

ORIGINAL ARTICLE

THE INFLUENCE OF CENTRAL CORNEAL THICKNESS ON INTRAOCULAR PRESSURE, MEASURED BY DIFFERENT TONOMETERS: NONCONTACT AND GOLDMANN APPLANATION TONOMETERS

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ABSTRACT

Aim: The aim of this study is to determine if the central corneal thickness (CCT) influences the concordance of intraocular pressure (IOP) readings taken with a noncontact tonometer (NCT) and a Goldmann applanation tonometer (GAT).

Methodology: 100 patients were enrolled in the present cross sectional comparative study. The difference in IOP readings between the 2 methods (NCT-GAT), were calculated and the relationship between the IOP readings, and CCT was analysed using a linear regression line.

Results: IOP measured by both NCT and GAT was significantly correlated with CCT. NCT readings were significantly higher in the thicker group (CCT>or=530 micron) than in the thinner group (CCT<530 microm). GAT readings had no difference between the thicker and thinner groups. An IOP value measured by NCT had a significant positive correlation with CCT. The value of IOP measured by NCT was significantly higher in the thicker group than in the thinner group.

Conclusion: NCT can be more affected by CCT than GAT. Therefore CCT can influence the discordance of IOP readings taken with NCT significantly, whereas only minor influence is observed with GAT.

Keywords: Central corneal thickness, Intraocular pressure, Tonometers, Noncontact, Goldmann applanation tonometers

INTRODUCTION

Glaucoma is the second leading cause of blindness worldwide.¹ The only preventable risk factor for the development and progression of glaucoma is IOP. Correctly measuring IOP is very important in diagnosing glaucoma and conducting follow-ups. Medical, laser, or surgical treatments of glaucoma concentrate on lowering IOP. Earlier studies have shown that every 1 mm Hg drop in IOP decreases visual field damage by 10%.² Therefore, precise measurements of IOP are very important. The various devices used for IOP measurement include the Schiottz tonometer, non-contact tonometer, Goldmann applanation tonometer, Dynamic contour tonometer (DCT), Ocular blood flow tonograph, Ocular Response analyser. The ideal device must be easy to use, rapid, safe, and precise, irrespective of patient posture or age.³ The Schiottz tonometer works on the principle on indentation while the Goldmann applanation tonometer (GAT), Tono-pen, Pneumatic tonometer, Perkins tonometer, work on the principle

of applanation. The DCT uses the principle of contour matching.

GAT is the most commonly used device and is the gold standard for measuring IOP.³ It calculates the IOP by measuring the force needed to flatten a constant corneal area, of 3.06mm.⁴

The non-contact tonometer (NCT; Shin Nippon, NCT 200, Japan), also called an airpuff tonometer. The NCT uses a puff of air, at the cornea with an applanation area, similar to that of the GAT. The force produced by the air puff is linearly increased over 8 ms and progressively flattens the cornea. When flat, the cornea reflects a light beam onto a sensor that triggers a reading.

In this study, we aim to compare IOP measurements done with two different tonometers: the NCT and GAT (Appasamy Associates, TN, India) in individuals having different Central Corneal thickness (CCT).

METHODOLOGY

This was a cross-sectional comparative study. A total of 100 eyes, randomly selected either eye of 100 patients in Dhiraj hospital from October 2014 to May 2015 were included. Permission from institutional review board was obtained and all the participants were volunteers.

All patients age of 18 years or more and of POAG, PACG, NTG, OHT, who are either newly diagnosed or on antiglaucoma drugs were included in the study.

Patients with corneal surgery or any intra-ocular surgery done; patients with corneal edema, corneal opacities & severe cases of corneal astigmatism or ocular surface disease and Patients with Neurological cupping were excluded from the study.

All patients underwent a complete ophthalmic examination including subjective and objective refraction, best corrected visual acuity, slit lamp biomicroscopy, gonioscopy, dilated fundus evaluation with stereoscopic biomicroscopic examination with a 90 D lens . Automated visual field analysis and optic disc photography were done in all patients to diagnose and assess the stage of glaucoma.

IOP of patients of POAG, PACG, NTG and OHT with appropriately calibrated applanation tonometer and with NCT with 10-minute intervals. All measurements were carried out between 10 am and 12 am. The NCT was used first to record three IOP readings. The device has a 5.7-inch color liquid crystal display and an auto puff control (APC), which provides a quieter and softer puff of air for the patient’s comfort. If the first puff is too strong, the device automatically uses a softer puff of air. The screen shows the results of three measurements, and their average value was recorded for the study.

