

ORIGINAL ARTICLE

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Correlation of central corneal thickness and Goldmann applanation tonometry among Filipinos

ABSTRACT

Objective

To determine the distribution of central corneal thickness (CCT) among Filipinos and to correlate CCT with intraocular pressure (IOP).

Methods

A prospective cross-sectional study was performed among Filipino patients consulting at the General Ophthalmology Clinic of the Philippine General Hospital. They underwent a comprehensive eye examination. CCT obtained by ultrasonic pachymetry and IOP by Goldmann applanation tonometry were correlated using linear regression analysis. Factors affecting CCT measurements were analyzed by ANOVA.

Results

Two hundred twenty two eyes of 112 patients were included in the study. CCT ranged from 451.0 m to 653.6 m with a mean of 531.5 m \pm 33.8 m. There was a significant linear correlation between CCT and IOP ($r = 0.63$). The IOP was noted to rise by 4.3 mm Hg/100 m CCT.

Conclusion

The CCT among Filipinos is normally distributed and is comparable to the distribution obtained by metaanalysis of worldwide data. The study also found a direct correlation between CCT and IOP among Filipinos.

Key words: *Applanation tonometry, Central corneal thickness, Glaucoma, Intraocular pressure*

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ACCURATE measurement of intraocular pressure (IOP) is essential not only in the diagnosis and management of glaucoma, but also in the postoperative monitoring of those who have undergone intraocular surgery. Currently, Goldmann applanation tonometry is the gold standard for clinical measurement of IOP. It works on the principle that the pressure inside an ideal sphere is equal to the force necessary to flatten its surface, divided by the area of flattening.¹

In calibrating this tonometer, Goldmann assumed a standard central corneal thickness (CCT) of 0.55 mm.¹ He predicted that variations from this standard corneal thickness, which he assumed to be rare, would be a source of error in measuring IOP. Currently, there is accumulating evidence that Goldmann's theoretical prediction is correct.

Several studies involving simultaneous IOP measurements by applanation tonometry and by manometry have demonstrated that thicker corneas yield an overestimation of IOP by applanation.²⁻⁴

Population-based studies have also demonstrated a positive correlation between CCT and IOP measured by Goldmann applanation tonometry^{5, 6} or Tono-Pen.⁷ A recent metaanalysis of IOP measured by applanation and CCT, which pooled 133 data sets, revealed a statistically significant correlation between the two.⁸ Studies involving patients who have undergone Photorefractive Keratectomy (PRK)⁹⁻¹³ and Laser in Situ Keratomileusis (LASIK)¹⁴ have demonstrated a corresponding drop in postoperative IOP with the cornea ablated.

Numerous studies have shown that patients diagnosed with ocular hypertension have significantly thicker corneas compared with normal subjects, suggesting that IOP in this group of patients is being overestimated.¹⁵⁻¹⁸ Similarly, patients diagnosed with normal-tension glaucoma have thinner corneas than normal subjects, suggesting that IOP in this group of patients is being underestimated.^{16, 18, 19, 20}

Given these, several authors have recommended that CCT be considered in interpreting IOP or adjustments be made in IOP based on CCT.^{2-5, 7, 11, 13-15, 17, 18, 21, 22}

To date, there are no published studies of CCT among Filipinos. It may be inappropriate to apply studies on IOP and CCT done in other countries to the Philippine setting because several studies have demonstrated interracial differences in the range of CCT and factors affecting these values.^{7, 8}

This study determined the following among Filipinos: the distribution of CCT, the correlation between CCT and IOP, and the association between CCT and other factors such as age, gender, diabetes, thyroid disease, hypertension, trauma, eye surgery, and family history of glaucoma.

METHODOLOGY

This is a prospective cross-sectional study involving Filipino patients seen consecutively at the General Ophthalmology Clinic of the Philippine General Hospital Outpatient Department from October 17 to 19, 2000. Patients over 10 years old with normal IOP, optic-nerve head, and cornea were included in the study. Patients with the following findings were excluded: glaucoma, use of glaucoma medication for the past month, intraocular surgery for the past 3 months, intraocular or retrobulbar tumor, contact lens use for the past 1 month, uveitis, retinal detachment, conjunctivitis, corneal ulcer, corneal dystrophy, and corneal refractive surgery. Patient consent was obtained.

