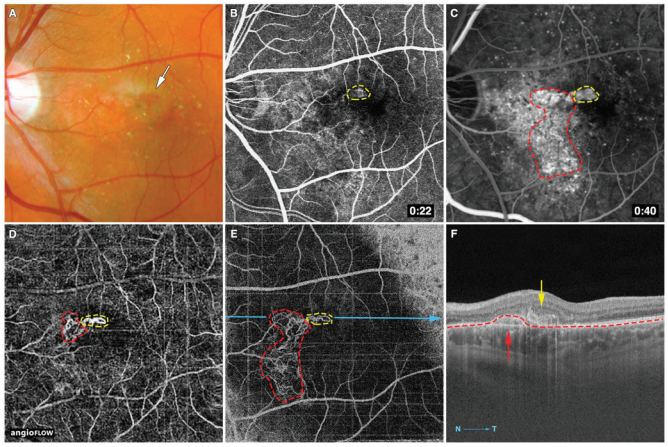
146 OCT Angiography 1
Sunday, May 01, 2016 3:15 PM–5:00 PM
6B Paper Session
Program #/Board # Range: 947–953
Organizing Section: Retina

Program Number: 947
Presentation Time: 3:15 PM–3:30 PM
Comparisons of optical coherence tomography angiography and fluorescein angiography in detecting neovascularization and capillary nonperfused areas in eyes with diabetic retinopathy
Yasuki Ito, Takeshi Iwase, Shunsuke Yasuda, Tetsu Asami, Norie Nonobe, Tomohiko Akahori, Satoshi Okado, Hiroko Terasaki. Ophthalmology, Nagoya University School of Medicine, Nagoya, Japan.
Purpose: Optical coherence tomography (OCT) angiography is a recently developed technique that can detect blood vessels and delineate the vascular pattern in the retina. This technique should be useful for studying the blood vessel patterns in eyes with diabetic retinopathy. However, its capabilities in detecting neovascularizations and nonperfused areas of the retina have not been determined. Thus, the purpose of this study was to evaluate the capability of OCT angiography in detecting neovascularization and capillary nonperfused areas in eyes with diabetic retinopathy.
Methods: Thirty-four eyes with diabetic retinopathy (23 patients, 14 men and 9 women, average age 53.2±13.8 years) were studied. OCT angiography was performed with the Cirrus OCT (Carl Zeiss Meditec). The entire posterior pole was scanned by moving the fixation point to 9 sites with the 6x6 mm scanning program. These images were combined and a wide-field OCT angiographic map was created. To evaluate the retinal vasculature, the segmentation was adjusted to be between the retinal pigment epithelium and the internal limiting membrane (ILM) for retinal *en face* maps. To evaluate neovascularization, the segmentation was adjusted to be between the internal limiting membrane and vitreous cavity for vitreo-retinal interface *en face* maps. Fluorescein angiography was performed with the Optos 200Tx (Optos PLC). The number of neovascularizations and local capillary nonperfused areas was counted and compared in the images obtained by OCT angiography and fluorescein angiography.
Results: The mean±SD number of neovascularization was 1.9±4.0 by both OCT angiography and fluorescein angiography. All of the neovascularizations were detected in the vitreous *en face* maps of OCT angiography. The mean±SD number of local capillary nonperfused areas by OCT angiography and fluorescein angiography was 2.9±1.9 and 2.2±1.8 respectively. The detection of capillary nonperfused areas was significantly better by OCT angiography than fluorescein angiography *(P*<0.05).
Conclusions: Our findings show that OCT angiography can be used to evaluate the neovascularization and capillary nonperfused areas in eyes with diabetic retinopathy.
Commercial Relationships: Yasuki Ito, None; **Takeshi Iwase**, None; **Shunsuke Yasuda**, None; **Tetsu Asami**, None; **Norie Nonobe**, None; **Tomohiko Akahori**, None; **Satoshi Okado**; **Hiroko Terasaki**, None

