Original Article

Comparative Assessment of The Goldmann Applanation and Noncontact Tonometers in Intraocular Pressure Measurements in a Sample of Glaucoma Patients in the Cape Coast Metropolis, Ghana

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Abstract

Objectives: The objective of the study was to explore the usage of the Goldmann applanation tonometry and noncontact tonometry interchangeably in the measurement of intraocular pressure (IOP) in glaucoma patients. **Materials and Methods:** The study involved 441 clinically diagnosed glaucoma patients receiving care at a referral facility. IOP measurements were obtained using both the Noncontact tonometer and Goldmann applanation tonometer The repeatability of the measures was analyzed by comparing the repeated measures of the devices using paired *t*-test and calculating the correlation coefficient. A Bland–Altman analysis was used to determine the limits of agreement between the two procedures. **Results:** There were 271 (61.5%) males and 170 (38.5%) females and their age ranged from 18 to 73 years (mean age = 49.37; standard deviation ± 14.81 years). The findings of the study showed significantly lower readings ($P < 0.001$) of the GAT (right eye = 17.40 ± 7.48 mmHg; left eye = 16.80 ± 7.49 mmHg) compared to the NCT (right eye = 20.15 ± 8.30 mmHg; left eye = 19.74 ± 8.31 mmHg). There was a strong positive correlation between the GAT and NCT findings in the right eye ($r = 0.871$, $n = 441$, $P < 0.001$) and in the left eye ($r = 0.887$, $n = 441$, $P < 0.001$). There was a wide limit of agreement between NCT and GAT measurements. **Conclusion:** There was statistically significant higher measures obtained with NCT than the GAT but did not exceed the allowable inter-device difference. There was a strong positive correlation between GAT and NCT measurements. However, it is strongly recommended that these devices are not used interchangeably in the monitoring of IOP in glaucoma due to the wide range of limits of agreement.

Keywords: Ghana, glaucoma, Goldmann applanation tonometer, intraocular pressure, noncontact tonometer

Introduction

Glaucoma has earned the notoriety of being the leading cause of irreversible blindness worldwide,[1,2] and Ghana[3] is one of the most affected countries. Chronic elevation of intraocular pressure (IOP) has been implicated in the pathogenesis of primary open-angle glaucoma.[4] The only modifiable risk factor in glaucoma pathogenesis is IOP.[5]

Several tonometric methods exist and the clinician's preference is mostly based on availability and convenience.[6,7] The Goldmann applanation tonometer (GAT) calculates IOP by measuring the force needed to flatten a constant corneal area.[6,7] The GAT is the most commonly used and is considered the gold standard device for measuring IOP.[8] The GAT flattens a small area on the cornea; measurements are not affected by scleral stiffness.[6,7] However, the thickness of the central cornea may affect GAT readings.[6,7]

The noncontact tonometer (NCT) uses a small puff of air directed at the cornea; the returning air from the surface of the cornea is measured by a membrane that records the force, which is converted into IOP.[7] It is one of the most widely used

Access this article online

Quick Response Code:

Website: www.nigeriamedj.com

DOI: 10.4103/nmj.NMJ_177_20

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Submitted: 22-May-2020 **Revised:** 16-Sep-2020
Accepted: 11-Oct-2020 **Published:** 19-Dec-2020

How to cite this article: Kyei S, Gboglu CP, Kwarteng MA, Assiamah F. Comparative assessment of the Goldmann applanation and noncontact tonometers in intraocular pressure measurements in a sample of glaucoma patients in the Cape Coast Metropolis, Ghana. Niger Med J 2020;61:323-7.

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device for IOP measurement across the globe.[9] Advantages of this method include the requirement of no topical anesthesia in children and adults who are unable to tolerate contact methods.[7] It has also been found to pose a lower risk of cross-infection.[10] Unlike the GAT which has to be used whiles mounted on a slit lamp, the NCT exists in table-top and portable forms.[9]

A number of researchers have compared the IOP readings between GAT and NCT. However, it has been acknowledged that the suitability of tonometric method is dependent on the setting, purpose, and patient population.[9] It is against this backdrop that this maiden study to compare IOP measures of GAT and NCT in a sample of glaucoma patients is necessary in Ghana.

Materials and Methods

Study setting

This study was carried out at the premises of the Bishop Ackon Memorial Christian Eye Center, Cape Coast. The center is the most utilized Christian eye care facility in the Cape Coast metropolis of Ghana.

Study design

This was a clinic-based prospective study of patients with glaucoma visiting the center. The study involved the comparison between IOP readings of the Goldman applanation tonometer (GAT) and noncontact tonometer (NCT) from January 2019 to December 2019.

Sampling technique

The sampling method was nonprobability convenience sampling. The sampling method was based on the fact that the study involved all clients with glaucoma visiting the center during the study period.