Patients included in the study were seen by a single examiner (PG). A case-report form was completed indicating demographic and other factors that could affect IOP and CCT. Proparacaine (Alcaine, Alcon, Fort Worth, TX, USA) was given as a topical anesthetic before IOP and CCT measurements were taken. IOP was measured twice using a Goldmann applanation tonometer (Haag-Streit, Bern, Switzerland) with both measurements within 1 mm Hg. The mean of the two measurements was then recorded. CCT was measured 10 times until all 10 measurements had a standard deviation (SD) of less than 5 using an ultrasound pachymeter (Bio & Pachy Meter AL-2000, Nishi-ku, Nagoya, Japan). Both instruments were disinfected with 70% isopropyl alcohol between each use. The calibration of both instruments was checked daily prior to the start of each study session.

Statistical analyses were performed using Epi Info version 6.02c (Centers for Disease Control and Prevention, Atlanta, GA, USA). *P* values less than 0.05 were considered statistically significant. For all statistical tests, the mean of the ten CCT measurements was used. The correlation between average CCT and IOP, and between CCT and age were determined by linear regression. The effect of gender; family history of glaucoma; diseases such as diabetes mellitus, systemic hypertension, and thyroid disease; trauma; and eye surgery on CCT was determined by analysis of variance (ANOVA). The right and left eyes were analyzed separately since IOP and CCT measurements between eyes are interdependent.

RESULTS

The study included 222 eyes of 112 patients of whom 36 were male and 76 were female. Two patients had 1 eye where IOP and CCT could not be measured because of corneal irregularity secondary to trauma. The patients' ages ranged from 16 to 86 years with a mean of 52.3 ± 17.5 years. Most of the patients were in the 51- to 70-year age group (Figure 1). CCT ranged from 451.0 mm to 653.6 mm with a mean of 531.5 ± 33.8 mm (Figure 2). The IOP

ranged from 11 mm Hg to 21 mm Hg with a mean of 16.2 ± 2.3 mm Hg. A direct linear correlation was found between CCT and IOP ($r = 0.63$). The IOP was noted to rise by 4.3 mm Hg/100 m CCT (Figure 3).

No significant correlation was found between CCT and age, gender, diabetes, thyroid disease, hypertension, trauma, eye surgery, or family history of glaucoma ($p > 0.05$). Neither was there a significant relationship between IOP and these factors ($p > 0.05$).

DISCUSSION

There is no general consensus on what is the average normal CCT. It has been estimated to range from 518 m²⁴ to 580 m.²¹ A recent metaanalysis of measured CCT in normal eyes pooled from 300 data sets worldwide reported a mean of 534 ± 31 m.⁸ Our study population had a comparable mean CCT of 531.5 ± 33.8 m. The CCT values were distributed normally (Figure 2).

Our study population also showed a direct correlation between CCT and IOP measured by Goldmann applanation tonometry ($r = 0.63$). An increase of 4.3 mm Hg per 100 m of CCT increase was noted. This correlation is lower compared with results reported in manometry studies. Ehlers et al.² reported a 5 mm Hg rise for every 70 m CCT (7.14 mm Hg/100 m CCT) while Whitacre et al.⁴ predicted an error of 3.5 mm Hg for every 70 m CCT (5 mm Hg/100 m CCT).

Compared with population-based studies by Dohadwala et al.,⁷ Foster, et al.,⁵ and Wolfs et al.,⁶ our computed slope for IOP rise for every m is steeper. Dohadwala et al.⁷ reported only a 2 mm Hg increase per 100 m CCT. Their study, however, used a Tono-Pen to measure IOP. In contrast, Foster et al.⁵ used an optical pachymeter and reported a 1.8 mm Hg/100 m slope for right eyes and 2.4 mm Hg/100 m for left eyes. Wolfs et al.⁶ reported a rise of 1.9 mm Hg/100 m. This study, however, only included patients aged

