Original Article

A Comparison of Goldmann Applanation Tonometry and Rebound Tonometry Measurements Among Patients Attending a Glaucoma Clinic in Southwest Nigeria

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ABSTRACT

Background: The accurate measurement of intraocular pressure (IOP) is a fundamental basic examination in daily ophthalmic practice and is important in managing many ophthalmic diseases and conditions such as glaucoma, uveitis, and following trauma. Accurate measurement of IOP is particularly important in glaucoma because the intraocular pressure is the most important modifiable risk factor in its management. **Aim:** To compare intraocular pressure (IOP) measurements obtained with the Goldmann applanation (GAT) tonometer to intraocular pressure measurements obtained with the iCare rebound tonometer (RBT) and evaluate the suitability of the iCare tonometer for routine clinical use among adult patients attending a glaucoma clinic in Southwest, Nigeria. **Patients and Methods:** The study was a comparative cross-sectional study. A total of 132 eyes of 132 patients were recruited for the study. Three consecutive IOP measurements were obtained with each of the instruments by the same observer. A difference in IOP of ± 3 mmHg between the two instruments was considered clinically significant in this study. **Results:** The mean IOP measurement from GAT was 15.18 mmHg (±4.26 mmHg) and 16.32 mmHg (±4.48 mmHg) from RBT. The mean central cornea thickness was 520.66 μm (±33.34). Pearson's correlation (r = 0.84) revealed a strong statistically significant correlation between GAT and RBT measurements and paired student t-test revealed a statistically significant difference in the means of IOP obtained by the GAT and RBT. There was a tendency for RBT to yield higher IOP measurements. **Conclusion:** The intraocular pressure measurements obtained with iCare RBT and GAT though strongly correlated, showed statistically significant differences in the means. The impact of central cornea thickness on measurements obtained by GAT and RBT was statistically insignificant. The iCare rebound tonometer, cannot replace GAT for routine use in the glaucoma clinic.

KEYWORDS: *Goldmann applanation tonometry, iCare, Rebound tonometry*

INTRODUCTION

Tonometry refers to the measurement of intraocular pressure. The intraocular pressure is the pressure exerted by the aqueous humor on intraocular tissues as a result of the balance between its production and drainage.[1] The accurate measurement of intraocular pressure (IOP) is a fundamental basic examination in daily ophthalmic practice and is important in managing many ophthalmic diseases and conditions such as glaucoma, uveitis, and following trauma. Accurate measurement

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of IOP is particularly important in glaucoma because intraocular pressure is the most important modifiable risk factor in its management.[2-6] The iCare rebound tonometer is a handheld device, designed as an alternative to the slit lamp-mounted Goldmann applanation tonometry. The iCare is fast and requires no anesthesia. The aim of this study was to compare the GAT to the iCare tonometer to determine its suitability for routine use in the glaucoma clinic.

The specific objectives were to compare the intraocular pressure measurements obtained with GAT to those obtained with iCare RBT; determine the effect of central cornea thickness on intraocular pressure measurement obtained by GAT and iCare RBT and provide recommendations on the suitability of iCare RBT in routine clinical use in a glaucoma clinic.

Methodology

This study was a comparative hospital-based study comparing GAT to the iCare RBT conducted over a 6-month period. All patients older than 18 years, attending the glaucoma clinic between June 2015 – December 2015, who met the study inclusion criteria and consented were included in the study. The first patient was recruited and thereafter, every 3rd patient who consented and meets the inclusion criteria were recruited into the included in the study.

Patients with corneal astigmatism higher than 3D, refractive error greater than ±5.00 DS, patients with active infective process e.g., conjunctivitis, corneal diseases, previous cornea surgeries, microphthalmos, history of intraocular surgery within the last 3 months, ocular inflammation, contact lens wear, patient with secondary causes of glaucoma or closed angle were excluded from the study. Only one eye of each participant was included in the analysis to avoid bias due to eyes-correlation.[7-9] The right eye of all participants were included and when the right eye did not meet the inclusion criteria, the left eye was used. The iCare rebound tonometry was performed first.[10] There were two observers (senior ophthalmology residents) taking measurements – one observer took the measurement for GAT, another took the measurement for RBT to avoid bias and the same observer took the measurements for the duration of the study.

