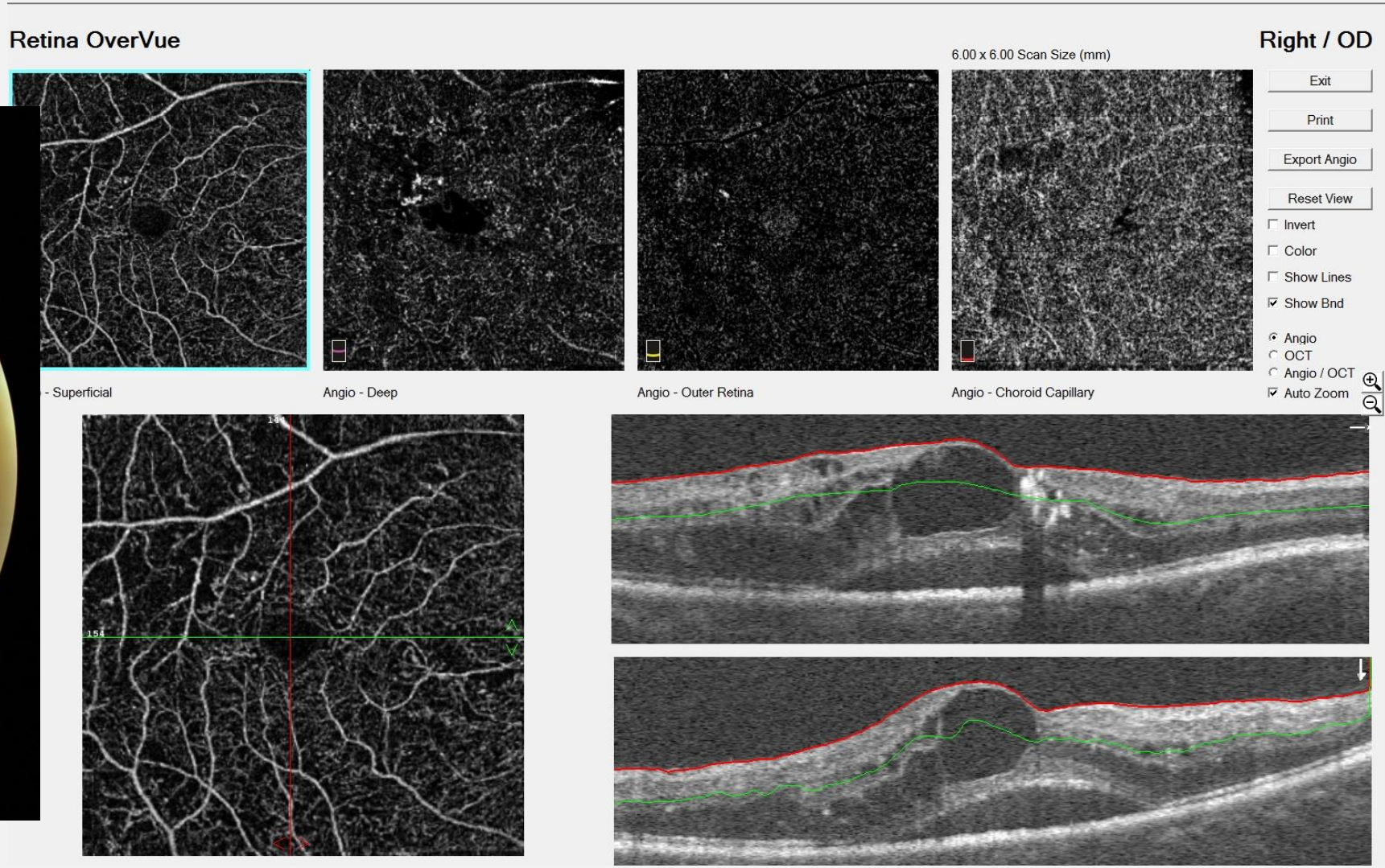
OCTA DETECTION OF MICROVASCULAR CHANGES IN DM



OCTA DETECTION OF MICROVASCULAR CHANGES IN DM



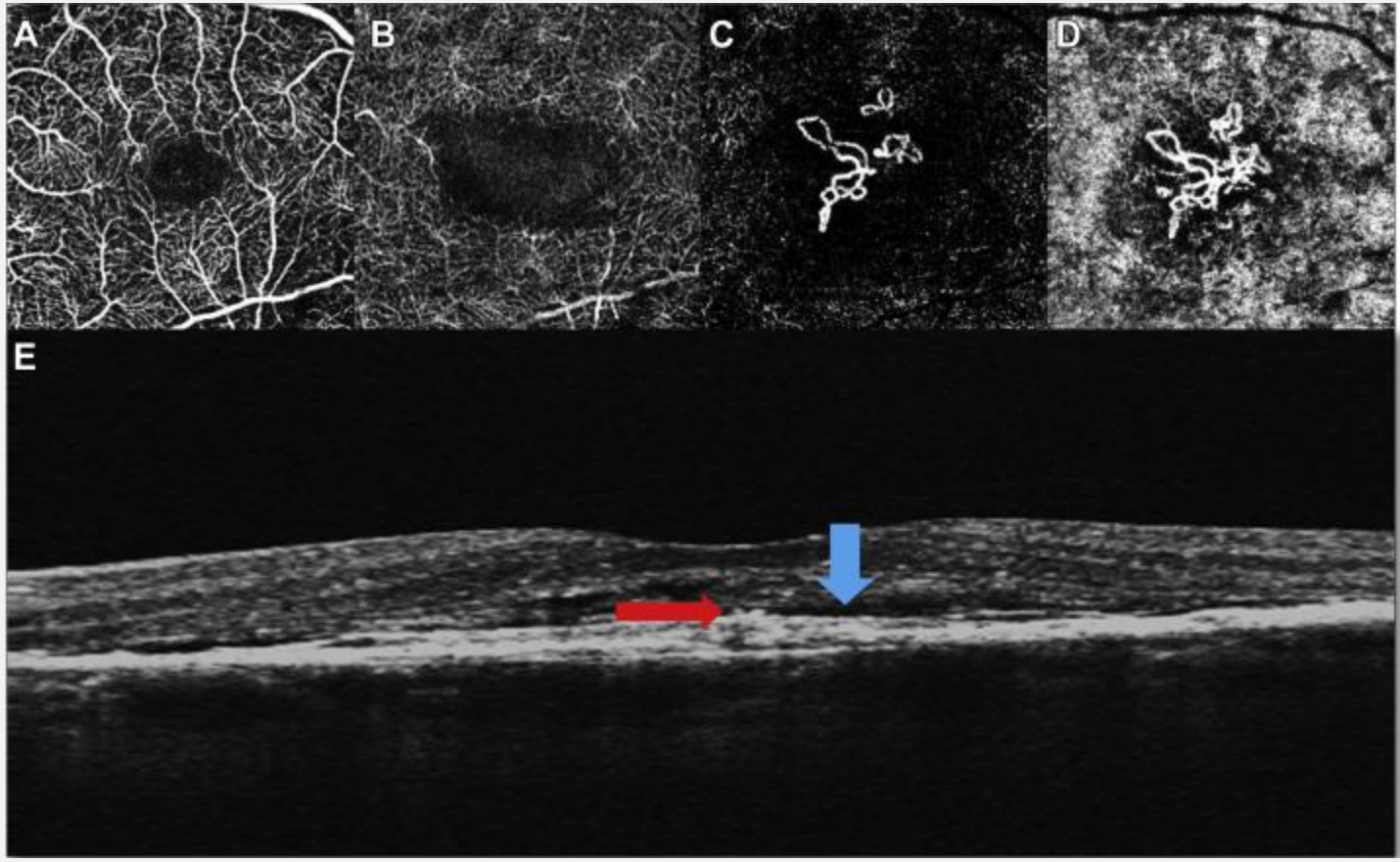
PROLIFERATIVE DIABETIC RETINOPATHY



AGE-RELATED MACULAR DEGENERATION

AGE RELATED MACULAR DEGENERATION

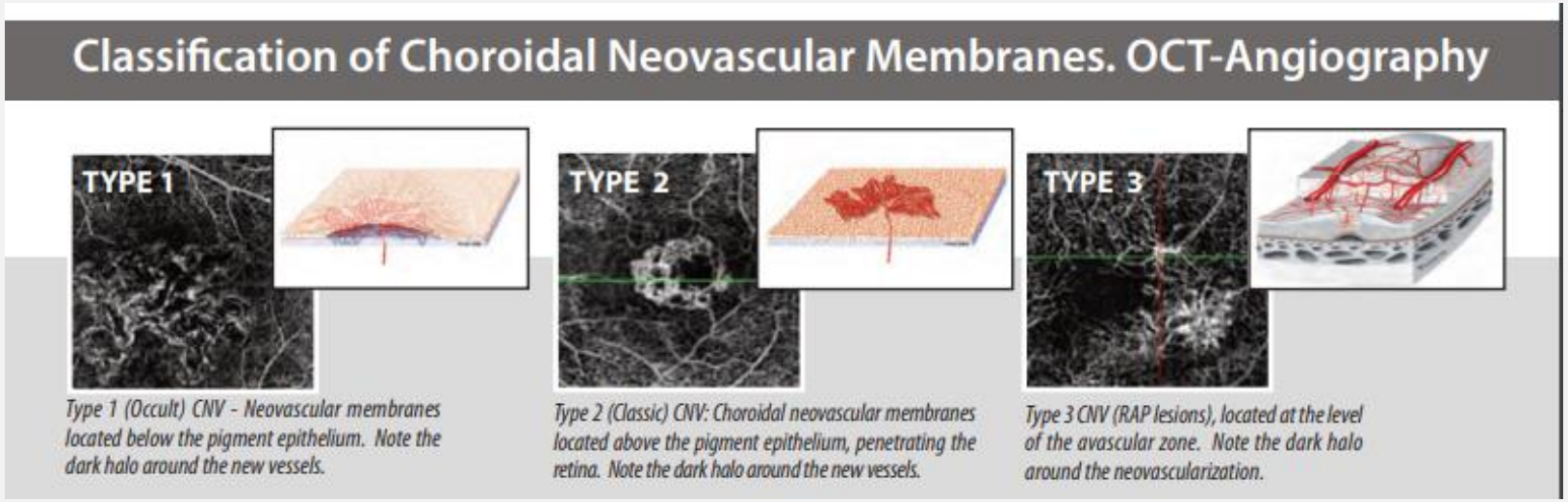
- OCTA is great tool for monitoring "Dry" to "Wet" conversion
  - Recognize subtle CNVM and get treatment promptly
- OCTA provides ability to visualize choroidal neovascularization in avascular layer or choriocapillaris
- Study with 48 eyes with confirmed CNV, specificity of CNV detection on OCTA compared to FA was high (91%) but sensitivity was low (50%). (Carlos et al. 2015)