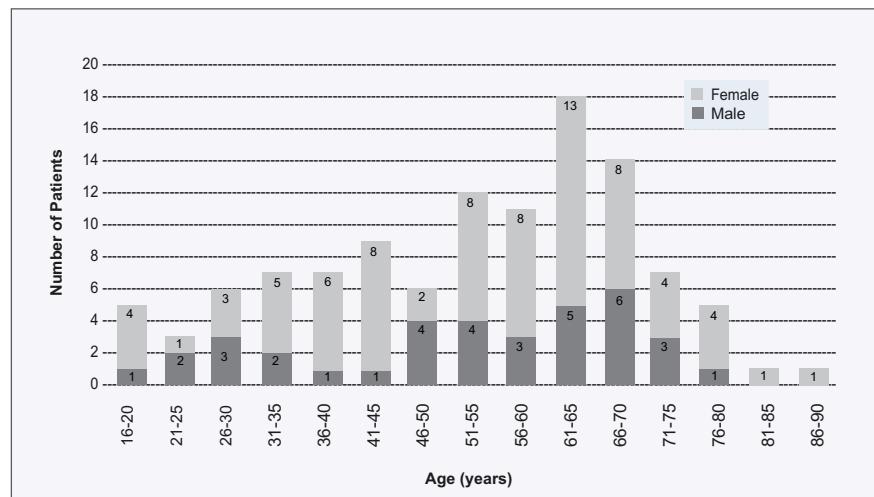


Figure 1. Age distribution of patients (n = 112).

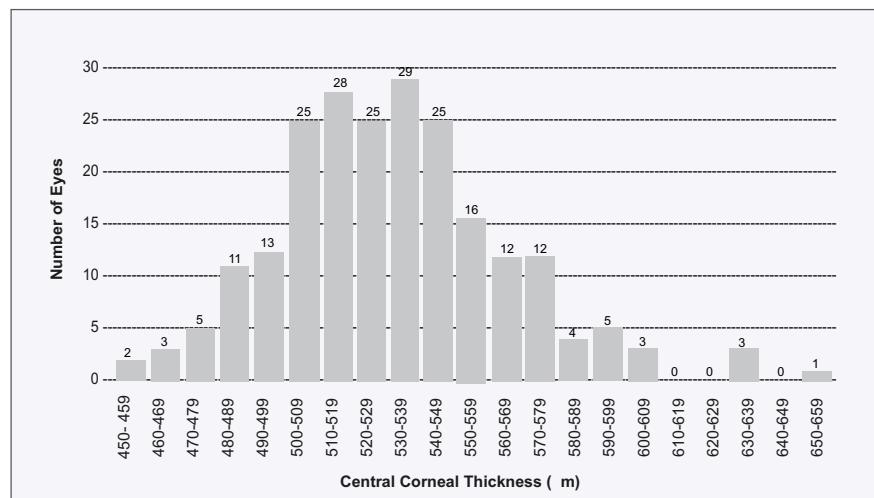


Figure 2. Distribution of central corneal thickness among Filipinos (n = 222).

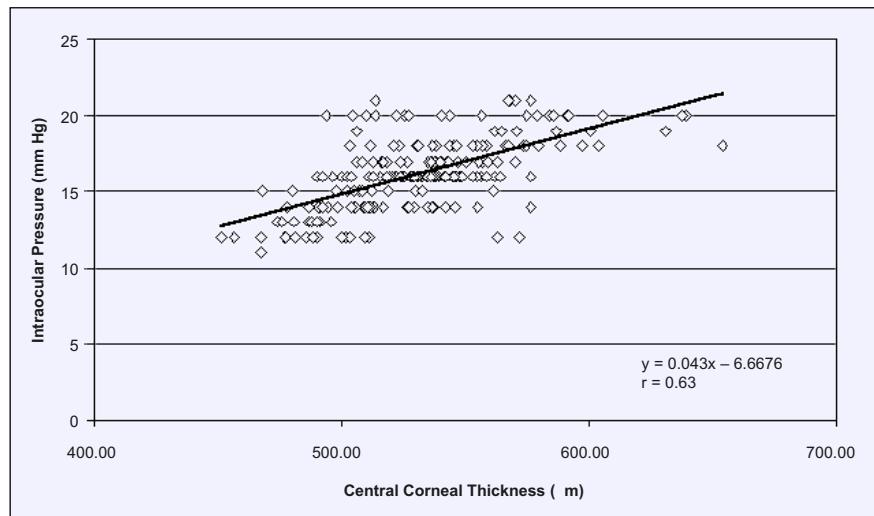


Figure 3. Scatterplot of central corneal thickness and intraocular pressure (n = 222).

