Choroidal thickness in high refractive errors using spectral-domain optical coherence tomography

Sumeet Chopra[1], Sehajpreet Kaur[2*]

[1]Associate Professor, [2]Resident, Dept. of Ophthalmology, Dayanand Medical College, and Hospital, Ludhiana, Punjab, Haryana, India

***Corresponding Author: Sehajpreet Kaur**
Email: sehaj2605@gmail.com

Abstract

Aims of Study: 1. To determine the choroidal thickness CT in eyes of subjects with high refractive errors, using SD-OCT.; 2. To correlate the CT with the refractive error and the axial length in these eyes.

Materials and Methods: In this cross-sectional observational study 87 subjects with high myopia, i.e., spherical equivalents (SE) >-6.0D and high hypermetropia, i.e., SE> +3.0 D, aged between 5 to 50 years and with a best-corrected visual acuity (BCVA) of 6/9 or better, were included. In each eye, the CT was measured using SD-OCT scanning at seven retinal points, i.e., subfovea and 0.5 mm, 1.0 mm and 1.5 mm nasal as well as temporal to the fovea.

Results: The CT in high myopic eyes was significantly less and in high hypermetropic eyes significantly more than in the controls, with the thinnest choroid present 1.5 mm nasal to the fovea in high myopic eyes and the thickest choroid present subfoveally in high hypermetropic eyes. The subfoveal CT in high myopic eyes had the strongest positive correlation with the SE of refractive error. In high hypermetropic eyes, the strongest positive correlation was found 1.5 mm temporal to the fovea, the point that also showed the strongest negative correlation between the axial length (AL) and the CT.

Conclusions: High myopic eyes, i.e., with SE>-6D, have significantly thinner choroids than emmetropes. The CT decreases with an increase in the degree of myopia. High hypermetropes (i.e., SE > + 3 D) have significantly thicker choroids than emmetropes. Higher degrees of hypermetropia and shorter eyeballs are associated with thicker choroids.

Keywords: Choroidal thickness, High myopia, High hypermetropia, Optical coherence tomography.

Introduction

High refractive errors are one of the main causes of abnormalities in the choroid. The choroid is the posterior part of the uveal tract extending from the optic nerve head to the ora serrata. It is 0.22 mm thick posteriorly and 0.15 to 0.10 mm thick anteriorly.[1] It is the most vascular tissue in the eye and it provides blood supply to the outer retinal structures.

Some studies of animal models[2,3] indicate that the choroid plays an important role in the modulation of refractive status. The retina moves to reduce the blur and permanently alter the ocular dimensions to maintain a clear image. In choroid of humans, similar changes have been seen in response to short-term unilateral image blur.[4]

High myopia is always accompanied by pathological structural changes, such as axial elongation, posterior scleral staphyloma, lacquer crack formation, thinning of the retina and choroid, and choroidal neovascularization (CNV). In high hypermetropia, the fundus examination reveals a small optic disc which may look hyperaemic with ill-defined margins and even may simulate papillitis (also called pseudopapillitis). Retina has a shot-silk appearance. It has been postulated that eyes with shorter axial lengths have smaller lamina cribrosa and narrower scleral canals through which the central retinal vein and artery could pass, causing physical blockage in the vein which predisposes to thrombus formation.

Recent interest has focused on the choroidal thickness as an important structure involved in the pathophysiology of high refractive errors. Optical Coherence Tomography (OCT), that has emerged as the most important tool for ocular imaging, uses the principle of low coherence interferometry of light to examine the retina in vivo. Now, the enhanced depth imaging mode of optical coherence tomography (EDI-OCT), first described by Spaide et al[5] can be used to visualise the chorio-scleral junction more accurately.

Several researchers have found that in high myopic eyes, the choroidal thickness is significantly thinner than in normal eyes.[6-8] However, most of these studies failed to adjust for potential compounding factors such as axial length (AL) and spherical equivalent (SE). There have been studies showing significantly thicker macular choroid in hypermetropic amblyopia as compared to the normal fellow eyes,[9-11] but not many studies have evaluated CT in high hypermetropia without amblyopia.

Aims and Objectives

1. To study changes in the choroid by measuring the choroidal thickness in high myopic and high hypermetropic eyes.
2. To correlate the choroidal thickness with the refractive error and the axial length (AL) in these eyes.

