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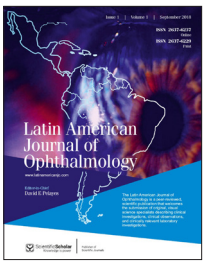

*Original Article* *Glaucoma*

# The impact of central corneal thickness on intraocular pressure measurement using Perkins applanation, iCare rebound, and Pulsair non-contact tonometers

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## ABSTRACT

**Objecives:** This study aims to compare the impact of central corneal thickness (CCT) on intraocular pressure (IOP) measurements using a non-contact tonometer (NCT), Pulsair, iCare rebound tonometer (RBT), and Perkins applanation tonometer (PAT) in adult patients at the Eye Clinic of University of Port Harcourt Teaching Hospital, Rivers State, Nigeria.

**Material and Methods:** This was a comparative cross-sectional study of 92 (184 eyes) adults aged 18 and older. Their sociodemographic data were collected and an ocular examination was performed. Intraocular pressure measurements were done first using the NCT, then RBT, and finally PAT. An average of two readings was taken for all the devices, and there was a 10-minute interval between measurements. CCT was then assessed.

**Results:** Using PAT, the mean pachymetrically corrected IOP by perkins applanation tonometer (cPAT) in the right eye (RE) was 15.48 ± 4.17 mmHg, and in the left eye (LE), cPAT was 14.16 ± 3.53 mmHg. Using NCT, pachymetrically corrected IOP with non-contact tonometer (cNCT) measured was 15.48 ± 3.55 mmHg (RE) and 15.55 ± 3.41 mmHg (LE). With RBT, pachymetrically corrected IOP using rebound tonometer (cRBT) was 16.54 ± 4.51 mmHg (RE) and 16.75 ± 4.09 mmHg (LE). There was a weak, statistically significant inverse correlation between pachymetrically corrected IOP and CCT for all instruments except with RBT in the RE. PAT was found to be the most affected by CCT following pachymetric correction, while RBT was the least affected.

**Conclusion:** The PAT was most affected by the CCT, while the iCare RBT was least affected. It is necessary to have measured IOP corrected for CCT to get the true IOP.

**Keywords:** Central corneal thickness, Impact, Intraocular pressure, Measurement, Tonometers

## INTRODUCTION

Central corneal thickness (CCT) has recently come to the limelight as an important factor in glaucoma diagnosis and progression. It is a measure of corneal rigidity and thus has an impact on the accuracy of intraocular pressure (IOP) measurement by tonometry. Opinions are varied on the significance in clinical practice of the effect of CCT on IOP measurements. Several researchers have found no direct correlation of IOP with CCT, while others have found a positive correlation of IOP with CCT.[1-3]

Several other studies have demonstrated that thicker corneas with greater rigidity offer more resistance when subjected to deformation, resulting in an artificially higher IOP reading.[4-7]

Besides its effect on IOP measurement, it is an independent risk factor and a better predictor than IOP in identifying those at higher risk of developing primary open-angle glaucoma when combined with some ocular risk factors.[8] Several studies have shown the importance of corneal thickness on readings obtained with the Goldmann applanation tonometer (GAT).[5,9-11] Studies have also shown that about half of the ocular hypertension and normal tension glaucoma patients are misdiagnosed and probably inappropriately treated due to significantly abnormal corneal thickness.[12-14] A meta-analysis of over 600 data sets demonstrated that a 10% difference in CCT would result in a 3.4 ± 0.9 mm Hg difference in IOP ($P \leq 0.001$, r = 0.419).[15]

Using a Pulsair non-contact tonometer (NCT) and GAT, Babalola *et al.* reported both instruments to be affected by variations in CCT, though the Pulsair (NCT) was more affected than GAT and tended to relatively overestimate IOP when CCT is high.[16] Similarly, Domke *et al.* found higher IOP values with NCT in thicker corneas when compared to GAT.[17] A better correspondence between both methods was observed in thinner corneas, suggesting that corneal rigidity increased with corneal thickness. This was unlike Rampersad *et al.,* who found no relationship between CCT and IOP for any of the devices using the rebound tonometer (RBT), GAT, and Tonopachy.[18] and Iliev *et al.,* who reported that both RBT and GAT were almost equally affected by CCT.[19]

Our practice, which initially depended more on the use of GAT and Perkins applanation tonometer (PAT), has recently seen the use of NCT and RBT. This study, therefore, aims to compare the impact of CCT on IOP measurement using PAT, Pulsair NCT, and iCare RBT.

