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Editorial

Optical Coherence Tomography Angiography

Spaide, Richard F.; Fujimoto, James G.; Waheed, Nadia K.

Original Study

IMAGE ARTIFACTS IN OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY

Spaide, Richard F.; Fujimoto, James G.; Waheed, Nadia K.

Purpose: To describe image artifacts of optical coherence tomography (OCT) angiography and their underlying causative mechanisms. To establish a common vocabulary for the artifacts observed.

Methods: The methods by which OCT angiography images are acquired, generated, and displayed are reviewed as are the mechanisms by which each or all of these methods can produce extraneous image information. A common set of terminology is proposed and used.

Results: Optical coherence tomography angiography uses motion contrast to image blood flow and thereby images the vasculature without the need for a contrast agent. Artifacts are very common and can arise from the OCT image acquisition, intrinsic characteristics of the eye, eye motion, image processing, and display strategies. Optical coherence tomography image acquisition for angiography takes more time than simple structural scans and necessitates trade-offs in flow resolution, scan quality, and speed. An important set of artifacts are projection artifacts in which images of blood vessels seem at erroneous locations. Image processing used for OCT angiography can alter vascular appearance through segmentation defects, and because of image display strategies can give false impressions of the density and location of vessels. Eye motion leads to discontinuities in displayed data. Optical coherence tomography angiography artifacts can be detected by interactive evaluation of the images.

Conclusion: Image artifacts are common and can lead to incorrect interpretations of OCT angiography images. Because of the quantity of data available and the potential for artifacts, physician interaction in viewing the image data will be required, much like what happens in modern radiology practice.

VOLUME-RENDERED ANGIOGRAPHIC AND STRUCTURAL OPTICAL COHERENCE TOMOGRAPHY

Spaide, Richard F.

Purpose: To demonstrate combined and integrated volume rendering of the retinal vasculature and selected structural abnormalities information derived from optical coherence tomography.

Methods: The eyes were scanned using optical coherence tomography using split-spectrum amplitude-decorrelation techniques to derive flow information. Various sublayers could be color coded as needed. The corresponding structural optical coherence tomography information was segmented for salient anatomic structures of interest, such as areas of edema fluid or intraretinal lipid deposits. The angiographic and structural data were integrated on a plane-by-plane basis and used to create volume-rendered images. The combined volume-rendered angiographic and structural optical coherence tomography data could be rotated about three different axes for evaluation.

Results: Representative images from the eyes with diabetic macular edema, Type 1 macular telangiectasis, choroidal neovascularization, and retinal veno-occlusive disease are shown. The interrelationships between areas of cystoid fluid accumulation or intraretinal lipid accumulation could be visualized.

Conclusion: Although structural and angiographic findings are typically shown in isolation, they can be integrated into a merged data set that is amenable to volume rendering. Using this new technique will allow investigation into the interrelationships between vascular and structural abnormalities of the retina and choroid.

CORRELATION OF FOVEAL AVASCULAR ZONE SIZE WITH FOVEAL MORPHOLOGY IN NORMAL EYES USING OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY

Samara, Wasim A.; Say, Emil A. T.; Khoo, Chloe T. L.; More

Purpose: To analyze the foveal avascular zone (FAZ) in normal eyes using optical coherence tomography angiography.

Methods: Prospective noncomparative case series. The parafoveal region of 70 eyes from 67 healthy subjects was imaged using optical coherence tomography angiography to visualize the superficial and deep capillary plexuses and correlated with standard macular volume scans using spectral domain optical coherence tomography to determine foveal morphology.

Results: In all 70 eyes imaged, 2 vascular plexuses could be detected within the retina: a superficial plexus within the ganglion cell layer and a deep plexus within the inner nuclear layer. A measurable FAZ was visualized in both plexuses in all imaged eyes. The FAZ area was variable in the study population with

a mean of 0.266 mm2 ± 0.097 mm2 in the superficial plexus (range: 0.071 mm2–0.527 mm2) and a mean of 0.495 mm2 ± 0.227 mm2 in the deep plexus (range: 0.160 mm2–0.795 mm2). The FAZ area was significantly larger in the deep plexus ($P < 0.0001$) compared with superficial plexus. The FAZ area in both plexuses correlated inversely with central macular thickness and central macular volume ($P < 0.0001$). No significant correlation was found between superficial plexus FAZ area and age ($P = 0.55$) or sex ($P = 0.34$). In the same manner, no significant correlation was found between deep plexus FAZ area and age ($P = 0.13$) or sex ($P = 0.13$).

Conclusion: Optical coherence tomography angiography provides a noninvasive method to visualize and measure the superficial and deep plexus FAZ in a normal population. The FAZ can vary in size and shape, with the FAZ area significantly larger in the deep compared with the superficial plexus. Both superficial and deep FAZ area correlate inversely with foveal thickness and volume.

IN VIVO CHARACTERIZATION OF RETINAL VASCULARIZATION MORPHOLOGY USING OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY

Savastano, Maria Cristina; Lumbroso, Bruno; Rispoli, Marco

Purpose: To evaluate retinal vessel morphology using split-spectrum amplitude-decorrelation angiography with optical coherence tomography in healthy eyes.

Methods: Fifty-two eyes of 26 healthy volunteers (age range from 35 to 48 years; mean age 41.94 years; SD: ±4.13) were evaluated by optical coherence tomography angiography in the macular region. The protocol acquisition consisted of a 216 × 216 A-scan that was repeated 5 times in the same position, in 3 × 3 mm centered into the fovea.