Statistical analysis was performed using the SPSS (software program for social sciences ver. 18.0; SPSS Inc., Chicago, IL). Descriptive statistics were used to analyze demographic data; means were generated for IOP measurements and for CCT measurements. The agreement between the mean IOP measurements from the GAT and iCare tonometers was assessed using the Bland-Altman plots and this included the calculation of the mean difference between measurements, the standard deviation (SD), and the 95% confidence interval (CI) of the differences.[11] A difference in IOP of ±3 mmHg between the two instruments was considered clinically significant in this study.[12]

Results

Data from a total of 132 eyes (84.1% right eye and 15.9% left eye) of 132 patients (264 observations = 132 with GAT + 132 with RBT) was analysed (Table 1). The mean age of the patients was 60.72 years ± 14.16 years (range 18 - 86 years). There were sixty-seven females and sixty-five males in this study (female: male ratio of approximately 1:1).

Table 1: Patient Demographics

Characteristics	Value
Demographics	
Mean age (years)	60.72±14.16
Gender (F:M %)	50.7:49.3
Diagnosis	
Primary Open Angle Glaucoma	96 (72.73)
Glaucoma Suspect	16 (12.12)
Ocular Hypertension	10 (7.58)
Juvenile Open Angle Glaucoma	7 (5.30)
Normal Tension Glaucoma	3 (2.27)
Total	132 (100)
Laterality *N*(%)	
Right eye	111 (84.1)
Left eye	21 (15.9)
Total	132 (100)

Table 1. Shows the patient demographics of study participants. The mean age was 60.72 years (±14.16 years) with an approximate 1:1 female: Male ratio. Primary open angle glaucoma was the most common diagnosis

Table 2: IOP and CCT distribution

	Range (mmHg)	Mean (±SD)
GAT	5.00-22.00	13.54 (3.57)
Corr. GAT	5.00-26.00	15.18 (4.26)
RBT	7.00-28.00	16.32 (4.48)
CCT (µm)	437-607	520.66 (33.34)
	GAT & RBT	**Corr.GAT & RBT**
Pearson's coefficient	0.84	0.66
P	0.001	0.001
Mean difference mmHg (±SD)	2.78 (±2.4)	1.14 (±3.6)
P	0.001	0.001

Table 2 shows the distribution of IOP and CCT among study participants and correlation between GAT and RBT measurements. Mean IOP measurements from RBT was found to be higher than GAT. GAT=Goldmann applanation tonometer; Corr. GAT=corrected GAT; RBT=Rebound tonometry; CCT=Central Cornea Thickness

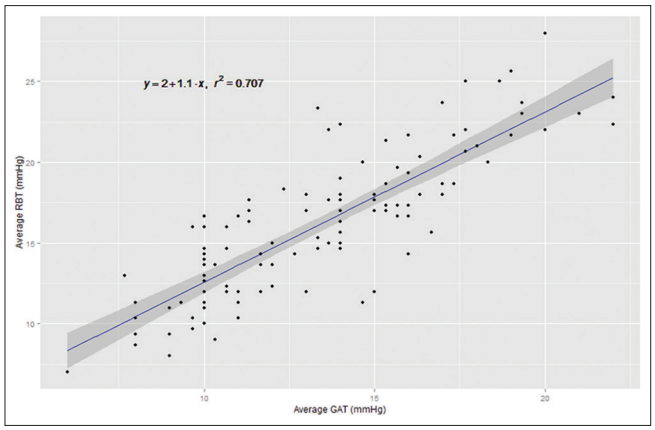

Figure 1: Regression Analysis of Relationship Between GAT and RBT. A very strong positive relationship was observed between GAT and RBT (r = 0.84; r^2 = 0.71 P < 0.001). Shaded region shows C.I. of the regression line at 95%. Linear regression equation RBT = 2 + 1.1 * GAT. The linear regression equation shows a tendency for RBT to overestimate IOP readings and the variance with GAT increases as the IOP increases

