Swept-Source Optical Coherence Tomography: Choroidal Analysis in Healthy Eyes

G. Gudauskienė*, I. Matulevičiūtė, D. Žaliūnienė

Department of Ophthalmology, Lithuanian University of Health Sciences, Lithuania

**E-mail: gailemazeikaite@gmail.com*

Introduction. The choroid plays an important role in ocular metabolism, volume regulation [1]. The choroid receives 65-85% of ocular blood flow and this supply plays a significant role in subfoveal region as in the foveal avascular zone there is no retinal vascular supply [2]. Choroidal thickness (CT) has been reported to change with daytime, axial length and age [3-6]. Choroidal blood flow is resistant to meaningful changes in young, healthy individuals. However, choroidal blood flow and CT may be affected when the eye is diseased [**7**]. Correct choroid structural evaluation is not possible using spectral-domain optical coherence tomography (OCT) because of its posterior location and the light dispersal caused by retinal pigment epithelium cells. OCT with longer wavelength light sources has been established [8, 9], which enables deeper penetration and more accurate choroidal assessment. Swept source OCT (SS-OCT) with a 1050-nm wavelength has been applied to examine the choroid in healthy [10] and diseased eyes [11, 12, 13], allowing precise visualization of the chorioscleral interface [14, 15].

The aim of this study was to evaluate CT in healthy individuals using SS-OCT.

Methods. 40 eyes of 20 healthy Lithuanian individuals were included in the prospective clinical study. The research was performed at the Department of Ophthalmology, Hospital of Lithuanian University of Health Sciences, Kaunas Clinics. The research followed the tenets of the Declaration of Helsinki. Informed consent was obtained from all subjects before examination and Kaunas Regional Biomedical Research Ethics Committee approved the study. Exclusion criteria were: myopia, hyperopia more than 3 D, eye dystrophies, degenerative diseases, prior ocular surgery, inflammation, glaucoma, choroidal abnormalities, nevus, pregnancy, arterial hypertension, haemangiomas, diabetes mellitus. Ophthalmological examination was performed, axial length was measured using Aladdin optical biometer based on optical low-coherence interferometry (Topcon, Tokyo, Japan) and CT was assessed using 1050 nm DRI Triton SS-OCT (Topcon, Tokyo, Japan). The CT measurements were obtained manually using callipers perpendicularly from the outer part of the hyper-reflective line (retinal pigment epithelial layer) to the line corresponding to the choroidal-scleral junction. Sub-foveal (SF) CT and CT at temporal distances from the central fovea of 1500 μm (T1500), 3000 μm (T3000), and nasal distances of 1500 μm (N1500), 3000 μm (N3000), were measured, total five different locations. Measurements were performed at the same time 1-2

PM. Statistical analysis for obtained data was performed using IBM SPSS Statistics (20.0). For comparisons between numeric data Mann Whitney U test was used, correlation was evaluated using Pearson's correlation coefficient. All parametric data were expressed as the mean and standard deviation (M (SD)). The level of significance was $p < 0.05$.

Results. Patients comprised (25%) males and (75%) females. Differences between the males (n = 5) and females (n = 15) were also evaluated. Women had a thicker choroid than men in all subfields, except N3000; statistically significant difference was observed in SF, T1500 and T3000 subfields ($p < 0.05$) (Table 1). The choroid in T1500 and T3000 was significantly thicker compared to N1500 and N3000 ($p < 0.001$). All subjects had the best corrected visual acuity more than ≥0.7.

Table 1. Variation with gender of mean CT

	CT (µm), M (SD)				
	SF	**T1500**	**T3000**	**N1500**	**N3000**
All patients	233.9 (53.1)	234.7 (56.4)	222.6 (62.3)	190.4 (58.1)	118.0 (59.8)
Men	209.3 (65.4)	194.0 (63.0)	195.3 (84.0)	173.2 (51.9)	127.3 (91.3)
Women	242.1 (46.8)	248.3 (47.8)	231.7 (51.9)	196.1 (59.7)	114.9 (46.7)
p value (men vs. women)	0.050	0.008	0.009	0.221	0.450

Statistical comparisons of non-normal distributed data were performed using the Mann-Whitney U test. The level of $p < 0.05$ was considered to be statistically significant.
CT - choroidal thickness, SF - subfoveal choroidal thickness, T1500 - choroidal thickness at temporal distances from the central fovea of 1500 µm, T3000 - choroidal thickness at temporal distances from the central fovea of 3000 µm, N1500 - choroidal thickness at nasal distances from the central fovea of 1500 µm, N3000 - choroidal thickness at nasal distances from the central fovea of 3000 µm. M (SD) - mean (standard deviation).

