It is necessary to distinguish high myopia from pathological myopia.

BY PROF. JOSÉ M. RUIZ-MORENO, MD, PHD

In recent years, a new classification of high myopia (HM), regarding the study of the eye fundus, has emerged. Myopic maculopathy can be classified into: myopic atrophic maculopathy (including diffuse atrophy, patch atrophy, and geographic atrophy); myopic neovascular maculopathy with myopic choroidal neovascularization (CNV), and tractional myopic maculopathy.

In order to identify this new pathology, it is necessary to be able to distinguish between high myopia, especially in cases beyond -6 diopters (D) and pathological myopia (PM), which is due to elongation of the eye, producing a staphyloma, the most characteristic finding of HM (Figure 1). Improvements in imaging technology make this new classification possible.

Complications resulting from PM are a frequent cause of blindness worldwide. PM patients can suffer visual loss due to macular, peripheral or optic nerve disorders. Posterior pole deformations and the appearance of staphylomas promote the development of these complications.

Posterior staphylomas are a typical finding of both HM and PM. This deformity is, in fact, one of the main reasons why it is difficult to obtain good quality images of these patients.

IMAGING EVOLUTION

It has been traditionally difficult to obtain good quality images in HM cases using OCT. Currently, we can use autofluorescence to, for instance, to delineate an atrophy patch in the eye fundus, and we can also use optical coherence tomography angiography (OCTA).

Figure 1. Elongation of the eye resulting from staphyloma.
Imaging improvements arrived with the evolution from time domain OCT (TD-OCT) to spectral domain (SD-OCT) and offered ophthalmologists an important improvement in the quality of OCT HM images. While TD offered sufficient quality, it typically did not provide enough information due to limitations in the technology. SD-OCT offered more detailed information, but there were still shortcomings. The options we had were to tweak the software to try to improve quality, or to average a high number of scans to try and obtain better imaging.

Currently, the optimal way to get clear HM images is to use Swept Source-OCT (SS-OCT). SS-OCT’s light high penetrance can visualize deep layers in the eye, such as the choroid and even the sclera. Another benefit of SS-OCT is that it can visualize both the vitreous and choroid in a single scan that are uniformly clear and noise-free. The DRI OCT Triton automatically detects seven boundaries, including the chorio-scleral interface, and enhances visualization of outer retinal structures, and deep pathologies.

Using SS-OCT, the imaging quality of HM eye has improved. This has enabled us to define new disease states, such as myopic traction maculopathy (MTM) and choroidal cavitations (CC) among others; and has permitted a simpler and clearer study of posterior staphylomas. Myopic staphylomas are defined as evaginations of the posterior wall of the eye with a curvature radius that is smaller than the curvature of the ocular structure surrounding it. This increase in axial length together with tissue thinning is responsible for the appearance of myopic maculopathy (MM) and its different manifestations. Various clinical signs of HM that we include under the name MM include atrophy, CNV, MTM, and dome shape maculopathy.

Using SS-OCT, and especially its 12 mm, single-line scanning mode, we are able to analyze in detail and study curvature modifications that staphylomas induce to the posterior pole of the eye, helping us classify them. This is especially useful in complex staphylomas. Horizontal scans show a progressive and regular augmentation of concavities as the staphyloma increases, from minimal to deep concavities that may even include the optic nerve. In some cases, the optic nerve will stay outside of the concavity, in others it will lay at the bottom of the concavity, in some others a convexity or sinusoidal profile (ascending or descending) can be seen. The majority of vertical scans are concave and regular. Of the more than 700 HM patients that we have studied, vertical scans show concave staphylomas in more than 90% of cases; very few exhibit dome shape morphology.

If we study myopic CNV, we can establish three different stages using OCT: active CNV with fluid; fibrotic scar caused by the evolution of the CNV; and atrophy around the fibrotic scar (Figure 2).

MTM is a new entity that we are able to study with OCT. We can detect it with SS-OCT and obtain high-quality images. We can separate the internal from external schisis, which can manifest concurrently in the same patient. SS-OCT can also be used to image foveal detachments and to detect and monitor myopic macular holes. It was not possible to do this with so much detail before the advent of SS-OCT.

