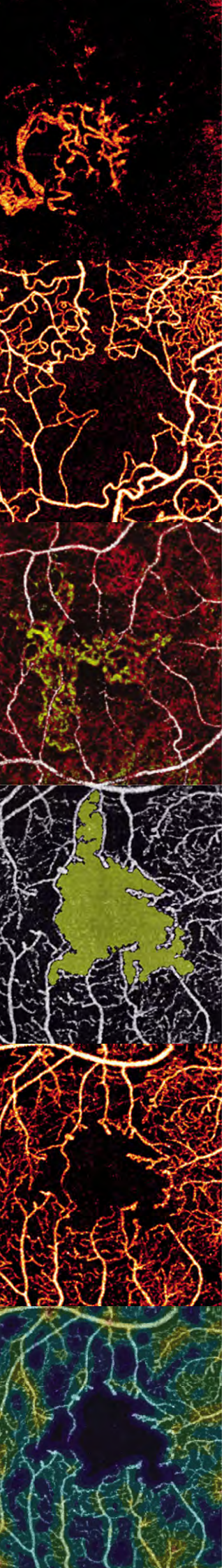


Optical Coherence Tomography Angiography with the AngioVue® Imaging System

A compendium of scientific articles and abstracts

November 30, 2016

Dear OCTA Congress Attendees,

OCT has undergone numerous innovations since its inception 25 years ago in 1991. This innovation cycle is best divided into three stages. The first two, Time-Domain (1991) and Fourier-Domain (2006), centered on advancements in speed and resulted in increased resolution of ocular structures. Visualization of the structural tissue provides clinicians with critical information that allows for a better understanding of pathology. Indeed, OCT structural information is now an essential tool for comprehensive disease diagnosis.

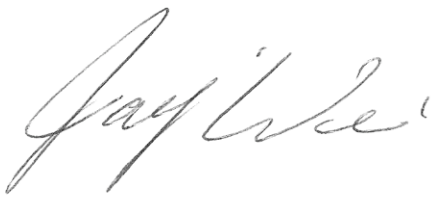
Although several methods have attempted to measure ocular function, or blood flow (e.g., Doppler OCT), only one approach—using OCT to detect the motion of blood cells—has yielded a clinically meaningful result. Several research groups have investigated this method over the last seven to eight years. This third stage of OCT innovation, OCT Angiography (OCTA) (2014), finally provides a much sought after method for non-invasively visualizing the function of retinal tissue.

Since its founding, Optovue has focused on innovating OCT technology, expanding clinical applications and improving accessibility to the technology. Six years ago, we began collaborating with researchers on the method of blood cell motion detection known today as OCTA. The technology challenges are tremendous because we are trying to detect motion within the eye, which by nature is a very fast and constantly moving organ. Along the development pathway, we exhausted multiple approaches, including phase variance, full spectrum speckle variance, and complex variance (i.e., OMAG). Nothing yielded clinically useful OCTA until Dr. David Huang's team at Oregon Health and Sciences University developed Split Spectrum Amplitude Decorrelation Angiography (SSADA), which produced a fundamental improvement in image quality. Since then our scientists and engineers have worked closely with Dr. Huang and Dr. Yali Jia to overcome obstacles and render OCTA a clinically viable tool.

We also developed a close relationship with Professor Jim Fujimoto and his team at MIT to develop technology that mitigates the motion issues inherent in OCTA. We call this MCT. Combining SSADA and MCT enabled the development of the AngioVue® Imaging System, the first commercially available OCTA product, introduced in 2014.

This third wave of OCT innovation, structural plus functional OCT, will spur additional innovation that further advances the entire spectrum of OCT technology. I am heartened to witness this new era of OCT development, especially the leading role Optovue has played, that will potentially redefine the understanding of retinal diseases and produce significant advancements in disease diagnosis, treatment and management.

Sincerely,



Jay Wei
Founder and CEO
Optovue, Inc.

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Advancing OCT Angiography Technology and its Clinical Impact with AngioVue®

Tony Ko, Ph.D., Miao Zhang, Ph.D. and Utkarsh Sharma, Ph.D.
Optovue, Inc., CA, USA

Early Development of OCT Angiography (OCTA) and Technical Challenges

OCT Angiography (OCTA) capable of generating a retinal angiogram was first demonstrated using a SD-OCT system in 2006. However, it was only sensitive for detecting larger vessels and lacked the capability to visualize micro-capillaries.[1] In the ensuing years, several groups proposed various methods, such as, speckle variance[2], phase variance[3], and complex signal differences[4], that used repeated B-scans to increase the detection sensitivity for retinal capillaries. However, the need to acquire large datasets implied longer acquisition times, a smaller field of view or the need for high-speed systems that were expensive and not commercially available. Longer acquisition times worsened the impact of motion artifacts and considerable post-processing steps were utilized to minimize bulk motion.[2,3] A bite-bar was even utilized during imaging to reduce the effect of subject motion.[5] These limitations prevented the use of OCTA in everyday clinical use.

