Original Article

Choroidal thickness in normal Indian eyes using swept-source optical coherence tomography

Amber A Bhayana, Vinod Kumar, Akshay Tayade, Mahesh Chandra, Parijat Chandra, Atul Kumar

Purpose: The purpose of this study is to provide normative database for subfoveal choroidal thickness in Indian eyes using swept-source optical coherence tomography. **Methods:** This is a cross-sectional study based at a tertiary eye care center in Northern India. Two hundred and thirty eight eyes of 119 healthy subjects were examined in terms of axial length, spherical equivalent, and choroidal thickness. Inclusion criteria included age 19–60 years, no retinal or choroidal disorder, and patients with clear media and good fixation. Patients with high hypermetropia (>4 D) or myopia (>6 D) or any systemic disease likely to affect choroidal thickness were excluded. Twelve radial line scans were obtained centered on the fovea that were used to calculate choroidal and retinal thickness in 9 early treatment diabetic retinopathy study (ETDRS) zones. **Results:** The mean age of all the subjects was 28.70 ± 11.28 years; mean axial length was 23.63 ± 1.96 mm, and mean spherical equivalent was − 0.92 ± 3.08 D. The mean subfoveal choroidal thickness was 299.10 ± 131.2 μ and mean foveal thickness was 239.92 ± 48.16 μ. A negative correlation was found between subfoveal choroidal thickness and age (r = −0.0961, P = 0.1392) and axial length (r = −0.3166, P < 0.001). A statistically significant positive correlation was found between subfoveal choroidal thickness and refractive error (r = 0.2393, P = 0.0002). **Conclusion:** This study provides normative database for subfoveal choroidal thickness and foveal thickness using swept-source optical coherence tomography. The choroidal thickness measured with swept-source platform is slightly higher than that reported with spectral domain platforms.

Key words: Choroidal thickness, normal subjects, normative data, swept-source optical coherence tomography

Access this article online
Website: www.ijo.in
DOI: 10.4103/ijo.IJO_668_18
Quick Response Code:

Choroid is the posterior most part of the uveal tissue and has the maximum vascular supply per unit mass in the eye. Structurally, it is made up of five layers, of which blood vessels form the major part. Choroid serves important functions such as providing nourishment and oxygen supply to the outer retina, especially photoreceptor cell layer and retinal thermoregulation. It also absorbs excess light and prevents internal reflection of light on account of the presence of melanocytes and also regulates intraocular pressure by modulating the ocular blood flow.[1]

Many diseases affecting the macula such as age-related macular degeneration, polypoidal choroidal vasculopathy, Vogt–Kayanagi–Harada disease, diabetic retinopathy, and central serous chorioretinopathy have been reported to be secondary to or correlated with choroidal dysfunction.[2-5] Dilation of choroidal vessels may lead to increased choroidal thickness, which further results in increase in hydrostatic pressure and vascular permeability. On the other hand, choroidal thinning leads to insufficient nourishment of the retina, resulting in retinal pigment epithelium (RPE) degeneration and photoreceptor cell loss.[6] Thus, information about choroidal thickness could be useful in many clinical situations for decision making regarding diagnosis, management, and monitoring of disease progression. It is, therefore, imperative to have normative data for choroidal thickness.

Indocyanine green angiography was the earliest used modality for assessment of choroid. However, it is an invasive procedure and gives no information about the thickness or cross-sectional assessment of choroid. The thickness of choroid has been measured using ultrasonography and magnetic resonance imaging (MRI), although their resolution within the choroid is limited.[7,8] With the introduction of enhanced depth imaging optical coherence tomography (EDI-OCT) by Spaide *et al.*,[9] choroidal visualization was possible. Swept-source OCT (SS-OCT; DRI-OCT, Topcon Japan)[6] is the latest milestone in retinal and choroidal imaging. Because it uses a light of a longer wavelength, it provides a better resolution of choroidal layers and its thickness. Due to several advantages offered by SS-OCT over SD-OCT (better resolution, simultaneous imaging of vitreous, retina and choroid, longer OCT scans, and penetration through hazy media), many retinal surgeons and centers are shifting to SS-OCT. Though the choroidal thickness profile for Indian population has been reported using SD-OCT,[10] normative data for choroidal thickness in

