Diurnal Variation of Central Choroidal Thickness in Healthy Turkish Subjects Measured by Spectral-Domain Optical Coherence Tomography*

Sağlıklı Türk Bireylerinde Santral Koroidal Kalınlığın Diürnal Varyasyonunun Spektral Domain Optik Kohorens Tomografi ile Değerlendirilmesi

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ABSTRACT

Purpose: To examine the pattern and the magnitude of diurnal variation of central choroidal thickness in healthy Turkish subjects measured by spectral-domain optical coherence tomography.

Materials and Methods: This study included thirty eyes of 15 volunteers with no retinal or choroidal disease and refractive error, who underwent high-definition raster scanning using SD-OCT on the same day at 10 fixed, one-hour time intervals beginning from 8 AM using a standardized protocol.

Results: The mean choroidal thickness at the center of the fovea showed a relative peak early in the morning hours at 8 AM with a mean thickness measurement of 317.06±45.42 µm. When we evaluate the thickness measurements we found a progressive decrease during the day. The mean choroidal thickness was 274.83± 48.46 µm at 5:00 PM which was the thinnest value of the day.

Conclusions: Choroidal thickness may vary with time during the day and this should be considered when evaluating choroidal thickness.

Key Words: Diurnal variation, choroidal thickness.

ÖZ

Amaç: Sağlıklı Türk bireylerinde santral koroid kalınlığında diürnal varyasyonun şeklinin ve miktarının spektral domain optik kohorens tomografi (SD-OKT) ile değerlendirilmesi.

Gereç ve Yöntem: Bu çalışmaya retina, koroid hastalığı ve kırma kusuru olmayan 15 gönüllünün 30 gözü dahil edildi. Olgulara standart protokol kullanılarak, aynı gün içinde sabah saat 8'de başlamak üzere bir saatlik aralarla toplam 10 adet yüksek çözünürlüklü SD-OKT taraması yapıldı.

Sonuçlar: Fovea santralinde koroid kalınlığının sabahın erken saatlerinde daha fazla olduğu ve saat 8'de pik yaparak ortalama 317.06 ±45.42 µm olarak ölçüldüğü saptandı. Koroid kalınlığının gün içinde progresif olarak inceldiği görüldü. Gün sonunda akşam saat 5'te kalınlık ölçümü ortalama 274.83± 48.46 µm ile günün en düşük değerini oluşturdu.

Sonuç: Koroidal kalınlık gün içinde değişiklik gösterebilir. Bu durum koroidal kalınlığı değerlendirirken akılda tutulmalıdır.

Anahtar Kelimeler: Diürnal varyasyon, koroidal kalınlık.

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INTRODUCTION

The choroid is a higly vascular tissue forming posterior uvea under the retina and the pigment epithelium layers. It is believed to play an important role in the physiology of the eye and in the pathogenesis of a variety of ocular diseases. It has functions like thermoregulation, regulating intraocular pressure by uveascleral aqeous drainage, adjustment of the position of the retina by changes in choroidal thickness, and secretion of growth factors.[1] Optical coherence tomography (OCT), in particular spectral domain OCT (SD-OCT) has allowed the choroid to be accessed in vivo with details. Spaide and colleagues,[2,3] described a technique called "enhanced depth imaging" or "EDI" to optimize the parameters of OCT acquisition to facilitate visualization of the full thickness of the choroid.

Choroid and its thickness can be affected in many ocular diseases. Choroidal neovascular membrane, uveal effusion syndrome, central serous chorioretinopathy, Vogt-Koynoagi-Harada disease, angioid streaks, polypoidal choroidal vasculopathy are clinical pathologies can affect the choroidal thickness.[4,5] These observations of variations in choroidal thickness suggested that the choroid and choroidal thickness could be important parameters in the evaluation of ocular disease. To understand the significance of these potential choroidal thickness variations, normative values for choroidal thickness would appear to be of paramount importance. Accordingly, a number of investigators have studied and reported normative values for choroidal thickness in different populations, observing mean subfoveal choroidal thickness values ranging from 191.5 to 342 µm.[6-8] Choroidal thickness has also been demonstrated to vary with age and refractive status in many studies.[9-13] The diurnal variation of the choroid has also been studied in a few studies. Given its vascular nature, it would not be surprising to find that the choroidal thickness could vary as result of systemic physiological changes such as hydration and blood pressure.