Program Number: 948
Presentation Time: 3:30 PM–3:45 PM
Choroidal Neovascularization Analyzed on Ultra-High Speed Swept Source Optical Coherence Tomography Angiography Compared to Spectral Domain Optical Coherence Tomography Angiography
Ricardo N. Louzada[1, 2], Eduardo A. Novais[3, 2], Mehreen Adhi[2], Emily Cole[2], Eric M. Moult[4], Lennart Husvogt[5, 4], Andre J. Witkin[2], Caroline R. Baumal[2], James G. Fujimoto[4], Jay S. Duker[2], Nadia K. Waheed[2]. [1]Ophthalmology, Federal University of Goiás, CEROF / UFG, Goiânia, Brazil; [2]Ophthalmology, New England Eye Center - Tufts University School of Medicine, Boston, MA; [3]Ophthalmology, Federal University of São Paulo / UNIFESP, São Paulo, Brazil; [4]Faculty of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, Cambridge, MA; [5]Pattern Recognition Lab, Friedrich-Alexander University Erlangen-Nürnberg (FAU), Erlangen-Nürnberg, Germany.
Purpose: Cross-sectional, observational study to compare visualization of choroidal neovascularization (CNV) secondary to age-related macular degeneration (AMD) using an ultra-high speed swept-source (SS)-optical coherence tomography angiography (OCTA) prototype versus a spectral-domain (SD)-OCTA device.
Methods: Patients were imaged on SD-OCT and SS-OCT devices on the same day. The SD-OCT device employed is the RTVue Avanti that operates at ~840nm wavelength and 70,000 A-scans/second. The SS-OCT device used is an ultra-high speed long-wavelength prototype that operates at ~1050nm wavelength and 400,000 A-scans/second. Two observers independently measured the CNV area on OCTA *en face* images from the two devices using ImageJ. The non-parametric Wilcoxon signed-rank test was used to compare area measurements.
Results: Fourteen eyes from 13 patients were enrolled. The CNV in 11 eyes (78.6%) were classified as type-1, 2 eyes (14.3%) as type-2, and 1 eye (7.1%) as mixed type. The mean CNV areas measured using SS-OCT and SD-OCT 3mm x 3mm OCTA were $0.949 \pm 1.168 mm^2$ and $0.340 \pm 0.301 mm^2$, respectively ($p=0.001$). For the 6mm x 6mm OCTA the CNV areas using SS-OCT and SD-OCT were $1.218 \pm 1.284 mm^2$ and $0.604 \pm 0.597 mm^2$, respectively ($p=0.0019$). The field of view did not significantly affect the measured CNV area ($p=0.19$ and $p=0.18$ for SS-OCT and SD-OCT respectively).
Conclusions: SS-OCTA measurements yielded significantly larger CNV areas than SD-OCTA. It is possible that SS-OCTA is better able to demarcate the full extent of CNV vasculature.



Multimodal imaging of a left eye with mixed type 1 and type 2 choroidal neovascularization. (A) Color fundus. Retinal pigment epithelium (RPE) clumps and mottling, and subretinal hemorrhage (white arrow) surrounded by hypocromic area and drusen.; (B) and (C) Fluorescein angiography at different stages. Red dashed-line representing the occult component; yellow dashed-line representing the classic component.; (D) Spectral-domain optical coherence tomography angiography (OCTA) image and; (E) Swept-source OCTA image. Red dashed-line representing the type 1 component; yellow dashed-line representing the type 2 component.; (F) Corresponding OCT B-scan. RPE represented as red dashed-line. Type 1 component (red arrow) and type 2 component (yellow arrow).

Commercial Relationships: Ricardo N. Louzada; **Eduardo A. Novais**, None; **Mehreen Adhi**, None; **Emily Cole**, None; **Eric M. Moult**, None; **Lennart Husvogt**, None; **Andre J. Witkin**, None; **Caroline R. Baumal**, Allergan (S), Optovue (R); **James G. Fujimoto**, Stock options Optovue Inc (C), Optovue Inc (C), Royalties from intellectual property owned by the Massachusetts Institute of Technology and licensed to Carl Zeiss Meditec Inc., (C); **Jay S. Duker**, CoDa Therapeutics (C), Eleven Biotherapeutics (S), Carl Zeiss Meditech (C), Alcon/Novartis (C), Thrombogenics (C), Lumenis (C), Omeros (C), Optovue (C), Allergan (C); **Nadia K. Waheed**, Carl Zeiss Meditec (F), Iconic therapeutics (C), OptoVue (S), Thrombogenics (S)
Support: This work was in part supported by a grant from the Macula Vision Research Foundation, New York, National Institute of Health (NIH R01-EY011289-28, R44-EY022864-03, R01-CA075289-17), Air Force Office of Scientific Research (AFOSR FA9550-10-1-0551 and FA9550-12-1-0499)