The eyes were then anesthetized using Paracain drops and a fluorescein strip was applied to the inferior conjunctival fornix. GAT measurements using the cobalt blue filter of a biomicroscope were taken.

After this the central corneal thickness was measured using pachymetry. (mention here make of pacha)

The patients were divided in two groups based on corneal thickness

Group A: Patients with low CCT (<530 μm) & Group B: Patients with high CCT (≥530 μm)

RESULTS

The mean age of the patients included in the study was 59.94 years. The minimum being 35 years and the maximum 82 years. Of these there were 49 male patients and 51 female patients.

There were 53% patients between the age group of 60-80 years. Of them 27 were female and 26 were male patients. 33 had POAG, 16 with PACG, 2 of NTG and 2 with OHT. Average CCT is 526.15μ and range from 445-560μ. The mean IOP of GAT was 23.69 mmHg and mean IOP by NCT was 24.48 mmHg.

33% patients were between 50 to 60 years of age. Of these 20 were male and 13 female patients. 20 patients were of POAG and 13 were of PACG. The average CCT was 513μ. The IOP range for GAT was from 13 to 50 mmHg and for NCT was from 11 to 43.4 mmHg.

There were 14 patients less than 50 years of age. 9 were female and 5 were male patients. 9 with POAG, 4 with PACG and 1 of OHT. The mean CCT was 535.2μ. The GAT was from 14 to 34 mmHg and that of NCT was from 17 to 40mmHg.

The mean of Central Corneal thickness was 527.14 μ. The maximum CCT was 565μ and the minimum was 445 μ.

IOP measured by NCT was from 11.00 mm of Hg to 43.40 mm of Hg . The mean of NCT was 22.13 with a standard deviation of 8.103 for corneal thickness<530 and the mean for corneal thickness ≥530 was 27.54 with a standard deviation of 6.565. IOP measured by Goldmann applanation tonometer was from 10.00 mm of Hg to 42.00 mm of Hg. The mean of GAT was 24.11 with a standard deviation of 9.196 for corneal thickness<530 and the mean was 24.72 with standard deviation of 24.72 for corneal thickness ≥530.

The measurements of IOP readings with GAT (F=0.964725, P=0.047) and NCT (F=2.682, P=0.105), followed a normal distribution (Levene’s test for equality of variances; P>0.05).

Table 1: Demography of subjects

Variables	Total (n=100)	POAG(n=58)	PACG(n=35)	OHT (n=4)	NTG (n=3)
Age in years	59.94(35-82)	59.58(35-78)	58.93(40-77)	58.5(40-72)	77(73-82)
Male	49	25	21	2	0
Female	51	30	12	2	3
GAT(mm Hg)	24.51(10-50)	25.65(10-50)	23.66(10-42)	22.75 (22-24)	14.6(10 to 20)
NCT(mm Hg)	25.64(11 - 43.4)	26.80(11 - 42)	24.72(11 - 43.4)	25.25(25-26)	15.6(12-19)
CCT (μ)	527.14(445 - 565)	529.1(470 - 565)	521.75(445- 560)	540(535 - 545)	527(512 - 535)

IOP measured by both GAT ($r=0.049$, $P=0.625$) and NCT ($r=0.325$, $P=0.001$) was significantly correlated with CCT (as $P<0.05$ and $r > 0.025$ is significant correlation). The correlation between CCT and IOP obtained by GAT was significant but weak ($r=0.049$, $P=0.625$). An IOP value of (NCT-GAT) ($r=0.325$, $P=0.001$)

The samples were divided into 2 groups by CCT - Thicker group $CCT \geq 530 \mu$; Thinner group $CCT < 530 \mu$

There were 64 patients in the study and 36 patients in the thinner group.

