Correlations of Optic Disc Morphological Parameters with Peripapillary Choroidal Thickness and Retinal Vessel Caliber Measurements

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ABSTRACT

Purpose: To examine the associations between the optic disc morphological parameters, peripapillary choroidal thickness, and retinal vessel caliber measurements.

Methods: This cross-sectional and descriptive study included 60 eyes of 60 healthy adults. The spectral domain optical coherence tomography was used to measure the retinal arteriolar caliber, retinal venular caliber, peripapillary choroidal thickness, and retinal nerve fiber layer (RNFL) thickness. Optic disc morphological parameters were measured via Heidelberg Retinal Tomography 3.

Results: The retinal arteriolar caliber was statistically significantly positively correlated with the rim volume ($r = 0.27$, $P = 0.035$) and RNFL cross-sectional area ($r = 0.30$, $P = 0.02$); but it was not associated with the other optic disc parameters ($P > 0.05$). The retinal venular caliber was not correlated with the optic disc parameters ($P > 0.05$). The peripapillary choroidal thickness was statistically significantly correlated only with the cup shape measurement ($r = -0.27$, $P = 0.039$), maximum contour elevation ($r = 0.50$, $P < 0.001$), and maximum contour depression ($r = 0.28$, $P = 0.033$). The RNFL thickness was statistically significantly positively correlated only with the disc area ($r = 0.30$, $P = 0.019$) and rim volume ($r = 0.27$, $P = 0.039$), and negatively correlated with the maximum contour elevation ($r = -0.32$, $P = 0.012$).

Conclusions: Optic disc maximum contour elevation is positively correlated with the peripapillary choroidal thickness and negatively correlated with the RNFL thickness in the healthy eyes.

Keywords: Optic disc; Peripapillary choroidal thickness; Retinal vessel caliber; Retinal nerve fiber layer; Maximum contour elevation.

INTRODUCTION

Devices using confocal scanning laser with digital image processing such as Heidelberg Retinal Tomography 3 (HRT 3), have been used to evaluate the optic disc. The morphological parameters of the HRT 3 are able to discriminate between healthy and abnormal optic nerve head.[1-3] Another sophisticated device, the spectral domain optical coherence tomography (SD-OCT), can give valuable data related to the layers of the retina, retinal vessels, and choroid.[4,5]

In the previous studies, some correlations were found between the optic disc parameters, choroidal thickness, retinal nerve fiber layer (RNFL) thickness, and retinal vessels.[6-11]

It was reported that thinner peripapillary choroid was independently associated with thinner RNFL.[6] Peripapillary choroidal thickness was found to be positively correlated with the prelaminar optic canal depth.[7] Retinal venous pulsation amplitudes were positively correlated with the cup margin distance.[8] In another study, retinal vessel diameter was found to be smaller in normal-tension glaucoma patients compared to healthy controls.[9] It was reported that peripapillary retinal vessel density has a clinically significant influence on the RNFL thickness.[10] Peripapillary choroidal thickness was noted to be negatively associated with the optic disc tilt.[11] Nevertheless, there is a gap in the literature related to the associations of the optic nerve head morphological parameters and the retina-choroidal structures.

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Received: 14.05.2021
Accepted: 18.08.2021

Ret-Vit 2022; 31: 44-49

DOİ:10.37845/ret.vit.2022.31.8

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The aim of this study was to demonstrate the correlations of the optic disc morphological parameters with the peripapillary choroidal thickness (ppCT), RNFL, and retinal vessel caliber measurements. It was hypothesized that the morphology of the vascular structures (i.e., retinal vessel diameter and choroidal thickness) around the optic nerve head may affect the morphology of the optic disc (i.e., parameters measured by means of HRT 3), since they have close relations in the aspect of anatomy and physiology. Evaluation of the optic disc parameters is crucial in several diseases such as glaucoma. In addition, noticing the confounding factors which could affect the optic disc parameters may better aid us in the diagnosis of the disorders related to optic nerve head.