## MATERIAL AND METHODS

It was a comparative hospital-based cross-sectional study of adult participants 18 years and older carried out at the Eye Clinic of the University of Port Harcourt Teaching Hospital, Port Harcourt. Participants with severe visual impairment resulting in poor fixation, a history of intraocular surgery, refractive corneal surgery, and contact lens wear were excluded from the study. Also excluded were participants with corneal pathology such as keratoconus, bullous keratopathy, ocular inflammation, uncontrolled diabetes mellitus and hypertension, and corneal astigmatism exceeding 3 diopters.

A calculated sample size of 92 participants was used, and the participants were recruited into the study using systematic sampling techniques. Ethical clearance was obtained from the Ethical Committee of the University of Port Harcourt Teaching Hospital, Port Harcourt. Informed written consent was also obtained from all the participants. In addition, the study was conducted in compliance with the Helsinki tenets for research involving human subjects.[20]

Interviewer-administered questionnaires were used to collect the sociodemographic data from the participants. All participants then had a comprehensive ocular examination of both eyes.

IOP was measured for each eye first with the Keeler Pulsair NCT (Intellipuff USA NCT), then the iCare RBT (TA01i - Tiolat Oy. Helsinki, Finland), and finally the PAT (Mk 2 Haag-Streit Diagnostics). This was because the tonographic effect of the RBT and NCT due to aqueous massage is almost negligible and much less than PAT.[21] An interval of 10 minutes was given between measurements using each IOP instrument to improve the accuracy of sequential measurements.[22] All readings of IOP were taken between 8:00 am and 12:00 noon each day, to prevent the effect of diurnal variation, and readings were taken by different independent observers, each using a single device and masked from the values of the measurements of other devices. CCT was measured using an ultrasound pachymeter (Sonomed PacScan 300 AP$^+$).

Data were analyzed using the Statistical Package for Social Sciences version 23. Results were presented in tables, bar charts, and scatter plots. Continuous variables were summarized with mean and standard deviation, while categorical variables were expressed with frequency and percentage. The relationship between the IOP measurements with the tonometers was assessed with Pearson correlation for significant correlation. A paired *t*-test was used to determine the mean difference between the IOP measurement levels of two instruments. Both NCT and RBT were validated with PAT. A linear regression model was used to determine the relationship between IOP and CCT between the instruments, in which the effect of the relationship, strength, and statistical significance (*P*-value) were determined. $P < 0.05$ was considered statistically significant in all cases (confidence level = 95%).

## RESULTS

There were 69 (75%) and 23 (25%) male and female respondents in the study; most of whom were within the age group of 40–49 years, constituting 34 (37%) of the total respondents. The mean age was 38.84 ± 13.34 years, with an age range of 18–71 years. Few of the respondents had attained a tertiary degree, but the majority ($n$ = 70; 76.1%) had a secondary level of education. There was a similar proportion of married and single respondents, about 48.9% ($n$ = 45) and 45.7% ($n$ = 42), respectively. The majority of the respondents were either semi-skilled, unemployed, or students [Table 1].

