Evaluation of Choroidal Thickness in Normal Eyes Using Enhanced Depth Optical Coherence Tomography
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Abstract

Purpose: To evaluate the choroidal thickness in normal Indian population and to determine its correlation with age and refractive error.

Design: Cross sectional study conducted at a tertiary eye hospital in North India.

Method: 512 eyes of 256 normal subjects with no ocular pathology were enrolled. Choroidal scans were obtained for all the eyes using enhanced depth imaging (EDI) using spectral-domain optical coherence tomography (SD-OCT). Choroidal thickness measurements were made of the subfoveal choroid and at 500μ intervals from the fovea to 2.5mm nasal, 2.5mm temporal, 2.5mm superior and 2.5mm inferior from the centre of the fovea.

Results: The mean subfoveal choroidal thickness observed in our study was 353.84±79μm. Mean choroidal thickness in the superior quadrant, inferior quadrant, nasal quadrant and temporal quadrant was 350.91±78 μm, 323.13±75μm, 294.25±70 μm and 335.33±73μm respectively. Subfoveal choroidal thickness was negatively correlated with age and refractive error indicating lesser subfoveal choroidal thickness with increasing age and myopia.

Conclusions: Choroidal thickness varies with the distance from the fovea. Age and increase in myopia have a negative correlation with choroidal thickness.

Keywords: choroidal thickness, normal Eyes, enhanced depth imaging optical coherence tomography

Introduction

The choroid is the vascular layer between the retina and the sclera that provides metabolic support to the outer retina including the retinal pigment epithelium (RPE) and the photoreceptors.1 Choroid plays a major role in the pathophysiology of diseases affecting retina like central serous chorioretinopathy, high myopia and age related macular degeneration.2,4 The changes in the thickness of the choroid, which indirectly reflects changes in the choroid provides useful information in diagnosing and managing many retinal disorders.5 Choroidal thickness measurements have been conventionally done by ultrasound B-scan and histologic studies. B-scan ultrasonography has poor axial and lateral resolution and therefore it is difficult to differentiate the retina from the choroid. The choroid is a highly vascular structure and its thickness varies with the intraocular pressure and perfusion pressure.6 Fixation of tissue in specimen for histolopathology causes shrinkage and thereby histologic specimen theoretically may underestimate the true thickness of the choroid.7 By using the spectral domain optical coherence tomography (SDOCT) in enhanced depth imaging (EDI) mode, closer to the eye such that an inverted image is obtained and the deeper structures are placed closer to zero-delay, the acquired images have improved ability to visualize deeper structures like the choroid and sclera.8 There are studies in which measurement of choroidal thickness was done in Japanese, Korean, and Chinese population.9-11 These studies have observed a mean subfoveal choroidal thickness of 354μm, 270.8μm and 262μm respectively. A demographic difference in the choroidal thickness is noted from these studies. This study aims to generate normative data for choroidal thickness for Indian population and its correlation with age and refractive error.

Methods

This was an observational, cross sectional study conducted at a tertiary eye hospital in Northern India. The study was reviewed and approved by Institutional Review Board. Normal subjects with no history of any systemic illness and with no retinal or choroidal disorder after a detailed ocular examination were recruited in this study. The visual acuity was tested on Snellen’s chart and subjects with best corrected visual acuity of 6/6 were included. Exclusion criteria for the study were high myopia or hyperopia (greater than 6 diopters of spherical equivalent refractive error), any retinal or RPE abnormality noted on OCT, previous intravitreal injections, focal laser, poor image quality because of unstable fixation, or significant media haze. The choroid was imaged by positioning a Heidelberg Spectralis (Heidelberg Engineering, Heidelberg, Germany) close enough to the eye to obtain an inverted image. To account for the diurnal variation, the choroidal thickness measurement was done between 9 am-12 noon. This image is averaged for 100 scans using the automatic averaging and eye tracking features. Seven sections, each comprising...
of the 100 averaged scans, were obtained in a 5X30-degree rectangle encompassing the macula, and the horizontal and vertical sections which went directly through the center of the fovea were selected. The resultant images were viewed and measured with the contained Heidelberg Eye Explorer software (version 1.5.12.0; Heidelberg Engineering). Choroidal segmentation was performed manually after the automated retinal layer segmentation software was disabled. Reference lines of the built-in automated segmentation were moved from the retinal boundaries to the choroidal boundaries. The internal limiting membrane line was moved to the posterior edge of the choroid as demarcated by the hyper-reflective margin line corresponding to the choriocapillary interface as shown in Figure 1. The choroid was measured from the outer portion of the hyper-reflective line corresponding to the RPE to the junction of choroid and sclera. The measurements were done of the subfoveal choroid and at 500μ intervals from the fovea to 2.5mm nasal, 2.5mm temporal, 2.5mm superior and 2.5mm inferior from the centre of the fovea.

Statistical Analysis
Statistical analysis was performed using SSPS statistical software (SSPS version 21. Inc, Chicago,IL, USA). Chi-square and Paired t-test were used to compare the choroidal thickness at different locations. Data were expressed as mean ± standard deviation. Pearson correlation and multiple regressions were calculated for variation in choroidal thickness relative to age. Statistical significance was defined at a level of 5% (p < 0.05).