55 or older (Table 1). Variations in the results obtained may also be partly explained by the differences in the number of eyes examined.

Dohadwala et al.⁷ reported a significant difference in CCT among Asians, Blacks, and Caucasians. It is likely that interracial variation could partly explain the difference in the magnitude of the relationship observed between other studies and our study. Differences in instrumentation and characteristics of the study population are also possible causes.

Other studies have reported that factors such as age,²⁵⁻²⁷ gender,^{7, 28, 29} hypertension,^{7, 30-32} diabetes,^{7, 20, 28, 33, 34} and family history of glaucoma^{28,35} have relationships to IOP and/or CCT. Our study, however, did not show any statistically significant relationship.

This study showed that CCT among Filipino patients consulting at the General Ophthalmology Clinic of the Philippine General Hospital is normally distributed and is comparable to the distribution obtained by metaanalysis of worldwide data. The study also found a direct correlation between CCT and IOP. Variation in CCT is a source of systematic error caused by the cornea's resistance to flattening. Further population-based and manometry studies with larger sample sizes are recommended to evaluate the relationship between CCT and IOP as measured by Goldmann applanation tonometry. Such studies could help generate a formula for adjusting IOP measured by applanation to compensate for variations in CCT.

References

1. Schottenstein EM. Intraocular pressure and tonometry. In: Ritch R, Shields MB, Krupin T, eds: *The Glaucomas*, 2nd ed. Missouri: Mosby, 1996; v. 1, chap. 20: 407-428.
2. Ehlers N, Bramsen T, Sperling S. Applanation tonometry and central corneal thickness. *Acta Ophthalmol (Copenh)* 1975; 53: 34-43.
3. Johnson M, Kass MA, Grodzki WJ. Increased corneal thickness simulating elevated intraocular pressure. *Arch Ophthalmol* 1978; 96: 664-665.
4. Whitacre MM, Stein RA, Hassanein K. The effect of corneal thickness on applanation tonometry. *Am J Ophthalmol* 1993; 115: 592-596.
5. Foster PJ, Baasunhu J, Alsbirk PH, et al. Central corneal thickness and intraocular pressure in a Mongolian population. *Ophthalmology* 1998; 105: 969-973.
6. Wolfs RC, Klaver CC, Vingerling JR, et al. Distribution of central corneal thickness and its association with intraocular pressure: The Rotterdam Study. *Am J Ophthalmol* 1997; 123: 767-772.
7. Dohadwala AA, Munger R, Damji KF. Positive correlation between Tono-Pen intraocular pressure and central corneal thickness. *Ophthalmology* 1998; 105: 1849-1854.
8. Doughty MJ, Zaman ML. Human corneal thickness and its impact on intraocular pressure measures: a review and metaanalysis approach. *Surv Ophthalmol* 2000; 44: 367-408.
9. Abbasoglu OE, Bowman RW, Cavanagh HD, McCulley JP. Reliability of intraocular pressure measurements after myopic excimer photorefractive keratectomy. *Ophthalmology* 1998; 105: 2193-2196.
10. Cennamo G, Rosa N, La Rana A, et al. Noncontact tonometry in patients that underwent photorefractive keratectomy. *Ophthalmologica* 1997; 211: 341-343.
11. Mardel PG, Piebenga LW, Whitacre MM, Siegmund KD. The effects of excimer laser photorefractive keratectomy on intraocular pressure using the Goldmann applanation tonometer. *Ophthalmology* 1997; 104: 945-949.
12. Munger R, Hodge WG, Mintsioulis G. Correction of intraocular pressure for changes in central corneal thickness following photorefractive keratectomy. *Can J Ophthalmol* 1998; 33: 159-165.
13. Rosa N, Cennamo G, Breve MA, La Rana A. Goldmann applanation tonometry after myopic photorefractive keratectomy. *Acta Ophthalmol Scand* 1998; 76: 550-554.