Thus, in this study we examined the magnitude of diurnal variation of central choroidal thickness in healthy Turkish subjects measured by SD-OCT.

MATERIAL AND METHODS

In this prospective study, 15 healthy volunteers with no history of ocular and systemic disease underwent SD-OCT scans of both eyes at ten different time points during the course of the same day spaced at 1-hour intervals. The study protocol was approved by the Institutional Review Board of the depertment and adhered to the tenets set forth in the Declaration of Helsinki. Written, informed consent was obtained from all participants. All participants underwent ocular examination by a trained ophthalmologist (GD) to exclude ocular diseases. The OCT scans were performed at ten different time points over a single day at 1-hour intervals beginning from 8:00 AM through the 5:00 PM. All OCT scans were performed by the same experienced OCT operator, without pupil dilation, and under standardized mesopic lighting conditions. Participants consumed fluids and food according to their normal dietary practice, and this was not controlled during the course of the study.A multimodal imaging device (Spectralis OCT; Heidelberg Engineering, Heidelberg, Germany) was used to perform all scans, using a standardized scanning protocol. For each eye, a 31-line raster scan centered on the fovea (with tracking on) was performed, with 25 frames averaged to improve the image quality. The EDI technique, with the zero delay line oriented to the choroidal side, was used to optimize choroidal sensitivity and enhance visualization of the full choroidal thickness. The first ("baseline") OCT scan (8:00 AM scan) was set as a reference and all subsequent scans were registered to this to ensure that the same point on the fovea was imaged and graded each time.

Measuring choroidal thickness of all OCT scans were performed independently by the same experienced researcher. Choroidal thickness at the fovea was measured using the caliper tools on the OCT machine. It was measured using a line drawn perpendicularly from the hyperreflective line believed to represent the retinal pigment epithelium (RPE) to the choroid-scleral junction (Figure 1, 2). Statistical analysis was performed using commercial analytical software (SPSS for Windows version 16.0; SPSS Inc. Chicago, IL). The variation of choroidal thickness was assessed using general linear models with repeated-measures ANOVA.

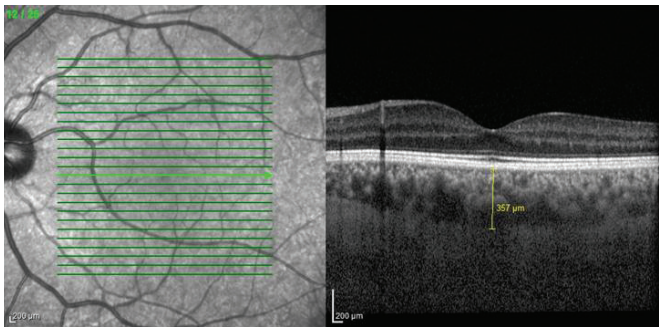

Figure 1: *Central choroidal thickness is 357 µm in an healthy 29 years old male subject at 08:00 AM.*

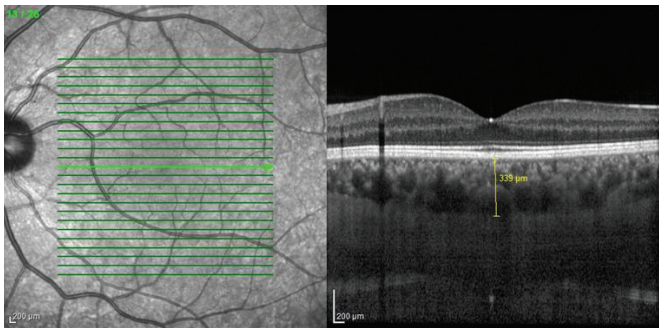

Figure 2: *Central choroidal thickness is 339 µm in the same subject at 05:00 PM.*