Dr. Rajendra Prasad Centre for Ophthalmic Sciences, All India Institute of Medical Sciences, New Delhi, India

Correspondence to: Dr. Vinod Kumar, Dr. Rajendra Prasad Centre for Ophthalmic Sciences, All India Institute of Medical Sciences, New Delhi, India. E-mail: drvinod_agg@yahoo.com

Manuscript received: 24.04.18; Revision accepted: 17.10.18

Cite this article as: Bhayana AA, Kumar V, Tayade A, Chandra M, Chandra P, Kumar A. Choroidal thickness in normal Indian eyes using swept-source optical coherence tomography. Indian J Ophthalmol 2019;67:252-5.

not available for SS-OCT. Here, we report normative data for choroidal as well retinal thickness in normal Indian eyes using SS-OCT.

Methods

This cross-sectional study was conducted at a tertiary eye care center in Northern India from January 2017 to October 2017. The study was conducted in accordance with the tenets of declarations of Helsinki. Institutional ethics committee approval was obtained and informed consent was taken from all subjects. The study population consisted of healthy volunteers/patients/relatives of patients with no evidence of eye disorders and between the age group of 19 and 60 years. Only patients with clear media and good fixation were included. Patients with history of any intraocular (retinal/choroidal) pathology; surgery or inflammation; myopia >6 D and hyperopia >4 D; any retinal or RPE pathology detected on OCT; any history of systemic diseases such as diabetes mellitus, hypertension, impaired renal function, thyroid disorders, or vascular diseases were excluded.

A comprehensive ophthalmic examination including best-corrected visual acuity, slit lamp examination, intraocular pressure measurement using noncontact tonometry, and dilated fundus examination was done. Axial length measurement was performed using ocular biometry (IOL Master 500, Zeiss Inc). Refractive error was measured using automated refractometer (Nidek Tonoref-2, Nidek Inc.).

The choroidal thickness was measured using SS-OCT (DRI-OCT Triton plus, TOPCON, Tokyo, Japan) according to the standard ETDRS grid[11] divided into different zones based on circles at 1 mm, 3 mm, and 6 mm from the centre of macula, between the Bruch's membrane, and choroido-scleral junction. The choroidal thickness in central 1 mm zone was labeled as subfoveal choroidal thickness. Twelve equidistant radial scans, each of 12 mm length, that were centered at fovea were obtained in each eye. The machine provides automated measurement of choroidal thickness. To avoid errors in the delineation of choroido-scleral junction, the layers identified in automated mode were manually checked in all the eyes and were corrected, if required [Fig. 1]. The quality of scan was ensured by the in-built scoring system in the SS-OCT machine. A score out of 10 is rewarded by the machine for every scan. Scans with score ≥6 (highlighted as green) were accepted for analysis. A single good quality scan was obtained per eye by a single observer who was blinded to the samples and the ongoing study. The retinal thickness values were similarly measured in the central 6 mm area corresponding to the standard ETDRS grid [Fig. 2]. All the scans in our study were taken between 10 am and 2 pm to avoid diurnal variation of choroidal thickness. The patients were made to sit comfortably for at least 20 min before the scan was performed.

The data obtained were entered in an excel sheet (Microsoft Inc). Descriptive statistics included mean and standard deviation for continuous variables. Commercial software (Stata 12.3, StataCorp LLC, Texas, USA) was used to calculate the above data as well as correlation of retinal and choroidal thickness with age (Pearson coefficient), axial length, and refractive error (Spearman coefficient).

Results

We included 238 eyes of 119 healthy subjects. Sixty patients were females and 59 were males. Mean age of all the subjects was 28.70 ± 11.28 years. Mean axial length was 23.63 ± 1.96 mm and mean refractive error (spherical equivalent) was −0.91 ± 3.08 D.

The mean subfoveal choroidal thickness was 299.10 ± 131.2 µ. Out of 238 eyes, 206 eyes required manual correction of the automatic segmentation. Out of nine ETDRS zones, the mean choroidal thickness was minimum in the nasal outer macula (241.98 ± 134.64 µ) while it was maximum in the superior inner macula (305.33 ± 130.78 µ). All the inner zones (closer to the fovea) had greater choroidal thickness than the outer zones.

