OCT Angiography

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Disclosure

Consulting Fee: Allergan; Carl Zeiss Meditec; Genentech; Optos; Regeneron

OCT Angiography

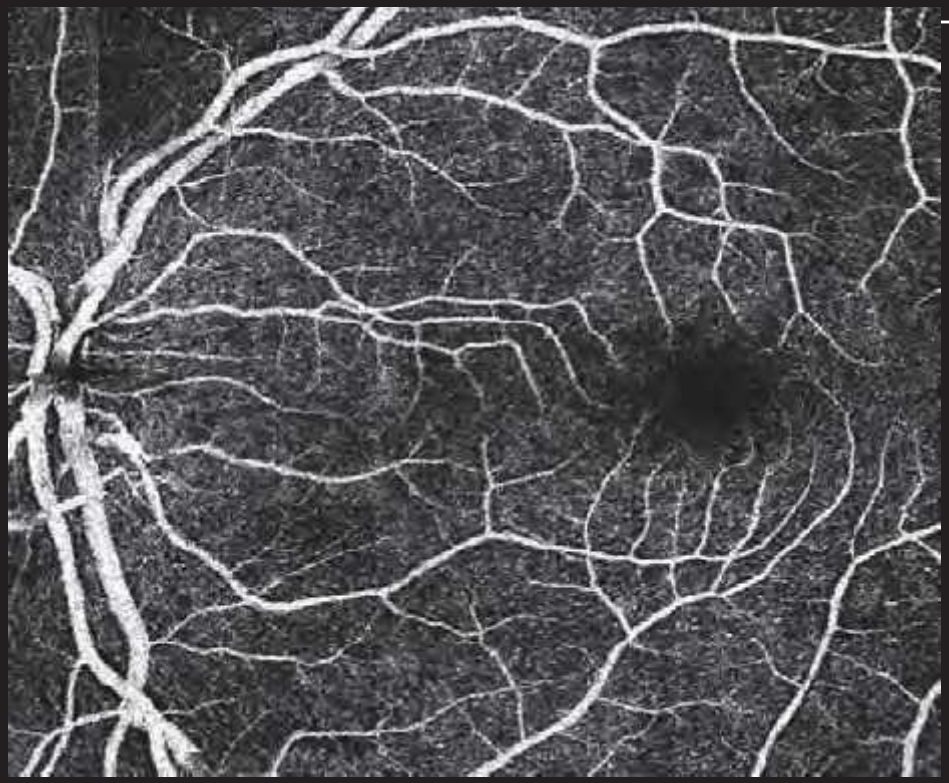
Phase Variance OCT

Phase Variance OCT

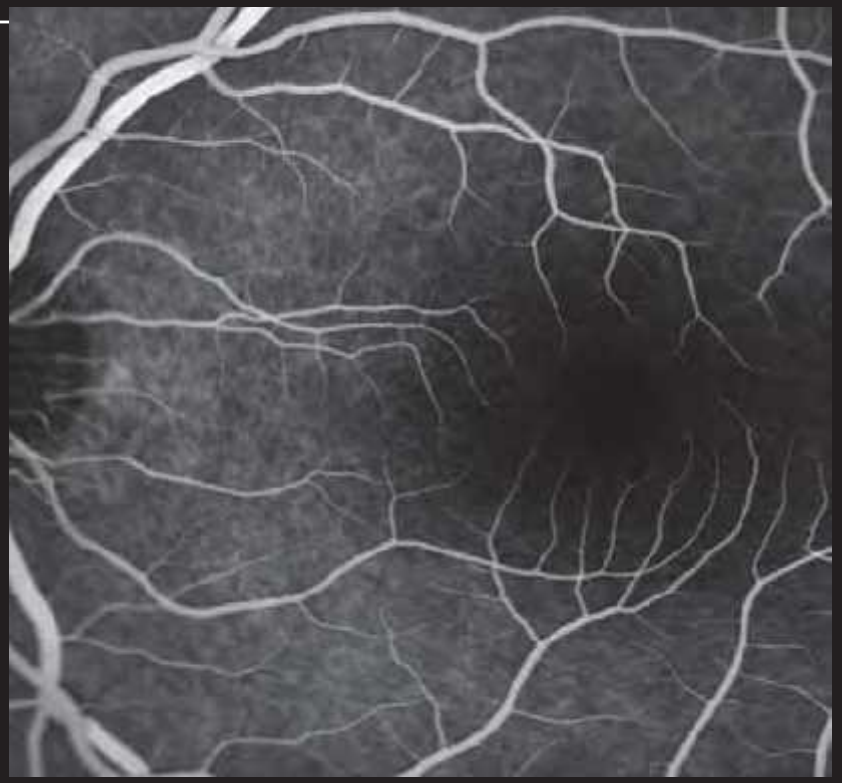
- Using the complex data encoded within the OCT images (complex data is generally discarded by most commercial devices), structures with motion may be selectively isolated.

- After eliminating Brownian motion and fixation artifact, most of the residual motion in the eye is blood flow.

Phase Variance OCT: Captures microvasculature



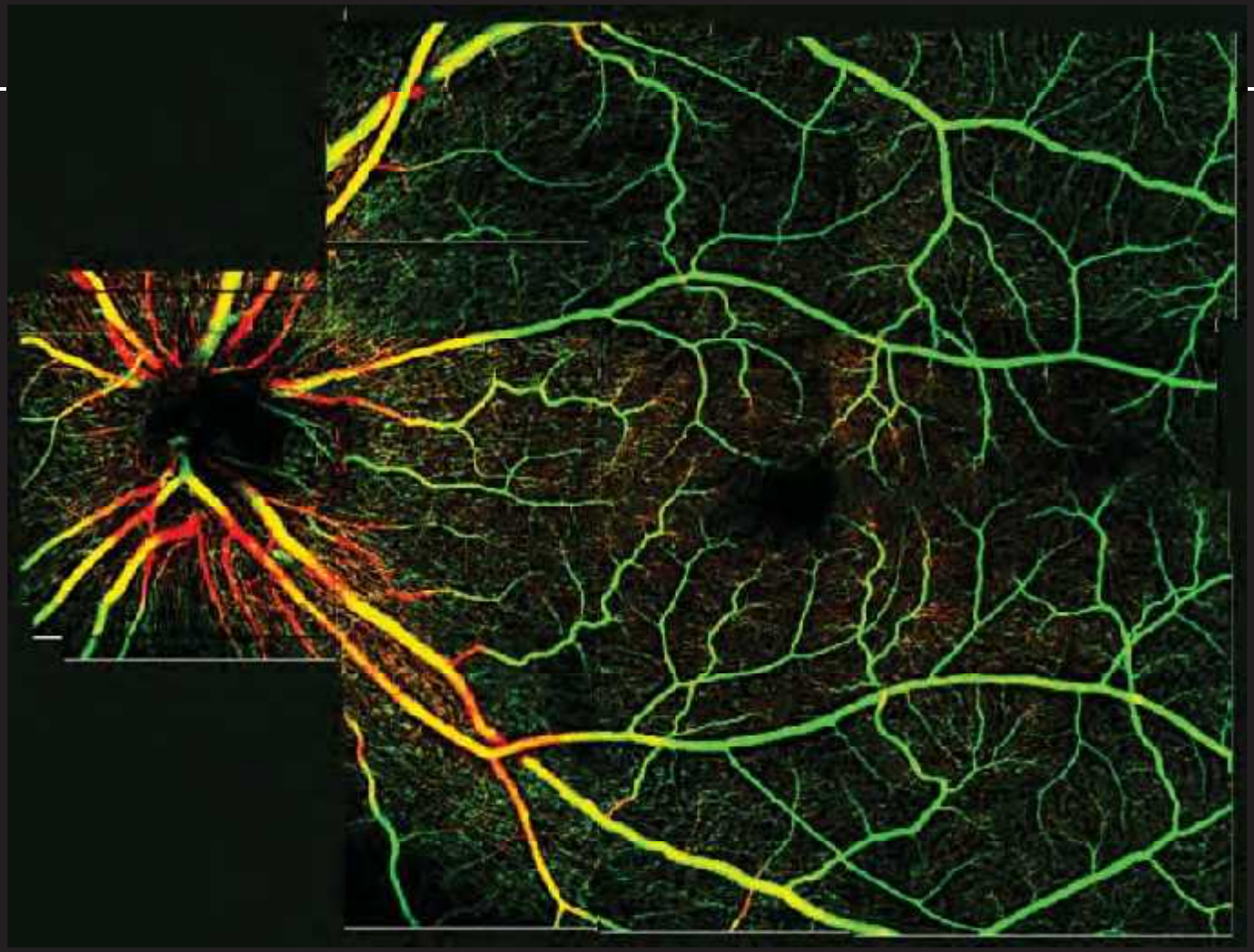
OCT Angiography



Fluorescein Angiography

Courtesy of Scott Fraser, Jeff Fingler, Dan Schwartz, Jack Werner

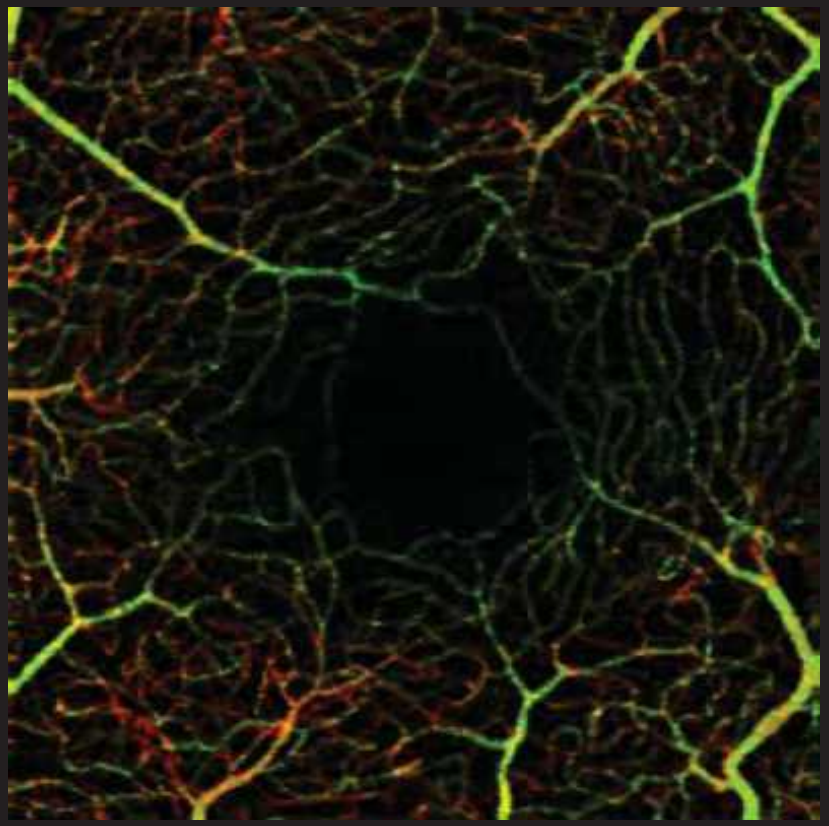
Large Composite PV-OCT Vascular Image



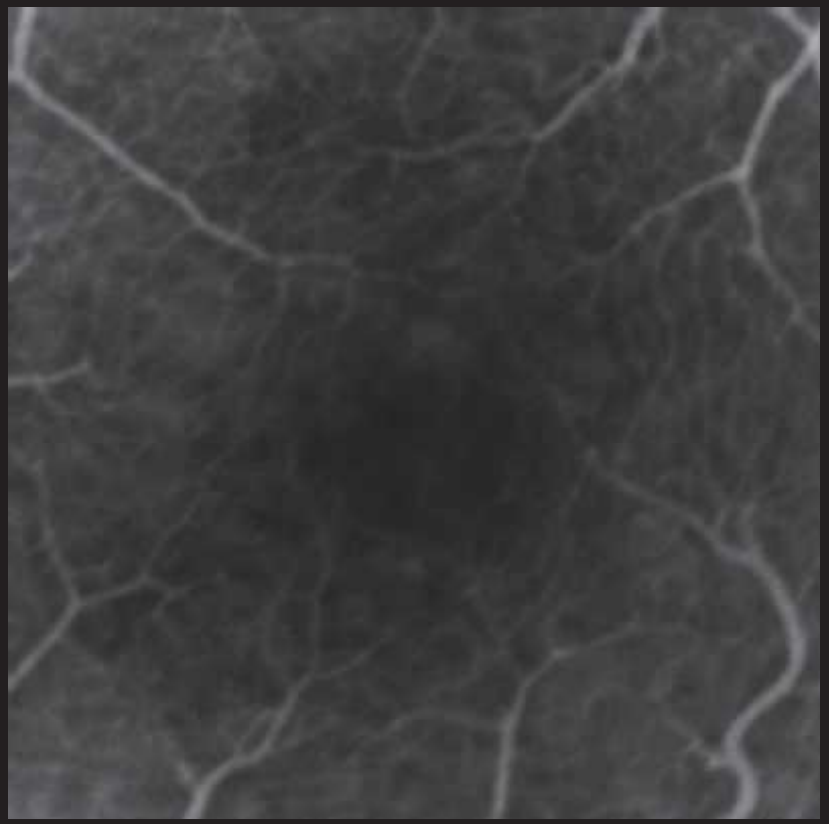
Color encodes depth: green=vitreal surface

Courtesy of Scott Fraser, Jeff Fingler, Dan Schwartz, Jack Werner

Comparing PV-OCT to FA (1.5mm x 1.5mm)