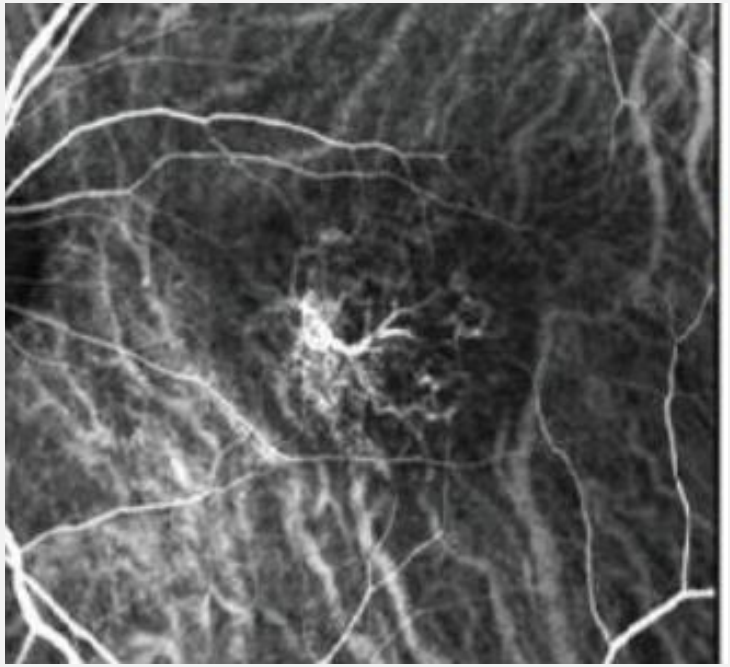
Sambhav et al 2017

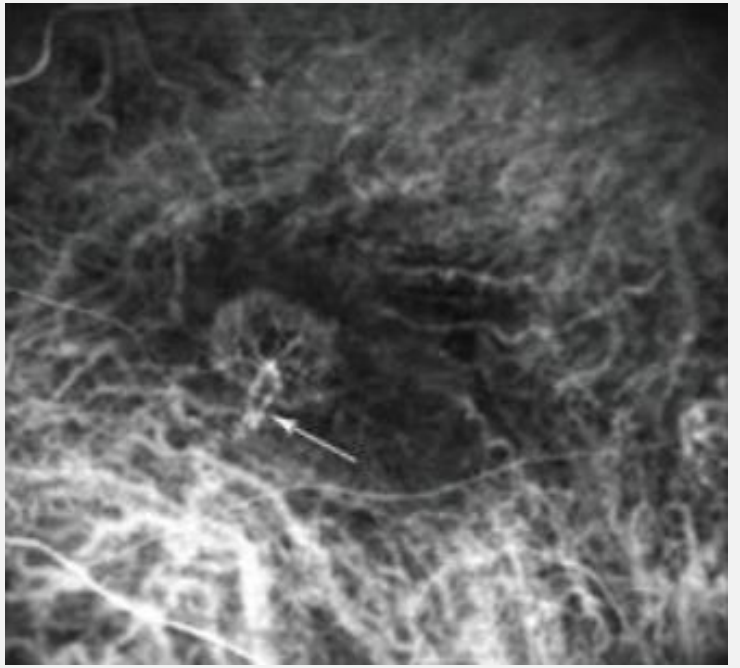
TYPES OF CNVM

- Type 1: Occult (beneath the RPE layer)
- Type 2: Classic (above the RPE layer and has adjacent SRF leakage)
- Type 3: RAP (Retinal Angiomatous Proliferation)

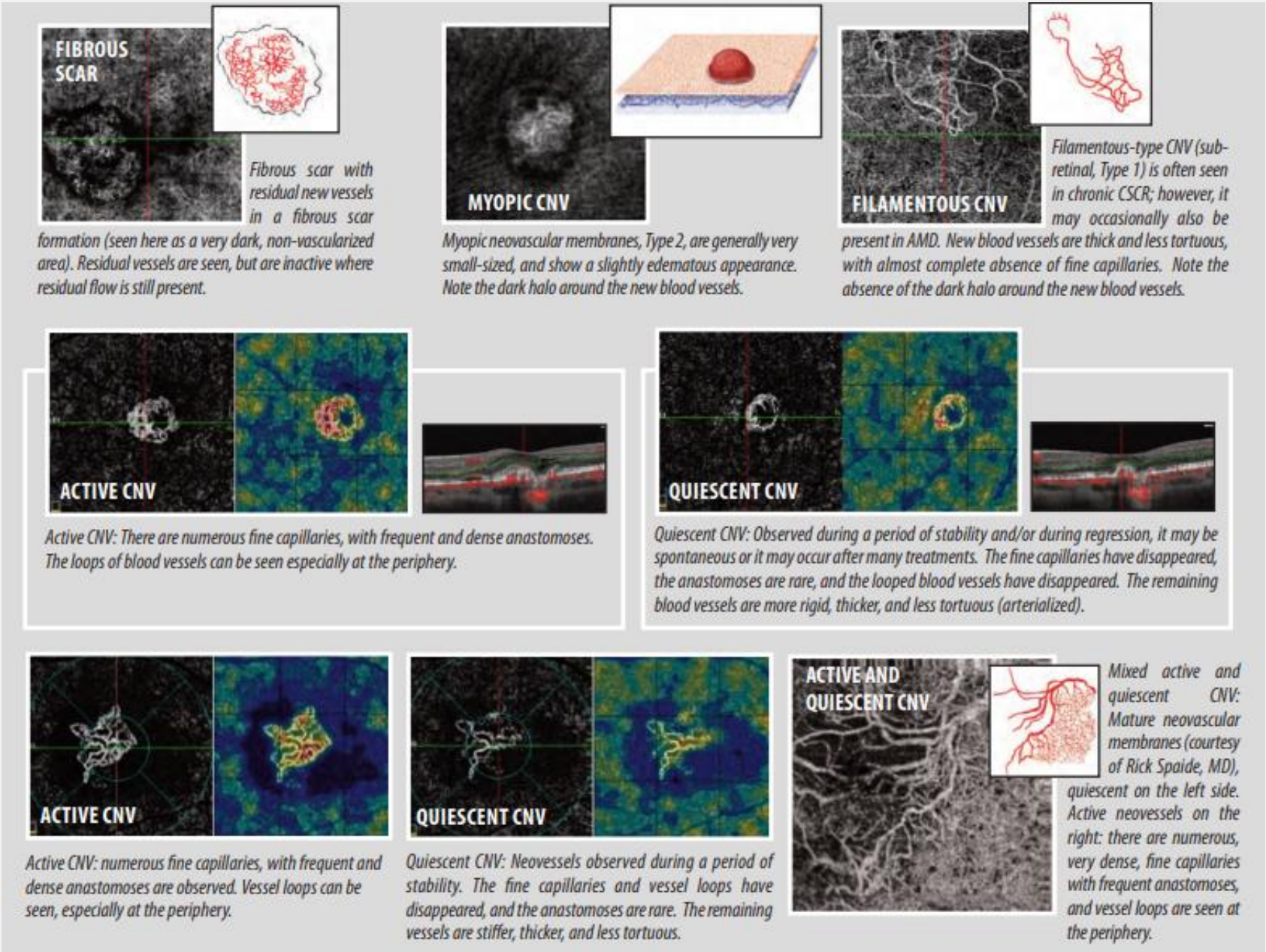


Modified classification from J. Jung and K.B. Freund. All OCT-Angiography images have been obtained using the AngioVue OCT system from Optovue (Fremont, California)





TYPES OF CNVM



Modified classification from J. Jung and K.B. Freund. All OCT-Angiography images have been obtained using the AngioVue OCT system from Optovue (Fremont, California)

POLYPOIDAL CHOROIDAL VASCULOPATHY

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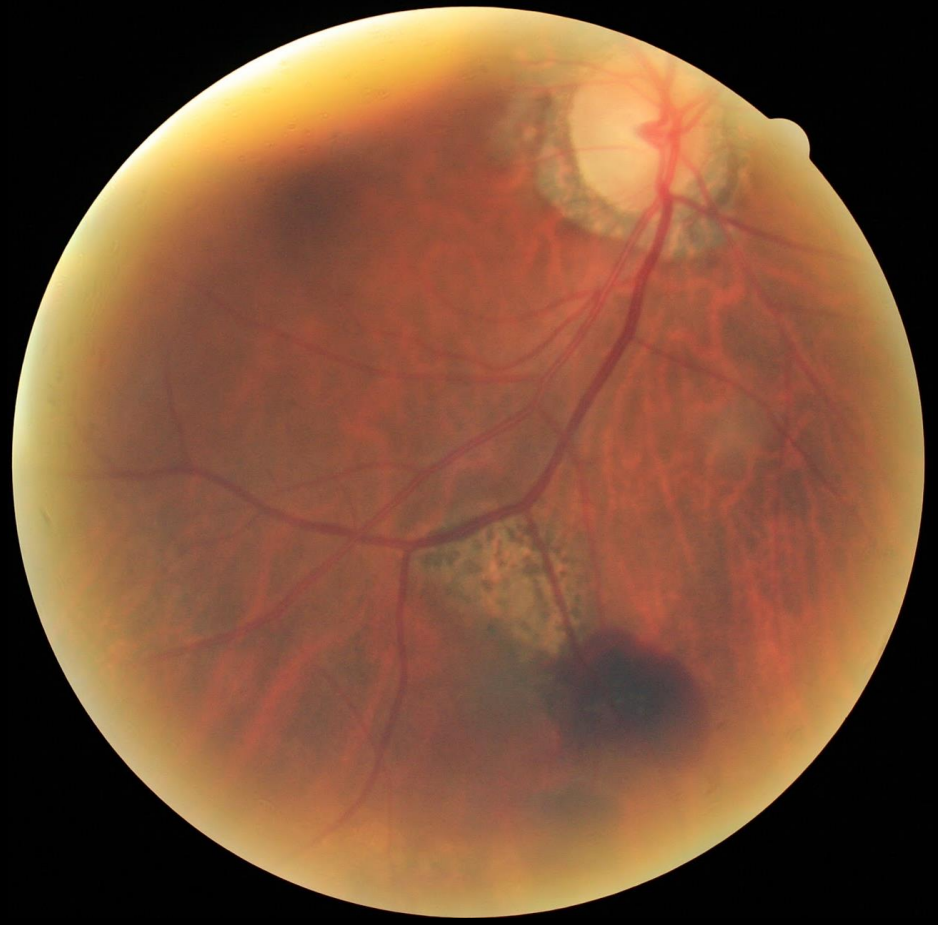


POLYPOIDAL CHOROIDAL VASCULOPATHY

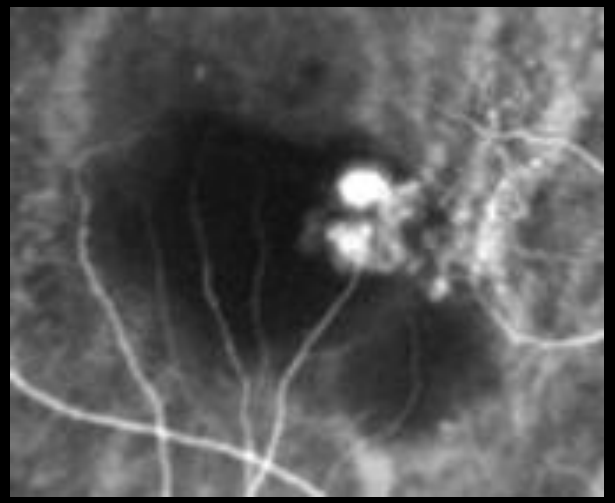
1982 by Yannuzzi:

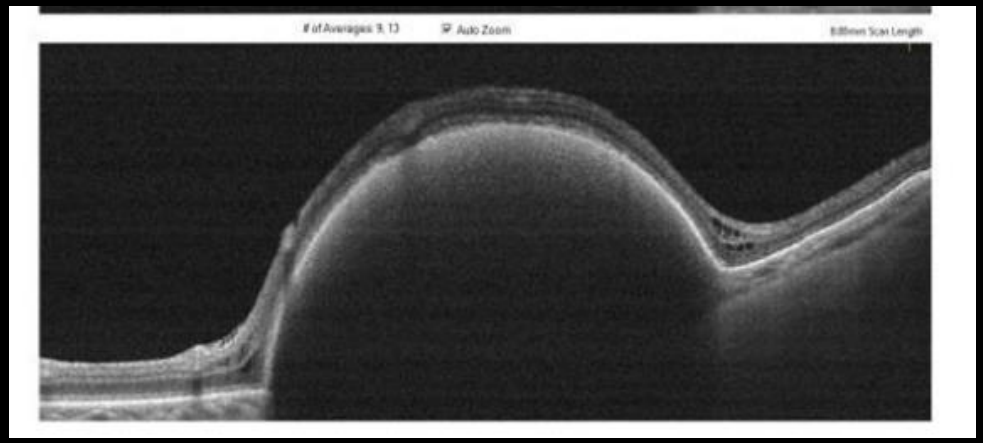
Characterized by **branching vascular network** (BVN) with adjacent **polypoidal lesions (dilations/polyps)** at the terminal ends

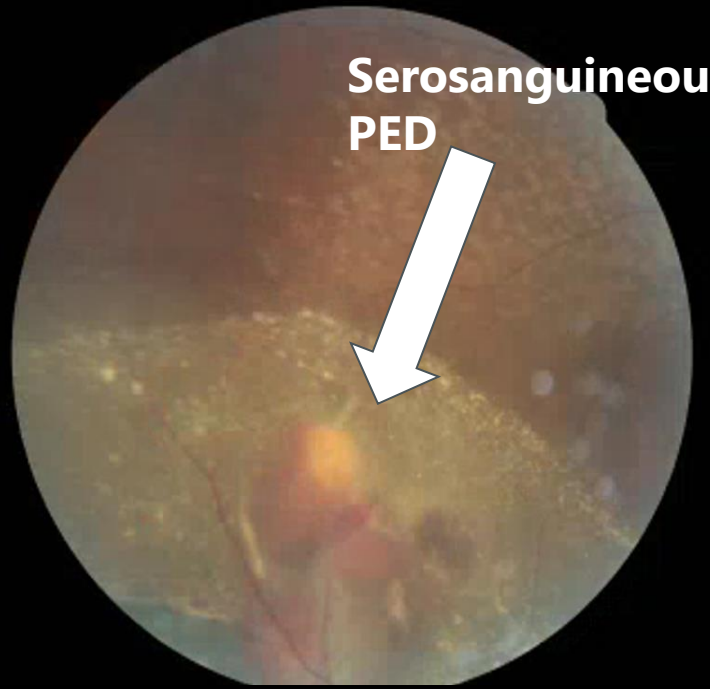
Multiple, recurrent serosanguineous detachments of the RPE (PED) and/or neurosensory retina

Associated with secondary bleeding or leakage from the polypoidal lesions.

