

Correlation between Central Corneal Thickness and Intraocular Pressure: A Cross Sectional Study

Ivana Beatrice Alberta¹, Titiek Ernawati², Rofiqi Rofiq³
¹⁻³Primasatya Husada Citra Hospital Surabaya, Indonesia

ABSTRACT

Purpose: To find out correlation between Central Corneal Thickness (CCT) and Intra Ocular Pressure (IOP).

Study Design: Observational Correlational study.

Place and Duration of Study: This study was conducted in Ophthalmology Clinic Primasatya Husada Citra Hospital Surabaya from September 2021 to October 2021.

Methods: One hundred and fifteen subjects were selected through consecutive sampling. Patients of 20 – 60 years age and visiting ophthalmology clinic were included. Patients with history of glaucoma, hypertension, body mass index (BMI) above 30 kg/m², under steroid treatment (topical, systemic, peri ocular, inhalation), undergone eye surgery including corneal and refractive surgery, smoker (> 100 cigarettes in his/her life and is still smoking), Alcoholic (> 1 time/month), chronic kidney disease (CKD) and myopia (> 6 diopters) were excluded. Association between CCT and IOP was calculated using Pearson's correlation coefficient.

Results: A total 115 patients were included, 69 (60%) females and 46 (40.0%) males. Mean age was 35.78 ± 11.64 years old. Mean CCT was 550.26 ± 31.66 µm and 551.43 ± 34.92 µm for right and left eye respectively. IOP was 16.06 ± 3.71 mmHg and 15.76 ± 3.52 mmHg in right and left eyes respectively. There was a moderate positive relationship of CCT and IOP. There was a good relationship between right and left "IOP (R = 0.830, p = 0.000) and CCT (R = 0.856, p = 0.000)."

Conclusion: CCT had a moderate positive correlation with IOP (right eyes: R = 0.355, p = 0.000; left eyes: R = 0.381, P = 0.000). There is a positive relationship between CCT and IOP in both eyes (p = 0.000).

Key Words: Central corneal thickness, intraocular pressure, Tonometry,

How to Cite this Article: Alberta IB, Emawati T, Rofiq R. Correlation between Central Corneal Thickness and Intraocular Pressure: A Cross Sectional Study. Pak J Ophthalmol. 2023, **39** (2): 111-115.

Doi: 10.36351/pjo.v39i2.1555

Correspondence: Rofiqi Rofiq
Primasatya Husada Citra Hospital Surabaya, Indonesia
Email: rofiqirofiq19@gmail.com

Received: December 15, 2022
Accepted: February 28, 2023

INTRODUCTION

Thickness of cornea in its central region affects the readings of intraocular pressure (IOP).¹ This may impact how glaucoma and ocular hypertension patients are screened for the disease, followed, and treated. Given this, one can see why precise IOP measurement is crucial. According to the Ocular Hypertension Study (OHTS) researchers, IOP is underestimated when the

central corneal thickness (CCT) is thin and vice versa.¹

A thin shell hypothesis was developed by Orsengo and Pye, with a statement explaining that there is a combination of factors that have an impact on the Applanation force required for an existing IOP of a certain size. The gap between the Applanation pressure and the actual IOP decreases as the applanation area decreases. It takes more energy to applanate a thicker cornea and less force if the cornea is thinner.^{1,2}

Therefore, the notion was that CCT can be a detrimental factor in terms of measuring IOP. CCT has been found to positively correlate with IOP in a number of investigations. As local data is scarce, we planned to assess the strength of link between CCT

and IOP, quantify the impact, and identify any differences in the correlation between the right and left eyes.

METHODS

The correlational study was conducted at in Ophthalmology Clinic Primasatya Husada Citra Hospital Surabaya from September 2021 until October 2021. The study was approved by the Health Research Ethics Commission of Medical Faculty Widya Mandala Catholic University based on “WHO-CIOMS International Ethical Guidelines for Health-related Research Involving Humans”. A sample size of 115 was calculated using Leme show formula. This calculation assumed a two-sided test, $\alpha = 0.05$. The inclusion criteria were patients visiting ophthalmology clinic with age 20 – 60 year old. The exclusion criteria were patients with history of glaucoma, hypertension, body mass index (BMI) above 30 kg/m², steroid treatment (topical, systemic, periocular, inhalation), previous eye surgery including corneal and refractive surgery, smoker (> 100 cigarettes in his/her life and is still smoking), Alcoholic (> 1 time/month), history of chronic kidney disease (CKD) and myopia (> 6 diopters).