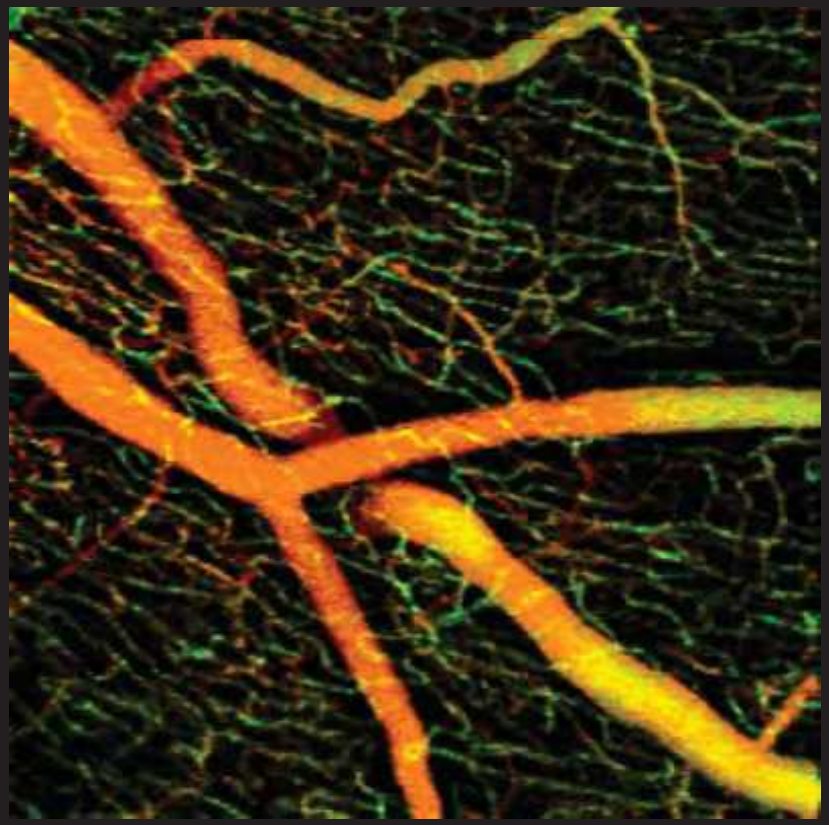
PV-OCT Retinal Vasculature



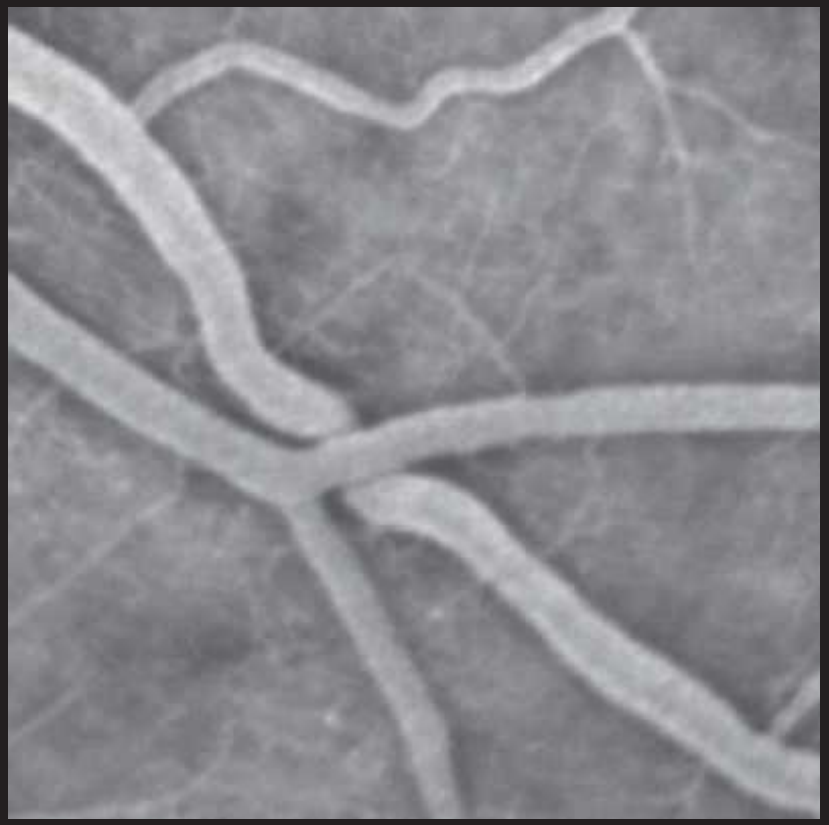
Cropped FA image

Courtesy of Scott Fraser, Jeff Fingler, Dan Schwartz, Jack Werner

Comparing PV-OCT to FA (1.5mm x 1.5mm)



PV-OCT Retinal Vasculature



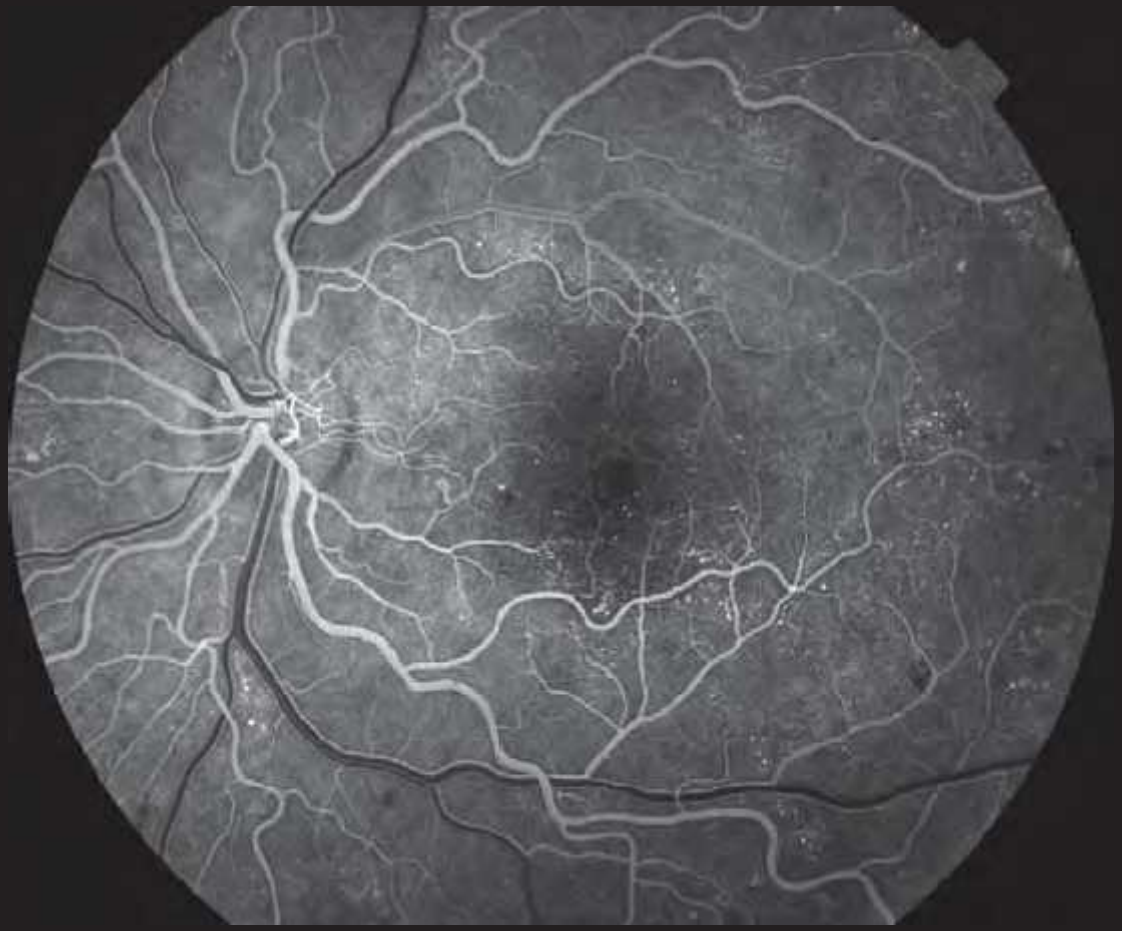
Cropped FA image

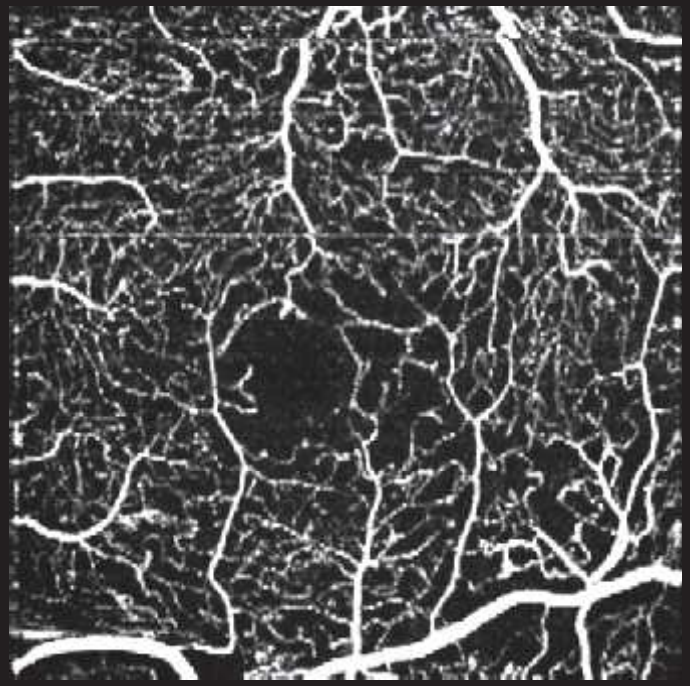
Courtesy of Scott Fraser, Jeff Fingler, Dan Schwartz, Jack Werner

Volume-Rendered Human OCT Angiography

Courtesy of Scott Fraser, Jeff Fingler, Dan Schwartz, Jack Werner

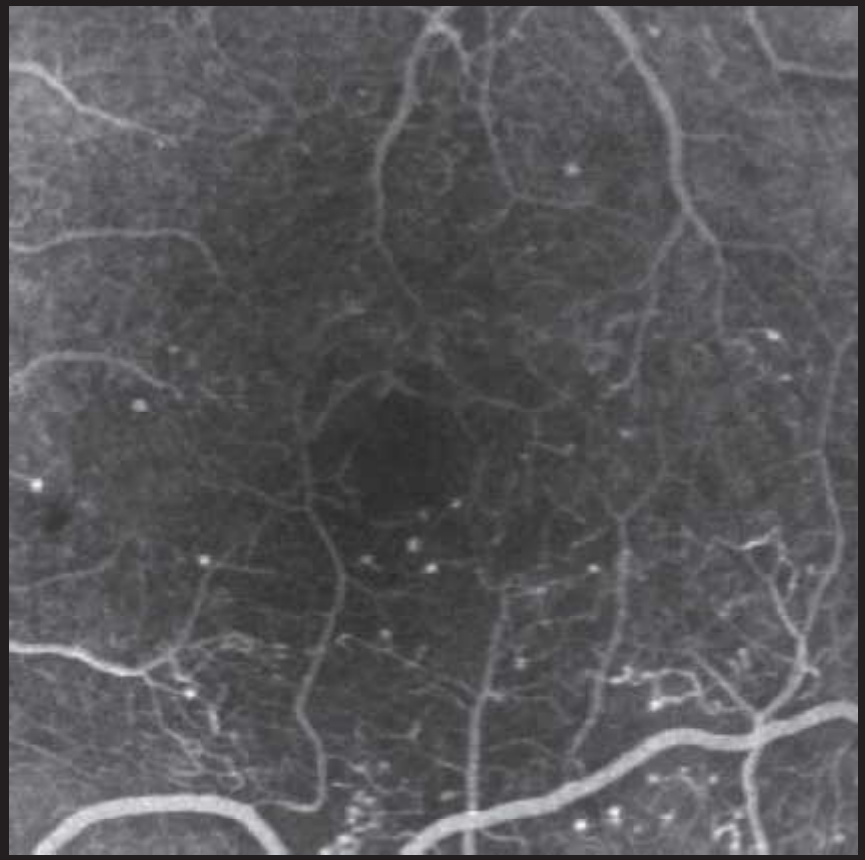
Diabetic Retinopathy imaged with 125kHz PV-OCT





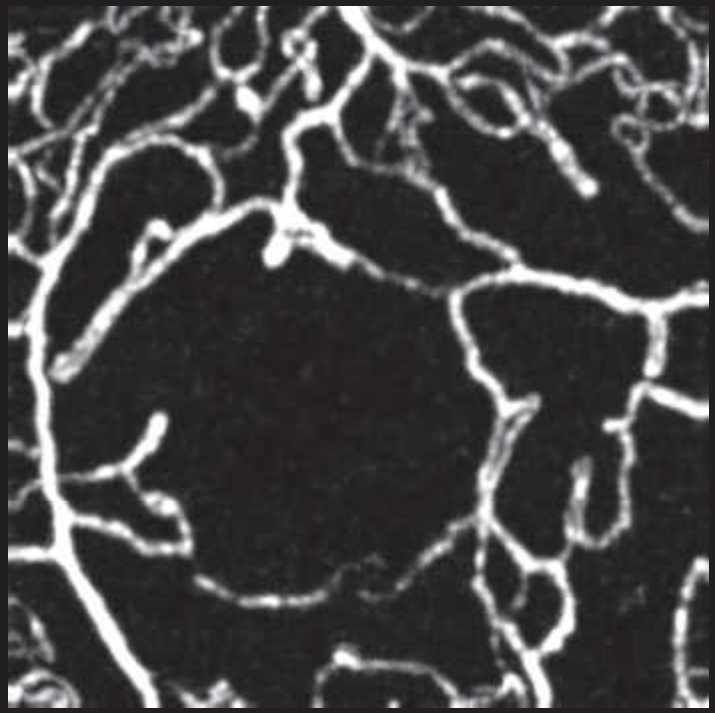
Courtesy of Scott Fraser, Jeff Fingler, Dan Schwartz, Jack Werner

Comparing FA to PV-OCT (3mm x 3mm)