ICG







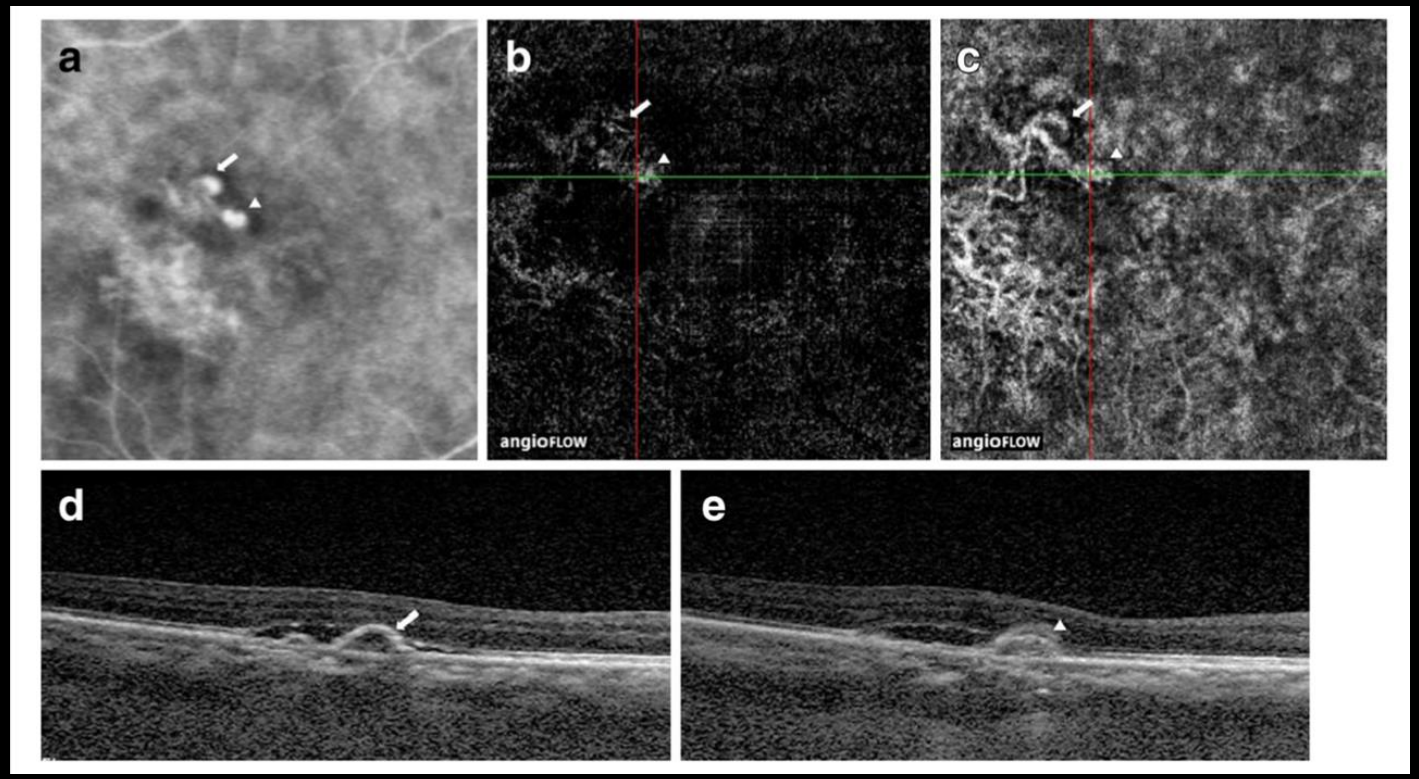
POLYPOIDAL CHOROIDAL VASCULOPATHY

ICGA VS OCTA?

Polyps detected:
- 100% by ICGA
- 85% by OCTA

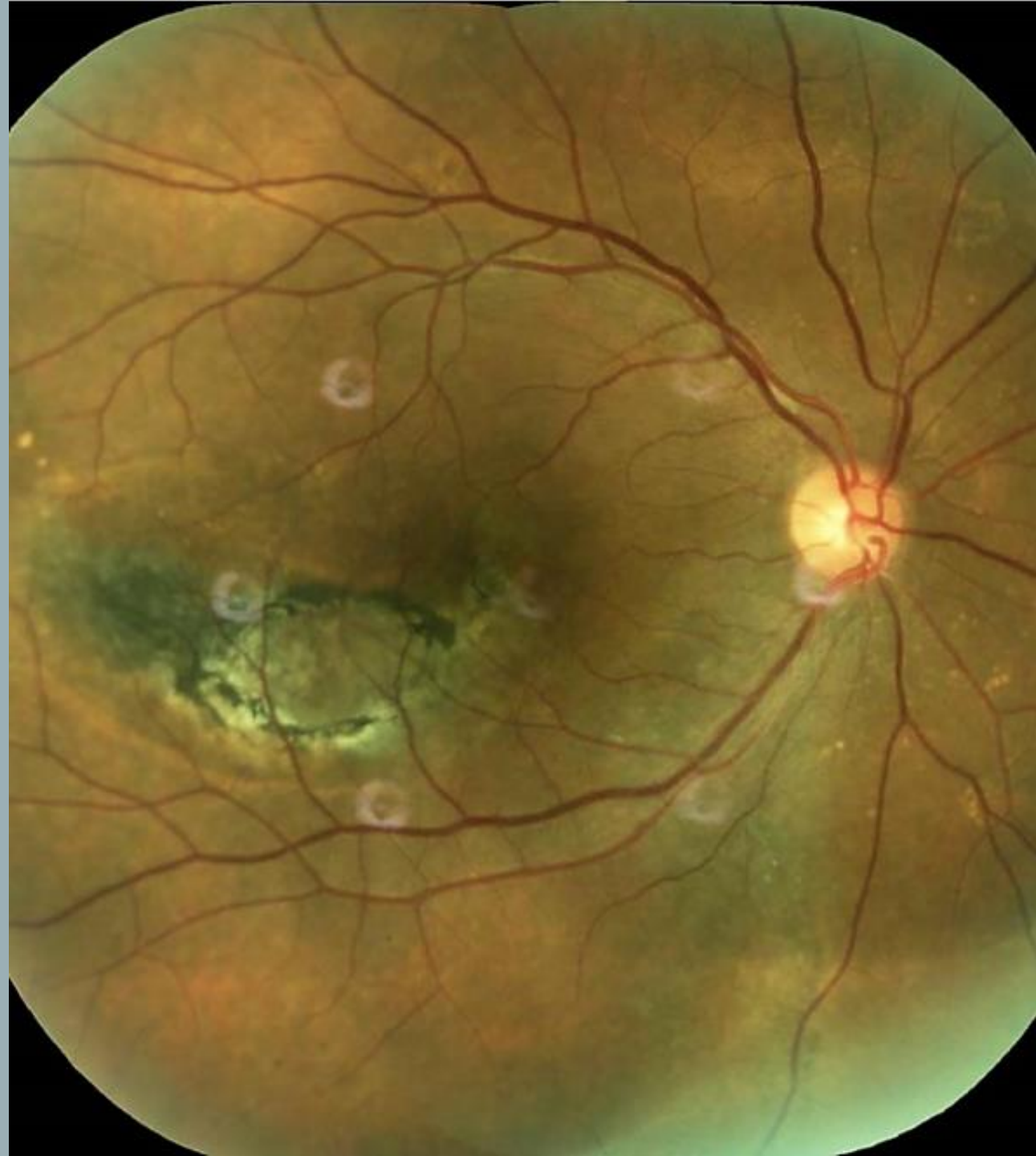
BVN detected:
- 70% ICGA
- 70% OCTA

ICG | OCTA: Outer Retina | OCTA: Choroidal Capillaries



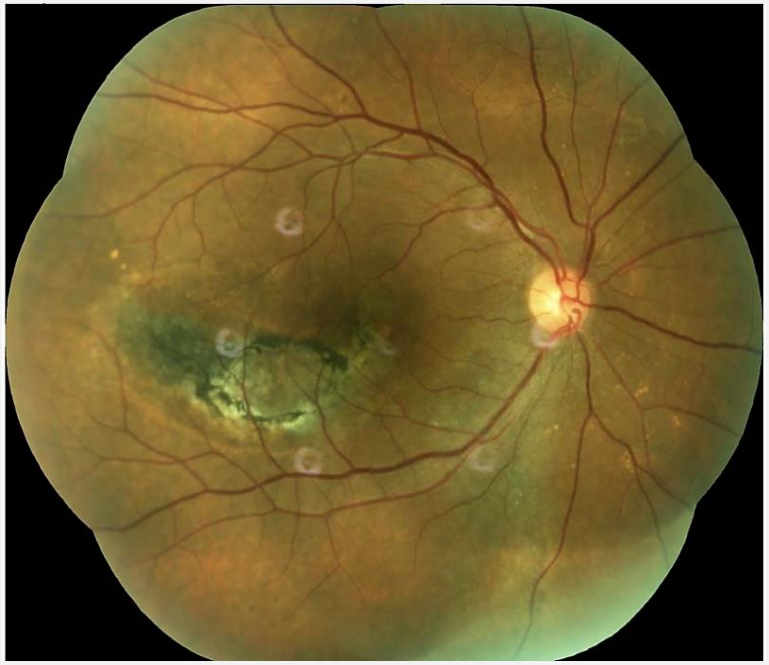
Takayama, K., Ito, Y., Kaneko, H., Kataoka, K., Sugita, T., Maruko, R., … Terasaki, H. (2017). Comparison of indocyanine green angiography and optical coherence tomographic angiography in polypoidal choroidal vasculopathy. *Eye*, *31*(1), 45–52. https://doi.org/10.1038/eye.2016.232