Inclusion and exclusion criteria

The study included all patients diagnosed with glaucoma who were 18 years and older. The study excluded clients with preexisting ocular surface disease, corneal disease, eye surgery, ocular trauma, and inflammatory eye disease.

Ethical consideration

The study adhered to the tenets of the Declaration of Helsinki and approval was sought from the Institutional Review Board of the University of Cape Coast (UCCIRB/CHAS/2019/178). The informed consent of the participants was obtained. The tonometric procedures were explained to the participants especially the risk of minimal discomfort involving the contact of the Goldmann tonometer probe with the cornea. They were assured that the anesthesia will help in the relief of the discomfort. No financial remunerations were offered to the participants. Participation in the study was voluntary and participants were informed that they could withdraw their participation at any point and that in the event of refusal/withdrawal of participation, they will not incur penalty or loss of treatment or other benefits to which they would normally be entitled.

Data collection procedure

Data collection involved the use of a data extraction sheet to collect data on demographics and IOP measures.

The data extracted included:

1. The examination of the anterior segment performed on each participant using a slit-lamp biomicroscope
2. The examination of the posterior segment conducted using an ophthalmoscope and slit-lamp biomicroscope
3. IOPs measured using the slit-lamp mounted Goldmann AT 900 (Haag Streit, Bern, Switzerland) and noncontact tonometer (NCT) using Topcon CT80 (Topcon Medical, NJ, USA)
4. All measurements were taken by a single experienced practitioner.

Statistical analysis

Data were analyzed using the IBM SPSS version 21 (SPSS Inc., Chicago, Illinois, USA). Categorical data were presented as frequencies. Pearson correlation coefficient was used to determine the association between GAT and NCT. Bland–Altman analysis was used to determine the level of agreement between GAT and NCT. $P < 0.05$ was considered statistically significant.

Results

Demographic profile

Four hundred and forty-one participants were involved in the study. Their ages ranged from 18 to 73 years (mean age = 49.37; standard deviation ± 14.81 years). Of the 441 participants, 271 (61.5%) were males and 170 (38.5%) were females.

Mean intraocular pressure findings in GAT and NCT

The mean IOP findings of the GAT and NCT in the right and left eyes were evaluated [Table 1].

Correlation test between GAT and NCT readings

A Pearson product-moment correlation coefficient was computed to assess the relationship between the GAT and NCT findings in the right eye. There was a strong positive correlation coefficient between the GAT and NCT findings in the right eye ($r = 0.871$, $n = 441$, $P < 0.001$), as shown in Table 2. A scatterplot has been used to summarize the results [Figure 1]. There was a statistically significant

Table 1: Mean intraocular pressure findings in Goldmann applanation tonometer and noncontact tonometer

IOP measures	Mean	*n*	SD	Median
OD GAT	17.40	441	7.48	16.00
OD NCT	20.15	441	8.30	18.00
OS GAT	16.80	441	7.49	14.00
OS NCT	19.74	441	8.31	17.00

IOP – Intraocular pressure; GAT – Goldmann applanation tonometer; NCT – Noncontact tonometer; SD – Standard deviation; OS – Left eye; OD – Right eye

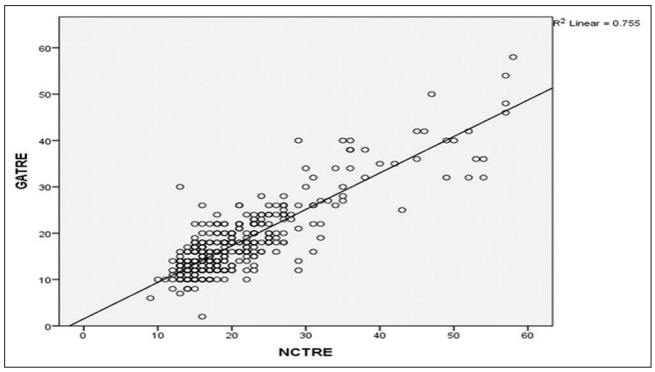

Figure 1: A correlation between intraocular pressure readings with GAT and NCT by participants who in the right eye. The x-axis and y-axis are the intraocular pressure readings. The line represents the equivalence line

