Optical Coherence Tomography

The OCT3 is a diagnostic imaging device that provides direct cross sectional images of the retina for objective measurement and subjective clinical evaluation in the detection of glaucoma and retinal diseases. The OCT3 images and analyzes macular thickness, the retinal nerve fiber layer and the optic disc using the latest technology for high resolution scans. The Optical Coherence Tomographer is a precision instrument that uses an optical measurement known as low-coherence interferometry. The principle is much like that of ultrasound, except that light is used instead of sound. This difference permits measurement of tissue and distance resolved to the scale of ≤ 10µm, versus the ≈ 200µm resolution with ultrasound. Clinically the most versatile and valuable technology available, the OCT3 uses high resolution scans in image acquisition without the problem of corneal birefringence. High resolution scans can acquire more than 500,000 data points, depending on user selected scan resolution. The OCT3 instrument scans an 820nm near infrared light beam from a super luminescent diode across the retina and generates a cross-sectional image of the tissue by recording the scattering profile versus depth of each transverse location of the beam. The scattering profile is measured by interfering the back-scattered light from the tissue with light from a variable length reference arm in a fiber optic Michelson interferometer. Retinal thickness and RNFL thickness are calculated through image processing of the resulting cross-sectional OCT3 image. The algorithm detects these boundaries by searching each A-scan axially for the highest rates of change in reflectivity.

Cystoid Macular Edema:

Cystoid macular edema (CME) is a cause of vision loss in a variety of disorders including uveitis, following cataract extraction and venous occlusions. The exact cause of CME remains unknown. Ophthalmoscopically, CME appears as elevation or thickening of the central macula. Intraretinal cyst formation is often present. The area of retinal elevation often has ill defined borders both on ophthalmoscopy and clinical examination. The presence of opacities and/or a small pupil, as is common in uveitis, may make determination of the presence and area of CME quite difficult.

The use of stereoscopic fluorescein angiography to assess the degree of macular thickening and area of leakage in patients is standard of care. The use of stereoscopic fundus photography may also be used to assess degree of macular thickening but like clinical ophthalmoscopy, the area of retinal elevation often has ill defined borders and the presence of media opacity or small pupil may make the determination of both the area of CME as well as the height of CME difficult.

The use of optical coherence tomography for the measurement of cystoid macular edema may be useful. Longitudinal measurement of either axial scans and/or topographic images as described above for diabetic macular edema can be utilized. Additionally, the amount

of media opacity and pupillary miosis in patients with uveitis will not likely interfere significantly with the images obtained by optical coherence tomography.

Age-Related Macular Degeneration:
Age-related macular degeneration is the leading cause of blindness in patients over the age of 65 in the developed world. Most of the vision loss in this disease is the result of choroidal neovascular membrane formation. Choroidal neovascularization typically appears as either classic choroidal neovascularization (well delineated) or occult neovascularization (less well delineated). The Macular Photocoagulation Study demonstrated that some patients with classic choroidal neovascularization may benefit from laser photocoagulation. The Treatment of Age-Related Macular Degeneration with Photodynamic Therapy Study demonstrated that patients with predominantly classic lesions (greater than or equal to 50% of total lesion area) benefited from treatment with photodynamic therapy.

A number of new surgical approaches and pharmacologic approaches are being applied to macular degeneration. Vision loss in age-related macular degeneration typically results when choroidal neovascular tissue, with or without hemorrhages and exudations, extend into the fovea area. The presence of hemorrhage, subretinal fluid or hard exudate under the fovea are usually detrimental to vision. The presence of choroidal neovascularization itself underneath the central fovea may likewise be detrimental to vision.

Optical coherence tomography, because of its high resolution capability, is able to image subretinal fluid, intraretinal thickening and sometimes choroidal neovascularization. As a result of these capabilities, OCT may have utility in the assessment of new treatment modalities for age-related macular degeneration.

