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Effect of Central Corneal Thickness on Intraocular Pressure Readings by Goldmann Applanation Tonometer and Non Contact Tonometer

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Abstract
Purpose: *To study the effect of CCT on IOP readings obtained by NCT and GAT across varying IOP ranges, and to correlate the IOP readings obtained by GAT and NCT.*
Methods: *230 eyes were included in this cross sectional study. CCT, IOP by GAT and NCT were measured. Correlation and linear regression between CCT and IOP obtained by GAT and NCT were analysed.*
Results: *The mean IOP obtained by GAT was 15.64 ± 6.27 mm Hg, and that by NCT was 16 mmHg. The mean CCT measured was 537.6 ± 39.3 µm.IOP by GAT showed a significant positive correlation with CCT ($r = 0.78$ and $p < 0.001$). IOP by GAT changes by 1.25 mm Hg per 10 µm change in CCT. IOP by NCT also shows positive correlation with CCT ($r = 0.72$, $p < 0.001$).IOP by NCT changes by 1.21 mm Hg per 10 µm change in CCT.IOP measured by GAT and NCT showed a significant positive correlation, with highest correlation in the IOP range of 11 – 20 mm Hg($r = 0.719$, $p < 0.001$).*
Conclusion*: A significant positive correlation exists between IOP measured by GAT and NCT in all IOP ranges.IOP measured by NCT also significantly correlates with CCT. Change in IOP by NCT is 1.21 mm Hg (1.06 to 1.36 mm Hg) per 10 µm change in CCT, and is comparable to that by GAT.*
Keywords: *Intraocular pressure, Goldmann applanation tonometer, noncontact tonometer, glaucoma.*

Introduction

Glaucoma is classically described as a chronic progressive optic neuropathy, caused by a group of ocular conditions which lead to damage of optic nerve with loss of visual function. Raised intraocular pressure (IOP) is an important risk factor for glaucoma. Hence, IOP measurement by tonometry plays an important role in both the diagnosis and follow up of patients with glaucoma.

Goldmann applanation tonometer (GAT) is currently the gold standard tonometer[1], which measures the force needed to flatten a standard area of the cornea, while Noncontact tonometer (NCT) measures the force of air puff to create a standard amount of corneal deformation. A significant advantage with NCT is the elimination of potential hazards associated with all contact tonometers like corneal abrasions, reaction to topical anaesthetic or

fluoresce in, and spread of infection. However, with NCT, the subject should be able to fixate on the target, limiting its use in patients with poor fixation, nystagmus, and irregular corneal surface.

Central corneal thickness (CCT) emerged as a risk factor for glaucoma in the Ocular Hypertension Treatment Study[2], which showed that the effect of central corneal thickness may influence the accuracy of applanation tonometry.

This study aims at analysing the effect of CCT on IOP readings obtained by both NCT and GAT across varying IOP ranges and to attempt to arrive at a probable correction formula.

This study also correlates the IOP measured by these two instruments.

Materials and Methods

This was a cross sectional study performed between January 2015 to January 2016, and enrolled patients visiting Glaucoma Clinic and outpatient department of our institution, after obtaining informed consent. 230 eyes of 130 patients were included. Exclusion criteria were history of previous intraocular surgery/refractive surgery, any corneal pathology, inability to fixate on an object, current corneal or conjunctival infection, astigmatism more than 3 diopters, and secondary glaucomas.

IOP was measured in all patients using both a Goldmann applanation tonometer and a non contact tonometer and recorded in mmHg. Next, central corneal thickness was measured using ultrasound pachymeter (Pacscan 300p – Sonomed). Five consecutive ultrasound pachymetric measurements of CCT was obtained and a mean value was computed and recorded in micrometers. All measurements were performed under topical anaesthesia.

The eyes were stratified on the basis of IOP readings as follows: IOP ≤ 10 mmHg (n=77), IOP 11-21mmHg (n=77), IOP ≥ 21mmHg (n=76).

Statistical analysis was doing using Statistical Package for Social Sciences version 20 (SPSS Inc.). A P-value of less than 0.05 was considered to be statistically significant.

Results

The mean age of patients recruited in this study was 55.6 ±4.8 years. 60.4 % of total patients were female, compared to 39.6 % males. In this study group, 68.7 % of the eyes included had primary open angle glaucoma, whereas 31.3 % had primary angle closure glaucoma.