Table: *Mean central choroidal thickness of subjects measured during the same day at 1 hour interval.*

Time of the measurement	Central Choroidal Thickness Mean±SD (µm)
08:00 AM	317.06±45.42
09:00 AM	308.90±47.15
10:00 AM	297.83±52.87
11:00 AM	291.73±53.07
12:00 AM	288.76±54.68
01:00 PM	283.70±57.67
02:00 PM	283.23±56.46
03:00 PM	276.80±59.54
04:00 PM	276.00±57.62
05:00 PM	274.83±48.46
P value	p>0.05

RESULTS

The mean age of the subjects was 28.6 (range, 26 to 30) years with 8 males and 7 females. All eyes had normal foveal contour with no retinal pathology and no abnormalities of the choroid. The visual acuity in all patients was 1.0 Snellen lines without any refractive correction. The range of the "baseline" (at 8:00 AM) choroidal thickness values were between 240 and 395 µm with a mean of 317.06±45.42 µm. When we evaluate the thickness measurements, the mean choroidal thickness at the center of the fovea showed a relative peak early in the morning hours at 8 AM and then decreased progressively over the subsequent time points to a low mean value of 274.83± 48.46 µm at 5:00 PM. A characteristic diurnal pattern was observed in choroid thickness (Figure 1, 2). Using repeated-measures ANOVA, the mean choroid thickness did not differ significantly between time points on the same day (p>0.05). Post hoc testing using the Bonferroni correction showed no statistically significant differences between all time points. The mean amplitude (difference between maximum and minimum values) in diurnal choroidal thickness change was 41.06 µm (range, 5 to 79 µm), (Table).

DISCUSSION

Untill recently, choroidal thickness assumptions were mostly based on histological techniques. The mean choroidal thickness was found to be 200 µm histologically.[14] However, during histological sample preparation steps, for instance fixation, tissue looses its water content and these samples are obtained from autopsies which blood vessels collapse. Thus, this explains why histological measurements are found to be less than OCT measurements. Other invivo techniques measuring choroidal thickness like partial coherence interferometry, extrapolated ocular radiofrequency velocities, optical low coherence reflectometry found choroidal thickness measurements ranging from 320 µm to 420 µm.[15-17] With advancements in OCT image processing software, more refined details of the posterior segment can be evaluated in vivo. Improvements to existing SD-OCT devices with the technique of EDI provided even better definition of choroidal tissue.[2,3]

Choroidal thickness measurements in different populations were reported in recent studies. Ding et al.,[18] reported normal subfoveal choroidal thickness using EDI technique of SD-OCT in healthy Chinese population for younger than 60 years age as 294.63±75.90 µm and for older than 60 years age as 196.52±74.42 µm. They mentioned significant negative correlation between age and choroidal thickness. Fujimara et al.,[19] reported mean subfoveal thickness as 265.5±82.4 µm in normal Japanese eyes. Ikuno et al., showed mean choroidal thickness as 354±111 µm (range, 80-641 µm) at the fovea for healthy Japanese subjects. Their study demonstrated positive correlation with refractive error and negative correlation with both axial length and age.[20] In another study, the mean central choroidal thickness in healthy Turkish subjects were found as 287.6 µm (range, 241 to 313).[8] It is reported in recent studies that refractive error and age could affect the choroidal thickness measurements.[10-13] There are also some studies including choroidal thickness measurements in different eye pathologies. Kim et al demonstrated that the choroid was thicker in eyes with polypoidal choroidal vasculopathy or central serous chorioretinopathy than in healthy controls or age-related maculopathy groups.[5] Koizumi et al.,[21] reported that the choroid under the fovea was thicker in eyes with polypoidal choroidal vasculopathy than those with typical age-related macular degeneration.