Results: All 52 eyes showed 2 separate vascular networks in the inner retina: the superficial network, located in the nerve fiber layer and in the ganglion cell layer, and the deep network, detected in the outer plexiform layer. The superficial and deep networks showed interconnections of vertical vessels. The reference planes to observe the 2 networks were defined at 60 μm, with an inner limiting membrane reference (6 μm offset), and 30 μm, with an inner plexiform layer reference (60 μm offset), respectively.

Conclusion: Optical coherence tomography angiography can separately detect the superficial vascular and the deep vascular networks. These networks are overlaid and seem to be fused when seen with standard angiographies. Furthermore, optical coherence tomography angiography technology allows for the visualization of abnormal blood column and vessel wall details.

DETECTION OF NONEXUDATIVE CHOROIDAL NEOVASCULARIZATION IN AGE-RELATED MACULAR DEGENERATION WITH OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY

Palejwala, Neal V.; Jia, Yali; Gao, Simon S.; More

Purpose: To evaluate eyes with age-related macular degeneration and high-risk characteristics for choroidal neovascularization (CNV) with optical coherence tomographic (OCT) angiography to determine whether earlier detection of CNV is possible.

Methods: Eyes with drusen, pigmentary changes, and with CNV in the fellow eye were scanned with a 70-kHz spectral domain OCT system (Optovue RTVue-XR Avanti). The split-spectrum amplitude-decorrelation angiography (SSADA) algorithm was used to distinguish blood flow from static tissue. Two masked graders reviewed scans for CNV, defined as flow in the outer retinal/sub-RPE slab. Choroidal neovascularization flow area repeatability and between-grader reproducibility were calculated.

Results: Of 32 eyes, 2 (6%) were found to have Type 1 CNV with OCT angiography. The lesions were not associated with leakage on fluorescein angiography or fluid on OCT. One case was followed for 8 months without treatment, and the CNV flow area enlarged slightly without fluid buildup on OCT or vision loss. Between-grader reproducibility of the CNV flow area was 9.4% (coefficient of variation) and within-visit repeatability was 5.2% (pooled coefficient of variation).

Conclusion: Optical coherence tomographic angiography can detect the presence of nonexudative CNV, lesions difficult to identify with fluorescein angiography and OCT. Further study is needed to understand the significance and natural history of these lesions.

TYPE 2 NEOVASCULARIZATION SECONDARY TO AGE-RELATED MACULAR DEGENERATION IMAGED BY OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY

El Ameen, Ala; Cohen, Salomon Y.; Semoun, Oudy; More

Purpose: Optical coherence tomography angiography is a novel and noninvasive technique for imaging retinal microvasculature by detecting changes in reflectivity that is related to blood flow. The purpose of this study was to describe Type 2 neovascularization characteristics in age-related macular degeneration using optical coherence tomography angiography.

Methods: Fourteen eyes of 14 consecutive patients with Type 2 neovascularization were prospectively included. All patients underwent a complete ophthalmological examination, including color and infrared fundus photography, fluorescein and indocyanine green angiography, spectral domain optical coherence tomography angiography, and optical coherence tomography angiography.

Results: In all cases, Type 2 lesions could be detected by optical coherence tomography angiography, presenting as a hyperflow lesion in the outer retina, with a glomerulus (4/14) or medusa shape (10/14), surrounded by a dark halo. The superficial layer and the deep retina showed no abnormal flow. Surprisingly, the Type 2 lesions could also be observed in the presumed choriocapillaris layer. These glomerulus- or medusa-shaped lesions were connected, in 10/14 eyes, to a thicker main branch, which seemed to continue deep into the choroidal layers.

Conclusion: Optical coherence tomography angiography may be a new imaging method for the diagnosis of Type 2 neovascularization in clinical routine. However, the specificity of the features needs to be investigated in further studies.

OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY VERSUS TRADITIONAL MULTIMODAL IMAGING IN ASSESSING THE ACTIVITY OF EXUDATIVE AGE-RELATED MACULAR DEGENERATION: A New Diagnostic Challenge

Coscas, Gabriel J.; Lupidi, Marco; Coscas, Florence; More

Purpose: To compare optical coherence tomography angiography (OCTA) with traditional multimodal imaging in patients with exudative age-related macular degeneration in terms of guiding the treatment decision.

Methods: Prospective case series of 80 eyes of 73 consecutive patients with exudative age-related macular degeneration (39 women, mean age: 79.4 ± 5.3

years) diagnosed with different types of choroidal neovascularization (CNV) (58 Type I, 2 Type II, 6 mixed Type I and II, 3 retinal angiomatous proliferation, and 11 age-related macular degeneration-related polyps). The data obtained from traditional multimodal imaging, based on fluorescein angiography, indocyanine green angiography, and OCT were used to assess the need for treatment, those obtained from OCTA to identify two different patterns of CNV. Traditional multimodal imaging and OCTA findings were then compared with evaluate possible correspondence between treatment decision and CNV aspect on OCTA.

Results: A CNV lesion was identified as Group A (requiring treatment) in 58 eyes (72.5%) in traditional multimodal imaging. On OCTA in 59 eyes (73.7%), the lesion was defined as Pattern I and the remaining 21 (26.3%) as Pattern II. There was 94.9% correspondence between the Pattern I CNV on OCTA and the cases Group A on conventional multimodal imaging. It was also computed 90.5% correspondence between Pattern II CNV on OCTA and the Group B (not requiring treatment) cases on conventional multimodal imaging. There was high ($P < 0.05$) interobserver agreement both for treatment decision in conventional multimodal and for Patterns (I or II) defining on OCTA imaging analysis.