Program Number: 949
Presentation Time: 3:45 PM–4:00 PM

Simultaneous RPE and vascular imaging of macular degenerations by Jones matrix optical coherence tomography

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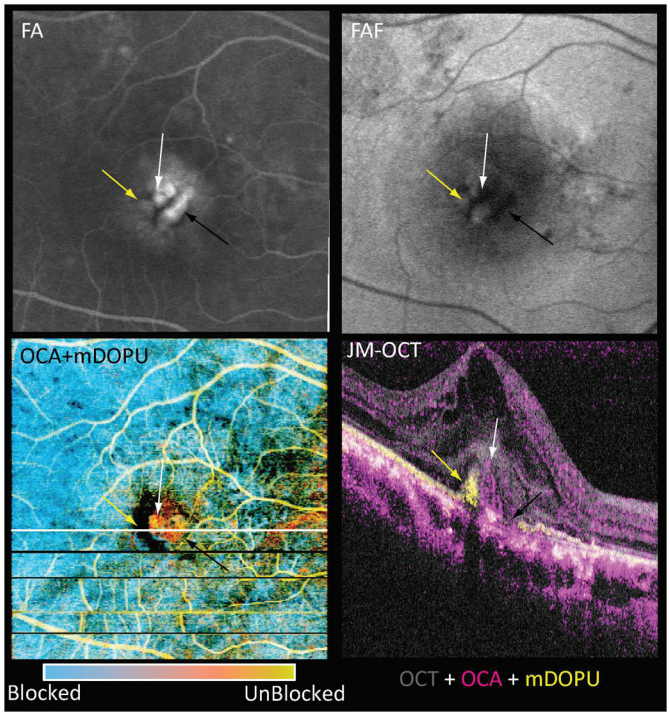
Purpose: Optical coherence angiography (OCA) technique non-invasively visualizes microvasculature of the posterior eye. However, from vascular imaging alone, it is difficult to delineate the related location of a vessel to the retinal pigment epithelium (RPE) and RPE integrity, which are an important factor to investigate macular degeneration. In this study, a combination of OCA and tissue pigment contrast is demonstrated to enhance the interpretation of vascular imaging.
Methods: Twenty three eyes of 17 subjects have been examined, which include 10 age-related macular degeneration, 1 neovascular maculopathy, 6 polypoidal choroidal vasculopathy. Subjects were scanned with 1-μm multi-contrast Jones matrix optical coherence tomography (JM-OCT). The scanning rate of the system is 100,000 lines/sec. Four repeated B-scan for blood flow imaging, and volumetric scans were applied. Complex correlation based OCA and Makita's quantitative degree-of-polarization-uniformity (mDOPU) were applied to contrast blood flow and pigmented tissue, respectively. They are combined to provide images of microvasculature with relative depth to the pigmented tissue. This microvascular-RPE images of macular degeneration are subjectively investigated.
Results: A representative images with JM-OCT are shown in Fig. 1. The subject is right eye of an AMD patient (68 yo). OCA and mDOPU represent the vasculature and relative depth to pigmented tissue, where a vessel appeared with red, yellow to blue as it is blocked by more pigmented tissue above it. High and low pigmentation (yellow and black arrows) are observed at the side of the abnormal blood flow (white arrows). Their locations are corresponding to hyper- and hypofluorescence in fluorescence angiography and fundus autofluorescence. Abnormal vessel unblocked by pigmented tissue were observed in 14 eyse of 15 eyes with exudative lesion. In 4 eyes of 5 geographic atrophy eyes, partial choroidal vessels are unblocked due to less pigmentation of RPE. All 3 eyes with drusen and/or pigment epithelial detachment do not exhibit unblocked vessels except retinal vessels.
Conclusions: Abnormality of vasculature and pigmentation of macular degeneration are visualized non-invasively using MC-OCT with OCA and mDOPU. The vascular imaging with MC-OCT might be powerful tool to detect and investigate vascular diseases of the posterior eye.