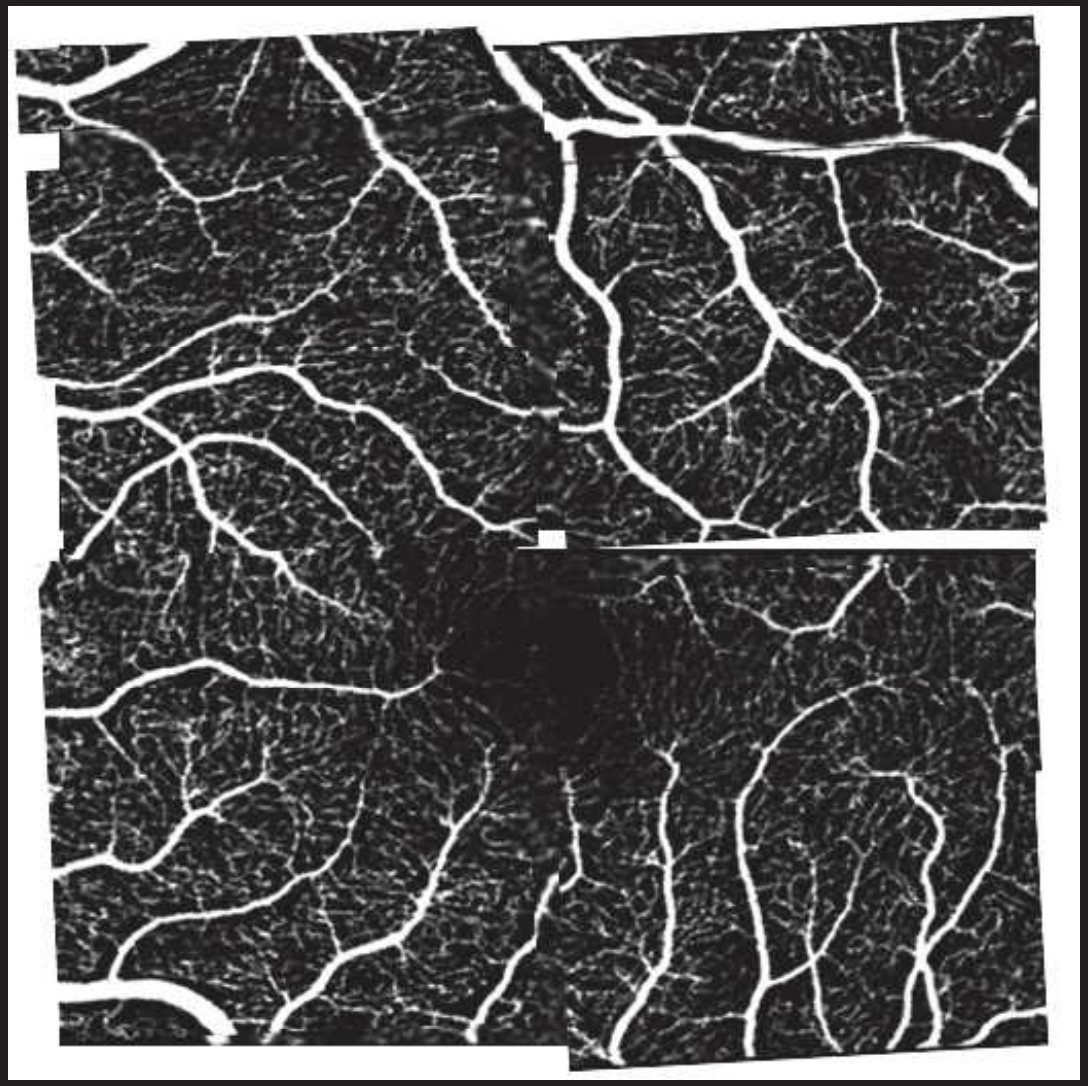
Courtesy of Scott Fraser, Jeff Fingler

3mm x 3mm vs 1mm x 1mm Retinal Scan



Courtesy of Scott Fraser, Jeff Fingler

Phase Variance OCT



"OCT Angiography"

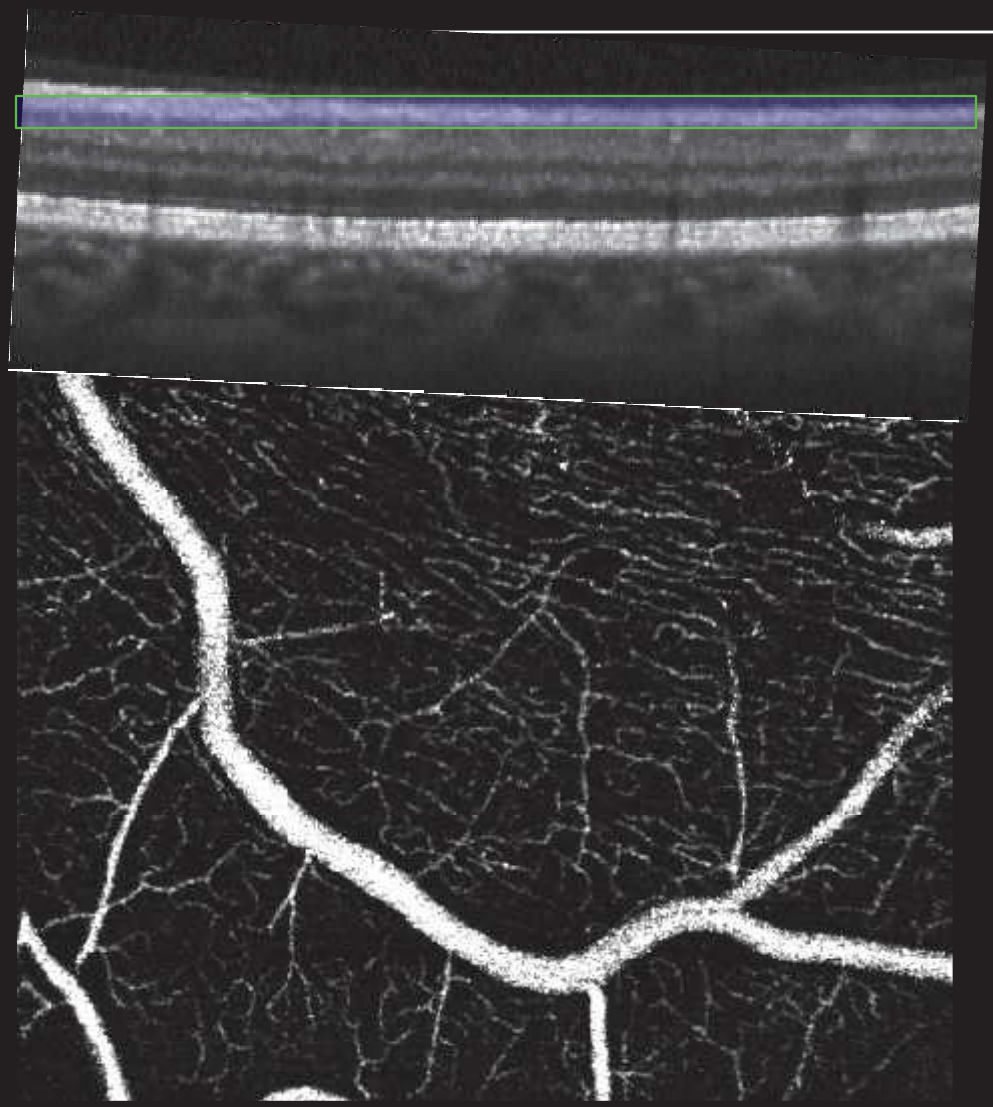
ADVANTAGES

- No Dye
- Depth Resolved

Composite image – Sadda's Eye Undilated

Collaborative work with Scott Fraser and Jeff Fingler (Caltech)

Phase Variance OCT



"OCT Angiography"

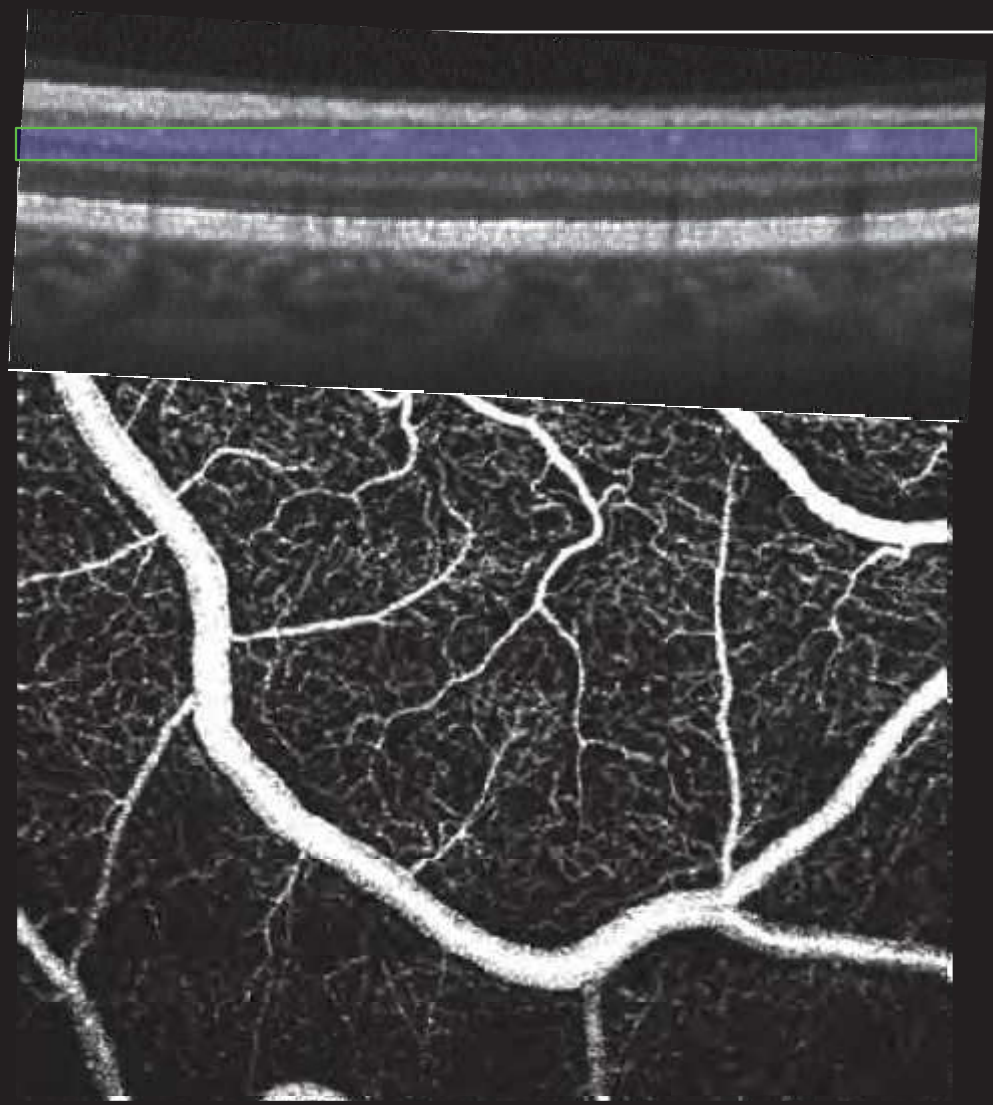
ADVANTAGES

- No Dye
- Depth Resolved

SLAB LEVEL:
Major Retinal Vessels

Courtesy of Jeff Fingler, Scott Fraser

Phase Variance OCT



"OCT Angiography"

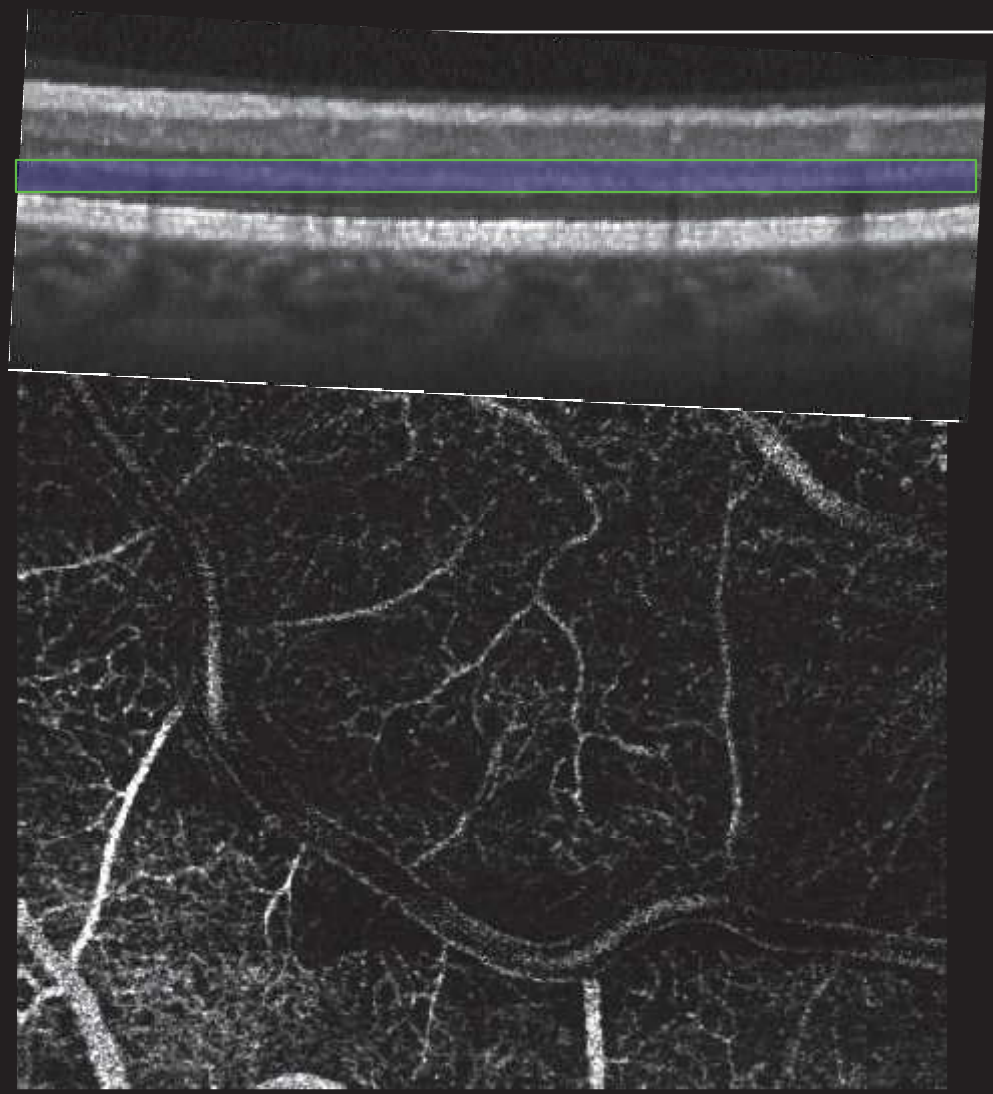
ADVANTAGES

- No Dye
- Depth Resolved

SLAB LEVEL:
Superficial Capillary Plexus

Courtesy of Jeff Fingler, Scott Fraser

Phase Variance OCT



"OCT Angiography"