### Characteristics of corrected IOP measurement by the various tonometers

The mean CCT corrected IOP using NCT in the right eye was 15.48 ± 3.55 mmHg and 15.55 ± 3.41 mmHg in the left eye. Using PAT, the mean CCT corrected IOP was 15.03 ± 4.17 mmHg in the right eye and 14.16 ± 3.53 mmHg in the left eye. For RBT,

**Table 1:** Sociodemographic characteristics of the study participants.

| Variables | Frequency (*n*=92) | Percentage |
|---|---|---|
| Sex | | |
| Female | 23 | 25.0 |
| Male | 69 | 75.0 |
| Age group (years) | | |
| <30 | 26 | 28.3 |
| 30–39 | 18 | 19.6 |
| 40–49 | 34 | 37.0 |
| ≥50 | 14 | 15.2 |
| Mean age (m±standard deviation) | 38.84±13.34 years, age range 18–71 years | |
| Education level | | |
| No formal education | 2 | 2.2 |
| Primary | 16 | 17.4 |
| Secondary | 70 | 76.1 |
| Tertiary | 4 | 4.3 |
| Marital status | | |
| Single | 42 | 45.7 |
| Married | 45 | 48.9 |
| Widowed | 3 | 3.3 |
| Separated/divorced | 2 | 2.2 |
| Occupation | | |
| Professional | 10 | 10.9 |
| Skilled | 24 | 26.1 |
| Semi-skilled | 29 | 31.5 |
| Student/unemployed | 29 | 31.5 |

the mean CCT corrected IOP was 16.54 ± 4.51 mmHg in the right eye and 16.75 ± 4.09 mmHg in the left eye [Table 2].

### Comparison of PAT, NCT, and RBT IOP measurements

RBT indicated elevated IOP in the greatest number of eyes, 8 right eyes and 12 left eyes, while PAT and NCT measured elevated IOP in the least number of eyes. PAT measured elevated IOP in 4 right eyes, whereas NCT did in 3, and on the left, PAT measured elevated IOP in 3 eyes, while NCT did in 4 eyes [Figure 1].

### Correlation between corrected IOP and CCT

There was a statistically significant weak positive correlation between corrected IOP and CCT of all three instruments in both eyes, except for cRBT and CCT on the right eye, $P = 0.05$ [Table 3].

### Correlation plots between corrected IOP and CCT using PAT, NCT, and RBT

There was a weak (−0.394) but statistically significant (<0.001) negative correlation between corrected IOP_PAT and CCT of the right eye. However, CCT accounted for a change in IOP in only 15.5% of the time. There was a weak (0.464) but statistically significant (<0.001) negative correlation between corrected IOP_PAT and CCT of the left eye. However, CCT accounted for a change in IOP in only 21.6% of the time [Figure 2].

Similarly, there is a weak (−0.383) but statistically significant (<0.001) negative correlation between corrected IOP_NCT and CCT of the right eye. The CCT accounted for a change in IOP in only 14.7% of the time. There was a weak (−0.392) but statistically significant (<0.001) negative correlation between corrected IOP_

**Table 2:** Descriptive characteristics of corrected IOP values from tonometers in the study.

| Descriptives | Corrected_Average_IOP | | |
|---|---|---|---|
| | NCT | PAT | RBT |
| Right eye | | | |
| Mean | 15.48 | 15.03 | 16.54 |
| Median | 15.25 | 14.30 | 16.30 |
| Standard deviation | 3.55 | 4.17 | 4.51 |
| Interquartile range | 3.40 | 4.35 | 4.92 |
| Minimum | 9.80 | 7.10 | 9.40 |
| Maximum | 36.00 | 39.00 | 41.50 |
| Left eye | | | |
| Mean | 15.55 | 14.16 | 16.75 |
| Median | 15.20 | 13.55 | 16.20 |
| Standard deviation | 3.41 | 3.53 | 4.09 |
| Interquartile range | 4.85 | 4.63 | 6.03 |
| Minimum | 9.90 | 7.00 | 9.10 |
| Maxi mum | 28.40 | 28.10 | 32.10 |

IOP: Intraocular pressure, NCT: Non-contact tonometer, PAT: Perkins applanation tonometer, RBT: Rebound tonometer

