Original Article

Choroidal Thickness in Healthy Subjects

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Abstract

Purpose: To measure the choroidal thickness by enhanced depth imaging optical coherence tomography (EDI-OCT) in normal eyes.
Methods: In a prospective case series, 208 eyes of 104 normal Iranian subjects were enrolled. Complete ophthalmic examination was performed. Inclusion criteria were best corrected visual acuity (BCVA) ≥20/20, ≤ ±1 diopter of refractive error in either spherical or cylindrical components, normal intraocular pressure (IOP) and no systemic or ocular diseases. The choroidal thickness was measured by EDI-OCT subfoveally, and 1500 µm and 3000 µm nasal and temporal to the fovea.
Results: Mean age was 34.6 ± 9.8 years (range, 18–57 years). Mean subfoveal choroidal thickness was 363 ± 84 µm. Choroidal thickness was 292 ± 76 and 194 ± 58 µm at 1500 and 3000 µm nasal to the fovea, respectively, and 314 ± 77 and 268 ± 66 µm at 1500 and 3000 µm temporal to the fovea, respectively. There was no statistically significant difference in the choroidal thickness between sexes and laterality of the eyes. Choroidal thickness at fovea ($P < 0.001$) and at all extrafoveal locations decreased significantly for every 10 years increase in age.
Conclusion: In normal Iranian subjects participating in this study, mean choroidal thickness was comparable with other reports.

Keywords: Enhanced Depth Imaging Optical Coherence Tomography; Healthy Subjects; Subfoveal Choroidal thickness

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INTRODUCTION

Choroid, the posterior portion of the uveal tract, is a vascular tissue that provides oxygen and nourishment to the outer portion of the retina and photoreceptors.[1] It has numerous functions; for example, it provides blood supply to the retinal pigment epithelium (RPE), outer retina, and prelaminar portion of the optic nerve;[2] acts as a heat sink; and choroidal melanocytes absorb excess light.[3] Therefore, choroidal abnormalities such as thinning and loss of vascular tissue play a vital role in the pathophysiology of many diseases affecting the retina. Compromised choroidal circulation can lead to vision-threatening eye diseases. It is believed that

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pathological changes in the choroid are the source of diseases such as age-related macular degeneration, central serous chorioretinopathy, polypoidal choroidal vasculopathy, and high myopia-related chorioretinal atrophies.[4-7] Furthermore, choroid is often affected in autoimmune and infectious posterior uveitis and is the source of the most common intraocular tumors in adults.[8-10]

Measurement of retinal thickness is important in the diagnosis, follow-up, and monitoring response to treatment of a number of eye diseases. Over the last few years, measurement of choroidal thickness and choroidal abnormalities have also become a subject of interest in ophthalmology. Choroidal thickness can be measured *in vivo* using ultrasonography, magnetic resonance imaging (MRI), and enhanced depth imaging optical coherence tomography (EDI-OCT). EDI-OCT is a noninvasive modality that enables cross-sectional imaging of the retina and choroid and has been used to measure choroidal thickness with an acceptable reproducibility and sensitivity.[11] Accurate *in vivo* measurement of choroidal thickness seems to be useful in the diagnosis and follow-up of choroidal vascular disorders. Choroidal thickness is influenced by age, refractive abnormalities, and ethnicity.[12,13] The normal range of choroidal thickness has been reported in western populations, Japan, China, and South Korea.[12,14-16] Previous studies in healthy adults reported a range of central choroidal thickness from 272 to 448 μm.[11,12,14,17-20]

To our knowledge, there is no published report on normal choroidal thickness in the Iranian adult population. The aim of this study was to determine choroidal thickness in healthy Iranian adult volunteers.

METHODS

In this prospective case series, 208 eyes of 104 normal Iranian individuals were studied. Participants were subjects over 18 years of age who accompanied patients in ophthalmology clinics at Torfeh Medical Center. This study was approved by the local Ethics Committee of the Ophthalmic Research Center and followed the tenets of the Declaration of Helsinki. After explaining the purpose of the study, written informed consent was obtained from all subjects.