I. RETINAL PATHOLOGY

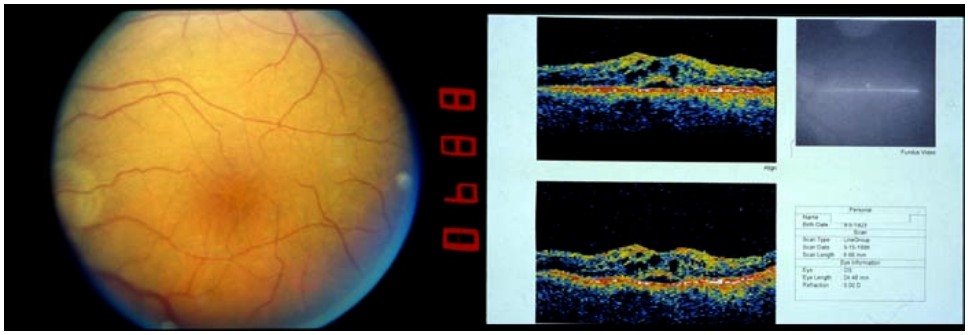
1. Intraretinal edema

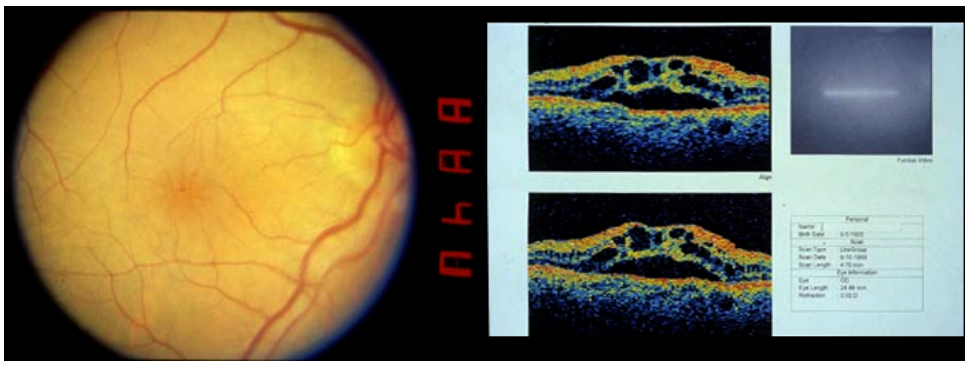
In a study of central macular thickness using 20 eyes of 10 healthy volunteers (6 radial scans per eye) the mean foveal thickness (120 scans) was 147 ± 17 um (4). Central foveal thickness is considered abnormal (intraretinal edema present) when central foveal thickness measures greater than 185 um (greater than 3 standard deviations away from the mean for normal subjects)

2. Intraretinal cysts

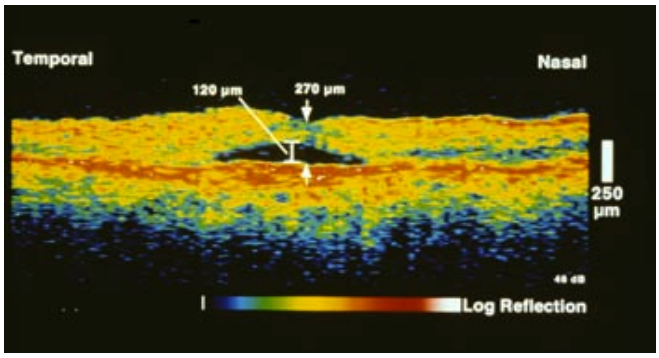
Round, minimally reflective (darker) spaces within the neurosensory retina represent intraretinal cysts. These intraretinal cysts often are not detectable on stereoscopic color fundus photography. These cysts are typically observed in the outer retinal layers and can vary in size. Small cysts are generally confined to the outer retinal layers while larger cysts may be observed to span nearly the entire thickness of the retina extending from the retinal pigment epithelium/choriocapillaris reflection to the highly reflective anterior boundary of the neurosensory retina. Cysts can range in number from one per scan to multiple. When intraretinal cysts are present in large numbers cystoid macular edema