Dome- shaped maculopathy occurs when there is a dome shape in the macula, along with the presence of fluid between retinal pigmented epithelium and the neuroretina. It is possible to study this defect thoroughly and with accurate detail using SS-OCT. Swept source imaging also provides vivid details of the sclera making it possible to measure its thickness in our HM patients.

Using SS-OCT, especially large, single-scan protocols (9-12 mm) with horizontal and vertical orientation, we can see and analyze the curvature modifications produced by staphylomas in the posterior pole and the involved structures. This is especially useful in complex staphylomas.

SS-OCT enables us to detect macular pits and monitor lacquer cracks; we can also detect and define CC and study myopic retinoschisis in the macula and around the optic nerve. The pathogenesis of all of these problems is the elongation of myopic eyes.

In conclusion, SS-OCT grants significant improvements in the quality of OCT images that we are able to obtain from HM eyes, and this has resulted in the identification of new myopic-related pathologies now known as MTM and CC, among others, as well as advancements in the visualization and study of posterior staphylomas.

**Figure 2.** Myopic choroidal neovascularization.

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Managing CNV With OCTA

Monitoring of exudative AMD at its best.

BY FLORENCE COSCAS, MD

Optical coherence tomography angiography (OCTA) is an emerging imaging technique that provides a clear visualization of blood flow both in retinal and choroidal tissue. This technology is able to obtain depth resolved images of a given retinal or choroidal tissue and provide a layer-by-layer visualization of the entire choroidal neovascularization (CNV). Today, I would like to discuss diagnosis and follow-up of CNV with Triton Swept Source Optical Coherence Tomography – Angiography (Topcon). Swept source-OCT (SS-OCT) dye-free angiography is a transformative approach to imaging ocular vessels based on flow, as opposed to simple reflectance intensity.

This innovative technology is excellent for noninvasive monitoring of the exudative age-related macular degeneration (AMD) because both functional blood flow and morphological fluid accumulation information is provided from a single scan. Such simultaneous monitoring, based both on OCTA activity criteria and structural OCT findings, may help in the diagnosis of CNV, guiding decisions for treatment, as well as in monitoring the evolution of CNV and its response to treatment.

MULTIMODAL CAPABILITIES

Structural and high-resolution OCT-B is effective for identifying exudative reaction and ICG-A to have the exact total CNV extension. The hyper-flow signal corresponding to active CNV can be obtained quickly and easily and without dye; the type of CNV can be detected and analyzed on different segmentations.

Multimodal imaging of type II CNV shows leakage on fluorescein angiography (FA), and indocyanine green angiography (ICGA) eliminates retinal angiomatous proliferation (RAP) or polypoidal choroidal vasculopathy (PVC). Structural OCT-B shows pigment epithelial detachment (PED) and subretinal hyper-reflective exudation (SHE) on high resolution. Topcon OCTA gives a wonderful hyper signal in a few seconds with good tracking.

ACTIVE CNV CRITERIA

OCTA activity criteria of CNV were described by Professor Gabriel Coscas, MD, and colleagues with Heidelberg technology 2 years ago.¹

- **Shape:** A well-defined CNV lesion (tortuous lacy-wheel shaped).
- **Branching pattern:** Numerous tiny capillaries.
- **Anastomoses:** Presence of anastomoses and loops.
- **Morphology of the vessel termini:** Presence of a peripheral arcade.
- **Perilesional Halo:** Presence of a perilesional hypo-intense halo, considered as regions of choriocapillaris alteration.

These criteria provide a basis for analysis and evaluation of CNV activity and the degree of CNV proliferation, persistence and/or recurrence; conversely, they provide for the stabilization and healing with vessels that become mature or quiescent.

Furthermore, last year we evaluated split-spectrum amplitude-decorrelation angiography (SSADA) technology with COFT-1 and found that the sensitivity and the specificity were excellent. We found the same parameters with Topcon instruments using the full spectrum algorithm with analysis ratio. OCTA criteria for active CNV are lacy wheel shaped with multiple anastomoses and loops, dense branching, peripheral arcade, and hyper-intense perilesional halo on Bruch segmentation. The presence of anastomoses and loops, numerous branching and tiny capillaries, and the presence of a peripheral arcade are easily detectable at diagnosis and during follow-up.