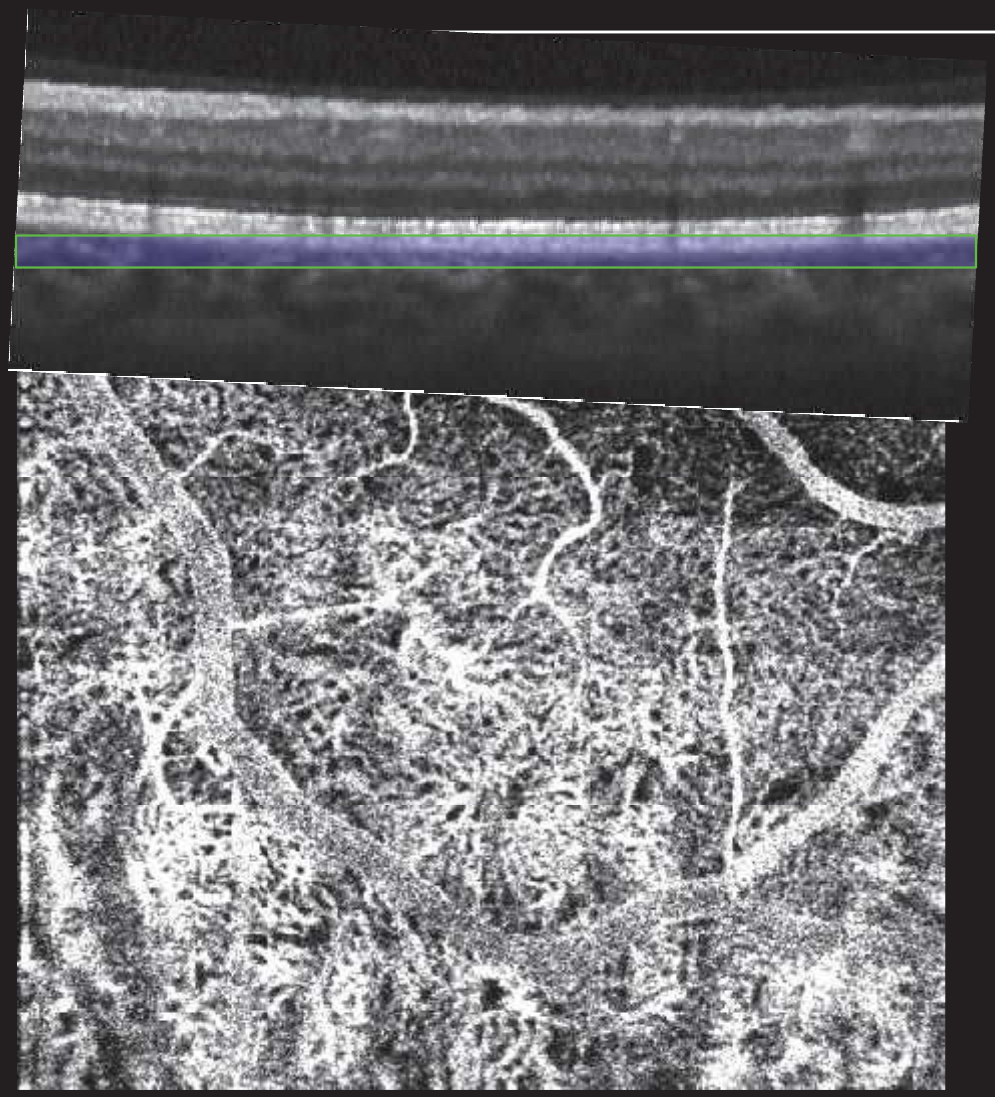
ADVANTAGES

- No Dye
- Depth Resolved

SLAB LEVEL:
Deep Capillary Plexus

Courtesy of Jeff Fingler, Scott Fraser

Phase Variance OCT



"OCT Angiography"

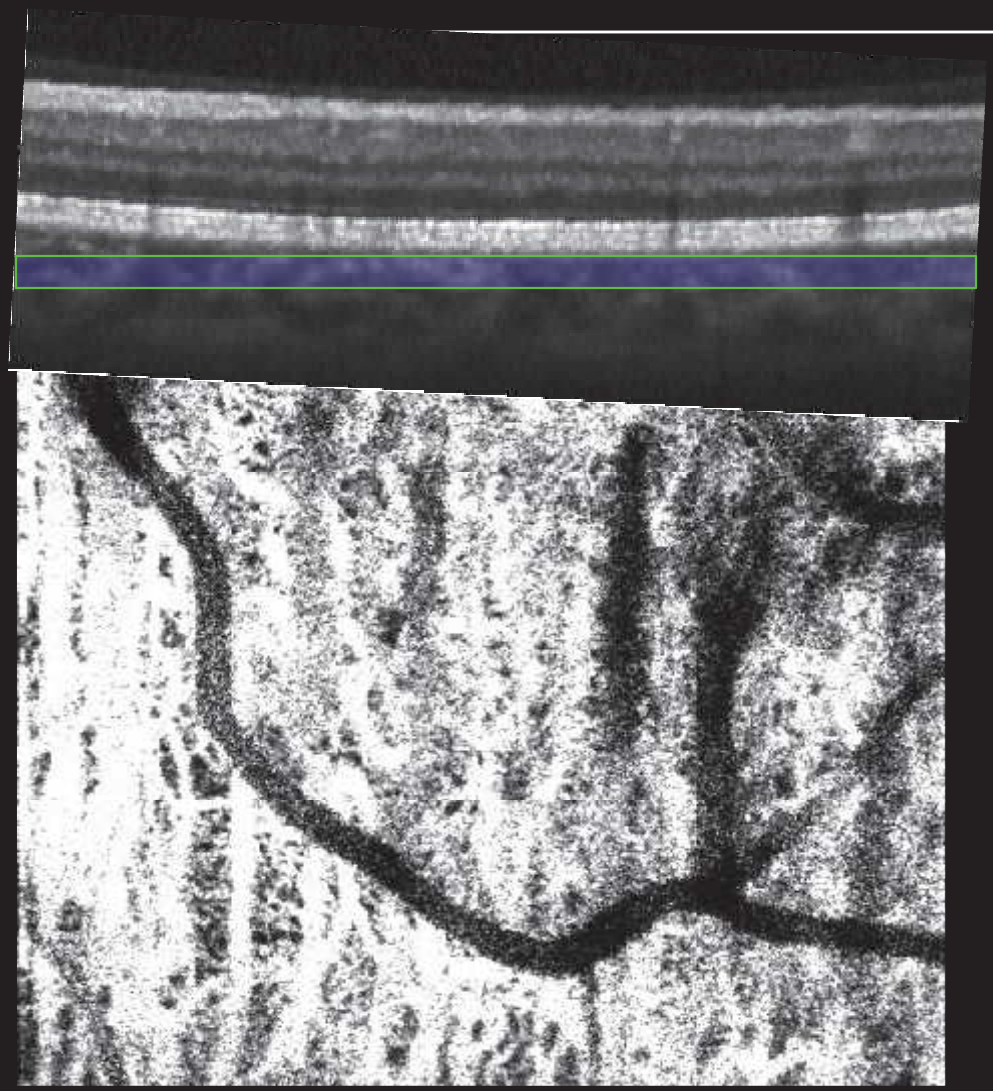
ADVANTAGES

- No Dye
- Depth Resolved

SLAB LEVEL:
Choriocapillaris

Courtesy of Jeff Fingler, Scott Fraser

Phase Variance OCT



"OCT Angiography"

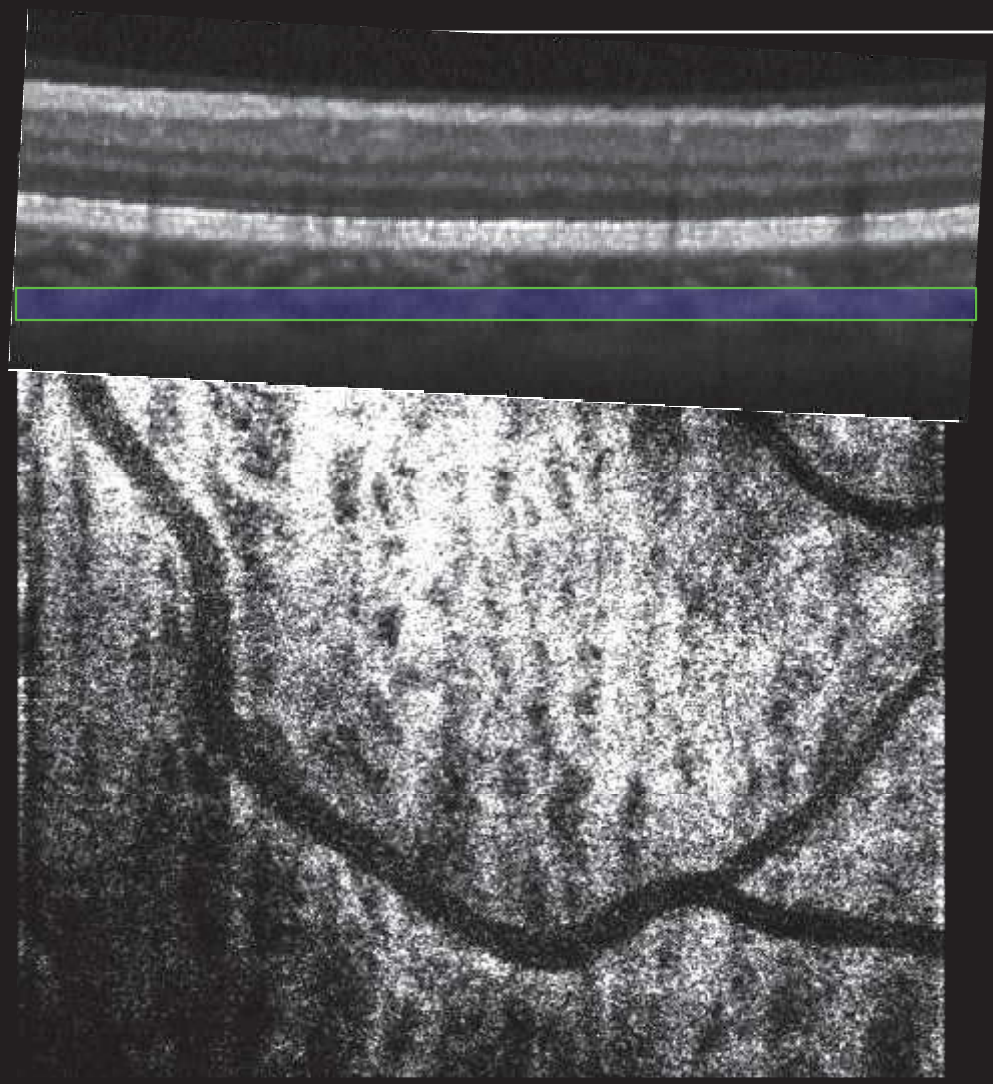
ADVANTAGES

- No Dye
- Depth Resolved

SLAB LEVEL:
Sattler's Layer *(medium choroid vessels)*

Courtesy of Jeff Fingler, Scott Fraser

Phase Variance OCT



"OCT Angiography"

ADVANTAGES

- No Dye
- Depth Resolved

SLAB LEVEL:
Haller's Layer *(large choroid vessels)*

Courtesy of Jeff Fingler, Scott Fraser

PV OCT pitfalls

- Motion artifact can be a problem for obtaining high-quality images in some patients.

- Fixation tracking may be a key requirement for optimal imaging

PV OCT

- Eye tracking can yield superb image quality

Real-time eye motion correction in phase-resolved OCT angiography with tracking SLO

Boy Braaf,[1,*] Kari V. Vienola,[1] Christy K. Sheehy,[2] Qiang Yang,[2] Koenraad A. Vermeer,[1] Pavan Tiruveedhula,[2] David W. Arathorn,[3] Austin Roorda,[2] and Johannes F. de Boer[1,4]

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[2]School of Optometry, University of California Berkeley, Berkeley, CA 94720, USA
[3]Montana State University, Bozeman, MT 59717, USA
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Abstract: In phase-resolved OCT angiography blood flow is detected from phase changes in between A-scans that are obtained from the same location. In ophthalmology, this technique is vulnerable to eye motion. We address this problem by combining inter-B-scan phase-resolved OCT angiography with real-time eye tracking. A tracking scanning laser ophthalmoscope (TSLO) at 840 nm provided eye tracking functionality and was combined with a phase-stabilized optical frequency domain imaging (OFDI) system at 1040 nm. Real-time eye tracking corrected eye drift and prevented discontinuity artifacts from (micro)saccadic eye motion in OCT angiograms. This improved the OCT spot stability on the retina and consequently reduced the phase-noise, thereby enabling the detection of slower blood flows by extending the inter-B-scan time interval. In addition, eye tracking enabled the easy compounding of multiple data sets from the fovea of a healthy volunteer to create high-quality eye motion artifact-free angiograms. High-quality images are presented of two distinct layers of vasculature in the retina and the dense vasculature of the choroid. Additionally we present, for the first time, a phase-resolved OCT angiogram of the mesh-like network of the choriocapillaris containing typical pore openings.

OCIS codes: (110.0113) Imaging systems; (170.3880) Medical and biological imaging; (110.4500) Optical coherence tomography; (170.4470) Ophthalmology; (280.2490) Flow diagnostics.