CCT and IOP measurements were carried out with non-Contact Tonometers Canon TX – 20P. To avoid the effect of diurnal variation, the readings were taken during 9-11 am.³ Age, sex, CCT, and IOP were all collected as primary data from patients. Shapiro-Wilk test was used to determine whether a variable can match a normal distribution. Because the data obtained did not match, we performed the Kruskal-Wallis test to compare the two groups. The association between CCT and IOP was calculated using Pearson's correlation coefficient. The following criteria were used to determine strength of any observed correlations: Weak or no relationship (0.01), slight/moderate association (0.025 – 0.49), moderate association (0.50 – 0.74), and strong association (> 0.75).

The impact of CCT on IOP of both eyes was evaluated using simple linear analysis, and the R² coefficient of determination was utilized. CCT and IOP measurements were compared between the two eyes using paired-sample t-tests. The analysis was done using SPSS 24.0 program, and the p-value < 0.05 was considered significant in statistical terms.

RESULTS

A total of 115 patients, 69 (60%) females and 46 (40.0%) males were included. Mean age was 35.78 ± 11.64 years. Mean CCT was 550.26 ± 31.66 µm and 551.43 ± 34.92 µm in right and left eyes respectively. Mean IOP was 16.06 ± 3.71 mmHg and 15.76 ± 3.52 mmHg in right and left eye respectively (Table 1).

We found a moderate positive correlation between CCT and IOP of the right eyes (Pearson Correlation Coefficient, $R = 0.355$, $P = 0.000$) and left eyes (Pearson Correlation Coefficient, $R = 0.381$, $P = 0.000$) (Table 1). Analysis showed that for 100 µm CCT, the measured IOP increased by 0.042 mmHg in right eye ($R^2 = 0.126$, $p = 0.000$) and by 0.038 mmHg in left eye ($R^2 = 0.145$, $p = 0.000$) (Figure 1).

We also analyzed inter-eye CCT and IOP. CCT of right and left eye had a strong relationship ($R = 0.856$, $p = 0.000$). There was no significant difference in IOP of right and left ($R = 1.51$, $p = 0.132$) with IOP of right eye 0.3 higher than IOP of left eye (95% CI [-0.09, 0.69]).

Table 1: Results.

	Right Eye	Left Eye
Number (eyes)	115	115
CCT (Mean ±SD)	550.26 ± 31.66	551.43 ± 34.92
IOP (Mean ±SD)	16.06 ± 3.71	15.76 ± 3.52
R, p value	$R = 0.355$, $p = 0.000$	$R = 0.381$, $p = 0.000$
R ² , p value	$R^2 = 0.126$, $p = 0.000$	$R^2 = 0.145$, $p = 0.000$
CCT OD-OS	$r = 0.856$, $p = 0.000$	
IOP OD-OS	$r = 0.830$, $p = 0.000$	

DISCUSSION

CCT has been shown to correlate positively with IOP in many studies (Table 2).⁴⁻⁹ This research found a good relationship between CCT and IOP. According to statistical analysis, the observed IOP rises by 0.042 mmHg ($R^2 = 0.126$, $p = 0.000$) on the right eye and 0.038 mmHg ($R^2 = 0.145$, $p = 0.000$) on the left eye for every 100 µm increase in CCT. Furthermore, a good relationship was found between binocular CCT ($r = 0.856$, $p = 0.000$) and IOP ($r = 0.830$, $p = 0.000$).

Alkhodari et al, confirmed similar findings, a positive connection between CCT and IOP in the right eye “($R = 0.358$, $P = 0.000$) and in the left eye ($R = 0.324$, $P = 0.000$). For every 100 µm increase in CCT, observed IOP rises by 0.024 mmHg ($R^2 = 0.138$, $P = 0.000$) on the right eye and 0.022 mmHg ($R^2 = 0.121$, $P = 0.000$)” on the left eye.⁴