Materials and Methods

This cross-sectional observational study consisted of 87 subjects initially, who visited the out-patient department at the department of Ophthalmology, Dayanand Medical College and Hospital, Ludhiana, Punjab, India and were randomly selected over a period of 15 months (January 2017 to March 2018). Out of these, 50 subjects (100 eyes) with high refractive errors[12,13] (myopia >-6.0 D SE and hypermetropia > + 3.0 D SE) with a BCVA of 6/9 or better,

and 20 healthy controls (40 eyes) were included for analysis, in whom the chorio-scleral junction could be identified on EDI SD-OCT imaging with an image quality of ≥ 6/10. Out of 50 subjects, 30 (60 eyes) were high myopes and 20 (40 eyes) high hypermetropes. 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 for research involving human subjects. Eyes with any previous retinal or choroidal pathology, with severe media opacities preventing fundus assessment, intra-ocular pressure (IOP) > 21 mmHg or with any one characteristic glaucomatous disc change, patients on medications known to cause maculopathy, patients with known neuro-ophthalmological diseases, patients of diabetes, hypertension and/or Koch's disease were excluded.

A written informed consent was obtained from all subjects before acquisition of the OCT scan. All patients underwent a clinical history taking and a complete ophthalmic examination.

OCT scanning was performed using cirrus HD-OCT (Model 5000, SD-OCT, CARL ZEISS Meditec, INC, DUBLIN, USA), which utilises spectral domain (SD)-OCT and has a scan speed of 27,000 - 68,000 A-scans per second with an axial resolution of 5 µm (in tissue) and a transverse resolution of 15 µm (in tissue). The choroid was visualized by enhanced depth imaging (EDI) technique. The vertical distance between the posterior edge of the hyper-reflective RPE layer and the chorio-scleral interface was measured manually using the software calipers. Choroidal thickness was measured subfoveally and at 500 microns intervals upto 1500 microns temporal and nasal to the fovea (Fig. 1).

The findings were recorded in the proforma attached. For analysis, the subjects were divided into the following three groups: group A - high myopic eyes, group B – high hypermetropic eyes and group C – control eyes.

Statistical Analysis

Data were described in terms of range, mean ± standard deviation (± SD), median, frequencies (number of cases) and relative frequencies (percentages) as appropriate. Comparison of quantitative variables between the study groups was done using Student t-test and Mann Whitney *U* test for independent samples for parametric and non-parametric data respectively. For comparing categorical data, Chi square ($\chi 2$) test was performed and exact test was used when the expected frequency is less than 5. Spearman's rho was used to find the correlation between various parameters. A probability value (*p* value) less than 0.05 was considered statistically significant. All statistical calculations were done using SPSS (Statistical Package for Social Science) 21 version statistical program for Microsoft Windows.