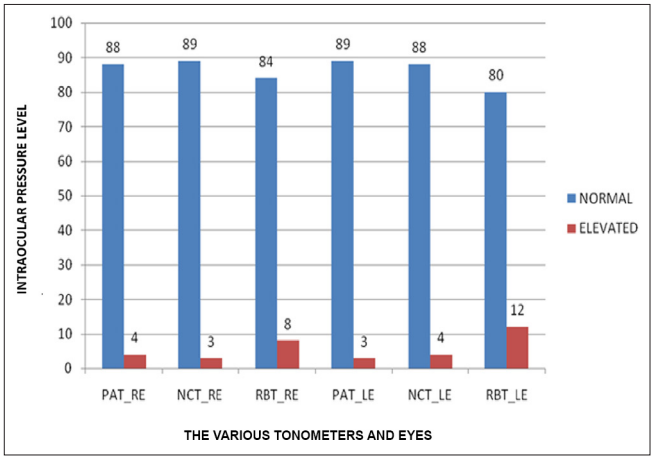


**Figure 1:** Intraocular pressure classification of non-contact Pulsair, Perkins, and rebound tonometer. RE: Right eye, LE: Left eye, PAT: Perkins applanation tonometer, RBT: Rebound tonometer, NCT: Noncontact tonometer.

NCT and CCT of the left eye, and the CCT accounted for the change in IOP only 15.3% of the time [Figure 3].

There was a weak (−0.205) statistically insignificant (0.050) negative correlation between corrected IOP_RBT and CCT of the right eye, and the CCT accounted for the change in IOP only 4.2% of the time. There was also a weak (−0.223) but statistically significant (<0.032) negative correlation between corrected IOP_RBT and CCT of the left eye. The CCT accounted for a change in IOP in only 5.0% of the time [Figure 4].

## DISCUSSION

There have been conflicting reports on the correlation between IOP and CCT. Several studies have shown a positive correlation between IOP and CCT.[2,6,11,23-25] On the other hand, several others have shown no correlation between IOP and CCT.[12,18,26,27] In this study, following pachymetric correction, there was a weak statistically significant inverse correlation between IOP and CCT using all three instruments except with RBT in the right eye ($P > 0.05$). Thus, as CCT was increasing, there was a corresponding decrease in pachymetrically corrected IOP. This mirrors the findings of other researchers such as Adegbehingbe *et al.*, Gustavo *et al.*, Rampersad *et al.*, and Brandt *et al.*, but is at variance with others such as Kohlhaas *et al.*, Wolfs *et al.*, and Farrahi *et al.*[12,18,23,26,28,29,30] Martinez-De-La-Casa *et al.* and Gustavo *et al.* compared all three and found a weak but significant correlation of IOP measurements using NCT, RBT, and GAT with CCT, resulting in overestimation of the IOP in subjects with thick corneas and underestimation in those with thin corneas.[29,31]

**Table 3:** Correlation between corrected intraocular pressure and central corneal thickness.

| Variables | Correlation coefficient | *P*-value |
|---|---|---|
| Right eye | | |
| cPAT and Central corneal thickness | −0.394 | 0.000* |
| cNCT and central corneal thickness | −0.383 | 0.000* |
| cRBT and central corneal thickness | −0.205 | 0.050 |
| Left eye | | |
| cPAT and central corneal thickness | −0.464 | 0.000* |
| cNCT and central corneal thickness | −0.392 | 0.000* |
| cRBT and central corneal thickness | −0.223 | 0.032* |

*means that p-value is statistically significant because p-value<0.005, cPAT: Pachymerically correced IOP with Perkins Applanation tonometer, cNCT: Pachymetrically corrected IOP with Non-Contact tonometer, cRBT: Pachymetrically corrected IOP with iCare Rebound tonometer.