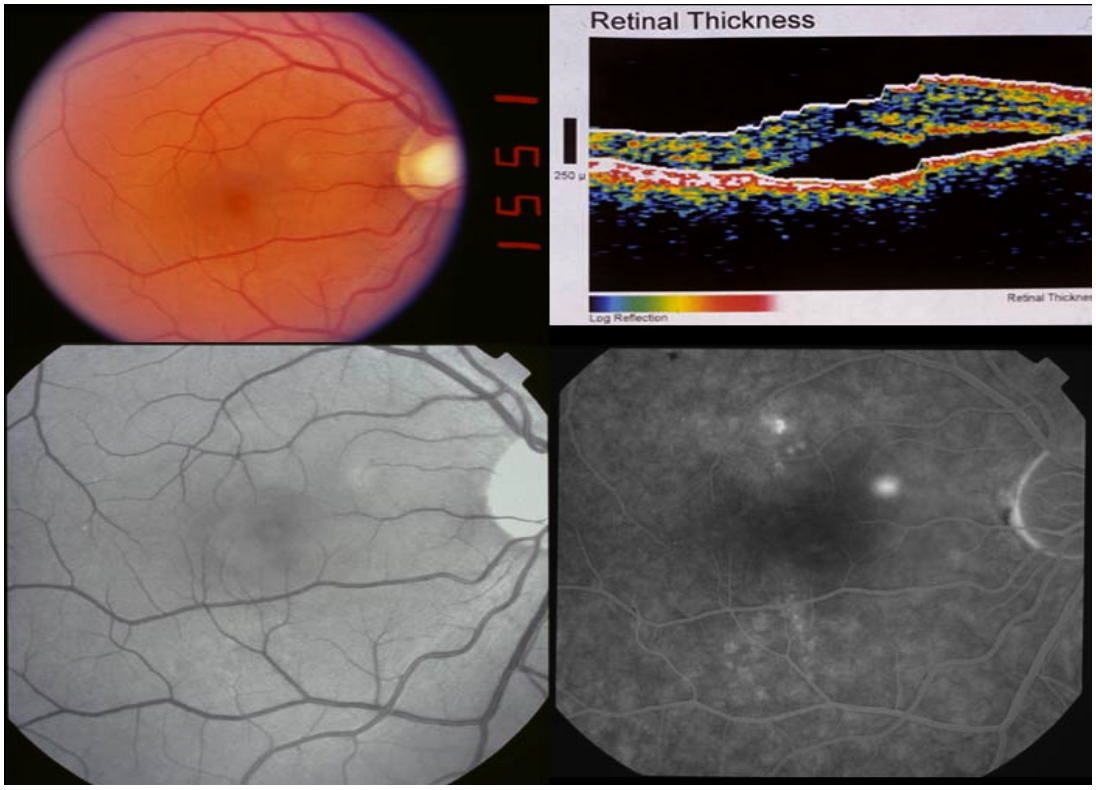
may be present on either/both stereoscopic fundus photography or fluorescein angiography.





3. Subretinal fluid (SSR) Subretinal fluid can be distinguished from intraretinal edema on OCT. Subretinal fluid appears as a non-reflective (dark) space between the posterior boundary of the neurosensory retina and the retinal pigment epithelium/choriocapillaris reflection. The retinal pigment epithelium/choriocapillaris reflection (red) is undisrupted and follows the contour of the globe. In distinction to intraretinal edema the non-reflective area is not present within the neurosensory retina. Additionally, the non-reflective space is not typically round. The non-reflective space corresponding the subretinal fluid is typically semicircular in shape with tapered lateral extensions (somewhat similar to the shape of a Bell curve). Numerous variations on this appearance may be present due to the presence of other abnormalities such as choroidal neovascularization and/or pigment epithelial detachments. The height of the neurosensory detachment can be quantified by measuring the distance between the posterior boundary of the neurosensory retina and the retinal pigment epithelium/choriocapillaris reflection. The neurosensory retina overlying the area of subretinal fluid is typically not thickened on OCT images except in cases where the subretinal fluid has been chronic.



