

# Comparison of Three Different Techniques of Intraocular Pressure Measurement by Non-Contact Tonometer, Goldmann Applanation Tonometer and Icare Rebound Tonometer

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**Abstract:** ***Background:** In daily ophthalmic procedures measurement of intraocular pressure is essential for glaucoma screening. Factors such as central corneal thickness and corneal rigidity can influence the accuracy of IOP measurement. The purpose of the study is to evaluate the accuracy and reliability of rebound tonometer, non-contact tonometer and Goldmann applanation tonometer and also to compare their IOP measurements obtained by those with the Goldmann applanation tonometer. **Methods:** In 200 eyes of 101 subjects, the intraocular pressure measurements were sequentially obtained by Topcon-CT800 non-contact tonometer, Goldmann applanation tonometer, iCare IC100 rebound tonometer respectively. Central corneal thickness was measured using SP-300P specular microscope. Pearson correlation and interclass correlation analysis were performed for evaluating the IOP measurement agreement among the tonometers. The influence of CCT on each IOP measurement methods was evaluated by linear regression analysis. **Results:** A significant strong positive correlation of  $p$  value  $<0.001$  was shown between the intraocular pressure measurement with GAT, iCare and NCT. In normal IOP ranges iCare IC100 shows slightly higher agreement with GAT and in higher IOP ranges NCT shows more significant agreement with GAT. Interclass correlation coefficient (ICC) also showed good consistency between the three tonometers. The IOP measurements of NCT, iCare and GAT were significantly correlated with CCT. **Conclusions:** In conclusion iCare IC100, NCT, GAT shows high consistency and reliability in IOP measurements. As a result, without need for a anaesthesia, ease of use, portability and space saving features rebound tonometry is a reliable alternative to Goldmann applanation tonometry and non-contact tonometry.*

**Keywords:** Intraocular pressure, non- contact tonometer, Goldmann applanation tonometer, iCare rebound tonometer, central corneal thickness

## Abbreviations

GAT- Goldmann applanation tonometer, NCT- Non- contact tonometer, iCare- iCare rebound tonometer, IOP-Intraocular pressure, CCT-central corneal thickness, ICC – interclass correlation coefficient, SD – standard deviation

## 1. Introduction

Glaucoma is a leading cause of irreversible blindness in the world. It is often called the “silent thief of sight” because most of its types are typically asymptomatic until there occurs noticeable vision loss.<sup>2</sup> The glaucoma is a group of progressive optic neuropathies characterized by degeneration of retinal ganglion cells and resulting changes in the optic nerve head. Loss of ganglion cells are related to the level of intraocular pressure (IOP), but other factors may also play a role. Reduction of intraocular pressure is the only proven method to treat the disease. Although treatment is usually initiated with ocular hypotensive drops, laser trabeculoplasty and surgery may also be used to slow disease progression.<sup>1</sup> One of the most important steps of routine examination for early diagnosis, follow up and treatment is the accurate measurement of the intraocular pressure.<sup>2</sup>

Intraocular pressure is the fluid pressure of the eye. It is determined by the production and drainage of aqueous humour by the ciliary body and its drainage via trabecular meshwork and uveoscleral outflow.<sup>3</sup> The true IOP inside the eyeball can be measured by inserting a probe in the anterior chamber to measure the manometric pressure. Numerous instruments and tonometers have been created since the 1800s to measure IOP, which have been designed to provide

accurate, reliable, precise, and reproducible measurements of IOP. Each method has advantages, disadvantages, and limits and is influenced by ocular factors, rendering some methods clinically acceptable and practical while others are obsolete. Tonometers are based on different concepts and principles of physics that define how IOP levels are measured and what factors can theoretically influence these readings. The force needed to applanate, indent, and or rebound the surface of the eye is used to estimate and calculate the IOP provided by the numerous tonometers used to date.<sup>5</sup> Most techniques for measuring IOP in clinical use are indirect in that they are based on the eye’s response to an applied force. Clinical measurement of IOP has undergone several technical advances from the initial digital tension measurements, through indentation tonometry, to applanation tonometry non-contact tonometry and rebound tonometry. The current gold standard for the measurement of IOP is the Goldmann applanation tonometer.<sup>4</sup>