All cases underwent a complete ophthalmologic examination including assessment of best corrected visual acuity (BCVA), measurement of intraocular pressure (IOP), slit lamp biomicroscopy, and dilated fundus examination. We only included participants with BCVA ≥20/20 and ≤±1 diopter of refractive errors in either spherical or cylindrical aspects of refraction with normal IOP. Ocular pathologies that might affect the choroid, history of intraocular surgery, refractive surgery, intravitreal injections, and media haziness that interfered with OCT examinations were among our exclusion criteria. We also excluded patients with any systemic diseases that might affect the eye and choroidal thickness, such as diabetes, impaired renal function, and hypertension.

The choroid was imaged by positioning the SD-OCT device (Spectralis OCT; Heidelberg Engineering, Heidelberg, Germany) close enough to the eye to obtain an inverted image without pupillary dilation. One horizontal 9-mm high quality line scan through the fovea was obtained of each eye. The line scan was saved for analysis after 100 frames were averaged. All EDI-OCT examinations were performed between 9:00 a.m. and 12:00 noon, to reduce the effect of diurnal variation on choroidal thickness. Therefore, complete ophthalmic examinations were performed one or two days before the day of EDI-OCT measurement at any time the subjects attended our clinic and the subjects were included in the study if all examinations were within normal limits. EDI-OCT was performed without pupillary dilation because all ophthalmic examinations were done one or two days before.

Images were viewed and measured with the software included in the device (Heidelberg Eye Explorer version 1.7.0.0; Heidelberg Engineering). Choroidal thickness was measured from the outer portion of the hyperreflective line corresponding to the retinal pigment epithelium (RPE) to the hyporeflective line corresponding to the sclerochoroidal interface by two experienced retina specialists. These measurements were performed at the fovea and at 1500 and 3000 μm nasal and temporal to the center of the fovea [Figure 1].

We divided cases into four age groups (18–28, 29–39, 40–50 and 51–60 years). Then the values were compared between age groups, sexes, and laterality of the eyes. Measurements by the two observers were compared to assess inter-grader reproducibility. In addition, observers repeated all measurements on a different day to determine the intraobserver variation. Values of the measurements by the two observers for each point were averaged for analysis.

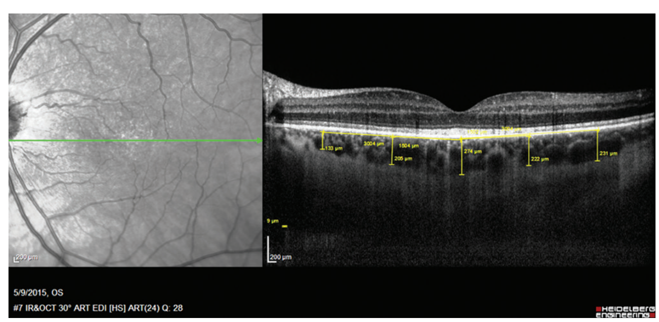

Figure 1. Choroidal thickness measured by EDI-OCT subfoveally and 1500 and 3000 μm nasal and temporal to the fovea. EDI-OCT, enhanced depth imaging optical coherence tomography.

Statistical Method

To present data, we used mean, standard deviation (SD), median, and range. To compare the groups when considering the correlation between eyes, we used the Generalized Estimating Equation (GEE). Also, this model was used to obtain the regression equation. All statistical analyses were performed using SPSS (IBM SPSS Statistics for Windows, Version 23.0. Released 2014. IBM Corp., Armonk, NY, USA). *P* values less than 0.05 were considered statistically significant.