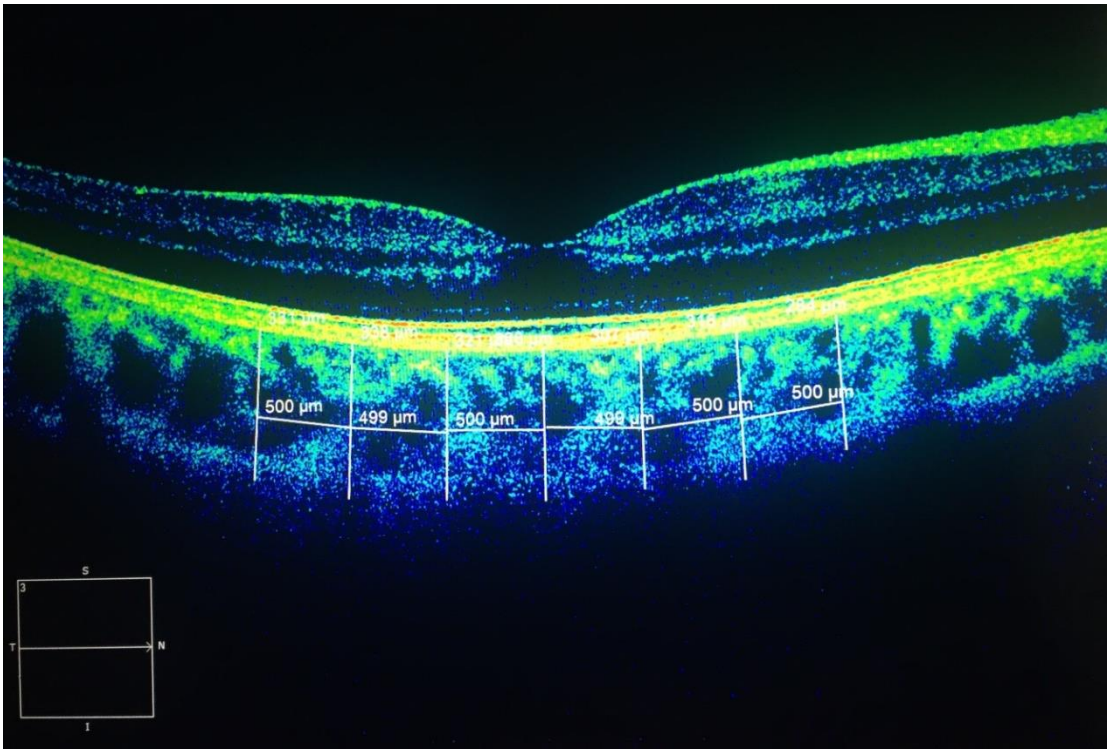

Fig. 1: Choroidal thickness sub foveally and at 500 microns intervals till 1500 microns nasal and temporal to the fovea, using EDI mode of SD-OCT

Results

Group A included 60 eyes of 30 high myopic subjects, group B had 40 eyes of 20 high hypermetropic subjects and group C included 40 eyes of 20 age and sex matched healthy controls.

The mean ages in group A, B and C were 24.10 ± 8.74 years, 27.05 ± 10.88 years respectively. The mean refractive errors (SE) in group A and B were -9.28 D and +4.92 D respectively. The mean axial lengths in groups A, B and C were 26.25 ± 1.39 mm, 21.09 ± 0.62 mm and 22.95 ± 0.61 mm respectively.

In group A, the mean CT was found to be less as compared to that of group C, and the difference was statistically significant at all the points ($p<0.05$), except at 1500 µm temporal to the fovea. The maximum and minimum CT were at 1500 µm temporal to the fovea (239.37 ± 33.26µm) and 1500 µm nasal to the fovea (230.32 ± 25.74 µm) respectively (Table 1).

In group B, the mean CT at all the retinal points was significantly more than the control eyes ($p<0.05$), except at 500 µm temporal to the fovea. The CT was maximum sub-foveally, i.e., 276.23 ± 34.37 µm. Overall, the CT at the nasal points was more than at the temporal (Table 2).

In group A, there was a positive correlation of CT with the SE of refractive error at all the retinal points. The subfoveal choroidal thickness showed the strongest correlation (r=0.428). There was no statistically significant correlation between the AL and CT at any point ($p>0.05$) (Table 3).

In group B, there was a positive correlation of SE of refractive error and the mean CT at all retinal points, with the strongest correlation at 1.5 mm temporally (r= 0.655). The AL showed a negative correlation with mean CT at all the points, with the maximum correlation at 1.5 mm temporal location (r=-0.682) (Table 4).

Table 1: Comparison of mean choroidal thickness in high myopic and control eyes

Location	Choroidal thickness (in µm)				A VS C
	Group A		Group C		
	Mean	SD	Mean	SD	p-value
Temporal 1.5 mm (T 1.5)	239.37	33.26	246.50	24.70	0.232
Temporal 1.0 mm (T 1.0)	239.10	32.80	255.00	21.25	0.007
Temporal 0.5 mm (T 0.5)	238.65	32.58	256.65	18.62	0.002
Sub-foveal (SF)	237.67	29.92	262.13	20.86	0.002
0.5 mm nasal (N 0.5)	236.07	27.76	256.43	18.22	0.009
1.0 mm nasal (N 1.0)	235.20	26.45	250.93	19.45	0.046
1.5 mm nasal (N 1.5)	230.32	25.74	250.45	23.48	0.008

