Original Article

www.ijrhs.com
ISSN (o):2321–7251

To study the influence of central corneal thickness on intraocular pressure, measured by noncontact and goldmann applanation tonometers in glaucomatous patients

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Abstract:
PURPOSE: The aim of this study is to determine if the central corneal thickness (CCT) influences intraocular pressure (IOP) readings taken with a noncontact tonometer (NCT) and a Goldmann applanation tonometer (GAT). METHODS: 100 patients of POAG, PACG, OHT, and NTG were enrolled in this 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. RESULTS: IOP measured by both NCT and GAT was significantly correlated with CCT. NCT readings were significantly higher in the thicker group (CCT≥530µ) than in the thinner group (CCT<530µ). 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 cornea group, in patients of primary open angle glaucoma (POAG), primary angle closure glaucoma (PACG), and ocular hypertension (OHT) and normal tension glaucoma (NTG) patients. CONCLUSIONS: Measurements of IOP by NCT are 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.

Key words:

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]. The various devices used for IOP measurement include the Schiotz tonometer, non-contact tonometer (NCT), Goldmann applanation tonometer (GAT), Dynamic contour tonometer (DCT), Ocular blood flow tonograph (OBF), Ocular Response analyser (ORA).The Schiotz 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, also called an airpuff tonometer 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 [5].

In this study, we compared IOP measurements done with two different tonometers : the NCT and GAT in individuals having different Central Corneal thickness (CCT) in normal persons and patients of POAG,PACG,OHT and NTG.

Materials and Methods

After obtaining approval by the ethical committee, a cross-sectional comparative study of 100 eyes, randomly selected for laterality, of 100 patients in Dhiraj hospital from October 2014 to May

2015 were included. All the participants were volunteers.

Inclusion criteria

All patients of POAG,PACG,NTG, OHT, who are either newly diagnosed or on anti glaucoma drugs of age 40 years or more.

Exclusion criteria

- Patients with corneal edema,corneal opacities , severe corneal astigmatism , ocular surface disease and corneal surgery done.

Patients with Neurological cupping.

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

IOP was measured with NCT ((NCT 200; Shin Nippon, Japan), three IOP readings were taken and their average value was recorded. After 10 minutes IOP was measured with calibrated goldman applanation tonometer (AATM 5001, Appasamy, India) as per the standard procedure, by the same examiner to avoid inter observer bias.All measurements were carried out between 10 am and 12 noon.

Then the central corneal thickness was measured using pachymtery. (Accutome, Inc., Pennsylvania,USA.)

Two groups based on corneal thickness were made of all the participants.

Group A: Patients with low CCT (<530 µ)

Group B: Patients with high CCT (≥530 µ)

Ethics

This study was conducted after obtaining approval by "Sumandeep Vidyapeeth Institutional Ethical Committee". This was a cross-sectional comparative study conducted adhering to the Declaration of Helsinki.

Results

Out of 100 patients, 49 (49%) were male and 51 (51%) were female. The age ranged from 40 to 82 years.

Table 1: Demography of the population

	Total (n=100)	POAG (n=58)	PACG (n=35)	OHT (n=4)	NTG (n=3)
Age	59.94(35-82) years	59.58(35-78) years	58.93(40-77) years	58.5(40-72) years	77(73-82) years
Male	49	25	21	2	0
Female	51	30	12	2	3
GAT	24.51(10-42)mm of Hg	25.65(10-34) mm of Hg	23.66(10-42) mm of Hg	22.75 (22-24) mm of Hg	14.6(10 to 18) mm of Hg
NCT	25.64(11 to 43.00) mm of Hg	26.80(11 to 37) mm of Hg	24.72(11 to 43.00) mm of Hg	25.25(25-26) mm of Hg	15.6(12-19) mm of Hg
CCT	527.14 (445 to 565) µ	529.10(470 to 565) µ	521.75(445 to 560) µ	540 (535 to 545) µ	527 (512 to 535) µ

For a further analysis 2 groups were made according to the CCT

Thicker group CCT ≥ 530 µ

Thinner group CCT<530 µ

There were 64 patients in the thicker and 36 patients in the thinner group. The relationship of CCT and IOP by NCT and GAT is shown in table 2