The mean foveal thickness (retinal thickness at fovea) was 239.92 ± 48.16 µ. Out of all the ETDRS zones, nasal inner zone had the thickest retina (307.49 ± 34.12 µ), whereas temporal outer zone had the thinnest retina (255.89 ± 31.46 µ).

The details of retinal and choroidal thickness in all the ETDRS zones are given in Table 1.

Mean subfoveal choroidal thickness was correlated with age of patients, axial length, and refractive error. A negative correlation was found between subfoveal choroidal thickness and age (r = −0.0961), which was not statistically significant (P = 0.1392). A statistically significant negative correlation was also found between subfoveal choroidal thickness and axial length (r = −0.3166, P = 0.0000). A statistically significant positive correlation was found

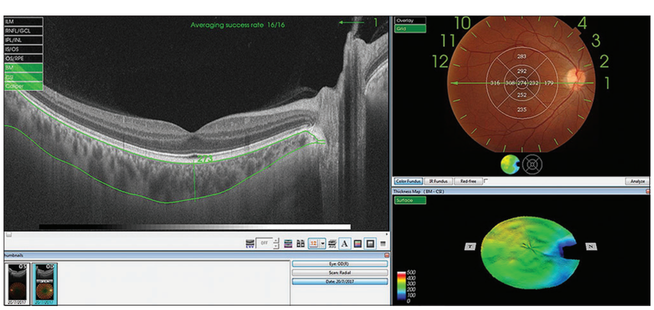

Figure 1: Swept-source optical coherence tomography radial B scan and ETDRS grid showing the choroidal thickness. Manual segmentation at the level of outer margin of RPE–Bruch's complex and choroido-scleral junction has been done in the B scan. The ETDRS grid provides corresponding values of the choroidal thickness

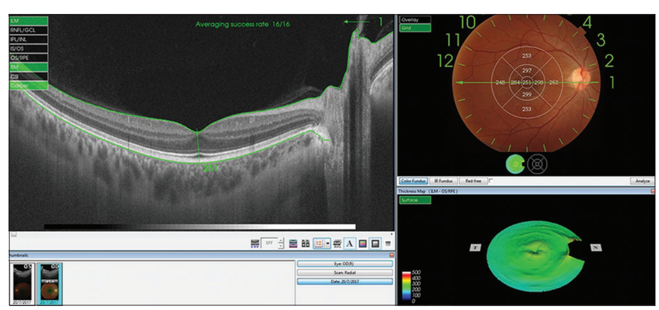

Figure 2: Swept-source optical coherence tomography radial B scan and ETDRS grid showing the retinal thickness. Automated segmentation at the level of internal limiting membrane and outer margin of RPE–Bruch's complex is visible in the B scan and ETDRS grid provides automated values of the retinal thickness

Table 1: Details of retinal and choroidal thickness (in μ) in all 9 ETDRS zones

	CSF	NIM	NOM	TIM	TOM	SIM	SOM	IIM	IOM
CT	299.10±131.20	282.69±131.90	241.98±134.64	294.40±123.18	281.63±118.60	305.33±130.78	304.71±119.88	298.47±140.92	286.50±139.02
RT	239.92±48.16	307.46±34.12	286.40±32.48	292.14±31.68	255.89±30.46	307.02±37.16	267.44±36.40	302.18±37.42	263.70±35.62

CT=Choroidal thickness, RT=Retinal thickness, CSF=Central subfoveal, NIM=Nasal inner macula, NOM=nasal outer macula, TIM=Temporal inner macula, TOM=Temporal outer macula, SIM=Superior inner macula, SOM=Superior outer macula, IIM=Inferior inner macula, IOM=Inferior outer macula

between subfoveal choroidal thickness and refractive error (r = 0.2393, P = 0.0002).

A multivariate analysis was performed with subfoveal choroidal thickness as the dependent factor and axial length and spherical equivalent as the independent factors. The subfoveal choroidal thickness was found to have the following correlations: (−) 15.41 × with axial length (P = 0.003) and (+) 6.18 × with the refractive error (P = 0.057). This signifies that, while choroidal thickness decreases with increase in axial length, increasing spherical equivalent increases the choroidal thickness.