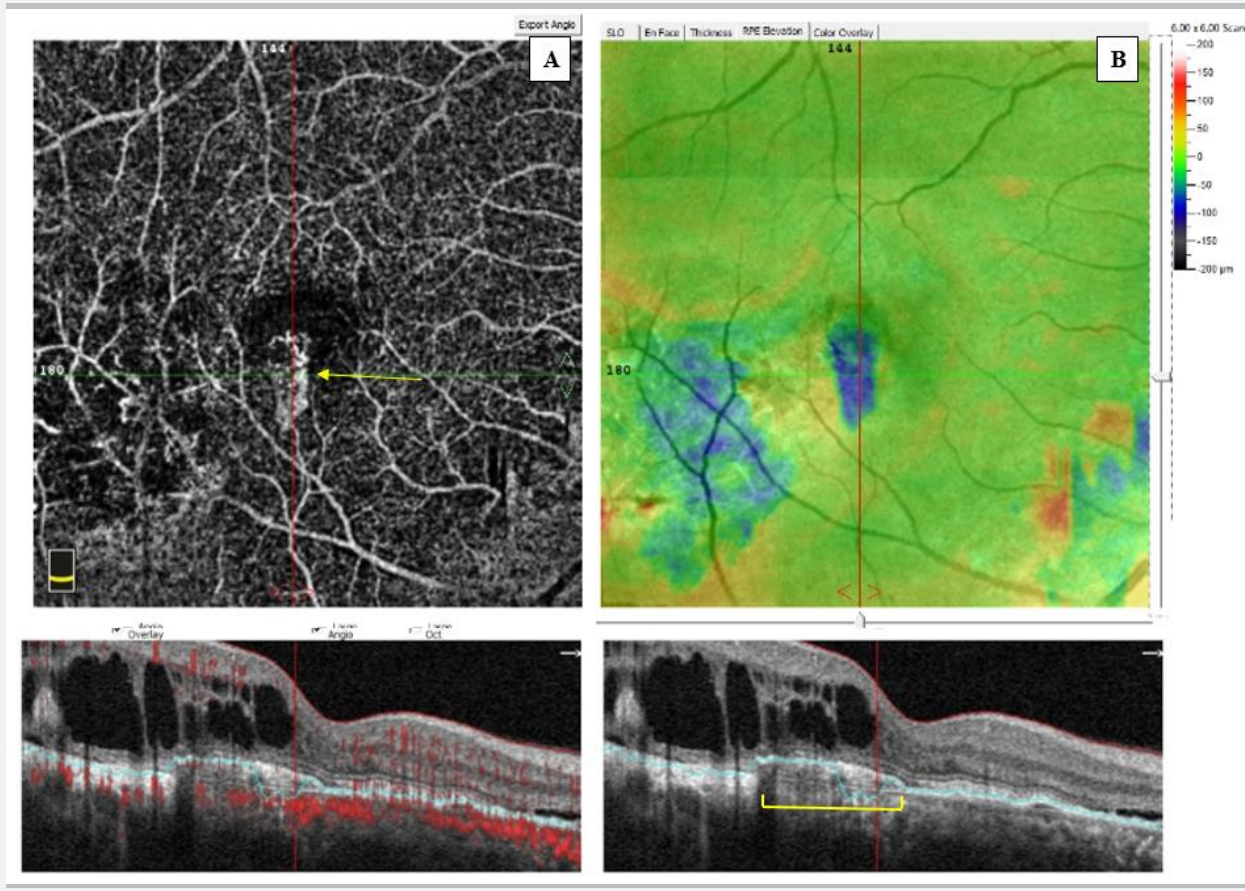
CHRONIC CENTRAL SEROUS CHORIORETINOPATHY



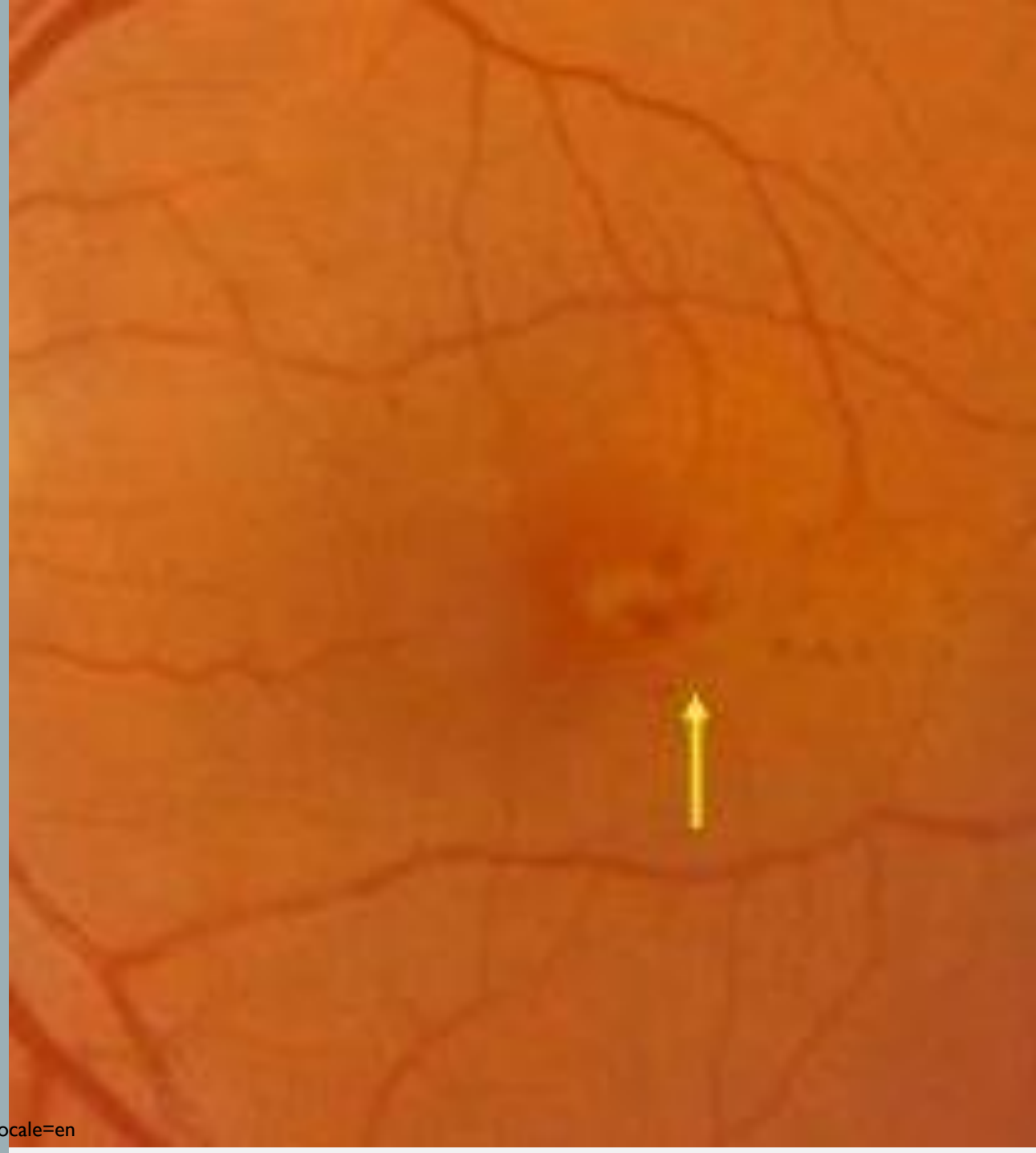
CHRONIC CSCR

- OCTA is helpful in identifying active CNVM
- Bonini Filho et al reports that OCTA has high sensitivity and specificity (compared to FA) for detection of CNV in eyes with chronic CSCR





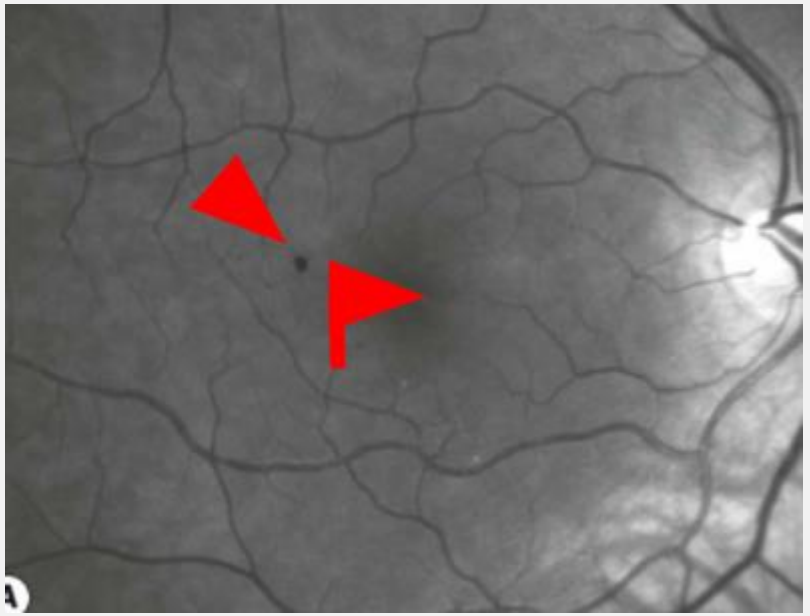
MACULAR TELANGIECTASIAS



https://www.atlasophthalmology.net/photo.jsf;jsessionid=BF992285CD3B3A7F4ACFC8C7D34AE4B6?node=8967&locale=en

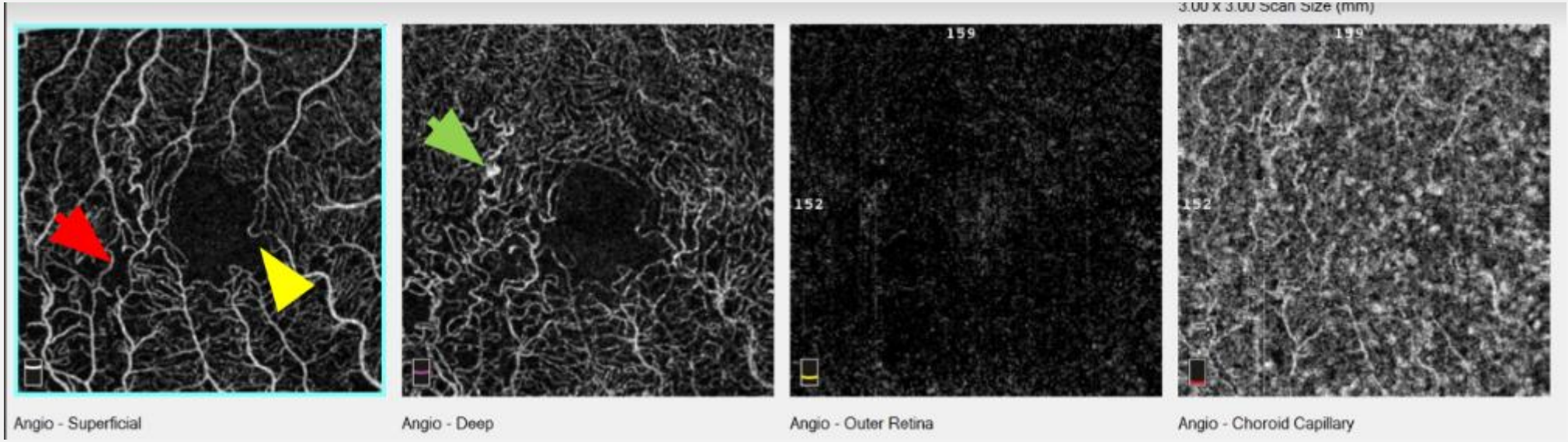
MACULAR TELANGIECTASIA

- A congenital or developmental vascular disorder
- Exudative dilations of perifoveal retinal capillaries
- Type 1: Aneurysmal
  - Males, unilateral, 4th or 5th decade
  - VA 20/40 or better
  - Dilation of capillaries, aneurysms, leakage and non-profusion to temporal macula
  - Limited to SCP and DCP