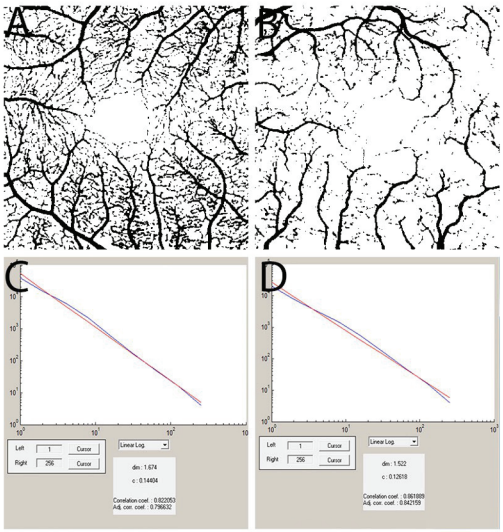


Imaging result of an AMD patient with CNV.

Commercial Relationships: Shuichi Makita, Tomey Corp. (F), Topcon (F), Canon (F), Nidek (F), Tomey Corp. (P); **Young-Joo Hong**, Tomey Corp. (F), Topcon (F), Canon (F), Nidek (F); **Masahiro Miura**, Santen (F), Alcon (F), Santen (R), Novartis (R), Bayer (F), Novartis (F); **Yoshiaki Yasuno**, Tomey Corp. (F), Topcon (F), Canon (F), Nidek (F), Tomey Corp. (P)

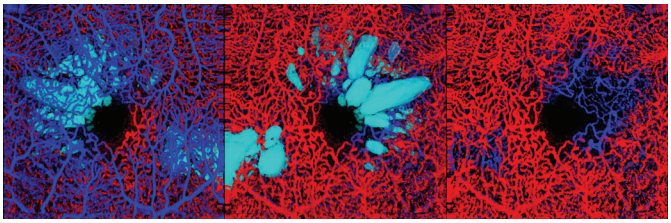
Program Number: 950
Presentation Time: 4:00 PM–4:15 PM
Retinal Microvascular Alterations Related To Diabetes assessed by Optical Coherence Tomography Angiography
Julien Gozlan[1, 2], Martine Mauget-Faysse[1], Olivier Lichtwitz[2], Nicolas Leveziel[2]. [1]Rothschild Foundation Hospital, Livry Gargan, France; [2]Department of Ophthalmology, University Hospital of Poitiers, Poitiers, France.
Purpose: Fluorescein angiography has been so far the gold-standard test to assess diabetic macular ischemia (DMI), an important cause of visual impairment in diabetic patients. The aim of this study was to investigate foveal avascular zone (FAZ) and perifoveal microcirculation changes in eyes with non-proliferative diabetic retinopathy (NPDR) using optical coherence tomography angiography (OCTA).
Methods:
Cross-sectional study including eyes of diabetic patients affected with NPDR. All patients underwent medical history, best-corrected visual acuity (BCVA) measurement, slit-lamp and fundus examination and multicolor, SD-OCT, Swept-Source OCT. OCTA, a new and non-invasive vascular imaging technique, was performed in order to assess macular superficial and deep capillary plexus in each included eye.
Results:
Fifty-eight eyes of 35 patients with a mean age of 61.8 with NPDR were included in this study. Among them, there was 19 eyes with mild NPDR, 24 eyes with moderate NPDR and 15 eyes with severe NPDR. There was a significant progression between NPDR stages for FAZ grade ($p < 0.0001$), surface ($p = 0.0036$) and perimeter ($p = 0.0001$), and for superficial capillary plexus non-perfusion index (NPI) ($p = 0.0009$). Moreover, a significant correlation was found between NPI and BCVA ($p = 0.007$).
Conclusions:
OCTA is a new retinal vascular imaging technique which is able to explore DMI in a non-invasive manner in NPDR. NPI, a newly described OCTA index, is able to explore, in a single measurement, both foveal and perifoveal microcirculation.
Commercial Relationships: Julien Gozlan, None; **Martine Mauget-Faysse**; **Olivier Lichtwitz**, None; **Nicolas Leveziel**, None

