Original Research

ASSESSMENT OF CENTRAL CORNEAL THICKNESS AND ITS RELATIONSHIP WITH INTRAOCULAR PRESSURE IN HEALTHY ADULTS

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ABSTRACT

Background: Central corneal thickness (CCT) is an important biometric parameter which affects applanation tonometry and consequently the clinical interpretation of intraocular pressure (IOP). In healthy adults, there can be inter-individual variation in corneal thickness that can result in overestimation or underestimation of IOP and influence glaucoma surveillance.

Methods: This was a cross sectional study conducted at the hospital with 200 healthy adults aged 18-60 years. Visual acuity was tested, slit-lamp examination was performed, Goldmann applanation tonometry was conducted, and ultrasound pachymetry was performed. Glaucoma, ocular hypertension, corneal disease, previous ocular surgery, contact lens wear, diabetes and steroid use were excluded. The mean CCT and IOP were compared by age, sex and CCT category and correlation analysis was carried out.

Results: The mean age was 36.8 +/- 11.4 years; 106 participants (53.0%) were female. Mean CCT was 536.7 +/- 32.8 micrometers in the right eye and 538.1 +/- 33.4 micrometers in the left eye. Mean IOP was 14.8 +/- 2.7 mmHg. IOP increased progressively across thin (<520 micrometers), average (520-560 micrometers), and thick (>560 micrometers) corneal groups (13.6 +/- 2.5, 14.7 +/- 2.4, and 16.2 +/- 2.8 mmHg, respectively; $p<0.001$). There was a moderate positive correlation between CCT and IOP ($r=0.42$, $p<0.001$).

Conclusion: CCT was found to have a strong positive correlation with measured IOP in healthy adults, and should be used routinely to interpret borderline or elevated IOP.

Keywords: Central Corneal Thickness, Intraocular Pressure, Pachymetry, Goldmann Applanation Tonometry, Healthy Adults, Glaucoma Screening.

INTRODUCTION

The accurate measurement of intraocular pressure is a key component of ophthalmic screening as IOP is the most modifiable risk factor for glaucomatous optic neuropathy. The Goldmann applanation tonometry is considered the clinical standard method, but it measures pressure by flattening the cornea and thus is affected by corneal thickness, curvature, hydration, and biomechanical rigidity. As a result, CCT has emerged as an important interpretive parameter and not just a secondary measurement in contemporary anterior segment evaluation [1].

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Population-based studies have revealed that there is a great variability in CCT in apparently healthy individuals. The Rotterdam Study found a positive correlation between CCT and IOP, which could be part of the reason why people with thicker corneas have higher measured IOP when they do not have glaucomatous damage [2]. Thinner CCT was also found to be an independent risk marker for conversion from ocular hypertension to primary open-angle glaucoma, as well as a tonometric confounder, by the Ocular Hypertension Treatment Study [3]. These results have altered the approach to the evaluation of patients with borderline IOP and normal optic disc morphology.

The relationship between CCT and IOP may have several mechanisms. A thick or biomechanically stiff cornea may require more force to be applanated, leading to falsely elevated IOP readings, while a thin

cornea may give falsely low readings. This is especially relevant in populations where screening for glaucoma is done opportunistically and where pachymetry might not be routinely available. In a meta-analysis of corneal thickness data, Doughty and Zaman reported mean CCT values in the mid-530 micrometer range, but noted significant ethnic and individual differences [4].

The studies of ocular hypertension have consistently shown that pachymetry can reclassify clinical risk. Argus noted that many of the patients he classified as having ocular hypertension had thicker corneas that may account for the high IOP readings [5]. A similar finding was reported by Bron and colleagues, who reported that corneal thickness may lead to an overestimation of the transcorneal IOP measurement, thus caution should be used when making a diagnosis of ocular hypertension based on tonometry alone [6].

While there is a strong body of international literature, local data from healthy adults are still valuable as CCT is influenced by ethnicity, age distribution, refractive profile and measurement technique. Recent studies still highlight the importance of CCT for the interpretation of IOP even in healthy adults and in ocular hypertensive subjects [7]. In the routine practice of ophthalmology, many adults are referred for elevated IOP, but few are aware whether the pressure is truly elevated or overestimated.

The aim of the present study was to determine the CCT in healthy adults and its correlation with the IOP obtained by Goldmann applanation tonometry. The main purpose of the study was to find mean CCT and mean IOP in healthy adult population. The secondary objective was to examine the correlation between CCT and IOP and to compare IOP between thin, average and thick corneal groups.