Conclusion: This study demonstrates a high level of correspondence, in patients with exudative age-related macular degeneration, between different CNV patterns identified on OCTA and treatment decisions established on conventional multimodal imaging. Although fluorescein angiography remains the gold standard for determining the presence of leakage, and OCT shows fluid accumulation and its variations, OCTA may now offer noninvasive monitoring of the CNV, aiding for each treatment decision during the follow-up.

OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY OF TYPE 3 NEOVASCULARIZATION SECONDARY TO AGE-RELATED MACULAR DEGENERATION

Kuehlewein, Laura; Dansingani, Kunal K.; de Carlo, Talisa E.; More

Purpose: To characterize the vascular structure of Type 3 neovascularization secondary to age-related macular degeneration using optical coherence tomography angiography.

Methods: Optical coherence tomography angiography cube scans (3 mm × 3 mm) were acquired in 29 eyes of 24 patients with Type 3 lesions secondary to age-related macular degeneration using the RTVue XR Avanti with AngioVue, Split-spectrum amplitude-decorrelation, and motion correction technology. Automated layer segmentation boundaries were adjusted to best visualize the neovascular complex on en face projection images.

Results: A distinct neovascular complex could be identified in 10 (34%) eyes, all of which were active on optical coherence tomography imaging. In all 10 eyes, the neovascular complex appeared as a small tuft of bright, high-flow tiny vessels with curvilinear morphology located in the outer retinal layers with a feeder vessel communicating with the inner retinal circulation (i.e., deep retinal capillary plexus). The mean (SD) size of the neovascular complex measured 0.07 (± 0.07) mm2.

Conclusion: With optical coherence tomography angiography, it is possible to identify small intraretinal neovascular complexes communicating with the deep retinal capillary plexus in eyes with Type 3 neovascularization secondary to age-related macular degeneration. Qualitative and quantitative analyses of Type 3 neovascular complexes can be performed using optical coherence tomography angiography.

OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY IN EARLY TYPE 3 NEOVASCULARIZATION

Miere, Alexandra; Querques, Giuseppe; Semoun, Oudy; More

Purpose: To report the imaging features of Type 3 neovascularization secondary to exudative age-related macular degeneration on optical coherence tomography angiography (OCTA).

Methods: All consecutive treatment-naive patients diagnosed with early-stage Type 3 neovascularization underwent imaging by color retinal photographs or multicolor imaging, fluorescein angiography, indocyanine green angiography, spectral domain optical coherence tomography, and OCTA. The OCTA features were analyzed and correlated with the findings of conventional angiography and spectral domain optical coherence tomography.

Results: A total of 18 treatment-naive eyes of 18 consecutive patients (13 females and 5 males; mean age 81.3 ± 6.0) were included in the analysis. Optical coherence tomography angiography showed lesions characterized by a retinal–retinal anastomosis that emerged from the deep capillary plexus, forming in all 18 eyes a clear tuft-shaped high-flow network in the outer retinal segmentation, finally abutting in the subretinal pigment epithelium space. In 15 of 18 eyes, in the choriocapillaris segmentation, there appeared a small clew-like lesion, which in 2 cases seemed connected with the choroid through a small caliber vessel.

Conclusion: Optical coherence tomography angiography of treatment-naive Type 3 neovascularization showed almost constantly a high-flow, tuft-shaped abnormal outer retinal proliferation, frequently associated to a small clew-like lesion in the choriocapillaris layer.

LONGITUDINAL OPTICAL COHERENCE TOMOGRAPHY-ANGIOGRAPHY STUDY OF TYPE 2 NAIVE CHOROIDAL NEOVASCULARIZATION EARLY RESPONSE AFTER TREATMENT

Lumbroso, Bruno; Rispoli, Marco; Savastano, Maria Cristina

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

Methods: Five eyes of five patients with naive CNV Type 2 were assessed by OCT-A in this observational longitudinal study. To perform, the OCT-A used an

840-nm wavelength OCT device (XR-Avanti, Freemont; 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, OCT-A 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, between 12 days and 18 days because of the further loss of smaller capillaries. Residual flow was always visible to the afferent trunk over the 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 OCT-A 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 OCT-A 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, OCT-A provides a useful approach for monitoring the CNV Type 2 over the time.

CHARACTERIZING THE EFFECT OF ANTI-VASCULAR ENDOTHELIAL GROWTH FACTOR THERAPY ON TREATMENT-NAIVE CHOROIDAL

CHARACTERIZING THE EFFECT OF ANTI-VASCULAR ENDOTHELIAL GROWTH FACTOR THERAPY ON TREATMENT-NAIVE CHOROIDAL NEOVASCULARIZATION USING OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY

Muakkassa, Nora W.; Chin, Adam T.; de Carlo, Talisa; More

Purpose: To use optical coherence tomography angiography (OCTA) to characterize the effects of anti-VEGF injections on treatment-naive choroidal neovascularization (CNV).

Methods: From August 2014 to May 2015, treatment-naive eyes with CNV were scanned using a prototype OCTA system on a commercially available SD-OCT device (Optovue Inc, Fremont, CA). Optical coherence tomography angiography scans were obtained before anti-VEGF injection and at follow-up visits. The CNV area and greatest linear dimension (GLD) were measured along with the maximum retinal pigment epithelial detachment (RPED) height. Changes in subretinal and/or intraretinal fluid were also assessed.

