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Use of Optical Coherence Tomography in the Diagnosis and Management of Uveitis

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Introduction

Uveitis is a challenging disease. It represents a major cause of ocular morbidity worldwide. More than half of all patients with uveitis develop sight threatening complications related to their disease, and up to 35% of patients suffer severe visual impairment ^{1, 2}. Uveitis and its complications are responsible for 5% to 10% of all causes of legal blindness in developed countries ^{1, 3}. The causes of uveitis are numerous, and include infectious conditions, autoimmune diseases, trauma and tumors (masquerade syndrome). To develop an accurate differential diagnosis, clinicians must consider all available information, including the patient history, anatomic location of the inflammation (anterior or posterior), character (granulomatous vs. non granulomatous), laterality, and chronicity of inflammation. Moreover, diagnostic tools, such as fluorescein angiography (FA), indocyanine green angiography (ICG), optical coherence tomography (OCT) and ultrasound, play an important role in the diagnosis and in the management of the uveitis ⁴.

Until recently, fluorescein FA was the primary imaging modality used to detect macular edema and other features related with uveitis like choroidal neovascularization and serous retinal detachment. Although FA is useful for determining the presence of vascular leakage, this technique does not provide any three-dimensional anatomic information about the retinal layers, the retinal pigment epithelium (RPE) or the choroid. The development of OCT makes it possible to have high-resolution cross-sectional images of the retina or optic nerve.

OCT is now proven to be an effective noninvasive method in detecting pathologic features in uveitis and is rapidly gaining popularity as an ancillary exam. It may be used to assist in the diagnosis of uveitis and may be repeated safely during follow-up to monitor response to any intervention ^{5, 6}.

Recently, the introduction of spectral domain OCT (SDOCT) has improved image quality. Spectral domain, a type of fourier domain detection, uses a high-speed spectrometer to

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Conflict of Interest

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measure light echoes from all time delays simultaneously enhancing OCT capabilities. The reference mirror does not require mechanical scanning. Improved sensitivity enables dramatic improvements in sampling speed and signal-to-noise ratio^{7,8}. SD detection, coupled with improvements in light sources, achieves axial scanning speeds of greater than 20,000 A-scans per second with an axial resolution of 3 μm to 7 μm in the eye. Consequently SDOCT has the advantage of detecting small changes in the morphology of the retinal layers and subretinal space, allowing for precise anatomic detection of microstructural changes that may corresponds to progression or regression of chorioretinal lesions or complications secondary to uveitis⁶. In addition, SDOCT is also used for anterior segment imaging where it may illustrate features of anterior uveitis and its complications.

This review focuses on SDOCT imaging in uveitis. It will first review OCT imaging in anterior uveitis; then, it will describe the image features observed in the posterior uveitis.

OCT and Anterior Uveitis

Anterior segment optical coherence tomography (ASOCT) allows the visualization of various features of the anterior segment, including iris thickness, anterior chamber (AC) depth, the extent of anterior synechiae, iris bowing, and angle lesions. *In vivo* cross-sectional imaging of the anterior segment from ASOCT is particularly useful in the presence of corneal opacity and ocular inflammation, where it is often difficult to use slit-lamp biomicroscopy to visualize the anterior segment. It can serve as a non-invasive method for assessment of anterior uveitis and its complications⁹, and can detect features of uveitis such as inflammatory cells, keratic precipitates (Figure 1A), fibrin (Figure 1B), and corneal edema (Figure 1C). In addition, positive posterior segment findings on OCT (*e.g.* increased macular thickness, retinal edema) can often reinforce anterior uveitis findings and may suggest its manifestation as part of a panuveitis associated with systemic illnesses such as sarcoidosis and Vogt-Koyanagi-Harada syndrome^{9,10}.

Anterior Chamber Inflammatory Cells on ASOCT—Lowder et al.¹¹ used a high-speed prototype SDOCT (2,000 A-scan/sec, 1.3 micron wavelength) to characterize inflammatory and pigmented cells in the anterior chamber (AC) as hyperreflective spots. In 28 non-granulomatous anterior uveitic eyes, a significant correlation was found between the cell count on OCT and the clinical grading from slit-lamp biomicroscopy. Similarly, a significant correlation was found between 6 eyes with pigmentary particles on OCT and clinical grading.

