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Original Research Article

Comparison of Intra-Ocular Pressure Values Obtained Using Goldmann Applanation Tonometer and Air-Puff Non-Contact Tonometer in Glaucoma Patients

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Abstract

Intraocular pressure (IOP) measurement is crucial for diagnosing and managing glaucoma. The Goldmann applanation tonometer (GAT) is the gold standard for IOP measurement, and while the Pulsair non-contact tonometer (NCT) has shortcomings, it appears to offer certain advantages and therefore is a viable option. The purpose of this study is to determine the reliability of NCT as a reliable alternative to GAT for assessing IOP in adult glaucoma patients. This cross-sectional study assessed 200 eyes of 101 patients at a tertiary hospital in Northern Nigeria. We measured IOP with both GAT and NCT. The mean age of the participants was 56 ± 13.2 years. The right eyes had mean IOP values of 16.44mmHg and 14.96mmHg ($p<0.05$) with GAT and NCT, respectively, while those of the left were 17.59mmHg and 17.01mmHg ($p < 0.05$). The pachymetrically corrected IOP values in the right eyes were 19.31mmHg and 18.20 mmHg ($p<0.05$) for GAT and NCT, respectively, while those in the left were 20.05mmHg and 19.22 mmHg ($p>0.05$). Pachymetrically corrected NCT and GAT showed a positive correlation of 0.861 ($p<0.0001$). Bland-Altman analysis showed good agreement, especially for pachymetrically corrected data of NCT and GAT, with a considerable majority of subjects (76% for right eyes, 80% for left eyes) showing differences of 1-3 mmHg, while an average of 14% of all eyes had no difference. In conclusion, the NCT provided reliable IOP measurements; however, CCT corrections may be required, as NCT results appear to be more subject to CCT variations.

Keywords: Noncontact tonometry, Goldmann applanation tonometry, central corneal thickness, intraocular pressure.

INTRODUCTION

Intraocular pressure (IOP) is an important clinical parameter in the diagnosis and management of glaucoma, the leading cause of irreversible blindness globally.(Pascolini and Mariotti 2012, Prum, Rosenberg *et al.,* 2016) Glaucoma is an optic neuropathy associated with characteristic structural damage to the optic nerve and associated visual dysfunction that may be caused by various pathological processes.(Foster, Buhrmann *et al.,* 2002) There are various risk factors for the development of glaucoma, with IOP being the most important and the only modifiable one.(Webers, Beckers *et al.,* 2008, Sultan, Mansberger *et al.,* 2009) Measurement of IOP is crucial for diagnosing and monitoring glaucoma, where each millimetre of mercury change in IOP can make a difference to the health of the optic nerve.(Arora, Roelofs *et al.,* 2013) Regular IOP measurements can help detect glaucoma early, with treatment instituted promptly and, hence preventing visual loss.

Goldmann applanation tonometry (GAT) is considered the gold standard for measuring IOP.(Sultan, Mansberger *et al.,* 2009) However, its validity can be affected by central corneal thickness (where a thin cornea underestimates, while a thick cornea overestimates the actual IOP), corneal biochemical properties and scleral rigidity. Newer technologies, such as the air-puff non-contact tonometer (NCT) have gained popularity due to

their ease of use and lack of need for anaesthesia. It employs the same principle as the GAT and offers the advantage of minimal or no spread of infection, making it suitable for use in patients with poor fixation, corneal oedema, or after anterior segment surgery.(Forbes, Pico *et al.,* 1974, Vernon 1995)

Several studies have demonstrated good clinical correlation between GAT and NCT in glaucoma patients; however, other studies showed conflicting results.(Climenhaga and Plucinska 1989, Moseley, Evans *et al.,* 1989, Chen, Zhang *et al.,* 2019, Dewi and Maharani 2025) The extent of the difference is thought to be dependent on the diversity of the study population and variation in the IOP of the study subjects. There is yet to be a single method of tonometry that is superior in all clinical scenarios and for all subjects, given the limitations of all methods. Therefore, the objective of this study is to evaluate the IOP values obtained with GAT and NCT over a range of IOPs in glaucoma patients.