References and links

1. L. A. Yannuzzi, K. T. Rohrer, L. J. Tindel, R. S. Sobel, M. A. Costanza, W. Shields, and E. Zang, "Fluorescein angiography complication survey," Ophthalmology **93**(5), 611–617 (1986).
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3. D. Huang, E. A. Swanson, C. P. Lin, J. S. Schuman, W. G. Stinson, W. Chang, M. R. Hee, T. Flotte, K. Gregory, C. A. Puliafito, and J. G. Fujimoto, "Optical coherence tomography," Science **254**(5035), 1178–1181 (1991).
4. J. F. de Boer, B. Cense, B. H. Park, M. C. Pierce, G. J. Tearney, and B. E. Bouma, "Improved signal-to-noise ratio in spectral-domain compared with time-domain optical coherence tomography," Opt. Lett. **28**(21), 2067–2069 (2003).
5. R. Leitgeb, C. Hitzenberger, and A. Fercher, "Performance of fourier domain vs. time domain optical coherence tomography," Opt. Express **11**(8), 889–894 (2003).
6. M. A. Choma, M. V. Sarunic, C. Yang, and J. A. Izatt, "Sensitivity advantage of swept source and Fourier domain optical coherence tomography," Opt. Express **11**(18), 2183–2189 (2003).
7. S. Yazdanfar, A. M. Rollins, and J. A. Izatt, "Imaging and velocimetry of the human retinal circulation with color Doppler optical coherence tomography," Opt. Lett. **25**(19), 1448–1450 (2000).

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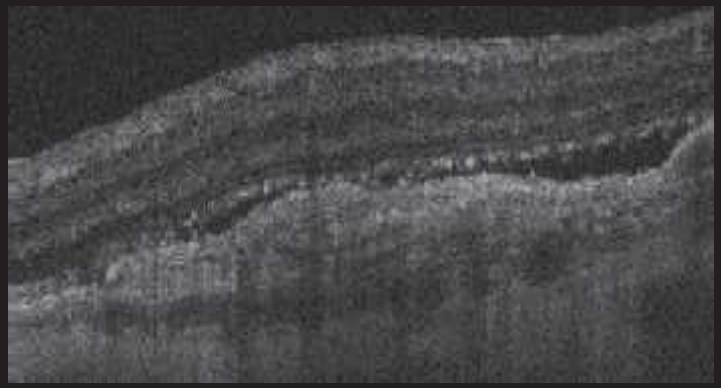
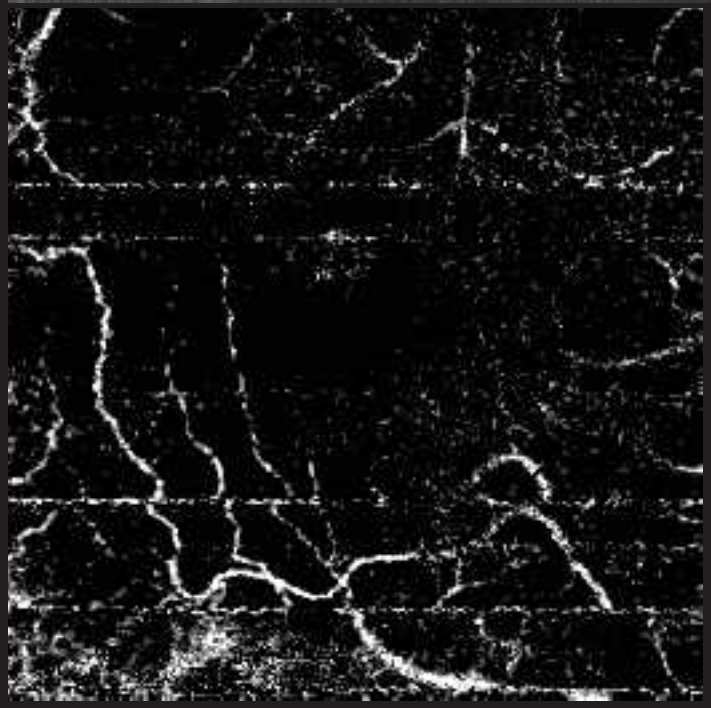
Phase Variance OCT for imaging CNV





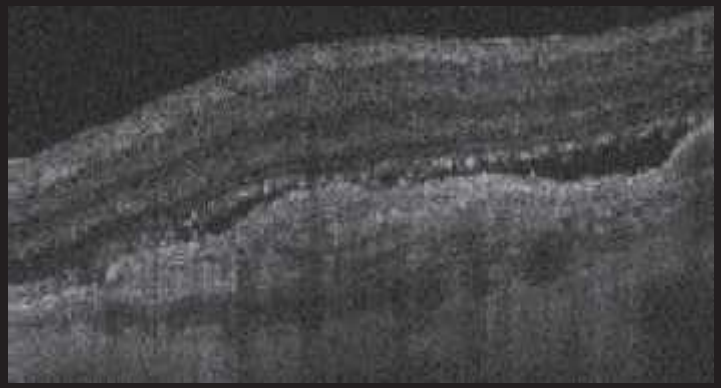
Neovascular AMD, FVPED s/p >30 ranibizumab injections

Old lesion – mature vessels within membrane

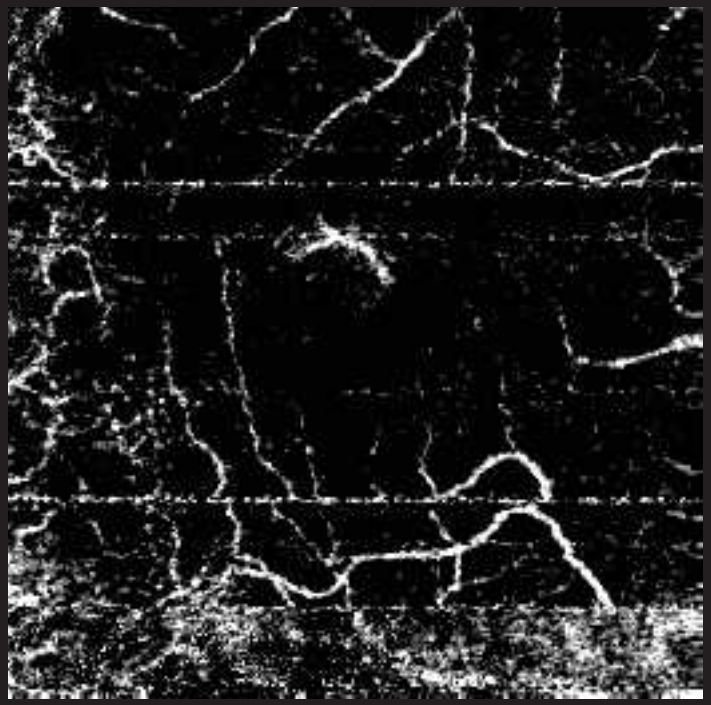
Deep Retinal Capillary Plexus

Courtesy of Jeff Fingler, Scott Fraser

Phase Variance OCT for imaging CNV



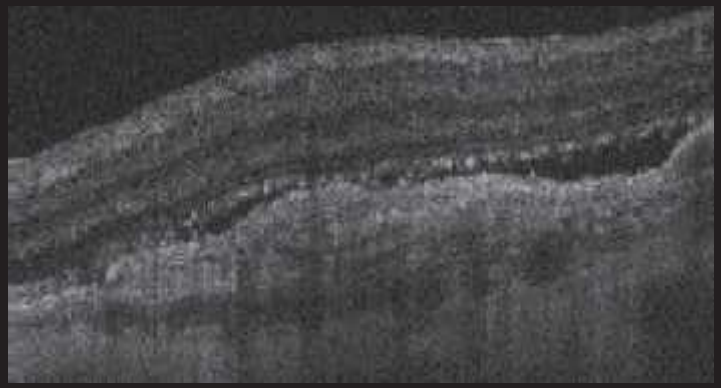
Neovascular AMD, FVPED s/p >30 ranibizumab injections



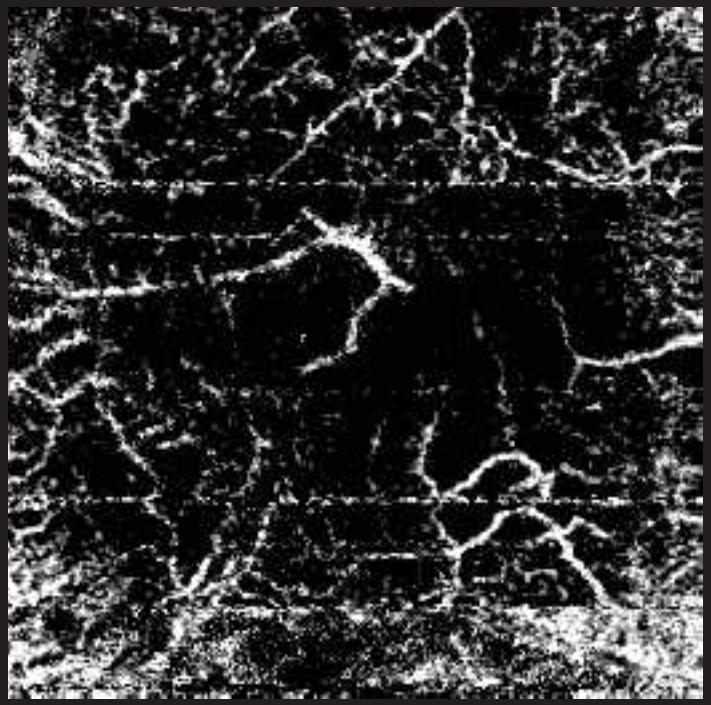
Retinal – Choroidal Anastomosis

Courtesy of Jeff Fingler, Scott Fraser

Phase Variance OCT for imaging CNV



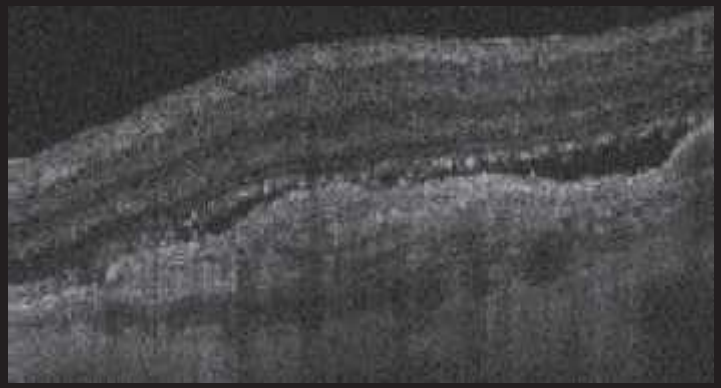
Neovascular AMD, FVPED s/p >30 ranibizumab injections



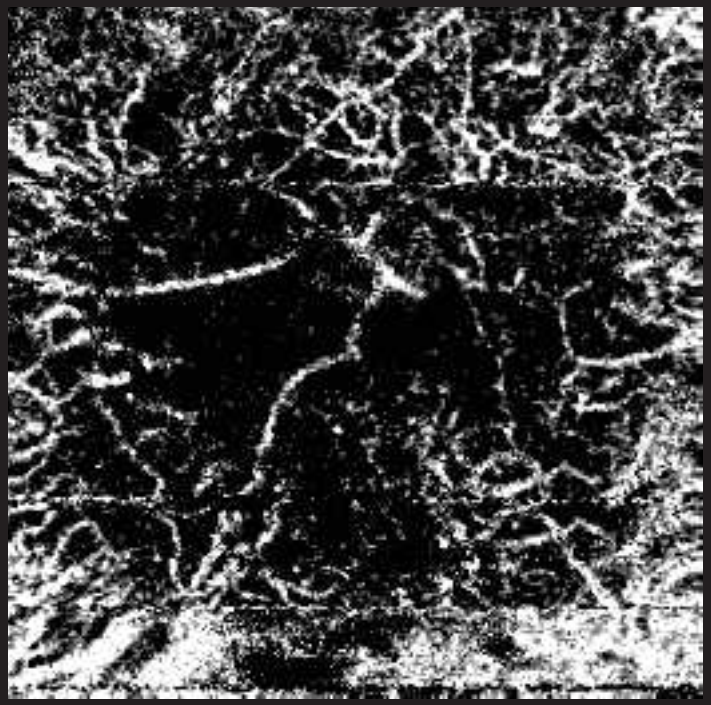
Retinal – Choroidal Anastomosis

Courtesy of Jeff Fingler, Scott Fraser

Phase Variance OCT for imaging CNV



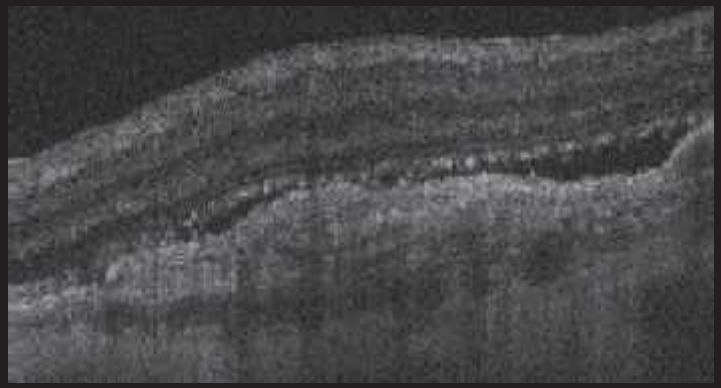
Neovascular AMD, FVPED s/p >30 ranibizumab injections