Table 2: Comparison of mean choroidal thickness in high hypermetropic eyes

Location	Choroidal thickness in µm				B VS C
	Group B		Group C		
	Mean	SD	Mean	SD	p-value
Temporal 1.5 mm	266.35	26.36	246.50	24.70	0.003
Temporal 1.0 mm	269.15	27.52	255.00	21.25	0.028
Temporal 0.5 mm	268.25	27.05	256.65	18.62	0.063
Subfoveal	276.23	34.37	262.13	20.86	0.032
Nasal 0.5 mm	271.18	30.20	256.43	18.22	0.013
Nasal 1.0 mm	273.75	31.56	250.93	19.45	0.000
Nasal 1.5 mm	270.33	30.76	250.45	23.48	0.001

Table 3: Correlation of choroidal thickness with refractive error and axial length in high myopic eyes

	Spearman's rho	T 1.5 CT	T 1.0 CT	T 0.5 CT	SF	N 0.5 CT	N 1.0 CT	N 1.5 CT
SE (ref error)	Correlation Coefficient	0.276	0.277	0.348	0.428	0.230	0.227	0.281
	p-value	0.033	0.032	0.006	0.001	0.077	0.080	0.030
Axial length	Correlation Coefficient	-0.005	-0.068	-0.069	-0.138	0.011	-0.082	-0.076
	p-value	0.969	0.605	0.600	0.295	0.933	0.532	0.566

Table 4: Correlation of choroidal thickness with refractive error and axial length in high hypermetropic eyes

	Spearman's rho	T 1.5 CT	T 1.0 CT	T 0.5 CT	SF	N 0.5 CT	N 1.0 CT	N 1.5 CT
SE (ref error)	Correlation Coefficient	0.655	0.436	0.528	0.444	0.425	0.455	0.449
	p-value	0.000	0.005	0.000	0.004	0.006	0.003	0.004
Axial length	Correlation Coefficient	-0.682	-0.546	-0.571	-0.468	-0.532	-0.573	-0.465
	p-value	0.000	0.000	0.000	0.002	0.000	0.000	0.002

Discussion

The mean CT in high myopic eyes was lesser than in emmetropic control eyes. The mean subfoveal choroidal thickness (SFCT) found in our high myopic eyes, i.e., 237.67 ± 29.92 µm, was close to that obtained in the previous reports by Shiming Wang et al[8] (200.54 ± 69.39 µm) and Gupta et al[7] (225.87±5.51 µm), who had used the EDI mode of SD-OCT, whereas it was more than the mean SFCT seen in the high myopic subjects of Fujiwara et al[14] (93.2 ± 62.5 µm) and Flores Moreno et al[6] (130 µm), who did not use the EDI mode of OCT. This corroborates the fact that the chorio-scleral junction is better visualized by the EDI mode of SD-OCT, which was also used in our study. Flores Moreno et al[8] found that the choroid was the thickest temporally, then subfoveally and thinnest nasally in high myopic eyes. Similarly, we found in our high myopic eyes, that the CT increased from 1.5 mm nasal to the fovea, to the sub-foveal location, till 1.5 mm temporal to the fovea. Thinner choroid, especially in the nasal region, agrees with the pathologic change of staphylomas where common myopic changes involve the macular and optic nerve regions. The temporally thickened choroid in our high myopic eyes might be explained by the buffering action of the choroid to prevent substances required for metabolism (for the continuous ocular growth in the temporal direction of macula) from penetrating it too quickly. Like the results of Fujiwara et al,[14] we also found in our study that in high myopic eyes, with an increase in the degree of myopia, there was a statistically significant decrease in the SFCT.

The high hypermetropic eyes in this study had significantly greater mean CT (mean SFCT 276.23 ± 34.37 µm) than the controls. This was in accordance with the previous studies conducted on hypermetropic anisometropic amblyopic subjects by Mori et al,[10] Tenlik et al[11] and Tomo Nishi et al,[9] in which SFCT was significantly greater than in the normal fellow eyes (407.3 ± 54.2 µm, 305.6 ± 26.0 µm and 351.3±54.7 µm respectively). The greater values of mean CT in these previous studies might be because they had taken 'amblyopic' subjects, in contrast to our study in which high hypermetropic subjects, with a BCVA of 6/9 or better, were included. We found that the choroid was the thickest subfoveally and the nasal choroid was thicker than the temporal one. Similar to the results of Tomo Nishi et al[9] we also found a statistically significant negative correlation between the CT and the AL. In addition, we found a positive correlation of the degree of hypermetropia with the thickness of choroid, which was the strongest 1500 µm temporally.