MATERIALS AND METHODS

Study Area

The study was carried out at the National Eye Centre, Kaduna. It is a mono-specialised ophthalmic hospital. It has a glaucoma and cataract department where glaucoma patients are referred from the general outpatient department. On average, 150 glaucoma patients are seen in the department weekly.

Study Population

All patients with Glaucoma who presented at the glaucoma department during the study period

Study Design: Cross-sectional study.

Study Period: 2nd to 31st October 2024.

Sample size

The following formula was utilised to calculate the sample size (Daniel 1978)

$$n = \frac{Z^2 P(1-P)}{d^2}$$

Were

n= minimum sample size

P= prevalence of glaucoma in Nigeria=5%(Kyari, Entekume *et al.,* 2015)

1-P =q

d= level of significance=0.05

z= standard normal deviation at 95% confidence interval=1.96

$$n = \frac{(1.96)^2 \times 0.05 \times (1-0.05)}{(0.05)^2} = 0.1825/0.0025 = 72.98$$

Therefore, the minimum sample size was 73

Inclusion Criteria

All patients with glaucoma who consented to take part in the study.

Exclusion Criteria

1. Patients < 18years
2. Any corneal abnormality preventing reliable IOP measurement
3. History of ocular trauma
4. History of Laser refractive surgery

Sampling technique

The sampling method used in the study was non-probability convenience sampling, which involved all clients with glaucoma visiting the center during the study period.

Survey team

Principal Investigator
Assistant Investigator
Ophthalmic nurse
Statistician

Instruments

Proforma
Slitlamp biomicroscope
Tumbling E chart
3 mirror goniolens
GAT
Pulsair tonometer
Humphrey visual field Analyzer
78D lens
Pachymeter

Data collection process

Patients who consented to take part in the study and met the inclusion criteria were recruited from the glaucoma clinic. Information on the age, gender, family history of glaucoma, diabetes, and hypertension was taken. The visual acuity was assessed using a tumbling E chart at 6m in a brightly lit room, pupils were examined with a pen torch, and the anterior segment was examined using the slit lamp biomicroscope.

Intraocular pressure was measured with both Pulsair NCT (Keeler) and GAT. Pulsair NCT was done first in each patient while seated on a chair, followed by applanation tonometry because touching the cornea with the applanation prism might affect NCT readings. The measurements by the Pulsair NCT were taken four times, out of which first reading was excluded (as specified by the manufacturer(Vernon 1995) (An average of three readings was taken)

The GAT applanation tonometry was done by a slit lamp-mounted applanation tonometer on the Haag-Streit R-900 device (Haag-Streit, Koeniz, Switzerland). After explaining the procedure, the subjects were seated on the slit lamp. Tetracaine (0.5%) eye drops were instilled as an anaesthetic agent, followed by the application of a sterilised strip of Fluorescein (1%) in the inferior fornix of the eye. The applanation prism tip was cleaned with isopropyl alcohol, and excess tear film was removed with a cotton swab and IOP readings were taken

by a properly calibrated GAT. The anterior chamber angle was assessed using a 1-mirror Gonio lens. The central visual field was assessed using the Humphrey field analyser, Fundoscopy performed with a 78D lens, and Central Corneal Thickness (CCT) was measured using a pachymeter (Topcon SP-3000P) to adjust intraocular pressure (IOP) readings for patients with thick or thin corneas. For instance, if the CCT measures 545 µm, no IOP correction is necessary. However, if the CCT is 645 µm (indicating a thicker-than-average cornea), the IOP is adjusted downward by 7 mmHg. Conversely, for a thinner cornea measuring 445 µm, the IOP is increased by 7 mmHg. These adjustments were applied to both Goldmann Applanation Tonometry (GAT) and Non-Contact Tonometry (NCT) readings. Consequently, we obtained the corrected values for GAT and NCT (designated as GATc and NCTc, with the small 'c' indicating pachymetric correction).