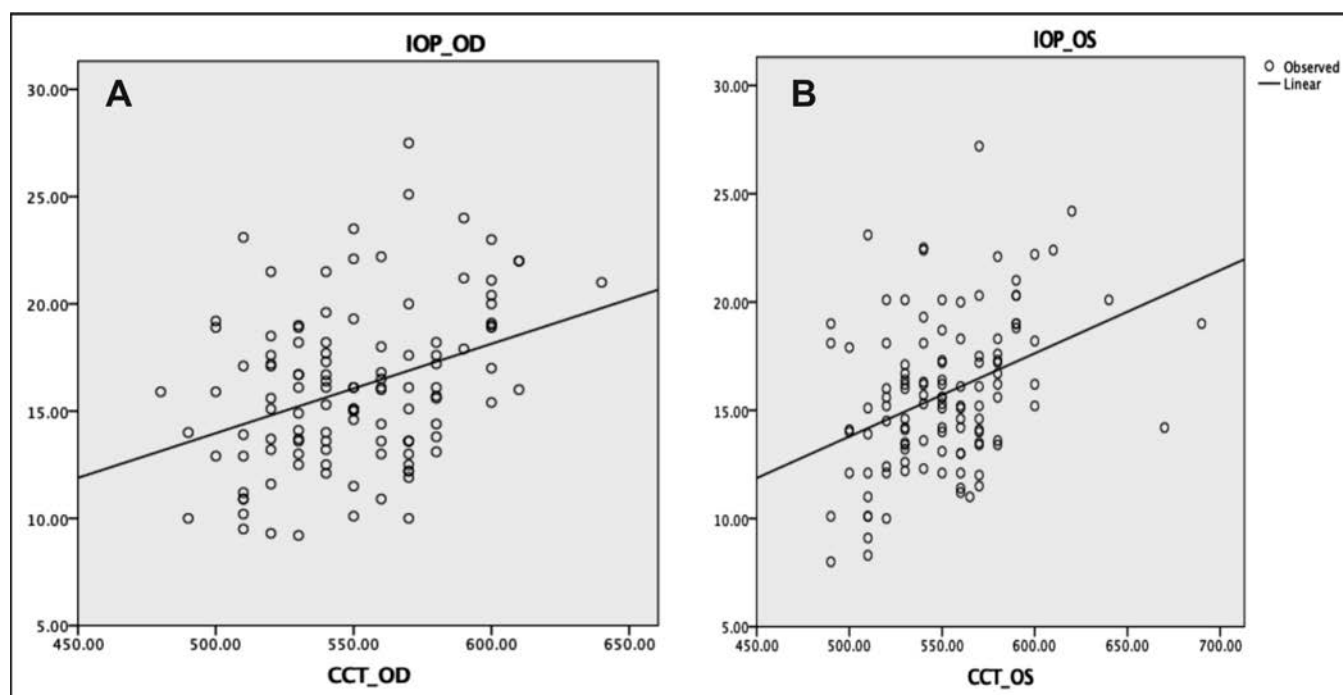


Figure 1: Scatter diagram of CCT and IOP ($n = 115$) in the right eye (A) and left eye (B). (OD: $R^2 = 0.126$, $p = 0.000$; OS: $R^2 = 0.145$, $p = 0.000$).

Table 2: Comparison of results of this study with other studies.

	CCT-IOP Relationship		Increase in IOP with Increase in CCT	
	Right Eye	Left Eye	Right Eye	Left Eye
This study	$R = 0.355$, $P = 0.000$	$R = 0.381$, $P = 0.000$	Every 100 μm : 0.042 mmHg ($R^2 = 0.126$, $p = 0.000$)	Every 100 μm : 0.038 mmHg ($R^2 = 0.145$, $p = 0.000$)
Al-Khodari et al ⁴	$R = 0.358$, $P = 0.000$	$R = 0.324$, $P = 0.000$	Every 100 μm : 0.024 mmHg ($R^2 = 0.138$, $P = 0.000$)	Every 100 μm : 0.022 mmHg ($R^2 = 0.121$, $P = 0.000$)
Nejabat ⁵	$R = 0.487$, $P = 0.000$	$R = 0.456$, $P = 0.000$	Every 100 μm : 3.3 mmHg	Every 100 μm : 2.9 mmHg
Hoffman et al ⁶	N/S	N/S	Every 10 μm : Male: 0.37 mmHg, $R^2 = 0.205$ Female: 0.35 mmHg, $R^2 = 0.235$	Every 10 μm : Male: 0.38 mmHg, $R^2 = 0.209$ Female: 0.45 mmHg, $R^2 = 0.229$
Ahmed et al ⁷	$R = 0.54$, $P = 0.001$		N/S	N/S
Lee et al ⁸	$R = 0.676$, $P = 0.001$		N/S	N/S
Wei et al ⁹	$R = 0.44$, $P = 0.05s$		N/S	N/S

*N/S: not stated

Using the same method for measuring IOP as the present investigation, Nejabat et al, found a moderate association between CCT and IOP (right eye: $R = 0.487$, $p = 0.000$; left eye: $R = 0.456$, $p = 0.000$). The right eye saw a more significant rise in IOP (3.3 mmHg) than the left eye (2.9 mmHg) for every 100 μm increase in CCT.⁵