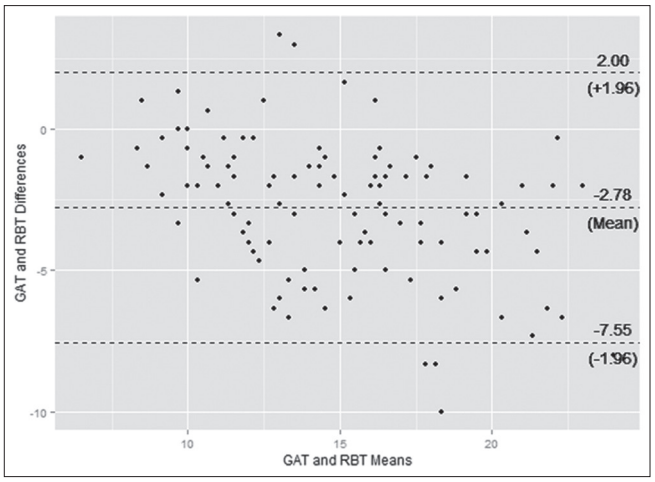

Figure 2: Bland-Altman Analysis of limits of Agreement between GAT and RBT Bland-Altman analysis of the distribution of differences in GAT IOP and RBT IOP values of each patient measured. Smaller dotted lines represent C.I. = 95%

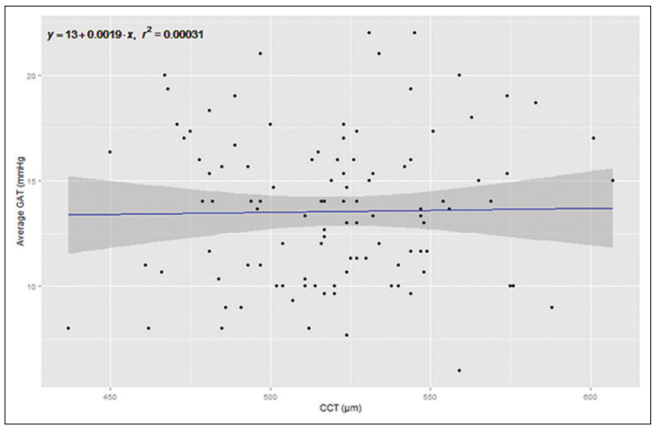

Figure 3: Correlation between CCT and GAT measurements. A weak statistically insignificant correlation between CCT and GAT was observed (r = 0.02; r² = 0.001). Shaded region shows C.I. of the regression line at 95%

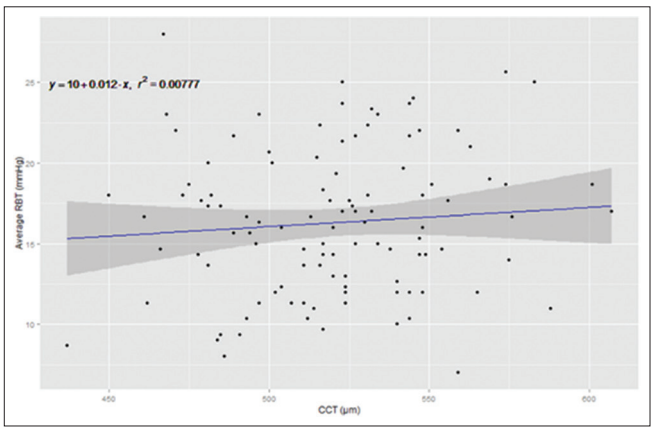

Figure 4: Correlation between CCT and RBT measurements. No significant relationship was observed between CCT and RBT (r = 0.08; r² = 0.01). Shaded region shows C.I. of the regression line at 95%

The average CCT was 520.66 µm (±33.34 µm) with a range of 437 µm – 607 µm [Table 2]. The average IOP measurement from GAT was 13.54 mmHg (±3.57 mmHg) and 16.32 mmHg (±4.48 mmHg) from RBT. Pearson's coefficient of the measurement between GAT and RBT was 0.84 and statistically significant (*P*-value 0.001). The mean difference between the IOP measured by GAT and RBT was statistically significant (P < 0.001).

