


OCT-A Technology and the Growing Importance of Diagnosing and Managing Eye Disease

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OCT Angiography Lesson Objectives


- Define Angiography
- Compare fluorescein angiography to OCT-A
- Explain the technology behind OCT-A
- Look at normal and abnormal OCT-A images
- Overview of OCT-A retinal findings that may correlate with systemic diseases or conditions



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Define Angiography

- *Angio*: blood vessel
- *Gram*: to write or draw
- Angiogram: a rendering of images of blood vessels
 - *Typically, a contrast dye is used to visualize the vasculature*
 - OCT-A is *atypical*

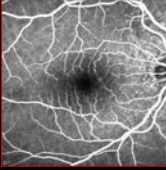



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Traditional Fluorescein Angiography
(First FA 1961, Novotny & Alvis)

Purpose: To illustrate retinal circulation

- Retinal fluorescein angiography is a diagnostic timed imaging procedure whereby dye is injected intravenously
 - Results in a 2 dimensional representation of retinal vessels
 - The dye may show leaking, staining, pooling, blocking and / or non-perfusion at different stages of the test


Images courtesy of Tim Bennett, CRA, OCT-C, FOPS

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Traditional Fluorescein Angiography

Purpose: To illustrate retinal circulation

- The dye appears and travels through the retinal vessels
 - Documents time to retina / 1st appearance of dye
- It is an invasive procedure that has risks
 - Nausea with or without emesis
 - Mild allergic reaction to anaphylaxis (rare)
- Contraindicated in pregnancy and breast-feeding




Images courtesy of Tim Bennett, CRA, OCT-C, FOPS

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Traditional Fluorescein Angiography

- IVFA and ICG cameras have several fields of view
 - 20 degree to 180 degrees

Optos Wide Field Camera
 17 seconds - Arterial Phase: Choroidal Flush
 24 seconds - Laminar Flow
 30 seconds - A/V Filling; NVE, non-perfusion, micro-aneurysms
 5 minutes - Mid Phase: NVE leakage
 10 minutes - Late Phase: more profuse NVE leakage with vasculitis



FA OptosWideField

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Traditional Fluorescein Angiography

Challenges with IVFA

- Patient's inability to tolerate bright lights (photophobia)
- Fear of needles / Vaso-vagal response to needles
- Poor venous access
 - May require multiple sticks or waiting for IV Team to place a line
 - Extravasation of dye from the vein into the tissue
- May take up to 20-30 minutes from prepping the dye, consenting the patient, dye injection to completion of the final phase of the angiogram



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OCT Angiography

(first described in 2006, Shuichi Makita *et al*)

Purpose: To illustrate retinal blood flow of normal eyes and those with vascular anomalies, non-perfusion and neovascularization

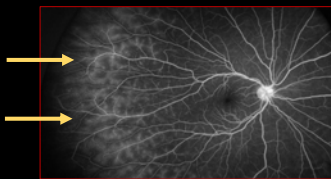
- Contrast dye is not required
- Non-invasive, non-contact imaging
- Uses infrared light (840 nm to 1050 nm)
- Capture time in a cooperative patient without opacities takes about 10 minutes
- Clinical OCT-As have a 10 to 30 degree field of view⁴
 - Up to 100 degree montage image
 - Extreme retinal peripheral vessels are not accessible
 - Newer OCT-A technology may not require montage for wider field of view



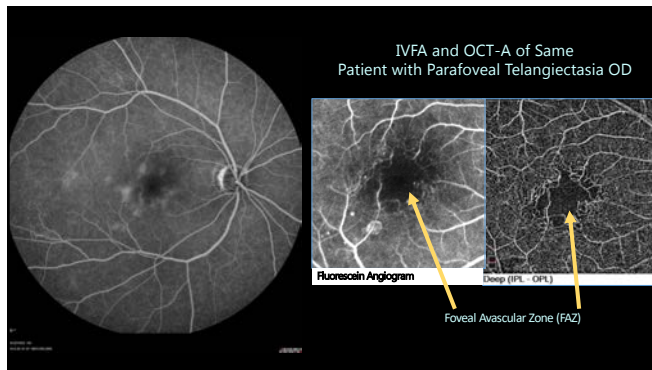
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OCT Angiography

