OCT Angiography for Beginners: Multimodal Imaging Platform Optimizes Ocular Fundus Diagnostics

The principle of OCT angiography (OCTA), its clinical applications and a detailed presentation of numerous OCTA case studies were the topics of a symposium held by Heidelberg Engineering at the 115th Congress of the German Ophthalmological Society in Berlin in September 2017.

OCTA is a non-invasive imaging modality that produces detailed three-dimensional representations of perfused retinal and choroidal vessels. In the speakers' opinion, this imaging modality offers many new insights into retinal diseases and has the potential to trigger a minor revolution in hospitals and practices.

The SPECTRALIS OCT Angiography Module relies on the core technologies of the multimodal SPECTRALIS platform and provides detailed, high resolution OCTA images. To obtain those images, the signal of each individual pixel is compared in consecutive OCT scans. White pixels are displayed when during the OCT scan a signal difference characteristic for flow is detected. In other words, blood flow in the vessels (= white pixels) is identified and differentiated from static tissue (= dark pixels). Vessels can be visualized in various slabs depending on the segmentation selected by the user [1] (Figure 1).

OCT angiography: Focus on retinal capillaries

According to Prof. Dr. Frank G. Holz (Bonn), the main difference between OCTA and fluorescein angiography (FA) is the fact that OCTA requires no dye injection. OCTA images are acquired within seconds, eliminating the need for repositioning, the placing of a venous catheter and further imaging after 10 or 15 minutes. In addition, since the wavelength is in the near infrared range, the examination is less blinding for patients, and images can even be taken through a dense cataract as well as when there is bleeding. Capillary leakage, staining and pooling, which can be observed with FA but are not detectable in OCTA alone, can nevertheless be frequently interpreted by combining OCTA with structural OCT. The focus is not on the large nasal and temporal arterioles and venules but on the abundant retinal capillaries.

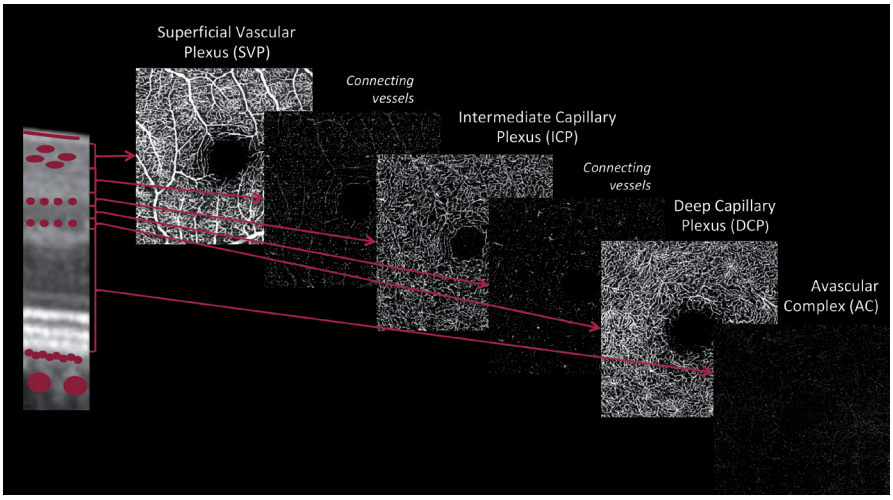

Figure: Heidelberg Engineering

Figure 1: Vessels can be visualized in various slabs depending on the segmentation selected by the user.

The resolution of a SPECTRALIS OCTA image is 5.7 µm/pix transversally in both directions and 3.9 µm/pix axially (vertically). This means that retinal capillaries, which are 8 µm in diameter on average [2], can be reliably identified. A lower resolution would make it difficult to display such delicate structures. Black gaps would then be difficult to interpret with certainty. They could represent either ischemia or a perfused area. The image size of 10° x 10° is of particular interest for macular disease, while the 20° x 20° option represents a good compromise between image resolution and field of view and is well suited for screening in the peripheral retina.