Hoffman et al. found that there was a correlation between IOP rise and CCT: right eye in male 0.37 mmHg, $R^2 = 0.205$, in female: 0.35 mmHg, $R^2 = 0.235$; left eye in male: 0.38 mmHg, $R^2 = 0.209$, in

female: 0.45 mmHg, $R^2 = 0.229$. Furthermore, they demonstrated a significant disparity in mean CCT between the two eyes ($p = 0.0001$).⁶

Sharma et al, found a moderate positive connection between CCT and IOP, statistically significant for both the right and left eyes ($p = 0.001$).¹⁰ Positive correlation between CCT and IOP was also found by other researchers.¹¹⁻¹⁴

Non-contact tonometry (NCT), which was used in our study is known to have a reasonable correlation

with CCT.¹⁵ The Goldmann Applanation tonometer (GAT) is less vulnerable to CCT than the NCT.¹⁵⁻¹⁹ NCT causes the cornea to flatten in a brief amount of time—roughly 8 ms—making the cornea more rigid than GAT, which measures the response of cornea to steady pressure or compression. Increased measured IOP with increased CCT are consistent across clinical and demographic research alike.^{20,21}

The limitations of this study are cross-sectional design for a period of one month. All confounders could not be controlled. Longer period and larger sample size are recommended for further study. In addition, non-Contact Tonometers were used to assess CCT and IOP in this investigation. We highly recommend the use of ultrasound pachymetry as the gold standard for measuring CCT and Goldmann applanation as the gold standard for measuring IOP.

CONCLUSION

CCT had a moderate positive correlation with IOP (right eyes: $R = 0.355$, $p = 0.000$; left eyes: $R = 0.381$, $P = 0.000$). There is a positive relationship between CCT and IOP in both eyes ($p = 0.000$). Observed IOP rises by 0.042 mmHg ($R^2 = 0.126$, $p = 0.000$) in the right eye and 0.038 mmHg ($R^2 = 0.145$, $p = 0.000$) in the left eye for every 100 micrometer increase in CCT. In addition, CCT was highly positively correlated between right and left eyes ($r = 0.856$, $p = 0.000$).

Conflict of Interest

Authors declared no conflict of interest.

Ethical Approval

The study was approved by the Institutional review board/Ethical review board (214/WM12/KEPK/DOSEN/T/2021).

REFERENCES

1. **Brandt JD, Beiser JA, Kass MA, Gordon MO.** Central corneal thickness in the Ocular Hypertension Treatment Study (OHTS). *Ophthalmology*, 2001; **108** (10): 1779-1788. Doi: 10.1016/s0161-6420(01)00760-6.
2. **Soriano JG, Lat-Luna MML, Khu PM.** Correlating central corneal thickness and intraocular pressure in ocular hypertension and glaucoma – Philip J *Ophthalmol* . 2007; 32 (1): 4-8.
3. **Syed Z, Srikanth K, Nagarajan S.** Diurnal variation of central corneal thickness and intraocular pressure in eyes with pseudoexfoliation. *Indian J Ophthalmol*. 2019; **67** (10): 1607-1609. Doi: 10.4103/ijo.IJO_1899_18.
4. **Alkhodari HT.** Distribution of central corneal thickness and intraocular pressure in emmetropic eyes of healthy children of Palestine: a representative cross-sectional study. *Int J Ophthalmol*. 2019; **12** (3): 496-503. Doi: 10.18240/ijo.2019.03.22. eCollection 2019.
5. **Nejabat M, Heidary F, Talebnejad MR, Salouti R, Nowroozzadeh MH, Masoumpour M, et al.** Correlation Between Intraocular Pressure and Central Corneal Thickness in Persian Children. *Ophthalmol Ther*. 2016; **5** (2): 235-243. Doi: 10.1007/s40123-016-0063-5
6. **Hoffmann EM, Lamparter J, Mirshahi A, Elflein H, Hoehn R, Wolfram C, et al.** Distribution of central corneal thickness and its association with ocular parameters in a large central European cohort: the Gutenberg health study. *PLoS One*, 2013; **8** (8): e66158 Doi: 10.1371/journal.pone.0066158
7. **Ahmed MAA, Abdelhalim AS.** Corrected Intraocular Pressure Variability with Central Corneal Thickness Measurement. *Clin Ophthalmol*. 2020; **14**: 4501-4506. Doi: 10.2147/OPTH.S288391
8. **Lee M, Ahn J.** Effects of central corneal stromal thickness and epithelial thickness on intraocular pressure using Goldmann applanation and non-contact tonometers. *PLoS One*, 2016; **11** (3). Doi: 10.1371/journal.pone.0151868
9. **Wei W, Fan Z, Wang L, Li Z, Jiao W, Li Y.** Correlation Analysis between Central Corneal Thickness and Intraocular Pressure in Juveniles in Northern China: The Jinan City Eye Study. *PLoS One*, 2014; **9** (8): 104842. Doi: 10.1371/journal.pone.0104842
10. **Sharma R, S NK, Sujatha R, N PC, Sharma S, Sharma A.** Central corneal thickness and intraocular pressure in primary open angle glaucoma suspects in a south Indian population. Is it time for “corneal anthropology”? *Indian J Clin Exp Ophthalmol*. 2020; **6** (4): 542-548. Doi: 10.18231/j.ijceo.2020.114
11. **Brandt JD, Roberts CJ.** The Impact of Central Corneal Thickness and Corneal Biomechanics on Tonometry. *Glaucoma: Second Edition*, 2015; **1**: 201-208.
12. **Mbatuegwu AI, Achigbu EO, Mbatuegwu CU, Nkwogu FU, Omoti AE.** Exploring the Relationship between Central Corneal Thickness and Intraocular Pressure Among Nonglaucoma Patients in a General Ophthalmology Clinic, South East Nigeria. *Nigerian J Ophthalmol* 2021; **29** (1): 17. Doi: 10.4103/njo.njo_26_20