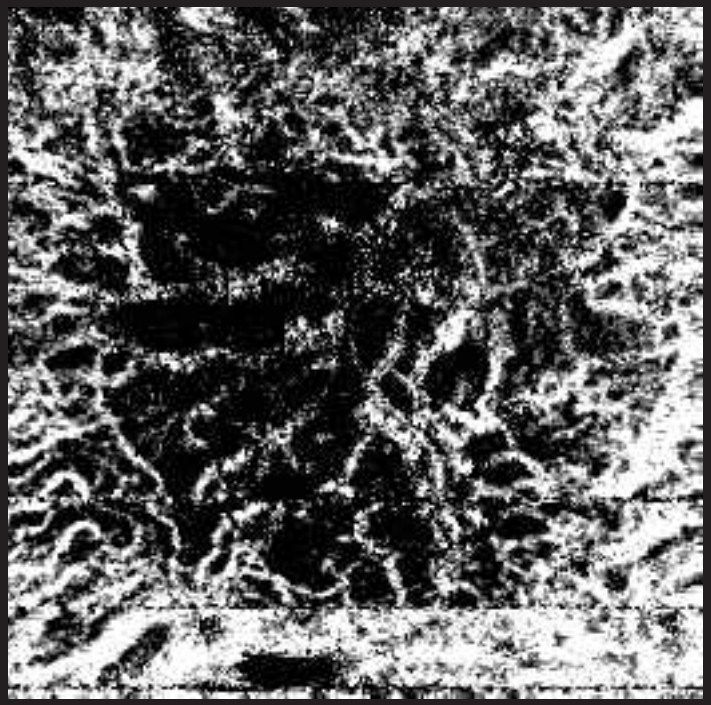


Superficial vessels of CNV

Courtesy of Jeff Fingler, Scott Fraser

Phase Variance OCT for imaging CNV



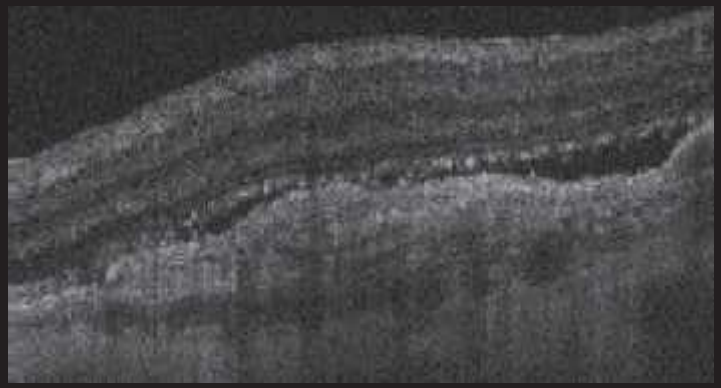


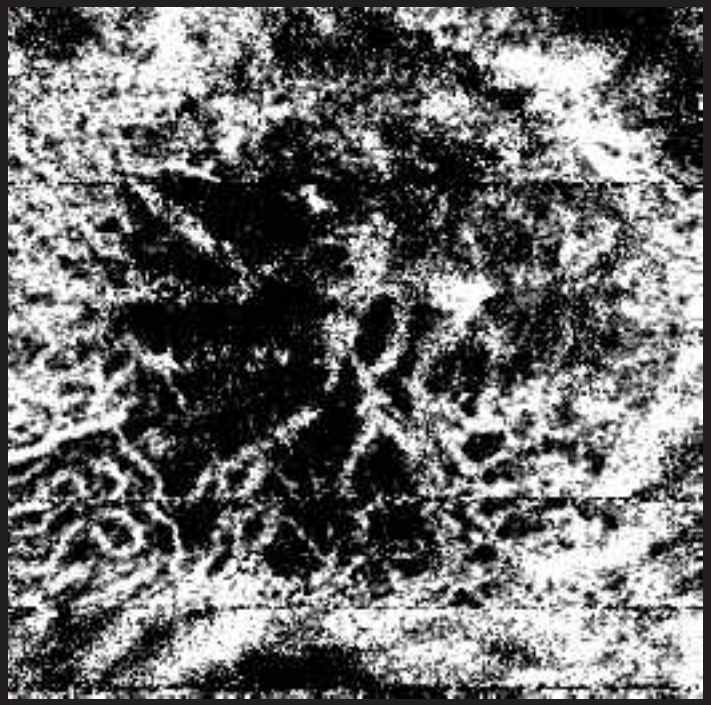
Neovascular AMD, FVPED s/p >30 ranibizumab injections

Larger CNV Vessels

Courtesy of Jeff Fingler, Scott Fraser

Phase Variance OCT for imaging CNV



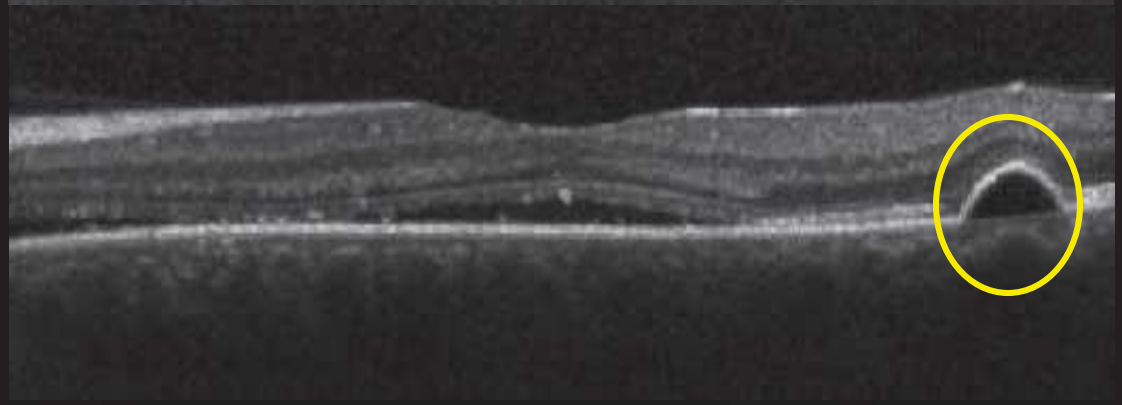


Neovascular AMD, FVPED s/p >30 ranibizumab injections

Larger CNV Vessels

Courtesy of Jeff Fingler, Scott Fraser

Increases confidence in our detection of CNV with OCT



Spectrum of Pigment Epithelial Detachments

Drusenoid PED
(medium homogenous)

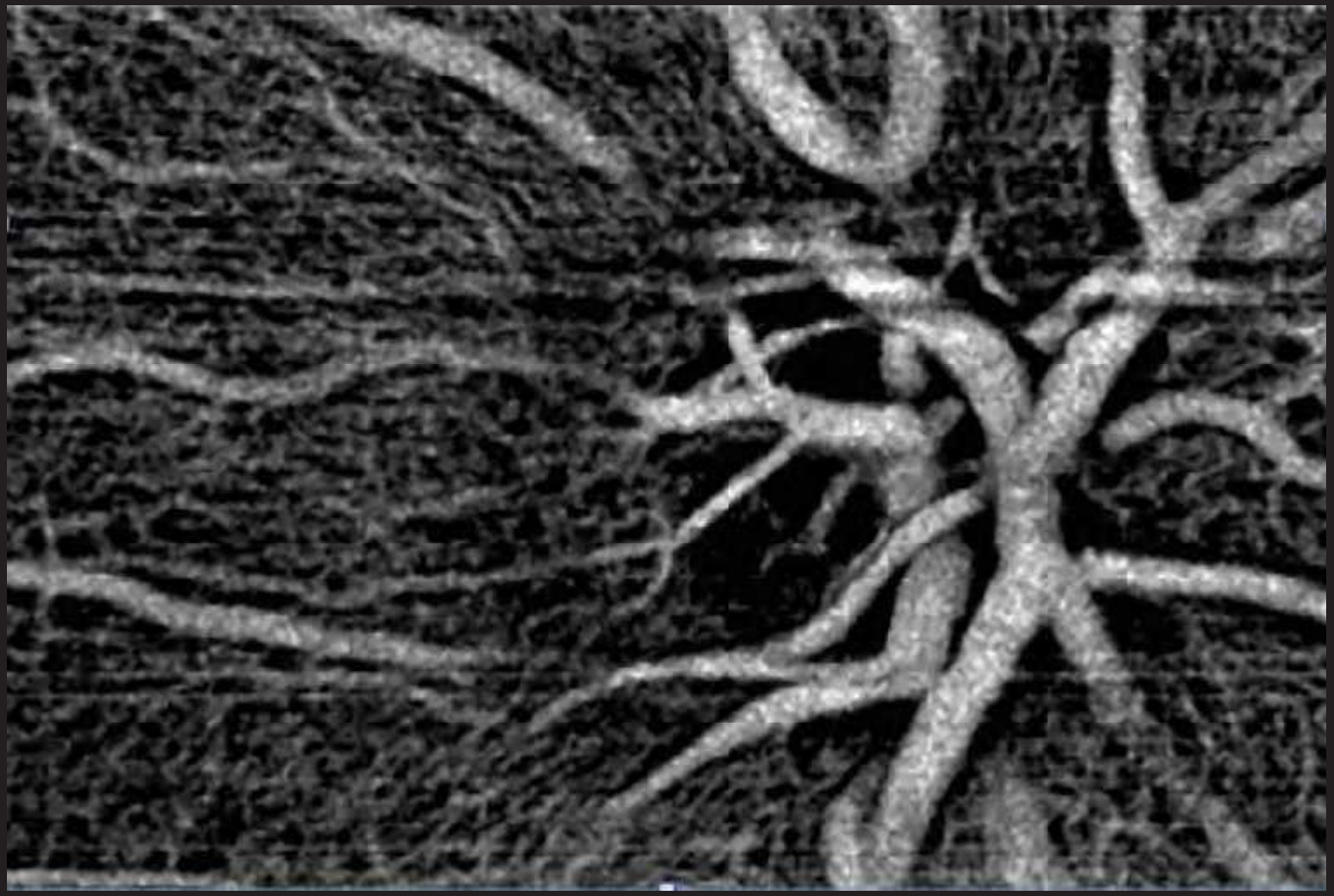
Serous PED
(low homogenous)

Fibrovascular PED
(low heterogenous)

Vascular Detail with PV-OCT

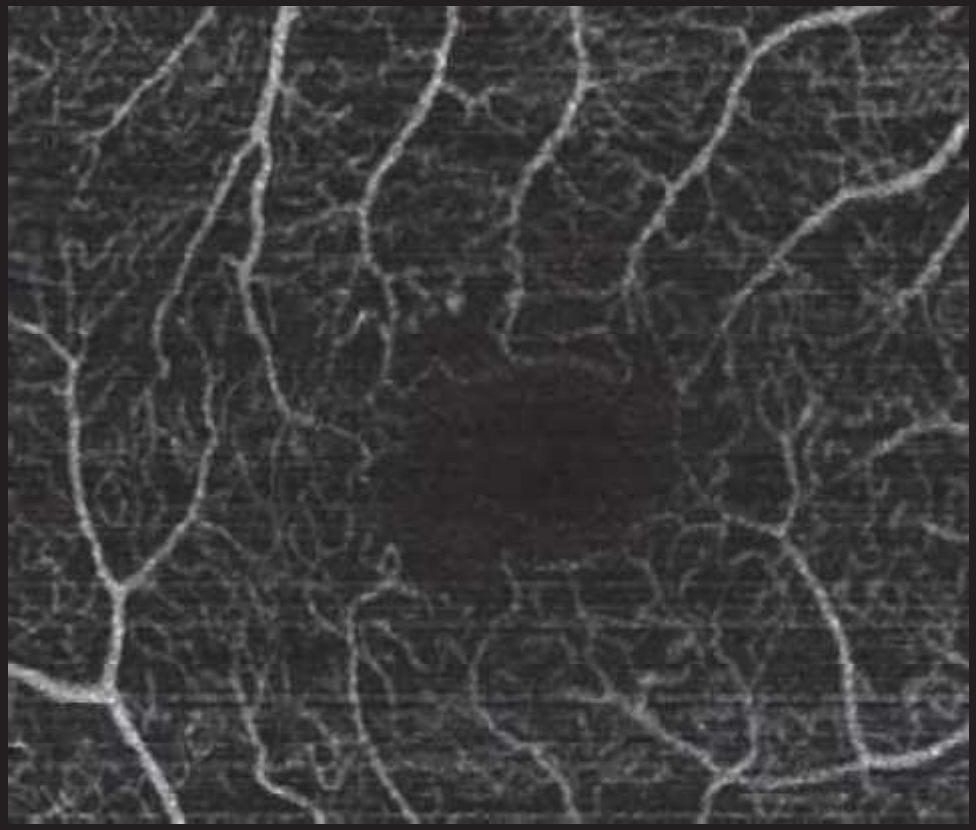
Zeiss SS-OCT prototype (investigational device, not FDA cleared)

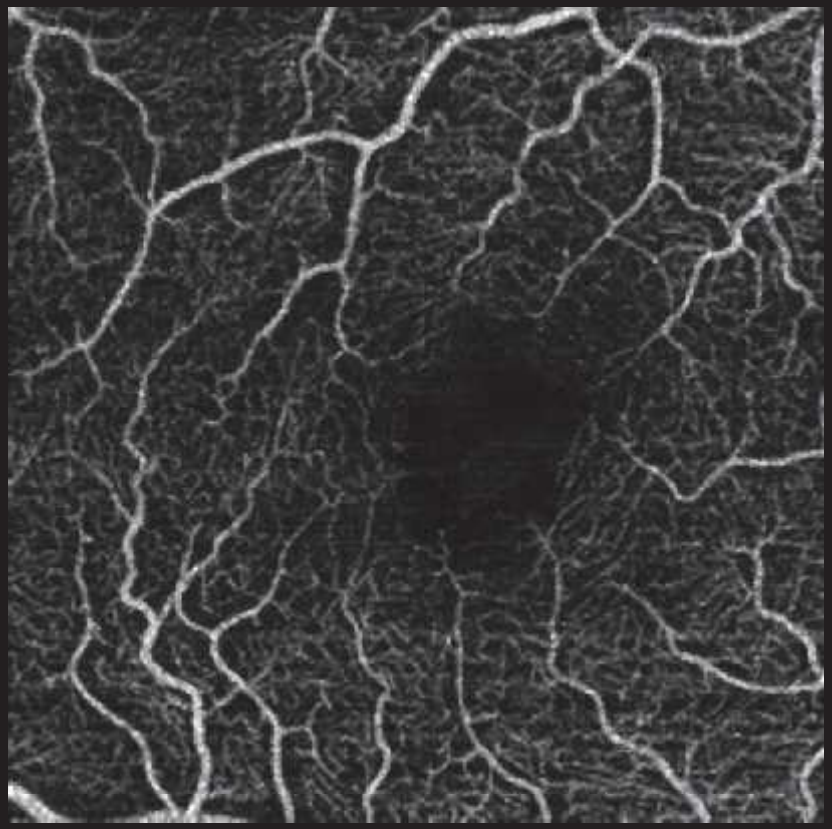
Vascular Detail with PV-OCT



Zeiss SS-OCT prototype (investigational device, not FDA cleared)