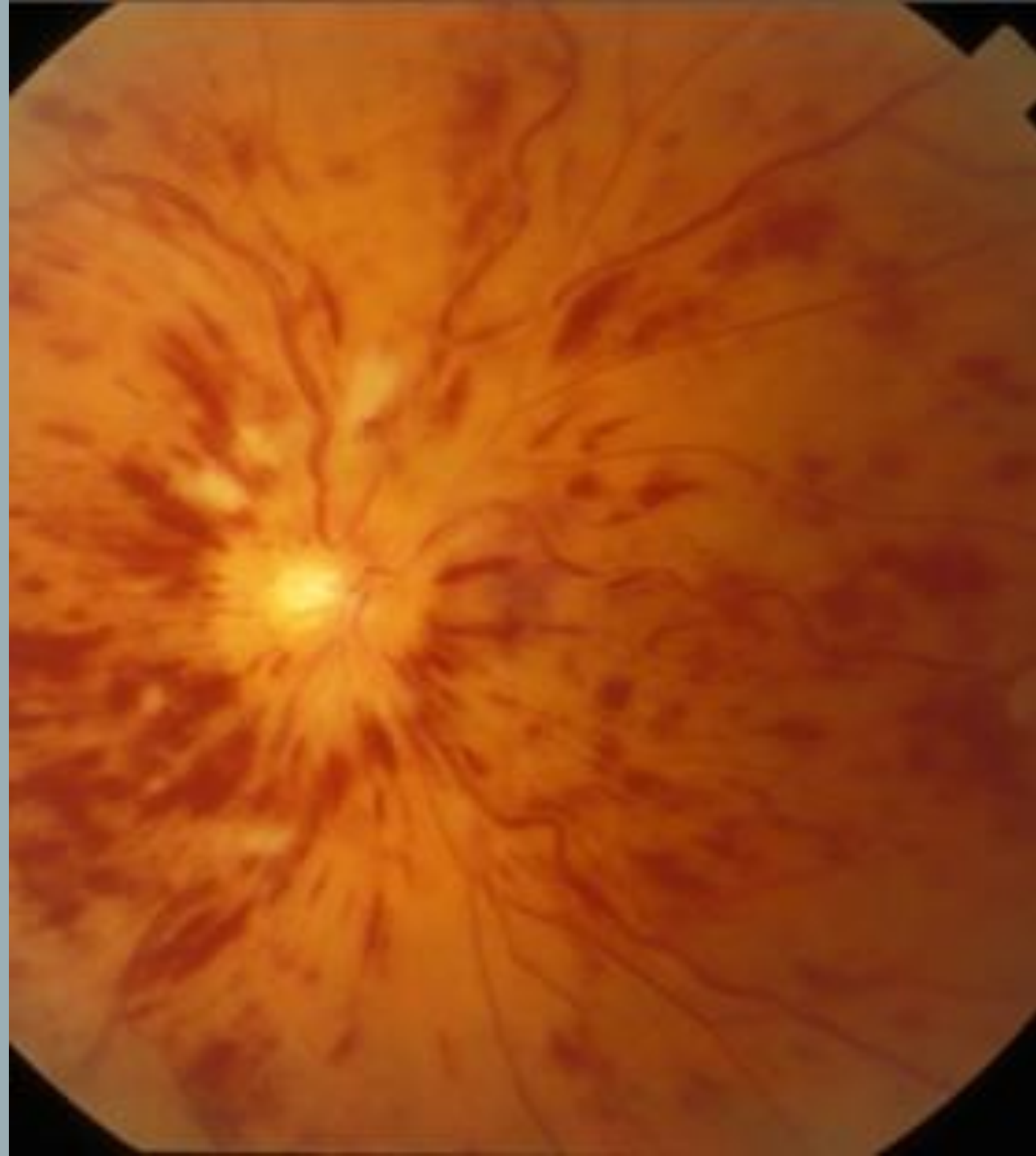


MACULAR TELANGIECTASIA

- Microaneurysms, capillary outbursts, vascular abnormalities and sclerotic vessels easy to visualize in SCP and DCP on OCTA
- Early identification leads to prompt treatment and appropriate blood work



RETINAL VASCULAR OCCLUSIONS



RETINAL VASCULAR OCCLUSIONS

- CRVO and BRVO is thrombosis of the retinal vein leading to impaired capillary profusion and retinal ischemia
- Kashani et al report findings in 26 eyes with RVO. They showed OCTA findings were consistent with clinical, anatomic and FA findings.
- Areas of ischemia are well delinated on OCTA and correspond with areas seen on FA.
- SCP and DCP can be separated allowing for better appreciation of lesions affecting primarily middle retina.
- OCTA often used as adjunct tool to characterize vascular occlusions

(Wu, Villegas, and Kovach 2018)

CASE: COMBINED CRAO AND CRVO

- 69 YO Female presented to ER with sudden, painless vision loss after cataract surgery with retrobulbar anesthesia OS
- BCVA: 20/40 OD, HM OS
- APD OS
- Anterior segment OS : corneal edema, tr cell 1+ flare
- Posterior segment OS: Mild disc edema, macular edema, whitening of the macula, subtle tortuosity of vessels, flame-shaped hemes and cotton wool spots in all quadrants

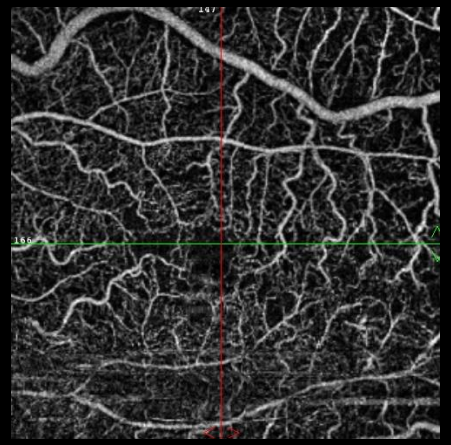
(Wu, Villegas, and Kovach 2018)

CASE: COMBINED CRAO AND CRVO

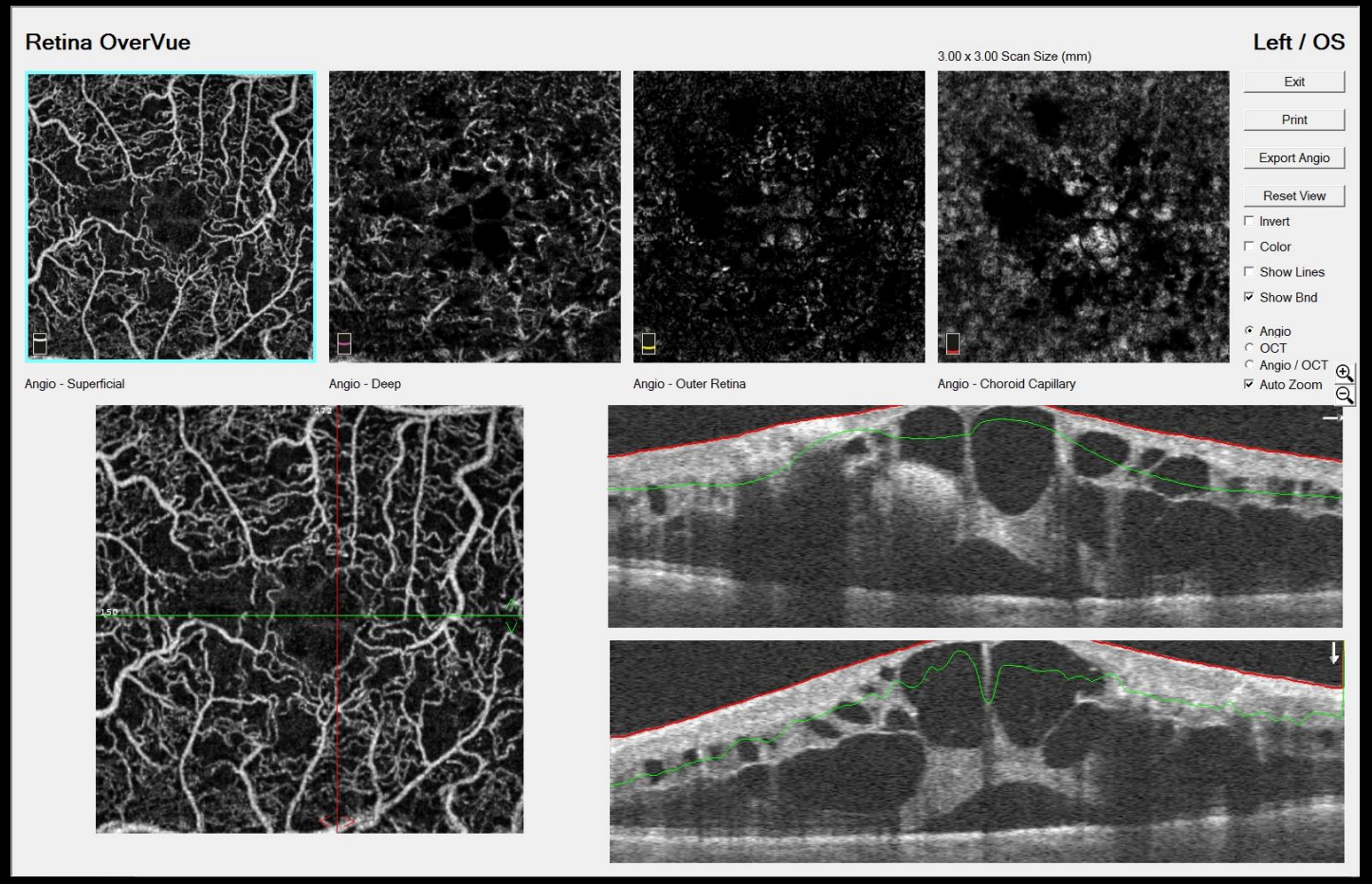
- SD-OCT OS: Hyperreflectivity and edema of the inner retina with disruption of ellipsoid zone
- OCTA OS: Absence of flow in foveal and perifoveal area in SCP and DCP. Normal choriocapillaris and choroid.

(Wu, Villegas, and Kovach 2018)

