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Effect of Central Corneal Thickness on Intra Ocular Pressure Measured by NCT and GAT

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Abstract: ***Purpose: To assess the effect of central corneal thickness (CCT) on intra ocular pressure measured by non-contact tonometer and goldmann applanation tonometer. Method: A hospital based observational study done on 60 eyes of 30 patients aged 18-40 years, without comorbidities and without history of ocular trauma. CCT was measured first using Tomey Specular microscope EM-4000, NCT (non-contact tonometer) using air puff Frey TN-100, followed by GAT (goldmann applanation tonometer). Results: Pearson Correlation:0.59 (p-value < 0.001), indicates a moderate positive correlation, confirming that higher CCT is associated with higher GAT readings. Linear Regression: Slope of 0.12 and R-squared of 0.35, suggests that about 35% of the variability in GAT readings is explained by CCT. Pearson Correlation: 0.84 (p-value < 0.001), indicating a strong positive correlation indicating a strong association between higher CCT and higher NCT readings. Linear Regression: Slope of 0.24 and R-squared of 0.71, shows that 71% of the variability in NCT readings can be explained by CCT. CCT significantly impacts both GAT and NCT readings, with NCT readings being more strongly affected by changes in CCT.***

Keywords: CCT (Central corneal thickness), NCT (Non-Contact Tonometer), GAT (Goldmann Applanation Tonometer), IOP (Intra Ocular Pressure)

1. Introduction

- Public sector health institutions in India primarily serve the underprivileged sections of the society and rural camps are the most effective measures to screen the population for debilitating vision disorders. In population screenings and rural camp settings for glaucoma detection, the ease of operability and cost significantly influence the selection of the tonometer. However, the accuracy of such cheap and user-friendly tonometer may be called into question in comparison with the gold standard. Therefore, it becomes essential to determine the reliability of these tonometers and also to determine their usefulness in special situations [1]
- GATs and AP (i.e., noncontact tonometer) are the most common devices for measuring IOP in daily practice. GAT remains the most suitable, reliable device and is the international GOLD standard for measuring IOP. Non contact tonometers are easier to use and are more convenient, for both the patient and the examiner, than GATs. Hence it is important to understand the difference in values obtained, if any, between IOP measurements taken by a Goldman Applanation Tonometer and those taken by NCT, and how factors like CCT can influence the values obtained[2]

2. Literature Survey

- Goldmann Applanation tonometer is inferred from the force required to flatten (applanate) constant area (3.06 mm) of the cornea as per the Imbert-Fick law[3] Surface anesthesia is required[4,5]. Non contact tonometer is invented by Bernard Grolman of Reichert, Inc. (formerly American optical). It uses a rapid air pulse to applanate (flatten) the cornea. Corneal applanation is detected via an electro optical system. The IOP is estimated by detecting the force of air jet at the instance of applanation[1] The NCT is very useful measurement tool in children, patients with infected eye and patients who have undergone recent surgery, since IOP can be measured without any risk of microbial contamination or contact[1]
- **Effect of age and gender:** With regards to effect of age and gender having an influence on IOP readings, Pimprikar et al[6] indicates towards a significant difference in IOP measurements among the 26-35 years and 46-55 years age group and Sood et al[7] found that there were no gender based statistical significance in the IOP readings
- **Inter instrument agreement in different ranges of IOP and CCT**: Maheshwari et al[8] , found there was an overestimation with NCT in higher IOP group (21-30mmHg), Shinde et al[9] came to a conclusion that NCT was consistently higher than GAT across all ranges of IOP. Das et al[10] , have found all the tonometers show significant correlation with CCT with GAT showing the strongest significant correlation taking a different stance against other comparable studies by Porwal et al[11] Mansoor et al [12] and Lee et al [13] , which conclude that although both GAT and NCT are affected by CCT, the NCT readings are more significantly influenced.

3. Material and Methods

This observational study is conducted on 60 eyes of 30 patients, selected by systematic sampling attending the Ophthalmology OPD at a south Indian tertiary care hospital.