Diabetic Retinopathy

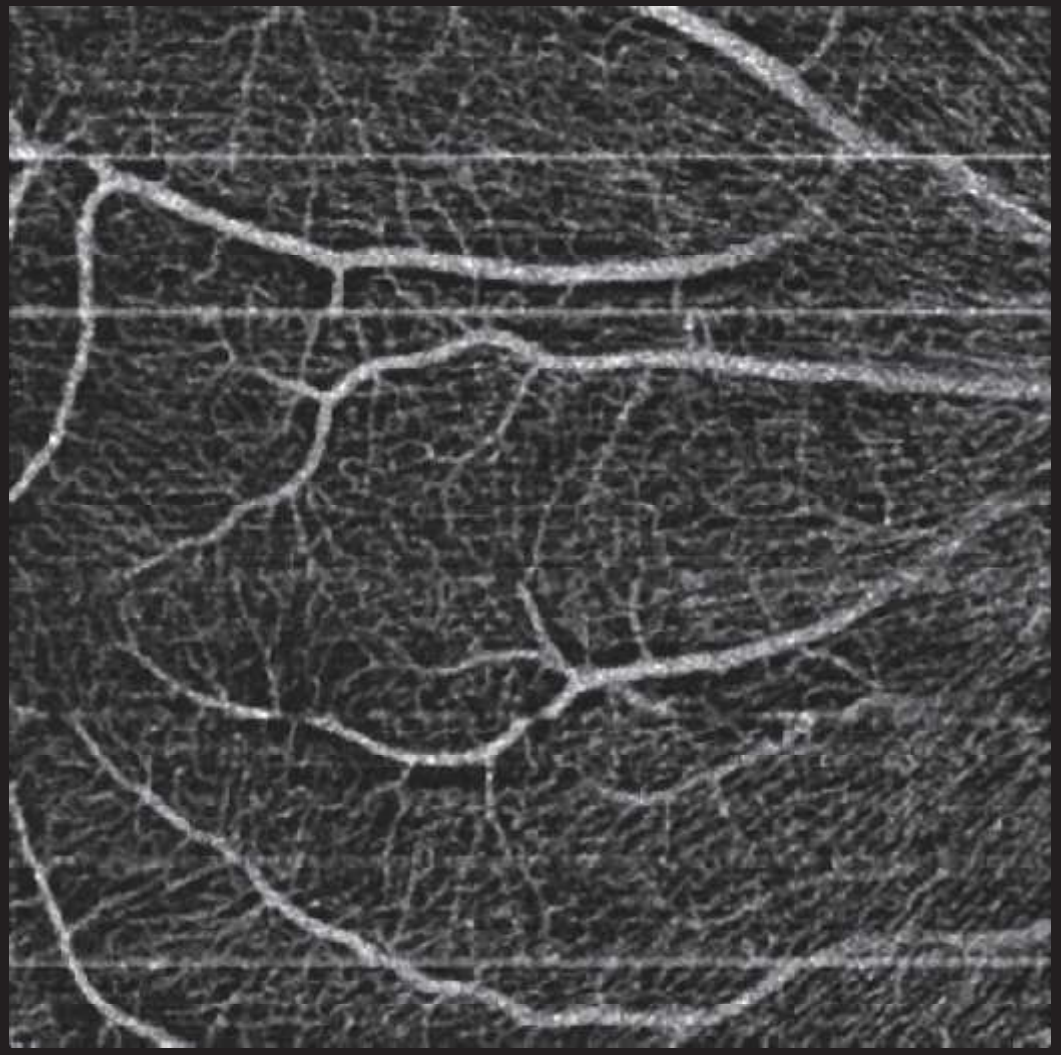




2 patients with NPDR --- note microaneurysms and enlarged foveal avascular zone

Zeiss SS-OCT prototype (investigational device, not FDA cleared)

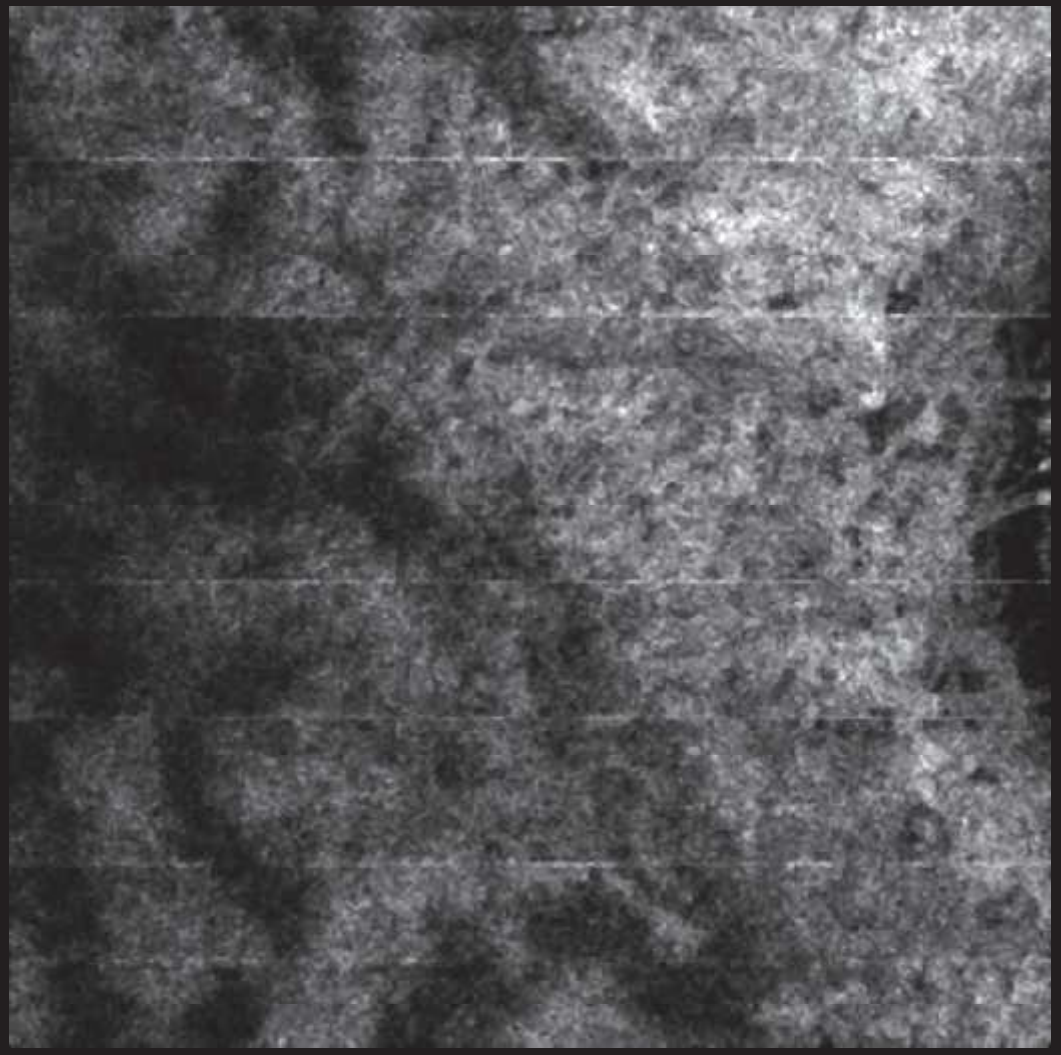
Depth resolved vascular imaging



Superficial
Retinal
Capillary
Plexus Level

Zeiss SS-OCT prototype (investigational device, not FDA cleared)

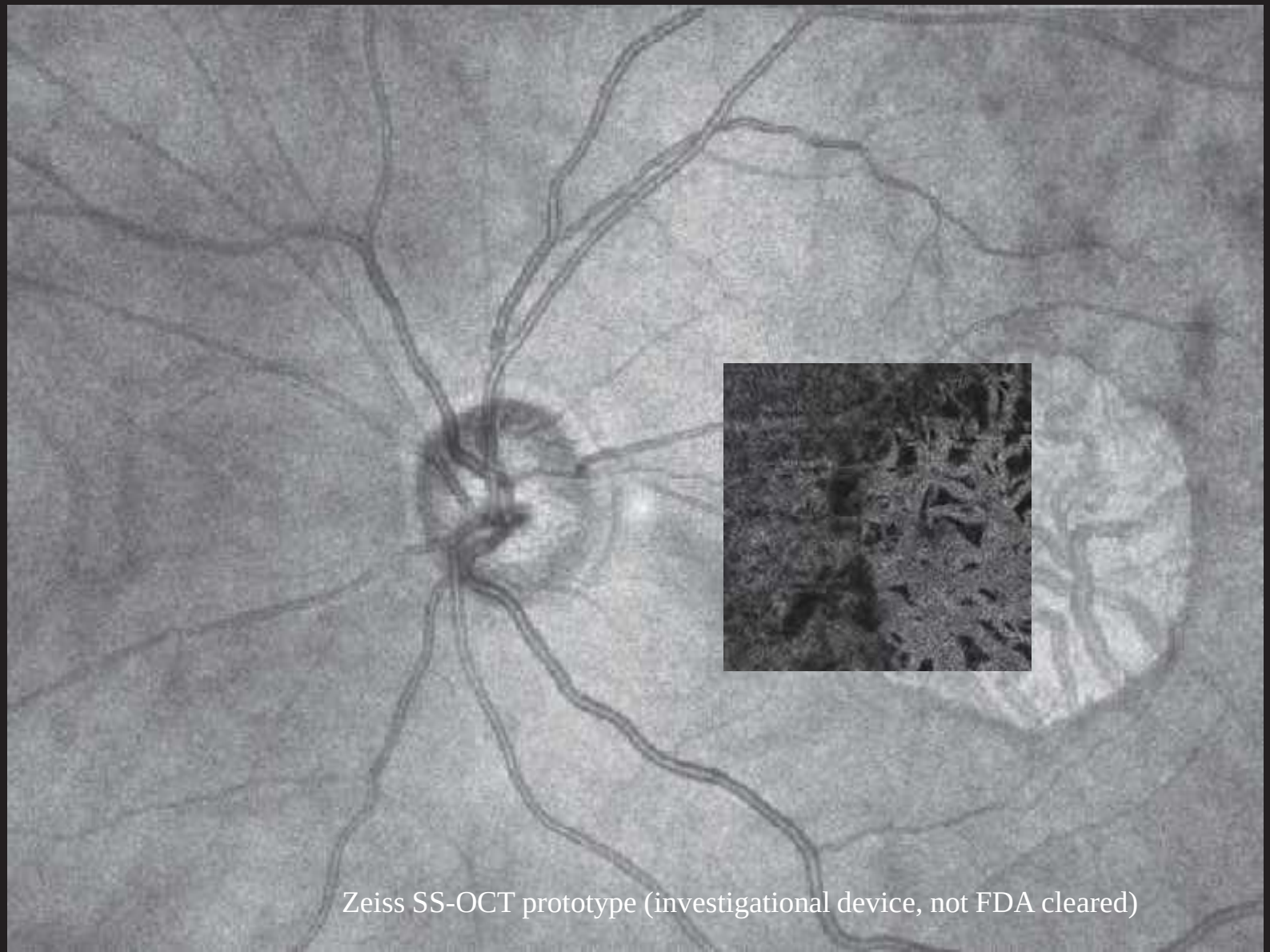
Depth resolved vascular imaging



Choriocapillaris Level!

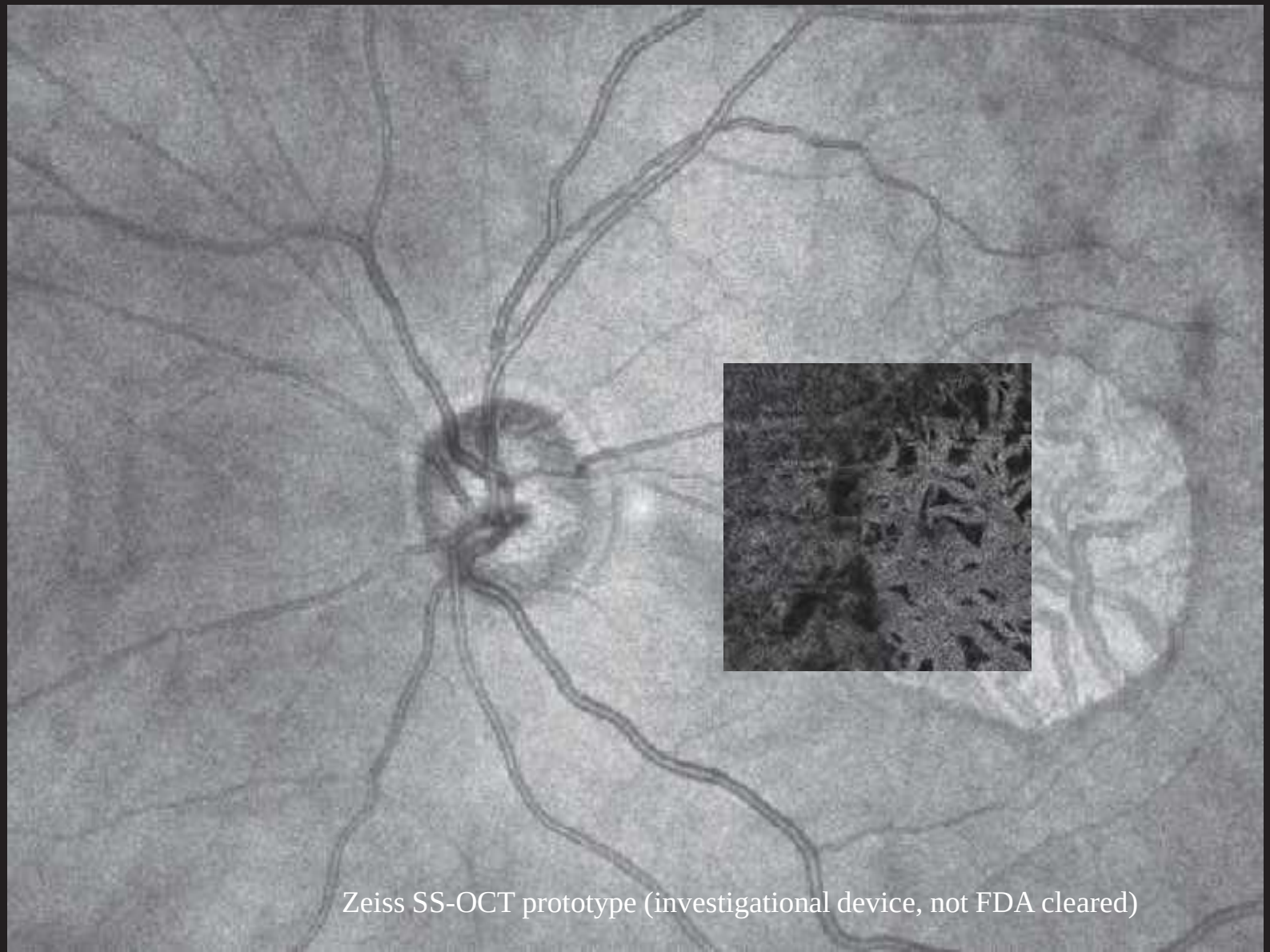
Zeiss SS-OCT prototype (investigational device, not FDA cleared)