Results: Six eyes of six patients with treatment-naive CNV were included. Diagnoses included neovascular age-related macular degeneration, idiopathic polypoidal choroidal vasculopathy, CNV secondary to central serous chorioretinopathy and multifocal choroiditis, and macular telangiectasia Type 2 with subretinal neovascularization. After treatment, all patients with fluid on OCT initially showed a decrease in the amount of fluid. Five of six patients demonstrated decreases in CNV GLD and area with an average reduction of 23.6% and 29.8% respectively.

Conclusion: Both CNV greatest linear dimension and area measured using OCTA decreased after anti-VEGF treatment in most patients. Optical coherence tomography angiography may be a useful tool for monitoring and quantifying the response of CNV to treatment.

OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY OF TIME COURSE OF CHOROIDAL NEOVASCULARIZATION IN RESPONSE TO ANTI-ANGIOGENIC TREATMENT

Huang, David; Jia, Yali; Rispoli, Marco; More

Purpose: To use optical coherence tomography (OCT) angiography to monitor the short-term blood flow changes in choroidal neovascularization (CNV) in response to treatment.

Methods: In this retrospective report, a case of exudative CNV was followed closely with OCT angiography over three cycles of antiangiogenic treatment. Outer retinal flow index, CNV flow area and central macular retinal thickness were measured.

Results: Quantitative measurements of CNV flow area and flow index showed rapid shutdown of flow over the initial 2 weeks, followed by reappearance of CNV channel by the fourth week, preceding fluid reaccumulation at 6 weeks.

Conclusion: Frequent OCT angiography reveals a previously unknown pattern of rapid shutdown and reappearance of CNV channels within treatment cycles. OCT angiographic changes precede fluid reaccumulation and could be useful as leading indicators of CNV activity that could guide treatment timing. Further studies using OCT angiography in short intervals between antiangiogenic treatments are needed.

OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY OF POLYPOIDAL CHOROIDAL VASCULOPATHY AND POLYPOIDAL CHOROIDAL NEOVASCULARIZATION

Inoue, Maiko; Balaratnasingam, Chandrakumar; Freund, K. Bailey

Purpose: To describe the use of optical coherence tomography angiography (OCT-A) for evaluating the spectrum of polypoidal vascular diseases.

Methods: Retrospective observational case series of seven patients with polypoidal choroidal vasculopathy (three cases) or polypoidal choroidal neovascularization (four cases). Optical coherence tomography angiography information was acquired using two different OCT-A devices (the Optovue RTVue XR Avanti SD-OCT and the Spectralis OCT angiography). Flow signals within branching vascular networks, type 1 neovascularization and polyps were evaluated. Comparisons were made between en face and cross-sectional OCT-A images. Vascular information from OCT-A was also compared with indocyanine green angiography.

Results: En face images from OCT-A provided anatomical information about branching vascular networks that were comparable to indocyanine green angiography. Polyps were poorly resolved on en face OCT-A images but were clearly defined on cross-sectional OCT-A images. Cross-sectional OCT-A revealed flow signals within focal regions of the polyps with a significant portion of the polyp lumen being devoid of flow signal. Flow signals from cross-sectional OCT-A images also showed that branching vascular networks, type 1 neovascularization, and polyps were confined to the anatomic compartment between the retinal pigment epithelium and Bruch's membrane. It was not possible to detect leakage on en face or cross-sectional OCT-A.

Conclusion: The combination of en face and cross-sectional OCT-A images provides anatomical information about polypoidal structures that is comparable to indocyanine green angiography. OCT-A may be a useful modality for the management of polypoidal diseases. However, the limitations of OCT-A identified in this study suggest that it is not a replacement for indocyanine green angiography.

OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY FEATURES OF SUBRETINAL FIBROSIS IN AGE-RELATED MACULAR DEGENERATION

Miere, Alexandra; Semoun, Oudy; Cohen, Salomon Yves; More

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.

SWEPT-SOURCE OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY OF NEOVASCULAR MACULAR TELANGIECTASIA TYPE 2

SWEPT SOURCE OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY OF NEOVASCULAR MACULAR TELANGIECTASIA TYPE 2

Zhang, Qinqin; Wang, Ruikang K.; Chen, Chieh-Li; More

Background/Purpose: To image subretinal neovascularization in proliferative macular telangiectasia Type 2 (MacTel2) using swept source optical coherence tomography based microangiography (OMAG).

Methods: Patients with macular telangiectasia Type 2 were enrolled in a prospective, observational study known as the MacTel Project and evaluated using a high-speed 1,050 nm swept-source OCT prototype system. The OMAG algorithm generated en face flow images from three retinal layers, and the region bounded by the outer retina and Bruch membrane, the choriocapillaris, and the remaining choroidal vasculature. The en face OMAG images were compared with images from fluorescein angiography and indocyanine green angiography.

Results: Three eyes with neovascular macular telangiectasia Type 2 were imaged. The neovascularization was best identified from the en face OMAG images that included a layer between the outer retinal boundary and Bruch membrane. Optical coherence tomography based microangiography images identified these abnormal vessels better than fluorescein angiography and were comparable to the images obtained using indocyanine green angiography. In all 3 cases, OMAG identified choroidal vessels communicating with the neovascularization, and these choroidal vessels were evident in the 2 cases with indocyanine green angiography imaging. In 1 case, monthly injections of bevacizumab reduced the microvascular complexity of the neovascularization, and the telangiectatic changes within the retinal microvasculature. In another case, less frequent bevacizumab therapy was associated with growth of the subretinal neovascular complex.