Inclusion criteria: Patients aged 18-40 years who consented for the study

Exclusion criteria: Patients with history of corneal disease, major ocular trauma, history of intra ocular surgery in the last 6 months, uncontrolled diabetes and hypertension, any abnormality preventing reliable IOP readings, inability to

maintain fixation and current use of anti-glaucoma medications.

3.1 Sample collection:

- Participants were selected by consecutive sampling, falling under inclusion criteria and out of exclusion criteria after taking detailed informed consent.
- Patients underwent detailed history taking, visual acuity, near vision and color vision tests using Snellen's chart, near vision charts and Ishihara's chart respectively.
- Slit lamp examination was done.
- CCT was measured first using Tomey Specular microscope EM-4000
- NCT using air puff was done using Frey TN-100.
- This was followed by GAT
- Data collected was analyzed using Descriptive and Inferential statistics, using statistical software SPSS v23 and MS EXCEL.
- Frequency, proportions, mean and standard deviation were used for descriptive statistics. Pearson correlation coefficient, Student 't' test and linear regression model were used as inferential statistics ($p<0.05$)

4. Results

4.1 Mean values of clinical parameters:

- GAT- 18.93mmHg +/-6.95mmHg, ranging from 8-42mmHg
- NCT- 22.40mmHg +/-9.53mmHg, ranging from 8-45mmHg
- CCT- 543.95 microns +/-33.55 microns ranging from 420-595 microns

4.2 Analysis based on age and gender

Table 1: Age and gender- based comparison

Age & Gender	Percentage	GAT (mmHg)	NCT (mmHg)	Difference	p value
18-22 years (n=6)	10%	18.98	21.11	2.13	0.0059 (Significant)
23-27 years (n=12)	20%	17.74	20.65	2.91	0.366 (Not significant)
28-32 years (n=24)	40%	17.89	21.33	3.44	0.155 (Not significant)
33-37 years (n=9)	15%	20.46	23.99	3.53	0.368 (Not significant)
>37 years (n=9)	15%	21.72	27.26	5.54	0.343 (Not significant)
Male (n=33)	55%	19.40	23.10	3.70	0.105 (Not significant)
Female (n=27)	33%	18.36	21.68	3.32	0.122 (Not significant)

4.3 Comparison of mean IOP measured by GAT and NCT

Table 2: IOP measured by GAT and NCT at different ranges of IOP

Group	GAT (mmHg)	NCT (mmHg)	Difference	p value
<12 mmHg	9.83	8.80	1.03	0.091 (Not significant)
12-21 mmHg	17.05	16.57	0.48	0.579 (Not significant)
>21 mmHg	25.66	29	3.4	0.023 (Significant)

4.4 Comparison of mean GAT & NCT values at different CCT

Table 3: GAT & NCT values at different CCT

CCT (microns)	GAT (mmHg)	NCT (mmHg)	Statistical significance
	Mean & SD	Mean & SD	p value
<510	13.023 +/- 4.423	10.698 +/- 3.830	0.165 (No significance)
511-535	16.290 +/- 4.997	16.975 +/- 4.546	0.718 (No significance)
536-560	20.858 +/- 4.570	24.818 +/- 5.340	0.0064 (No significance)
>560	22.927 +/- 7.390	31.201 +/- 5.710	0.00016 (Significant)
Entire Group	18.930 +/- 6.950	22.400 +/- 9.530	0.024 (Significant)

4.5 Correlation matrix heatmap for GAT and NCT when CCT >560 microns

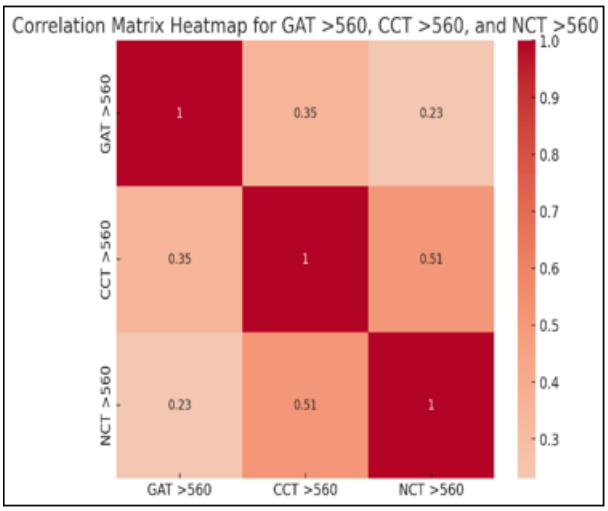

Figure 1: GAT and NCT when CCT >560 microns

The heatmap shows moderate positive correlations between CCT and both NCT (0.51) and GAT (0.35) above 560 microns, indicating that as CCT value increase, NCT values tend to increase more strongly than GAT.

