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Comparison of three types of tonometers in healthy Indian eyes

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Abstract
Tonometry has evolved over centuries to find an ideal instrument to correctly measure IOP. Goldmann applanation tonometer (GAT) remains the gold standard for tonometry. The newer tonometers have been developed which operate without anaesthesia, fluorescein dye and with no or minimal contact. This non-interventional, cross-sectional study was done to know the agreement between three types of tonometers –Goldmann applanation tonometer, rebound tonometer (RT) and non-contact tonometry (NCT), in Indian eyes of healthy individuals. When compared to GAT, the measured IOP difference was found to be within ±3 mm Hg in two seventy-six eyes (84.6%; 95% CI: 80.6-88.5%) with RT, and in two eighty-one eyes (86.1%; 95% CI: 82.3-89.8%) with NCT. Both RT and NCT can be used as screening tools for IOP measurement in clinical practice within a relative range of IOP and CCT.

Keywords: tonometers, goldmann applanation tonometer, non-contact tonometer, rebound tonometer, Intra-ocular pressure

Introduction
Measuring intraocular pressure (IOP) is an integral part of comprehensive ocular examination. Although, IOP is no more a part of glaucoma definition and diagnosis, but remains sole modifiable risk factor in management of glaucoma [1]. Reduction of IOP has been shown to decrease chances of conversion to glaucoma in ocular hypertensive patients, as well to slower the progression of visual fields [2]. Hence, accurate, precise, reproducible measurement of IOP is cornerstone of glaucoma management in clinical practice [3]. Tonometry has evolved over centuries to find an ideal instrument to correctly measure IOP. At present Goldmann applanation tonometer (GAT) remains the gold standard for tonometry; however, it has certain technical and logistic limitations in clinical use. The newer tonometers have been developed which operate without anaesthesia, fluorescein dye and with no or minimal contact [4].
The present study was planned to study the agreement between three types of tonometers – Goldmann applanation tonometer, rebound tonometer (RT) and non-contact tonometry (NCT), in Indian eyes of healthy individuals.

Material and Methods
This non-interventional, cross-sectional study was conducted in ophthalmology department of a tertiary care teaching hospital in northern India. The study complied with the protocols laid in the 'Declaration of Helsinki' for research involving human subjects, and was approved by the institutional ethical committee. Subsequently, a written informed consent was obtained from all participants to have their IOP checked using three different instruments, namely-GAT, NCT and RT, and to measure central corneal thickness.
The healthy subjects were enrolled from among the persons coming to hospital for glasses for their refractive errors or presbyopia. Inclusion criterion, specified those were-aged 18 years and above, did not have history of any ocular or systemic disease, no previous ocular or refractive surgery, no current use of topical eye drops. Patients with significant astigmatism or spherical equivalent of refractive error more than ±2.0D, nuclear sclerosis grade more than II and active ocular inflammation were excluded. All enrolled participants underwent a complete ophthalmic examination including a review of ocular and systemic medical history, best corrected visual acuity, slit lamp examination, gonioscopy with four mirror gonioscopy and dilated fundus biomicroscopy with +60 D lens and indirect with +20 D lens. Any clinical examinations with the potential of affecting IOP measurement, such as

gonioscopy or dilatation, were carried out after IOP measurements were performed.

IOP was measured in sitting position by using different tonometers in a fixed sequence: NCT, RT and GAT, with a recovery time of about three minutes between the methods. Central corneal thickness (CCT) was measured with pachymeter after tonometric measurements had been performed. All measurements were done in masked manner, between 10 am to 12 noon. First examiner obtained measurements with NCT and RT, and then eyes were anaesthetized using paracain eye drops. A second examiner took measurements with GAT after applying a fluorescein strip to the inferior conjunctival fornix. All the reading were read and recorded, and documented in study proforma. Data was obtained from both eyes but only one eye was selected for analysis using computer based random selection.

Non-contact tonometry

The non-contact tonometer (NT-2000; Nidek Co., Ltd., Gamagori Aichi, Japan), also called puff tonometer, uses air to flatten the cornea. The NCT automatically recorded three IOP readings.

Rebound tonometer

The rebound tonometry (Icare; Finland) was done in sitting position without any anaesthetic drops. Six readings are taken to minimize deviation. An auditory signal alerts examiner of completion of reading taking process and an average value is displayed on LCD screen along with any variability in measurements (7).

Goldmann applanation tonometer

GAT (L-5110, Inami, Tokyo, Japan) was mounted on slit lamp and calibrated according to manufactures' guidelines before recording IOP for each participant underwent. Two readings were taken for each eye, and observer recoding readings reset the dial for each measurement.