MATERIALS AND METHODS

This cross-sectional study included 60 eyes of 60 healthy adult volunteers. The present study was conducted in a tertiary setting upon the approval of the institutional ethical committee and adhered to the principles of the Declaration of Helsinki.

Study Population

A standardized ophthalmological examination, including auto-refractometer measurement, visual acuity assessment via Snellen chart, slit-lamp biomicroscopy, air-puff tonometer, retinal examination, SD-OCT and HRT 3 was performed in all the participants. The study population consisted of participants from Caucasian origin. The age range of the participants was between 18 and 40 years. Volunteers who had any ocular surgery history, any systemic diseases such as diabetes mellitus, systemic hypertension, vascular diseases, and any ocular diseases were excluded. Participants having any glaucomatous findings such as optic disk changes, peripapillary hemorrhage, retinal nerve fiber layer loss, retinal disorders, optic neuropathies, and intraocular pressure readings >21 mmHg were excluded. Exclusion criteria also included a low image and measurement quality in the SD-OCT (i.e., quality score < 20) and HRT 3 (i.e., standard deviation > 30). The participants were not taking any medications regularly. Participants with very flat or very steep keratometry readings (e.g., <40.0 D or >48.0 D) or with refractive error higher than 2 diopters spherical equivalent were not included, since those could influence the image quality and measurements. The systolic / diastolic blood pressure values were ranged between 90-140 / 60-90 mmHg. Only the right eyes of the participants were included in the statistical analysis.

Ocular Measurements

Ocular measurements were performed without instillation of mydriatic eye drops. For intraocular pressure, the average value of the three consecutive measurements was recorded. The SD-OCT (Spectralis software version 6.0, Heidelberg, Germany) was used in order to measure the retinal arteriole caliber (RAC), retinal venule caliber (RVC), ppCT, and RNFL. The manual caliber tools of the Spectralis device were used in order to measure the retinal vessel calibers on the optic disc examination screen. The superior and inferior temporal retinal arterioles and venules that pass through an area one-half to one-disc diameter from the optic disc margin were measured for the retinal vessel caliber analysis (Figure 1). The markers were placed on the outer vessel boundary at image magnification of 400%. The mean thickness values of the superior and inferior temporal retinal vessels were calculated for each eye. Temporal retinal vessels were chosen for the analysis, since they are generally the thickest vessels that may affect optic disc measurements. The ppCT was measured vertically from the outer border of the hyper-reflective band corresponding to the retina pigment epithelium to the inner surface of the sclera in the four quadrants (i.e., superior, inferior, nasal, temporal), by using the caliber tools of the Spectralis (Figure 2). During choroidal

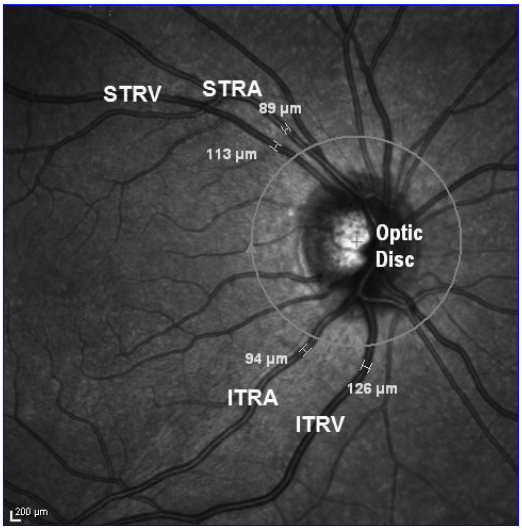


Figure 1: *The method for retinal vessel caliber analysis is shown (STRA: supero-temporal retinal arteriole, STRV: supero-temporal retinal venule, ITRA: infero-temporal retinal arteriole, ITRV: infero-temporal retinal venule).*

