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Comparability of IOP Measurements by Goldmann Applanation Tonometry (Gat) &; Non Contact Tonometry (NCT) in Different IOP Ranges and Influence of Central Corneal Thickness on Tonometry in a Tertiary Eye Care Centre in West Bengal

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Abstract:-

Background :-

Intraocular pressure is one of the most important modifiable risk factors in the management of glaucoma. Though different tonometers are available, their measurement is not always interchangeable & reproducible. Central corneal thickness is known to affect the accurate IOP measurements & it has different effects on different tonometers.

Aim:-

To compare measurements of IOP using GAT and NCT in different IOP ranges (<11, 11-25, >25 mm Hg) and evaluate the influence of CCT on IOP measurements by these techniques.

Materials and Methods:-

IOP was measured by NCT followed by GAT in 218 eyes of 112 patients (both eyes of 106 patients and single eye of 6 patients due to various reasons; eg – one eyed patient, corneal scar in one eye) attending the eye OPD of a tertiary hospital of West Bengal by a single observer. Mean of three consecutive readings were taken for analysis by both techniques. IOP values were compared in the three IOP ranges (<11, 11-25, >25 mm Hg) between the two techniques. CCT values were obtained from them using ultrasonic pachymeter. Statistical analysis was done to know whether the two methods were interchangeable across the three IOP ranges.

Results:-

Though good agreement was seen between GAT and NCT, the later showed a tendency to overestimate IOP in the lower IOP range and underestimate in the normal and high IOP range. Mean values of GAT and NCT showed a statistically significant difference in the normal IOP range (11 - 25 mm Hg, significance level) and high IOP range (>25 mm Hg). However in the lower range, the difference did not reach the level of significance. NCT is more influenced by CCT. To conclude, though NCT has good accuracy and predictability to be used as a screening tool, but GAT is accurate in all IOP ranges.

Keywords:- *Tonometers , Intraocular Pressure, Central Corneal Thickness, Goldmann Applanation Tometry , Non Contact Tonometry.*

I. INTRODUCTION

Glaucoma is characterized as a progressive irreversible optic neuropathy of multi factorial origin. [1] Intraocular pressure is identified as a major and modifiable risk factor having strong association with disease onset and progression. Bannister described the relation between blindness and firmness of the eye in sixteenth century and since then IOP is being regarded as the vital parameter of the eye.

Measurements of an ideal tonometer should be accurate, reproducible and repeatable and the instrument should be portable, easy to use, which can be simply calibrated and standardized. Direct manometric measurements of IOP, though theoretically the most accurate method, is not only an invasive process, it is impractical also. Hence we have to rely on indirect measurements which is bound to be fraught with errors. [2]

Clinical measurement of IOP has undergone several technical advances from the initial digital tension measurements, through indentation tonometry, to applanation tonometry and noncontact tonometry (NCT).

Goldmann's applanation tonometer (GAT) has received a great importance because this method is less dependent on ocular rigidity. It is little influenced by variations in corneal curvature and it records the IOP directly by applanating the cornea. In Goldmann's applanation tonometry, for a particular area of applanation(of 3.06mm diameter), surface tension of tear film and the force required to bend the cornea cancel each other, thus making Imbert-Fick-law applicable to this method. Goldmann's applanation tonometer shows excellent repeatability, validity & reliability. The tonometry head is a plastic tip with bi prism, which divides the image visible through the tonometer head into two equal semicircles with great accuracy. Thus an observer can easily see the flattened cornea for an accurate IOP measurements, the semicircles should be equal, of moderate width, and should move with the ocular pulse. The endpoint is reached when inner edges of the semicircles contact each other at the midpoint of their split. [4] In clinical practice, Goldmann Applanation Tonometry (GAT) is the gold standard and the most widely accepted method for measuring IOP. [5-6]

Noncontact (also called air-puff) tonometer uses a puff of air to applanate the cornea. IOP is measured by the amount of force by air puff required to flatten the cornea to a fixed level. NCT facilitates quick measurements without the requirement of topical anesthesia and fluorescence and can be performed by ancillary staff and hence employed as a screening tool. [7] The reason of NCTs gaining popularity is they eliminate the risk of contaminated disease transmission, and are free from operator bias.