Pachymetry

Central corneal thickness (REM 3000, Tomey Corporation, Japan) was measured after three minutes of GAT measurement. For the purpose to study variation of IOP with CCT, the CCT was grouped as low (<516µm), normal (516-556µm) and high (>556µm).

Statistical analysis

To estimate the level of IOP according to different tonometers, the mean and standard deviation of the same were worked out. Comparison of different pair of tonometers was done by estimating the mean difference of IOP between the two tonometers along with standard deviation. Paired t-test was applied to test the significance of difference in the IOP according to two tonometers. Consistency in the IOP according to different tonometers was examined for different levels of CCT and IOP also. Data entry and quality control checks were carried out using MS Excel and all the analyses were carried out using SPSS version20.

Results

Three hundred twenty-six (188 (57%) men and 138(43%) women) consecutive eligible healthy subjects were included in the study. The mean age of participating subjects was 42±13 years (Range 19-74 years). Figure 1 shows the distribution of IOP measured with GAT. The mean and range of IOP obtained with three tonometers is summarized in Table 1. The mean IOP measured with GAT was lower than measured by other two tonometers. The mean CCT of the eyes was 510±29.6 µm (Range 434-597).

There was no statistically significant difference between the IOP measurements by three different tonometers. Table 2 presents the mean difference, level of statistical significance and inter-correlation coefficient correlation (ICC) between measurements in eyes by three different tonometers. When compared to GAT, the measured IOP difference was found to be within ±3 mm Hg in two seventy-six eyes (84.6%; 95% CI: 80.6-88.5%) with RT, and in two eighty-one eyes (86.1%; 95% CI: 82.3-89.8%) with NCT. The IOP difference within ±3 mm Hg between NCT and RT was found in two ninety eyes (88.9%; 95% CI: 85.4-92.3%).

The difference in IOP measurements by different tonometers was significant in relation to a range of CCT (Table 3). The IOP measured by RT and NCT were lower compared to GAT for CCT less than 556 µm. Both the tonometers over-estimated the IOP if CCT was more than 556 µm, however difference was not significant. The RT over-estimated IOP at lower CCT and under-estimated IOP at higher CCT, compared to NCT, but there was no statistically significant difference at any range of CCT (Figure 2)

The difference in IOP measurements by different tonometers in relation to IOP range is shown in table 4. Both NCT and RT significantly under-estimated IOP compared to GAT for IOP less than 18 mm Hg on GAT. The difference was not significant for IOP more than 18 mm Hg. The RT underestimated IOP than NCT if GAT IOP was more than 12 mm Hg, however, difference was not significant (Figure 3).

The Bland-Altmann plots shows agreement between different tonometers (Figure 4).

Table 1: Intra-ocular pressure measured in the eyes by different tonometers

Tonometer	Mean ±SD	Range
GAT	14.51±3.0	8-30
NCT	15.63±3.3	8-38
RT	15.57±3.3	7-38

GAT-Goldmann applanation tonometer, RT-Rebound tonometer, NCT-Non-contact tonometer

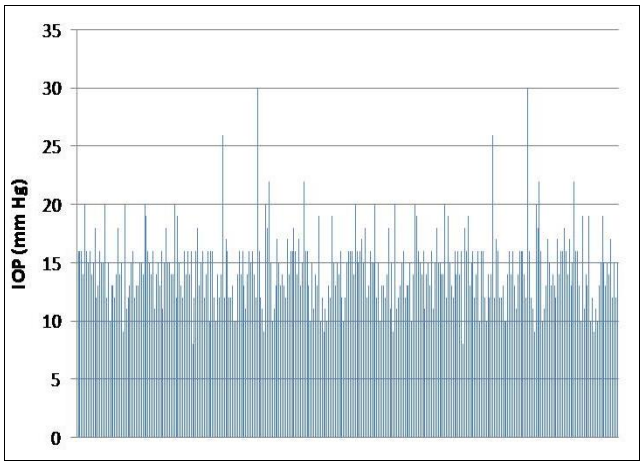

Fig 1: Distribution of IOP measured with Goldman applanation tonometer

Table 2: Comparison of the difference in mean IOP measured by three tonometers

Tonometers	Mean ±SD	p value	ICC (95% CI)
GAT-RT	0.5±3.1	0.5	0.89 (0.86-0.91)
GAT-NCT	0.06±2.7	0.9	0.86 (0.83-0.89)
RT-NCT	-0.44±1.7	0.2	0.88 (0.86-0.91)

GAT-Goldmann applanation tonometer, RT-Rebound tonometer, NCT-Non-contact tonometer; ICC-, CI-Confidence interval