Another study by Agarwal et al¹², inflammatory cells in the AC were visualized on ASOCT as hyperreflective spots (Figure 1D) in eyes compromised AC visualization secondary to corneal edema or opacity. In their study of 62 eyes with AC inflammation, 91.6% of eyes with corneal edema (n=12) had identifiable hyperreflective spots consistent with AC cells on ASOCT, which were manually counted and graded using the standardization of uveitis nomenclature (SUN) criteria. At the same time, keratic precipitates (Figure 1A) were seen in 12 eyes as discrete hyperreflective spots attached to the cornea endothelium, and fibrinous membrane (Figure 1B) were detected in 4 eyes in the papillary area or endothelium of the cornea.

Tuberculosis—In the diagnosis of uveitis secondary to tuberculosis, SDOCT has been demonstrated to be useful in assessing anterior and posterior lesions such as iris or choroidal tuberculoma^{13, 14}. In a case study by Noriyasu et al¹⁵, imaging of a patient with tuberculosis showed corneal edema, narrowing and synechiae of the iridocorenal angle, as well as exudates and inflammatory cells in the anterior chamber. ASOCT showed the anatomic structures of the anterior segment, which was helpful to confirm the site of accumulated necrotic cells and exudates.

OCT and Posterior Uveitis

Patients with posterior uveitis can develop complications including macular edema, epiretinal membrane, vasculitis, retinal artery or vein occlusions, retinal necrosis, tractional retinal detachment, choroidal or retinal neovascularization and vitreal or intraretinal bleeding^{16, 17}. In this section, the most of these complications and how OCT can be helpful in the management of them will be covered.

Macular Edema

Macular edema is the leading cause of visual loss in uveitic patients, and is a predictable feature of pars planitis, Behcet's and sarcoid uveitis, HLA-B27 related uveitis and birdshot retinochoroidopathy. It is present up to 64% of patients with intermediate uveitis and may lead to irreversible visual loss in 8.5% of cases¹⁸. Early detection of macular edema is critical as chronic intra-retinal fluid may permanently damage the inner and outer retina, leading to irreversible vision loss from retinal atrophy. However, if diagnosed early and appropriate treatment is initiated, the retina may deturgesce with corresponding improvement in vision.

Prior to the advent of OCT, fluorescein angiography was the standard tool used to diagnosis macular edema. The finding of a "petaloid" pattern of late leakage is classic for the diagnosis of cystoid macular edema. However, angiography only provides a qualitative assessment of retinal edema. Its interpretation is subjective, and may be hindered in the presence of hemorrhage, pigment migration or lipid exudation. Because of this, angiography is less suitable tool for tracking patients or monitoring response to therapy. Furthermore, it is invasive, requiring the injection of sodium fluorescein dye. Vasovagal episodes, nausea, and mild allergic reactions are not uncommon. Anaphylaxis and death fortunately are rare but have been reported¹⁹.

Since its introduction, OCT has quickly become a necessary adjunct in the diagnosis of uveitic macular edema. When compared to angiography, time domain OCT has been found to be 96% sensitive and 100% specific in the detection of macular edema²⁰. SDOCT has been shown to be even more sensitive than FA in the diagnosis of CME, not surprising given its superior resolution and sampling⁶. OCT also has obvious advantages in that it is non-contact and non-invasive, which makes it a near perfect tool for following patients longitudinally, before and after therapy. Eye tracking and other hardware improvements have improved the reproducibility of its measurements. As such, it gives clinicians an ability to follow macular edema in a quantitative fashion which is clearly essential in assessing response to therapy.

There appears to be two clear patterns of macular edema in uveitic patients: diffuse macular edema (Figure 2) and cystic macular edema (CME) (Figure 2)^{21, 22}. Subretinal fluid can co-exist with either pattern. The pattern of macula edema does not seem to correlate with the anatomic location of the uveitis. In one study, diffuse macular edema and CME represented 41.8% and 58.2% of macular edema respectively²². In diffuse macular edema, there is a generalized increase in macular thickness with a “spongy” appearance to the retina. It is theorized that this appearance represents swollen Muller cells. As edema persists, the Muller cells necrose and cystoid spaces ultimately appear^{23, 24}. The fact that there is higher incidence of CME in patients with long-standing uveitis is evidence for this²². Serous subretinal fluid is also commonly found with macular edema. Like intraretinal edema, the presence of subretinal fluid does not seem to correlate with any category of uveitis²². Finally, these studies also illustrated that there is a negative correlation between macular thickness or volume and visual acuity, similar to that found in diabetic macular edema^{21, 22}.