Central corneal thickness (CCT) is known to affect the accuracy of IOP measurements. A thicker cornea requires greater force to applanate and conversely, a thinner cornea is more easily flattened. According to OHTS a thin cornea is a significant risk factor for the development of glaucoma. [8] CCT is thought to be an independent risk factor and has become part of routine glaucoma evaluation today. CCT can be measured by several methods of which ultrasound pachymetry is the most commonly used method & known as the gold standard. We know that CCT varies greatly among the general population to a degree that impacts the accuracy of GAT in daily practice. The technique of measurement and CCT predominantly influence IOP measurements. But NCT is affected by CCT more than GAT. [9]

Aim:-

This study was conducted to compare IOP measurements using GAT and NCT in different IOP ranges (<11, 11-25, >25 mm Hg) and to evaluate the effect of CCT on IOP measurements by these techniques.

II. MATERIALS AND METHODS

This was a cross sectional study done on 112 patients (218 eyes) who attended eye OPD of RKMSP, VIMS, Kolkata during the period of January – May,2021. Both eyes of 106 patients were included in the study and single eye of 6 patients were included due to various reasons; eg – one eyed patient, corneal scar in one eye.

The study was done after taking proper informed consent from all the patients and the study methods adhered to the tenets of Declaration of Helsinki.

Inclusion Criteria:- Patients attending Ophthalmology OPD of RKMSP, Kolkata –

1) For glaucoma check up, age ranging from 40 – 70 years.
2) Both glaucoma patients (irrespective of types of glaucoma) and non glaucoma patients.
3) Both treated and untreated patients.

Exclusion Criteria:-

1) Corneal scarring, opacity.
2) Active corneal / conjunctival infection or wound / epithelial defect.
3) Previous corneal surgery including LASIK / PRK.
4) Congenital corneal abnormality – microphthalmos, nanophthalmos.
5) High corneal astigmatism (>3 D cylinder).
6) Keratoconus and other corneal ecstatic disorder.
7) Blepharospasm.

All patients underwent routine refraction, slit lamp examination for anterior segment and undilated fundus evaluation followed by IOP estimation. Each patient's IOP was measured using both GAT and NCT.

IOP was measured first by NCT by Topcon CT 80 NCT machine which was followed by GAT measurement after 15 minutes.

GAT (GAT AT900, Haag Streit) was performed with the Goldmann applanation device mounted on a slit–lamp biomicroscope. After instillation of a drop of 0.25% fluorescein with 0.5% proparacaine hydrochloride in each eye, three sequential measurements were performed. Then, GAT reading was taken by same ophthalmologist. A mean of 3 readings was used for both GAT & NCT. Both instruments were weekly calibrated. CCT measurement was done by ophthalmic ultrasound pachymeter (Appascan with pachymeter) after 1 hour after topical anaesthesia by 0.5% proparacaine drop. A mean of 10 readings were noted for each study eye. The patients were categorized into 3 groups of IOP range <11 mm Hg, 11 – 25 mm Hg and >25 mm Hg.

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All of the measurements were taken between 10 AM to 1 PM in order to minimize the effect of diurnal variation. Statistical analysis was done with the data collected.

III. RESULTS

We have considered total 218 eyes of 112 patients for this study. 6 eyes were excluded from this study. The highest recorded IOP was 59 mm Hg and the lowest IOP recorded was 7 mm Hg. Patients were divided into three IOP ranges according to AT values <11mm Hg, 11- 25 mm Hg, >25 mm Hg.

In our study the mean age of the study population was 55.21 years and 71.10% of the population had virgin eyes with no use of anti glaucoma drops. (**Table-2**)

The mean IOP measured by GAT was 20.52 mm Hg, while that measured by NCT was 18.5 mm Hg. The mean difference between the 2 methods of measurement was 3.19 mmHg. In the <11 mm Hg group GAT had lower values than NCT whereas in the other two IOP ranges NCT values were lower than GAT values. The reading difference was most obvious in IOP range of more than 25 mm Hg group. (**Table-3**)

Mean CCT of our study group was 520.86 µm, highest recorded CCT in our study was 605 µm and lowest recorded CCT was 444 µm. (**Table-1**)

Cross tabulation of NCT and AT data -

Cross tabulation was done among the NCT & GAT values in the 3 groups. A Pearson chi square test was applied on the cross tabulated values and a significance was found between the GAT & NCT values.