Linear regression analysis of the relationship between IOP measurements from GAT and RBT showed a positive relationship between the measurement from the two instruments with a tendency for RBT to overestimate IOP readings and the variance with GAT increases as the IOP increases. A very strong positive relationship [Figure 1] was observed between GAT and RBT (r = 0.84; r^2 = 0.71 P < 0.001).

Bland-Altman [Figure 2] analysis of the distribution of the mean differences in GAT IOP and RBT IOP showed that 95% of the difference were within 2 standard deviations of the mean. The mean difference between the instrument was 2.78 mmHg (95% limit of agreement of 2.00 to -7.55 mmHg).

A weak statistically insignificant correlation [Figure 3] between CCT and GAT was observed (r = 0.02; r² = 0.001). A weak statistically insignificant correlation between CCT and GAT was observed (r = 0.02; r² = 0.001).

A weak and statistically insignificant relationship was observed between [Figure 4] CCT and RBT (r = 0.08; r² = 0.01).

Discussion

The accurate measurement of intraocular pressure is important in ophthalmic practice especially, in the

management of glaucoma because, IOP is the only known modifiable risk factor.[2] The most accurate method of measuring intraocular pressure remains cannulation of the anterior chamber and direct manometry.[13] However, because of its invasive nature and the risk of adverse effects like infection, this method is reserved for experimental designs only.[13]

The Goldmann applanation tonometer is considered the gold standard for clinical IOP measurement.[11] GAT is not without limitations, it requires the use of fluorescein dye, local anesthetic agents, and a slit-lamp microscope. It is not portable and requires the patient to be in an upright position and may be difficult to use in the elderly, children, and people with disabilities.[14,15] Potential sources of error with the GAT, include inadequate precorneal tear film; not measuring IOP with fluorescein; corneal edema; blepharospasm; arterial perfusion pressure; central venous pressure; eye position and repeated applanation in a short span of time.[16] The accuracy of GAT may be influenced by corneal thickness (with a tendency to underestimate pressure in thinner corneas and overestimate in thicker corneas[1,17,18], curvature, and biomechanical properties, such as rigidity, viscosity, elasticity, hydration. It has been suggested that GAT is inaccurate in the context of the irregular cornea, cornea scarring, and high astigmatism as seen in keratoconus[19-21] as well as following penetrating keratoplasty (PKP)[22] and refractive surgery.[23,24]

The Rebound tonometer introduced into clinical practice in the year 2000, was designed to overcome some of the limitations of the GAT.[1,25-26] The iCare rebound tonometer has the advantage of being portable; has no requirement for anesthesia and requires a short learning curve. The aim of this study was to compare the accuracy and reliability of IOP measurements obtained with GAT to measurements from the iCare RBT and to evaluate the suitability of iCare RBT for routine clinical use in a glaucoma clinic.

The mean age of patients in this study was 60.72 ± 14.16 years this was similar to the mean age obtained in similar studies.[12,27] The majority of the patients (65.5%) were 60 years and older, this is in keeping with the finding that older age was a risk for glaucoma and glaucoma progression.[3,28] In this study, most of the participants (72.73%) had primary open angle glaucoma; glaucoma suspects accounted for 12.12% of the study participant; 7.58% of the respondents had ocular hypertension and 5.3% had juvenile open angle glaucoma. Normal tension glaucoma accounted for 2.27% of participant diagnoses. From this study, there was a very strong correlation between IOP measurements obtained by GAT and RBT (r = 0.84 P < 0.001). This was similar to findings by Martinez de la Casa *et al*.[29,30] (r = 0.82 P < 0.001); Lopez *et al*.[31] (r = 0.87, P <.001) and Kim *et al*.[15] (r = 0.6995, P < 0.001).