Program Number: 951
Presentation Time: 4:15 PM–4:30 PM
Significant Difference Between Fractal Dimension of OCT Angiography of Eyes With and Without Nonproliferative Diabetic Retinopathy
Emma Young[1], Sarwar Zahid[1], Joshua Young[1], Kunal Dansingani[2], Chandra Bala[2], K Bailey Freund[2], Lawrence A. Yannuzzi[2]. [1]Ophthalmology, New York University, New York, NY; [2]Vitreous Retina Macula Consultants of New York, New York, NY.
Purpose: Optical Coherence Tomography Angiography (OCTA) provides largely qualitative vascular information. We compared quantitatively the retinal fractal dimension in eyes with nonproliferative diabetic retinopathy (NPDR) with control eyes using OCTA.
Methods: A retrospective study was performed of ten eyes with different stages of NPDR without macular edema and six control eyes. OCTA images were obtained using the RTVue XR Avanti (Optovue, Inc., Fremont, CA). Automated segmentation was obtained through the superficial and deep retinal capillary plexuses for each eye. The grayscale OCTA images were standardized, cropped, and converted to black and white using GIMP (GIMP Development, Berkeley, CA). Fractal dimensional box-counting analyses were performed using Fractalyse (ThéMA, Besançon Cedex, France). Fractal dimensions (FD) of superficial and deep capillary plexuses were compared between NPDR and control eyes. Two-tailed t-tests were used to compare the average FD between groups.
Results: The superficial and deep plexuses from six control eyes and ten NPDR eyes were processed and analyzed as described above (Figure 1). The average FD for NPDR eyes (1.5324, SD=0.0210) was significantly lower than control eyes (1.6777, SD=0.0191) for the superficial capillary plexus ($p = 1.2078 \times 10^{-8}$). For the deep capillary plexus, the average FD for NPDR eyes (1.5695, SD=0.05999) was significantly lower than control eyes (1.7833, SD=0.0131) ($p = 5.469 \times 10^{-7}$).
Conclusions: The fractal dimension is significantly lower in both superficial and deep capillary plexuses in NPDR compared to control eyes. Fractal analysis holds the potential to establish quantitative disease parameters for microvascular pathology.



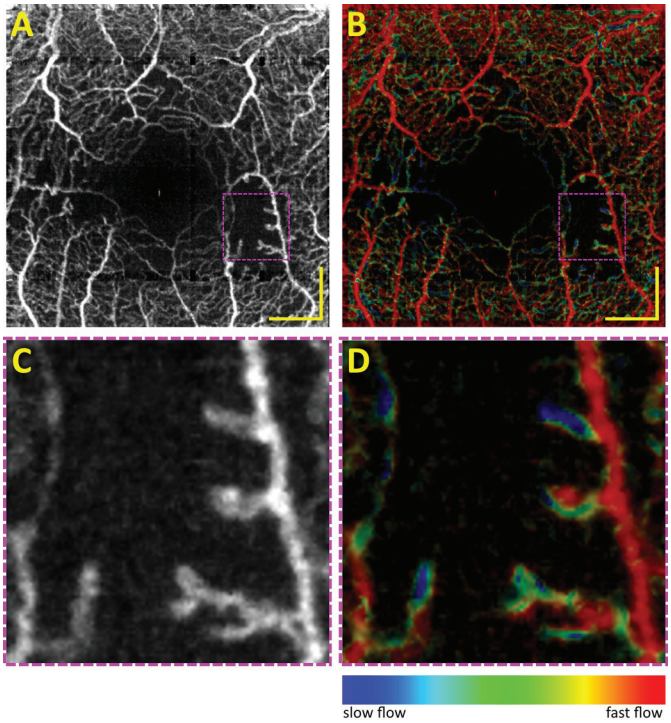
A: OCTA image of the superficial retinal capillary plexus of a control eye after cropping, standardization and conversion to black and white.
B: OCTA image of the superficial retinal capillary plexus of an NPDR eye after cropping, standardization and conversion to black and white.
C: Fractal analysis of the superficial capillary plexus from a control eye.
D: Fractal analysis of the superficial capillary plexus from an NPDR eye.
Commercial Relationships: Emma Young, None; **Sarwar Zahid**, None; **Joshua Young**, None; **Kunal Dansingani**, None; **Chandra Bala**, None; **K Bailey Freund**, None; **Lawrence A. Yannuzzi**, None
Support: LuEsther T. Mertz Retinal Research Center and the Macula Foundation Inc.