From the regression analysis for corrected IOP and CCT in both eyes, PAT was the most affected by CCT, and RBT was the least affected by CCT, as illustrated by the lower r values. This varies with the findings of Tonnu *et al.*[32] and Babalola *et al.*[16] who reported that GAT was less affected by CCT than NCT.[16,33] Also, Iliev *et al.* reported both RBT and GAT to be almost equally affected by CCT.[19] These discrepancies could have been because Tonnu's study used only glaucoma patients and suspects, or because Iliev's study had a much smaller sample size (about half that of this study), or because PAT rather than GAT was used in this study, in contrast to all three studies.

Thus, to sum up, similar to other studies, with increasing CCT, there was a corresponding decrease in corrected IOP, and $_C$PAT was the most affected by CCT of all three tonometers.[2,6,11,23-25,31] The weak correlation between CCT and IOP with all the instruments suggests that other factors other than CCT are responsible for changes in

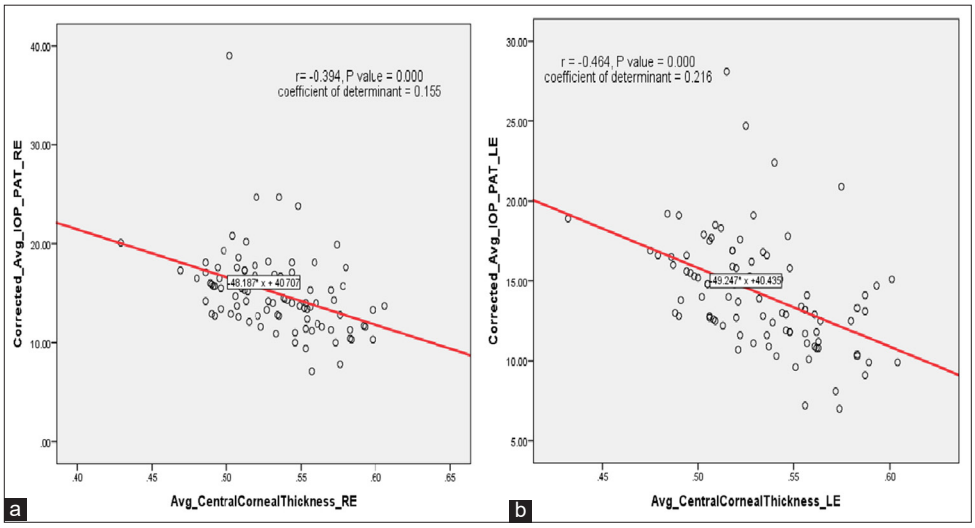


**Figure 2:** Correlation plot (a and b) between cPAT and central corneal thickness in the right and left eyes. cPAT: Pachymetrically corrected IOP with Perkins applanation tonometer, CCT: Central corneal thickness, RE: Right eye, LE: Left eye, PAT: Perkins applanation tonometer.