AngioVue OCTA Technology Development: Progression from Laboratory to Clinics

The key challenges of limited sensitivity, speed and motion correction, were identified by Optovue as it embarked on the challenge to progress OCTA technology from academia to commercialization. These challenges were addressed by innovative technologies including Split-Spectrum Amplitude-Decorrelation Angiography (SSADA), Motion Correction Technology (MCT), and more recently, DualTrac™, which have all been instrumental in making OCTA a clinical reality.

SSADA

In 2012 an OCTA technique named SSADA was developed.[6] In contrast to previous techniques, SSADA required considerably fewer repeated B-scans to generate high sensitivity OCTA information capable of visualizing retinal microvasculature. Therefore, SSADA can reduce the acquisition time while also minimizing the effect of motion artifacts. Optovue obtained an exclusive license to utilize the SSADA technology for ophthalmology, and developed it further to achieve better imaging performance than previous OCTA approaches.[7]

Motion Correction with MCT and DualTrac™

While most OCT systems use real-time trackers to address motion artifacts, these systems almost always have insufficient accuracy (~50-60 μm) required to visualize retinal capillaries. This resolution mismatch between the OCTA system (~ 10 μm sampling) and the tracker means that motion artifacts can be introduced from the tracking system itself. In 2012, MIT introduced a new high-resolution software-based motion correction technology, MCT.[8] This new approach provided unprecedented accuracy by performing a 3D pixel-level registration using orthogonal OCT datasets. AngioVue incorporated MCT and is the only OCTA device that utilizes software based motion artifact correction.[9] DualTrac is the most recent technology developed at Optovue, that further combines the advantages of both MCT and real-time tracking, thereby, improving the motion correction technology in OCTA and taking it to the next level of accuracy and robustness.[10] By incorporating and further developing the latest technology advances from academia, AngioVue has overcome the challenges of performing OCTA in everyday clinical practice.

Newer Features: High-definition (HD) OCTA at Large Field of View (FOV) Imaging

Powered by innovative technologies like SSADA, MCT and DualTrac, AngioVue now includes newly developed HD scan patterns that provide best-in-class OCTA image quality for 6x6mm macular scans. The new HD scans provide 33% better resolution compared to older scans and should provide greater confidence to physicians for imaging pathologies that may extend beyond central 3x3mm region. When used in montage mode, the same HD AngioVue scans can provide greater than 10x6mm of coverage, while still visualizing retinal microvasculature with clear details (Fig 1A). Figure 1B demonstrates the new HD AngioVue scan over 20° FOV and clearly depicts areas of impaired flow in an eye with CRVO (image courtesy of Dr. Michael Hee, Daly City, CA, USA).

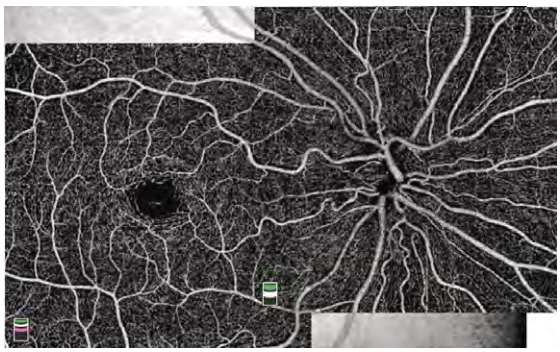

Fig 1A. HD Angio Montage with FOV 10x6 mm.

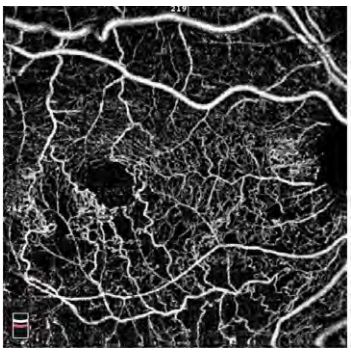

Fig 1B. OCTA image of CRVO eye (6x6 mm)

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DualTrac™ Motion Correction Technology for OCTA

Utkarsh Sharma, Ph.D., Tzu-Yin Wang, Ph.D., Uday Thummalapalli and Miao Zhang, Ph.D.
Optovue, Inc., CA, USA

Motion Artifact Challenge in OCT Angiography (OCTA)

Artifacts introduced by eye motion can significantly impact the interpretation of OCTA images and the quantification of OCTA parameters, thereby reducing the confidence in clinical information that can be extracted from the data. In the past, two main approaches have addressed motion artifacts including MCT. However, both of these approaches have several limitations and the residual artifacts in either of these approaches reduce the integrity of clinical information, as well as the repeatability and accuracy needed for longitudinal quantitative studies or management of disease.

Limitations of Existing Technologies

Typical tracking systems perform adjustment during the scan while discarding the data with motion.[1-3] MCT is a post-processing approach that aligns and registers two orthogonally scanned OCT cubes to correct for motion and improve OCTA signal. MCT performance is challenged by big saccadic motion leading to missing regions and subsequent issues with erroneous registration. Tracking also has its own set of challenges including:

1. Tracking accuracy is limited by the pixel-level resolution of fundus images being used for fundus monitoring during the scan (typically ≈ 50-60 μm).
2. Tracking systems usually increase the scanning times and lead to poor OCTA quality due to gradual loss of focus because of breakup, as well as increased motion artifacts.
3. Tracking systems have finite tracking response time (typically >50-100 ms) causing the system to lag behind, potentially providing false impressions of vessel tortuosity by introducing wiggle artifacts.