The first applanation tonometer was built by Adolph Weber in 1867, which was later improved and used in clinics in 1885 by Alexei Maklalloff. A more modern version of this applanation tonometer was then later proposed by Posner-Inglima in 1967. Most of these early instruments did not gain widespread use because of several limitations, which included measurements subject to various errors, difficulties in using the instrument, non-practicability in a clinical

setting, etc. Hans Goldmann invented GAT in 1948, and to this date, it remains the gold standard technique for measuring IOP. Although the Imbert-Fick principle assumes that the sphere is thin-walled without rigidity and elasticity, Goldmann was convinced that corneal elastic properties and thickness were not significantly variable among individuals.<sup>5</sup> Central corneal thickness (CCT) is known to affect the accuracy of intraocular pressure (IOP) measurements by applanation tonometry.<sup>5</sup> A thicker cornea requires greater force to applanate and, conversely, a thinner cornea is more easily flattened. A thin cornea is a significant risk factor for the development of glaucoma, and it has yet to be determined whether this is an independent effect or a result of the influence of CCT on IOP measurements. Applanation tonometry can be classified as either contact or non-contact. GAT and Perkins are considered as contact applanation tonometers. Air-puff tonometry and ocular response analyzer are defined as non-contact tonometry (NCT). These NCT instruments generate force by air as opposed to direct contact with the cornea and do not require fluorescein and local topical anesthesia.<sup>5</sup>

Non-contact tonometry seemed to overcome the need for corneal anaesthesia, as well as facilitating the IOP measurement procedure. A series of devices have been marketed and are currently being used in several practices as the default screening test for IOP.<sup>7</sup> The non-contact tonometer is used in the routine patient examination, even though GAT is accepted as the gold standard. NCT was first designed by Zeiss and developed by Grolman in 1972.<sup>6</sup> The non-contact tonometer is useful for screening programs because it can be operated by non-medical personal, it does not absolutely require topical anaesthesia and there is no direct contact between the instrument and the eye. The IOP readings obtained with the non-contact tonometer correlate fairly well with readings taken by Goldmann applanation tonometer, but differences of several millimeters of mercury are not unusual, particularly with pressure higher than the low 20s.<sup>8</sup> Non-contact air-puff tonometry uses a column of air emitted with increasing intensity to applanate the cornea to measure IOP. Sensors and light beams in the instrument are used to regulate the production of air, which is then halted when the cornea is flattened. The IOP measurements, which are based on the force needed to applanate the cornea, are taken by the waveforms of the reflected lights that are analysed by the sensor detectors and converted by the internal algorithm of the instrument.<sup>9</sup> The NCT is assumed to underestimate the actual intraocular pressure in eyes with thinner cornea and to overestimate it in eyes with thicker cornea.<sup>12</sup>

The rebound tonometer has a unique mechanism for measuring intraocular pressure (IOP) and has become popular worldwide due to its ease of use. The most notable advantages are the lack of an air-puff and need for topical anesthesia, ease of operation and transport, and the ability to use it with children. Four rebound tonometers (Icare<sup>®</sup> TA01i, Icare PRO, Icare HOME, and Icare ic100) are currently available for clinical examination.

The detailed mechanism of the rebound tonometer was first described in 1997 by Kontiola. This type of tonometer is still available as Icare<sup>®</sup> TA01i (Helsinki, Finland) released in

2003.<sup>10</sup> The method includes the processing of the rebound movement of a rod probe resulting from its interaction with the eye. Each disposable probe consists of a magnetized steel wire shaft covered with a round plastic tip at the end that minimizes the risk of corneal injury from the probe impact during the acquisition. After pressing the measurement button, the probe hits the eye and bounces back. This movement is detected by a solenoid inside the instrument. Then, the moving magnet induces voltage into the solenoid and the motion parameters of the probe are monitored. The probe bounces faster as the IOP increases and, consequently, the higher the IOP, the shorter the duration of the impact. The software is pre-programmed for six measurements, discarding the highest and lowest IOP readings and calculating the average IOP value from the rest.<sup>7</sup>

The mechanism of this tonometer is superior to that of the Goldmann applanation tonometer (GAT), still regarded as the gold standard tonometer in glaucoma management, because there is no need for topical anaesthesia and staining fluorescein, slit lamp mounting, and unnecessary infection care due to the use of a disposable probe. Additionally, this new tonometer does not require an air-puff compared to the conventional noncontact tonometer; therefore, it can easily be used for children or animals.<sup>10</sup> IOP measurements obtained with this tonometer have also shown to be influenced by central corneal thickness, with higher IOP readings with thicker corneas. This tonometer has been shown to be affected by other biomechanical properties of the cornea, including corneal hysteresis and corneal resistance factor.<sup>11</sup>

The purpose of this study is to evaluate the correlation of the IOP measurements obtained by rebound tonometer and non-contact tonometer to applanation tonometer, and to compare their reliability and consistency with the Goldmann applanation tonometer. Also, to compare the agreement and variability of rebound tonometer, non-contact tonometer and Goldmann applanation tonometer with central corneal thickness.