The SPECTRALIS OCT Angiography Module is able to generate a fusion image that contains both structural information (OCT) and functional information (OCTA). Flow signals are displayed in yellow and can be interpreted as retinal vessels. The OCTA Module also allows for en face scrolling through the retina to obtain detailed views of all vascular or structural layers. In the choriocapillaris, the limits of resolution are reached; in the healthy eye, it can be visualized as a texture only. On the OCTA image, gaps in the choriocapillaris that are smaller than 5.7 microns are considered physiological. Larger gaps in the form of dark spots that correspond to a disturbance of perfusion in the choriocapillaris and do not represent shadowing artifacts may be visible in various retinal diseases. These disturbances may be associated with arterial hypertension and could be used for the early detection of ocular complications due to hypertension. The SPECTRALIS OCTA Module has the option of scrolling manually through the retinal and choroidal layers by using various layer selections and also offers time-saving predefined default slabs.

Removal of projection artifacts facilitates interpretation

F. G. Holz particularly highlighted the issue of projection artifacts, which are highly relevant in the interpretation of OCTA images [1, 3, 4]. They are caused by the outer retinal layers, which are highly reflective in OCTA and act like a mirror. Vessels of the inner retina, for instance, are projected into the outer retina. For instance, the OCTA image of a patient with central serous chorioretinopathy (CSCR) shows flow around the fovea, although there are normally no vessels in that region. The OCT/OCTA fusion image, however, reveals that there is no flow over the lesion in the foveal avascular zone but definitely in the choroidal neovascularization (CNV) underneath (Figure 2). In the en face OCTA image, even the smallest neovascularizations can be visualized. The projection artifact removal (PAR) tool allows for automatic artifact removal (SPECTRALIS software 6.9) to help clinicians differentiate pathological findings from projection artifacts.

In the patient with CSCR with a reduction in visual acuity to 0.5 shown in Figure 2, it was initially unclear whether the complaints were caused by an exudation only or due to neovascularization as well. The PAR tool permitted the unambiguous identification of CNV (Figure 3), with the therapeutic consequence of anti-VEGF therapy instead of photodynamic therapy or laser coagulation. Under treatment, visual acuity improved to 0.8.

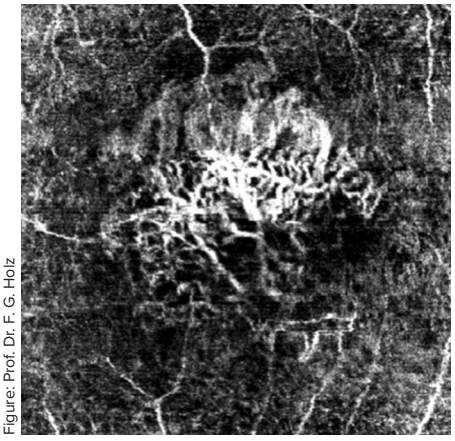

Figure: Prof. Dr. F. G. Holz

Figure 2: Central serous chorioretinopathy (CSCR) with a reduction in visual acuity to 0.5.

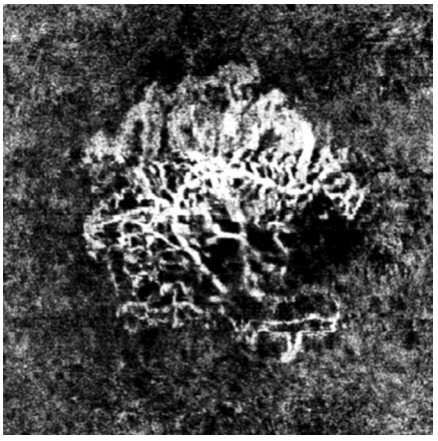

Figure 3: Same patient as in Figure 2. With projection artifact removal, a CNV can be clearly identified.

OCTA optimizes the diagnostics of neovascularization

Prof. Dr. Antonia Joussen (Berlin) considers OCTA a useful tool for the examination of vessel growth and vascular pathology in various diseases. She stated that diabetes mellitus actually

calls for traditional angiography, which displays capillary leakage, increased vascular permeability and ischemic areas. Nevertheless, she believes that microaneurysms can be visualized much better on OCTA images. She finds the non-invasive visualization of extraretinal neovascularizations fascinating. They can be precisely segmented and, thanks to the noise reduction feature, displayed even more clearly. The post-therapeutic regression of neovascularization buds can thus be non-invasively documented.