Technological Solution: DualTrac Motion Correction Technology

Recently developed at Optovue, DualTrac Motion Correction Technology is an intelligent integration of two technologies, namely, tracking and MCT that enables high quality imaging by employing two levels of motion correction. The first, IR image based eye tracking, performs high-speed real-time OCT scan correction to mitigate eye blinks, saccades, and fixation drifts. The second level, MCT, performs precise pixel level registration in 3D to further reduce residual motion and improve signal-to-noise ratio through merging of two orthogonal scans. The response of the AngioVue® tracking system is fastest (30 frames per second) amongst its commercial counterparts as it employs IR camera-based imaging. If a blink or fixation change is detected, the tracking system monitors for the completion of offending motion. When the eye has stopped moving, the OCT beam is steered to the correct position and the data acquisition is resumed to re-acquire the portion of 3D volume data that was impacted by motion. The MCT algorithm requires acquisition of two 3D volume scans, first in horizontal direction (Fast-X) and the second in vertical direction (Fast-Y). MCT then combines the complementary information contained in the two volumes to allow for the high accuracy registration of each A-scan in three-dimensional space. Besides the benefits of increased accuracy in motion artifact removal, MCT effectively doubles the amount of OCT data available for averaging, thereby resulting in much improved OCT and OCTA image quality.

Acner et al. evaluated relative motion correction performance of tracking alone, MCT alone and DualTrac, and concluded that DualTrac provided superior performance over both tracking and MCT. Especially in diseased eyes, DualTrac demonstrated >80% reduction in motion artifacts compared to tracking alone and >50% reduction compared to MCT alone.[4] Figure 1A and 1B show the relative improvement of DualTrac over MCT in a difficult subject. Figure 1C and 1D show the relative improvement of DualTrac over tracking alone. It can be seen that motion artifacts are greatly reduced and image quality is further improved with the use of DualTrac in both cases.

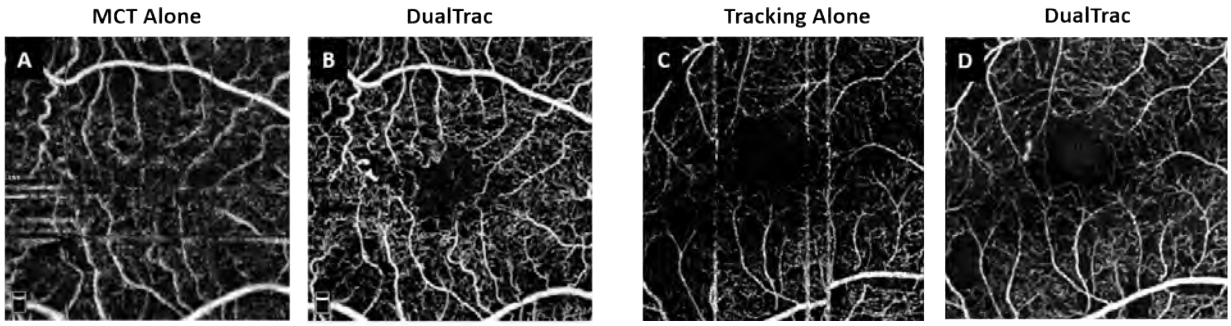

Figure 1: Comparison of motion correction performance in diseased eyes.

A. MCT only. **B.** DualTrac image of the same eye. **C.** Tracking only. **D.** DualTrac image of the same eye.

Images courtesy of Adil El Maftouhi, OD, Centre Rabelais, Lyon (A & B); and Prof. Yali Jia, OHSU, Portland, OR (C & D).

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AngioAnalytics™ Based on Retinal Tissue Layer en face Images

Qienyuan Zhou, Ph.D., Tina Yi-Sing Hsiao, Ph.D., Jing Tian, Ph.D., Xingwei Wang, Ph.D., Ben Jang, Ph.D., Optovue, Inc., CA, USA

Optical coherence tomography angiography (OCTA) with AngioVue® generates depth-resolved images of the vascular structure of the retina and the choroid, depicting detailed capillary architecture. With AngioVue, the three-dimensional OCTA data is displayed as several en face images corresponding to specific retinal tissue layers and vascular complexes. For a scan of the macula, the commonly displayed en face images with AngioVue are as follows: the "Superficial" image shows the vascular structure within the tissue slab from the inner limiting membrane (ILM) to the inner plexiform boundary (IPL); the "Deep" image shows the vascular structure within the tissue slab from the IPL boundary to the outer plexiform (OPL) boundary; the "Outer" image consists of the tissue slab from the OPL boundary to Bruch's membrane (BM), a region which is avascular in normal eyes and reveals choroidal neovascularization (CNV) in affected eyes; the "Choriocapilaris" image consists of the thin tissue slab immediately posterior to the BM boundary; and the "Full" image consists of the tissue slab from ILM to the retinal pigment epithelium (RPE). For a scan of the optic disc, another set of en face images are provided, including the "RPC" image, which consists of the tissue slab from the ILM to the posterior retinal nerve fiber layer (RNFL) boundary for assessing microvascular change inside the RNFL tissue.