Conclusions

High myopes, i.e., myopia of more than -6D SE, have significantly thinner choroids than the emmetropic controls at all the retinal points studied, with the thinnest choroid at 1.5 mm nasal to the fovea. With an increase in the degree of myopia, the choroidal thickness decreases, and this correlation was the strongest at the subfoveal location. High hypermetropes, i.e., hypermetropia of more than +3 D SE, on the other hand, have significantly thicker choroids, as compared to the emmetropic controls, at most of the locations, with the maximum thickness being at the subfovea. Higher degrees of hypermetropia are associated with thicker choroids, the maximum correlation being at 1.5 mm temporal to the fovea. Further, shorter is the eyeball, thicker is the choroid, which is again best seen at the temporal 1.5 mm location.

To the best of our knowledge, this is the first study, at least in the Northern Indian population, that has compared the changes in choroidal thickness in high myopic and high hypermetropic eyes, with emmetropic healthy control eyes, together, in the same study. However, further longitudinal studies are required to be conducted to evaluate the changes in choroidal thickness with time, that is, whether the choroidal thickness changes with increasing age and the changing refractive error.

Conflict of Interest: None.

References

1. Green, WR: The choroid. In Spencer, WH. Ed: Ophthalmic Pathology: an atlas and textbook, 3rd edition. Philadelphia: WN Saunders; 1986. P. 1221-426.
2. Troilo D, Nickla DL, Wildsoet CF. Choroidal thickness changes during altered eye growth and refractive state in a primate. *Invest Ophthalmol Vis Sci* 2000;41:1249–58.
3. Wallman J, Winawer J. Homeostasis of eye growth and the question of myopia. *Neuron* 2004;43:447–68.
4. Chiang STH, Phillips JR, Backhouse S. Effect of retinal image defocus on the thickness of the human choroid. *Ophthalmic Physiol Opt J Br Coll Ophthalmic Opt Optom* 2015;35:405–13.
5. Spaide RF, Koizumi H, Pozonni MC. Enhanced depth imaging spectral-domain optical coherence tomography. *Am J Ophthalmol* 2008;146:496–500.
6. Flores-Moreno I, Lugo F, Duker JS, Ruiz-Moreno JM. The relationship between axial length and choroidal thickness in eyes with high myopia. *Am J Ophthalmol* 2013;155:314–9.
7. Gupta P, Saw S, Cheung CY, Girard MJ, Mari JM, Bhargava M, et al. Choroidal thickness and high myopia a case–control study of young Chinese men in Singapore. *Acta Ophthalmol* 2015;93:585-92.

8. Wang S, Wang Y, Gao X, Qian N, Zhuo Y. Choroidal thickness and high myopia: A cross-sectional study and meta-analysis. *BMC Ophthalmol* 2015;15:70.
9. Nishi T, Ueda T, Hasegawa T, Miyata K, Ogata N. Choroidal thickness in children with hyperopic anisometropic amblyopia. *Br J Ophthalmol* 2014;98:228–32.
10. Mori T, Sugano Y, Maruko I, Sekiryu T. Subfoveal Choroidal Thickness and Axial Length in Preschool Children with Hyperopic Anisometropic Amblyopia. *Curr Eye Res* 2015;40:954–61.
11. Tenlik A, Güler E, Kulak AE, Totan Y, Dervişoğulları MS, Gürağaç FB. Evaluation of Choroidal Thickness in Amblyopia Using Enhanced Depth Imaging Optical Coherence Tomography. *Curr Eye Res* 2015;40(10):1063–7.
12. Morgan IG, Ohno-Matsui K, Saw SM. Myopia. *Lancet* 2012;379:1739-48.
13. Kurultay-Ersan l, Emre S. Impact of Valsalva maneuver on central choroid, central macula and disk fibre layer thickness among high myopic and hyperopic patients. *Eur J Ophthalmol* 2016;27:331-5.
14. Fujiwara T, Imamura Y, Margolis R, Slakter JS, Spaide RF. Enhanced depth imaging optical coherence tomography of the choroid in highly myopic eyes. *Am J Ophthalmol* 2009;148:445-50.

How to cite this article: Chopra S, Kaur S. Choroidal thickness in high refractive errors using spectral-domain optical coherence tomography. *Indian J Clin Exp Ophthalmol* 2019;5(2):236-40.