Program Number: 952
Presentation Time: 4:30 PM–4:45 PM
Volume Rendered Optical Coherence Tomography of Retinal Vascular Cystoid Macular Edema
Richard F. Spaide. Ophthalmology, Vitreous Retina Macula Consultants NY, New York, NY.
Purpose: To investigate the retinal vascular findings and associated anatomic abnormalities in the central macula of eyes with retinal vascular cystoid macular edema using volume rendered angiographic and structural optical coherence tomography.
Methods: Patients were imaged using optical coherence tomography (OCT) using split-spectrum amplitude decorrelation. The structural OCT data was segmented for cystoid spaces, and integrated into the angiographic data for subsequent volume rendering. These images were evaluated to assess the inner and deep vascular plexus in relation to cystoid spaces. The retinal vascular diseases investigated were diabetic retinopathy, 25 eyes, retinal vein occlusion, 12 eyes, Type 1 macular telangiectasis, 2 eyes, and radiation retinopathy, 2 eyes.
Results: Retinal vascular flow abnormalities were demonstrated by flow voids with abnormal vascular morphology in the inner vascular layer and varying flow loss in the deep vascular plexus in all affected eyes. Areas of cystoid edema were associated with topographically colocalizing flow voids in the deep vascular layer. Treatment with intravitreous anti-vascular endothelial growth factor injections resulted in resolution of edema but no change in flow patterns in either the inner or deep plexus. With resolution of edema, particularly in diabetics, a thinner featureless retina consistent with disorganization of retinal inner layers was seen. Recurrence of edema happened in the same areas of altered inner and absent deep vascular plexus flow signal.
Conclusions: Cystoid macular edema in retinal vascular disease occurred in relation to altered inner plexus and absent deep vascular plexus flow. These findings suggest functions for the deep vascular plexus may exist in addition to oxygen and metabolite delivery to the retina.

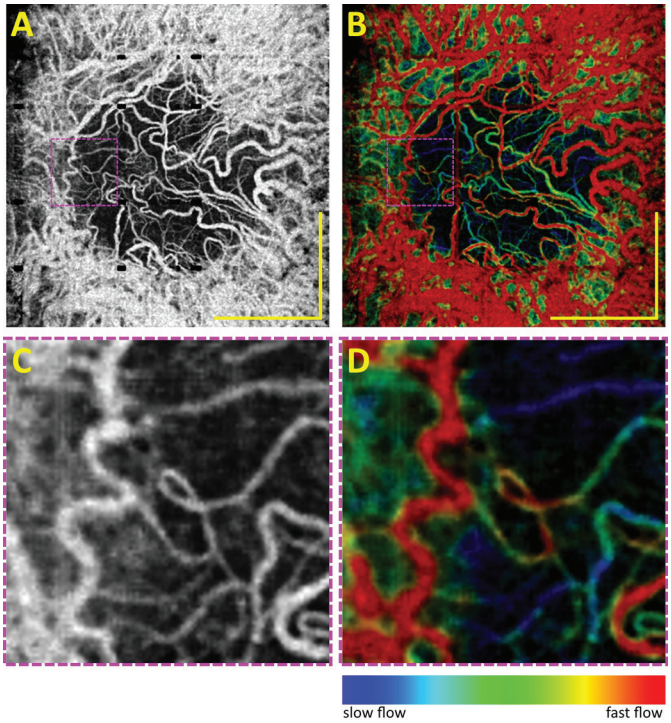


Left panel. View of the retinal vessels, as visualized by volume rendered optical coherence tomography angiography, of an eye with cystoid macular edema secondary to diabetic retinopathy. The inner vascular plexus is blue, the deep plexus is red, and cystoid spaces are cyan. Middle panel. The retina viewed from the underside of the retina. Right panel. When the cystoid spaces were taken from view the cystoid spaces are seen to have occurred in the context of decreased or absent flow in the deep vascular plexus.
Commercial Relationships: Richard F. Spaide
Support: Macula Foundation