This technology enables us to recognize type II CNV based on the appearance of dense branching and numerous tiny capillaries with a complete peripheral vascular arcade. Hemorrhages are detectable on color images, fluid is visible on the OCT-B scan, and leakage is visible on the fluorescein angiograph (FA). The imaging modalities are all included in the complete version of Topcon’s SS-OCT angiography. OCTA allows complete description of the CNV activity and CNV type.

When initially diagnosing CNV, we use these criteria of activity: sea-fan shape, multiple anastomoses and loops, branching, peripheral arcade, and perilesional halo. After injection, we use these criteria of quiescence: absence of a defined shape, no branching, only large and voluminous
mature vessels without anastomoses, no loops, no arcade, and no peri-lesional halo.

DRI OCT Triton SS OCTA fosters effective follow-up and treatment with a point-by-point post-processing tracker. For example, after a loading dose of anti-VEGF, we might observe dramatic decrease in hyper signal, hyper flow, and PED. We may continue to inject until visual acuity is stable. In another instance, if after 3 months we observe persistence of partial peripheral arcade, we would continue to inject, and then if after 4- and 6-month follow-ups we observe regression of loops, branching, and vessel termini, we would adapt the rhythm of injection to those findings.

CUSTOMIZED FOLLOW-UP

In routine practice, when patients ask if a treated lesion is still active, we can respond by checking the criteria. If we have, for instance, a well-defined shape, few anastomoses, and partial peripheral arcade, the CNV is still active with three of five essential criteria corresponding to fluid persistence on OCT-B scan. A closer look at the still active hyper-signal on the OCT-B scan indicates no colorized flow, indicating that it is an inactive lesion. CNV activity offers diagnosis guidance, but OCTA enables a customized follow-up approach. We can adapt the rhythm of injections with more qualitative information (Figure). When improvement is seen at each follow-up visit, we can choose to treat and extend for longer periods. Evaluation of the findings in those types of cases provide a solid foundation for the decision to treat or not to treat.

That is not always the case. There are instances where OCTA will show an evolution toward extensive atrophy or an evolution toward an extensive scarring process with an increase of fibrosis. We know that an active hyper-signal on OCTA corresponds to CNV, but cases such as those that evolve toward extensive atrophy, scarring, and increased fibrosis need more than injections. Comprehensive multimodal imaging provides diagnostic information and specific treatment about these inflammatory CNV cases, which are distinctly different from those of AMD at diagnosis. These CNV are more fibrous and are associated with dilated choroidal vessels. Imaging shows voluminous hyper-signal, less branching, and less vessel termini.

SS-OCT AND OCTA: GAME CHANGERS

Two game-changing benefits of SS-OCT and OCTA are no dye injection and no side effects. We have to perform, however, a careful segmentation to identify the presence and the type of hyper-signal on OCTA and to recognize all artifacts, such as back-shadowing on OCT-B scans, and other artifacts to avoid potential diagnostic pitfalls.

In conclusion, I find that OCTA provides a complete description of type and activity of CNV and active versus quiescent versus scarring. Triton OCTA achieves a customized follow-up adapting rhythm of injections. SS-OCT angiography is a useful tool in clinical practice, and we are waiting for quantification of flow.

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SS-OCTA in RAP Lesions

SS-OCT is extremely effective for monitoring flow reduction following intravitreal anti-VEGF treatment of RAP lesions.

BY LUIS ARIAS BARQUET, MD

Retinal angiomatous proliferation (RAP) or type 3 neovascularization, is a subtype of age-related macular degeneration (AMD) characterized by intraretinal new vessels that can penetrate in the subretinal space and then eventually grow into the subretinal pigment epithelium (RPE) space. Currently, multimodal imaging, including fluorescein angiography (FA), indocyanine green angiography (ICGA), and cross-sectional optical coherence tomography (OCT) offer well-defined clinical findings for the diagnosis of RAP lesions.