Depth resolved vascular imaging



Zeiss SS-OCT prototype (investigational device, not FDA cleared)

Depth resolved vascular imaging



Zeiss SS-OCT prototype (investigational device, not FDA cleared)

OCT Angiography

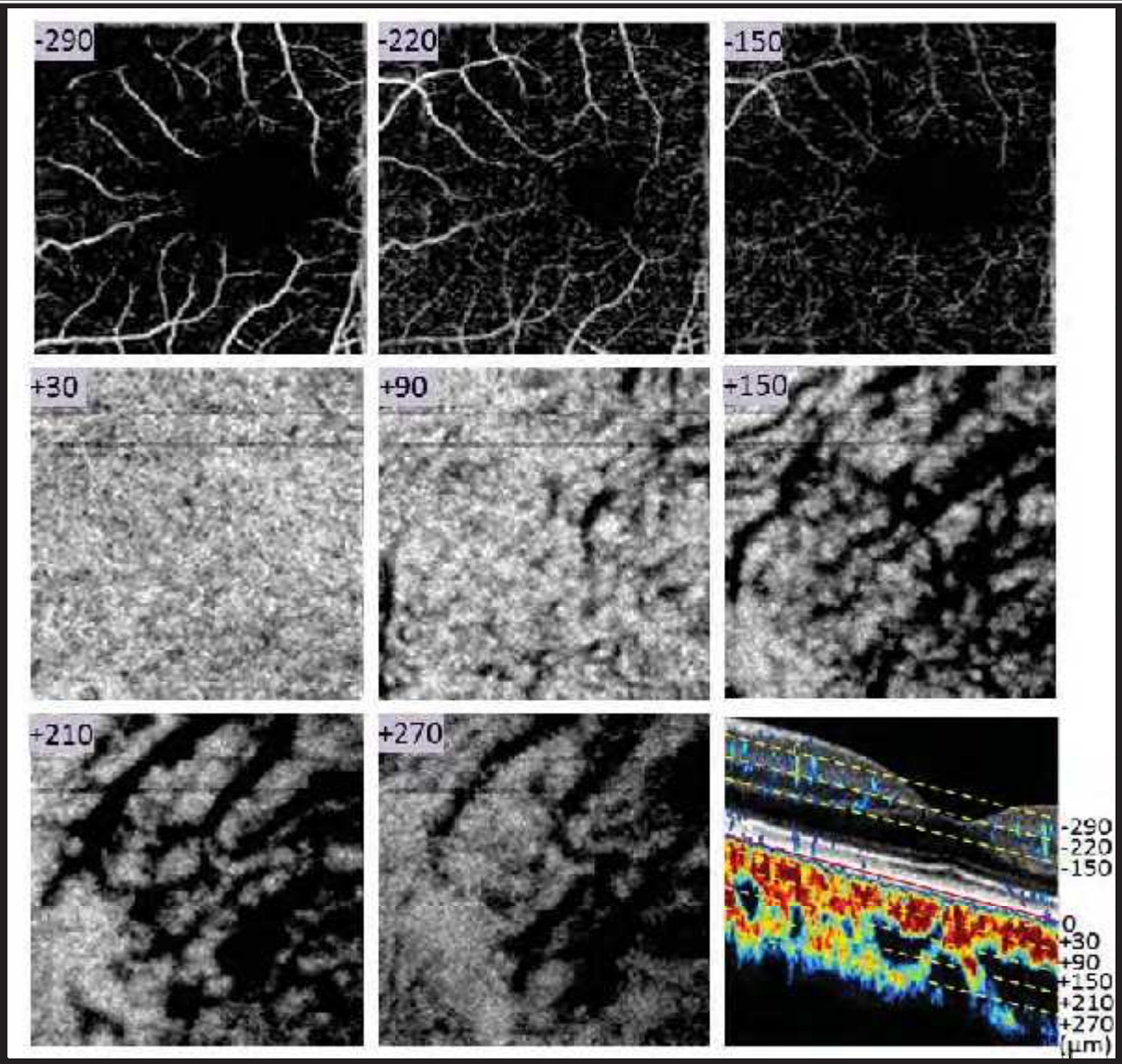
Split-Spectrum Amplitude Decorrelation Angiography

SSADA

- “Decorrelation” refers to fluctuating values of OCT intensities
- Blood flow results in fluctuation in the amplitude of the OCT fringes ad RBCs enter and exit a particular voxel
- Greater fluctuation means greater flow

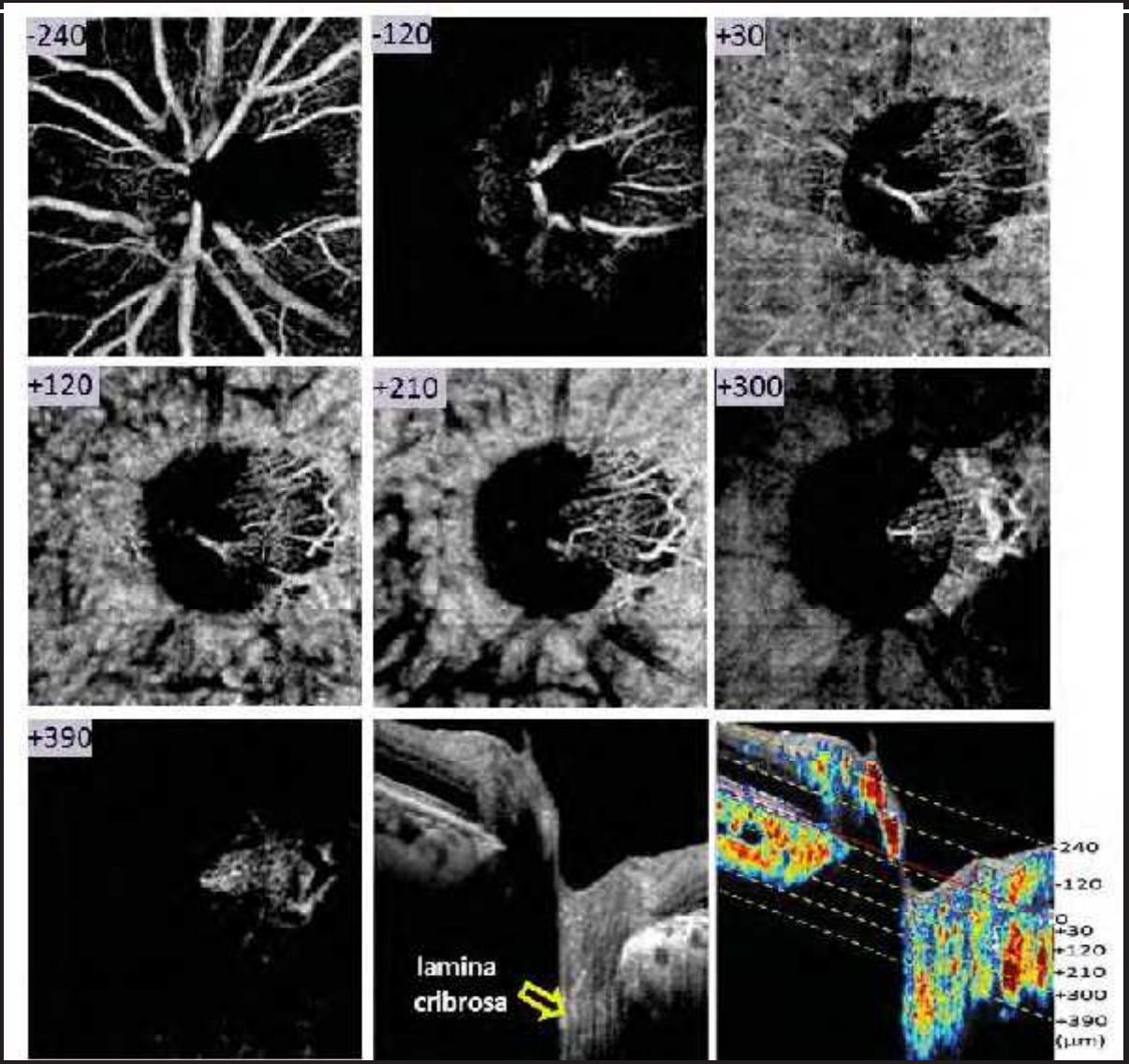
Jia et al, Biomed Opt Exp 2012

En face retinal and choroidal angiograms at different Z coordinates at macula



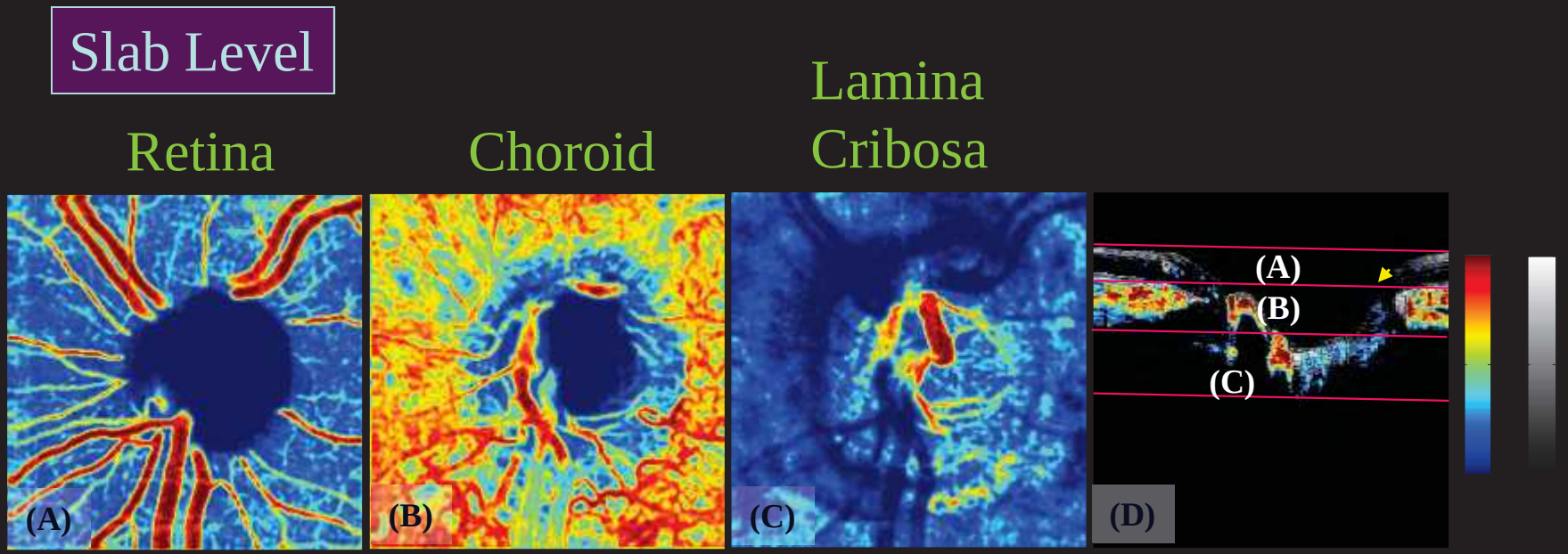
Yali Jia, PhD; David Huang, MD, PhD. www.COOLLab.net

En face retinal and choroidal angiograms at different Z coordinates at ONH



Yali Jia, PhD; David Huang, MD, PhD. www.COOLLab.net

En face ONH angiograms separately showing the microcirculation within retina , choroid and lamina cribrosa



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Quantitative OCT Angiography

Quantitative OCT angiography of optic nerve head blood flow

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Abstract: Optic nerve head (ONH) blood flow may be associated with glaucoma development. A reliable method to quantify ONH blood flow could provide insight into the vascular component of glaucoma pathophysiology. Using ultrahigh-speed optical coherence tomography (OCT), we developed a new 3D angiography algorithm called split-spectrum amplitude-decorrelation angiography (SSADA) for imaging ONH microcirculation. In this study, a method to quantify SSADA results was developed and used to detect ONH perfusion changes in early glaucoma. *En face* maximum projection was used to obtain 2D disc angiograms, from which the average decorrelation values (flow index) and the percentage area occupied by vessels (vessel density) were computed from the optic disc and a selected region within it. Preperimetric glaucoma patients had significant reductions of ONH perfusion compared to normals. This pilot study indicates OCT angiography can detect the abnormalities of ONH perfusion and has the potential to reveal the ONH blood flow mechanism related to glaucoma.

OCIS codes: (170.3880) Medical and biological imaging; (170.4470) Ophthalmology.

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Table 1. OCT disc perfusion measurements on the whole disc region[a]

Parameters	Normal	PPG	p-value	CV (%)
Flow index (dimensionless)	0.160 ± 0.031	0.104 ± 0.009	0.040	6.81
Vessel density (%)	74.2 ± 14.3	49.1 ± 5.20	0.045	6.23

[a]PPG, preperimetric glaucoma; CV, coefficient of variation of repeated measurements; p-values based on unpaired t tests.

Flow and vessel density was reduced in glaucoma patients

Summary

- OCT angiography is an exciting new development in non-invasive imaging
- The ability to acquire detailed imaging of the retinal and choroidal microvasculature in a depth-resolved fashion, without dye injection, represents a significant advance
  - The prospect of quantitative flow data is an additional major benefit
- Further refinement of the technology is required to allow ascertainment of leakage
- The scope/purview of conventional angiography will likely continue to narrow

Thank you!