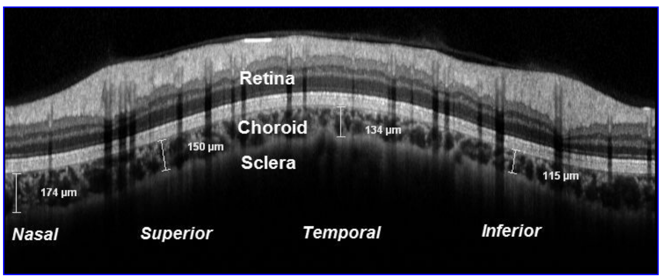
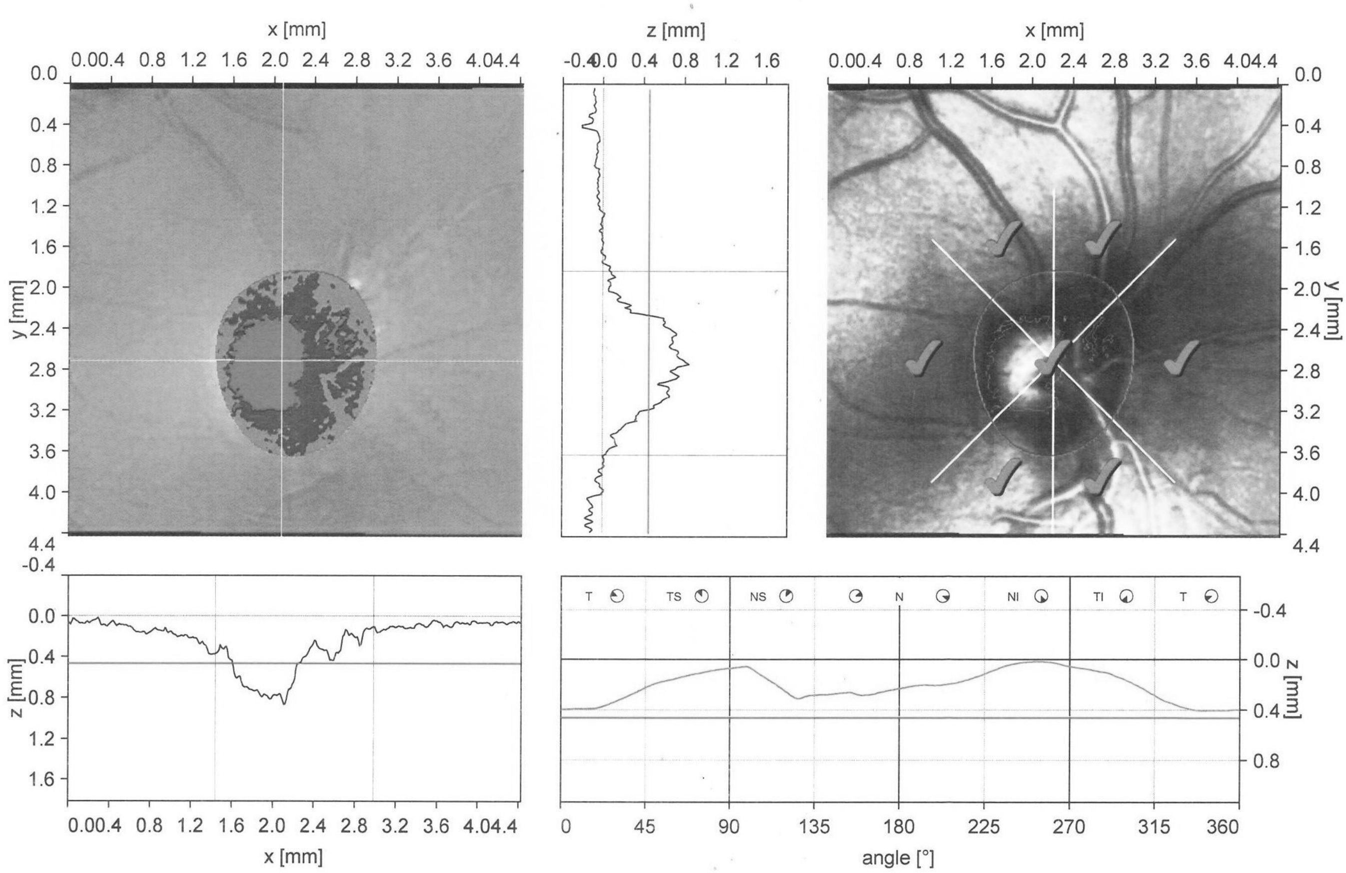


