Original Article

Choroidal thickness profile in healthy Indian subjects

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Purpose: The aim was to study choroidal thickness (CT) and its profile based on location in healthy Indian subjects using Cirrus high definition (HD) optical coherence tomography. **Materials and Methods:** A total of 211 eyes of 115 healthy subjects with no retinal or choroidal disease were consecutively scanned using Cirrus HD 1 line raster scan mode without pupillary dilation. Eyes with any ocular disease or axial length (AXL) >24 mm or <20 mm were excluded. Experienced technician measured CT from the lower border of the retinal pigment epithelium (RPE) to the lower border of choroid. CT was measured from the posterior edge of the RPE to the choroid/sclera junction at 500-µm intervals up to 3000 µm temporal and nasal to the fovea. Generalized estimating equations were used to evaluate the correlation between CT at various locations and age, AXL, spherical equivalent, and macular thickness. **Results:** Mean age was 42.8 ± 13.6 years. Mean AXL was 22.84 ± 0.78 mm. Median spherical equivalent was 0.16 ± 0.64 D. Mean central macular thickness was 216.4 ± 30.03 µm. Choroidal was thinnest nasally and thickest subfoveally. On multivariate regression, age was the most significant factor affecting subfoveal CT (P = 0.000). Regression analysis showed an approximate decrease in CT of 1.18 µm every year. **Conclusions:** Our study provides CT profile in Indian healthy subjects in various age groups. CT depends on its location, subfoveal being the thickest and nasal being the thinnest. Age is a critical factor, which is negatively correlated with CT.

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The choroid is the most vascular tissue in the eye, provides a blood supply to the outer retinal structures. Choroidal abnormalities such as vascular hyperpermeability and loss, and thinning are critical to the onset and progression of many chorioretinal diseases such as central serous chorioretinopathy,[1] Vogt–Koyanagi–Harada disease,[2] high myopia-related chorioretinalatrophies,[3] age-related macular degeneration,[4] and polypoidal choroidal vasculopathy.[5]

With the recent development of recent enhanced depth imaging (EDI), *in-vivo* assessment of choroid has become an area of interest. EDI helps better visualization of choroid, which allows accurate quantitative assessment of the choroid, which was not possible before.[6] Information about the choroidal thickness (CT) could be useful in many clinical situations for decision making regarding the management and monitoring of disease progression. Recent literature has shown the effect of age, sex, axial length (AXL), refractive error, and diurnal variation on the CT.[7,8]

Various studies have reported normal range of CT.[9-14] However, none of these reports provides range of CT measurements in each decade, which could help to differentiate between diseased or normal choroid in a given patient. Retinal parameters have been reported to vary in various ethnic groups.[15] Previous reports on CT are mostly from the western world and from the Asian countries including Japan and China.[9-14] However, there is no literature available on normative CT profile in Indian population.

This prospective observational study aimed to report normative database of CT in healthy Indian subjects in various age groups.

Materials and Methods

This study was performed from January 2010 to June 2012. Prior approval from the Institutional Review Board of the institute was taken, and informed consent was obtained from each subject. This study was conducted in accordance with the tenets of the Declaration of Helsinki. About 81 healthy volunteers with no history of eye disorders were recruited for this study. Exclusion criteria included high myopia (>−6 D), or hyperopia (>+4 D), any retinal or retinal pigment epithelium (RPE) abnormality detectable on optical coherence tomography scan, poor image quality because of unstable fixation, or any history of any intraocular surgery.

All participants underwent a comprehensive ophthalmic examination including visual acuity testing using, slit-lamp biomicroscopy, intraocular pressure measurement using Goldmann applanation tonometer and dilated fundoscopic examination. AXL measurement was performed using ocular biometry (IOL Master; Carl Zeiss Meditec, Jena, Germany).