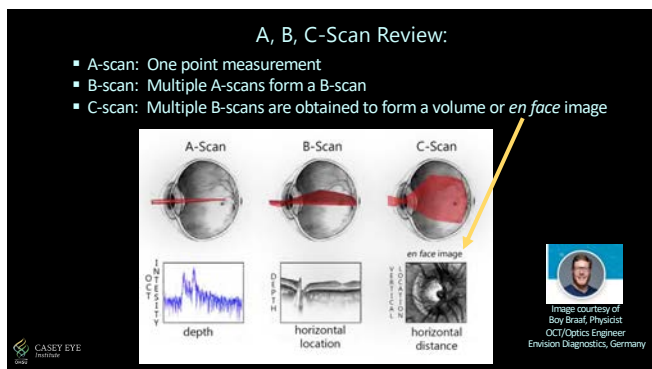
- Unable to assess dye appearance time or arterial / venous filling
- OCT-A does not illustrate leakage
 - Unable to appreciate vasculitis, leaking blood vessels from inflammation
- Image artifacts may be problematic in quantifying data and interpreting results, sometimes requiring physician interaction¹⁰



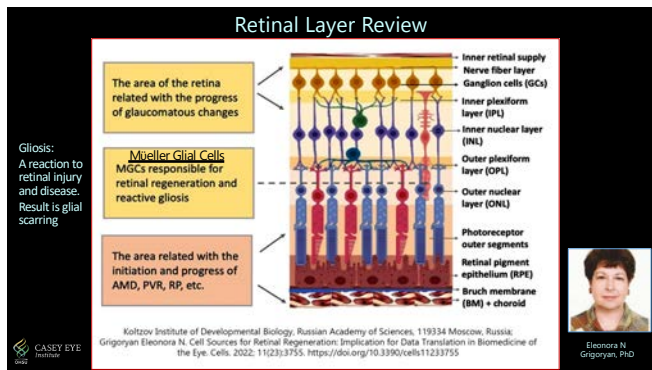
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Macular and Peripapillary Capillary Plexuses

Plexus: A network of anastomosing or interlacing blood vessels (or nerves)
Greek - "to braid"

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Macular and Peripapillary Capillary Plexus Grouping in OCT-A¹

Superficial Vascular Complexes

Deep Vascular Complexes

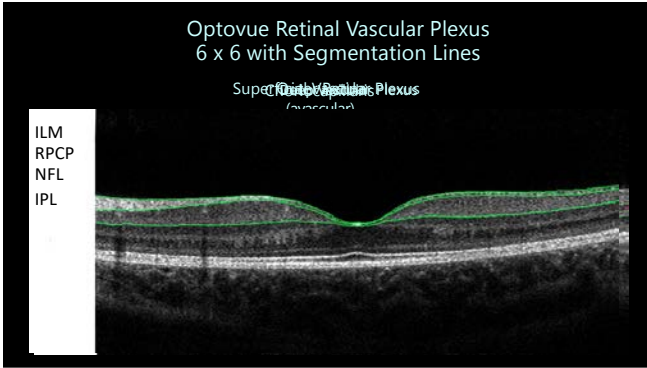
Choriocapillaris

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Retinal Vascular Plexus (6 x 6) Corresponding B-scans with Flow Overlays

Superficial vascular plexus Deep vascular plexus Outer Retina (Avascular) Choriocapillaris

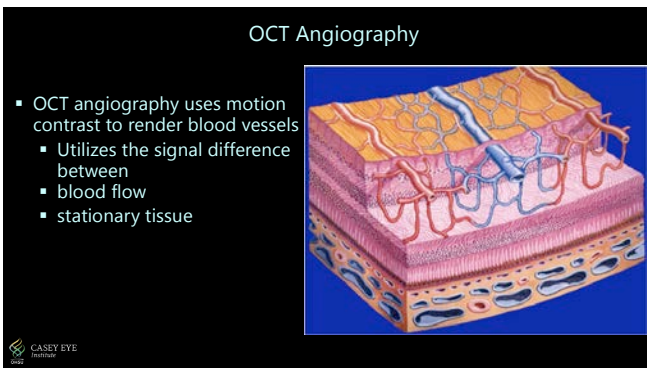
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Repeated A-scans at the same point