NCT values have been compared with GAT values taken as baseline which shows that in the IOP range < 11 mm Hg, NCT corresponds to GAT in 60% cases and does not tally rather overestimates 40% of eyes identified by GAT. In the IOP range 11 - 25 mm Hg, NCT underestimates 4.59% of eyes identified by GAT and in the IOP range >25 mm Hg, 41.17% of eyes are underestimated by NCT. (**Table-4**)

Table 1:- Demographic and Clinical data

Variable	Mean	Standard Deviation	Range
Age (years)	55.21	9.18	16-68
NCT (mm Hg)	18.50	6.23	7-59
GAT (mm Hg)	20.52	6.44	7-54
CCT (µm)	520.86	34.33	444-605

Table 2:- Patients data on use of anti glaucoma treatment

	Virgin eyes	Eyes on anti-glaucoma treatment
Count	155	63
Percentage	71.10	28.90

Table 3:- Difference between GAT & NCT values in different IOP ranges

GAT range (mm Hg)	Average value of the difference between NCT and GAT	Standard deviation
Entire group	3.19	2.13
<11	(+)1.8	1.30
11-25	(-)2.61	1.88
>25	(-)4.59	2.69

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Table 4:- GAT coded NCT coded cross tabulation

			NCT coded							
			<11		11-25		>25		Total	
			Count	% across this NCT category	Count	% across this NCT category	Count	% across this NCT category	Count	% across this NCT category
GAT coded	<11	Count	6	42.857	4	2.198	0	0	10	4.587
		% across this AT category	60		40		0		100	
	11-25	Count	8	57.143	164	90.110	2	9.091	174	79.817
		% across this AT category	4.598		94.253		1.149		100	
	>25	Count	0	0	14	7.692	20	90.901	34	15.596
		% across this AT category	0		41.176		58.824		100	
	Total	Count	14	100	182	100	22	100	218	100
		% across this AT category	6.422		83.486		10.092		100	

A Pearson Chi square test was applied on the cross-tabulated values and a significance was found between the GAT and NCT values.

Table 5:- Chi square tests

	Value	Degrees of Freedom	Significance (p value)
Pearson Chi square test	154.562	4	0 (significant)
N of valid cases	109		

The following is a scatter plot of the GAT and NCT values obtained:

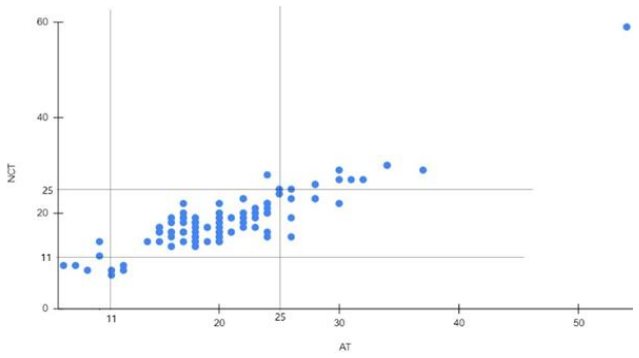

Figure 1:- Scatter plot of the GAT and NCT values

A Kolmogorov-Smirnov test was done on the difference between the values of NCT and AT, which gave a p value of 0.393. From this, it can be inferred that the differences do not significantly differ from a normal distribution, and it can be safely assumed that the NCT and AT values are normally distributed.

Thus, a paired t-test was done on the NCT and GAT values. It gave a significant value which shows that there is statistically significant difference between the mean values of GAT and NCT in the IOP ranges of 11 – 25 mm Hg and >25 mm Hg group.

Table 6:- Paired t-test of NCT & GAT values

Group	T value	Significance
Entire group	7.105	0 (significant)
Less than 11	-1.723	0.160 (not significant)
11-25	-6.412	0 (significant)
Greater than 25	4.642	0.00027 (significant)

Next, we calculate the correlation of CCT with GAT and NCT using Pearson Correlation test:

Table 7:- Regression analysis of CCT with GAT & NCT

	GAT	NCT
R	0.0552	0.1701 (not significant)
Significance	0.569 (not significant)	0.078 (not significant)

We then applied a linear regression of CCT with GAT and CCT:

Table 8:- Regression analysis of CCT with GAT & NCT

		Unstandardised coefficient (B)	Standard Error	Standardised coefficient (Beta)	t	Significance
NCT and CCT	(Constant)	2.4124	9.0320	0	0.267	0.79 (not significant)
	CCT	0.0309	0.0173	0.1701	1.786	0.077 (not significant)
GAT and CCT	(Constant)	15.1344	9.4454	0	1.602	0.112 (not significant)
	CCT	0.0104	0.0181	0.0552	0.572	0.569 (not significant)

Observation from the regressions were:
CCT influences NCT more than it influences GAT.