4.6 Linear regression graphs comparing over all GAT and NCT to over all CCT

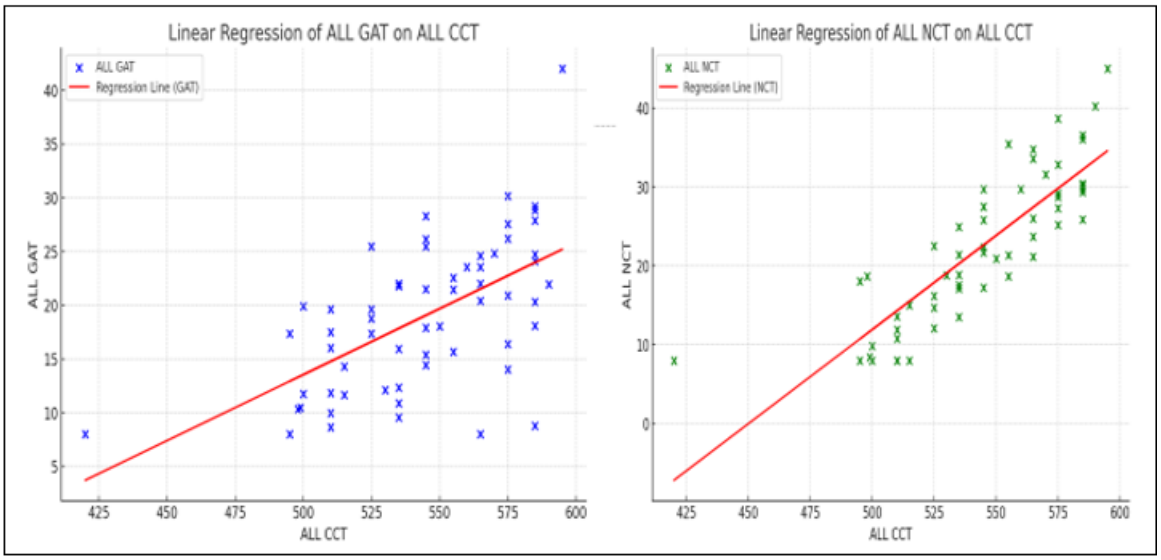

Figure 2: Over all GAT and NCT to over all CCT comparison

- The correlation between overall CCT and overall NCT is stronger (r = 0.84) compared to overall CCT and overall GAT (r = 0.59), indicating a more robust relationship between CCT and NCT.
- The R-squared values from the regressions (0.35 for GAT and 0.71 for NCT) reinforce that CCT explains a larger portion of the variability in NCT than in GAT, suggesting CCT is a better predictor of NCT in this dataset.
- **CCT and GAT**:
- **Pearson Correlation**: 0.59 (p-value < 0.001), indicates a moderate positive correlation, confirming that higher CCT is associated with higher GAT readings.
- **Linear Regression**: Slope of 0.12 and R-squared of 0.35, suggests that about 35% of the variability in GAT readings is explained by CCT.
- **CCT and NCT**:
- **Pearson Correlation**: 0.84 (p-value < 0.001), indicating a strong positive correlation indicating a strong association between higher CCT and higher NCT readings.
- **Linear Regression**: Slope of 0.24 and R-squared of 0.71, shows that 71% of the variability in NCT readings can be explained by CCT.