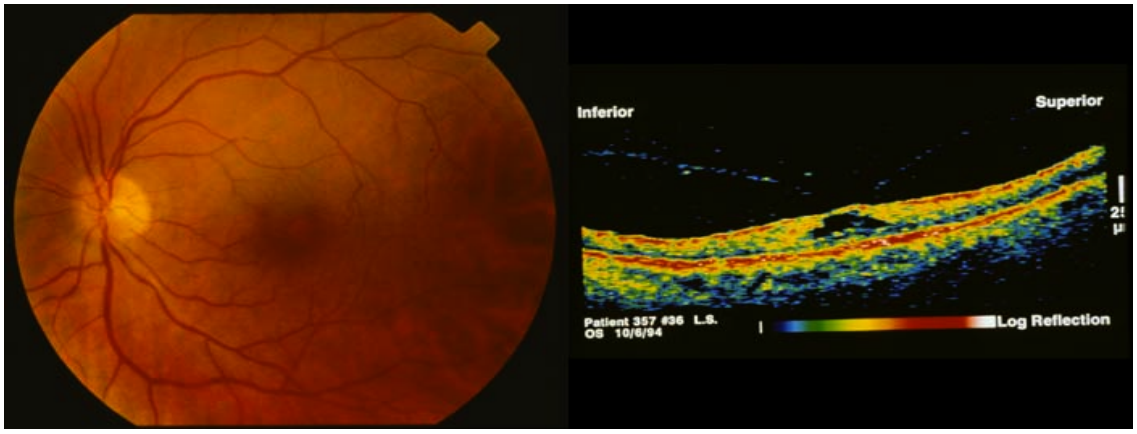


II. PATHOLOGY OF THE VITREORETINAL INTERFACE

1. Macular hole

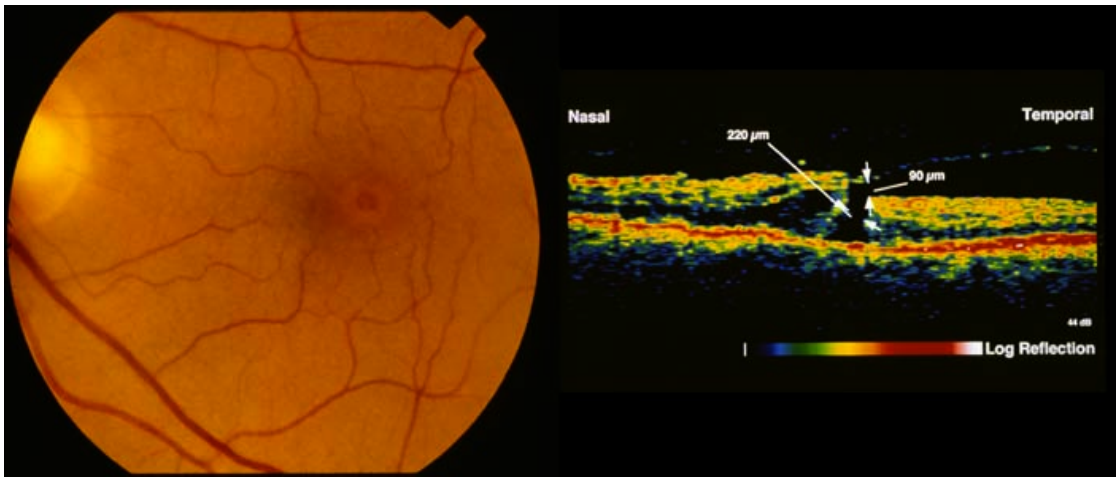
A macular hole is a retinal lesion that is typically the result of either abnormal tangential or anterior-posterior vitreoretinal traction. Macular holes progress through 4 stages.

A stage 1 macular hole is a pre-macular hole lesion that sometimes is difficult to identify on stereoscopic color fundus photography.

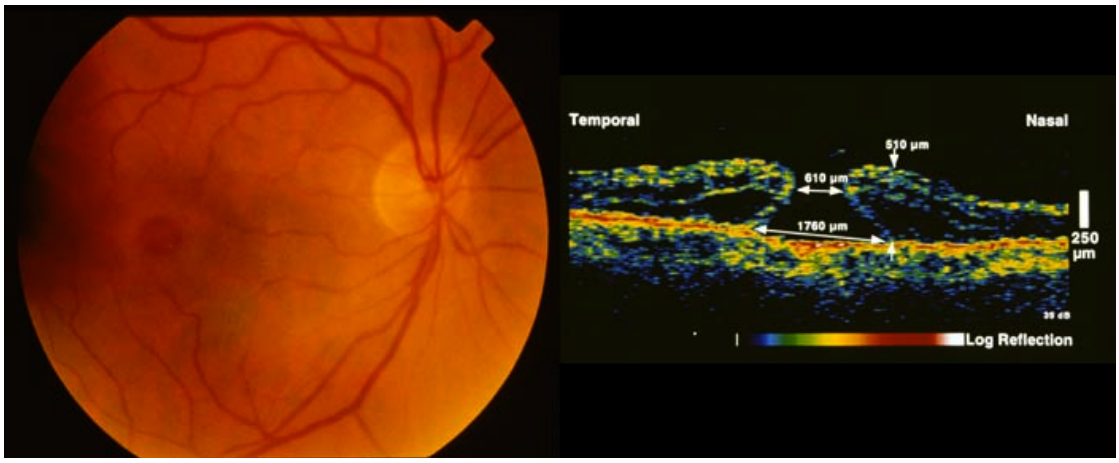


It may appear as either a small yellow dot centered on the fovea or as a small yellow ring surrounding the fovea. On OCT images, a full thickness retinal defect is not present. On OCT images, a stage 1 macular hole appears as a distinct foveal thickening often with a large intraretinal cyst present under the fovea.