A-scan A-scan

1 1 STATIC

2 2 Blood

3 3 vessels

4 4 STATIC

5 5 Time

- Several successive scans are captured at the same point
- Stationary tissue is given a low value → 1, 2, 5
- Moving RBCs are given a high value → 3, 4
- These signal values are used to generate an image with a process known as decorrelation

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Signal to Noise Ratio
High signal from RBCs
Low signal from tissue
Decorrelation clears out the noise

$$SNR = \frac{P_{signal}}{P_{noise}}$$

Red Blood Cells
Wanted component

Surrounding Tissue
Unwanted component

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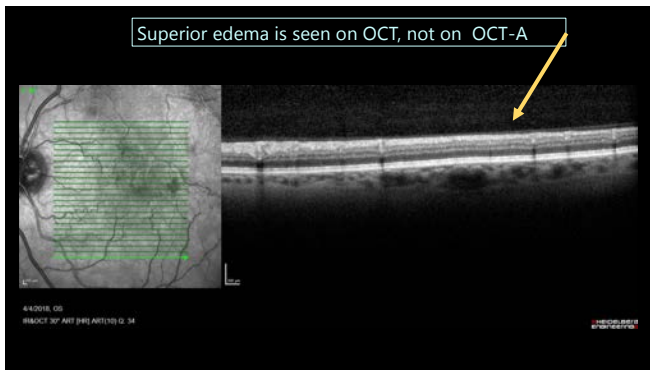
- OCT-A is a metabolic rendering of the retina (OCT is structural)
 - Proper retinal metabolic performance demands oxygen
 - Reduced oxygen may cause apoptosis, cell death, esp. to neural tissue, resulting in vision loss.²

BRVO OS
Visual Acuity
OD 20/30
OS 20/70+2

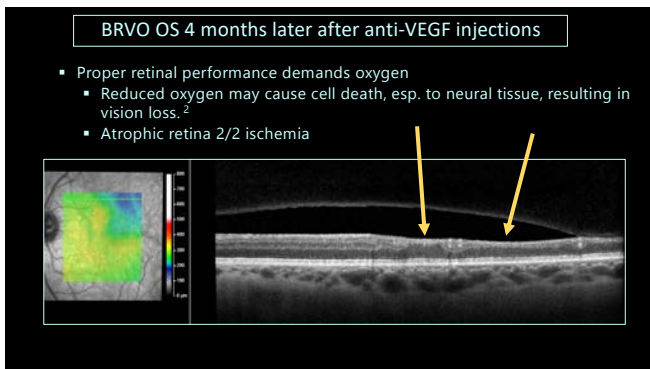
Non-perfusion and collaterals

Angio - Superficial Angio - Deep

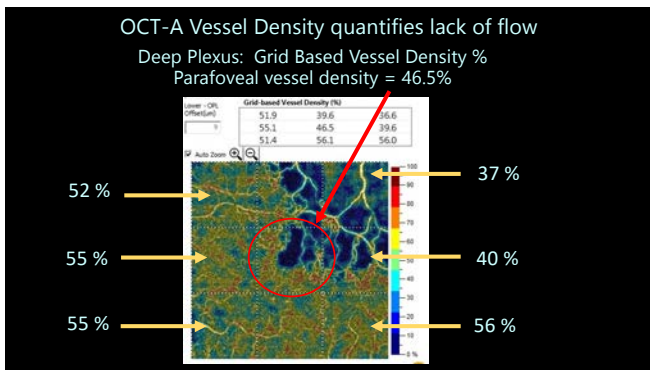
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Glaucoma: Thinning Retinal Nerve Fiber & Damaged Ganglion Cells
 These cells assist in transmitting retinal stimuli to the brain via the optic nerve

Several Mechanical Causes:

- High IOP damages RNFL
- Too much aqueous fluid production
- Blockage of Schlemm's canal – 'outgoing plumbing'
 - Pigment
 - Exfoliation
 - Neovascularization in the angle
- Uveitis (vasculitis)
- Some medications
- Congenital
- Trauma

Compromised Vascular Supply:

- RNFL blood supply is the RPCP (Radial Peripapillary Capillary Plexus)
- Ganglion cells are in the macula and are supplied by the SVP (Superficial Vascular Plexus)

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Vessel Densities of Radial Peripapillary (RPCP)

Normal Optic Nerve →

Mild POAG →

Moderate POAG →

Severe POAG →

Vessel Densities Superficial Vascular Plexus (SVP)

Capillary loss is noted with OCT-A before visual field changes are documented.