## 2. Material and Methods

This was a hospital based cross sectional retrospective study carried out at the ophthalmology department of Amrita Institute of Medical Sciences and Research Centre, Kochi. 200 eyes of 101 subjects were included in this study. IOP was measured sequentially with non-contact tonometry applanation tonometry, rebound tonometry and the influence of CCT on each method of measurements was also evaluated. None of the subjects had any history of refractive surgery.

### Study Design

The Intra ocular pressure measurements were obtained by Topcon-CT800 non-contact tonometer, Goldmann applanation tonometer, Icare IC100 rebound tonometer respectively. Central corneal thickness was measured using SP-300P specular microscope.

All patients underwent the following ophthalmic examination on the same day. IOP measurement was

performed on the study eyes in a sitting position using an NCT- iCare- GAT sequence. Initially NCT was performed in each subject with an air puff tonometer (Topcon CT800). GAT was performed with the Goldmann applanation device mounted on a slit lamp biomicroscope. Before acquisition, one drop of proparacaine hydrochloride eye drops was instilled and a fluorescein strip was applied to the inferior conjunctival fornix and measurement were performed. In rebound tonometry, measurements were obtained with an iCare IC100 tonometer. During the iCare tonometry measurement, a disposable multi-user probe was loaded to the device and aligned 4-8 mm perpendicular to the central cornea. Six consecutive measurements were performed, and the software automatically calculate the mean value. The central corneal thickness (CCT) was measured using a SP-300P specular microscope.

**Statistical Analysis**

Pearson correlation analysis, the interclass correlation coefficient were used to assess the correlation and consistency among the IOP measurements provided by each instrument. Pearson correlation coefficient,  $r = 0-0.2$  indicates very weak or no correlation,  $r = 0.2-0.4$  indicates mild correlation,  $r = 0.4-0.6$  indicates moderate correlation,  $r = 0.6-0.8$  indicates good strong correlation, and  $r = 0.8-1.0$  indicates very strong correlation. Interclass correlation coefficient (ICC) ranges usually from 0-1. If  $ICC < 0.2$  indicates poor consistency, 0.2-0.4 indicates general consistency, 0.4-0.6 indicates moderate consistency, 0.6—0.8 indicates strong consistency and 0.8-1 indicate very strong consistency. Simple linear regression analysis was applied to assess the agreement to compare the IOP measurement of non-contact tonometry and rebound tonometry and GAT. Simple linear regression analysis was also used to assess the correlation between CCT and IOP measurements by each tonometer.

**3. Results**

In this study of the 101 participants, 53 were females and 48 males with a mean age range of  $54.19 \pm 21.801(13-91\text{yrs})$ . The mean IOP measured by NCT, iCare and GAT were  $18.4 \pm 4.302$ ,  $17.64 \pm 5.313$ ,  $20.5 \pm 6.004$  respectively. The mean CCT as measured with the specular microscope was  $522.66 \pm 36.23\mu\text{m}$ . No significant difference was found between the IOP measured by three methods.