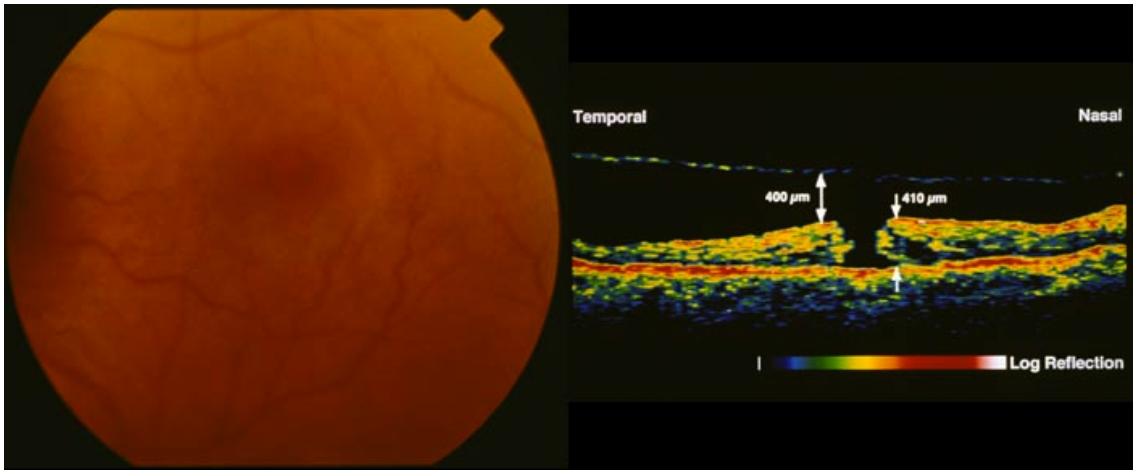
A stage 2 macular hole is a small macular hole measuring less than 400 um in diameter.



A posterior vitreous detachment (a separation of the vitreous body from the surface of the retina) is not present. A stage 3 macular hole is a larger macular hole measuring 400 um or more without a posterior vitreous detachment.

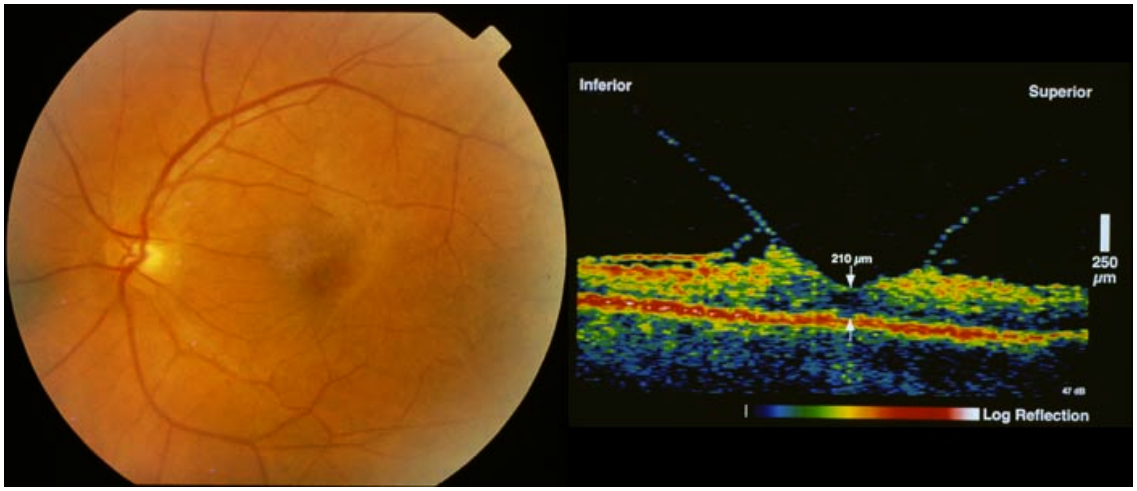


A stage 4 macular hole measures 400 microns or more but a posterior vitreous detachment is present.