Improving vascular structure depiction accuracy

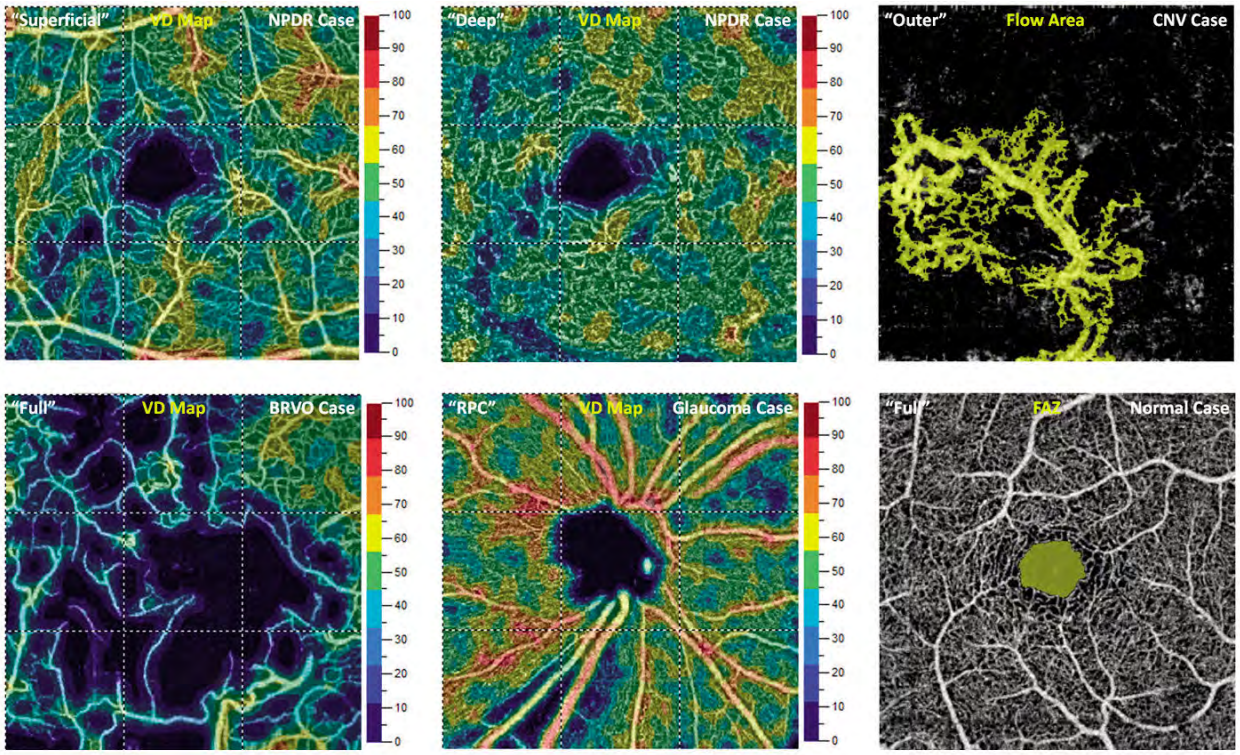
En face images, with anatomical bases that are consistent between scans and between subjects, not only provide a consistent basis for qualitative assessment across observers and across patients, but also facilitate quantitative analysis of the vascular structure. To improve the accuracy of the depth-resolved depiction of the vascular structure, a common OCTA imaging artifact, i.e., the projection of the anterior vessels onto the posterior space in the 3D OCTA volume, is minimized first, and then the en face images are generated for the tissue slabs. AngioAnalytics refers to a set of analysis tools in the AngioVue software that measures the various traits of the vascular structure based on the en face images.

Quantitative OCTA

Quantitative analysis may aid in the detection of vascular change in eyes affected by ocular diseases and provide objective assessment of change in vascular structure, which may be associated with disease progress or treatment. The non-invasive and simple nature of OCTA enables it to be performed anywhere needed and as often as needed. Quantitative OCTA opens up research opportunities to search for biomarkers incorporating vascular traits that may be more closely associated with visual functional outcomes than morphological traits alone to potentially improve patient care. AngioAnalytics, in conjunction with OCT structural analysis, may potentially improve ocular disease detection, progression monitoring, and treatment efficacy assessment.

AngioAnalytics now and in the future

As illustrated in the images below, the analysis tools include, but are not limited to, vessel density (VD) analysis of the "Superficial", "Deep", and "Full" images, flow area measurement for CNV based on the "Outer" image, foveal avascular zone (FAZ) measurement based on the "Full" image, and the VD analysis of the "RPC" image of the optic disc. The development of AngioAnalytics software continues with increasing understanding of the clinical applications of OCTA.



NPDR, CNV and BRVO images courtesy of Pravin Dugel, MD., Retinal Consultants of Arizona, Phoenix, AZ, USA. Glaucoma image courtesy of Robert N. Weinreb, MD, Hamilton Glaucoma Center, University of California at San Diego, La Jolla, CA, USA.

Investigative Ophthalmology and Visual Science 2016

A Comparison Between Optical Coherence Tomography Angiography and Fluorescein Angiography for the Imaging of Type 1 Neovascularization.