13. **Fayed MA, Chen TC.** Major review Pediatric intraocular pressure measurements: Tonometers, central corneal thickness, and anesthesia. *Surv Ophthalmol.* 2019; **64 (6)**: 810-825.
Doi: 10.1016/j.survophthal.2019.05.003
14. **Doughty MJ, Zaman ML.** Human corneal thickness and its impact on intraocular pressure measures: a review and meta-analysis approach. *Surv Ophthalmol.* 2000; **44 (5)**: 367-408.
15. **Badran T, El-Shereif R.** Comparison between corrected intraocular pressure using contact versus noncontact methods in glaucoma patients. *J Egypt Ophthalmol Soc.* 2019; **112 (2)**: 39.
16. **Chen M, Zhang L, Xu J, Chen X, Gu Y, Ren Y, et al.** Comparability of three intraocular pressure measurement: iCare pro rebound, non-contact and Goldmann applanation tonometry in different IOP group. *BMC Ophthalmol.* 2019; **19 (1)**: 1–10.
Doi: 10.1186/s12886-019-1236-5
17. **Üçer MB, Bozkurt E.** Comparison of central corneal thickness measurements with three different optical devices. *Ther Adv Ophthalmol.* 2021; **13**: 2515841421995633. Doi: 10.1177/2515841421995633.
18. **Mansoori T, Balakrishna N.** Effect of central corneal thickness on intraocular pressure and comparison of Topcon CT-80 non-contact tonometry with Goldmann applanation tonometry. *Clin Exp Optom.* 2018; **101 (2)**: 206–212. Doi: 10.1111/cxo.12620.
19. **Lubbad A, Oluwatoba-Popoola I, Haar M, Framme C, Bajor A.** The influence of corneal density and thickness on tonometry measurement with goldmann applanation, non-contact and iCare tonometry methods. *Int Ophthalmol.* 2022; **42 (7)**: 2167–2174.
Doi: 10.1007/s10792-022-02216-6.
20. **Copt RP, Thomas R, Mermoud A.** Corneal thickness in ocular hypertension, primary open-angle glaucoma, and normal tension glaucoma. *Arch Ophthalmol.* 1999; **117 (1)**: 14-16. Doi: 10.1001/archophth.117.1.14.
21. **McCafferty S, Tetrault K, McColgin A, Chue W, Levine J, Muller M.** Intraocular Pressure Measurement Accuracy and Repeatability of a Modified Goldmann Prism: Multicenter Randomized Clinical Trial. *Am J Ophthalmol.* 2018; **196**: 145-153.
Doi: 10.1016/j.ajo.2018.08.051.

Authors' Designation and Contribution

Ivana Beatrice Alberta; General Practitioner: *Concepts, Design, Literature search, Data acquisition, Data analysis, Statistical analysis, Manuscript preparation, Manuscript editing, Manuscript review.*

Titiek Ernawati; Consultant Ophthalmologist: *Concepts, Design, Literature search, Data acquisition, Data analysis, Statistical analysis, Manuscript preparation, Manuscript editing, Manuscript review.*

Rofiqi Rofiq; Resident: *Concepts, Design, Literature search, Data acquisition, Data analysis, Statistical analysis, Manuscript preparation, Manuscript editing, Manuscript review.*