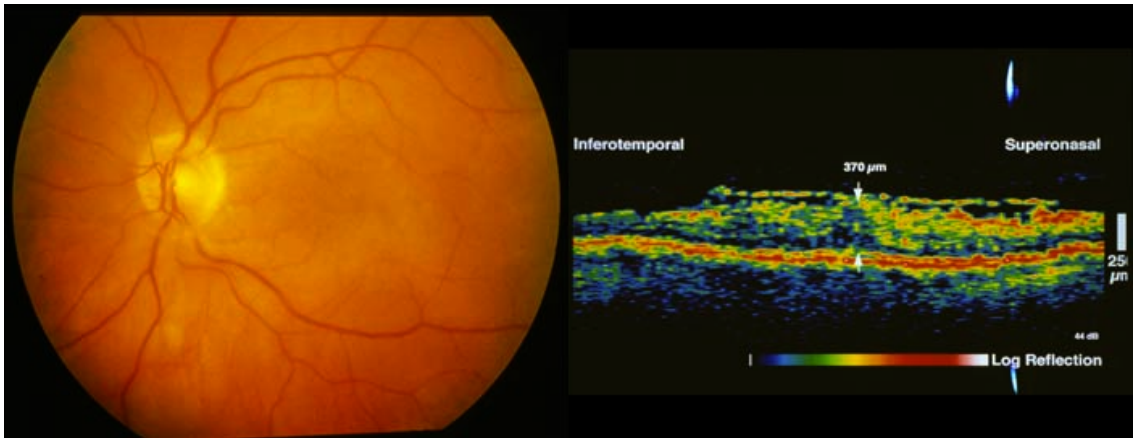
2. Vitreomacular traction

Vitreomacular traction syndrome (VMT) is an entity that is similar to a stage 1 macular hole. VMT is the result of abnormal anterior-posterior traction on the fovea/perifoveal retina. Secondary retinal thickening is present both on stereoscopic fundus photography and OCT images. Vitreomacular traction differs from a stage 1 macular hole in that the area of retina involved by traction is generally larger. On clinical examination and/or stereoscopic fundus photography a diffuse, thickened posterior hyaloid can be detected. On OCT images this thickened posterior hyaloid is observed to insert in the foveal/perifoveal area



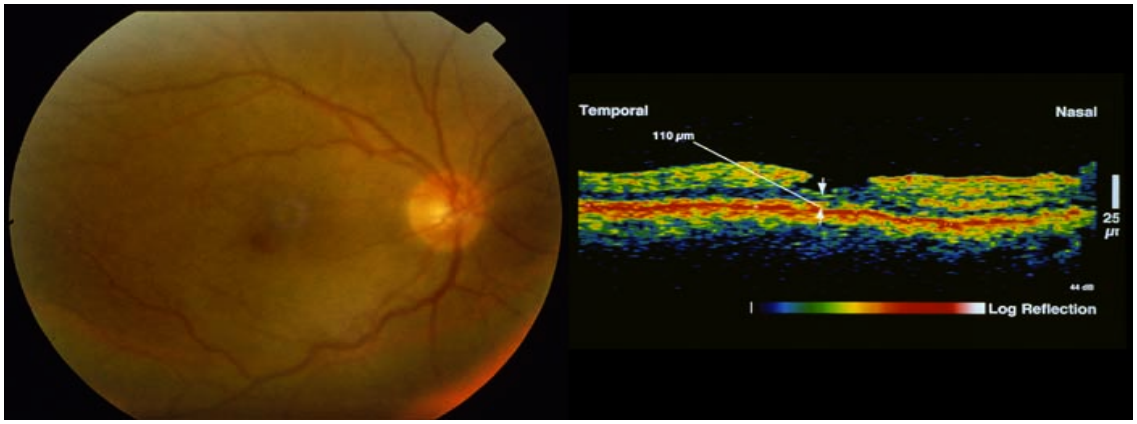
3. Epiretinal membrane

An epiretinal membrane (ERM) represents abnormal fibrocellular proliferation on the surface of the retina. Commonly these proliferations occur over the central fovea. OCT images of ERMs can be classified into 2 broad categories: Globally adherent or partially non-adherent. Both types of epiretinal membranes are visible on OCT images as reflective tissue contiguous with or anterior to the inner retinal surface. Intraretinal edema with or without retinal cysts may be present under the ERM as a result of traction on the retina by the ERM. Partially non-adherent ERMs are clearly visible on OCT images as they have sections that are separated from the anterior surface of the retina.



Globally adherent ERMs may also present as a macular pseudo hole. The OCT images display an adherent ERM contiguous with the anterior retinal surface. An abnormally steep and narrow foveal contour is present. The appearance on the OCT image is similar to that of a macular hole but in the case of a macular pseudo hole, full thickness retinal