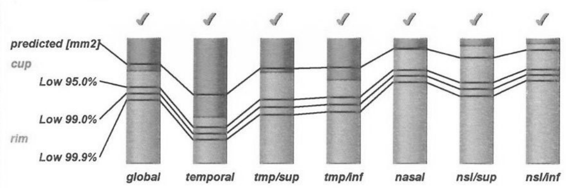
Figure 2: The method for the measurement of peripapillary choroidal thickness is demonstrated.

thickness measurements, the chorio-scleral interface was clearly seen. The measurements were done perpendicular to the Bruch's membrane.

The HRT 3 (Heidelberg Engineering, Heidelberg, Germany) is a confocal scanning laser ophthalmoscope (CSLO), which is used as an optic disc imaging tool. The HRT 3 scans the fundus by means of a 675 nm diode laser with a transverse resolution of 384 x 384 pixels. Its measurements included the disc area, cup area, rim area, cup to disc area ratio, rim to disc area ratio, cup volume, rim volume, mean cup depth, maximum cup depth, cup height variation contour, cup shape measurement, RNFL cross-sectional area, maximum contour elevation, and maximum contour depression. An example for HRT 3 scan of one of the participants is shown in Figure 3.



Stereometric Analysis ONH		Normal Range
Disc Area	2.27 mm²	1.63 - 2.43
Cup Area	0.59 mm²	0.11 - 0.68
Rim Area	**1.68 mm²**	**1.31 - 1.96**
Cup Volume	0.10 mm³	-0.01 - 0.18
Rim Volume	**0.40 mm³**	**0.30 - 0.61**
Cup/Disc Area Ratio	0.26	0.07 - 0.30
Linear Cup/Disc Ratio	0.51	0.27 - 0.55
Mean Cup Depth	0.20 mm	0.10 - 0.27
Maximum Cup Depth	0.55 mm	0.32 - 0.76
Cup Shape Measure	**-0.16**	**-0.28 - -0.15**
Height Variation Contour	**0.39 mm**	**0.31 - 0.49**
Mean RNFL Thickness	**0.25 mm**	**0.20 - 0.32**
RNFL Cross Sectional Area	1.32 mm²	0.99 - 1.66
Reference Height	453 µm	
Topography Std Dev.	58 µm	
FSM	0.37	
RB	2.06	



Moorfields Classification: Within normal limits (*)

(*) Moorfields regression classification (Ophthalmology 1998;105:1557-1563). Classification based on statistics. Diagnosis is physician's responsibility.

Comments:

Figure 3: *HRT 3 scan of one of the participants is shown.*

Statistical Analysis

For statistical analysis, the Statistical Package for the Social Sciences version 17.0 software for Windows (SPSS Inc., Chicago, IL, USA) was used. All data are expressed as the 'mean' ± 'standard deviation'. '*P*' values lower than 0.05 were accepted as statistically significant. The comparative analysis of the studied parameters between the male and female participants was done with the independent samples *t* test. The Levene's test *P* values were > 0.05 for the studied variables. The Pearson correlation test was used to examine the relationship between RAC, RVC, ppCT, RNFL, and optic disc measurements. In order to test the normality of the data, the Shapiro Wilk test was used. Since, there are multiple comparisons in the present study, the Bonferroni correction was also applied and the only statistically significant outcome became the correlation between the mean ppCT and maximum contour elevation.

RESULTS

The mean age of the participants was 25.7 ± 6.2 years. This study included 30 male and 30 female individuals. The mean intraocular pressure was 15.8 ± 2.5 (range, 10-20) mmHg. Table 1 shows the mean, minimum, and maximum values of the optic disc parameters which were taken with the HRT 3. Table 2 shows the mean, minimum, and maximum values of the RAC, RVC, ppCT, and RNFL.