Use at least 6x6 macular scan to evaluate glaucoma.

The RPC and macular vascular vessel density showed a significant correlation with the degree of glaucoma severity.¹² Al-Nashar Haltham Y, et al.¹³

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Normal

Red arrows = microaneurysms

Diabetes

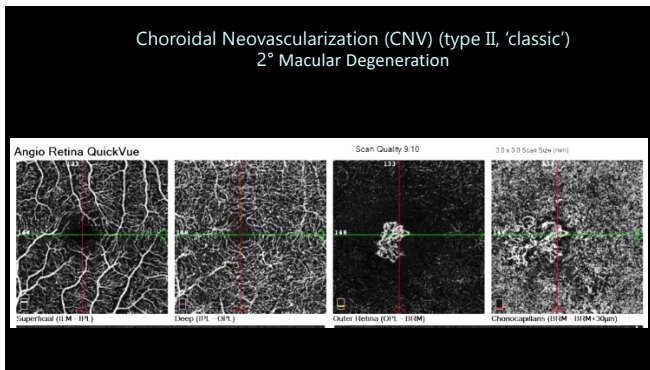
3x3 OCT Fovea

Wide field OCT-A Non-perfusion

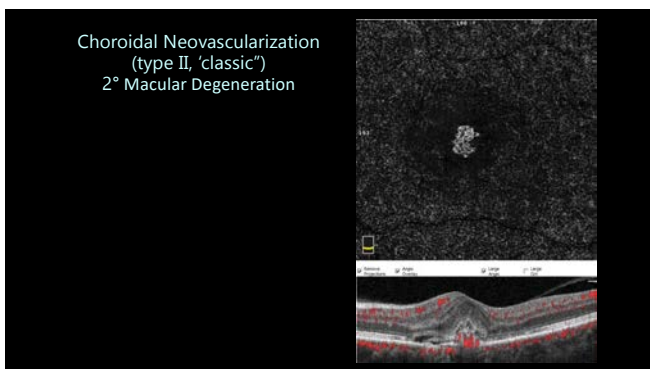
Non-perfusion

Optical Coherence Tomography Angiography in Diabetes and Diabetic Retinopathy. *Journal of Clinical Medicine*. 2020; 9(6):1723.