Until recently, ICGA was considered the gold standard diagnostic method for this condition. Swept source-OCT (SS-OCT), however, is growing in use because it allows for accurate analysis of the choroid due to the use of a longer wavelength in comparison to that which is used in spectral-domain (SD) OCT. This is especially important in RAP lesions, in which the choroid is thinner compared with other AMD subtypes. In addition, the typical RAP findings consisting of RPE detachment, intraretinal cysts, drusen, and hyperreflective dots can be easily identified with SS-OCT.

IMAGING IMPROVEMENTS

In addition to being a useful tool for RAP diagnosis, SS-OCT is extremely effective for monitoring flow reduction following intravitreal anti-VEGF treatment of RAP lesions. SS-OCT provides a significant improvement over conventional OCT due to its long wavelength scanning light (1050 nm) and because of its superior penetration of the deeper layers of the eye. In clinical use, I also find SS-OCT’s En Face imaging modality to be ideal for observing RAP associated cysts. En Face imaging allows for independent dissection of the vitreoretinal interface, retina, RPE, and choroid. It also uniquely projects these layers so that macular pathology throughout the posterior pole can be studied and correlated with a patient’s symptoms, their abnormality, and their progression. I find that En Face technology is easy to use and helpful on a daily basis to clearly visualize segmentations of these diseased vessels.

OCT angiography (OCTA) is also quite effective in our efforts to diagnose and monitor RAP with its capability to demonstrate flow when these lesions are in the early stages of growth. Moreover, OCTA is valuable for its ability to quantify flow reduction following intravitreal therapy. These findings are more apparent in the deep retinal plexus of the OCTA. On the other hand, in some cases neovascularization is clearly shown in the outer retina of the OCTA. Likewise, a reduction in the lesion area can be monitored with OCTA following intravitreal therapy.

RAP REVIEW

RAP lesions typically evolve through three clinical vasogenic stages, as described by Yannuzzi and colleagues.1 In stage 1, intraretinal neovascularization (IRN) involves proliferation of intraretinal capillaries originating from the deep retinal complex; this is associated with some moderate staining or leakage but is not very significant on FA. In stage 2, subretinal neovascularization (SRN) involves growth of the retinal vessels into the subretinal space. This is the stage when these lesions are diagnosed as pigmented epithelial detachment and cystoid macular edema. Stage 3 occurs when CNV can clearly be determined clinically or angiographically.

In many cases, RAP is not distinguishable from other retinal conditions. In the CATT trial investigators observed that more than 10% of the study cohort were diagnosed as having RAP lesions in a study comparing visual acuity and morphologic outcomes in eyes of patients with neovascular age-related macular degeneration (NVAMD) treated with anti-VEGF therapy.2

RAP lesions are different from ordinary wet AMD in that they tend to have less macular fluid, less leakage on FA and less scarring. They are, however, more likely to develop geographic atrophy. In polypoidal lesions, the choroid is very thick in comparison to RAP lesions where the choroid is typically thinner. OCTA, as well as En Face technology, can be used effectively in these cases to observe patchy vessel atrophy to aid in precise diagnosis, treatment, and monitoring. I find that En Face technology is easy to use and helpful on a daily basis to clearly visualize segmentations of these diseased vessels.
RAP IMAGING DEVELOPMENTS

As imaging technology improvements develop, new suggestions and recommendations regarding the most effective way to diagnose RAP are emerging as well. For instance, Kim and colleagues propose that RAP can be diagnosed without the assistance of ICG angiography. They say that if at least three of the following five features are present, a diagnosis of RAP can be made: sub-foveal choroidal thickness less than 200 microns; presence of intraretinal fluid; absence of sub-retinal fluid; a gently sloping dome-shaped RPE detachment or trapezoid-shaped RPE detachment without an obvious peak; and intra-retinal mass lesion.3

Ravera and colleagues have proposed a multi-imaging approach to diagnosing these lesions.4 Their retrospective study utilized FA, ICGA, spectral domain OCT, and infrared confocal scanning laser ophthalmoscopy (IrcSLO) imaging to evaluate markers for RAP. These included the presence of shunting of blood flow, the presence of light leakage on ICG angiography, and with the spectral domain OCT, the presence of intraretinal cysts, and RPE interruption or a break in the RPE on reticular pseudodrusen with infrared autofluorescence and spectral domain OCT. They concluded that all the signs investigated were strongly associated with RAP lesions. A multimodal imaging approach may help differentiate subtypes of neovascularization.