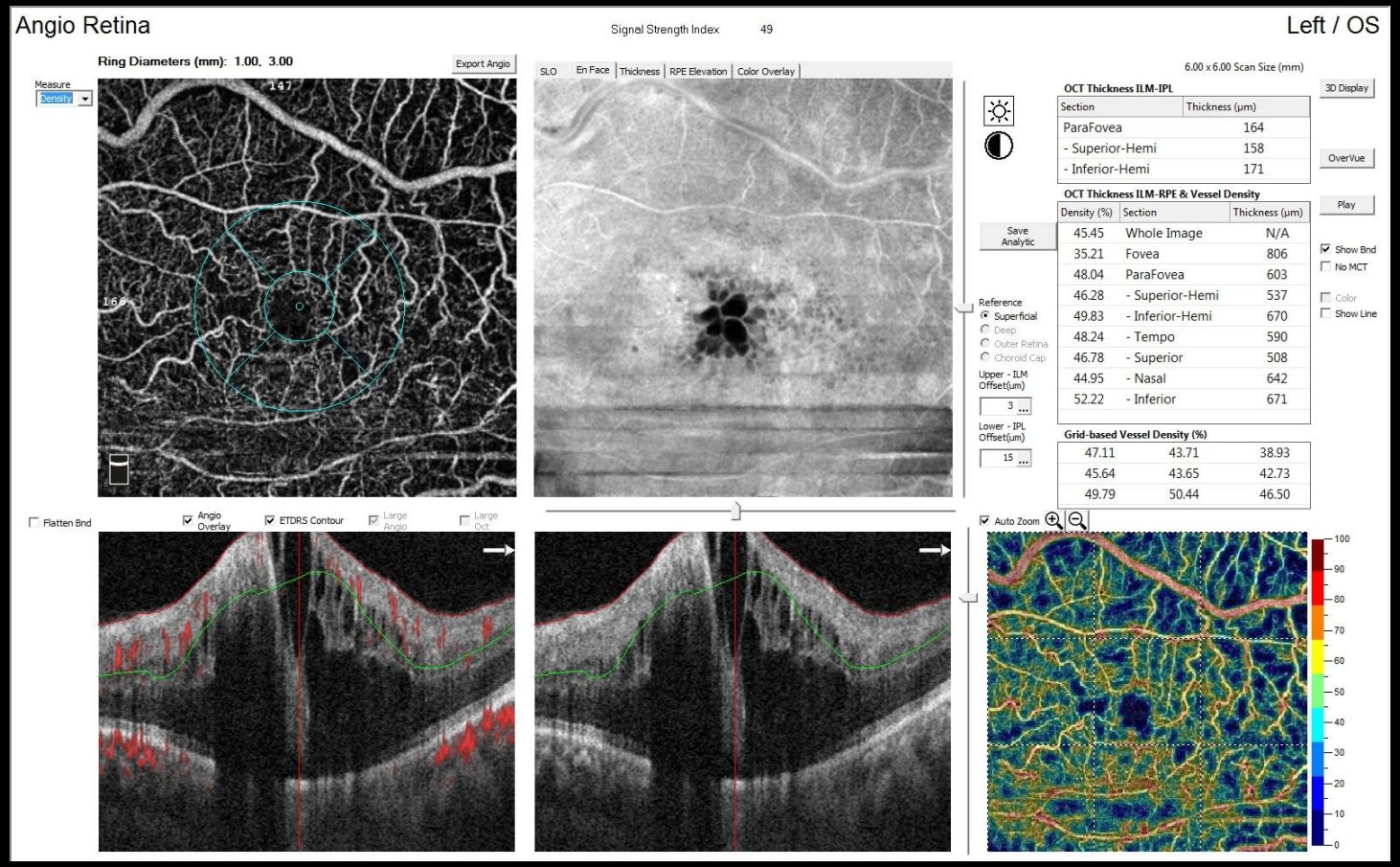
CENTRAL RETINAL VEIN OCCLUSION

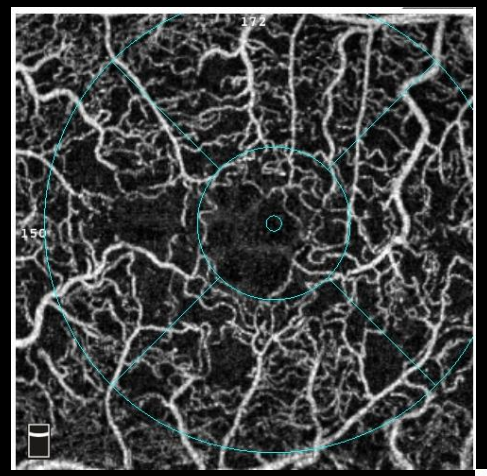


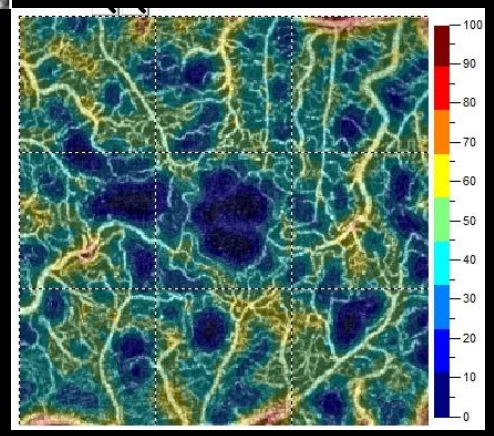
CENTRAL RETINAL VEIN OCCLUSION



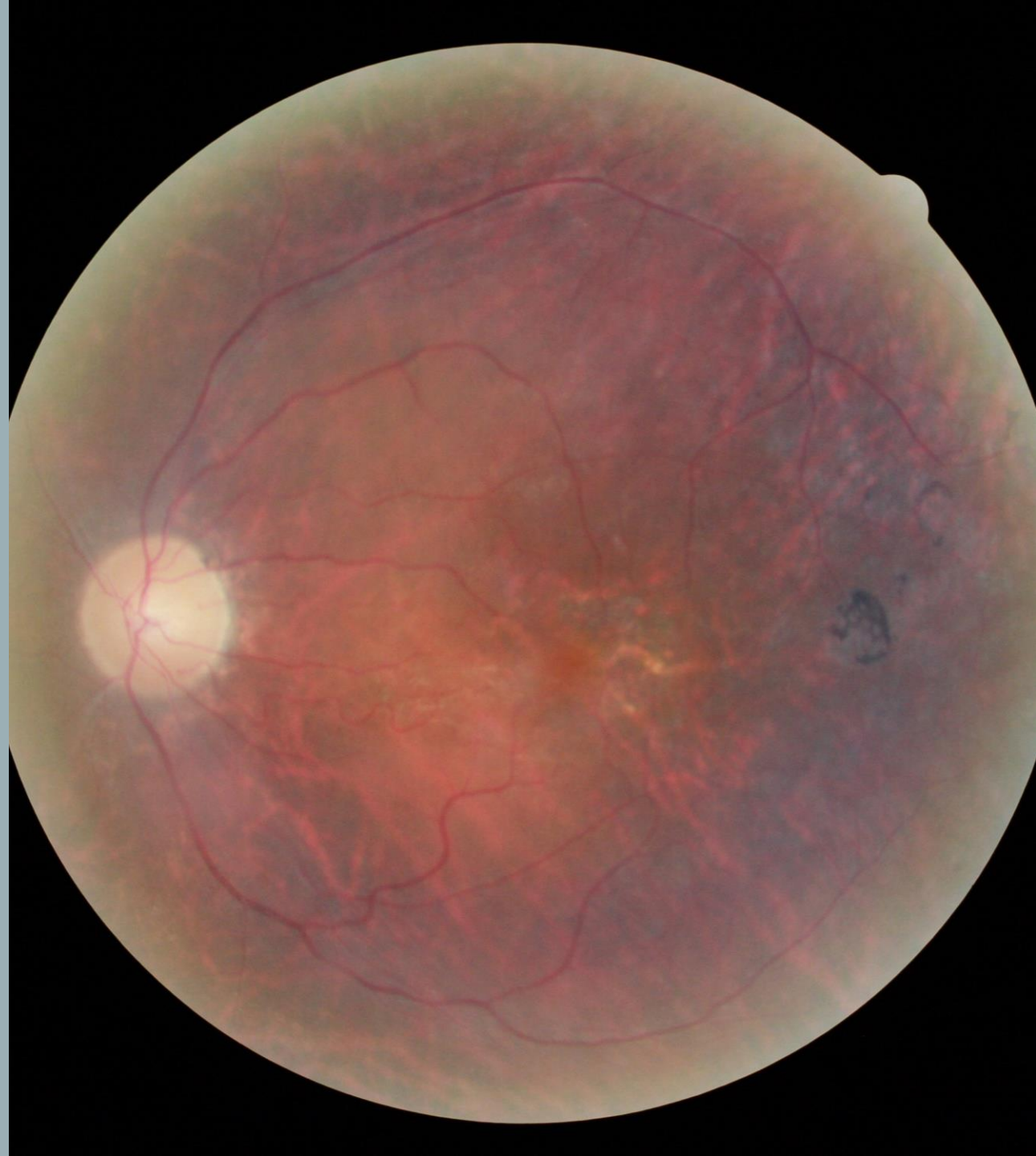
CENTRAL RETINAL VEIN OCCLUSION







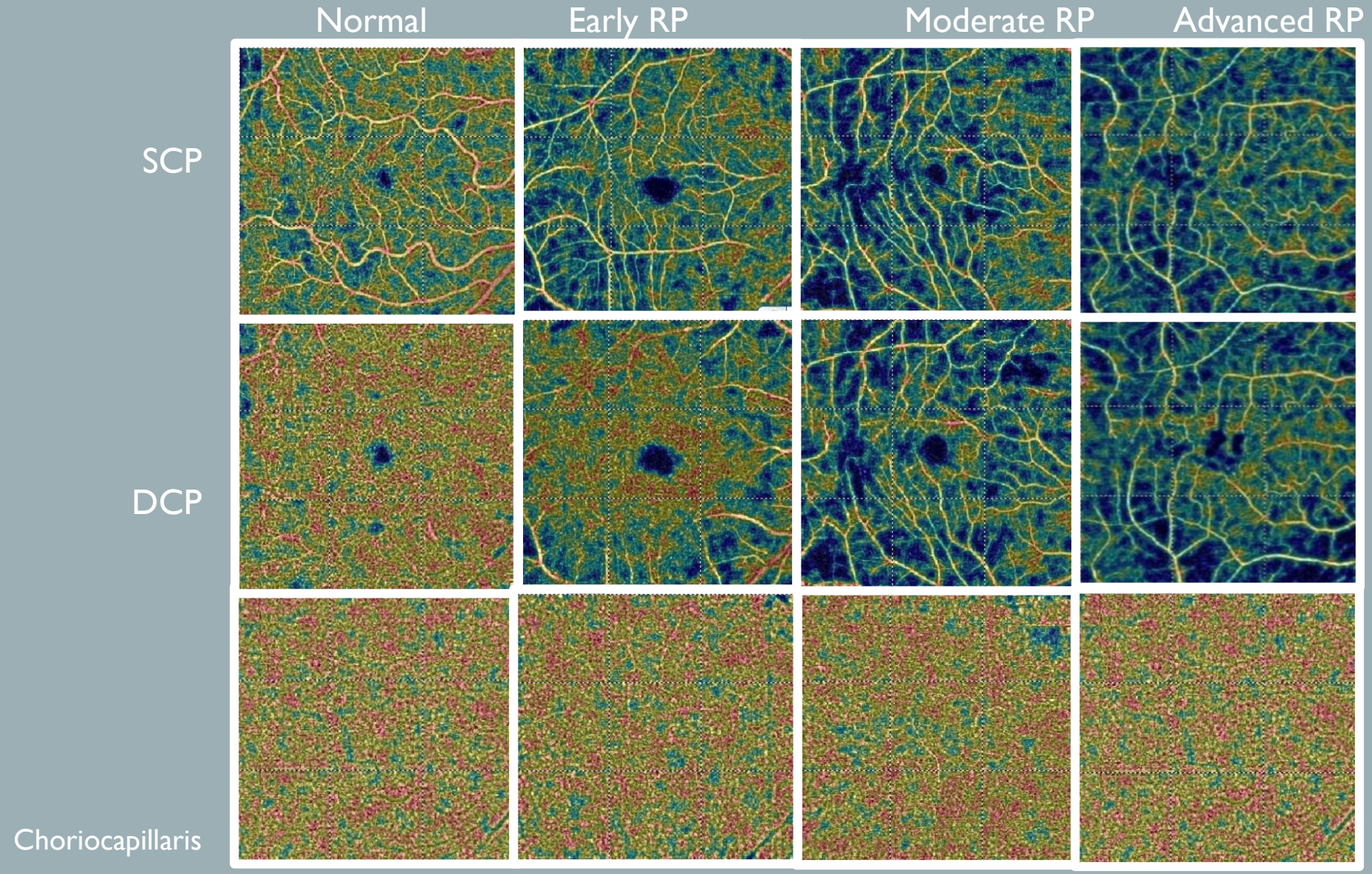
RETINITIS PIGMENTOSA



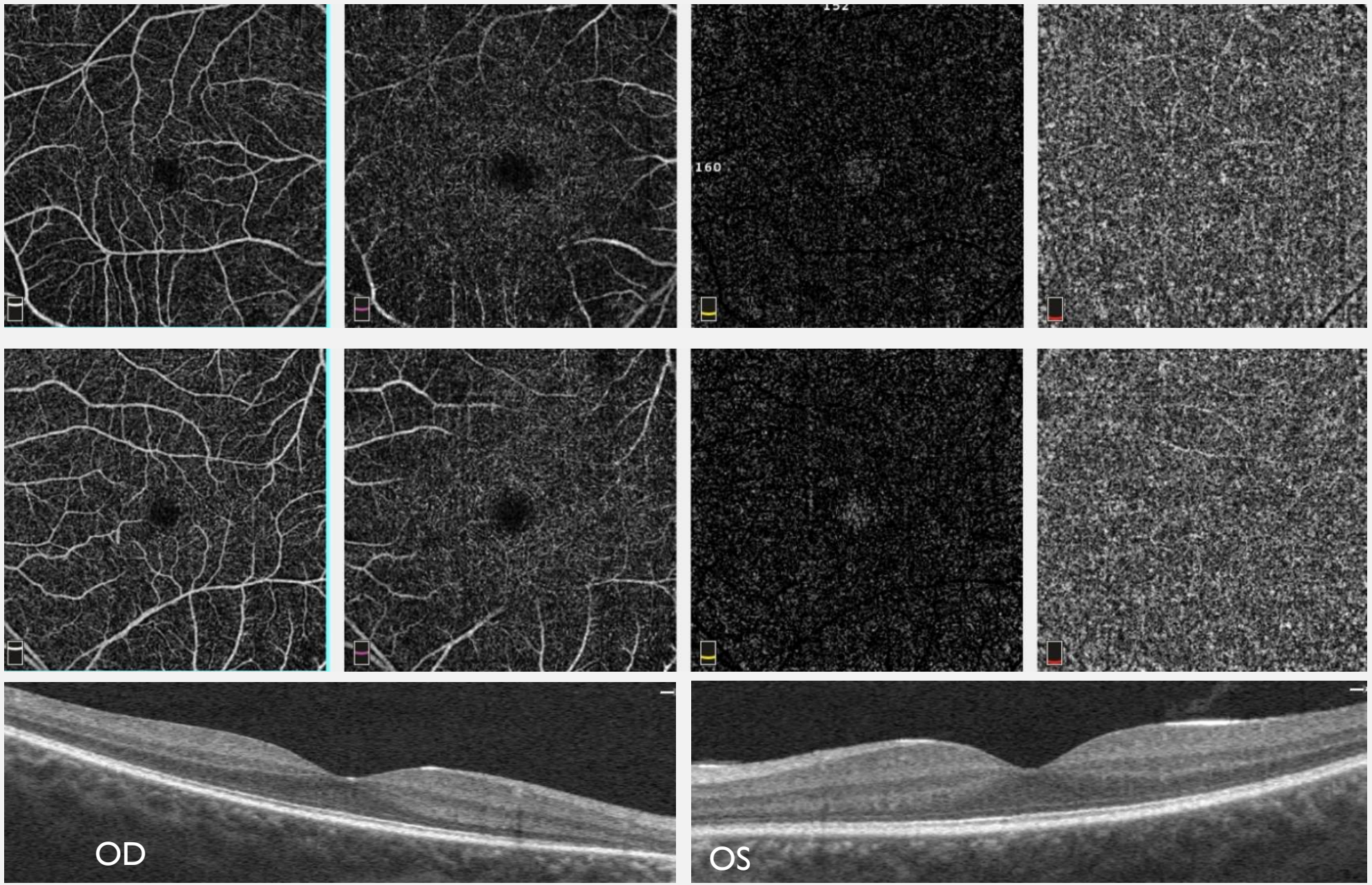
RETINITIS PIGMENTOSA

- RP demonstrates alterations in all macular vasculature, mostly reduction in SCP and DCP.
- Reduction in blood flow occurs early in disease and can lead to ischemia, retinal damage and cell death
- Vessel density abnormalities at the level of the DCP appear to be directly related to macular function and visual potential