Choroidal imaging

An optical coherence tomography (OCT) scans were obtained by using Cirrus high definition (HD)-OCT (Carl Zeiss Meditec, Inc., Dublin, CA, USA. Software Version 5.0.0.326) with undilated pupil. The scan used for imaging in this study is HD

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1 line raster. Scan 3 of the 5, which passes through the fovea and was used for all the measurements. Scans with a signal strength of ≥6 were used for analysis.

Using the Cirrus linear measurement tool, experienced observer measured CT perpendicularly from the outer portion of the hyperreflective line corresponding to the RPE to the inner surface of the sclera at 500 µm intervals temporal and nasal from the fovea, up to 2500 µm [Fig. 1]. Inter-observer reproducibility and intra-observer repeatability was measured for 30 eyes.

Statistical analysis

Descriptive statistics included mean and standard deviation for continuous variables. As both eyes of most subjects were included for analysis, the correlation between the two eyes of the same subject was adjusted using generalized estimating equations (GEE) during the calculation of summary descriptive parameters. Multivariate models adjusted using GEE methods were fit to assess the effects of age, gender, AXL, and macular thickness on the CT measurements. Statistical analyses were performed using commercial software (Stata ver. 12.1; StataCorp, College Station, TX, USA). The alpha level (type I error) was set at 0.05.

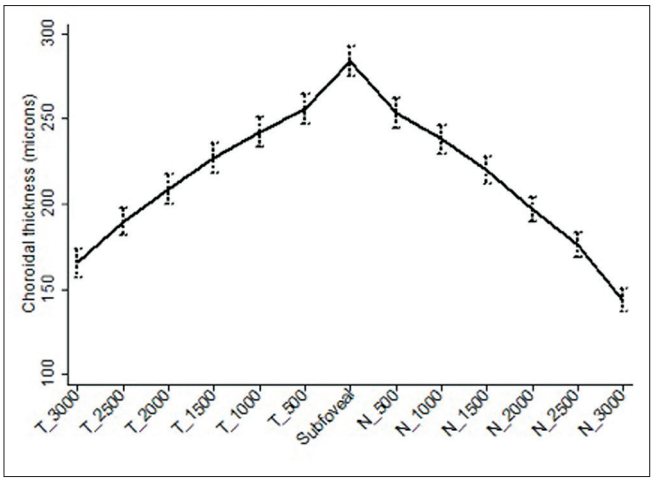

Figure 1: The mean choroidal thickness (CT) with confidence intervals measured at different locations across a horizontal section through the fovea at 500 µm intervals from 3 mm nasal to the fovea to 3 mm temporal in healthy eyes. Maximum CT is noted at the fovea with gradual decrease with the distance from fovea, thinner on the nasal side of the fovea

Results

We included 211 eyes of 115 healthy subjects with 50 (91 eyes) men and 65 (120 eyes) women. About 19 eyes were excluded because of poor quality of images. Mean age was 42.8 ± 13.6 years. Mean AXL was 22.84 ± 0.78 mm. Median spherical equivalent was 0.16 ± 0.64 D. Mean central macular thickness (CMT) was 216.4 ± 30.03 µm. All patients were phakic.

Choroidal thickness at various locations from fovea in various age groups is shown in Table 1. Intraclass correlation coefficient for intra-observer reproducibility and inter-observer repeatability was 0.95 and 0.97. There was a gradual decrease in CT at all locations from 3rd to 8th decade. The mean subfoveal CT in 3rd decade was 294.8 ± 46.5 µm and that of in 8th decade 249.6 ± 36.0 µm. The decrease in CT was observed to be more in older subjects (>60 years). However, this difference was statistically insignificant due to a small number of subjects with age >60 years. When compared between two eyes of one patient, there was no significant difference in CT at all locations.