In addition to new diagnosis methods and criteria, a new classification system for type 3 neovascularization has been proposed.5 Investigators retrospectively analyzed 34 eyes with new-onset type 3 neovascularization using SD-OCT. The new classification defines the following three stages of type 3 neovascularization. Stage 1 consists of a larger intra-retinal hyper-reflective lesion associated with CME, but without outer retinal disruption; stage 2 comprises outer retinal disruption that occurs with RPE disruption in most of the cases; and stage 3 is defined by an intra-retinal hyper-reflective lesion that extends through the RPE to vascularize a drusenoid pigment epithelial detachment creating a serous component of the pigment epithelial detachment.

We, too, are performing our own studies aimed at gathering additional information regarding imaging and diagnosis of type 3 neovascularization – RAP – including our current trial, which is open and enrolling patients. We have enrolled 33 eyes from 26 patients diagnosed as having RAP lesions so far. We have more female than male participants, which is not surprising because this disease predominantly affects women. The mean age of participants is 79; this condition affects more elderly people than other subtypes of wet AMD. All participants were imaged with fundus photography, SS-OCT, En face, and OCTA. All of this multimodal technology is available in a single device – Triton (Topcon).

Imaging from selected cases of these 33 eyes illustrates Triton’s wide range of options and their value in the diagnosis and treatment of RAP. For instance, this 76-year-old male patient presented with 20/200 visual acuity, and an intra-retinal mass was clearly imaged with OCTA, En Face, and SS-OCT. En face presented a perfect map of the intra-retinal cyst and its evolution over time. The patient received three injections of Aflibercept, and we saw a clear reduction in the intra-retinal mass (Figure).

As we continue to enroll patients in this study, we expect our findings to reflect what we have seen anecdotally. SS-OCT is helpful in the diagnosis of RAP lesions; OCTA is an effective aid in monitoring flow reduction following anti-VEGF therapy in RAP lesions; and En Face is excellent for monitoring intra-retinal cyst reduction, among other things.

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Evaluation and follow-up of choroidal tumors requires multimodal imaging. Swept source-OCT (SS-OCT) is one of the options that can be used effectively. An advantage of SS-OCT is its longer wavelength of 1050 nm, which enables better penetration of the retinal pigment epithelium (RPE) and choroid and better analysis of choroidal tumors.

SS-OCT and swept source-OCT Angiography are both helpful for the diagnosis and follow-up of choroidal tumors, but they have their limitations as well. SS-OCT enables an accurate diameter measurement, however, measurement of the thickness of most pigmented tumors remains elusive. Angio OCT enables early diagnosis, as well as follow-up of radiation maculopathy and analysis of choroidal tumor vessels. However, capillary density quantification is not yet possible with either of these modalities. These observations stem from a small preliminary study that we recently performed.

STUDY PARAMETERS

The purpose of the pilot study was to describe and compare imaging capabilities of various modalities for the diagnosis of a series of choroidal tumors. Images were acquired with spectral domain OCT (SD-OCT), enhanced depth imaging OCT (EDI-OCT), and SS-OCT. Retinal and choroidal vasculature of these tumors and macular retinopathy were also analyzed using swept source OCT angiography. Choroidal and retinal tissue involvement and the vascular components of these tumors were analyzed and comparisons were drawn between the swept source and EDI-OCT findings.

We evaluated 18 cases: nine nevi, four melanomas before treatment, two melanomas with radiation maculopathy, two hemangiomas, and one choroidal metastasis. Multimodal imaging was performed using Heidelberg’s HRA-OCT with EDI mode, and Topcon’s Triton SS-OCT. We also used color fundus photography, ultrasonography (US), fundus auto-fluorescence (FAF), fluorescein angiography (FA), and ICG angiography.

Overall, we found that measurement and analysis of the vascular components of posterior pigmented nevi, melanomas, and hemangiomas was more precise using SS-OCT and EDI-OCT. Characteristics of retinal involvement associated with the tumors that we studied were the same using both types of OCT analysis. Retinal maculopathy was diagnosed earlier, and we were able to evaluate it better with A-OCT than with fluorescein angiography. Swept source OCT angiography and A-OCT showed superficial and deep retinal capillaries; choroidal vessels decreased density.

