Original Article

Influence of Central Corneal Thickness (CCT) on Intraocular Pressure (IOP) Measured with Goldmann Applanation Tonometer (GAT) in Normal Individuals

Irfan Shafiq

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See end of article for authors affiliations

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Correspondence to:
Irfan Shafiq
A-2 / 304, Rabia Petal,
Abul Hasan Isphani Road,
Karachi.

Purpose: This study investigated the relationship between intraocular pressure (IOP) and central corneal thickness (CCT) in normal healthy individuals.

Material and Methods: The central corneal thickness (CCT) and intraocular pressure (IOP) of 250 subjects (500 eyes) of age 11-54 years from general population were assessed. The IOP was measured with Goldmann applanation tonometer (GAT) and CCT was measured with Orbscan II scanning slit topographer. The relationship was assessed using SPSS software.

Results: The mean IOP value was 15.35 mmHg and mean CCT value was 531.50 µm in 250 subjects (500). The mean IOP value was 15.16 mmHg SD ± 2.89 mmHg in men and 15.53 mmHg SD ± 3.11 mmHg in women. The mean CCT value was 529.07 µm SD ± 35.19 µm in men and 533.75 µm SD ± 38.11 µm in women. No significant difference in CCT and IOP was found between male and female subjects or between the right and left eye. Both genders had positive correlation between CCT and IOP.

Conclusion: CCT was significantly correlated with IOP.

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Measurement of intraocular pressure (IOP) is one of the essential and routine examinations in every ophthalmology clinic. It means that every patient who comes to an ophthalmologist, his or her IOP has to be checked. For this purpose, Goldmann applanation tonometer (GAT) is considered to be the gold standard. Central corneal thickness (CCT) is known to affect the accuracy of IOP measurements by applanation tonometry[1,2]. A thicker cornea requires greater force to applanate and conversely, a thinner cornea is more easily flattened. A thin cornea is a significant risk factor for the development of glaucoma[3]. The GAT is based on the Imbert-Fick law, which assumes that the cornea has a dry surface, is infinitely thin, and behaves as a "membrane" where the applanating pressure will equal the IOP. In practice, a resistance force, because of the thickness of the cornea and a surface tension force, the result of the tear film, act upon the applanator causing this membrane assumption to be incorrect. These forces balance each other for the GAT (applanation diameter of 3.06 mm) when the CCT is 520µm, providing a "reference" value where the applanating pressure does equal the IOP[1]. Since the early 1970s there have been several reports on the relationship between CCT and IOP measured with the GAT[4,5]. Attempts at measuring the actual IOP by manometry were described by Ehlers et al. in 1975[1] and Whitacre et al. in 1993[2]. It has been reported that thinner corneas result in artificially lower IOP readings and that thicker corneas cause artificially high IOP readings, thus producing apparent normal tension glaucoma (NTG) and ocular hypertension (OHT) respectively[6]. This has become more of a practical problem recently with the advent of photorefractive keratectomy for myopia[7], where there is artificial thinning of the central cornea, possibly creating underestimates in central applanation tonometry. For the measurement of CCT ultrasonic pachymetry is the most commonly used technique. Recently, other sophisticated non-contact Scanning Slit based (Orbscan) pachymetry instruments have been developed in an attempt to correlate the CCT with the measured IOP. The Orbscan II scanning slit topography (Bausch and Lomb, Rochester, NY, USA) has multiple functions in the assessment of the cornea, including its thickness profile, anterior and posterior topography, elevation and anterior chamber depth. The usefulness of this system has been reported previously[8]. Orbscan pachymetry measures corneal thickness like manual ultrasound pachymetry but it is more repeatable, simpler to perform, non-invasive and returns a map of corneal thickness rather than a point measurement. It combines a slit scanning system and a Placido disk (with 40 rings) to measure the anterior elevation and curvature of the cornea and the posterior elevation and curvature of cornea, it offers a full corneal pachymetry map with white to white measurements. Orbscan pachymetry is able to acquire over 9000 data points in 1.5 seconds and measure anterior chamber depth, angle kappa, pupil diameter, simulated keratometry readings and the thinnest corneal pachymetry reading[9].

Various formulae have been generated to predict the effect of CCT on IOP. With the advent of excimer laser refractive surgery, an increasing number of patients will have iatrogenically thinned corneas. Myopes have a 2–6-fold increased risk of developing glaucoma compared with nonmyopes, rising as their degree of myopia increases[10,11]. Considering that if there are over 1 million refractive procedures performed per year, 10000–30000 of these patients may eventually develop glaucoma. The measurement of their IOP is an integral part of their management, so strategies to accurately know the 'true' reading are vital. Many ophthalmic practitioners currently do not use any form of pachymetry; however, as the number of patients with altered corneal structure increase, should corneal thickness measurement become part of the routine examination.