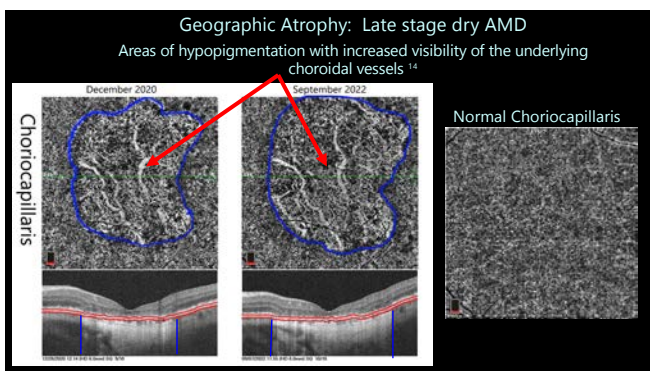
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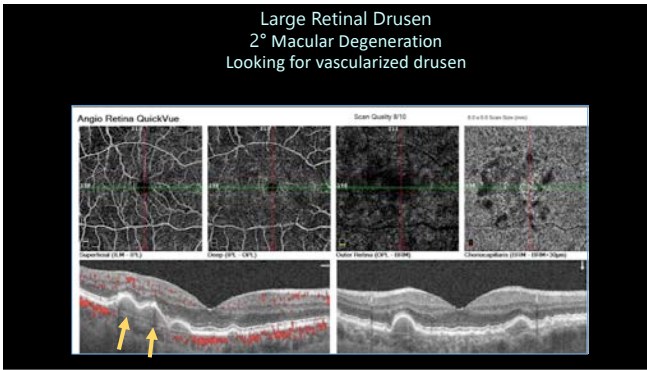
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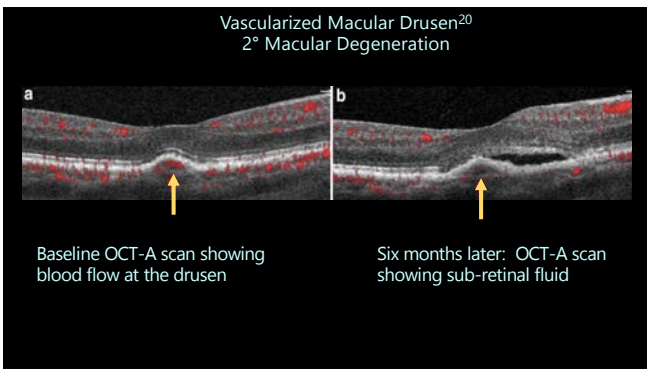
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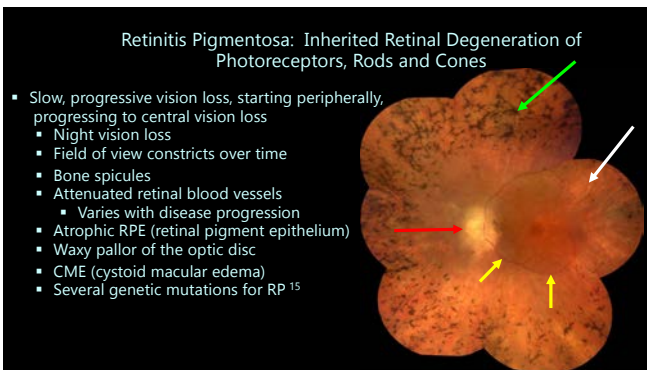
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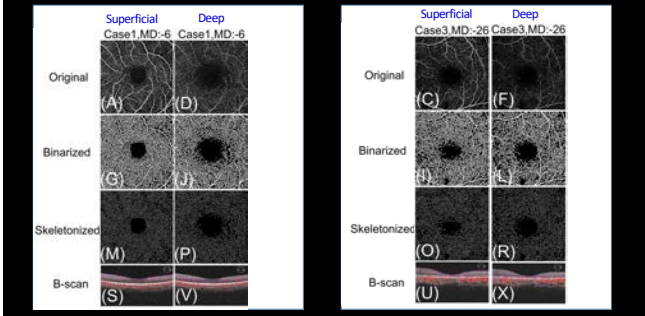
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Retrospective Clinical Study to Quantify Macular Microvascular Changes in Patients with RP¹⁶

- 53 patients with RP scanned with OCT-A
 - These images were processed and analyzed with Angio Exercisor software
 - Quantified the microvasculature, vessel density, thickness, length using processes that binarized and skeletonized the original scans
 - Available for research only (Carl Zeiss Meditec)
 - FAZ (foveal avascular zone) was measured using ImageJ software
 - Openly provided by NIH (National Institutes of Health)

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MD = Mean Deviation: Two RP patients Humphrey Visual Field results compared to patients of similar age from the normative database



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Retinitis Pigmentosa With CME

- The pathogenesis of Cystoid Macular Edema in RP is unclear.
- Theories include¹⁷:
 - Blood-retina barrier breakdown (leakage from compromised blood vessels)
 - RPE (retinal pigment epithelial) pump failure
 - Müller cell failure
 - Cells that regulate homeostasis within the retinal tissue
 - Oxidative stress and inflammation associated the degenerating retina may result in macular edema

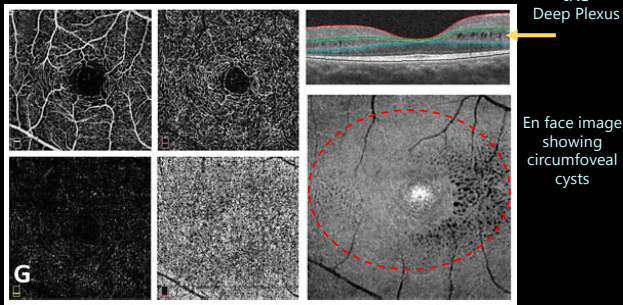
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Retinitis Pigmentosa
With CME

- Another retrospective study of 42 patients with RP scanned with OCT-A¹⁷
 - The authors suggest that the CME may not be from leaky blood vessels, but from malfunctioning Müller cells
 - Müller cells regulate retinal tissue osmosis
 - RP-CME was located in the INL (Inner Nuclear Layer) in the parafoveal macula of the Deep Plexus