Choroidal thickness distribution was found to be uniform on the nasal side of the fovea compared to the temporal side. Maximum CT was noted subfoveal and gradual decrease as the distance increases. The CT on both sides, nasal and temporal, to fovea, was thinner compared with the subfoveal CT, this difference was statistically significant ($P < 0.001$ at all locations). CT progressively reduces as the distance from fovea increase, more prominent thinning noted on the nasal side of the fovea. Hence, the choroid was noted to be thinnest near optic nerve head [Table 1 and Fig. 2].

We found that the age was the only significant variable correlating with CT at all locations. Age had a negative correlation with the CT [Fig. 2]. There was 1.18 µm/year

Table 1: Mean choroidal thickness at various locations from fovea in various age groups

Choroidal locations	20-29 years	30-39 years	40-49 years	50-59 years	60-69 years	70-79 years
Number of eyes	45	55	53	35	17	6
Nasal 2500	211.0±57.3	195.9±46.0	198.7±48.5	205.6±45.9	157.8±56.7	227.1±33.6
Nasal 2000	219.7±45.8	207.3±31.6	201.6±39.6	205.2±36.5	168.2±54.7	208.8±32.9
Nasal 1500	228.4±42.2	219.2±30.2	212.2±41.9	204.0±31.7	179.4±59.0	198.8±32.2
Nasal 1000	235.1±43.4	232.4±36.5	219.2±50.0	201.8±29.8	186.1±62.4	187.1±35.9
Nasal 500	235.1±47.6	241.1±49.4	224.3±64.0	198.1±39.6	193.1±65.1	173.5±35.3
Subfoveal	294.8±46.5	291.6±39.7	287.4±43.2	258.1±32.8	237.6±61.3	249.6±36.0
Temporal 500	260.5±44.8	265.0±37.0	251.2±42.1	229.7±33.3	208.9±55.0	214.8±18.6
Temporal 1000	244.2±42.5	250.9±35.6	233.1±38.0	219.3±31.4	187.4±57.2	205.1±25.4
Temporal 1500	226.1±43.2	238.4±35.8	219.8±34.3	208.0±34.2	171.2±60.7	196±27.7
Temporal 2000	213.0±41.1	220.3±36.4	205.9±31.3	193.2±33.0	148.2±61.3	189.6±23.0
Temporal 2500	194.6±40.4	199.8±36.8	182.9±33.7	178.0±35.3	142.8±57.1	176.5±21.1
CMT	215.4±24.7	221.3±32.4	219.9±32.2	209.6±28.8	218.4±28.2	184.5±12.3

CMT: Central macular thickness

choroidal thinning observed. CMT had a weak correlation with CT at all locations. There was no significant difference between the males and females. Relationship of variables with subfoveal CT has been shown in Table 2.

Discussion

Ours is the first study, which reports normative CT profile in various age groups in healthy Indian eyes and discusses various factors affecting CT.

Normative CT profile is necessary to make the diagnosis of the choroidal abnormalities. All the previous normative studies on CT have included eyes with larger AXL s as well; therefore, these studies do not give a correct impression of the normal variation of CT [Table 3]. Spherical equivalent may not be a true determinant for the actual length of the eye, and hence it may not correspond with anatomical variation such as thinning of the choroid. In our study, we excluded eyes with AXL of >24 mm or <20 mm. Therefore, our study provides a genuine database for CT based on AXL, a more objective variable.

Compared with previous studies in healthy subjects, our study shows a slight difference in CT with a lesser variation.[9-13] This difference may result from a difference in spectral domain (SD)-OCT machines, ethnicity and patients profile (AXL, spherical equivalent variability). However, in our study, the study population was classified on the basis of age group within normal range of AXL (20-25 mm). Studies by Ikuno *et al*.,[11] Hirata *et al*.,[10] and Ding *et al*.[9] included subjects with longer AXL, up to 28 mm. Manjunath *et al*.[12] and Margolis and Spaide *et al*.[13] did not mention the range of AXL in study population and ethnic distribution of their subjects.

