The role of optical coherence tomography angiography (OCTA) in the evaluation of the retinal and choroidal vasculature is still evolving as we learn more about this fascinating technology. Since 2015, we have seen numerous papers published comparing OCTA to conventional fluorescein angiography (FA) and indocyanine green angiography (ICGA) to evaluate various disease states. Retina specialists are trying to process this flood of data as we lack a review of the literature regarding this topic.

I asked Colin S. Tan, MBBS, MMed (Ophth), FRCSEd (Ophth), Louis W. Lim, MBBS, and SriniVas R. Sadda, MD, to provide us with an overview of the merits of each OCTA, FA, and ICGA in evaluating various retinal and choroidal diseases as well as other widely recognized retinal vascular features. They will also summarize for us the pros and cons of each of the three angiography methods.

Obviously, OCTA is a very useful technology and its role will only increase as advances in processing algorithms continue. The insights and expertise that Drs. Tan, Lim, and Sadda share with us will be very helpful as we apply OCTA into our clinical practices.

Optical coherence tomography angiography (OCTA) is an exciting new technology that promises to revolutionize the imaging of patients with various ocular conditions. OCT scans provide high-resolution structural detail of the retina and choroid. In contrast, OCTA allows visualization of blood flow within the layers of the retina and choriocapillaris. Optical coherence tomography angiography (OCTA) is an exciting new technology that promises to revolutionize the imaging of patients with various ocular conditions. OCT scans provide high-resolution structural detail of the retina and choroid. In contrast, OCTA allows visualization of blood flow within the layers of the retina and choriocapillaris.
green dyes may cause allergic reactions.\textsuperscript{1,3} OCTA is also faster and cheaper, and hence can be performed more frequently compared to conventional angiograms.

Since its introduction, OCTA has been applied to the management of many common retinal conditions.

**AGE-RELATED MACULAR DEGENERATION**

In neovascular age-related macular degeneration (AMD), choroidal neovascularization (CNV) lesions are traditionally imaged using fluorescein angiography (FA) and indocyanine green angiography (ICGA). OCTA is useful in detecting the CNV lesion (Figure 1) and monitoring its progress during treatment. In one study, CNV lesions were reported to have been detected in 64.4% of eyes when compared to FA.\textsuperscript{4} On OCTA, the CNV lesions are located in the outer retina and choriocapillaris layers (Figure 1B),\textsuperscript{5} consistent with the pathophysiology of the disease. In contrast,
the superficial and deep retinal vascular plexuses appear normal.

**Nomenclature for CNV Lesions**

Although a consensus nomenclature is currently lacking, several patterns of CNV have been described, including:

- Well-defined patterns, which may be lacy-wheel or sea-fan shaped.
- Long, filamentous linear vessels.
- “Medusa”: The vessels arise from a large main trunk, and branch in all directions from this location.
- “Seafan”: A large main trunk or feeder
vessel is seen, but the majority of the CNV membrane radiates in one direction.

- Glomerulus shape.
- A “dead tree” appearance.

**Prognostic Indicators**

The pattern of the CNV lesion may be of prognostic significance. A study of 80 eyes reported that among eyes that clinicians judged to require treatment based on multimodal imaging, 94.9% had three or more features of neovascular AMD seen on OCTA. In contrast, 90.5% of eyes that did not require treatment had fewer than three features. The branching vascular network (BVN) has been compared with ICGA as the gold standard, the pattern of the CNV lesion characteristics following the initiation of treatment. The fine vessels exhibit attenuation, together with a reduction in total lesion area.

**POLYPOIDAL CHOROIDAL VASCULOPTHY**

Currently, ICGA is the gold standard for diagnosis of polypoidal choroidal vasculopathy (PCV). Although the ICGA diagnostic criteria of PCV and baseline characteristics have been well-described, there are only a few reports of the features of PCV seen on OCTA.

**Detection of Polyps**

Compared with ICGA as the gold standard, the polyps are detected on OCTA in 50% to 85% of eyes, respectively. The polyps were located beneath the retinal pigment epithelium (RPE) and have variable appearances on OCTA. Some polyps appear as areas of high flow signal, whereas others have reduced flow or hypoflow. In addition, in one study, a hypo-intense halo was reported surrounding the area of increased flow signal, whereas reduced flow signal was reported in 75% of eyes.

**Detection of Branching Vascular Network**

The branching vascular network (BVN) has been reported to be seen on OCTA in 70% to 100% of eyes and is located between the RPE and Bruch’s membrane. Using OCTA, BVN appears clearer compared to ICGA, and various morphologic patterns have been described, such as seafan or medusa.