Data Management

It was entered into the data collection tool and analysed using SPSS version 23. Electronic data cleaning was done to identify errors during collection and entry. The collected data were presented in tables. Chi-square test was used to determine association. A p-value of less than or equal to 0.05 was considered statistically significant

Ethical Approval

Ethical approval for the study was sought and obtained from the Ethics and Research Committee of National Eye Centre, Kaduna. Before the commencement of data collection informed consent was obtained from the subject.

RESULTS

One hundred and one glaucoma patients were studied. The age ranged from 25 to 87 years (mean age 56 years; standard deviation ± 13.2 years). Most patients were between 46 and 73 years old. Among them, 33.7% of patients were aged 46-59 years, and 34.7% were aged 60-73 years. The males were 58(57.4%) and females were 43(42.6%).

Table 1

Variable	Frequency	Percentage
Age Group		
18-31	4	4.0
32-45	18	17.8
46-59	34	33.7
60-73	35	34.7
74-87	10	9.9
TOTAL	101	100.0

Table 2: Mean of IOP using GAT and NCT with and without CCT correction.

IOP	*N*	Mean in mmHg	SD	t-value	Df	p-value
NCT OD	101	14.96	5.82	-2.810	100	0.006
GAT OD	101	17.01	7.93			
NCT OS	99	16.44	6.90	-2.559	98	0.012
GAT OS	99	17.59	7.71			
NCTc OD	97	18.20	5.68	-2.211	96	0.029
GATc OD	97	19.22	7.47			
NCTc OS	97	19.31	6.67	-1.858	96	0.066
GATc OS	97	20.05	7.73			

IOP – Intraocular pressure; GAT – Goldmann applanation tonometer; NCT – Noncontact tonometer; CCT -Central corneal thickness; NCTc – Pachymetric corrected noncontact tonometer; GATc- Pachymetric corrected Goldmann applanation tonometer; SD-standard deviation; OS – Left eye; OD – Right eye.

There was a statistically significant difference between the mean GAT and NCT findings in the right eye (P = 0.006), Left eye (P = 0.012), and the corrected mean NCTc and GATc of the right eye (P =0.029). Only the left eye was not statistically significant (P = 0.066), as shown in Table 2. The mean IOP measures in both the right and left eye were found to be significantly higher with GAT than NCT, with and without CCT correction

Table 3: Pearson correlation between NCT measurements of IOP and those of GAT

		N	Correlation	Sig.
Pair 1	NCT OD & GAT OD	101	0.466	.0001
Pair 2	NCT OS & GAT OS	99	0.821	.0001
Pair 3	NCTc OD & GATc OD	97	0.794	.0001
Pair 4	NCTc OS & GATc OS	97	0.861	.0001

Pearsons's product-moment correlation coefficient was computed between the pairs to assess the relationship between the GAT/NCT, GATc/NCTc, GATc/ NCT, and GAT/NCTc. There was a strong positive correlation coefficient between the measurements with highest correlation (0.861) obtained between GATc and NCTc.

Table 4: Distribution of intraocular pressure variations of the noncontact tonometer compared to the Goldmann applanation tonometer Bland-Altman analysis

IOP measurement by NCT	OD (%)	OS (%)	ODc	OSc
Equal to GAT measurement	11%	14%	12%	16%
Higher than GAT measurement	37%	31%	37%	33%
Lower than GAT measurement	52%	55%	51%	51%

NCT of right eye was equal to GAT in 9%, higher than GAT in 39% and lower than GAT in 52% and NCT of left eye was equal to GAT in 14%, higher than GAT in 31% and lower than GAT in 55%. NCTc of right eye was equal to GAT in 10%, higher than GAT in 39% and lower than GAT in 51%. NCTc of left eye was equal to GAT in 16%, higher than GAT in 33% and lower than GAT in 51%. The difference was within 3 mmHg in 73% of RE, 77% of LE and for the corrected IOP values 76% in RE and 80% in LE.