A correlation analysis was performed between the retinal and choroidal thickness but the correlation was weak and insignificant (r = 0.0561, P value = 0.3890).

Discussion

The normative data of choroidal thickness in Indian population has been reported earlier using SD-OCT.[10] Due to the advantages offered by SS-OCT, its incorporation in the routine clinical practice is on the rise. Matsuo *et al*. compared the subfoveal choroidal thickness on two different SD-OCT platforms and SS-OCT.[12] The authors found that the choroidal thickness was greater when measured with SS-OCT and attributed it to the better delineation of choroido-scleral junction, especially in eyes with thicker choroid. Later, Copete *et al*. and Adhi *et al*. also documented the superiority of SS-OCT over SD-OCT in terms of better visualization of choroido-scleral interface.[13,14] It is, therefore, prudent to have normative data for choroidal thickness on SS-OCT. This is the first study providing normative data of choroidal and retinal thickness using SS-OCT in Indian population.

In our study, mean subfoveal choroidal thickness was 299.10 ± 131.2 μ (mean age 28.70 years) compared to 294.8 ± 46.5 μ (in 20–29 years age group) as reported earlier on SD-OCT.[10] Similar findings have been reported before, where increased choroidal thickness was found on SS-OCT compared to SD-OCT.[12-14] The small difference may not be significant in clinical practice.[12] Because majority of the research nowadays is depending upon SS-OCT for choroidal imaging due to better delineation of sclera-choroidal junction, we think that the subfoveal choroidal thickness obtained with SS-OCT may be more appropriate for comparison in future studies.

A negative correlation was found between subfoveal choroidal thickness and age in our study that was statistically not significant. Ikuno *et al*. reported a decrease in choroidal thickness by 14 μ with every decade.[15] Similar findings were reported by Chhablani *et al*.[10] As compared to other studies this decrease in choroidal thickness with age was not statistically significant. This may be due to the fact that most patients in our study were in the age range of 20–40 years, while age related choroidal thinning is seen mostly after 60 years.[16] The mean choroidal thickness was not statistically different among males and females.

Similar to previous studies longer eyes had thinner subfoveal choroid while shorter eyes had thicker choroid and the relationship of subfoveal choroidal thickness with axial length as well as spherical equivalent was statistically significant. This may be useful while interpreting the subfoveal choroidal thickness in longer or shorter eyes.

There occurs a topographical variation of the choroidal thickness.[17-19] It is usually maximum at the fovea or just superior/temporal to fovea. Thick choroid act as a metabolic sink for the highly active foveal area. It gradually tapers centrifugally. On the nasal side, it tapers quickly and stops abruptly at the margin of the optic disc. Therefore, it is the thinnest in the nasal half. With myopia (predominantly high myopia where posterior pole elongates), there occurs temporal stretching, and therefore displacement of the choroid with respect to the fovea.[20] This leads to greater thickness observed in such cases temporally instead of the central subfield.

Similarly, retinal thickness also follows a topographic pattern.[21,22] Being the thinnest at the fovea, it becomes the maximum in the inner 3 mm zone and then tapers to become thin again in the outer macular zone (between 3 and 6 mm). The temporal quadrant is thinner compared to the nasal quadrant where maximum nerve fiber layers are converging to join the optic disc. The superonasal quadrant is thickest, which may be due to thick arcuate nerve fiber bundles in that area.

The limitation of this study is that the subject age group in our study ranged from 19–45 years, majority of which fall between 20 and 30 years. Although scans of all the subjects were obtained between 10 am and 2 pm, the variation of choroidal thickness through the day cannot definitely be ruled out. Moreover, multiple observers did not verify the thicknesses of choroid and retina.