Inoue M, Jung JJ, Balaratnasingam C, Dansingani KK, Dhrami-Gavazi E, Suzuki M, de Carlo TE, Shahlaee A, Klufas MA, El Maftouhi A, Duker JS, Ho AC, Maftouhi MQ, Sarraf D, Freund KB; COFT-1 Study Group.

Purpose

To determine the sensitivity of the combination of optical coherence tomography angiography (OCTA) and structural optical coherence tomography (OCT) for detecting type 1 neovascularization (NV) and to determine significant factors that preclude visualization of type 1 NV using OCTA.

Methods

Multicenter, retrospective cohort study of 115 eyes from 100 patients with type 1 NV. A retrospective review of fluorescein (FA), OCT, and OCTA imaging was performed on a consecutive series of eyes with type 1 NV from five institutions. Unmasked graders utilized FA and structural OCT data to determine the diagnosis of type 1 NV. Masked graders evaluated FA data alone, en face OCTA data alone and combined en face OCTA and structural OCT data to determine the presence of type 1 NV. Sensitivity analyses were performed using combined FA and OCT data as the reference standard..

Results

A total of 105 eyes were diagnosed with type 1 NV using the reference. Of these, 90 (85.7%) could be detected using en face OCTA and structural OCT. The sensitivities of FA data alone and en face OCTA data alone for visualizing type 1 NV were the same (66.7%). Significant factors that precluded visualization of NV using en face OCTA included the height of pigment epithelial detachment, low signal strength, and treatment-naïve disease ($P < 0.05$, respectively).

Conclusions

En face OCTA and structural OCT showed better detection of type 1 NV than either FA alone or en face OCTA alone. Combining en face OCTA and structural OCT information may therefore be a useful way to noninvasively diagnose and monitor the treatment of type 1 NV.

Retina 2015

Longitudinal Optical Coherence Tomography Angiography Study of Type 2 Naive Choroidal Neovascularization Early Response After Treatment.

Lumbroso B, Rispoli M, Savastano MC.

Purpose

To assess the longitudinal development of choroidal neovascularization (CNV) Type 2 after intravitreal anti-vascular endothelial growth factor by optical coherence tomography-angiography (OCTA).

Methods

Five eyes of five patients with naive CNV Type 2 were assessed by OCTA in this observational longitudinal study. To perform, the OCTA used an 840-nm wavelength OCT device (XR-Avanti, Fremont; Optovue) based on split-spectrum amplitude-decorrelation angiography algorithm. The timing of analysis was after 24 hours, between 7 days and 10 days, between 12 days and 18 days, and 30 days after the intravitreal anti-vascular endothelial growth factor injections. The protocol of analysis was 3-mm × 3-mm OCT angiograms centered at the macula. The day after the injection, OCTA showed the decrease of neovascularization, with apparent vessel fragmentation. The CNV area was reduced with pruning of thinner anastomoses and loss of smaller vessels. Decrease of dimensions of CNV area, microvascular rarefaction, and vessels narrowing was observed between 7 days and 10 days, and between 12 days and 18 days because of the further loss of smaller capillaries. Residual flow was always visible to the afferent trunk over time.

Results

The mean age of patients was 72.6 (SD ±16.22) years. All were women, naive cases, and followed from 5 months to 14 months. Over that time, they had a mean number of 5.5 intravitreal injections (from 3 to 8) and a mean number of 11 OCTA examinations each (from 8 to 26). The most salient result emerging from this study is the consistency in the patterns of cyclic CNV variations after treatment in different patients. This CNV cycle was approximately 62 days long.

Conclusion

This study suggests that OCTA is able to detect the Type 2 CNV developments. This new method allows noninvasive analysis of CNV networks remodeling during anti-vascular endothelial growth factor follow-up. In conclusion, OCTA provides a useful approach for monitoring the CNV Type 2 over the time.

JAMA Ophthalmology 2015

Association of Choroidal Neovascularization and Central Serous Chorioretinopathy with Optical Coherence Tomography Angiography.

Bonini Filho MA, de Carlo TE, Ferrara D, Adhi M, Baumal CR, Witkin AJ, Reichel E, Duker JS, Waheed NK.

Importance

Choroidal neovascularization (CNV) is a major cause of vision loss in chronic central serous chorioretinopathy (CSCR). Detecting CNV using fluorescein angiography (FA) may be challenging owing to the coexistence of features related to the primary diagnosis of CSCR. Optical coherence tomography angiography (OCTA) allows noninvasive visualization of retinal and choroidal vasculature via motion contrast and may contribute to the unequivocal diagnosis of CNV in this population.

Objective

To evaluate the sensitivity of spectral-domain OCTA in detecting CNV associated with chronic CSCR.

Design, Setting and Participants

Observational cross-sectional study including 23 patients (27 eyes) who presented at the New England Eye Center between August 1, 2014, and November 30, 2014, with suspected CNV complicating chronic CSCR and underwent standard assessment for CNV diagnosis, including FA imaging. Participants were prospectively recruited to receive imaging tests using prototype OCTA software on a commercially available spectral-domain OCT. Orthogonal registration and the merging of 2 consecutive image sets were used to obtain 3×3-mm and 6×6-mm OCT angiograms centered at the macula. Two independent readers masked to other imaging findings performed a qualitative analysis on OCTA depictions of vascular flow representing CNV and the morphologic appearance of CNV.