**DIABETIC RETINOPATHY AND DIABETIC MACULAR EDEMA**

Diabetes mellitus causes microvascular changes in the retina, which manifests as diabetic retinopathy (DR) and diabetic macular edema (DME). Although OCT is useful in assessing the location, pattern, and extent of retinal edema, as well as detecting the presence of intraretinal fluid, it does not provide information on the perfusion of the retina. Currently, FA is required to assess the microvascular changes caused by diabetes, such as capillary dropout, enlargement of the foveal avascular zone (FAZ), microaneurysms, and the presence of retinal neovascularization.

**Microaneurysms**

Microaneurysms are a hallmark of DR and appear as pinpoint areas of hyperfluorescence on FA. Using OCTA (Figure 2), microaneurysms appear as focally dilated saccular or fusiform capillaries. The microaneurysms have been reported to occur in both the superficial and deep capillary plexuses, although they are more numerous in the deep capillary plexus (Figure 2B). There is incomplete agreement in detection of microaneurysms using FA and OCTA — lesions that are detected using FA may not be seen on OCTA scans, and vice versa. In one study, it was reported that 62% of microaneurysms detected on FA were visualized on OCTA, with a mean of 7.3 microaneurysms per eye on OCTA compared to 11.7 on FA.

**Microvascular Changes**

Patients with diabetes manifest with microvascular changes on OCTA, even in eyes without clinically evident DR. Eyes with DR have reduced paramacular vessel density, with capillary dropout (Figure 2) and increased spacing between the large vessels. In addition, vascular abnormalities such as clustered capillaries, dilated capillary segments, tortuous vessels, reduced capillary density, intraretinal microvascular abnormalities, and retinal neovascularization have been detected using OCTA. OCTA has been reported to be superior to FA in characterizing microvascular changes, in particular the boundaries of areas of ischemia. Using FA, masking may occur from fluorescein dye leakage in the intermediate and late phases of the angiogram.

**Foveal Avascular Zone**

Eyes with DR have a larger FAZ area and maximum FAZ diameter compared to normal controls when measured using OCTA (Figure 2). This was found in both the superficial and deep retinal plexuses. OCTA was closely correlated to FA findings in terms of FAZ parameters such as size, outline, and loss of perifoveal capillaries. An assessment of the FAZ parameters, however, should take into account the wide variation in FAZ parameters among normal eyes. The mean FAZ size has been reported to vary from 0.04 mm² to 0.48 mm² in the superficial plexus and 0.10 mm² to 0.70 mm² in the deep retinal plexus and is influenced
by factors such as the central subfield retinal thickness, sex, and choroidal thickness.

CONCLUSION

OCTA is a useful investigation that helps in the diagnosis, monitoring, and management of common retinal diseases. Its role will increase as advances continue to be made in imaging techniques and processing algorithms.

REFERENCES


Colin S. Tan, MBBS, MMed (Ophth), FRCSed (Ophth), can be reached at National Healthcare Group Eye Institute, Tan Tock Seng Hospital, 11 Jalan Tan Tock Seng, Singapore; email: ColinTan_eye@yahoo.com.sg.

Louis W. Lim, MBBS, can be reached at National Healthcare Group Eye Institute, Tan Tock Seng Hospital, 11 Jalan Tan Tock Seng, Singapore; email: limwy1987@gmail.com.

Srinivas R. Sadda, MD, can be reached at Doheny Eye Institute, University of California Los Angeles, 1450 San Pablo St #3000, Los Angeles, CA 90033; email: ssadda@doheny.org.

Seenu M. Hariprasad, MD, can be reached at the Department of Ophthalmology and Visual Science, University of Chicago, 5841 S. Maryland Avenue, MC2114, Chicago, IL 60637; email: retina@uchicago.edu.

Disclosures: Dr. Tan receives research funding from the National Medical Research Council Transition Award (NMRC/TA/0039/2015) and travel support from Bayer, Heidelberg Engineering, and Novartis. Dr. Lim has no financial disclosures. Dr. Sadda serves as a consultant for Allergan, Genentech, Roche, Regeneron, Alcon, Bausch & Lomb, Optos, and Carl Zeiss Meditec. He also receives research support from Allergan, Genentech, Optos, and Carl Zeiss Meditec. Drs. Tan, Lim, and Sadda have no financial or proprietary interests in the subject of this manuscript. Dr. Hariprasad is a consultant for Alcon, Allergan, Bayer, OD-OS, Clearday Biomedical, Ocular Therapeutics, Janssen, Leica, Spark, and Regeneron.