14. Emara B, Probst LE, Tingey DP. Correlation of intraocular pressure and central corneal thickness in normal myopic eyes and after laser in situ keratomileusis. *J Cataract Ref Surg* 1998; 24: 1320-1325.
15. Argus WA. Ocular hypertension and central corneal thickness. *Ophthalmology* 1995; 102: 1810-1812.
16. Copt R, Thomas R, Mermoud A. Corneal thickness in ocular hypertension, primary open-angle glaucoma, and normal-tension glaucoma. *Arch Ophthalmol* 1999; 117: 14-16.
17. Herndon LE, Choudhri SA, Cox T, et al. Central corneal thickness in normal, glaucomatous, and ocular hypertensive eyes. *Arch Ophthalmol* 1997; 115: 1137-1141.
18. Shah S, Chatterjee A, Mathai M, et al. Relationship between corneal thickness and measured intraocular pressure in a general ophthalmology clinic. *Ophthalmology* 1999; 106: 2154-2160.
19. Ehlers N, Hansen FK. Central corneal thickness in low-tension glaucoma. *Acta Ophthalmol (Copenh)* 1974; 56: 97-105.
20. Tomlinson A, Leighton DA. Ocular dimensions in low-tension glaucoma. *Br J Ophthalmol* 1972; 56: 97-105.
21. Stodmeister R. Applanation tonometry and correction according to corneal thickness. *Acta Ophthalmol Scand* 1998; 76: 319-324.
22. Tanaka GH. Corneal pachymetry: a prerequisite for applanation tonometry? *Arch Ophthalmol* 1998; 116: 544-545.
23. Ederer F. Shall we count number of eyes or number of subjects? *Arch Ophthalmol* 1973; 89: 1-2.
24. Mishima S. Corneal thickness. *Surv Ophthalmol* 1968; 13: 57-96.
25. Alsbirk PH. Corneal thickness. I. Age variation, sex difference and oculometric correlation. *Acta Ophthalmol (Copenh)* 1978; 56: 95-104.
26. Polse KA, Brand RJ, Mandell R, et al. Age differences in corneal hydration control. *Invest Ophthalmol Vis Sci* 1989; 30: 392-399.
27. Yee RW, Matsuda M, Schultz RO, Edelhauser HF. Changes in the normal corneal endothelial cellular pattern as a function of age. *Curr Eye Res* 1985; 4: 671-678.
28. Armaly MF. On the distribution of applanation pressures: statistical features and the effect of age, sex, and family history of glaucoma. *Arch Ophthalmol* 1965; 73: 11-18.
29. Hirvela H, Tuulonen A, Laatikainen L. Intraocular pressure and prevalence of glaucoma in elderly people in Finland: a population-based study. *Int Ophthalmol* 1994; 18: 299-307.
30. Dielemans I, Vingerling JR, Algra D, et al. Primary open-angle glaucoma, intraocular pressure, and systemic blood pressure in the general elderly population. *Arch Ophthalmol* 1995; 102: 54-60.
31. Shiose Y. The ageing effect on intraocular pressure in an apparently normal population. *Arch Ophthalmol* 1984; 102: 883-887.
32. Tielsch JM, Katz J, Sommer A, et al. Hypertension, perfusion pressure, and primary open-angle glaucoma. A population-based assessment. *Arch Ophthalmol* 1983; 101: 891-894.
33. Keoleian GM, Pach JM, Hodge DO, et al. Structural and functional studies of the corneal endothelium in diabetes mellitus. *Am J Ophthalmol* 1992; 113: 64-70.
34. Larsson LI, Bourne WM, Pach JM, Brubaker RF. Structure and function of the corneal endothelium in diabetes mellitus type I and type II. *Arch Ophthalmol* 1996; 114: 9-14.
35. Seddon JM, Schwartz B, Flowerdew G. Case-control study of ocular hypertension. *Arch Ophthalmol* 1983; 101: 891-894.

Table 1. Correlation of central corneal thickness and intraocular pressure in various studies.

Study	Increase in IOP per 70 μ m Increase in CCT (mm Hg)	Increase in IOP per 100 μ m Increase in CCT (mm Hg)
<i>Manometry studies</i>		
Ehlers, et al.	5	7.14
Whitacre, et al.	3.5	5
<i>Population-based studies</i>		
Lat-Luna, et al.	3	4.3
Dohadwala, et al.	1.4	2
Foster, et al.		
right eye	1.26	1.8
left eye	1.68	2.4
Wolfs, et al.	1.33	1.9