Main Outcomes and Measures

Choroidal neovascularization location as well as retinal pigment epithelial detachment internal reflectivity and the presence of subretinal and intraretinal fluid. Sensitivity and specificity of OCTA in detecting CNV were estimated using FA as the standard examination reference.

Results

Choroidal neovascularization was diagnosed in 8 of 27 eyes (30%) based on FA imaging analysis. Optical coherence tomography angiography and corresponding OCT B-scans detected 100% (8 of 8) of these CNV lesions and correctly excluded 100% (19 of 19) of eyes with CSCR without CNV. Sensitivity was 100% (95% CI, 0.62-1) and specificity was 100% (95% CI, 0.82-1). Morphologic appearance, location, and position of the CNV relative to the retinal pigment epithelium and Bruch's membrane were described using OCTA that combined flow and structural information.

Conclusions and Relevance

This study suggests that OCTA alone (OCTA and coregistered OCT B-scans) features sensitivity and specificity comparable with FA for the detection of CNV in eyes with chronic CSCR.

British Journal of Ophthalmology 2016

Optical Coherence Tomography Angiography of Type 3 Neovascularization in Age-Related Macular Degeneration After Antiangiogenic Therapy.

Phasukkijwatana N, Tan AC, Chen X, Freund KB, Sarraf D.

Background and Aims

To assess the microvascular response of type 3 neovascularization secondary to age-related macular degeneration (AMD) after antivascular endothelial growth factor (anti-VEGF) therapy using optical coherence tomography angiography (OCTA).

Methods

Consecutive patients diagnosed with AMD and type 3 neovascularization based on clinical examination, structural optical coherence tomography and fluorescein angiography when available were retrospectively evaluated. En face OCTA imaging (3 mm x 3 mm scans) with quantitative microvascular analysis was performed at baseline and after a single anti-VEGF intravitreal injection.

Results

17 eyes of 14 patients underwent OCTA before and after anti-VEGF treatment. OCTA demonstrated significant regression of small calibre type 3 neovascular tufts in all eyes. Median lesion area was 0.061 mm^2 (range 0.003-0.198 mm^2) at baseline and 0.009 mm^2 (range 0-0.085 mm^2, p=0.0003) at follow-up. Cystoid macular oedema and/or subretinal fluid resolved in all cases after treatment. The type 3 lesions became undetectable with OCTA post-treatment in 5 of the 17 eyes. However, in 11 eyes, large feeder vessels were identified and remained unchanged after treatment.

Conclusions

The microvascular morphology of type 3 neovascularization secondary to AMD was assessed at baseline and follow-up and showed significant regression in response to anti-VEGF therapy by OCTA. Quantitative OCTA analysis was also performed and confirmed remarkable regression in response to a single intravitreal anti-VEGF injection.

Ophthalmology 2016

Visual Acuity Is Correlated with the Area of the Foveal Avascular Zone in Diabetic Retinopathy and Retinal Vein Occlusion.

Balaratnasingam C, Inoue M, Ahn S, McCann J, Dhrami-Gavazi E, Yannuzzi LA, Freund KB.

Purpose

To determine if the area of the foveal avascular zone (FAZ) is correlated with visual acuity (VA) in diabetic retinopathy (DR) and retinal vein occlusion (RVO).

Design

Cross-sectional study.

Participants

Ninety-five eyes of 66 subjects with DR (65 eyes), branch retinal vein occlusion (19 eyes), and central retinal vein occlusion (11 eyes).

Methods

Structural optical coherence tomography (OCT; Spectralis, Heidelberg Engineering) and OCT angiography (OCTA; Avanti, Optovue RTVue XR) data from a single visit were analyzed. FAZ area, point thickness of central fovea, central 1-mm subfield thickness, the occurrence of intraretinal cysts, ellipsoid zone disruption, and disorganization of retinal inner layers (DRIL) length were measured. VA was also recorded. Correlations between FAZ area and VA were explored using regression models. Main outcome measure was VA.

Results

Mean age was 62.9±13.2 years. There was no difference in demographic and OCT-derived anatomic measurements between branch retinal vein occlusion and central retinal vein occlusion groups (all $P \geq 0.058$); therefore, data from the 2 groups were pooled together to a single RVO group for further statistical comparisons. Univariate and multiple regression analysis showed that the area of the FAZ was significantly correlated with VA in DR and RVO (all $P \leq 0.003$). The relationship between FAZ area and VA varied with age ($P = 0.026$) such that for a constant FAZ area, an increase in patient age was associated with poorer vision (rise in logarithm of the minimum angle of resolution visual acuity). Disruption of the ellipsoid zone was significantly correlated with VA in univariate and multiple regression analysis (both $P < 0.001$). Occurrence of intraretinal cysts, DRIL length, and lens status were significantly correlated with VA in the univariate regression analysis ($P \leq 0.018$) but not the multiple regression analysis ($P \geq 0.210$). Remaining variables evaluated in this study were not predictive of VA (all $P \geq 0.225$).