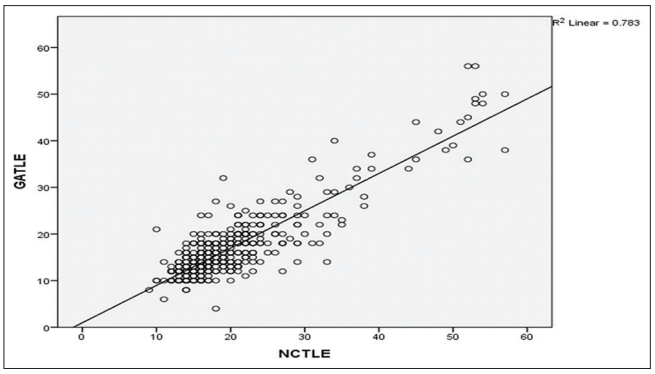

Figure 2: A correlation between intraocular pressure readings with GAT and NCT by participants in the left eye. The x-axis and y-axis are the intraocular pressure readings. The line represents the equivalence line

difference between the mean GAT and NCT findings in the right eye. A mean difference of − 2.75 mmHg ± 4.09 mmHg was obtained between the mean GAT and NCT findings in the right eye with $P < 0.001$, as shown in Table 3.

A Pearson product-moment correlation coefficient was computed to assess the relationship between the GAT and NCT findings in the left eye. There was a strong positive correlation coefficient between the GAT and NCT findings in the left eye ($r = 0.887$, $n = 441$, $P < 0.001$), as shown in Table 2. A scatterplot has been used to summarize the results [Figure 2]. There was a statistically significant difference between the mean GAT and NCT findings in the left eye. A mean difference of − 2.95 mmHg ± 3.84 mmHg was obtained between the mean GAT and NCT findings in the left eye with $P < 0.001$, as shown in Table 3.

The mean IOP measures in both the right and left eyes were found to be significantly higher with NCT than GAT; however, the proportionate analysis indicated that some 26% of the IOP readings with NCT deviated from this trend [Table 4].

The results of the Bland–Altman plot are as shown in Figures 3 and 4 and suggest that the mean difference between the measurements in the right eye by the two techniques was 2.75 mmHg for NCT-GAT [Figure 3] and 2.95 mmHg for NCT-GAT [Figure 4] in the left eye. The 95% agreement range of IOP measured with GAT and NCT was from − 5.26–10.77 mmHg to − 4.58–10.46 mmHg in the right and left eyes, respectively.

Association between age, gender, and intraocular pressure

A Chi-square test was performed to determine the association between age, gender, and IOP measures of GAT and NCT. There was no significant association between age and IOP measures of GAT and NCT in the right and left eye, respectively ($P > 0.05$). Furthermore, there was no significant association between gender and IOP measures of GAT and NCT in the right and left eye, respectively ($P > 0.05$).

Table 2: Correlation test between Goldmann applanation tonometer and noncontact tonometer readings

	IOP measures	*n*	Correlation	Significant
Pair 1	OD GAT and OD NCT	441	0.871	0.000
Pair 2	OS GAT and OS NCT	441	0.887	0.000

IOP – Intraocular pressure; GAT – Goldmann applanation tonometer; NCT – Noncontact tonometer; OS – Left eye; OD – Right eye

Table 3: Mean differences between Goldmann applanation tonometer and noncontact tonometer readings

IOP measures	Mean ± SD	Significant (two-tailed)
OD GAT – OD NCT	−2.75±4.09	0.000
OS GAT – OD NCT	−2.95±3.84	0.000

IOP – Intraocular pressure; GAT – Goldmann applanation tonometer; NCT – Noncontact tonometer; SD – Standard deviation; OS – Left eye; OD – Right eye

Table 4: Distribution of intraocular pressure variations of noncontact tonometer to Goldmann applanation tonometer

IOP measurement by noncontact	Right eye (%)	Left eye (%)	Total (%)
Equal to GAT measurement	37 (8.4)	37 (8.4)	74 (8.4)
Higher than GAT measurement	333 (74.8)	350 (79.4)	683 (77.4)
Lower than GAT measurement	74 (16.8)	54 (12.2)	124 (14.2)
Total	441 (100)	441 (100)	882 (100)

IOP – Intraocular pressure; GAT – Goldmann applanation tonometer

Discussion

This study compared the IOP measures of NCT with GAT in a sample of glaucoma patients in Ghana. The participants involved in this study were mainly adults consistent with reports that the burden of glaucoma is high among adults.[11,12] There were more males than females in this study as the male-to-female ratio was 1.6:1, which is consistent with the findings in most clinic-based studies[13-15] in sub-Saharan Africa among patients with glaucoma. Poor socioeconomic status of women in Africa which serves as an obstacle to access to quality eye care might have led to the gender disparity.