Our study findings suggest that OCT analysis of choroidal tumors compared with B-echography and fluorescein and indocyanin analysis is limited to posterior tumors and lacks tumor density and dye impregnation and vascular filling. Both SS-OCT and EDI-OCT, however, may offer improved imaging. They appear to be a significant contributing factor in the diagnosis of choroidal tumors compared with SD-OCT. Diagnosis and evaluation of retinal maculopathy is also better diagnosed and followed up using both SS-OCT and A-OCT.

Because of the small number of cases, it was impossible to draw statistical conclusions about all of our findings. We could measure the diameter, however, in 78% of our cases, with a slightly larger diameter observed with swept source compared to EDI for hemangiomas and metastasis. Thickness measurement was only possible in 38% of all cases; the limitation was the presence of a melanotic tumor.

EDI-OCT also appears interesting for the accurate measurement and follow-up of posterior pole nevi and is 55% underestimated compared with ultrasound, similar to Shields’ findings.1 For pigmented nevi analysis, SS-OCT has been proven by Francis to be more efficient than EDI-OCT analysis.2 Angio OCT could also be worthwhile for the differential diagnosis of melanomas compared to nevi, since it has been observed that there is retinal capillary density decrease compared to the contralateral eye, only in melanomas. Angio OCT also enables us an early diagnosis of radiation maculopathy.

SELECTED STUDY OBSERVATIONS

Both OCT machines displayed similar features of the nevi cases: regular dome shape with choroidal shadowing tumor. The main sign was a thinned choriocapillary
layer at the nevi location in more than 80% of the nevi tumors. RPE atrophy was observed in 44% of nevi, and RPE loss was observed in 11% of the nevi cases. Photoreceptor loss was observed in 44% of these cases, and irregularity of external nuclear and plexiform layer was seen in 11%, while serous detachment was observed in 22% of the nevi cases.

In our melanoma cases, both OCTs displayed similar features of posterior cone shadowing, anterior chorio-capillary compression, and the presence of shaggy photoreceptors, which is a main characteristic of melanomas compared to nevi, according to Shields and West. Lipofuscin, which are associated with serous detachment deposits, were also seen in all melanoma cases.

In one of our medium-size melanoma cases, both angioand fluorescein angio show large choroidal vessels. SS-OCT showed shaggy photoreceptors, and angio OCT with swept source showed a large, abnormal choroidal vessel associated with retinal capillary density decreased in the deep and superficial plexus.

In one of our melanoma cases that was treated by proton beam, we can see with FA that there is radiation retinopathy, as well as radiation maculopathy. We followed this with HRA-OCT angio and saw a decrease in the superficial and deep capillary layers with time. This was also observed with SS-OCT, which showed progressive decrease in capillary density at the superficial and deep capillary layer.

Choroidal Hemangioma was well-diagnosed with FA and ICG in our study. Also, swept source and EDI showed that it is an acutely dome-shaped and smooth tumor with characteristic signs of thick, sponge-like choroidal vessels without compression and partial posterior shadowing. Sub-retinal fluid is always associated with these cases, but thickness could not be measured because the tumor was too thick. SS-OCT angio showed dilated intratumoral choroidal vessels.

For one particular macular choroidal tumor, a diagnosis could not be made by angio, FA, or ICG, but was made by SS-OCT showing the characteristic irregular lumpy, bumpy anterior contour that has been shown by Shields to be a diagnostic sign found in 64% of cases (Figures 1 and 2).

In conclusion, SS-OCT and swept source AOCT are effective for the diagnosis and follow-up of choroidal tumors. With respect to B-echography and fluorescein and indocyanin angio analysis, both SS-OCT and EDI-OCT appear to be very contributive, compared with SD-OCT, for the diagnosis and follow up of choroidal tumors and should be systematically performed during evaluation. A-OCT analysis is also important for radic maculopathy diagnosis, as well as for evaluation of choroidal tumor vascular components; more studies should be performed for this evaluation.


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