Conclusions

The area of the FAZ is significantly correlated with VA in DR and RVO and this relationship is modulated by patient age. Further study about FAZ area and VA correlations during the natural course of retinal vascular diseases and following treatment is warranted.

Retina 2015

Retinal Vascular Perfusion Density Mapping Using Optical Coherence Tomography Angiography in Normal and Diabetic Retinopathy Patients.

Agemy SA, Scripsema NK, Shah CM, Chui T, Garcia PM, Lee JG, Gentile RC, Hsiao YS, Zhou Q, Ko T, Rosen RB.

Purpose

To describe a new method of retinal vascular perfusion density mapping using optical coherence tomography angiography and to compare current staging of diabetic retinopathy based on clinical features with a new grading scale based on perifoveal perfusion densities.

Methods

A retrospective review was performed on subjects with diabetic retinopathy and age-matched controls imaged with a spectral domain optical coherence tomography system (Optovue XR Avanti, Fremont, CA). Split-spectrum amplitude-decorrelation angiography (SSADA) generated optical coherence tomography angiograms of the superficial retinal capillaries, deep retinal capillaries, and choriocapillaris. Skeletonized optical coherence tomography angiograms were used to create color-coded perfusion maps and capillary perfusion density values for each image. Capillary perfusion density values were compared with clinical staging, and groups were compared using analysis of variance and Kruskal-Wallis analyses.

Results

Twenty-one control and 56 diabetic retinopathy eyes were imaged. Diabetic eyes were grouped according to clinical stage. Capillary perfusion density values from each microvascular layer were compared across all groups. Capillary perfusion density values were significantly lower in nearly all layers of all study groups compared with controls. Trend analysis showed a significant decrease in capillary perfusion density values as retinopathy progresses for most layers.

Conclusion

Quantitative retinal vascular perfusion density mapping agreed closely with grading based on clinical features and may offer an objective method for monitoring disease progression in diabetic retinopathy.

American Journal of Ophthalmology 2016

Quantitative Optical Coherence Tomography Angiography Features and Visual Function in Eyes with Branch Retinal Vein Occlusion.

Samara WA, Shahlaee A, Sridhar J, Khan MA, Ho AC, Hsu J.

Purpose

To measure the vascular density and foveal avascular zone (FAZ) area in the deep and superficial retinal vascular networks using optical coherence tomography angiography (OCTA) in patients with branch retinal vein occlusion (BRVO).

Design

Retrospective observational case series.

Methods

Patients with unilateral BRVO involving the macula were enrolled. OCTA was performed on the BRVO and fellow eyes. Macular vascular density, FAZ area, and foveal thickness were measured in all eyes.

Results

Seventeen eyes of 17 patients met inclusion criteria. The mean overall vascular density measured in the entire scan was lower in BRVO eyes compared to fellow eyes in both the superficial (48.07% vs. 52.60%, respectively; $P < .001$) and deep (52.60% vs. 57.67%, respectively; $P < .001$) networks. In both networks, the density was lower in the affected BRVO sector compared to the unaffected sector in the same eye and in the fellow eye ($P < .001$). In the deep network, the density was lower in the unaffected sector of the BRVO eye compared with the corresponding sector in the fellow eye (58.87% vs. 61.65%, respectively; $P = .04$). A negative correlation was found between the logarithm of the minimal angle of resolution (logMAR) visual acuity and the overall density in superficial ($r = -0.40$, $P = .02$) and deep ($r = -0.38$, $P = .03$) networks. The mean FAZ area in BRVO eyes was significantly lower only at the level of the deep network when compared to the fellow eyes (0.519 mm(2) vs. 0.410 mm(2), respectively; $P = .02$) and correlated positively with logMAR ($r = 0.34$, $P = .04$).

Conclusion

In eyes with BRVO, quantitative OCTA measurements confirm decreased vascular density in both the superficial and deep vascular networks. Moreover, vascular density and FAZ area appear to correlate with visual function.

Retina 2015

New Insight into the Macular Deep Vascular Plexus Imaged by Optical Coherence Tomography Angiography.

Bonnin S, Mané V, Couturier A, Julien M, Paques M, Tadayoni R, Gaudric A.

Purpose

To describe the macular deep capillary plexus (DCP) in normal eyes using optical coherence tomography angiography.

Methods

Retrospective study including 41 consecutive normal eyes imaged using optical coherence tomography angiography (RTVue XR Avanti; Optovue Inc.). Default autosegmentation of the superficial capillary plexus (SCP) and DCP, and manual adjustments of "deep settings" were used to analyze the organization of the normal macular microvascularization and to investigate in vivo the connection between these capillary networks.

Results

Mean age was 31 years (range 22-55 years). The SCP and DCP had 2 different organizations, but the plexus autosegmentation was imperfect: In 68% of cases, the image of the SCP variably superimposed on the DCP, interfering with its analysis. The SCP was composed on average of 7 pairs of arterioles and venules obvious on each 3-mm × 3-mm optical coherence tomography angiography scanning area. The DCP was composed of a capillary vortex arrangement, whose centers were aligned along the course of the macularsuperficial venules.