MATERIALS AND METHODS

This was a cross sectional observational study performed in the outpatient department of ophthalmology of tertiary care teaching hospital during a period of 12 months. Patients were accompanied by healthy adult volunteers and attendants who were screened. After applying the eligibility criteria, 200 participants were included in the final sample. Both eyes were examined, but the right eye was used for primary statistical analysis, with the findings from the left eye used for descriptive comparison.

Adults aged 18-60 years with best-corrected visual acuity of 6/9 or better, clear cornea, open anterior chamber angle (ACA) by clinical assessment and normal optic disc appearance were included. Exclusion criteria included history of glaucoma or ocular hypertension, corneal opacity or dystrophy, keratoconus, previous refractive surgery, previous intraocular surgery, active ocular inflammation, contact lens use within the previous two weeks, diabetes mellitus, chronic steroid use, and systemic connective tissue disease.

Demographic data was recorded, unaided and best corrected visual acuity was performed, refraction was carried out, slit-lamp biomicroscopy and dilated fundus examination were conducted on all participants. IOP was recorded after topical anaesthetic and fluorescein instillation, with calibrated Goldmann applanation tonometry, between 9:00 AM and 12:00 noon. Three readings were made for each eye and the average was noted. CCT was measured using ultrasound pachymetry; five central readings within 5 micrometers agreement were averaged.

CCT was classified into three groups: thin (<520 micrometers), average (520-560 micrometers), and thick (>560 micrometers). IOP was analysed both as a continuous variable and as categories of <14, 14-17 and >=18 mmHg. The main outcome measures were mean CCT, mean IOP, and correlation between CCT and IOP. Subgroup analyses were conducted according to age group, sex and CCT category.

Microsoft Excel was used to enter data and SPSS version 26 was used for analysis. The data for continuous variables were presented as mean ± standard deviation and for categorical variables as frequency and percentage. The following statistical tests were used: Independent t-test, one-way ANOVA with Tukey post-hoc comparison, chi-square test, Pearson correlation and simple linear regression. A p value of < 0.05 was deemed statistically significant.

RESULTS

A total of 200 healthy adults were analysed. The sample had balanced representation across age groups, and no participant had clinical evidence of optic neuropathy, corneal disease, or posterior segment pathology. The overall mean CCT and IOP were within ranges expected for healthy adult populations, but clinically meaningful variation was observed among individuals.

Table 1. Baseline Demographic and Ocular Profile of the Study Participants (N=200).

Variable	Category/Measure	Value
Age (years)	Mean +/- SD	36.8 +/- 11.4
Age group	18-30 years	62 (31.0%)
Age group	31-45 years	89 (44.5%)
Age group	46-60 years	49 (24.5%)
Sex	Male	94 (47.0%)
Sex	Female	106 (53.0%)
Mean spherical equivalent	Diopters	-0.42 +/- 1.18
Right-eye CCT	Micrometers	536.7 +/- 32.8
Right-eye IOP	mmHg	14.8 +/- 2.7

Table 1 shows that the study population was clinically healthy and predominantly young to middle-aged. Mean CCT values were similar between right and left eyes, with no statistically significant inter-eye difference.

Table 2. Intraocular Pressure According to Central Corneal Thickness Category.

CCT category	Number (%)	Mean CCT (micrometers)	Mean IOP (mmHg)	p-value
Thin (<520 micrometers)	54 (27.0%)	501.4 +/- 12.6	13.6 +/- 2.5	<0.001
Average (520-560 micrometers)	96 (48.0%)	540.2 +/- 10.9	14.7 +/- 2.4	
Thick (>560 micrometers)	50 (25.0%)	578.6 +/- 15.1	16.2 +/- 2.8	

As shown in Table 2, IOP increased stepwise with increasing CCT category. Post-hoc analysis showed significantly higher IOP in the thick-cornea group compared with both thin and average groups.

Table 3. Correlation and Regression Analysis between CCT and IOP.

Parameter	Correlation/Estimate	95% CI	p-value
CCT vs IOP	r=0.42	0.30 to 0.53	<0.001
Regression beta	0.035 mmHg per 1 micrometer	0.022 to 0.048	<0.001
Model R squared	0.176	-	<0.001
Age-adjusted beta	0.033 mmHg per 1 micrometer	0.020 to 0.046	<0.001

Table 3 demonstrates a statistically significant positive correlation between CCT and IOP. Linear regression suggested that each 10 micrometer increase in CCT corresponded to an approximate 0.35 mmHg rise in measured IOP.

Sex-wise analysis showed no significant difference in mean CCT between males and females (539.2 +/- 34.1 vs 534.5 +/- 31.5 micrometers; p=0.31), although males had marginally higher mean IOP (15.1 +/- 2.8 vs 14.5 +/- 2.6 mmHg; p=0.09). Age-wise comparison revealed a mild decline in CCT with increasing age, but this did not reach statistical significance. No participant had IOP exceeding 21 mmHg, and all optic discs were clinically normal. The findings indicate that even within the conventional normal IOP range, corneal thickness measurably influences tonometry values.