Table 2: Comparison of two groups

Variables	CCT(<530 μ) (n= 36)	CCT (≥ 530) (n=64)
Age in years	59.97(42-78)	59.93(35-82)
Male	21	30
Female	15	34
GAT (mm HG)	24.11(12-50)	24.72(10-42)
NCT	22.12(11-42)	27.54(11-43.4)
CCT (μ)	500.4(445-525)	540.95(530-565)

DISCUSSION

CCT affects the accuracy of IOP measurements by applanation tonometer.^{6,7,8} Goldmann applanation tonometer (GAT) is the most commonly used device and is the gold standard for measuring IOP.³ It calculates the IOP by measuring the force needed to flatten a constant corneal area, measurements are not affected by scleral stiffness.⁴ A thicker cornea requires greater force to applanate, a thinner cornea is more easily flattened. A thin cornea is a significant risk factor for the development of glaucoma.⁵

Most published studies concerning the effect of CCT on measured IOP relate to the Goldmann applanation tonometer (GAT). However, there is increasing evidence that other tonometers share this problem.⁵ Thin shell theory was used by Orsengo and Pye to demonstrate that corneal radius, thickness and material stiffness affect the applanation pressure for a given IOP. Reducing the applanation area reduces the difference between the applanation pressure and IOP, because the corneal resistance for a smaller contact area is less.³ There may also be some reduced effects from surface tension.

The GAT is based on the Imbert-Fick law,³ which assumes that the cornea has a dry surface, is infinitely thin, and behaves as a "membrane" where the applanating pressure equals the IOP. In practice, a resistance force, by the corneal thickness, and a surface tension force, by the tear film, act upon the applanator. Thus, this membrane assumption becomes incorrect. These forces balance each other for the GAT (applanation diameter of 3.06 mm) when

the CCT is 520 μ m, providing a "reference" value where the applanating pressure equals the IOP.³ Thus the Imbert-Fick law stands when the ocular rigidity matches the surface tension. A cornea thinner than 530 μ may not have enough ocular rigidity. In this study, there were 36 subjects with less than 530 μ (thinner group) and 64 subjects with 530 μ and more (thicker group). We compared some factors between both groups. Table 2 shows the results.

Silis and Hawlina⁹ concluded that in keratoconus patients, the IOP measured by NCT was significantly lower than GAT. Tonnu and associates¹⁰ found that NCT significantly underestimated GAT measurements at lower IOP and overestimated at higher IOP in a study including 105 eyes with ocular hypertension or glaucoma. Sanchez-Tocino and co-workers¹¹ determined a statistically significant difference ($p < 0.001$) between the measurements using NCT (15.6 ± 2.9 mmHg) and GAT (15.4 ± 2.7 mmHg). The mean of the differences between the two tonometers was 0.24 mmHg.

The present results confirmed a significant correlation between the IOP readings of NCT, GAT, and CCT. However, the coefficient of correlation between GAT and CCT was relatively low. This indicates that measurements with both NCT and GAT are affected by ocular rigidity. Ehlers concluded that GAT gives accurate IOP measurements only when CCT was 520 μ . Our data showed, in the normal IOP range, the value of NCT is closely correlated with the value of GAT, as NCT was calibrated on the basis of GAT.¹¹ But for higher values of IOP, the NCT overestimates while for lower values it underestimates.

However, NCT was not made on the basis of careful considerations of the CCT.¹¹ Thus value of NCT corresponds with the value of GAT in 530 μ thickness (near to 520). In a cornea that is thicker than 530 μ , the IOP readings are overestimated by ocular rigidity. The present study showed that the readings taken with NCT were higher than GAT in corneas thicker than 530 μ .

In NCT, fixed corneal area is applanated by a jet of air, which increases in force linearly. The GAT emits a beam of light that is reflected from the corneal surface with maximal intensity when a corneal area with 3.60 μ diameter is applanated.¹¹ The time required to detect is directly related to IOP. The area applanated with NCT is larger than that with GAT, thus NCT gives higher IOP readings. Schmidt¹² showed that a change of internal pressure (when the cornea is applanated) was so small that it could be negligible.

CONCLUSION

The GAT readings had no significant difference between the 2 groups, but NCT was significantly higher

in the thicker than the thinner group. Thus NCT is more affected by CCT (ocular rigidity) rather than GAT. Previous reports support our results.

The IOP measurement with NCT is higher than GAT for thicker corneas, as the applanation area is more and thicker corneas are more affected by ocular rigidity (CCT) than the thinner corneas (CCT <530 μ)

Therefore, the IOP measurements may be lower than the true IOP levels in a thinner cornea, and higher in a thicker cornea.

Thus this article suggests that we should take the characteristics of each tonometer into consideration when we evaluate the IOP.

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