A scatter plot was obtained by plotting the GAT & NCT values. A Kolmogorov- Smirnov test was done on the difference between the values of NCT & GAT & inference was the values are normally distributed. A paired t-test was done on the NCT & GAT values of different IOP ranges.

Then we applied the linear regression on the NCT vs CCT & on the GAT vs CCT & from the regression analysis it was observed that CCT influences NCT values more than GAT values.

The correction factor has been obtained from the slope of the best fitting straight line found using linear regression. The coefficient of the independent variable in the linear equation obtained is the slope of the straight line, which is the number of units the dependent variable would increase for a unit increment of the independent variable and that yields the correction factor. In our study the correction factor of GAT is 0.1 for 10 micron change in CCT & for NCT this correction factor is 0.31.

IV. DISCUSSION

A clinician should be aware of the variability between different instruments to predict the accuracy of IOP recorded during the follow up of a glaucoma patient. NCT being automatic, the inter observer variability is expected to be low while in GAT measurements due to various parameters being involved, the inter observer variability is expected to be high. [10-12]

Several studies have been done earlier in this regard but our endeavour in this study is to know whether GAT and NCT could be interchangeable in various IOP ranges.

Most studies with NCT showed that it overestimates at low pressures and underestimates at high pressures when IOP readings are compared with GAT. [13-16] The same shown in our study too with a difference that the percentage of underestimation was higher in the midrange of IOP (11 – 25 mm Hg) compared to the higher IOP. Tonnu et al [17] were the only authors to show that NCT underestimated in lower ranges and overestimated at higher IOP ranges.

It is also essential to know the quantitative effect of CCT on different IOP measuring techniques. It is shown in some studies that glaucoma patients with thin CCT are more likely to present at advanced stages of glaucoma and also among those patients with NTG & underestimation of IOP by GAT can be a reason in those cases. Our study showed a correction factor of 0.3 mm Hg on an average per 10µ change in CCT, very less than the accepted Ehlers et al [2] study which showed 0.7 mm Hg per 10µ change in CCT. Previous studies have shown a correction factor ranging from 0.18 to 0.63 mm Hg change in CCT.

Some authors have noted NCT to be minimally influenced by CCT [13, 18] while others have shown as much as 3 mm Hg change in IOP with NCT for 10 microns change in CCT than GAT in glaucomatous eyes studied in our sample. This can be attributed to the fact that NCT applanates a wider area as compared to GAT.

According to the study of Singh et al [19] a significant association was found between CCT & NCT, but they failed to find any significant association between CCT & GAT. CCT had an association with age, but it was independent of gender & ethnicity.

The number of patients were lesser in the <11 mm Hg and >25 mm Hg IOP range. Studies with large number of patients in the higher and lower IOP ranges should be able to bring about more accurate comparison.

This difference between various studies may be due to the lack of accurate evaluation of corneal histology and rigidity. Different corneal hysteresis and rigidity at similar corneal thickness may lead to different IOP measurements. Studies measuring corneal hysteresis with measurement of wide corneal thickness distribution, study among different ethnic groups, measurement of corneal thickness with similar technical methods, and a comparison of different studies may be able to bring more accurate results. In our study, corneal hysteresis or rigidity could not be evaluated.

The shortcomings of the present study was small sample size. In our study to avoid bias the GAT was done by single observer in all patients to avoid observer bias. The IOP measurement time was also similar in all cases to avoid the effects of diurnal variations. Our study population had both glaucoma patients and non glaucoma patients. There may be some effect of anti glaucoma drops on the hydration properties of the cornea, which was overlooked in our study.

V. CONCLUSION

In our study the IOP measurements by NCT overestimated in lower ranges (<11 mm Hg). There was statistically significant difference but the values of GAT and NCT in the range of 11 – 25 mm Hg and >25 mm Hg IOP range where NCT underestimated the GAT values.

It was also concluded from this study that pachymetry affects both GAT and NCT values but the influence of CCT is more on NCT than GAT. Our study re- emphasizes that NCT can be a good screening tool, but GAT gives accurate results in all IOP ranges.

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