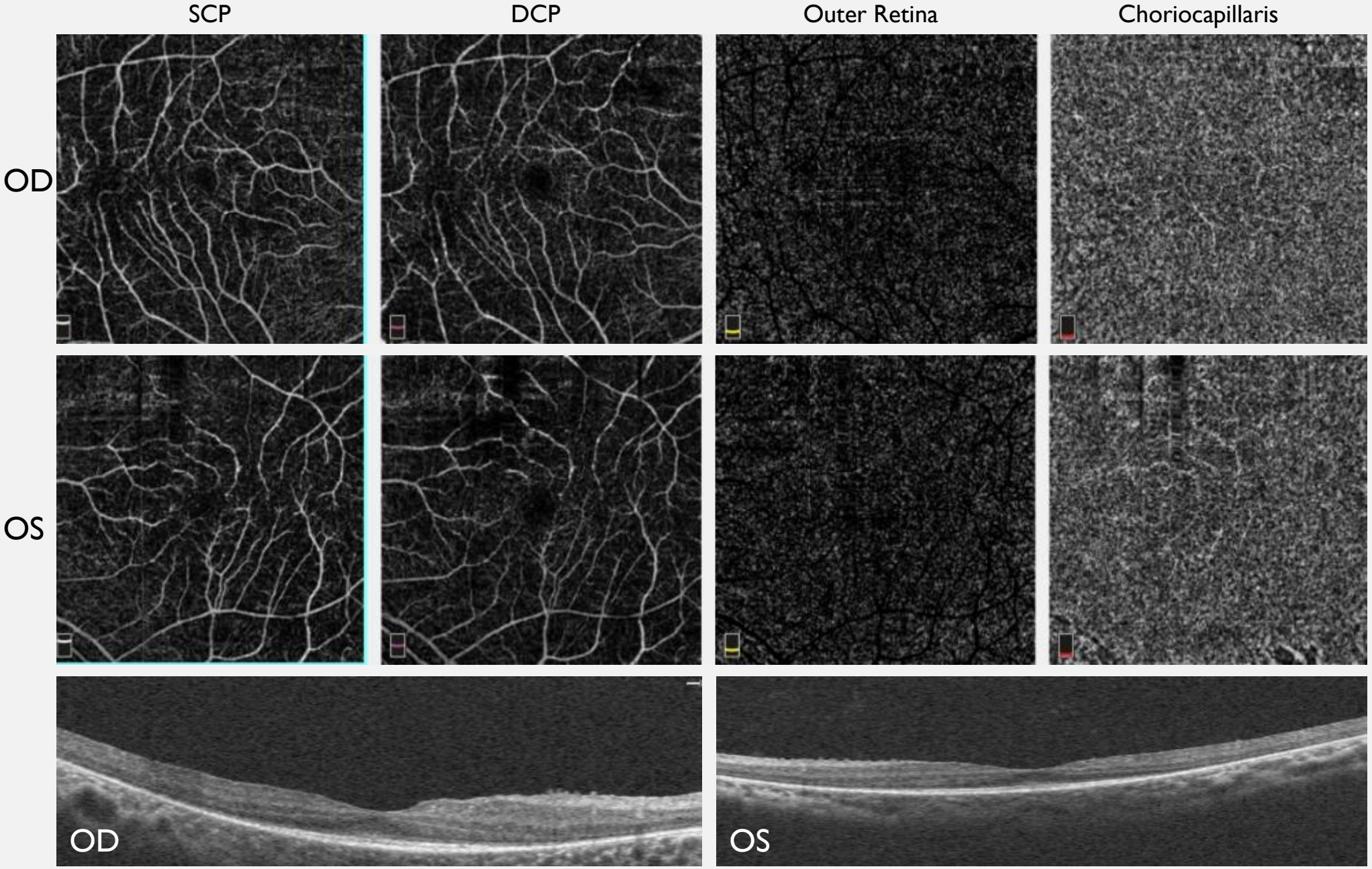
OCTA Macular Capillary Density at Different Stages of RP



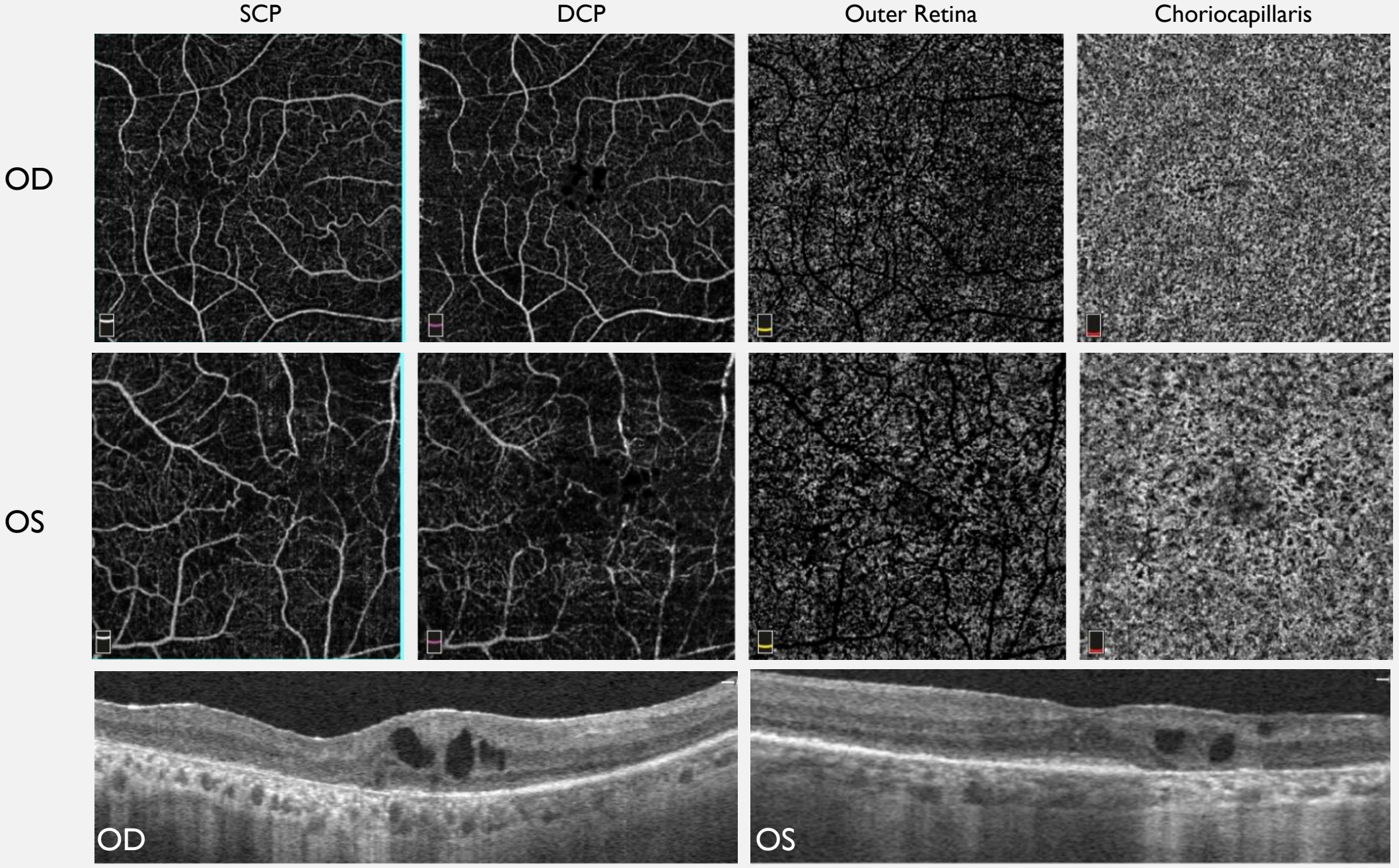
Mild RP



Moderate RP



Severe RP



GLAUCOMA AND OPTIC NEUROPATHIES

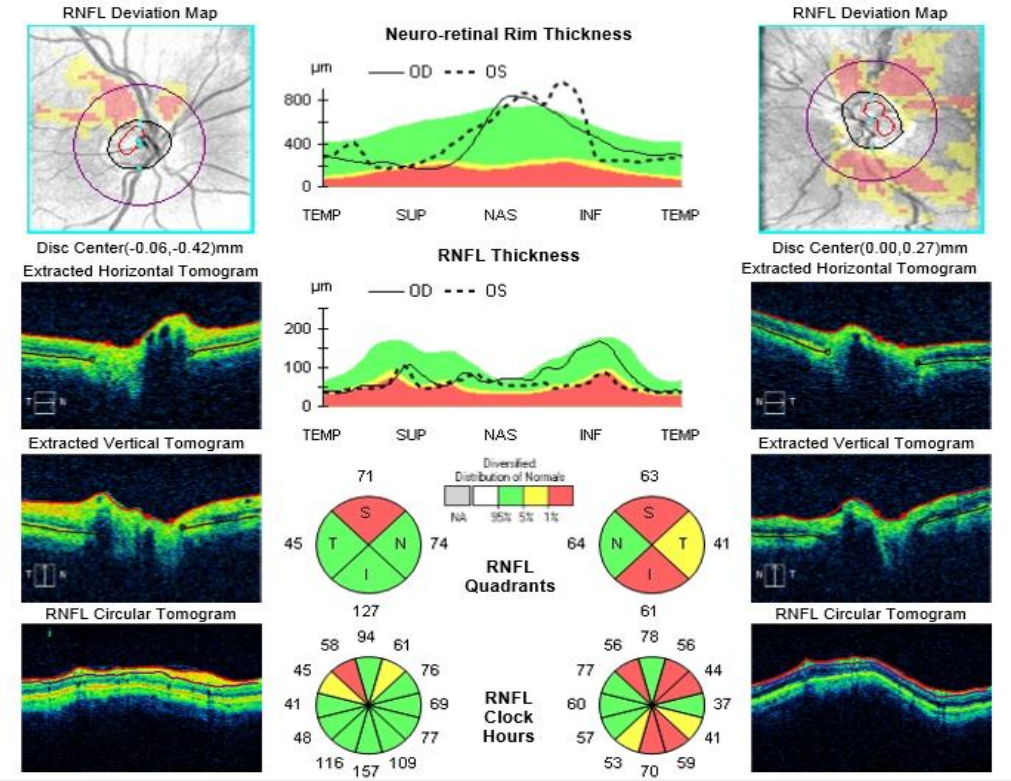
BLOOD SUPPLY TO ONH

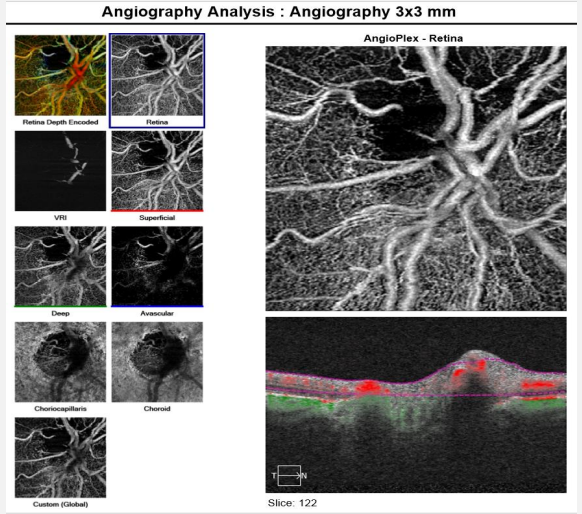
- ONH supplied by two main sources:
  - Central retinal artery =superficial layers (NFL)
  - Posterior ciliary artery = deeper layers (prelaminar, lamina cribosa, and retrolaminar regions)