Conclusion

The SCP and DCP had two different topographic organizations. The pattern of the capillary units converging into capillary vortexes highly suggests that they drain into the superficial venules. The different structural properties of the SCP and DCP could explain the differences in flow resistance and perfusion.

Retina 2015

Optical Coherence Tomography Angiography Features of Subretinal Fibrosis in Age-Related Macular Degeneration.

Miere A, Semoun O, Cohen SY, El Ameen A, Srour M, Jung C, Oubraham H, Querques G, Souied EH.

Purpose

To report the imaging features of subretinal fibrosis secondary to exudative age-related macular degeneration (AMD) on optical coherence tomography angiography.

Methods

All consecutive patients diagnosed with subretinal fibrosis complicating exudative AMD were imaged by color retinal photographs or multicolor imaging, fluorescein angiography, spectral domain optical coherence tomography, and optical coherence tomography angiography. Eyes with active exudative features observed during the last 6 months were compared with those without any sign of exudation >6 months.

Results

Forty-nine eyes of 47 consecutive patients were included. A blood flow inside the fibrotic scar could be detected in 46 of 49 cases (93.8%). Three patterns of vascular networks could be distinguished, that were described as pruned vascular tree (26 of 49 eyes; 53.1%), tangled network (14 of 49; 28.6%), and/or vascular loop (25 of 49; 51.0%). Furthermore, 2 types of hyporeflective structures, large flow void, and/or dark halo were observed in 63% and in 65% of eyes, respectively. The observed patterns did not differ between eyes with active or inactive lesions.

Conclusion

Optical coherence tomography angiography of subretinal fibrosis showed almost constantly a perfused, abnormal vascular network and collateral architectural changes in the outer retina and the choriocapillaris layer. These features were associated with both active and inactive fibrotic choroidal neovessels.

American Journal of Ophthalmology 2016

Choriocapillaris Flow Features Follow a Power Law Distribution: Implications for Characterization and Mechanisms of Disease Progression.

Spaide RF.

Purpose

To investigate flow characteristics of the choriocapillaris using optical coherence tomography angiography.

Design

Retrospective observational case series.

Methods

Visualization of flow in individual choriocapillary vessels is below the current resolution limit of optical coherence tomography angiography instruments, but areas of absent flow signal, called flow voids, are resolvable. The central macula was imaged with the Optovue RTVue XR Avanti using a 10-μm slab thickness in 104 eyes of 80 patients who ranged in age from 24 to 99 years of age. Automatic local thresholding of the resultant raw data with the Phansalkar method was analyzed with generalized estimating equations.

Results

The distribution of flow voids vs. size of the voids was highly skewed. The data showed a linear log-log plot and goodness-of-fit methods showed the data followed a power law distribution over the relevant range. A slope intercept relationship was also evaluated for the log transform and significant predictors for variables included age, hypertension, pseudodrusen, and the presence of late age-related macular degeneration (AMD) in the fellow eye.

Conclusions

The pattern of flow voids forms a scale invariant pattern in the choriocapillaris starting at a size much smaller than a choroidal lobule. Age and hypertension affect the choriocapillaris, a flat layer of capillaries that may serve as an observable surrogate for the neural or systemic microvasculature. Significant alterations detectable in the flow pattern in eyes with pseudodrusen and in eyes with late AMD in the fellow eye offer diagnostic possibilities and impact theories of disease pathogenesis.

Retina 2016

Optical Coherence Tomography Angiography to Assess Pigment Epithelial Detachment.

Veronese C, Maiolo C, Morara M, Armstrong GW, Ciardella AP.

Purpose

To assess pigment epithelial detachment using optical coherence tomography angiography.

Design

Retrospective observational case series.

Methods

The pigment epithelial detachment was imaged with the Optovue RTVue XR Avanti using four manually segmented layers in 44 eyes of 44 patients who ranged in age from 45 to 70 years of age. 24 (54.5%) patients were female and 20 (45.5%) were male.

Results

Of the 44 eyes, 28 had vascularized PED (63.6%), and 2 had mixed PED (4.6%), 4 had drusenoid PED (9%), 10 had serous PED (22.7%). No single eye had more than one category of PED. In all 28 eyes with vascularized pigment epithelial detachments (vPEDs) and in the 2 eyes with mixed PED, OCTA imaging identified CNV. In the 10 eyes with serous PEDs and 4 eyes with drusenoid PEDs, OCTA discerned PED without neovascularization.

Conclusions

In conclusion, this is the first study that demonstrates the ability of OCTA to noninvasively analyze PED subtypes for the presence or absence of CNV and subretinal fluid. In our study, we used OCTA to assess specific vascular and nonvascular features of PED in patients with AMD and other retinal pathologies. We were able to show that OCTA imaging is capable of differentiating between nonvascular and vPED and that OCTA can also assess and measure CNV in vPED. Similar to previous studies, we found that OCTA was capable of visualizing PED through semiautomated segmentation of the outer retina and subretinal or sub-RPE space.

OCTA Bibliography: Peer-Reviewed Articles Highlighting the AngioVue® Imaging System

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