The mean age was 59.80 (4.85), (range, 51-67 years). A negative correlation between CT and age was detected in all subfields ($p < 0.05$) (Table 2).

Table 2. Correlation coefficients between CT and age

	CT regions according to age				
	SF	**T1500**	**T3000**	**N1500**	**N3000**
r	-0.33	-0.37	-0.52	-0.37	-0.31
p value	0.036	0.018	0.001	0.019	0.048

Statistical comparisons were performed using Pearson correlation coefficient. The level of $p < 0.05$ was considered to be statistically significant. CT - choroidal thickness, r - correlation coefficient, SF - subfoveal choroidal thickness, T1500 - choroidal thickness at temporal distances from the central fovea of 1500 µm, T3000 - choroidal thickness at temporal distances from the central fovea of 3000 µm, N1500 - choroidal thickness at

nasal distances from the central fovea of 1500 μm, N3000 - choroidal thickness at nasal distances from the central fovea of 3000 μm.

The mean axial length was 23.46 (0.70), (range, 22.35-24.72 mm). A negative correlation was observed between axial length and SF, T1500 and N1500 subfields (Table 3).

Table 3. Correlation coefficients between CT and axial length

	CT regions according to axial length				
	SF	**T1500**	**T3000**	**N1500**	**N3000**
r	-0.32	-0.38	-0.21	-0.39	-0.28
p value	0.047	0.017	0.190	0.012	0.084

Statistical comparisons were performed using Pearson correlation coefficient. The level of $p < 0.05$ was considered to be statistically significant. CT - choroidal thickness, r - correlation coefficient, SF - subfoveal choroidal thickness, T1500 - choroidal thickness at temporal distances from the central fovea of 1500 μm, T3000 - choroidal thickness at temporal distances from the central fovea of 3000 μm, N1500 - choroidal thickness at nasal distances from the central fovea of 1500 μm, N3000 - choroidal thickness at nasal distances from the central fovea of 3000 μm.

Discussion. Plenteous studies have measured the mean CT of normal subjects. Some reported values of less than 300 μm [16-17], while others reported values greater than 300 μm [18-21]. Our mean SF CT in normal Caucasian subjects was 233.9 (53.1) μm and the mean age was 59.80 (4.85) years. Ikuno et al. [14] reported the mean CT of 354 μm in Japanese subjects with a mean age of 39.4 years. Sanchez-Cano et al. [22] reported the mean CT of 345.67 μm in normal Caucasian subjects with a mean age of 24 years. Ding et al. [16] reported that the CT in normal less than 60 year-old Chinese subjects was 294.63 μm. Moussa et al. reported the mean CT of 300.87 μm for ring measurements with mean age of 36.85 years [23]. Analyzing different results, findings suggest that CT varies with age and race. In our study, we found that the temporal choroid was significantly thicker than the nasal choroid. This finding is consistent with other previous researches [4, 5]. Many studies also reported that the CT decreases in the nasal quadrant and that the temporal choroid is significantly thicker than the nasal quadrant [15–19]. Also we defined that women had a thicker choroid than men in all subfields, except N3000. Conversely, Moussa et al. [23] reported that males had unsignificantly thicker choroid than females in all subfields. Park et al. [19] reported no significant difference between the genders and CT. However, Manjunathet al. [17] reported a greater thickness in males than females. In our study a significant negative correlation was observed between axial length and SF, T1500 and N1500 subfields, which is consistent to Moussa et al. findings [5, 14, 20]. We also found a statistically significant negative correlation between CT and age in all subfields. Other studies have also reported a decrease in CT with age [14, 23]. The thinning of the choroid with age reduces the supply of

oxygen and metabolites to the RPE and outer retina, which may be the explication of the development of degenerative macular diseases.

Conclusions. Choroid was significantly thicker in females compared to males in SF, T1500 and T3000 subfields. A negative statistically significant correlation between CT and age was detected in all subfields. A negative statistically significant correlation was observed between axial length and SF, T1500 and nasal 1500 subfields. Further investigations should be continued to confirm and better clarify our findings.

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Department of Ophthalmology, Lithuanian University of Health Sciences, Lithuania

The purpose of the study was to evaluate choroidal thickness (CT) in healthy individuals using swept-source optical coherence tomography (SS-OCT). Ophthalmological examination, axial length using Aladdin optical biometer and choroidal thickness using SS-OCT in 40 healthy eyes were assessed. Females had a thicker choroid than males in all subfields, N3000 region. A negative correlation between CT and age was detected in all subfields and between axial length and SF, T1500 and N1500 subfields ($p < 0.05$). A negative statistically significant correlation between CT and age and between axial length and SF, T1500 and N1500 subfields were observed.