The GAT was considered as the gold standard tonometer for the comparison.[16,17] A highly significant relationship was observed

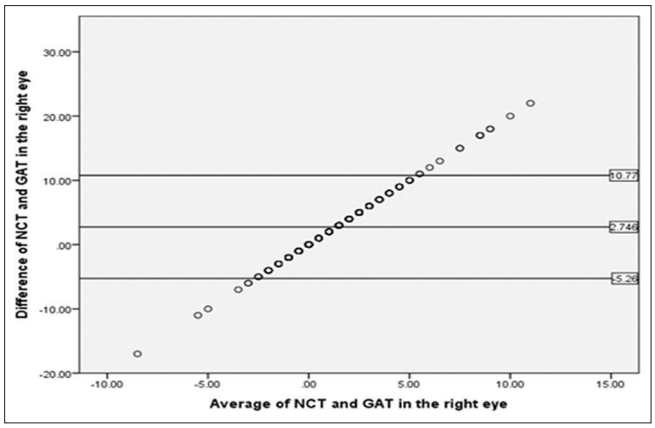

Figure 3: Bland–Altman test for correspondence between intraocular pressure measurements (mmHg) taken with NCT and GAT in the right eye

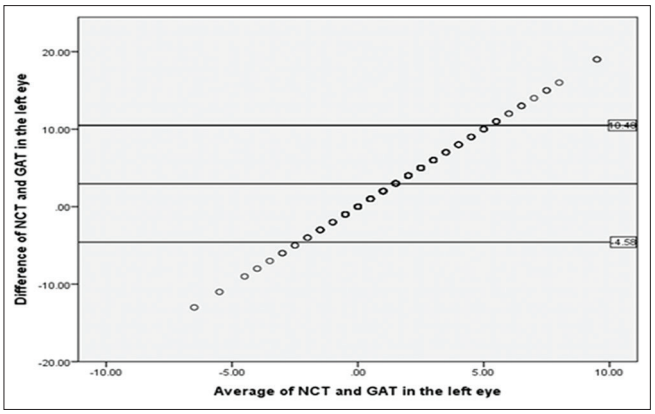

Figure 4: Bland–Altman test for correspondence between intraocular pressure measurements (mmHg) taken with NCT and GAT in the left eye

between the readings of the NCT and GAT [Table 2]. This is similar to reports from studies among nonglaucomatous as well as glaucomatous populations.[18-21] It can be concluded that the results from NCT can provide a reliable IOP readings among the glaucomatous population.

However, the average IOP readings with NCT in this study were significantly ($P < 0.001$) higher than readings of the GAT with a mean difference of 2.77 ± 4.12 mmHg and 2.97 ± 3.87 mmHg in the right and left eyes, respectively. The slightly exaggerated outcome of the NCT over the GAT will often show borderline IOP as elevated IOP.

Several studies comparing GAT and NCT measures of IOP have concluded that GAT has lower readings compared to that of NCT.[18-22] In recent studies, repeatability tests conducted have reported that a maximum change of 3.00 mmHg in tonometer readings is clinically acceptable.[23,24] In Africa, Babalola *et al*.[25] reported that the mean NCT reading (17.36 mmHg) was similar to the mean GAT reading (17.42 mmHg). Forty-five percent (45%) of the differences in IOP readings between GAT and NCT were within 1 mmHg, while up to 79% were within 3 mmHg. [25] Furthermore, Ogbuehi[26] reported that there was no statistically significant difference between IOP measured with GAT and NCT.

This implies that the NCT is considered a good device to be used in clinical practice as well as screening to measure of both glaucoma severity and IOP change that affects the visual function. However, practitioners should be consistent with the type of tonometer and not interchange, as the differences in the IOP measures could lead to poor monitoring of IOPs.

To further substantiate this assertion, a Bland and Altman[27] test was performed to determine the limits of agreement. From Figures 3 and 4, it can be concluded that there was no consistent measurement bias of NCT against the GAT. In this study, the proportion of measurement where NCT readings were higher than GAT was 77.4% against 14.2% where GAT measurements were higher than NCT. A small proportion of the readings 8.4% had no mean difference between NCT and GAT measurements. A wide range of limits of agreement was observed [Figures 3 and 4] and this is similar to a study by Toprak and Kilic[28] who reported of a wide range of limits of agreement. This wide range may limit the use of NCT and GAT interchangeably in the measurement of IOP. Hence, documentation of the type of tonometer used is highly recommended in clinical practice.

There was no significant association between age, gender, and IOP measures with GAT and NCT ($P > 0.05$), indicating that GAT and NCT provide the same measures across gender and age. This is consistent with a study by Kouchaki *et al*.,[6] which reported of similar findings.

Conclusion

In summary, this study found that NCT readings were significantly different and higher than IOP readings of the GAT; but within the clinically acceptable inter device measure for IOP. The GAT and NCT measurements correlated positively and strongly. However, it is strongly recommended that these devices are not used interchangeably in the monitoring of IOP in glaucoma due to the wide range of limits of agreement and the observed deviation in trend.

Acknowledgment

We thank the management of Bishop Ackon Memorial Christian Eye Centre, Cape Coast, Ghana, for giving us access and consent to take the data from their facility.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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