Conclusion: Optical coherence tomography based microangiography imaging provided detailed, depth-resolved information about subretinal neovascularization in macular telangiectasia Type 2 eyes demonstrating superiority to fluorescein angiography imaging, and similarities to indocyanine green angiography imaging for documenting the retinal microvascular changes, the size and extent of the neovascular complex, the communications between the neovascular complex and the choroidal circulation, and the response to monthly bevacizumab therapy.

OUTER RETINA CAPILLARY INVASION AND ELLIPSOID ZONE LOSS IN MACULAR TELANGIECTASIA TYPE 2 IMAGED BY OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY

Gaudric, Alain; Krivosic, Valérie; Tadayoni, Ramin

Purpose: Macular telangiectasia Type 2 (MacTel2) is a neurodegenerative and vascular disease limited to the macular area, resulting ultimately in Muller cell and photoreceptor loss and intra or subretinal proliferation. Optical coherence tomography angiography was used to correlate the proliferation of capillaries in the outer retina with the topography of the ellipsoid zone (EZ) loss.

Methods: Thirty eyes of 15 patients with MacTel2 were examined using optical coherence tomography angiography. Images of the superficial and deep capillary plexus were analyzed and compared with en-face angio-flow images of the outer retina and en-face image of the EZ.

Results: Twenty-one eyes were available for the study, including 12 with invasion of the outer retina capillary on optical coherence tomography angiography but without subretinal neovascularization. The outer retina capillary proliferation had a radial pattern in eight cases, formed loops in four, and was circumscribed to an area of EZ loss on en-face images. In nine cases, there was no outer capillary proliferation including two cases with foci of EZ loss.

Conclusion: Optical coherence tomography angiography shows capillary proliferation in the outer retina corresponding to areas of EZ loss, which could be a useful marker to monitor the efficacy of possible treatments in MacTel2 disease.

ASSOCIATION BETWEEN CHANGES IN MACULAR VASCULATURE IN OPTICAL COHERENCE TOMOGRAPHY- AND FLUORESCEIN- ANGIOGRAPHY AND DISTRIBUTION OF MACULAR PIGMENT IN TYPE 2 IDIOPATHIC MACULAR...

Zeimer, Meike; Gutfleisch, Matthias; Heimes, Britta; More

Purpose: We investigate the association between morphologic findings in optical coherence tomography angiography (OCTA) as a new method offering the visualization of deeper layers of retinal vasculature and fluorescein angiography (FA) and macular pigment imaging and in Type 2 macular telangiectasia.

Methods: Fourty-two eyes of 21 patients with macular telangiectasia (38–68 years, 14 female) were examined by FA and OCTA and 24 eyes additionally with dual-wavelength autofluorescence. Early and late FA, macular pigment density images, and (after segmentation of retinal vasculature into superficial and deep capillary network and outer) OCTA images were graded into standardized categories. Agreement between the methods was evaluated statistically.

Results: In OCTA, a reduction of density of superficial capillaries, dilated vessels in the deep capillary network, anastomoses toward the superficial capillary network, and “new” vessels in the outer retina layers can be detected. The described anatomical features, especially in the deep capillary plexus and outer retina corresponded well with changes in FA. Classes of macular pigment distribution correlated most with classes of changes in OCTA superficial capillary plexus.

Conclusion: Progressive changes in macular telangiectasia apparent in FA and macular pigment imaging are most obvious in the deep capillary network and outer retina in OCTA. Optical coherence tomography angiography offers a noninvasive technology to analyze vascular changes in the retina and choroid of patients with macular telangiectasia.

POSSIBLE CHOROIDAL NEOVASCULARIZATION IN MACULAR TELANGIECTASIA TYPE 2

Balaratnasingam, Chandrakumar; Yannuzzi, Lawrence A.; Spaide, Richard F.

Purpose: To use volume-rendered optical coherence tomography angiography to investigate vascular proliferation in macular telangiectasia type 2 (MacTel2), extending beyond the retinal pigment epithelium (RPE).

Methods: Six eyes of four patients with MacTel2 with neovascularization proliferating external to the RPE confines were studied. Eyes were scanned using optical coherence tomography using split-spectrum amplitude-decorrelation techniques to derive flow information (RTVue XR; Optovue). These data were extracted and used to create volume rendered images of the area of vascular proliferation.

Results: Mean age was 66.2 years. There was demonstrable vascular proliferation in the sub-RPE space observable by both optical coherence tomography and optical coherence tomography angiography. Fibrovascular RPE detachments were identified in all eyes. The topographic distribution of abnormal vessels located below the plane of the deep retinal vascular plexus and above the RPE closely matched the pattern of hyperfluorescence and leakage on fluorescein angiography. Vessels under the RPE demonstrated different branching patterns and larger diameter lumens than those above the RPE, but anastomosis with the choroidal circulation was difficult to demonstrate.

Conclusion: This study provides evidence that sub-RPE vascular proliferation may be a complication of MacTel2. Retinal pigment epithelium abnormalities

are known to occur in MacTel2 and may provide a conduit for abnormal vessels in the subretinal space to proliferate into the sub-RPE compartment. The authors have no reason to exclude the possibility that the choroid contributes to the deep proliferation.

OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY OF RETINAL VENOUS OCCLUSION

Kashani, Amir H.; Lee, Sun Young; Moshfeghi, Andrew; More

Purpose: To noninvasively evaluate the retinal microvasculature in human subjects with retinal venous occlusions using optical coherence tomography angiography and assess potential clinical applications.

Methods: This was a prospective, observational study of adult human subjects with clinical and imaging findings demonstrating retinal venous occlusion. Subjects underwent complete ophthalmic examination and fluorescein angiography as appropriate for their standard of care. Optical coherence tomography angiography was performed on a prototype spectral domain-OCTA system in 3 mm × 3 mm and 6 mm × 6 mm regions centered on the fovea and parafoveal areas. Retinal vasculature was assessed within three horizontal slabs consisting of the superficial, middle, and deep retina. The vasculature within each slab was reconstructed using intensity contrast-based algorithms and visualized as en-face images. Optical coherence tomography angiograms were manually segmented to verify the accuracy of the automated segmentation algorithms.

Results: Optical coherence tomography angiography was able to demonstrate almost all of the clinically relevant findings in 25 subjects with acute and chronic retinal venous occlusion. These findings were consistent with clinical, anatomic, and fluorescein angiographic findings including areas of impaired vascular perfusion, retinal atrophy, vascular dilation, shunt vessels, and some forms of intraretinal edema.

Conclusion: Optical coherence tomography angiography is an investigational method that generates high-resolution, noninvasive angiograms that qualitatively illustrate most of clinically relevant findings in retinal venous occlusion. Optical coherence tomography angiography corresponds well with fluorescein angiograms and in many cases provides more detailed anatomic and blood flow information. Optical coherence tomography angiography, in conjunction with standard spectral domain-OCT, is at least equally as effective as fluorescein angiography for evaluation and management of the macular complications of retinal venous occlusions.

CAPILLARY NETWORK ANOMALIES IN BRANCH RETINAL VEIN OCCLUSION ON OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY

Rispoli, Marco; Savastano, Maria Cristina; Lumbroso, Bruno

Purpose: To analyze the foveal microvasculature features in eyes with branch retinal vein occlusion (BRVO) using optical coherence tomography angiography based on split spectrum amplitude decorrelation angiography technology.

Methods: A total of 10 BRVO eyes (mean age 64.2 ± 8.02 range between 52 years and 76 years) were evaluated by optical coherence tomography angiography (XR-Avanti; Optovue). The macular angiography scan protocol covered a 3 mm × 3 mm area. The focus of angiography analysis were two retinal layers: superficial vascular network and deep vascular network. The following vascular morphological congestion parameters were assessed in the vein occlusion area in both the superficial and deep networks: foveal avascular zone enlargement, capillary non-perfusion occurrence, microvascular abnormalities appearance, and vascular congestion signs. Image analyses were performed by 2 masked observers and interobserver agreement of image analyses was 0.90 ($\kappa = 0.225$, $P < 0.01$).

Results: In both superficial and deep network of BRVO, a decrease in capillary density with foveal avascular zone enlargement, capillary non-perfusion occurrence, and microvascular abnormalities appearance was observed ($P < 0.01$). The deep network showed the main vascular congestion at the boundary between healthy and nonperfused retina.

Conclusion: Optical coherence tomography angiography in BRVO allows to detect foveal avascular zone enlargement, capillary nonperfusion, microvascular abnormalities, and vascular congestion signs both in the superficial and deep capillary network in all eyes. Optical coherence tomography angiography technology is a potential clinical tool for BRVO diagnosis and follow-up, providing stratigraphic vascular details that have not been previously observed by standard fluorescein angiography. The normal retinal vascular nets and areas of nonperfusion and congestion can be identified at various retinal levels. Optical coherence tomography angiography provides noninvasive images of the retinal capillaries and vascular networks.

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OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY IN RETINAL ARTERY OCCLUSION

Bonini Filho, Marco A.; Adhi, Mehreen; de Carlo, Talisa E.; More

Purpose: To describe the retinal microvasculature of the eyes with nonarteritic retinal artery occlusion (RAO) based on optical coherence tomography angiography.

Methods: Cross-sectional, prospective, observational study performed from September 2014 through February 2015. En face projection of optical coherence tomography angiography images centered at the macula and optic disk of the eyes presenting with RAO were acquired using the RTVue XR Avanti with AngioVue software. Qualitative analysis of the morphology of the superficial and deep retinal capillary plexuses, and radial peripapillary capillaries was performed. Retinal vasculature images using optical coherence tomography angiography were correlated with fluorescein angiography images.

Results: Seven patients (seven eyes) were enrolled in the study, including three eyes with central RAO and four eyes with branch RAO. Distinct differences in the distribution of zones of decreased vascular perfusion between the superficial and deep retinal capillary plexus corresponding to areas of delayed dye perfusion on fluorescein angiography were demonstrated in 6 of 7 (86.5%) eyes.

Conclusion: This small series suggests that optical coherence tomography angiography imaging can accurately discern retinal capillary plexuses at different levels in the eyes with RAO and may be sensitive for more precisely characterizing the extent of macular ischemia and monitoring vascular flow changes during the course of the disease.

NEW INSIGHT INTO THE MACULAR DEEP VASCULAR PLEXUS IMAGED BY OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY

Bonnin, Sophie; Mané, Valérie; Couturier, Aude; More

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 macular superficial 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.

RETINAL VASCULAR PERFUSION DENSITY MAPPING USING OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY IN NORMALS AND DIABETIC RETINOPATHY PATIENTS

Agemy, Steven A.; Scripsema, Nicole K.; Shah, Chirag M.; More

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.