In this study I evaluated the influence of CCT on IOP measurement made with the GAT in normal healthy individuals.

MATERIALS AND METHODS

This is a prospective cross sectional study of 500 eyes of 250 individuals conducted at the Hashmani Eye Hospital, Karachi between January, 2005 and January, 2006 for period of 12 months. The objects of this study were to evaluate the relationship of CCT with IOP and to determine the influence of CCT on IOP in normal individuals. IOP and CCT were recorded for both eyes of 250 normal subjects who had come for routine ophthalmic examination. IOP was measured with the GAT and CCT was measured with Orbscan II topographer. The relation of measured IOP and CCT was analyzed by SPSS software.

Inclusion criteria

Healthy individuals with CCT of any range and IOP within normal range with no upper age limit were included in this study.

Informed consent was taken from every patient for measurement.

Exclusion criteria

Patients with glaucoma in one or both eyes, eyes with any corneal disorder like opaque or disfigured cornea, corneal ulcer, corneal inflammation, corneal dystrophy, corneal degeneration, keratoconus and large pterygium were excluded.

Eyes with history of any other ocular disease or surgery were also not included in this study.

Measuring IOP

The Goldmann applanation tonometer was mounted on the end of the lever hinged on the slit-lamp. The patient's head and the microscope were positioned so that the bar was against the patient's forehead and well above the eyebrows, allowing for maximal separation of the patient's eyelids. A drop of proparacaine 0.5% (Alcaine 2%) was instilled into the lower conjunctival cul-de-sac and fluorescein impregnated paper strip was touched to the tear film. With the cornea and tonometer biprism maximally illuminated by the cobalt light from the slit-lamp, the biprism was brought into gentle contact with the apex of the cornea. When contact with the eye had been established, the semicircular patterns were observed through the left ocular of the slit-lamp. The slit-lamp was then raised or lowered until the two semicircles were equal in size, and the tension dial was adjusted so that the inner edge of the upper and lower semicircles became aligned. Ocular pulsations create excursions of the semicircular tear meniscus, and the pressure is read as the median over which the arcs glide. This is the desired end point at which a reading can be taken from a graduated dial. The reading on the dial was multiplied by 10 to obtain IOP in mmHg.

Measuring CCT

For CCT measurement, the patient's chin was placed on the chin rest of Orbscan II topographer. The patient was asked to look at a blinking red fixation light. The examiner adjusted the optical head using a joystick to align and focus the eye so that the cornea was centered on the video monitor. The video image was then captured and measured anterior and posterior corneal elevation (relative to a best fit sphere), surface curvature and corneal thickness. Pachymetry is determined by this instrument from the difference in elevation between the anterior and posterior surface of the cornea. This instrument averages pachymetry in nine circles of 2mm diameter that are located in the center of the cornea and at eight locations in the mid peripheral cornea (superior, superotemporal, temporal, inferotemporal, inferior, inferonasal, nasal, superonasal) each located 3mm form the visual axis.

RESULTS

Out of 250 patients (500 eyes) included in this study, 120 (48%) patients were males and 130 (52%) patients were females. The minimum age of patient was 11 years, maximum was 54 years and mean age was 27.98 standard deviation (SD) ± 8.27 years. The minimum age of male patient was 17 years, maximum was 54 years and mean age was 29.28 SD ± 8.62 years. The minimum age of female patient was 11 years, maximum was 50 years and mean age was 26.78 SD ± 7.77 years.

A total number of 500 eyes were investigated using the Orbscan II corneal topography system and GAT. The minimum CCT was 423 µm, maximum CCT was 650 µm and mean CCT was 531.5 µm SD ± 36.78 µm. The minimum IOP was 8 mmHg, maximum IOP was 21 mmHg and mean IOP was 15.35 mmHg SD ± 3.01 mmHg.

In this study 120 patients (240 eyes) were males. The minimum CCT of male patients was 423 µm, maximum CCT was 629 µm and mean CCT was 529.07 µm SD ± 35.19 µm. The minimum IOP was 8 mmHg, maximum IOP was 21 mmHg and mean IOP was 15.16 mmHg SD ± 2.89 mmHg.

One hundred thirty patients (260 eyes) were females. The minimum CCT of female patients was 425 µm, maximum CCT was 650 µm and mean CCT was 533.75 µm SD ± 38.11 µm. The minimum IOP was 10 mmHg, maximum IOP was 21 mmHg and mean IOP was 15.53 mmHg SD ± 3.11 mmHg.