We found a few recent publications reporting diurnal variation for choroidal thickness. Tan et al.,[22] reported a significant diurnal variation in twelve healthy volunteers (mean age was 30 years) measured by Heidelberg SD-OCT and averaging 33.7 µm, with the thickest being at 9AM and the thinnest at 5PM. They also demonstrated that the magnitude of the variation appears to depend on the baseline or average choroid thickness. In this study, eyes with thinner baseline choroids (≤300 µm) demonstrated a variation with a mean amplitude of 10.5 µm compared with approximately 40 µm for those with thicker baseline choroids. They concluded that the time of OCT acquisition may be of particular importance when assessing choroidal thickness in individuals with thicker choroids.

In our study we included the subjects with similar ages (mean 28.6 years) however we did not divide eyes into groups according to their baseline thicknesses. We found the thickest choroid at 8 AM and the thinnest choroid at 5 PM. Also there was a diurnal variation we did not find any significance as Tan et al.

In another recent study, Osmanbasoglu et al.,[23] measured the choroidal thickness twice a day, during working hours (early in the morning and late in the afternoon), using EDI technique of SD-OCT in the healthy emetropic Turkish population, to investigate diurnal variation. The mean choroidal thickness in this study was 308.7 µm, ranging between 140 µm and 496 µm and the mean central choroidal thickness did not show significant variation during working hours. Also the conclusion is similar, this study differs in design from our study which included only two measurements in a day compared with ten measurements in our study.

Usui et al.,[24] reported a significant subfoveal choroidal thickness circadian change by using a high penetration OCT (Topcon). The magnitude of change averaged 33 µm in the thirty-eight eyes of nineteen healthy subjects (mean age was 34.8 years), with the thickest at 3 AM (mean, 290.8±110.8 µm) and thinnest at 6 PM (mean, 271.9±103.5 µm). And they reported that fluctuations in the choroidal thickness may be related to systolic blood pressure. However, unlike our study, most of the subjects were at myopic range with a mean refractive error of -4.4±2.4 and myopia could affect the results.

Chakraborty and colleagues[25] used the signal processing technique with a noncontact optical biometer performing five sets of measurements each day at approximately 3-hour intervals, with the first measurement taken at ~9 AM and final measurement at ~9 PM in thirty healthy eyes. They showed that choroidal thickness increases progressively from 12 PM to 6 PM and the mean amplitude of thickness change was 29±16 µm.

Toyokawa et al.,[26] performed two measurements (in the morning and in the evening) reported a significant diurnal variation of 20 µm, with the thickest being in the evening in an older study population with a mean age of 62.6±14.5 years.

In studies by Usui et al.,[18] and Tan et al.,[19] the mean choroidal thickness decreased during day. İn the study by Osmanbasoglu et al., it was stable, while Chakraborty et al.,[24] and Toyokawa et al.,[26] population showed an increase. In our study also we observed a diurnal variation in choroidal thickness in our population, although it was not significant. The differences in mean choroidal thickness between the studies may result from differences in the study population, OCT machine used, and measuring software.

The main limitations of our study are that systemic factors such as diastolic and systolic blood pressure were not assessed, diurnal IOP and AL change were not analysed, and only healthy emetropic patients with a limited range of age were included. Also the choroidal thickness was assessed during the same day only in working hours so the variation during evening and night and the variation on different days were not assessed in this study.

As a conclusion, the choroid is a highly vascular tissue, necessitating in vivo imaging to accurately determine its true structure and thickness. Choroidal thickness can change in some ocular pathologies and also can be used to monitor some of these. Choroidal and macular thickness may vary with location and this should be considered when evaluating choroidal and macular thickness. Improved in vivo visualization of the choroid and measurement of choroidal thickness using OCT is likely to improve our understanding of a variety of ophthalmic diseases in the future.

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