Table 1: *The mean, minimum, and maximum values of the optic disc parameters of the participants, which were taken with the Heidelberg Retina Tomography 3 (HRT III).*

	Mean ± SD	Min.	Max.
Disc area *(mm²)*	2.58 ± 0.54	1.63	3.99
Cup area *(mm²)*	0.46 ± 0.27	0.01	1.12
Rim area *(mm²)*	2.11 ± 0.47	1.36	3.59
c/d area ratio	0.18 ± 0.09	0.01	0.35
r/d area ratio	0.82 ± 0.09	0.65	0.99
Cup volume *(mm³)*	0.10 ± 0.10	0.00	0.47
Rim volume *(mm³)*	0.64 ± 0.24	0.25	1.40
Mean cup depth *(mm)*	0.19 ± 0.08	0.07	0.41
Max. cup depth *(mm)*	0.58 ± 0.21	0.19	1.04
Height var. cont. *(mm)*	0.41 ± 0.11	0.18	0.72
Cup shape measure	-0.24 ± 0.08	-0.43	-0.03
RNFL cross. area *(mm²)*	1.60 ± 0.42	0.79	2.95
Max. cont. elevation *(mm)*	-0.10 ± 0.07	-0.28	0.03
Max. cont. depression *(mm)*	0.32 ± 0.11	0.10	0.63

SD: standard deviation, c/d: cup to disc ratio, r/d; rim to disc ratio, max.: maximum, var. cont.: variation contour, cross.: cross-sectional, RNFL: retinal nerve fiber layer

Table 2: *The mean, minimum, and maximum values of the RAC, RVC, ppCT, and RNFL of the participants.*

	Mean ± SD	Minimum	Maximum
RAC *(μm)*	90.9 ± 4.9	78	107
RVC *(μm)*	126.5 ± 11.1	100	156
Mean ppCT *(μm)*	211.3 ± 58.7	115	343
Inferior ppCT *(μm)*	191.0 ± 61.2	100	342
Superior ppCT *(μm)*	218.3 ± 58.8	110	351
Nasal ppCT *(μm)*	220.0 ± 68.0	113	378
Temporal ppCT *(μm)*	215.5 ± 62.8	105	338
Mean RNFL *(μm)*	103.3 ± 7.7	83	120
Inferior RNFL *(μm)*	133.0 ± 14.4	103	173
Superior RNFL *(μm)*	126.8 ± 12.0	101	162
Nasal RNFL *(μm)*	76.3 ± 11.4	47	108
Temporal RNFL *(μm)*	77.5 ± 10.5	59	104

RAC: retinal arteriole caliper, RVC: retinal venule caliper, ppCT: peripapillary choroidal thickness, RNFL: retinal nerve fiber layer, SD: standard deviation

The mean age of the male participants was 25.7 ± 5.8 years and the mean age of the female participants was 25.7 ± 6.7 years (*P* = 0.98). The male volunteers had thicker inferior ppCT (*P* = 0.02) and larger maximum contour depression (*P* = 0.04) measurements when compared to the female volunteers; whereas the female volunteers had thicker mean (*P* = 0.003) and temporal (*P* = 0.006) RNFL. The other studied ocular parameters were similar between the male and female participants (*P* > 0.05).

The RAC was statistically significantly correlated with the rim volume (r = 0.27, *P* = 0.035) and RNFL cross-sectional area (r = 0.30, *P* = 0.02); but it was not associated with the other optic disc parameters, as well as the ppCT and RNFL thickness measurements (*P* > 0.05). The RVC was not correlated with the studied parameters (*P* > 0.05), except for the RAC (r = 0.34, *P* = 0.007).

The mean ppCT was statistically significantly correlated only with the cup shape measurement (r = -0.27, *P* = 0.039), maximum contour elevation (r = 0.50, *P* < 0.001), and maximum contour depression (r = 0.28, *P* = 0.033). The mean RNFL thickness was statistically significantly correlated only with the disc area (r = 0.30, *P* = 0.019), rim volume (r = 0.27, *P* = 0.039), and maximum contour elevation (r = -0.32, *P* = 0.012).