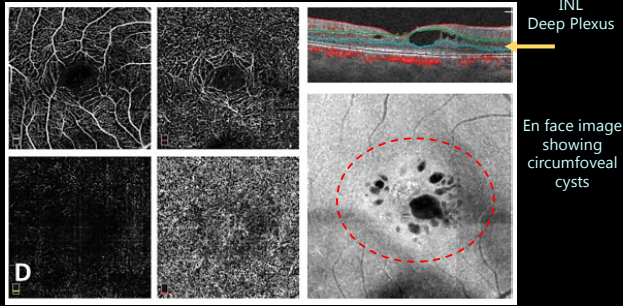
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Retinitis Pigmentosa
With Mild CME

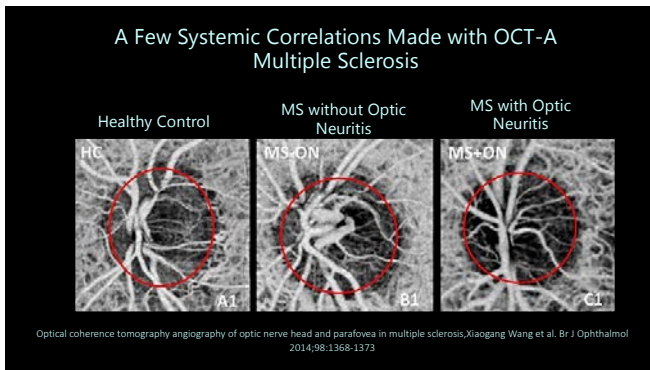


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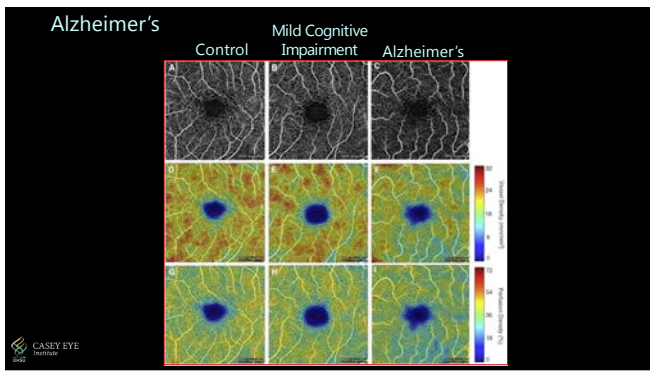
Retinitis Pigmentosa
With Moderate CME



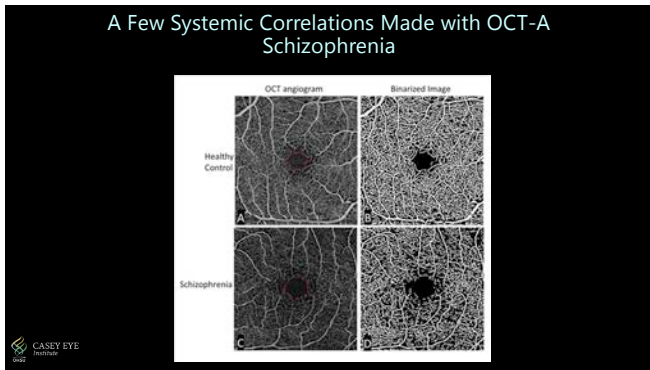
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OCT-A and Associated Artifacts¹⁰

- Human :
 - Eye Movements / Saccades / Blinking
 - Motion detection technology uses a two-level approach to:
 1. real-time correction for rapid eye movements or blinking
 - a) 'eye-tracker'
 2. Post-processing correction of smaller motion artifacts
 - Poor focus / dry eyes
 - Instilling moisturizing drops for every patient may help the patient hold blinks during the scan
 - Poor fixation
 - So poor that eye trackers cannot resolve



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Signal strength is, in part, dependent on the OCT-A operator

- **Focus, focus, focus!**
- Patient positioning
 - We want them to hold still
 - Avoid head tilt
- Instill moisturizing drops
 - We want them to hold blinks for several seconds
- Educate & coach your patient through the capture process
- Sometimes, you can only get what you can get