DISCUSSION

The present study revealed a mean CCT of ~537 micrometers and a mean IOP of 14.8 mmHg in healthy adults. The main result was that there was a moderate positive correlation between CCT and measured IOP, and that those with thicker corneas had significantly higher IOP. This is consistent with previous findings that applanation IOP should not be used alone to assess corneal anatomy [2,4].

The mean CCT was comparable to the pooled estimates of Doughty and Zaman and to that of a number of population-based cohorts [4]. Some variations between studies could be due to ethnicity, age, instrument type, timing of the day and inclusion criteria. Confounding from corneal disease, diabetes, and contact lens use was minimized by excluding these conditions from the present study.

The clinically relevant correlation between CCT and IOP is demonstrated. The mean IOP difference between the thin and thick corneal groups was

almost 2.6 mmHg, which may impact referral decisions, follow-up frequency, and glaucoma risk stratification. The same positive correlation between CCT and IOP was found by Wolfs et al. and our results support this correlation in a healthy adult hospital population [2].

This is particularly relevant for patients with a diagnosis of ocular hypertensive. Argus and Bron et al demonstrated that there is a partial correlation between corneal thickness and falsely elevated IOP readings [5,6]. Thin corneas, on the other hand, can mask the actual pressure elevation and result in underestimation of glaucoma risk. Thin CCT is shown to be a predictor of glaucoma conversion in the Ocular Hypertension Treatment Study, and thus pachymetry is important for measurement correction and biological risk assessment [3].

Simple correction formulas should be avoided. CCT is only part of corneal biomechanics and IOP error is influenced by corneal hysteresis, rigidity, and curvature and viscoelastic behaviour. Thus, pachymetry should be used to put IOP into perspective and not be used to adjust it in every patient. A thin cornea and borderline IOP is more concerning than a thick cornea with the same IOP and a normal optic nerve.

The advantages of this study are that the IOP was measured at a standardized time, Goldmann applanation tonometry was used, repeated pachymetry measurements were taken, and the exclusion of ocular and systemic conditions that could affect corneal thickness. CCT was also analysed as a continuous and categorical variable, providing clinically interpretable results.

Some limitations are single centre design, hospital-based sampling and lack of advanced corneal biomechanical parameters like corneal hysteresis. Diurnal variation was minimized but not eliminated and longitudinal glaucoma outcomes were not evaluated. Larger community-based samples, comparison with optical pachymetry and biomechanical parameters should be included in future studies to further refine risk stratification [4-9].

The results are supportive of a tiered interpretation of IOP, with the use of age, family history, optic disc appearance, refractive status, and CCT. A patient with an IOP of 20 and a CCT of 585 could not be at the same risk as a patient with an IOP of 20 and a CCT of 495. This is particularly important in an outpatient department where multiple IOP measurements without pachymetry can cause unnecessary anxiety and follow-up visits.

Another practical implication is related to documentation. A baseline CCT value is a reference to use for future glaucoma assessment, counselling for refractive surgery and evaluation of corneal disease. While the changes in CCT are not as dynamic as IOP, the technique of measurement, probe placement and corneal hydration can affect readings. So, if clinical decisions are based on abnormal values, they should be confirmed.

Another important finding of the study is that there is a significant physiological variation in the thickness of the cornea in healthy adults. This is a normal variation which should be taught to trainees as it avoids relying on a single numerical threshold. The most safe clinical strategy is to use tonometry in conjunction with structural and functional examination, such as optic nerve head examination, retinal nerve fibre layer examination (if available) and visual field examination (if indicated) [10-16].

Beyond glaucoma screening, there are other implications of pachymetry. It is pertinent prior to refractive surgery, in keratorefractive counselling, when evaluating corneal oedema and when interpreting postoperative pressure measurements. One baseline value can thus be clinically useful in subspecialty settings over time.

The results also enable patient-specific follow-up. Normal optic discs, thick corneas and borderline IOP may be treated differently than adults with thin corneas, suspicious optic discs and family history of glaucoma. This personalized evaluation prevents underdiagnosis, and overdiagnosis.

CONCLUSION

There was a significant positive correlation between the measured intraocular pressure and central corneal thickness in healthy adults. Thicker corneas were associated with higher applanation IOP in the absence of any ocular abnormalities. When evaluating borderline IOP values, routine pachymetry should be taken into account, especially in glaucoma screening and ocular hypertension evaluation.

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