The junction between the inner and outer segments of the photoreceptors (IS/OS junction), and the junction between the inner segments and the Müller cells, the external limiting membrane (ELM), can be clearly detected on SDOCT images. The integrity of the IS/OS junction can be used as a predictor factor of visual acuity recovery after macular edema treatment or epiretinal membrane removal.

Epiretinal membrane (ERM) formation is also clearly linked with intermediate uveitis, and is noted on fundus exam in 30% of patients with intermediate uveitis with or without macular edema¹⁸. ERM appears on OCT as a hyperreflective line immediately above the nerve fiber layer. In one study of uveitic macular edema, OCT was nearly twice as sensitive in detecting the presence of ERM¹⁸. Often, there is an associated component of vitreo-macular traction. Thus, in these cases, it is presumed that there is a tractional as well as inflammatory etiology of the macular edema.

Epiretinal membrane

Many factors may lead to the development of epiretinal membranes. Epiretinal membranes cause variable effect on visual acuity. Depending on the severity, epiretinal membranes may lead to tractional retinal detachment, and or macular edema which may cause significant reduction in visual acuity²⁵. Epiretinal membranes are identified clinically by the presence of white striae or stress lines, straightening of the vessels (superficial hemorrhage might occur), and tortuous vessels²⁵.

OCT is helpful in identifying epiretinal membranes, and in grading the severity of traction. On OCT, an epiretinal membrane appears as a hyper reflective thin band at the vitreoretinal interface, immediately above the nerve fiber layer, that is distinct from the underlying retina²⁵. The presence of fibrillary changes underneath the membrane is a sign of strong adherence of the membrane to the retina, which might be helpful in planning surgery (figure 3). In one study of uveitic macular edema, OCT was nearly twice as sensitive in detecting the presence of ERM. OCT is also helpful in the post operative period to monitor the restoration of normal retinal architecture.

Retinitis

Posterior uveitis can cause severe inflammation within the retina that leads to necrosis. Retinitis is most often associated with acute retinal necrosis, progressive outer retinal necrosis, and acute toxoplasmosis, but can also be seen with neoplastic and inflammatory conditions ²⁶. Retinitis is recognized clinically as an area of retinal whitening (Figure 3). On OCT, the initial focus of retinitis appears as a hyper reflective area in the inner retina with localized shadowing of the outer retinal layers (Figure 3). As the inflammation progresses, retinal necrosis occurs. Retinal necrosis results in the formation of cystic spaces which are easily visible on OCT (Figure 3). In acute toxoplasmosis chorioretinitis, a focal area of retinitis starts in the inner retinal layers, and as the disease progresses the rest of the retina and choroid become affected ²⁷.

Serous retinal detachments

Serous retinal detachment is commonly observed in patients with posterior uveitis ^{28, 29}. The retinal detachment can be localized to the foveal area, associated with macular edema (Figure 1B and 1G) ²⁹, or it can be diffuse (Figure 4D). In patients with serous retinal detachment OCT parameters can be a reliable real-time indicator of the severity of the inflammation and the effectiveness of the treatment. Often, these parameters can be more reliable than the visual acuity in assessing response to intervention. Additionally relatively preserved visual acuity in eyes with a serous retinal detachment is a characteristic of exudative retinal detachment especially in eyes with Vogt-Koyanagi-Harada (VKH) syndrome where the metabolic activity of the photoreceptor outer segments and RPE may not be greatly compromised because the supply from the choroid is not significantly altered ²⁸.

VKH is granulomatous panuveitis characterized by serous retinal detachments. In VKH the detachments are usually multifocal and reflect the diffuse involvement of the retina [8]. In this disease OCT shows a multibulbated detachment with subretinal septa which is thought to be composed of inflammatory products such as fibrin. Moreover, OCT can detect a significant decrease in the height of the SRD immediately after the first and second intravenous corticosteroid injections, which maybe useful as a parameter for response to treatment ³⁰.