RESULTS

In this study, choroidal thickness of 208 eyes of 104 subjects was evaluated by EDI-OCT. Sixty-one cases (58.7%) were male, and 43 cases (41.3%) were female. Mean age of subjects was 34.6 ± 9.8 years (range, 18–57 years). Mean subfoveal choroidal thickness (SFCT) was 363 ± 84 µm. There was good agreement between observers, with an intraclass correlation coefficient (ICC) of 0.98. The mean difference in measurements between observers was 2.0 ± 10 µm, with a maximum difference of 20 µm. Intraobserver agreement was very good, with an ICC of 0.99. Choroidal thicknesses were 292 ± 76 and 194 ± 58 µm at 1500 and 3000 µm nasal to the fovea, respectively, and 314 ± 77 and 268 ± 66 µm at 1500 and 3000 µm temporal to the fovea, respectively. Choroid was thickest subfoveally and thinnest 3000 µm nasal to the fovea.

Mean SFCT was 371 ± 78 and 352 ± 91 µm for male and female subjects, respectively, and was 366 ± 83 and 360 ± 86 µm for right and left eyes, respectively. We did not find any statistically significant difference between sexes (*P* = 0.247) or laterality of the eyes (*P* = 0.627) [Tables 1 and 2].

In terms of age groups (18–28 years, n = 39; 29–39 years, n = 36; 40–50 years, n = 20; and 51–60 years, n = 9), choroidal thickness decreased significantly at all locations for every 10-year increase in age [Table 3].

Table 1. Choroidal thicknesses in male and female genders

	Sex		$P^{\ddagger}$
	Male (*n*=61, 58.7%)	Female (*n*=43, 41.3%)	
F			
Mean±SD	371±78	352±91	0.247
Median (range)	377 (162, 525)	352 (117, 513)	
N_1500			
Mean±SD	299±75	283±78	0.652
Median (range)	305 (110, 501)	280 (77, 481)	
N_3000			
Mean±SD	202±59	182±56	0.075
Median (range)	202 (70, 340)	178 (68, 310)	
T_1500			
Mean±SD	318±74	310±81	0.816
Median (range)	314 (135, 503)	312 (113, 508)	
T_3000			
Mean±SD	265±62	271±71	0.084
Median (range)	265 (85, 474)	275 (121, 481)	

F, subfoveal; N, nasal; SD, standard deviation; T, temporal; *P*-values are based on the GEE, Generalized estimating equation

Table 2. Choroidal thicknesses according to the laterality of eyes

	Eye		*P*
	OD (*n*=104)	OS (*n*=104)	
F			
Mean±SD	366±83	360±86	0.627
Median (range)	373 (117, 525)	360 (147, 513)	
N_1500			
Mean±SD	293±79	291±74	0.838
Median (range)	295 (77, 501)	293 (95, 481)	
N_3000			
Mean±SD	195±59	192±58	0.699
Median (range)	192 (68, 340)	192 (70, 313)	
T_1500			
Mean±SD	317±78	312±76	0.624
Median (range)	312 (113, 503)	314 (138, 508)	
T_3000			
Mean±SD	273±65	263±66	0.283
Median (range)	270 (121, 474)	263 (85, 481)	

F, subfoveal; N, nasal; SD, standard deviation; T, temporal; OD, oculus dexter; OS, oculus sinister; *P*-values are based on the GEE, Generalized Estimating Equation

DISCUSSION

In this study, we investigated 208 eyes of 104 healthy Iranian subjects. Mean SFCT was 363 ± 84 µm, which is comparable to previous reports.[14,15] Mean choroidal thickness at 1500 and 3000 µm nasal to the fovea was 292 ± 76 and 194 ± 58 µm, respectively. Corresponding values for choroidal thicknesses at 1500 and 3000 µm temporal to the fovea were 314 ± 77 and 268 ± 66 µm, respectively.