Measurement of IOP

Table 1: Mean IOP by GAT in each group

IOP	N	GAT (IOP in mmHg)		F	p
		Mean	Sd		
≤ 10	77	7.76	1.00	1677.05	<0.001
11 – 20	77	16.77	1.98		
≥21	76	22.61	1.53		
Total	230	15.64	6.27		

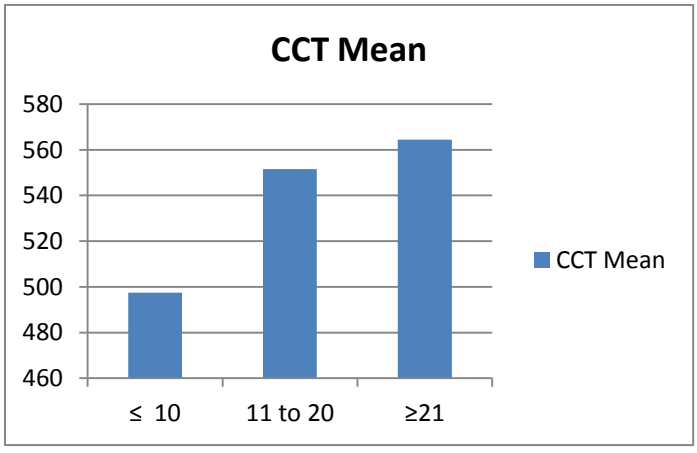
Table 2: Mean IOP by NCT in each group

IOP	N	NCT (IOP in mm Hg)		F	p
		Mean	Sd		
≤ 10	77	8.9	0.9	1677.05	<0.001
11 – 20	77	14.8	1.8		
≥21	76	24.3	2.0		
Total	230	16.0	6.5		

Central Corneal Thickness

The mean CCT measured in this study was 537.6 ± 39.3 µm, with the lowest value obtained being 432 µm and highest 632 µm.

Fig 1: Bar diagram showing mean CCT in each group



There was a significant difference of CCT among the three groups, with p value < 0.001.

Correlation between CCT and IOP by GAT

Table 3: Correlation between CCT and IOP by GAT

Correlation Between CCT and GAT (N=230)	Pearson Correlation r	P
Whole data (N=230)	.784	<0.001
In GAT ≤10 group	.470	<0.001
In GAT 11-20 group	.631	<0.001
GAT ≥21 group	.450	<0.001

IOP by Goldmann applanation tonometry showed a significant positive correlation with CCT with r = 0.78 and p < 0.001.

IOP and CCT showed a significant positive correlation in all three groups; with highest correlation in the normal IOP range;

r = 0.47, p < 0.001 in IOP ≤ 10 mm Hg

r = 0.63, p < 0.001 in IOP 11 – 20 mm Hg

r = 0.45, p < 0.001 in IOP ≥ 21 mm Hg.

Table 4: Linear regression for CCT with IOP by GAT

Model	Unstandardized Coefficients		Standardized Coefficients	t	P	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	-51.785	3.545		-14.610	.000	-58.769	-44.800
CCT	.125	.007	.784	19.073	.000	.112	.138

a. Dependent Variable: GAT

From the above linear regression model, the following conclusions can be arrived at:

- IOP by GAT = -51.785 + 0.125 x CCT
- For 1 µm change in CCT, the IOP measured by GAT changes by 0.125 mm Hg
- IOP by GAT changes by 1.25 mm Hg per 10 µm change in CCT
- The change in IOP by GAT can range from 1.12 to 1.38 mm Hg per 10 µm change in CCT

Correlation of CCT with IOP by NCT

Table 5: Correlation between CCT and IOP by NCT

Correlation of NCT with CCT	Pearson Correlation r	P
TOTAL (N=230)	.727	0.000
IOP ≤ 10 mm Hg	.572	0.000
IOP 11- 20 mm Hg	.714	0.000
IOP ≥ 21 mm Hg	.394	0.000

IOP by NCT showed a significant positive correlation with CCT, with r = 0.72, p < 0.001.

There was a significantly positive correlation between CCT and IOP in each subgroup as well; with highest correlation in normal IOP range;

- r = 0.57, p < 0.001 in IOP ≤ 10 mm Hg
- r = 0.71, p < 0.001 in IOP 11- 20 mm Hg
- r = 0.39, p < 0.001 in IOP ≥ 21 mm Hg

Table 6: Linear regression for CCT with IOP by NCT

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-48.934	4.075		-12.008	.000	-56.964	-40.904
	CCT	.121	.008	.727	15.974	.000	.106	.136

a. Dependent Variable: NCT

From the above linear regression model, the following conclusions can be drawn:

- IOP by NCT = -48.934 + 0.121 x CCT
- For 1 µm change in CCT, IOP by NCT changes by 0.121 mm Hg
- IOP by NCT changes by 1.21 mm Hg per 10 µm change in CCT.
- The change in IOP by NCT can range from 1.06 to 1.36 mm Hg per 10 µm change in CCT.