The minimum IOP of the right eyes was 10 mmHg, maximum IOP was 21 mmHg and mean IOP was 15.34 mmHg SD ± 3.04 mmHg. The minimum IOP of the left eyes was 8 mmHg, maximum IOP was 21 mmHg and mean IOP was 15.36 mmHg SD ± 2.99 mmHg. The minimum CCT of the right eyes was 423 µm, maximum CCT was 650 µm and mean CCT was 531.43 SD ± 37.50 µm. The minimum CCT of the left eyes was 430 µm, maximum CCT was 650 µm and mean CCT was 531.58 SD ± 36.12 µm.

Patients were divided into eight groups. The findings of CCT an IOP are tabulated in table 2.

DISCUSSION

There are several reports on the relationship between CCT and IOP[12-15]. Wolfs *et al.*[13,] and Herndon *et al.*[15] also found significant correlation between IOP and CCT in their subjects. However, Lam and Douthwaite[14] reported no significant relationship between CCT and IOP in their 45 HK-Chinese subjects of age 19–23 years. Our results show a statistically significant positive correlation between CCT and IOP and this is true for both male and female subjects. No significant difference was found in CCT and IOP between male and female subjects.

The IOP is an essential physiological parameter for diagnosis and management of glaucoma. Goldmann applanation tonometry is one of the most common method used for measuring IOP worldwide, even though many factors such as tear film, shape of the anterior cornea, corneal thickness or scleral rigidity can influence its accuracy in healthy corneas. It has been suggested that CCT is a major source of error in applanation tonometry[16,17], a thick cornea leading to an overestimation of IOP and a thin one leading to an underestimation[1,12,18-19].

Table 1: Gender distribution, Mean CCT and Mean IOP.

Gender	Number	Mean CCT				Mean IOP			
		Right Eye		Left Eye		Right Eye		Left Eye	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Male	240	529.25	35.95	528.89	34.57	15.13	2.88	15.18	2.90
Female	260	533.44	38.90	534.06	37.46	15.53	3.17	15.52	3.07
Total	500	531.43	37.50	531.58	36.12	15.34	3.04	15.36	2.99

Table 2: Relationship between CCT and IOP in different groups.

Groups	CCT		IOP		
	No. of eyes	Mean	No. of eyes	Mean	SD
420-449	11	434.82	11	11.27	2.37
450-479	24	464.38	24	12.25	1.94
480-509	91	495.95	91	13.62	1.53
510-539	162	524.65	162	15.02	2.22
540-569	140	552.73	140	16.17	3.13
570-599	54	579.28	54	17.93	2.77
600-629	16	608.56	16	19.38	2.87
630-659	2	650	2	21	0.0

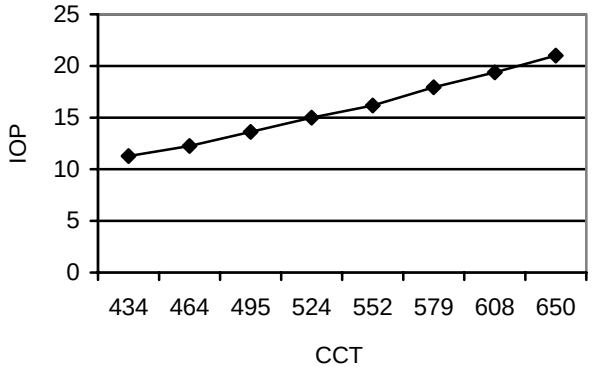

Fig.1: Relationship between IOP and CCT.

We found the mean IOP for both sexes combined to be 15.3 mmHg. This finding is similar to the 15.8 mmHg found in a previous Icelandic population survey which used standardized Schiötz tonometry[20] and to the 15.2 mmHg found by Klein et al., who surveyed using Goldmann applanation tonometry[21]. We found the mean IOP in females and males was 15.53 mmHg and 15.1 mmHg respectively. This finding is similar to the several large population samples surveyed using applanation tonometry[22].

Mean CCT we found was 531.5 µm for both males and females. This finding is statistically not different from previous Japanese population study which showed 517.5 µm CCT.

CONCLUSIONS

Central corneal thickness was significantly correlated with intraocular pressure in both men and women. A thick cornea leads to an overestimation of IOP, and a thin one leads to an underestimation of IOP. No significant difference in central corneal thickness and intraocular pressure was found between the right and left eyes or between male and female subjects.

Author's affiliation

Irfan Shafiq
Assistant Professor
Department of Ophthalmology
Dow University of Health Sciences &
Civil Hospital, Karachi

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