4.7 Percentage of glaucoma risk IOP readings by CCT range

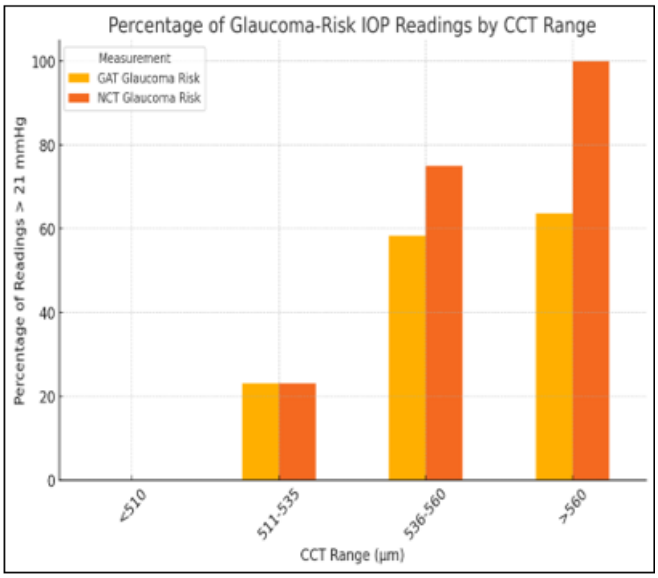

Figure 3: Glaucoma risk IOP readings by CCT range

The bar chart illustrates that thicker corneas (CCT > 535 µm) have a markedly higher proportion of glaucoma-risk IOP readings, particularly on NCT. This suggests that without adjusting for CCT, thicker corneas might lead to overestimated IOP readings, potentially impacting glaucoma diagnosis. Conversely, thinner corneas (<510 µm) showed no glaucoma-risk readings, indicating a risk of underestimating IOP and potentially missing a diagnosis in these cases

4.8 Interpretation

The results confirm that CCT significantly impacts both GAT and NCT readings, with NCT readings being more strongly affected by changes in CCT. Therefore, adjusting IOP readings based on CCT is crucial for accurate glaucoma risk assessment, as thicker corneas tend to yield higher IOP values, which might lead to overestimation of glaucoma risk without CCT adjustments.

5. Discussion

- In our study, mean GAT readings were 18.93 ±6.95mmHg ranging from 8-42mmHg while that of NCT was 22.40mmHg +/-9.53mmHg ranging from 8-45mmHg. CCT had an average mean of 543.95 +/-5.690 microns ranging from 420-595 microns. These are comparable to study by Pimprikar et al[6]. While their study indicates towards a significant difference in IOP measurements among the 26-35 years and 46-55 years age group, our study indicated similar differences among the 18-22 years age group.
- We also found that there were no gender based statistical significance in the IOP readings, which is similar to a study done by Sood et al[7]
- Study by Maheshwari et al[8] , found there was an overestimation with NCT in higher IOP group (21-30mmHg) which align with our findings that NCT overestimates at higher IOP levels >21mmHg.
- Shinde et al[9] came to a conclusion that NCT was consistently higher than GAT across all ranges of IOP.
- This has been contrasted by Sahasranamam et al, where they concluded that the strongest correlation with CCT was at the 11-20mmHg IOP range[14]
- Das et al[10] , have found all the tonometers show significant correlation with CCT with GAT showing the strongest significant correlation taking a different stance against our study, along with other comparable studies by Porwal et al[11] Mansoor et al[12] and Lee et al[13] , which conclude that although both GAT and NCT are affected by CCT, the NCT readings are more significantly influenced

6. Conclusion

- Based on the findings from our data, thicker corneas (CCT >560 µm) lead to elevated IOP readings and thin corneas may lead to lower-than-actual IOP readings, potentially masking glaucoma risk.
- For High CCT a threshold closer to 23-24 mmHg and for low CCT follow-up can be considered if IOP reaches 19-20 mmHg.
- Given that thicker corneas (CCT >560 µm) lead to elevated IOP readings, a downward adjustment by 2-3mmHg for GAT and 4-5mmHg for NCT can be considered to avoid overestimating glaucoma risk.
- For patients with low CCT (<510 µm), an upward adjustment by 2-3mmHg for GAT and 3-4mmHg for NCT can be considered to reflect a more accurate IOP assessment.
- These CCT-based personalized adjustments in IOP readings can enhance glaucoma screening precision, reduce false positives for thicker corneas, and avoid underestimation of glaucoma risk in patients with thinner corneas. Integrating these practices can lead to earlier and more accurate detection of glaucoma, improving patient outcomes.

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