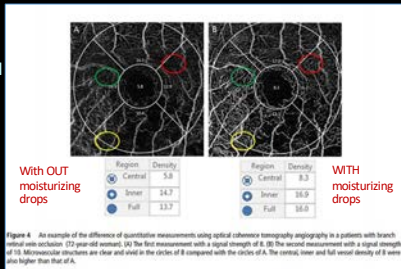
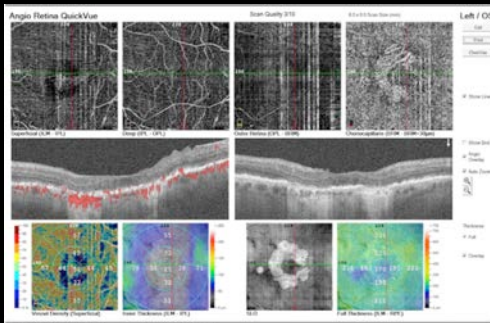


Figure 4. An example of the difference of quantitative measurements using optical coherence tomography angiography in a patient with branch retinal vein occlusion (72-year-old woman). (A) The first measurement with a signal strength of 8. (B) The second measurement with a signal strength of 18. Microvascular structures are clear and vivid in the circles of B compared with the circles of A. The central, inner and full vessel density of B were also higher than that of A.

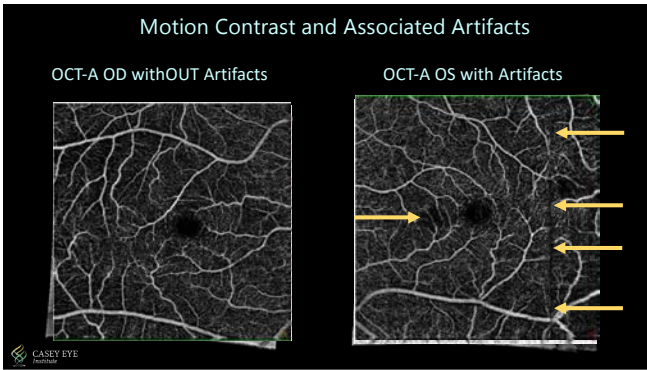
Lee M, Kim K, Lim H, et al. Repeatability of vessel density measurements using optical coherence tomography in retinal diseases. *British Journal of Ophthalmology* 2018;102:704-710.

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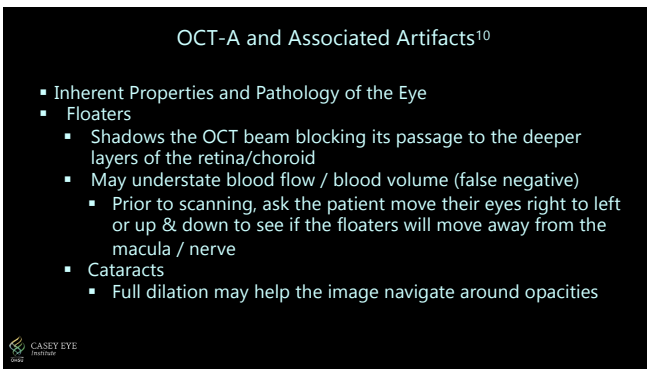
Geographic Atrophy patient with poor fixation



