A new frontier has been opened in the study of the choroid with the development of enhanced depth imaging, cross scans and en face scans with modern spectral domain optical coherence tomography (SD-OCT) technology. Traditional OCT images are captured on a plane parallel to the optical axis and perpendicular to the retina. En face scans, by contrast, are parallel to the retinal pigment epithelium (RPE), at a constant depth in the retina. This is convenient because it makes these images comparable to confocal scanning laser ophthalmoscope images.

Penetrating deeper into the ocular layers, cross and en face scans increase our understanding of ocular pathology. We recently used the RTVue SD-OCT (Optovue) in choroid mode to conduct a study of the dimensions and characteristics of the normal, healthy choroid.1 Study of the healthy choroid gives us normative data to compare and identify pathologic variations of choroidal morphology and structure.

CHOROID IN THE NORMAL EYE

In the normal eye, the choroid brings nourishment to the RPE and outer retina, produces the visible pigmentation of the fundus, and plays an important role in heat regulation. The choriocapillaris is thin and hyporeflective, while the larger vessels of the choroid appear hyporeflective. The connective tissue between vessels has low to high reflectivity depending on patient age and vascular sclerosis. On enhanced depth imaging SD-OCT en face images, choroidal vessels in the normal eye appear like a hyporeflective net immersed in hyporeflective connective tissue and extravascular space. The large vessel layer is in contact with the lamina fusca, a pigmented structure separated from the sclera by the suprachoroidal space. The suprachoroidal space layer is normally virtual and seen only when filled with fluid.

Even in a normal retina, there is great variability in the thickness of the choroid according to age, refraction, and even the time of day. A person with a normal choroid may manifest differences in thickness at intervals of a few hours or days. The choroid is thicker at the fovea, and the thickness decreases toward the nasal and temporal sides. By establishing standard thickness ranges, a number of ocular disorders may be detected based on abnormal increases or decreases in the thickness of the choroid.

THICKNESS VARIATIONS

Forty-eight eyes of volunteer subjects were recruited for study. Twenty-three eyes were normal, 7 had low...
myopia, defined as between -1 and -6 D, and 18 had high myopia, defined as more than -7 D. Horizontal ultrasound B-scan images were acquired for all eyes. Choroidal thickness was obtained at the foveal center and at distances of 200 µm, 400 µm, 500 µm, 1000 µm, and 1500 µm away from the center for all eyes (Figure 1A-C).

Our study showed that in normal eyes, choroidal thickness decreases with age, with increasing myopia, and with increasing axial length, and it increases with hypermetropia. Choroidal thickness varies at locations in the posterior pole. It is generally thicker underneath the fovea than temporal and nasal to the fovea, and it is not significantly different between the fovea and superior or inferior to the fovea.

The mean choroidal thickness directly under the center of the fovea was found to be 316.6 µm for the normal group, 233.9 µm for the myopia group, and 96.8 µm for the high myopia group. There was an obvious and similar amount of reduction in choroidal thickness associated with myopia at all measured distances from the center of the fovea.

We also saw significant choroidal thinning associated with increasing age in normal eyes at all locations measured. In young people, choroidal thickness was about 320 µm. Choroidal thickness decreased to 230 µm in people older than 50 years and 160 µm in those older than 70 years. The subfoveal thickness changed with age at an estimated rate of -2.31 µm per year in normal eyes.

CHOROIDAL DISORDERS

Once standard variations in thickness have been established for the normal choroid, it is possible to detect abnormalities that may indicate a disorder. These may be indicated by deviations of increased or decreased thickness.

Increased choroidal thickness. Disorders of increased choroidal thickness, such as central serous chorioretinopathy (CSC), show greatly increased vessel diameters in the Sattler and Haller layers. Choroidal thickness is significantly increased from a normal range of 200 to 320 µm to 450 µm or more (Figure 2). En face scans performed deep in the choroid show dilatation of vessels, and the choroid remains enlarged even after classical laser treatments that improve visual acuity. Following photodynamic therapy, we generally observe a decrease in choroidal thickness after 4 to 6 months.

In the large group of pathologies causing choroidal inflammation we find some common aspects. Choroidal thickness is significantly increased, and the connective interstitial tissue is less reflective. The vessels may appear hyperreflective and granular, while the RPE may appear thinned even if it remains hyperreflective. It is evident in en face scans that the choriocapillaris layer may be missing in choriocapillaritis.

Harada disease is a classic example that fits all of the above parameters. The choroid is thicker than normal, vessel diameter is greatly increased in the Sattler and Haller layers, and vessels may appear hyperreflective and granular.

Decreased choroidal thickness. A decrease in choroidal thickness can also indicate a variety of disorders. As discussed above, choroidal thickness shows a tendency to decrease with higher myopia. Mean thickness is 231 µm for myopic eyes from 3 to 8 D and 89 µm in myopia greater than 8 D.

When there is an atrophic process, the OCT light beam more easily penetrates into the deep ocular layers. In atrophic macular degeneration, cross scans show a thin and well-defined choroid, with thicknesses that can be greatly reduced to 80 µm or less. Sattler and Haller layer vessel walls and connective interstitial tissue between the vessels appear denser and more reflective.

OCT scans frequently allow discrimination of a choroidal tumor from the surrounding normal choroid. Scans show a highly reflective strand in the anterior choroid below the RPE with a dense shadow on the posterior layers. OCT scans allow discrimination of melanomas from the normal choroid but do not allow the laser beam to penetrate inside the malignancy.

CONCLUSION

The normal choroid exhibits variations in thickness, but compiling data on the ranges of normal variation makes it possible to detect abnormal thicknesses. Enhanced capabilities with SD-OCT devices allow us to penetrate the interior of the eye and expose pathologies that might otherwise remain hidden.

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