Program Number: 953
Presentation Time: 4:45 PM–5:00 PM
Toward quantitative OCT angiography: visualizing flow impairment using variable interscan time analysis (VISTA)
Stefan B. Ploner[1, 2], Eric M. Moult[1, 3], Nadia K. Waheed[4], Lennart Husvogt[2], Julia J. Schottenhamml[1, 2], ByungKun Lee[1], Joachim Hornegger[2, 5], Jay S. Duker[4], Philip J. Rosenfeld[6], James G. Fujimoto[1]. [1]Electrical Engineering and Computer Science, Massachusetts Institute of Technology, Cambridge, MA; [2]Pattern Recognition Lab, Friedrich-Alexander University Erlangen-Nürnberg, Erlangen, Germany; [3]Health Sciences and Technology, Harvard-MIT, Cambridge, MA; [4]Ophthalmology, New England Eye Center - Tufts University School of Medicine, Boston, MA; [5]School of Advanced Optical Technologies, Friedrich-Alexander University Erlangen-Nürnberg, Erlangen, Germany; [6]Ophthalmology, Bascom Palmer Eye Institute - University of Miami Miller School of Medicine, Miami, FL.
Purpose: Optical coherence tomography angiography (OCTA) is a promising modality for visualizing vascular alterations in a variety of ocular diseases, including age-related macular degeneration (AMD) and diabetic retinopathy (DR). However, most OCTA techniques have limited dynamic range and do not provide information about the relative flow velocities within the imaged vasculature. Visualizing relative flow speed would be especially valuable when assessing diseases in which progression is linked to flow impairment, not just vasculature loss.
Methods: OCTA imaging of patients with various stages of AMD and DR was performed with a 1050 nm swept source OCT system at a 400 kHz A-scan rate using a 5 repeated B-scan protocol. Variable interscan time analysis (VISTA) was used to compute the OCTA decorrelation data from pairs of B-scans having 1.5 ms and 3.0 ms separations. The two resulting OCTA data sets were used to compute relative flow speeds, which were then mapped to a color space for display.
Results: The VISTA flow maps for a representative patient with non-proliferative DR (NPDR), and for a patient with geographic atrophy (GA) are shown in Figures 1 and 2, respectively. The VISTA map of the NPDR eye shows slower flows associated with capillary loops in the OCTA image. The VISTA map of the GA eye shows slower flows in the area of atrophy, and on the borders of atrophy.
Conclusions: A method for visualizing VISTA OCTA data is developed and used to differentiate flow speeds in DR and AMD eyes featuring GA. Differentiation of flow speeds is an important first step towards quantitative OCTA and may be useful for assessing vascular diseases at a reversible stage.



OCTA and VISTA flow maps of NPDR (51 y/o female). (A) En face projection of the OCTA volume showing the retinal vasculature. (B) Corresponding VISTA flow map. (C) Enlargement of (A), showing a region of intercapillary loops. (D) Corresponding enlargement of the VISTA flow map, showing flow impairment within intercapillary loops. Scale bars: 1 mm.



OCTA and VISTA flow maps of non-exudative AMD with GA (77 y/o male). (A) En face projection of the OCTA volume through a ~35 um slab beginning at the choriocapillaris. (B) Corresponding VISTA flow map. (C) Enlargement of (A), showing selected choroidal vessels within the region of GA. (D) Corresponding enlargement of the VISTA flow map showing flow impairment in some vessels. Scale bars: 1 mm.

Commercial Relationships: Stefan B. Ploner, None; **Eric M. Moult**, None; **Nadia K. Waheed**, Carl Zeiss Meditec Inc. (R), Iconic Therapeutics (C), Optovue Inc. (R), ThromboGenics (C); **Lennart Husvogt**, None; **Julia J. Schottenhamml**, None; **ByungKun Lee**, None; **Joachim Hornegger**; **Jay S. Duker**, Optovue Inc. (C), Carl Zeiss Meditec Inc. (C), Carl Zeiss Meditec Inc. (F), Optovue Inc. (F); **Philip J. Rosenfeld**, Carl Zeiss Meditec Inc. (F); **James G. Fujimoto**, Optovue Inc. (P), Optovue Inc. (I), Carl Zeiss Meditec Inc. (P)

Support: R01-EY011289-29A, R44-EY022864, R01-CA075289-16, FA9550-15-1-0473, FA9550-12-1-0499