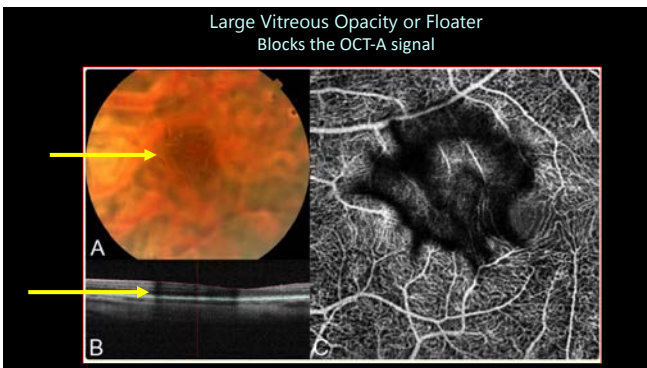
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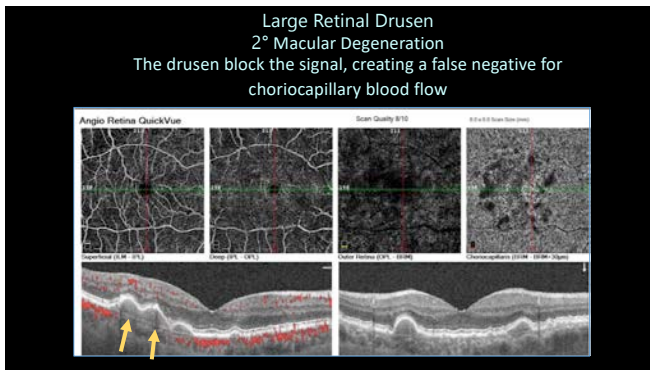
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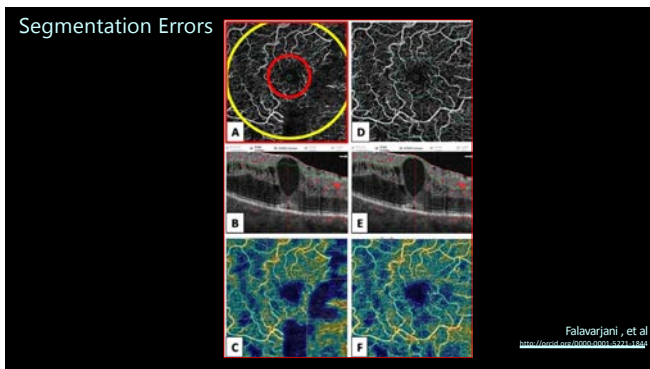
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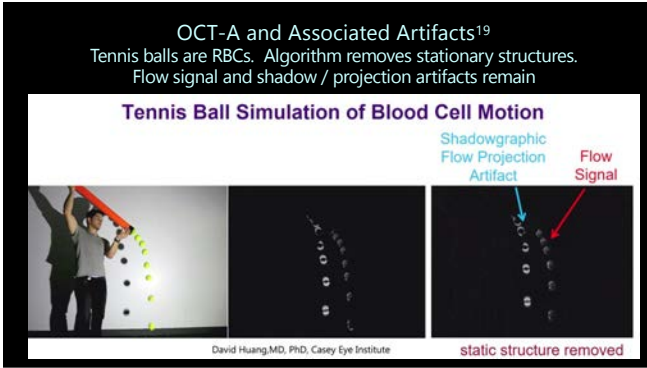
OCT-A and Associated Artifacts¹⁰

- OCT-A Projection Artifacts
 - Light reflected from moving blood cells is the basis of OCTA.
 - The light that has passed through moving blood also encounters tissue below the blood vessel
- When this light strikes the RPE it is reflected back to the OCT instrument, misrepresenting blood vessel that particular retinal layer
 - Projection artifacts occur from superficial retinal vessels to the deeper retinal layers
 - These artifacts are nearly always present and appear in any structure that is located below vasculature

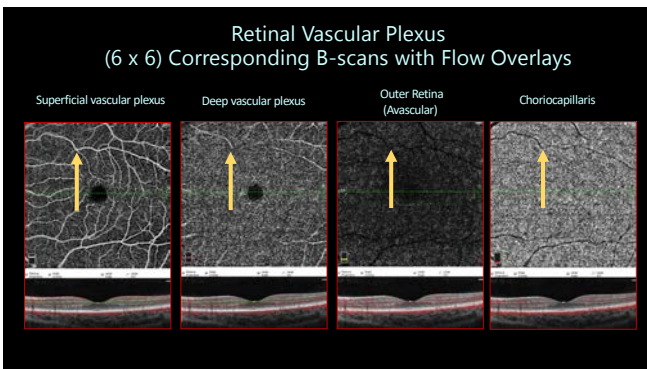
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Imaging

Image Artifacts in Optical Coherence Angiography
Spaide, et al

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In Summary

- OCT-A is a relatively new diagnostic tool that enhances our ability to observe ocular vasculatures, including blood flow, vessel volume, and vessel anomalies.
- It's technology is intriguing in that it does not require contrast dye, but renders vessel images with red blood cells
- It has clinical and research applications to improve our understanding of disease processes and to consider introducing new biomarkers for disease.
 - Early intervention is BEST!
- Imaging artifacts may require more 'in depth' diagnostic interpretation
 - The degree of image artifact should be reduced

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