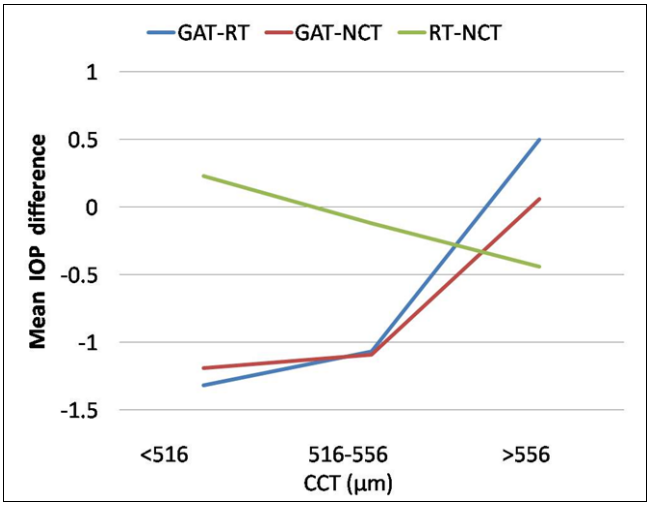

Fig 2: The mean difference of IOP between tonometers in reference to CCT

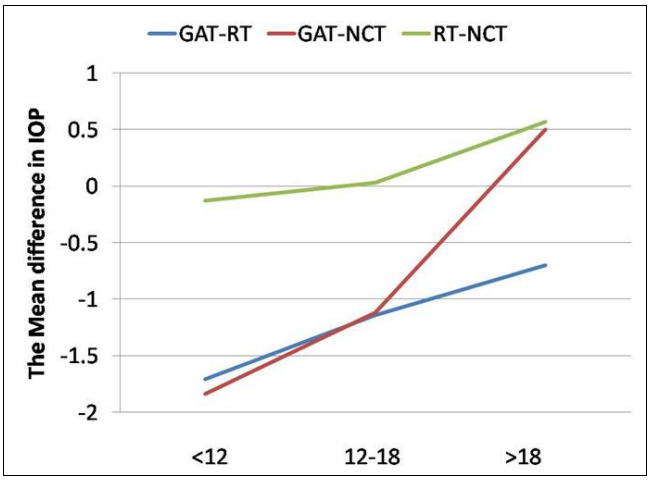

Fig 3: The mean difference in IOP measured with three tonometers over range of IOP

Table 3: Comparison of the mean IOP measured by different tonometers in relation to central corneal thickness

Tonometers	Mean ±SD	p value	ICC (95% CI)
CCT <516			
GAT-RT	-1.32±1.8	0.0	0.87(0.83-0.90)
GAT-NCT	-1.19±2.2	0.0	0.83(0.77-0.85)
RT-NCT	0.23±2.0	0.1	0.86(0.81-0.89)
CCT 516-556			
GAT-RT	-1.07±1.9	0.0	0.84(0.77-0.89)
GAT-NCT	-1.09±2.2	0.0	0.78(0.70-0.85)
RT-NCT	-0.12±2.2	0.5	0.81(0.73-0.86)
CCT >556			
GAT-RT	0.50±3.1	0.5	0.93(0.81-0.97)
GAT-NCT	0.06±2.7	0.9	0.94(0.84-0.97)
RT-NCT	-0.44±1.7	0.2	0.98(0.95-0.99)

GAT-Goldmann applanation tonometer, RT-Rebound tonometer, NCT-Non-contact tonometer; ICC-, CI-Confidence interval; CCT-Central corneal thickness (in µm)

Table 4: Comparison of the mean IOP measured by different tonometers in relation to measured IOP range by GAT

Tonometers	Mean±SD	p value	ICC (95% CI)
IOP <12			
GAT-RT	-1.71±1.8	0.0	0.59(0.26-0.77)
GAT-NCT	-1.84±1.8	0.0	0.44(-0.01-0.69)
RT-NCT	-0.13±1.7	0.6	0.86(0.81-0.89)
IOP 12-18			
GAT-RT	-1.14±1.89	0.0	0.69(0.60-0.76)
GAT-NCT	-1.12±2.20	0.0	0.64(0.54-0.72)
RT-NCT	0.03±2.19	0.8	0.73(0.65-0.79)
IOP>18			
GAT-RT	-0.07±2.9	0.9	0.84(0.67-0.92)
GAT-NCT	0.5±2.4	0.2	0.88(0.75-0.94)
RT-NCT	0.5±1.9	0.1	0.95(0.89-0.97)

GAT-Goldmann applanation tonometer, RT-Rebound tonometer, NCT-Non-contact tonometer; ICC-, CI-Confidence interval; IOP (in mm Hg)