In non-proliferative diabetic retinopathy with macular edema, OCTA can display both an enlarged foveolar avascular zone and microaneurysmal changes in the deep vascular complex (DVC). To quantify such findings and achieve reproducibility, however, the layer in which the flow is located has to be defined. In OCTA, it is important to consider that hard exudates appear as black areas since they do not allow any light to pass. In the layers below, it is therefore impossible to differentiate between perfused and ischemic areas.

In patients with longstanding macular edema and extensive ischemia, the clinical question is whether the foveolar avascular zone can be reduced by means of anti-VEGF therapy. Some publications support this idea. However, using special examinations by R. Spaide as well as her own examinations, A. Joussen showed that the vessels are forced apart by the edema, particularly in the deep vascular complex, and that the disorganization is very extensive there. OCTA can also offer new insights in disease progression: Following anti-VEGF therapy, the edema completely resolves, and the vessels move closer together again, meaning that the avascular zone only seems to be smaller. This suggests that the deep vascular complex plays a much greater role in retinal vascular diseases than previously assumed. OCTA has also permitted interesting observations of the superficial vascular complex (SVC). For instance, premature babies appear to have no avascular zone, which is also true for other diseases with immature vasculature.

Case studies of glaucoma versus macropapilla and CNV without exudation

OCTA can also be helpful in glaucoma diagnostics, as demonstrated by Dr. Maximilian Pfau (Bonn), who compared two papillas with approximately equally sized excavation. While in one patient, the papilla circularly exhibited a strongly reduced Bruch's membrane opening rim width with Bjerrum scotoma, another patient had a physiological macropapilla with normal rim width and only a slightly enlarged blind spot in the visual field. Corresponding to the Bjerrum scotoma, the OCTA showed a massive loss of capillaries in a superior and inferior temporal area, whereas the capillary plexus was circularly intact in the macropapilla.

Another patient complained of metamorphopsia in the temporal visual field. The OCT showed pigment epithelial detachment (PED) with minimal cystic areas and slight evidence of subretinal fluid. The stippled hyperfluorescence in the FA was nonspecific, while in the indocyanin green angiography (ICGA) image a vascular network could be suspected. The superficial and deep vascular complexes in OCTA were un-

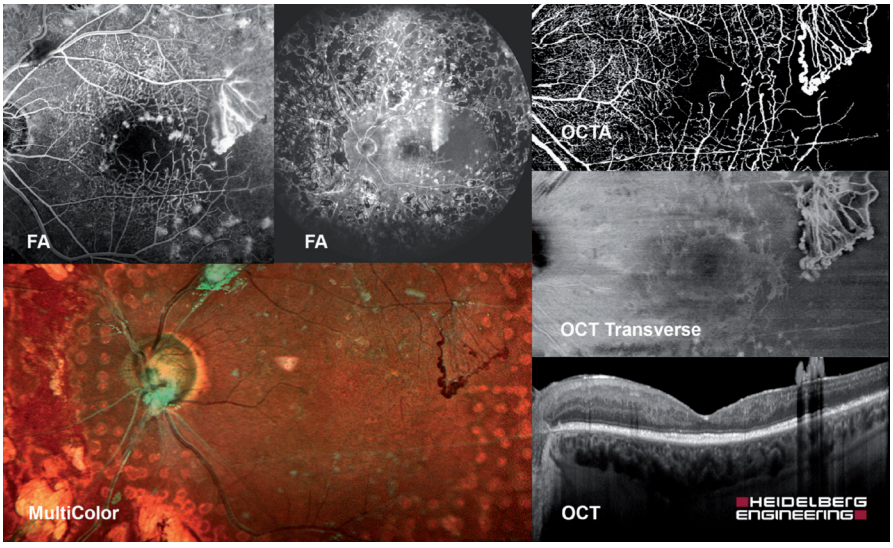

Figure: Heidelberg Engineering

Figure 4: The multimodal imaging platform SPECTRALIS can be expanded by adding the OCT Angiography Module. This allows OCTA en face imaging in addition to MultiColor fundus imaging, fluorescein angiography, structural OCT and transverse OCT imaging.