DISCUSSION

The outcomes of the present study show that the optic disc morphological parameters are correlated with the ppCT, RAC and RNFL thickness in healthy individuals. It may be helpful to take those associations into consideration while evaluating patients with optic disc abnormalities such as glaucoma suspects. As it is accepted, HRT 3 seems as a valuable tool for the examinations of optic disc in detail.

The rim volume and RNFL cross-sectional area were the only optic disc parameters which were found to be correlated with the RAC in the present study. It was reported that the rim volume and RFNL cross-sectional area are significantly smaller in glaucomatous eyes than in non-glaucomatous eyes.[12] Decreased RAC was found to be associated with thinner RNFL in both the glaucomatous and non-glaucomatous eyes.[13-15] So it is likely to make inferences that decreased RAC is related to the smaller rim volume and the RFNL cross-sectional area in healthy eyes. Indeed, larger retinal vessels are often included in the segmentation of the RNFL and rim tissue. Hence, it would not be surprising that eyes with larger vessels have thicker RNFL and rim tissue.

In a large population based study, it was reported that the ppCT was not associated with the intraocular pressure and prevalence of glaucoma.[16] On the other hand, outcomes of a meta-analysis suggested that glaucoma patients have significantly decreased ppCT compared to healthy subjects.[17] Karahan et al. found that there was not an association between ppCT and RNFL thickness in normal eyes.[18] The cup shape measure taken by HRT 3 is considered to be an indicator of glaucomatous damage.[2] The mean ppCT was found to be negatively correlated with the cup shape measurement, whereas positively correlated with the maximum contour elevation and depression in the present study.

As it would be expected, it is found that the disc area and rim volume were positively correlated with the mean RNFL thickness in the present study. The RNFL thickness was reported to be associated with age, race, axial length, and optic disc area.[19-23] The optic disc maximum contour elevation was negatively correlated with the mean RNFL thickness in the present study. It can be speculated that elevated optic disc contour may cause stretching and thus thinning in the RNFL. It was reported that the maximum contour elevation is less in glacomatous eyes compared to the healthy eyes.[24]

The present study has several limitations. First, the sample population was only consisted of healthy adults; it would be nice to evaluate patients with glaucoma in further studies. Second, the age range was relatively young, and there may be changes in some of the studied parameters in healthy older individuals. Third, some additional parameters such as Bruch membrane opening minimum rim width and optic disc blood flow measurements might be investigated.

In conclusion, optic disc maximum contour elevation is positively correlated with the mean peripapillary choroidal thickness and negatively correlated with the mean RNFL thickness in the healthy eyes. The optic disc rim volume was positively correlated with the RAC. The mean RNFL thickness was positively correlated with the disc area. It would be helpful to take those variables into account when evaluating younger individuals with glaucoma suspicion. The optic disc parameters may be affected by the surrounding ocular structures such as choroid and retinal arterioles, which in turn may affect diagnosis of the disorders related to optic nerve head.