DETECTION OF MICROVASCULAR CHANGES IN EYES OF PATIENTS WITH DIABETES BUT NOT CLINICAL DIABETIC RETINOPATHY USING OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY

de Carlo, Talisa E.; Chin, Adam T.; Bonini Filho, Marco A.; More

Purpose: To evaluate the ability of optical coherence tomography angiography to detect early microvascular changes in eyes of diabetic individuals without clinical retinopathy.

Methods: Prospective observational study of 61 eyes of 39 patients with diabetes mellitus and 28 control eyes of 22 age-matched healthy subjects that received imaging using optical coherence tomography angiography between August 2014 and March 2015. Eyes with concomitant retinal, optic nerve, and vitreoretinal interface diseases and/or poor-quality images were excluded. Foveal avascular zone size and irregularity, vessel beading and tortuosity, capillary nonperfusion, and microaneurysm were evaluated.

Results: Foveal avascular zone size measured 0.348 mm2 (0.1085–0.671) in diabetic eyes and 0.288 mm2 (0.07–0.434) in control eyes (P = 0.04). Foveal avascular zone remodeling was seen more often in diabetic than control eyes (36% and 11%, respectively; P = 0.01). Capillary nonperfusion was noted in 21% of diabetic eyes and 4% of control eyes (P = 0.03). Microaneurysms and venous beading were noted in less than 10% of both diabetic and control eyes. Both diabetic and healthy control eyes demonstrated tortuous vessels in 21% and 25% of eyes, respectively.

Conclusion: Optical coherence tomography angiography was able to image foveal microvascular changes that were not detected by clinical examination in diabetic eyes. Changes to the foveal avascular zone and capillary nonperfusion were more prevalent in diabetic eyes, whereas vessel tortuosity was observed with a similar frequency in normal and diabetic eyes. Optical coherence tomography angiography may be able to detect diabetic eyes at risk of developing retinopathy and to screen for diabetes quickly and noninvasively before the systemic diagnosis is made.

OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY FEATURES OF DIABETIC RETINOPATHY

Hwang, Thomas S.; Jia, Yali; Gao, Simon S.; More

Purpose: To describe the optical coherence tomography angiography features of diabetic retinopathy.

Methods: Using a 70 kHz optical coherence tomography and the split-spectrum amplitude decorrelation angiography algorithm, 6 mm × 6 mm 3-dimensional angiograms of the macula of 4 patients with diabetic retinopathy were obtained and compared with fluorescein angiography for features cataloged by the Early Treatment of Diabetic Retinopathy Study.

Results: Optical coherence tomography angiography detected enlargement and distortion of the foveal avascular zone, retinal capillary dropout, and pruning of arteriolar branches. Areas of capillary loss obscured by fluorescein leakage on fluorescein angiography were more clearly defined on optical coherence tomography angiography. Some areas of focal leakage on fluorescein angiography that were thought to be microaneurysms were found to be small tufts of neovascularization that extended above the inner limiting membrane.

Conclusion: Optical coherence tomography angiography does not show leakage but can better delineate areas of capillary dropout and detect early retinal neovascularization. This new noninvasive angiography technology may be useful for routine surveillance of proliferative and ischemic changes in diabetic retinopathy.

ENLARGEMENT OF FOVEAL AVASCULAR ZONE IN DIABETIC EYES EVALUATED BY EN FACE OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY

Takase, Noriaki; Nozaki, Miho; Kato, Aki; More

Purpose: To evaluate the area of the foveal avascular zone (FAZ) detected by en face OCTA (AngioVue, Avanti OCT; Optovue) in healthy and diabetic eyes.

Methods: Retrospective chart review of patients who underwent fundus examination including en face OCTA. Eyes with proliferative diabetic retinopathy and history of laser photocoagulation were excluded. The FAZ area in the superficial and deep plexus layers were measured and evaluated using ImageJ

software.

Results: The FAZ area in the superficial layer was 0.25 ± 0.06 mm2 in healthy eyes (n = 19), whereas it was 0.37 ± 0.07 mm2 in diabetic eyes without retinopathy (n = 24) and 0.38 ± 0.11 mm2 in eyes with diabetic retinopathy (n = 20). Diabetic eyes showed statistically significant FAZ enlargement compared with healthy eyes, regardless of the presence of retinopathy (P < 0.01). The FAZ area in the deep plexus layer was also significantly larger in diabetic eyes than in healthy eyes (P < 0.01).

Conclusion: Our data suggest that diabetic eyes show retinal microcirculation impairment in the macula even before retinopathy develops. En face OCTA is a useful noninvasive screening tool for detecting early microcirculatory disturbance in patients with diabetes.

CAPILLARY PLEXUS ANOMALIES IN DIABETIC RETINOPATHY ON OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY

Couturier, Aude; Mané, Valérie; Bonnin, Sophie; More

Purpose: To analyze the foveal microvasculature in eyes with diabetic retinopathy (DR) using optical coherence tomography angiography (OCTA) and fluorescein angiography (FA).

Methods: In this retrospective study of 20 eyes of 14 patients with DR imaged using OCTA and FA, clinical features of DR such as microaneurysms, capillary nonperfusion areas, and intraretinal microvascular abnormalities were analyzed.