The statistical analysis showed that, even though the measurements obtained with both devices in the present study demonstrated a strong correlation, the RBT consistently gave a higher IOP compared to the GAT and the difference between the two instruments was statistically significant. The average IOP measurements from GAT in this study was 13.54 mmHg (±3.57 mmHg) and from RBT, 16.32 mmHg (±4.48 mmHg), this is similar to findings by Martinez-De-La-Casa[30] who obtained mean IOP measurements of 18.1 mmHg from GAT (±5.4 mmHg) and 19.9 mmHg (±5.3 mmHg) from RBT. This tendency to overestimate IOP by the iCare tonometer is contrary to the findings by Salvetat who also observed that the average IOP measurements from GAT (15.3 mmHg ± 3.8 mmHg) were higher compared to RBT (13.9 mmHg ± 4.1 mmHg).[12]

The mean difference between the instrument (RBT – GAT) was 2.78 mmHg with a 95% limit of agreement of 2.00 to -7.55 mmHg. In the study by Martinez de la Casa,[30] the RBT yielded an IOP value averaging a mean difference of -1.8 mmHg (±2.8 mmHg 95% limits of agreement -3.7 mmHg to 7 mmHg), higher than those obtained via GAT. Similarly, Kyoung *et al*.[15] found a tendency for RBT to overestimate IOP measurement with a mean difference of -1.92 mmHg (±3.29 mmHg SD) and this finding was also corroborated by Lopez *et al*.[31] From the linear regression equation (see Figure 1) "y = 2 + 1.1 * x" where y is the IOP obtained from RBT and x is the GAT IOP measurement, it was observed that for IOP between 10 mmHg and 14 mmHg the IOP was overestimated by about 3 mmHg; between 15 mmHg and 19 mmHg, the IOP was overestimated by 3.5 mmHg and for IOP 30 mmHg and higher, the IOP was overestimated by as much as 5 mmHg. The 95% limit of agreement between, GAT and RBT, found in this study is outside the a priori difference set[12] and on this account, the RBT cannot be used as a replacement for the GAT in glaucoma patients.

The central cornea is believed to be important in the estimation of IOP with a tendency for IOP overestimate in the thicker cornea and underestimation in the thin cornea.[17,32] Brandt *et al*.[33] a re-analysis of data obtained from the Ocular Hypertension Treatment Trial, to evaluate the predictive value of CCT corrected IOP on glaucoma risks concluded that correcting IOP for CCT did not improve the prediction model for risk of developing glaucoma and that CCT was a powerful independent risk factor for developing glaucoma.

In this study, a weak statistically insignificant correlation was found between the IOP obtained with both tonometers and the CCT. This is similar to findings by Kyoung *et al*.[15] and Gordon *et al*.[28] Conversely, Martinez de la Casa *et al*. and Salvetat *et al*.[12] found a small but statistically significant correlation between IOP measurements from both instruments and CCT[29] (GAT $r = 0.267$, $P = 0.005$; RBT $r = 0.375$).

The iCare rebound tonometer represents a relatively new tonometry modality. It is a portable, battery-powered device that can be utilized independent of a slit lamp and with its short learning curve, has the potential for a wide range of clinical applications such as routine clinical use, screening, and as a home self-monitoring device. However, the findings from this study would suggest that significant disparities exist between the performance of the iCare rebound tonometer and the current clinical gold standard – the Goldmann applanation tonometer. These disparities can have a significant impact on management decisions in patients managed for glaucoma. It is important to note that this study was conducted among patients attending the glaucoma clinic with stringent exclusion criteria and the findings may not be applicable to a wide range of patients.

Conclusion

In conclusion, though the IOP measurements obtained from both instruments were highly correlated, they are not interchangeable. The impact of central cornea thickness on measurements obtained by GAT and RBT was statistically insignificant. The iCare rebound tonometer in its current design, cannot replace the Goldmann applanation tonometer in a glaucoma clinic.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/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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Nil.

Conflicts of interest

There are no conflicts of interest.

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