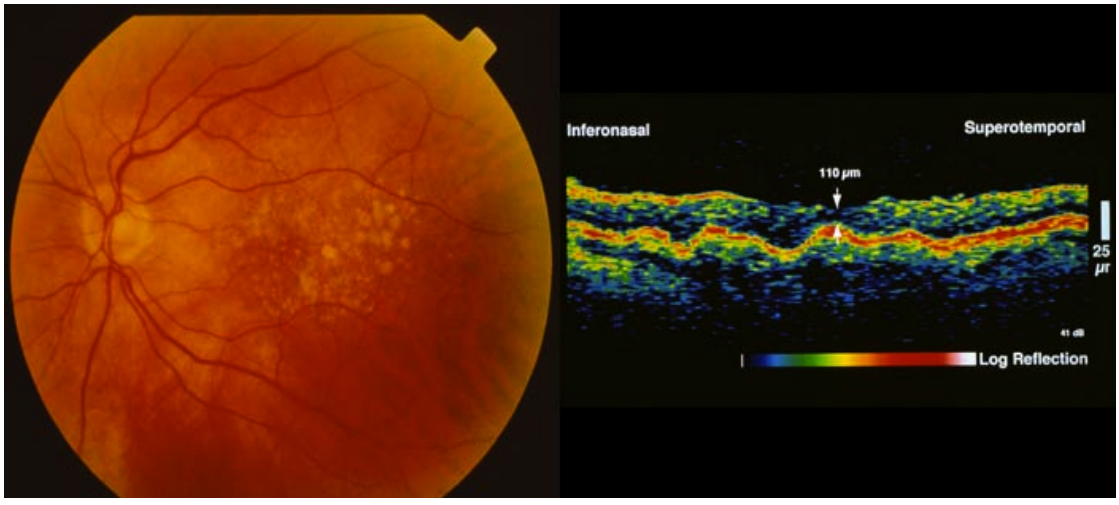
tissue is present at the base of the steepened foveal contour. This retinal tissue typically is of normal foveal thickness.



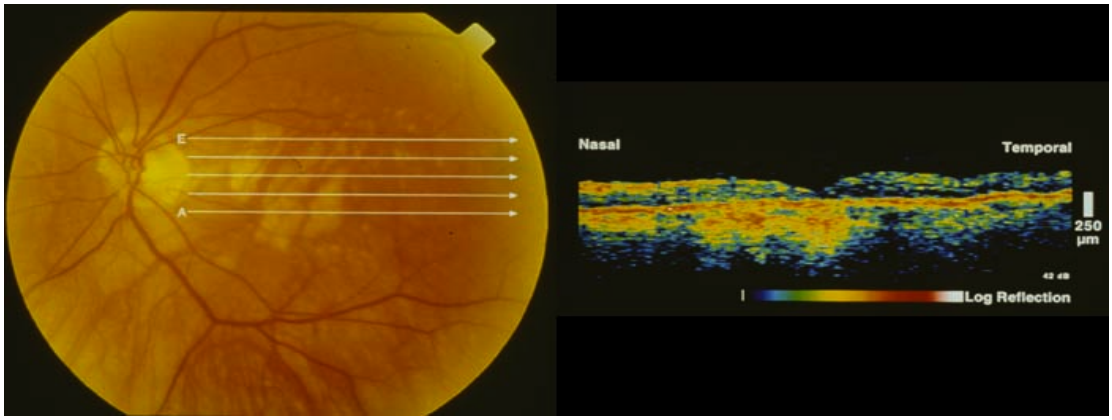
III. CHOROIDAL PATHOLOGY

1. Non-exudative age-related macular degeneration

OCT is particularly well suited to image the pathologic changes in age-related macular degeneration (AMD). The retinal pigment epithelium (RPE), the site of many pathologic changes in AMD, is well delineated on OCT. Small elevations of the well defined RPE/choriocapillaris reflection on OCT images indicate soft drusen and are consistent with the accumulation of material within or beneath Bruch's membrane. Confluent soft drusen may present as larger areas of elevation and may be distinguished from small pigment epithelial detachments by the lack of shadowing beneath the area of elevation. Elevation of the RPE/choriocapillaris reflection due to retinal pigment epithelial detachment typically exhibits shadowing of structures beneath the area of elevation. This may be the result of changes in the retinal pigment epithelium that do not occur with drusen.