To interpret results in pathologic conditions, we need normative data of choroidal thickness in healthy subjects. SFCT has been reported to be between 272 and 448 µm in healthy eyes.[11,12,14,17-20] Margolis and Spaide, who investigated 54 patients (mean age, 50.4 years) with normal vision reported choroidal thickness measurements of 287, 145, and 261 µm, for the subfovea, 3000 µm nasal, and 3000 µm temporal to the fovea, respectively.[12] Ikuno *et al*. studied 86 eyes in healthy Japanese subjects. They reported a mean choroidal thickness of 354 µm at the fovea, 227 µm nasally, and 337 µm temporally.[14] The differences between various studies may result from differences in the measuring software, OCT light source, ethnicity, or patient profiles

Table 3. Choroidal thicknesses in different age categories

	Age				*P*	Pairwise comparison
	18-28 years (*n*=39)	29-39 years (*n*=36)	40-50 years (*n*=20)	51-60 years (*n*=9)		
F						
Mean±SD	406±59	360±78	325±90	306±97	<0.001	1, 4
Median (range)	417 (265, 510)	351 (162, 525)	329 (117, 468)	350 (147, 442)		
N_1500						
Mean±SD	317±67	297±83	269±79	228±70	0.006	1, 4-2, 4
Median (range)	313 (191, 501)	277 (121, 485)	292 (77, 374)	229 (130, 358)		
N_3000						
Mean±SD	208±50	203±66	169±46	170±68	0.051	
Median (range)	207 (125, 322)	187 (85, 340)	163 (68, 246)	150 (96, 279)		
T_1500						
Mean±SD	353±66	304±69	295±85	263±90	0.001	1, 4
Median (range)	345 (248, 503)	294 (135, 447)	276 (132, 443)	300 (113, 383)		
T_3000						
Mean±SD	308±62	265±54	241±64	221±53	<0.001	1, 4-2, 4
Median (range)	307 (178, 474)	268 (155, 400)	238 (121, 366)	222 (150, 301)		

P-values are based on the GEE, Generalized Estimating Equation, F, subfoveal; N, nasal; SD, standard deviation; T, temporal

such as age, refractive error, or axial length. It has been shown that SFCT is affected by age and axial length, so it is crucial to consider both age and axial length when choroidal thickness is evaluated.[12,14,16]

Our subjects did not have significant refractive error (-1 to +1 diopter) and were aged 18 to 57 years (mean age, 34.6 ± 9.8 years). Previous studies demonstrated that increasing age was significantly correlated with decreasing choroidal thickness, and regression analysis suggested that the SFCT decreased by 15.6 µm for every 10 years of life.[12] In the present study, choroidal thickness was correlated negatively with age ($P < 0.001$).

We did not find any difference in choroidal thickness between genders. There were no differences between choroidal thicknesses of the right and the left eyes, either. Spaide reported that the SFCT was 318 µm in the right eye and 335 µm in the left eye.[11]

In this study, the choroid was thickest at the fovea and thinnest nasally, which is comparable with the results of other studies.[14,18] The high oxygen demand at the fovea may be the drive for choroid to be thickest sub-foveally. The relatively thinner choroid nasally may be the result of the presence of choroidal watershed area in this region, which bisects the choroidal circulation and is visible on indocyanine green angiography.[21]

The present study has some limitations. Participants may not represent all Iranian ethnicities. Moreover, the RPE line and the chorioscleral border were determined manually, which may be a source of error in determining choroidal thickness. A study with polarization sensitive, swept-source OCT, which can determine the sclerochoroidal interface automatically and measure the choroidal thickness more accurately is recommended.

In Conclusion, we studied choroidal thickness in 104 normal Iranian volunteers and determined the choroidal thickness subfoveally and 1500 and 3000 µm nasal and temporal to the fovea. Mean SFCT was 363 ± 84 µm and was negatively correlated with age. There was no correlation between SFCT and sex or laterality of the eyes.

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Nil.

Conflicts of Interest

There are no conflicts of interest.

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