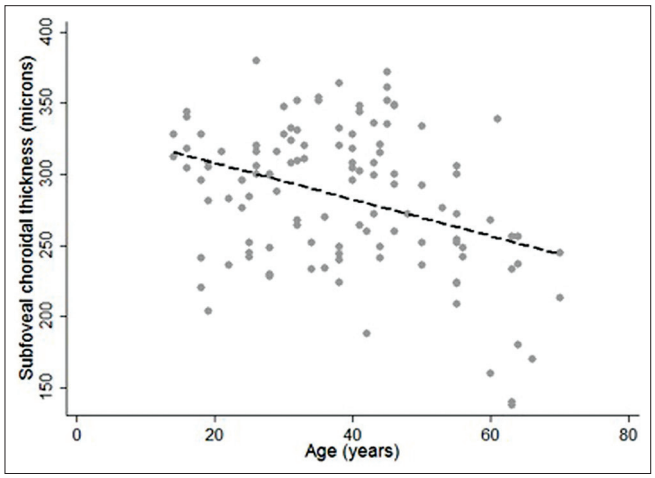

Figure 2: Scatterplot showing negative correlation between subfoveal choroidal thickness and age in healthy subjects. R2 = 0.13

In our study of healthy subjects, age was the only significant factor, which had a negative correlation with CT similar to previous reports.[7] Margolis and Spaide *et al*.[13] reported 15.6 µm decrease in CT every 10 years, similarly 14 µm decrease every decade was reported by Ikuno *et al*.[11] In our study, we found a decrease of approximately 11.8 µm in CT every decade. Ding *et al*.[9] reported that this age-related thinning occurs only in age older than 60 years of age. Our study did not have the power to show a statistically significant difference between younger subjects and subjects older than 60 years of age due to small number of subjects of subjects older than 60 years with good quality images.

Strengths of the present study include stringent criteria of study population, including phakic eyes with AXL of 20-25 mm, excellent inter-observer repeatability and intra-observer reproducibility for manual measurement of CT. Limitations of our study include small sample size; especially age >60 years. We excluded many SD-OCT images of healthy subjects of older subjects due to poor image quality due to lens opacity. We included pseudophakic eyes, to avoid any confounding effect of surgery on CT.

Table 2: Relationship between various factors with subfoveal choroidal thickness

Age group	Coefficient	*P*
Age	–1.18	0.00
Female	3.77	0.614
Axial length	–3.5	0.451
Spherical equivalent	2.76	0.604
Central macular thickness	0.12	0.272

Table 3: Comparison of present study with previously published literature on choroidal thickness in healthy subjects

Studies	Place of study	Number of subjects (eyes)	Mean age±SD (years)	Ethnicity	Mean AXL±SD (mm)	Mean CT±SD (microns)
Ikuno *et al*.[11]	Japan	43 (43)	39.4±16.0	Japan	24.40±1.24 (21.76-27.35)	354±111
Ding *et al*.[9,10]	China	210 (420)	49.73±17.89	China	Not mentioned	261.93±88.42
Hirata *et al*.[10]	Japan	31 (31)	64.6±17.3	Japan	24.6±2.1 (21.35-28.66)	191.5±74.2
Rahman *et al*.[14]	United Kingdom	50 (100)	38±5	22 Caucasian, 16 Asian, 8 Oriental, and 4 Afro-Caribbean	24.46±1.12 (22.09-26.89)	332±90
Manjunath *et al*.[12]	USA	34 (34)	51.1 (22-78)	Not mentioned	Not mentioned	272±81
Margolis and Spaide[13]	USA	30 (54)	50.4 (19-85)	Not mentioned	Not mentioned	287±76
Present study	India	71 (124)	42.8 (21-80)	Indian	22.84±0.78 (20.91-25.0)	280.1±46.5

SD: Standard deviation, AXL: Axial length, CT: Choroidal thickness

Conclusions

Our study provides a valid normative database of CT in healthy Indian subjects in various age groups. This database could be useful for further studies evaluating choroidal changes in various chorioretinal disorders.

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