Results
A total of 512 eyes of 256 patients were enrolled in this study. 167 (65.2%) were men and 89 (34.7%) were women. Mean age of participants was 31.06 ± 12.48 years (Range: 11-71 Years). Difference of mean age among male and female participants was not statistically significant (p=0.08)

Average subfoveal choroidal thickness (SFCT) of enrolled participants was 353.84±79μm. The mean SFCT among women was 351.83± 83μ and among men was 354.9±73μ (p=0.66). Negative correlation of choroidal thickness with refractive error was found (Figure 2) (r=-0.34, Pearson co-efficient of correlation). SFCT was also found to have a negative correlation with age (r=-0.43, Pearson co-efficient of correlation) (Figure 3) The mean choroidal thickness in the superior quadrant was 350.91±78μ and it was not statistically different from the SFCT. The mean choroidal thickness in the other quadrants are lesser compared to the SFCT and were statistically significant. (Table 1)

Choroidal thickness measurement done at 500μ intervals upto 2500 μm from the center of the fovea in the superior quadrant showed no statistically significant difference from the SFCT except at 2500 μm which is significantly thinner in comparison to the SFCT (Table 2). Choroidal thickness at 500μ intervals in inferior and temporal quadrant upto 2500μm from the center of the fovea was lesser in comparison to SFCT at all points and was statistically significant (Table 2).

Choroidal thickness measurement at 500μ intervals in temporal quadrant upto 2500μ was lesser at all points in comparison to the SFCT but was statistically significant at 1500μm, 2000μm, 2500μm. Choroidal thickness in the nasal quadrant was lesser at all corresponding points compared to temporal quadrant.
Discussion

The invent and further advancement in the OCT machines have made it possible to have an in vivo biopsy of the choroid. The knowledge of structure and thickness of the choroid is imperative to the clinicians for evaluation and management of various diseases. However the measurement of choroidal thickness may offer a challenge. The pigment and light scattering by the dense vascular structure of the choroid hamper imaging of the choroid using conventional OCT. The other problem being the delay in resolution and sensitivity with increasing displacement from zero-delay. Recent advancements in OCT enable in vivo and non invasive imaging of the choroid using EDI or high penetration 1060-nm OCT.

The increase in sensitivity using the EDI mode allows penetration of an additional 500-600 microns deeper into the eye. In our study we used Heidelberg Spectralis (Heidelberg Engineering, Heidelberg, Germany) for the measurement of choroidal thickness. In this study, 512 eyes of 256 participants with a mean age of 31.06 ± 12.48 years (Range: 11-71 years) were included. The mean SFCT was observed to be 353.84 μm, which is approximately the same value obtained in the study by Ikuno et al. The value of SFCT observed in this study is higher in comparison to the value observed by other studies (Table 3). A wide variation in choroidal thickness was reported in various studies. Even in comparison with Indian studies our measurement of choroidal thickness is significantly higher. This could be due to differences in measuring software, differences in the wavelength of the light source, differences in ethnicity, age, refractive error of the participants. The average choroidal thickness in the superior quadrant observed in this study is 350.91 μm, which was not significantly different from the choroidal thickness in the subfoveal region. The choroidal thickness in the other quadrants was lesser compared to the SFCT. The choroidal thickness in the nasal quadrant was observed to be the thinnest being 294.25 μm, which was the same observation in other similar studies. Negative correlation of SFCT with age was found indicating lesser SFCT with increasing age. Age is a major determining factor in the choroidal thickness.

Table 3: Comparision of Subfoveal choroidal thickness measured by various authors

| Study                  | Sub foveal choroidal thickness |
|------------------------|-------------------------------|
| Present study          | 353.84 μm                     |
| Ikuno et al⁹           | 354μm                         |
| Joong Won Shin et al¹⁰ | 270.8 μm                      |
| Xiaoyan Ding et al¹¹   | 262μm                         |
| Margolis and Spaide¹²  | 287 μm                        |
| VarshaManjunath, et al¹³| 271μm                        |
| Supriya Arora et al¹⁷  | 301.80 μm                     |
| Jay chhabalani et al¹⁹ | 280.1 μm                      |

Table 2: Choroidal thickness at 500μ intervals in different quadrant

| Quadrant     | Mean SFCT | Difference from SFCT | P Value  |
|--------------|-----------|----------------------|----------|
| Superior     | 353.84 μμ | -2.52 μμ             | 0.001    |
| Inferior     | 353.84 μμ | 7.4 μμ               | <0.01    |
| Nasal        | 353.84 μμ | 14.46 μμ             | <0.01    |
| Temporal     | 353.84 μμ | 3.73 μμ              | 0.15     |

Figure 4: Distribution of choroidal thickness along the horizontal meridian. Choroidal thickness in the nasal quadrant is lesser at all corresponding points compared to temporal quadrant

Figure 5: Distribution of the choroidal thickness along the vertical meridian. Choroidal thickness in the inferior quadrant is lesser at all corresponding points compared to superior quadrant
factor for choroidal thickness, especially after the age of 60 years. A negative correlation with refractive error indicating a lesser choroidal thickness with increasing myopia was also found. Choroidal thickness is shown to have a variation with refractive error in other studies as well. There was no difference noted in choroidal thickness on the basis of gender in this study as reported in other studies.

In conclusion, this study provides data for choroidal thickness and topographical profile of thickness of choroid depending on distance from centre of fovea for Indian population which would help clinicians to monitor and understand various diseases affecting retina and choroid. Also, our study shows that aging and myopic shift are important variables for interpretation of choroidal thickness.

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