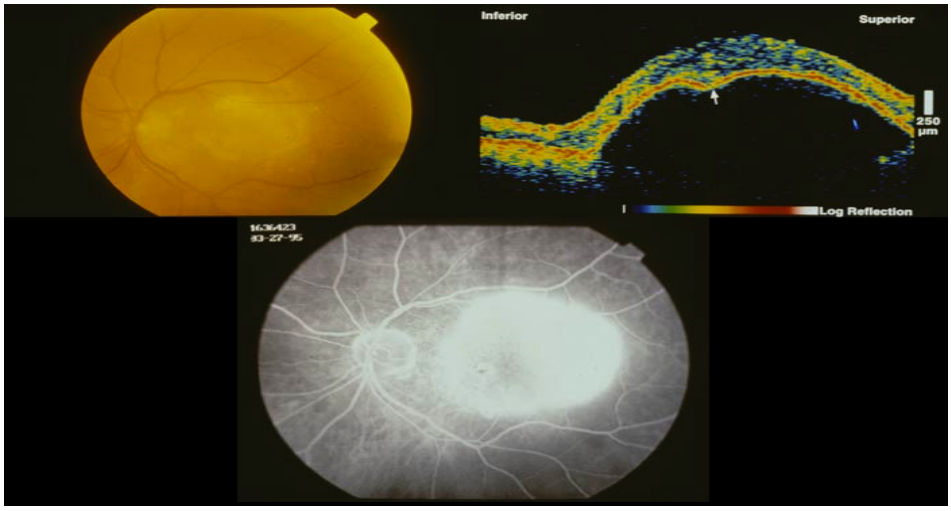
Geographic atrophy is also well imaged on OCT. OCT images demonstrate absence of the minimally reflective band corresponding to the retinal photoreceptor layer. Because of increased penetration of the OCT probe light through atrophic neurosensory retina and RPE the choroid exhibits a well-defined area of increased optical reflectivity. Images taken through an atrophic fovea will lack the normal contour of the foveal depression.



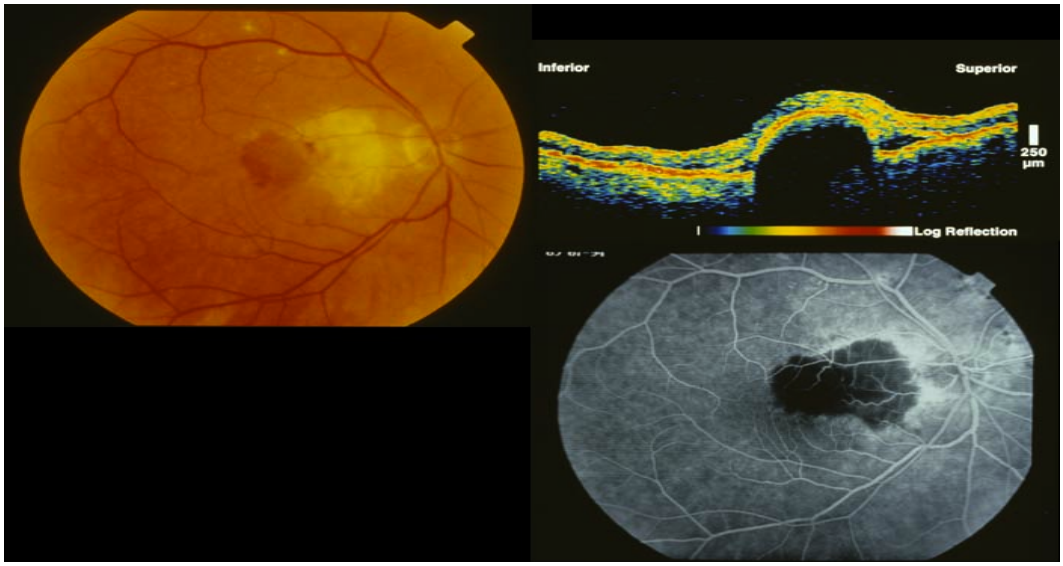
2. Exudative age-related macular degeneration

a. Retinal pigment epithelial detachment

1. Serous RPE detachment: These appear as focal elevations of the reflective RPE band over an optically clear space. The detached RPE is slightly more reflective than normal, perhaps as a result of morphologic changes in detached RPE. The increased reflectivity of the RPE band severely shadows reflections from the underlying choroid.



2. Hemorrhagic RPE detachments: These are distinguished by a moderately reflective layer directly beneath the detached RPE. The blood directly underneath the RPE is only moderately reflective because of attenuation of the OCT probe light through detached RPE. Penetration through the hemorrhage is usually less than 100 microns. Reflections from deeper portions of the hemorrhage and the choroid are severely attenuated.



3.Fibrovascular RPE detachment: Fibrovascular RPE detachments demonstrate moderate reflectivity throughout the entire sub-RPE space. The lower scattering coefficient of the fibrovascular proliferation compared with blood allows for penetration of the OCT probe light through the entire lesion down to the level of the choroid, where attenuation of the choroidal reflection is typically noted.