Correlation of IOP measured by GAT and NCT

Table 7: Correlation of IOP by GAT and NCT

Correlation of NCT with GAT	Pearson Correlation r	P
TOTAL (N=230)	.952	<0.001
IOP ≤ 10 mm Hg	.626	<0.001
IOP 11- 20 mm Hg	.719	<0.001
IOP ≥ 21 mm Hg	.685	<0.001

IOP measured by GAT and NCT showed a significant positive correlation, with r = 0.952, P < 0.001, with highest correlation in the IOP range of 11 – 20 mm Hg (r = 0.719 , p < 0.001).

Discussion

This study was done to evaluate the effects of central corneal thickness on IOP measured by both GAT and NCT, among varying ranges of IOP, and also to correlate the IOP obtained by these two tonometers.

Central Corneal Thickness

The mean CCT measured in this study was 537.6 ± 39.3 µm, with the lowest value obtained being 432 µm and highest 632 µm. This is similar to a study done in Indian population, which found the mean CCT to be 536 ± 19 µm[3].

Correlation of IOP with CCT

The present study found a significantly positive correlation between IOP by both GAT and NCT with CCT in all IOP ranges.

A study on 100 patients of POAG, PACG, OHT, and NTG concluded that measurements of IOP by NCT are more affected by CCT than GAT and hence, CCT can influence the discordance of IOP readings taken with NCT significantly, whereas only minor influence is observed with GAT[4]. A study on 135 eyes of healthy subjects showed that there was a significant correlation between CCT with both NCT (r = 0.260, p = 0.003) and GAT measurements (r = 0.257, p = 0.005)[5]. Linear regression analysis in our study showed that IOP by NCT changes by 1.21 mm Hg per 10 µm change in CCT and that IOP by GAT changes by 1.25 mm Hg per 10 µm change in CCT. A study by Vinay Gupta et al[6] showed that NCT were more affected by corneal thickness (0.4 mmHg / 10 µ corneal thickness) while GAT was the least affected by corneal thickness (0.3 mmHg / 10 µ corneal thickness) though the difference was not statistically significant (P=0.42). In a population-based study, Eysteinsson et al[7] found 0.22-0.28 mmHg correction for 10 microns change in CCT using NCT (Nidek 2000).

A previous study[5]using linear regression analysis showed a mean change of 2.1 mmHg in IOP measured by NCT and 1.9 mmHg in IOP measured by GAT per 10 µm variation in CCT. A higher regression coefficient was obtained in a study by Ko YC et al[8], where the NCT measurements showed the greatest regression coefficient (β = 0.063, r = 0.650), while the GAT measurements showed the least regression coefficient (β = 0.037, r=0.496) Their study also showed that every 10µm change in CCT would yield a 0.98 mmHg deviation in NCT measurements (r = 0.896).

The correlation between IOP obtained by GAT and NCT was significant in all three IOP ranges in the present study. IOP measured by GAT and NCT showed a significant positive correlation, with r = 0.952, P < 0.001. The highest correlation was seen in IOP ranging from 11 to 20 mm Hg.

A study by S Mohan et al[3] showed a positive Pearson's correlation coefficient of 0.909 between GAT and NCT. Further analysis showed a fair agreement between the two tonometers in the lower IOP range. They concluded that NCT can be used as a screening tool in the community but is not reliable in subjects with higher IOP range. Another study[9] concluded that the CT80 NCT provides IOP measurements that are comparable to those obtained by the GAT in patients with normal and high IOP. Our study shows that values obtained by NCT can be reliable across a wider range of IOP and has a similar correction factor with respect to CCT.

Conclusion

A significant positive correlation exists between IOP measured by GAT and NCT. Change in IOP by GAT is 1.25 mm Hg (1.12 – 1.38 mm Hg) per 10 µm change in CCT. IOP measured by NCT also

significantly correlates with CCT. Change in IOP by NCT is 1.21 mm Hg (1.06 to 1.36 mm Hg) per 10 μm change in CCT. IOP measured by NCT and GAT have significant correlation in all IOP ranges.

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