DISCUSSION

Both GAT and NCT are techniques of IOP measurement that influence IOP values, with GAT being the 'gold standard' and NCT having the advantages of being mobile, with no contact with the cornea.

This study compared the IOP measures of NCT with GAT with and without CCT correction in a sample of glaucoma patients in Kaduna, Nigeria**.** The study had a male-to-female ratio of 1.35:1, which is comparable with previous clinic-based research findings in glaucoma patients in sub-Saharan Africa.(Babalola, Kehinde *et al.,* 2009, Samuel, Gboglu *et al.,* 2020) this may be due to access of health care services are usually poor amongst women in sub-Saharan Africa

The NCT and GAT readings of our study patients were found to be significantly correlated with P=0.0001, which is why the instruments are used in everyday clinics. Reports from other studies in both glaucomatous and non-glaucomatous populations showed good agreement with correlation values being highly significant,(Babalola, Kehinde *et al.,* 2009, Kyei, Assiamah *et al.,* 2020, Joshi, Shinde *et al.,* 2023), signifying that NCT can be used in practice as the GAT.

However, the average IOP readings with GAT in this study were significantly ($P < 0.05$) higher than readings of the NCT in both eyes. Studies comparing NCT and GAT differ with some showing GAT to be higher(Parvin, Mian *et al.,* , Ko and Hsu 2005, Stock, Ströher *et al.,* 2021, Dewi and Maharani 2025, Peng, Wang *et al.,* 2025) similar to findings in our study, while others show NCT to be higher than GAT (Babalola, Kehinde *et al.,* 2009, Kyei, Assiamah *et al.,* 2020), The measurements may be subject to influence from specifications of the measuring devices and the units employed by the models, as well as human factors (Stock, Ströher *et al.,* 2021).

The mean differences in pachymetric-corrected intraocular pressure (IOP) observed in our study were closely aligned between Goldmann Applanation Tonometry (GAT) and Non-Contact Tonometry (NCT). It is important to note that IOP values are influenced by central corneal thickness (CCT)(Biswas, Kumar *et al.,* 2023). This suggests that pachymetric-corrected IOP should be incorporated into our daily clinical practice, particularly when NCT is utilized for routine assessments, as it provides a more accurate reflection of the true IOP, consistent with findings from other studies(Babalola, Kehinde *et al.,* 2009, Biswas, Kumar *et al.,* 2023).

A direct comparison of intraocular pressure (IOP) data from the two methods offers valuable insights. Our sample demonstrated strong agreement between non-contact tonometry (NCT) and Goldmann applanation tonometry (GAT), with over 75% of eyes showing a difference of 3 mmHg or less. These findings align with previous studies that reported similar results.(Babalola, Kehinde *et al.,* 2009, Kyei, Assiamah *et al.,* 2020) Consequently, this approach can be effectively used for screening, particularly in high-volume clinics.

The limitation of this study is probe bias, which was not considered and may affect intraocular pressure (IOP) testing, as the use of eye drops during Goldmann Applanation Tonometry (GAT) alters corneal hydration(Mohan, Tiwari *et al.,* 2014, Dewi and Maharani 2025).

CONCLUSION

This study revealed that GAT readings were significantly higher than the IOP measurements obtained from the NCT, although they generally remained within acceptable limits for inter-device variation. The NCT (Keeler Pulsair) provided reliable IOP measurements in our assessment; however, it may be necessary to apply CCT corrections, as NCT results can be more influenced by variations in CCT. Therefore, it is recommended that

monitoring IOP in glaucoma patients with these devices should not be interchanged.

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Conflicts of interest: There are no conflicts of interest.

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