Conclusion

To conclude, we report normal choroidal and retinal thickness in healthy Indian eyes using SS-OCT that can serve as normative data for various studies. The choroidal thickness decreases with increasing age and axial length.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Nickla DL, Wallman J. The multifunctional choroid. Prog Retin Eye Res 2010;29:144-68.
2. Chung SE, Kang SW, Lee JH, Kim YT. Choroidal thickness in polypoidal choroidal vasculopathy and exudative age related macular degeneration. Ophthalmology 2011;118:840-5.
3. Maruko I, Iida T, Sugano Y, Ojima A, Sekiryu T. Subfoveal choroidal thickness in fellow eyes of patients with central serous chorioretinopathy. Retina 2011;31:1603-8.
4. Fong AH, Li KK, Wong D. Choroidal evaluation using enhanced depth imaging spectral-domain optical coherence tomography in Vogt-Koyanagi-Harada disease. Retina 2011;31:502-9.
5. Regatieri CV, Branchini L, Carmody J, Fujimoto JG, Duker JS. Choroidal thickness in patients with diabetic retinopathy analyzed by spectral-domain optical coherence tomography. Retina 2012;32:563-8.
6. Michalewska Z, Michalewski J, Nawrocki J. Swept Source OCT: Wide-field simultaneous choroid, retina and vitreous visualization, Retina Today 2013;9:50-6.
7. Townsend KA Wollstein G Schuman JS. Clinical application of MRI in ophthalmology. NMR Biomed 2008;21:997-1002.
8. Coleman DJ Silverman RH Chabi A. High-resolution ultrasonic imaging of the posterior segment. Ophthalmology 2004;111:1344-51.
9. Spaide RF, Koizumi H, Pozonni MC. Enhanced depth imaging spectral-domain optical coherence tomography. Am J Ophthalmol 2008;146:496-500.
10. Chhablani J, Rao PS, Venkata A, Rao HL, Rao BS, Kumar U, *et al*. Choroidal thickness profile in healthy Indian subjects. Indian J Ophthalmol 2014;62:1060-3.
11. Early Treatment Diabetic Retinopathy Study Research Group. ETDRS report number 10: Grading diabetic retinopathy from stereoscopic color fundus photographs--an extension of the modified Airlie House classification. Ophthalmology 1991;98:786-806.
12. Matsuo Y, Sakamoto T, Yamashita T, Tomita M, Shirasawa M, Terasaki H. Comparisons of choroidal thickness of normal eyes obtained by two different spectral-domain OCT instruments and one swept-source OCT instrument choroidal thickness with SS-OCT and SD-OCT. Invest Ophthalmol Vis Sci 2013;54:7630-6.
13. Adhi M, Liu JJ, Qavi AH, Grulkowski I, Lu CD, Mohler KJ, *et al*. Choroidal analysis in healthy eyes using swept-source optical coherence tomography compared to spectral domain optical coherence tomography. Am J Ophthalmol 157;6:1272-81.e1
14. Copete S, Flores-Moreno I, Montero JA, Duker JS, Ruiz-Moreno JM. Direct comparison of spectral-domain and swept-source OCT in the measurement of choroidal thickness in normal eyes. Br J Ophthalmol 2014;98:334-8.
15. Ikuno Y, Kawaguchi K, Nouchi T, Yasuno Y. Choroidal thickness inhealthy Japanese subjects. Invest Ophthalmol Vis Sci 2010;51:2173-6.
16. Ding X, Li J, Zeng J, Ma W, Liu R, Li T, *et al*. Choroidal thickness in healthy Chinese subjects. Invest Ophthalmol Vis Sci 2011;52:9555-60.
17. Manjunath V, Taha M, Fujimoto JG, Duker JS. Choroidal thickness in normal eyes measured using Cirrus HD optical coherence tomography. Am J Ophthalmol 2010;150:325-9.
18. Margolis R, Spaide RF. A pilot study of enhanced depth imaging optical coherence tomography of the choroid in normal eyes. Am J Ophthalmol 2009;147:811-5.
19. Tan CS, Cheong KX. Macular choroidal thicknesses in healthy adults—Relationship with ocular and demographic factors. Invest Ophthalmol Vis Sci 2014;55:6452-8.
20. Lee K, Lee J, Lee CS, Park SY, Lee SC, Lee T. Topographical variation of macular choroidal thickness with myopia. Acta Ophthalmol 2015;93:e469-74.
21. Chan A, Duker JS, Ko TH, Fujimoto JG, Schuman JS. Normal macular thickness measurements in healthy eyes using stratus optical coherence tomography. Arch Ophthalmol 2006;124:193-8.
22. Wang J, Gao X, Huang W, Wang W, Chen S, Du S, *et al*. Swept-source optical coherence tomography imaging of macular retinal and choroidal structures in healthy eyes. BMC Ophthalmol 2015;15:122.