Results: In the superficial plexus, a rarefaction of capillaries with capillary nonperfusion areas was present in all eyes. Some of these nonperfused areas were not detected on FA and were better delimited on OCTA. Conversely, in the deep plexus, capillary nonperfusion areas were seen only in 35% (7/20) of eyes, whereas DR led to an alteration of the normal capillary vortex pattern in all eyes. Only 62% of microaneurysms visualized on FA were detected by OCTA (P = 0.02). Intraretinal microvascular abnormalities were well detected by both FA and OCTA.

Conclusion: Optical coherence tomography angiography allowed detecting DR anomalies in both superficial and deep capillary plexus in all eyes. The ability of OCTA to detect microaneurysms was lower than that of FA although its accuracy for assessing capillary nonperfusion was better and may enable a proper grading of DR progression.

RETINAL AND CHOROIDAL VASCULATURE IN BIRDSHOT CHORIORETINOPATHY ANALYZED USING SPECTRAL DOMAIN OPTICAL COHERENCE TOMOGRAPHY ANGIOGRAPHY

de Carlo, Talisa E.; Bonini Filho, Marco A.; Adhi, Mehreen; More

Purpose: To describe retinal and choroidal vascular changes in eyes with birdshot chorioretinopathy using optical coherence tomography angiography.

Methods: Patients underwent imaging using the AngioVue prototype software of the RTVue XR spectral domain optical coherence tomography device (Optovue, Inc) between September and December 2014. Two trained patients evaluated the optical coherence tomography angiography images for changes in the retinal and choroidal vasculature in the posterior pole.

Results: Four of eight eyes (50%) had birdshot lesions in the posterior pole as demonstrated on fundus photography. All of these eyes demonstrated the areas of decreased choroidal blood flow below the disrupted retinal pigment epithelium. Larger choroidal vessels bordered the birdshot lesions. All eyes analyzed showed retinal thinning, telangiectatic vessels, and an increased intercapillary space. Capillary dilatations and loops were each seen in 7 of 8 eyes (88%).

Conclusion: Optical coherence tomography angiography provides precise microvascular detail of the retinal vasculature and choriocapillaris that allows for the noninvasive visualization of the birdshot lesions and changes in the inner retina. The optical coherence tomography angiography images delineated widespread retinal vascular findings not previously described in the literature. In the future, optical coherence tomography angiography could be a useful tool to evaluate the natural history of birdshot chorioretinopathy, its progression, and the effect of treatment in these patients.

NONINVASIVE GRADING OF RADIATION RETINOPATHY: The Use of Optical Coherence Tomography Angiography

Veverka, Kevin K.; AbouChehade, Jackson E.; Iezzi, Raymond Jr; More

Purpose: Previous studies have shown that spectral domain optical coherence tomography can diagnose radiation retinopathy (RR) before ophthalmoscopic findings. Recently, optical coherence tomography angiography (OCT-A) has been helpful in seeing vascular findings undetected by spectral domain optical coherence tomography. The authors wish to demonstrate the OCT-A grading at varying levels of RR.

Methods: The OCT-A, spectral domain optical coherence tomography, and ophthalmoscopic findings on 7 patients from December 2014 to March 2015 with varying levels of RR are demonstrated.

Results: Findings on OCT-A could be demonstrated before spectral domain optical coherence tomography findings. Patients can be graded on a scale of increasing severity from 0 to 5, based on positive or negative clinical findings of RR between OCT-A. Optical coherence tomography increased central macular thickness, optical coherence tomography evident cysts, and ophthalmoscopy (Grade 0: −,−,−,−; Grade 1: +,−,−,−; Grade 2: +,+,−,−; Grade 3: +,+,+,−; Grade 4: ++,+,+,+; Grade 5: unreadable,++,++,+).

Conclusion: The use of OCT-A allows for earlier detection of RR; thus, existing grading systems should be modified to include OCT-A.

Surgical Technique

Thru-the-Trocar Administration of Dexamethasone Intravitreal Implant During 23-G Pars Plana Vitrectomy: A Small Case Series

Rodríguez-Valdés, Patricio J.; Newman-Sánchez, Oscar A.; González-Madrigal, Pedro Mario

No-Touch Removal of Anterior Segment-Migrated Dexamethasone Implant

Rahimy, Ehsan; Pitcher, John D. III; Abbey, Ashkan M.; More

Diagnostic and Therapeutic Challenges

Photo Essay

Review

Purpose: To evaluate the effect of supplemental scleral buckle (SB) in pars plana vitrectomy (PPV) for rhegmatogenous retinal detachment.

Methods: MEDLINE, EMBASE, and CENTRAL were searched to identify studies comparing PPV with supplemental SB (PPV + SB) to PPV alone for the repair of rhegmatogenous retinal detachment. The outcome measures were primary and final reattachment rates, and postoperative complications. Odds ratio with 95% confidence interval in random effects for the comparison of outcomes between PPV + SB and PPV alone was calculated.

Results: Ten studies consisting of 1,704 patients were included. Meta-analysis showed that the overall primary reattachment rate was significantly higher in PPV + SB than PPV alone (odds ratio, 1.70; 95% confidence interval, 1.21–2.39; P = 0.002). The final reattachment rate was equally high in both groups. Postoperative development of epiretinal membrane was more frequent in PPV + SB than in PPV alone (odds ratio, 1.89; 95% confidence interval, 1.30–2.76; P = 0.001), whereas no significant difference in postoperative development of macular edema, proliferative vitreoretinopathy, or elevation of intraocular pressure was found.

Conclusion: Supplemental SB increases the primary reattachment rate in PPV for rhegmatogenous retinal detachment, although final reattachment rate was equally high with or without SB.

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