Table 2: Comparison of CCT and IOP by NCT and GAT

	CCT(<530 µ) (n=36)	CCT (≥ 530) (n=64)
Age	59.97(42-78) years	59.93(40-82) years
Male	21	30
Female	15	34
GAT	24.11(12-40.00)mmHg	24.72(10-42.00) mmHg
NCT	22.12(11-44) mmHg	27.54(9-44.00) mmHg
CCT (µ)	**500.4(445-525)µ**	**540.95(530-565)µ**

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. (F is the constant for Levene's test for equality of variances; P>0.05).

IOP measured by both GAT (r=0.049, P=0.625) and NCT (r=0.325, P=0.001) was significantly correlated with CCT in all age groups as well as in all category of patients. The correlation between CCT and IOP obtained by GAT is insignificant. (P<0.05 and r > 0.025 is a significant correlation).

For patients with CCT≥530µ

Table 3 : Demography of patients with CCT≥530µ

	POAG	PACG	NTG	OHT
Total No.	39	18	3	4
Mean CCT	542.4 µ	540µ	535µ	540µ
Range of CCT	530-565µ	530-560µ	532-538µ	535-545µ
Mean GAT	25.34 mmHg	25.81 mmHg	12 mmHg	22.75 mmHg
Range of GAT	10-34 mmHg	10-42 mmHg	10-14 mmHg	22-24 mmHg
Mean NCT	28.19 mmHg	28.91 mmHg	14 mmHg	25.25 mmHg
Range of NCT	9-37 mmHg	9-44.00 mmHg	9-16 mmHg	25-26 mmHg

Table 4: Demography of patients with CCT<530µ

	POAG	PACG	NTG
Total No.	19	14	1
Mean CCT	500.38µ	489.16µ	512µ
Range of CCT	470-525µ	445-520µ	
Mean GAT	24.27 mmHg	26.83 mmHg	18 mmHg
Range of GAT	13-35 mmHg	12-40 mmHg	
Mean NCT	23.94 mmHg	24.63 mmHg	17 mmHg
Range of NCT	11-37 mmHg	12-44 mmHg	

Thus for higher values of IOP, the NCT overestimates while for lower values it underestimates in cases of POAG,PACG and OHT when compared with GAT[6,7,8,9] irrespective of corneal thickness.

Discussion

CCT affects the accuracy of IOP measurements by applanation tonometer [10-12].

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 also share this problem[5]. Thin shell theory was used by Orssengo 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 µm, 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 530µ may not have enough ocular rigidity. In this study, there were 36 subjects with less than 530µ (thinner group) and 64 subjects with 530µ and more (thicker group). We compared some factors between both groups as shown inTable 2.

Silis and Hawlina [9] concluded that in keratoconus patients, the IOP measured by NCT was significantly lower than GAT. Tonnu and associates[10]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-workers [11] 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.

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 3.60µ 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.

The present results of our study 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,but the correlation between GAT and ocular rigidity is statistically insignificant. Ehlers concluded that GAT gives accurate IOP measurements only when CCT was 520µ.

The NCT was not made on the basis of careful considerations of the CCT[11] hence the values of NCT corresponds with the values of GAT in the range of 520-530µ thickness (near to 520). In a cornea that is thicker than 530µ , 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 530µ.

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 in cases of POAG,PACG and OHT when compared with GAT [12-14].

Conclusion

The GAT readings had no significant difference between the thicker and the thinner cornea groups in POAG, PACG,OHT and NTG but NCT was significantly higher in the thicker than the thinner group irrespective of the type of glaucoma.Thus NCT is more affected by CCT than GAT. 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 <530µ) for all types of glaucomas. NCT is thus a good screening tool while GAT has higher accuracy for measuring IOP.

Acknowledgement

Authors acknowledge the immense help from the urban and rural mothers and the scholars whose articles are cited and included in references of this manuscript. The authors are also grateful to authors/editors/publishers of all those articles, journals and books from where the literature for this article has been reviewed and discussed.

Source of funding: Nil
Conflicts of interest: Nil

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