REFERENCES

1. Rohrschneider K, Burk RO, Kruse FE, et al. Reproducibility of the optic nerve head topography with a new laser tomographic scanning device. Ophthalmology. 1994;101:1044-9.
2. Mikelberg FS, Parfitt CM, Swindale NV, et al. Ability of the heidelberg retina tomograph to detect early glaucomatous visual field loss. J Glaucoma. 1995;4:242-7.
3. Iester M, Mikelberg FS, Drance SM. The effect of optic disc size on diagnostic precision with the Heidelberg retina tomograph. Ophthalmology. 1997;104:545-8.
4. Murthy RK, Haji S, Sambhav K, et al. Clinical applications of spectral domain optical coherence tomography in retinal diseases. Biomed J. 2016;39:107-20.
5. Adhi M, Duker JS. Optical coherence tomography--current and future applications. Curr Opin Ophthalmol. 2013;24:213-21.
6. Gupta P, Cheung CY, Baskaran M, et al. Relationship Between Peripapillary Choroid and Retinal Nerve Fiber Layer Thickness in a Population-Based Sample of Nonglaucomatous Eyes. Am J Ophthalmol. 2016;161:4-11.e1-2.
7. Sigler EJ, Mascarenhas KG, Tsai JC, et al. Clinicopathologic correlation of disc and peripapillary region using SD-OCT. Optom Vis Sci. 2013;90:84-93.
8. Lam J, Chan G, Morgan WH, et al. Structural characteristics of the optic nerve head influencing human retinal venous pulsations. Exp Eye Res. 2016;145:341-346.
9. Yabana T, Shiga Y, Kawasaki R, et al. Evaluating retinal vessel diameter with optical coherence tomography in normal-tension glaucoma patients. Jpn J Ophthalmol. 2017;61:378-387.
10. Pereira I, Weber S, Holzer S, et al. Compensation for retinal vessel density reduces the variation of circumpapillary RNFL in healthy subjects. PLoS One. 2015;10:e0120378.
11. Yamashita T, Sakamoto T, Yoshihara N, et al. Correlations between local peripapillary choroidal thickness and axial length, optic disc tilt, and papillo-macular position in young healthy eyes. PLoS One. 2017;12:e0186453.
12. Okimoto S, Yamashita K, Shibata T, et al. Morphological features and important parameters of large optic discs for diagnosing glaucoma. PLoS One. 2015;10:e0118920.
13. Tham YC, Siantar RG, Cheung CY, et al. Inter-Relationships Between Retinal Vascular Caliber, Retinal Nerve Fiber Layer

Thickness, and Glaucoma: A Mediation Analysis Approach. Invest Ophthalmol Vis Sci. 2016;57:3803-9.

14. Russo A, Costagliola C, Rizzoni D, et al. Arteriolar Diameters in Glaucomatous Eyes with Single-Hemifield Damage. Optom Vis Sci. 2016;93:504-9.

15. Tham YC, Cheng CY, Zheng Y, et al. Relationship between retinal vascular geometry with retinal nerve fiber layer and ganglion cell-inner plexiform layer in nonglaucomatous eyes. Invest Ophthalmol Vis Sci. 2013;54:7309-16.

16. Jiang R, Wang YX, Wei WB, et al. Peripapillary Choroidal Thickness in Adult Chinese: The Beijing Eye Study. Invest Ophthalmol Vis Sci. 2015;56:4045-52.

17. Lin Z, Huang S, Xie B, et al. Peripapillary Choroidal Thickness and Open-Angle Glaucoma: A Meta-Analysis. J Ophthalmol. 2016;2016:5484568.

18. Karahan E, Tuncer İ, Er D, et al. Correlation of Peripapillary Choroidal Thickness and Retinal Nerve Fiber Layer Thickness in Normal Subjects and in Patients with Glaucoma. Semin Ophthalmol. 2017;32:602-6.

19. Alasil T, Wang K, Keane PA, et al. Analysis of normal retinal nerve fiber layer thickness by age, sex, and race using spectral domain optical coherence tomography. J Glaucoma. 2013;22:532-41.

20. Budenz DL, Anderson DR, Varma R, et al. Determinants of normal retinal nerve fiber layer thickness measured by Stratus OCT. Ophthalmology. 2007;114:1046-52.

21. Bendschneider D, Tornow RP, Horn FK, et al. Retinal nerve fiber layer thickness in normals measured by spectral domain OCT. J Glaucoma. 2010;19:475-82.

22. Cheung CY, Chen D, Wong TY, et al. Determinants of quantitative optic nerve measurements using spectral domain optical coherence tomography in a population-based sample of non-glaucomatous subjects. Invest Ophthalmol Vis Sci. 2011;52:9629-35.

23. Poon LY, Antar H, Tsikata E, et al. Effects of Age, Race, and Ethnicity on the Optic Nerve and Peripapillary Region Using Spectral-Domain OCT 3D Volume Scans. Transl Vis Sci Technol. 2018;7:12.

24. de la Rosa MG, Gonzalez-Hernandez M, Lozano-Lopez V, et al. Optic disc tomography and perimetry in controls, glaucoma suspects, and early and established glaucomas. Optom Vis Sci. 2007;84:33-41.