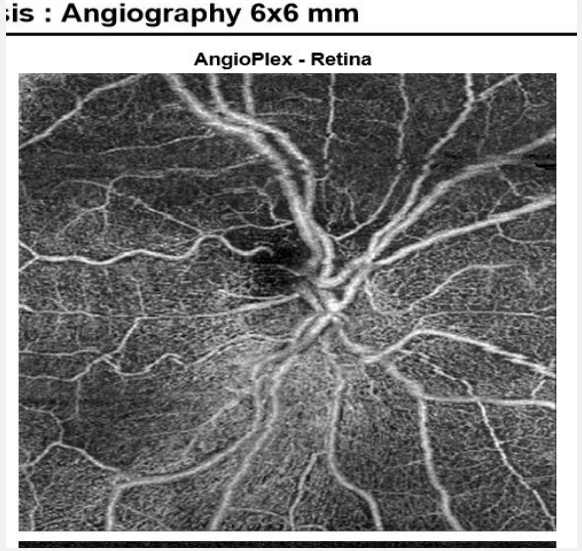
CASE: NON-ARTERITIC ANTERIOR ISCHEMIC OPTIC NEUROPATHY

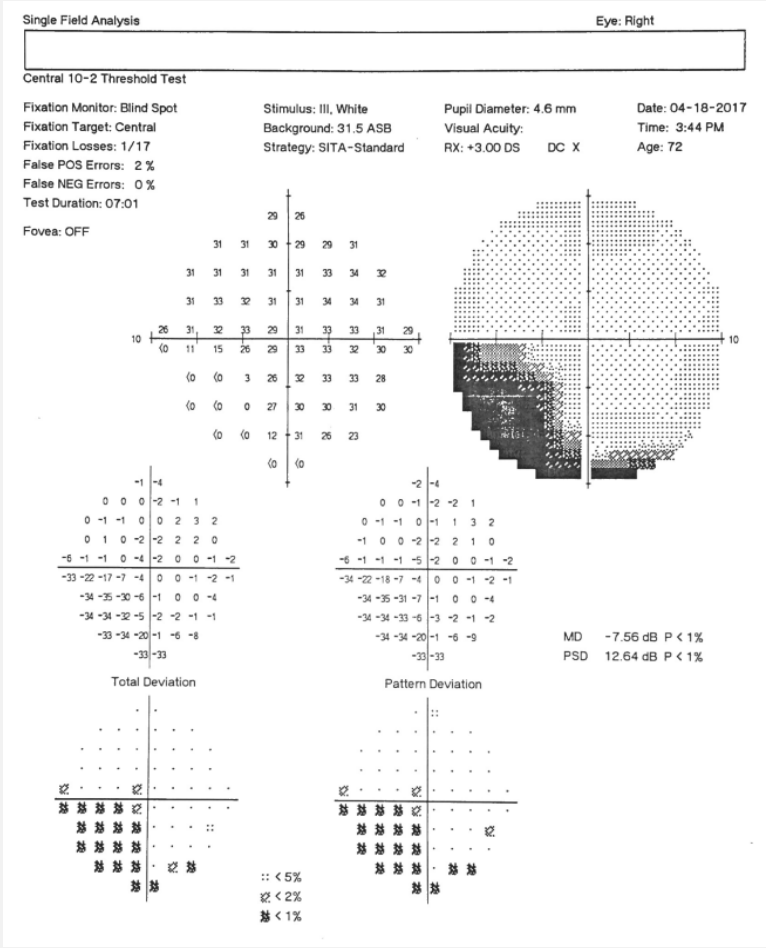
- 72 yo Caucasian male presented with chronic NAION
- H/O: NAION occurred in right eye 13 years ago followed by a similar event in the left eye the following year.
- Medical Hx: HIV, diabetes type 2, and hypertension.
- BCVA: 20/20-3 OD, 20/25 OS.
- Mild APD OS. Mild R-G color deficiency OS, while the right eye was normal.
- Anterior segment findings were unremarkable except for a small posterior subcapsular cataract in the visual axis of the left eye.
- Fundus examination revealed superior temporal pallor of the right optic nerve head and generalize pallor of the left optic nerve head. Both optic nerves had distinct margins and 0.1 C/R ratio.

CASE: NON-ARTERITIC ANTERIOR ISCHEMIC OPTIC NEUROPATHY

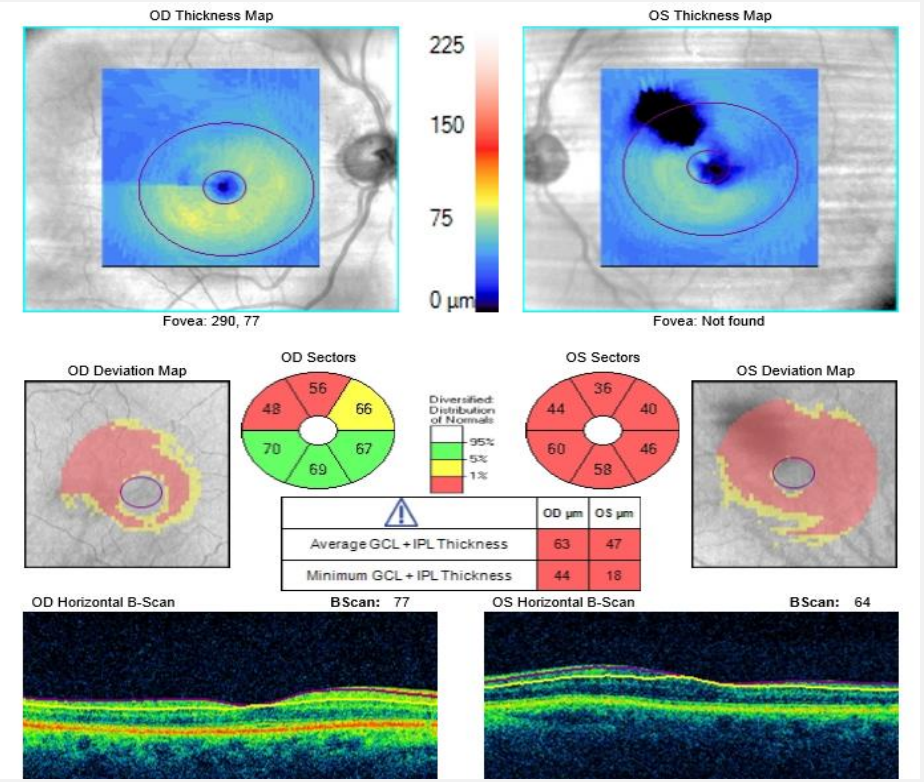


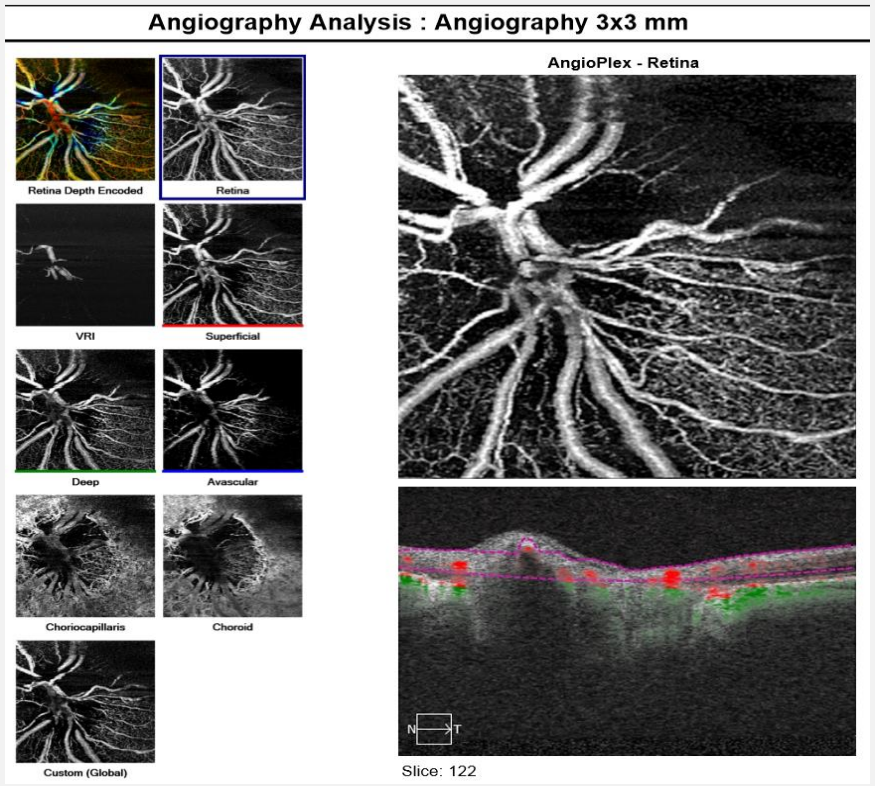


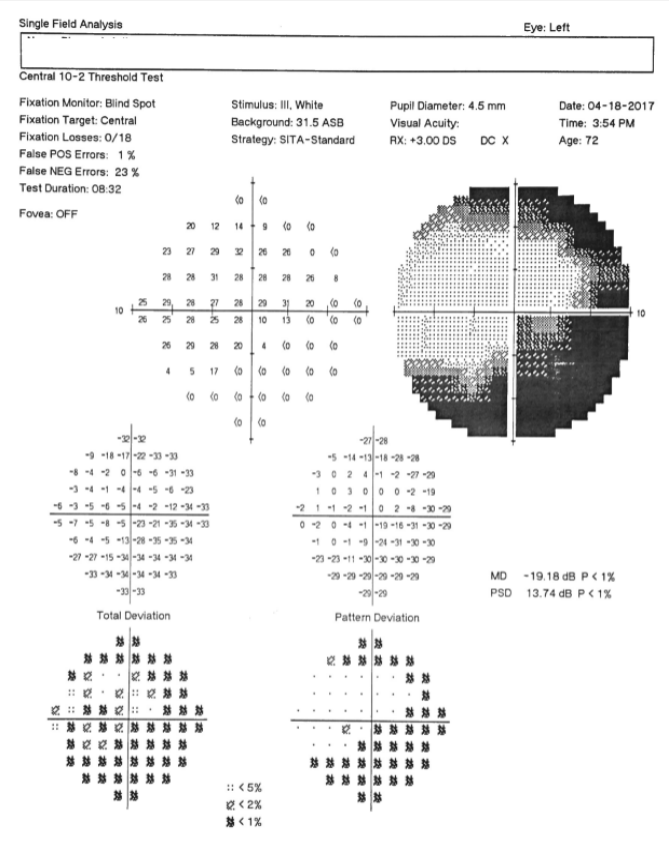




CASE: NON-ARTERITIC ANTERIOR ISCHEMIC OPTIC NEUROPATHY







CASE: NON-ARTERITIC ANTERIOR ISCHEMIC OPTIC NEUROPATHY

- OCT angiography provides high resolution imaging of the optic nerve and peripapillary vasculature that spatially corresponds to optic nerve atrophy, retinal nerve fiber layer thickness and visual field defects in cases of chronic optic neuropathy such as NAION.
- Optic neuropathies are a heterogeneous group of optic nerve disorders that require different management within different timelines, but yet many have similar ophthalmoscopic presentation, usually as optic disc edema or atrophy.
- The characterization of these various disorders using OCTA could provide a tool that would facilitate their differential diagnosis, allowing for prompt and accurate management of the condition.

TAKE HOME POINTS

TAKE HOME POINTS

- OCTA is an innovated technology that can provide insight into the pathophysiology of retinal and optic nerve diseases
- OCTA can aid in diagnosis and prompt management of a variety of retinal and optic nerve diseases

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