Optic Neuritis

Inflammation of the optic nerve is another possible cause of visual loss in patients suffering from inflammatory or infectious eye disease. Diagnosis of papillitis traditionally has relied on ophthalmoscopy, where blurring of disc margins, nerve fiber layer edema with loss of transparency, or peripapillary hemorrhages are all suggestive of optic nerve edema. When clinical evaluation is equivocal, fluorescein angiography can often be helpful as late disc leakage is typical of optic nerve edema. However, angiography is invasive, subjective, and can be associated with untoward events.

Spectral domain OCT has evolved to be a useful adjunct in the evaluation of optic nerve pathology, and it recently has been shown to be useful in the diagnosis and management of

optic disc swelling^{31–33}. Retinal nerve fiber layer thickness analysis is the most commonly used algorithm. Segmentation algorithms measure the distance between the ILM and the posterior border of the NFL to calculate thickness.

Another way of detecting subtle optic nerve edema is the measurement of total peripapillary retinal thickness with the macular cube protocol centered on the optic disc. This has been shown to be even more sensitive in the detection of mild optic nerve swelling³⁴. This protocol calculates ILM-RPE thickness and therefore includes, if present the subretinal hyporeflective space, which likely represents subretinal fluid. This finding has been theorized to be an early sign of papilledema^{33–36}.

For mild disc edema, interpretation of OCT images correlates well with stereo disc photos read by expert graders³⁵. Certain qualitative and quantitative findings on OCT are felt to be characteristic of optic nerve edema³⁶. For example, an elevated optic nerve head associated with a smooth internal contour is thought to be specific for nerve swelling. This is in contrast to optic nerve drusen, where the internal contour is often bumpy. Another critical qualitative finding involves the appearance of the subretinal hyporeflective space. The tapering subretinal hyporeflective space (“V” pattern) is nearly diagnostic of optic nerve swelling. Finally, a thickened RNFL layer, especially nasal, is also suggestive of optic nerve swelling.

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Figure 1. Representative ASOCT images show different features of anterior uveitis (A) Keratic precipitates (arrow) on ASOCT; (B) Fibrin deposition (arrow); (C) Corneal edema (arrow); (D) Inflammatory cells in the anterior chamber, visualized as hyperreflective spots (arrow).

Figure 2.

Representative images of both eyes of a 50 year old male with bilateral macular edema due to pars planitis. The patient was treated with systemic corticosteroids. Three months after starting the treatment a complete resolution of the macular edema was observed in both eyes and the visual acuity was restored. (A and F) Fluorescein angiography images on late phase show leakage on the fovea and on the optic disc; (B and G) Cross-sectional SDOCT images show intraretinal fluid (arrowhead) and subretinal fluid (arrow). Note that the fluid accumulation is more pronounced on the right eye which correspondent with the bigger leakage on the fluorescein angiography; (C and H) Retinal thickness maps show a thicker retina due to intra and subretinal fluid in both eyes; (D and I) Cross-sectional SDOCT images show a restoration of the retinal architecture after systemic steroid treatment; (E and J) Retinal thickness maps show the complete resolution of the macular edema.

Figure 3.

(A) Fundus image of a patient with active toxoplasmosis. Note that the retinitis appears as an area of retinal whitening with unclear edges. (B) Cross-sectional SDOCT image. Acute retinitis appears as a hyper reflective area in the inner retina (arrow). Note that there is a disruption on the ELM and IS/OS junction (arrowhead). (C) Fundus image of the same patient 3 month after presentation. Pigmentary changes are noted in the previous area of retinitis. (D) Corresponding SDOCT image shows cystic spaces developed in the previous area of retinitis as a result of retinal necrosis (arrow). There is involvement of the outer retinal layers (arrowhead) as well with localized atrophy of the RPE.

Figure 4.

Representative image of 2 patients with active toxoplasmosis. (A) Infrared image shows the active toxoplasmic lesion close to the inferior temporal arcade. The green line represents the scan area; (B) Corresponding SDOCT image shows a hyperreflective area affecting the full thickness retina (arrow), a thickened posterior hyaloid (open arrowhead) and cells on the vitreous cavity (arrowhead); (C) Infrared image shows the active toxoplasmic lesion on the fovea. The green line represents the scan area; (D) Cross-sectional SDOCT image shows a hyperreflective area (arrow) corresponding with the active lesions. A diffuse serous retinal detachment can be noted.