remarkable, but at the level of the PED, a neovascularization could be clearly identified. This patient was initially merely observed without treatment. In this regard, M. Pfau noted that although OCTA now supplies additional information, the treatment consequences remain unclear. Since in this case, no subepithelial, subretinal or intraretinal fluid could be identified, the antipermeability effect of anti-VEGF would be ineffective. The patient was examined at close intervals, and M. Pfau reported that the PED decreased and increased in size for months, but the CNV remained stable.

Birdshot chorioretinopathy in OCTA: Vascular loops and telangiectasia

Among the case studies presented by Dr. Dominika Pohlmann (Berlin), a 56-year-old patient who suffers from HLA-A29.2-positive birdshot chorioretinopathy is worth mentioning. The rare posterior uveitis is a chronic autoimmune disease that affects both eyes. Its exact etiology is still unknown. It is characterized by peripapillary, hypopigmented choroidal lesions with a birdshot-like distribution pattern. The disease most often begins with retinal vasculitis and vitreous opacity. The risk of developing cystoid macular edema is elevated. Additional complications include CNV, night vision problems, visual field defects and papillitis. In the FA, vascular leakages as signs of vasculitis can be appreciated and hypofluorescent lesions, so-called dark dots, as signs of chorioiditis are to be interpreted in an ICGA. Despite that, in a published study including a total of 32 patients (64 eyes) with birdshot chorioretinopathy, changes in the microvascular layer could also be displayed by OCTA. In the superficial vascular complex (SVC), and particularly in the deep vascular complex (DVC), vascular loops, telangiectasia and increased intercapillary distance were detected. With disease progression, changes in the vascular layer were especially apparent. They were characterized by vascular rarefaction due to the reduced photoreceptor layer. The study provided information on the mechanisms and progression of the disease which could be instrumental for the development of treatment options.

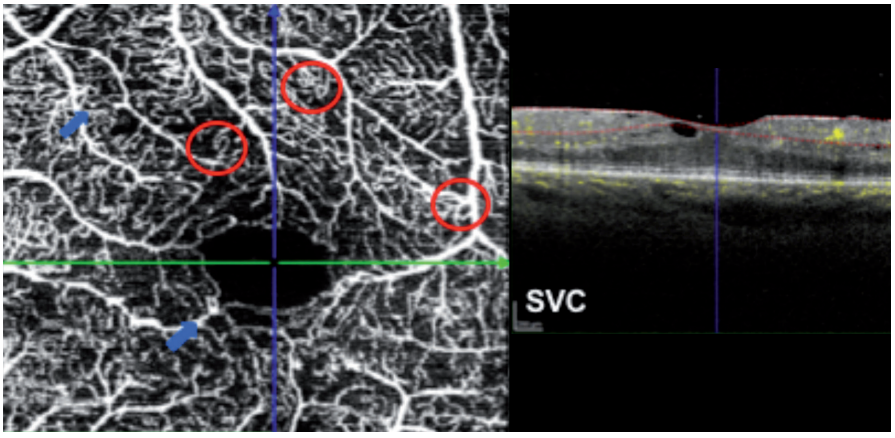

Figure: Dr. Dominika Pohlmann

Figure 5: Patient with birdshot chorioretinopathy exhibits vascular loops (circles) and telangiectasia (arrows) in the superficial vascular complex.

Conclusion

F. G. Holz concluded by noting that OCT angiography is a new, non-invasive imaging modality for retinal and choroidal vessels that supplies information beyond that offered by conventional angiography. The latest, more precise retinal segmentation options permit a clear matching to the retinal layers. With growing clinical experience and optimization of the learning curve, non-invasive OCTA will largely be able to replace invasive FA in several areas (e. g. CNV diagnostics).

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