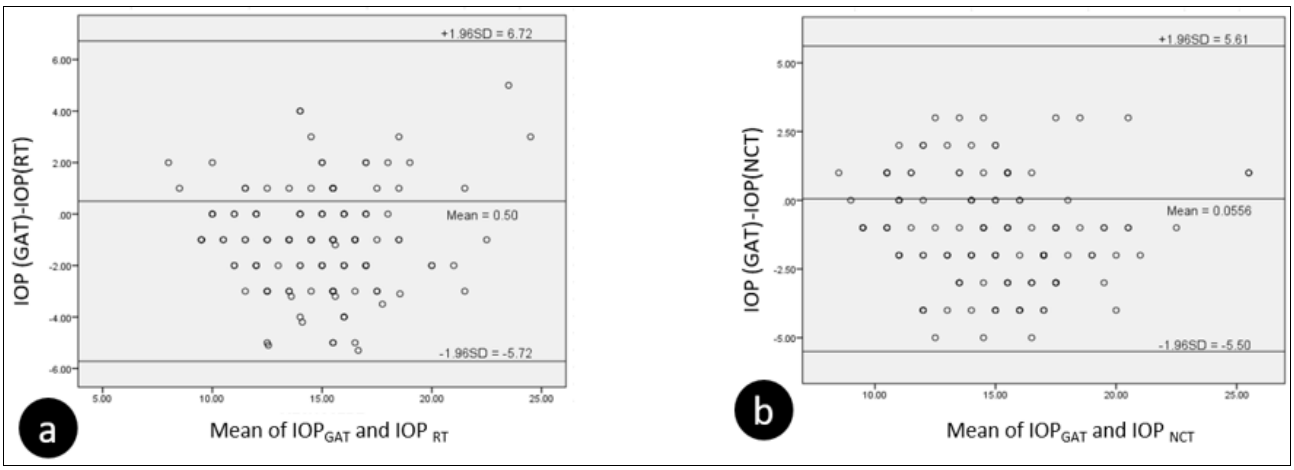

Fig 4: The Bland-Altman plot for correspondence between IOP taken with (a) GAT and RT, and (b) GAT and NCT

Discussion

This study found agreement for IOP measurement with three different tonometers in healthy individuals. The results show any of the tonometer can be used for IOP screening

purpose in clinical practice.

The mean IOP measured in our study subjects was slightly higher with RT and NCT compared to GAT, though difference statistically significant. The findings are consistent with study done by Ouguchi *et al*. [5]. A study by Mohan *et al*. in north Indian population reported lower reading with NCT compared to GAT [6]. This is not consistent with our study results, despite similar population being under study. This could be due to variation in many variables that affect IOP measurement [7].

In this study we found that IOP was slightly underestimated with RT at all range of IOP when compared to GAT, however the difference was not statistically significant. The NCT underestimated IOP at range of IOP <18 mm Hg, where as it overestimated at range higher than 18 mmHg. Similar to our study, a hospital-based study by Chen *et al*., found consistency between three tonometers in low and normal range of IOP and overestimation of IOP with RT and NCT at higher range of IOP [8]. However, in our study we took cut off value for high IOP as IOP >18 mmHg unlike study by Chen *et al*., in which >21 mmHg was taken as high IOP [10]. We preferred 18 mmHg as cut off so that during clinical screening overestimation is not overlooked. We prefer to subject all patients with IOP >18 mmHg for confirmation with GAT in our clinical practice. This observation has been reported by some other studies also [9-11].

Some studies have found overestimation of IOP with RT, while other have found underestimation [12, 13]. Interestingly, use of topical anaesthesia has been suggested to influence IOP measurement with RT [13]. The agreement of IOP measurement at low IOP range (≤12 mmHg) was poor for NCT and GAT, whereas it was moderate for RT and GAT in our study. This finding along with overestimation at higher range indicate that RT and NCT are best used IOP range within “teens”.

The association between IOP and CCT has been reported by various studies [14, 15]. All tonometers compared in our study were affected by CCT [16, 17]. In our study, at lower range of CCT, both RT and NCT underestimated the IOP compared to GAT. This could also have contributed to underestimation of IOP at lower range of IOP. The clinically acceptable error for IOP estimation is ± 3 mmHg [4, 12]. In our study, according to the Bland -Altman plot, most values of IOP difference were falling within 3 mmHg. However, in some cases difference was up to 5 mm Hg.

The study has some limitations. First the study only included healthy persons. The agreement between three tonometers in persons with glaucoma was not studied. The corneal characteristics are affected in glaucomatous eye, which conversely affect IOP measurement. Secondly, the average age of subjects in this study was in early 40’s, whereas prevalence of glaucoma increases with age.

In conclusion, the study shows that both RT and NCT can be used as screening tools for IOP measurement in clinical practice within a relative range of IOP and CCT.

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