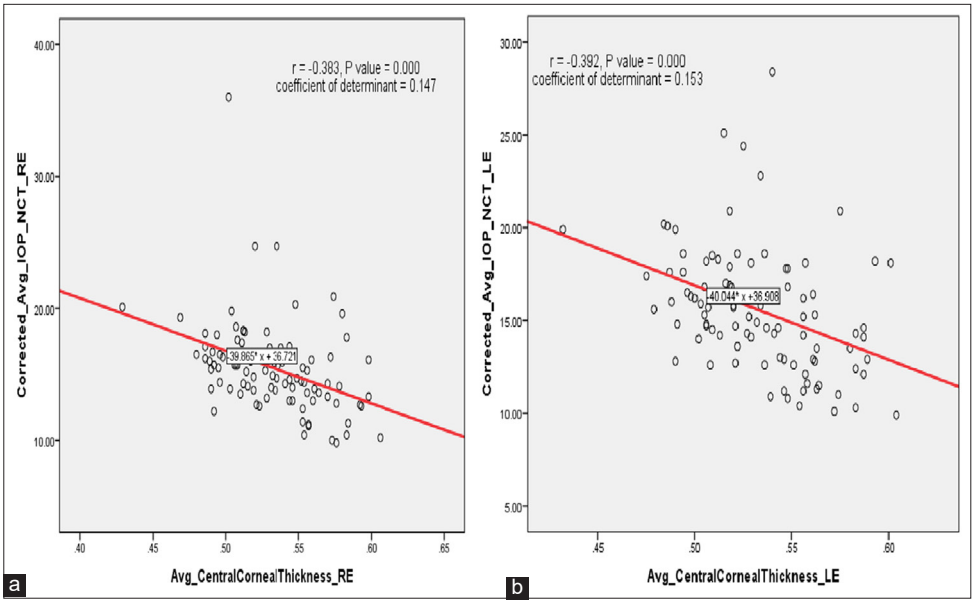


**Figure 3:** Correlation plot (a and b) between cNCT and central corneal thickness in the right and left eyes. cNCT: pachymetrically corrected IOP measured with non-contact tonometer, IOP: Intraocular pressure, NCT: Non-contact tonometer, RE: Right eye, LE: Left eye, CCT: Central corneal thickness

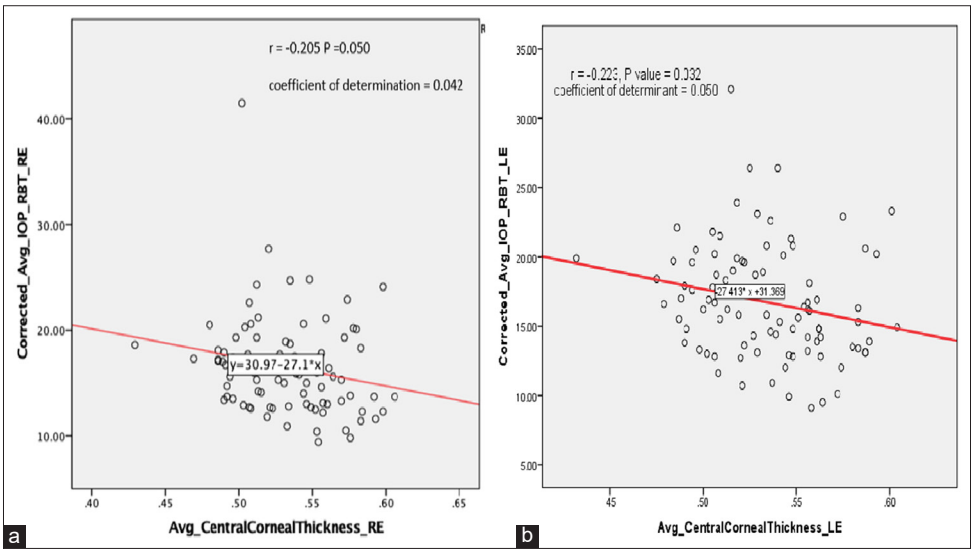


**Figure 4:** Correlation plot (a and b) between cRBT and central corneal thickness in the right and left eyes. cRBT: Pachymetrically corrected intraocular pressure with Rebound tonometer, RE: Right eye, LE: Left eye, CCT: Central corneal thickness.

IOP measurements. These factors include central corneal curvature, corneal hysteresis, and corneal resistance factor.[29,33,34]

Essentially, RBT and NCT show an overestimation of IOP measurements relative to GAT/PAT, tonometer preference is varied, could even be said to be equivocal, but the majority of studies show a proclivity for instruments with minimal patient contact such as RBT and NCT. There are conflicting reports on the association of CCT and IOP.

## CONCLUSION

The PAT was most affected by the CCT, while the iCare RBT was least affected. It is necessary to have measured IOP corrected for CCT to get the true IOP.

**Ethical approval:** The research was approved by the Ethics Committee of the University of Port Harcourt Teaching Hospital, Port Harcourt with the approval number UPTH/ADM/90/S.II/VOL.XI/616 dated 12th June 2018.

**Declaration of patient consent:** The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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