**Frequencies**

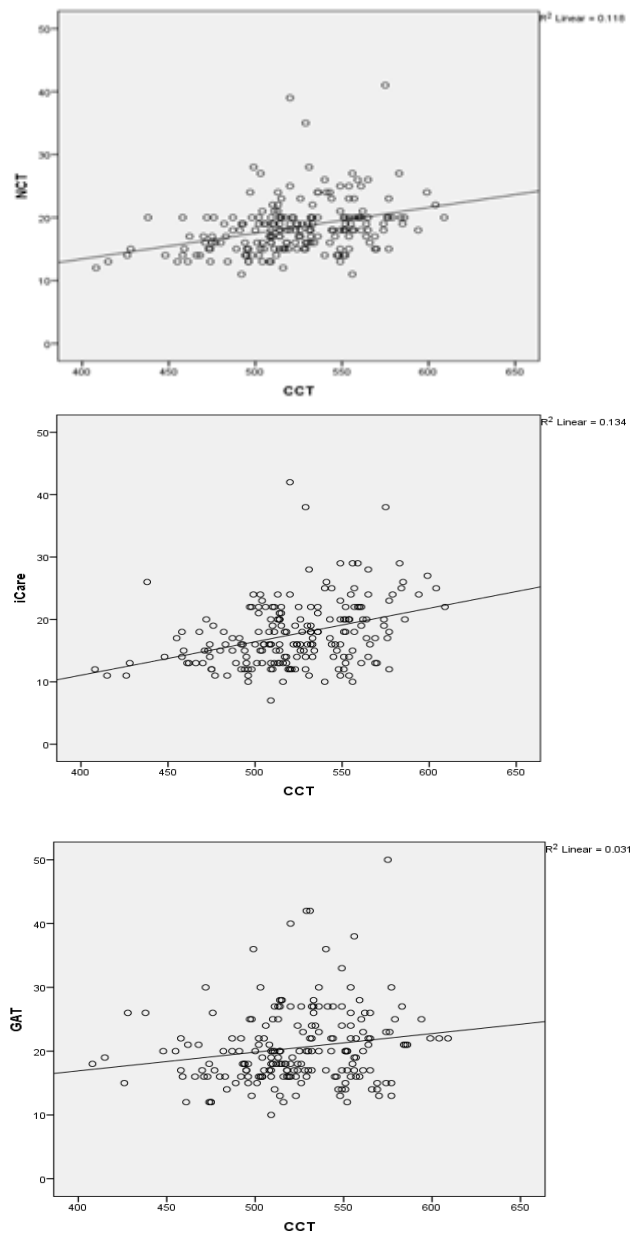
	Frequency	Percentage
M	53	52.5
F	48	47.5
Total	101	100

**Relationship between CCT and three tonometers**

All the three tonometers can be affected by central corneal thickness. In our study IOP measured by NCT GAT and iCare were have significant positive correlation between CCT. iCare seemed to be influenced the most by CCT ( $r^2 = 0.134$ , P value  $< 0.001$ ) followed by NCT ( $r^2 = 0.118$ , p value  $< 0.001$ ) and GAT ( $r^2 = 0.031$ , p value 0.012)

	CCT	NCT	GAT	iCare
Pearson correlation	1	.344	.177	.366
P value		$< 0.001$	0.012	$< 0.001$
N	200	200	200	200

The correlation between CCT and three tonometers



The linear regression analysis between CCT and IOP measured by NCT, iCare and GAT.

**Comparison between NCT iCare and GAT**

A strong significant positive correlation was shown between the IOP values obtained by the NCT GAT and iCare tonometers, also a significant high consistency by interclass correlation coefficient (ICC) was observed between the three tonometers. Pearson correlation and interclass correlation between NCT iCare and GAT.

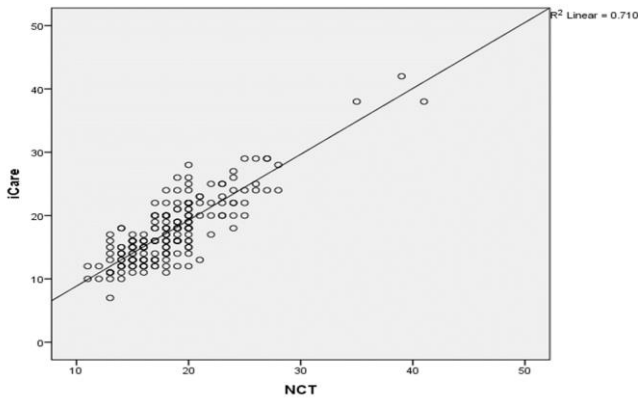
	NCT vs iCare	iCare vs GAT	GAT vs NCT
R	.843	.754	.785
P value	$< 0.001$	$< 0.001$	$< 0.001$
ICC	.904	.856	.853

Correlation is significant at the 0.01 level (2-tailed)

NCT non-contact tonometer, iCare rebound tonometer GAT Goldmann applanation tonometer, r Pearson correlation coefficient, ICC inter class correlation coefficient.

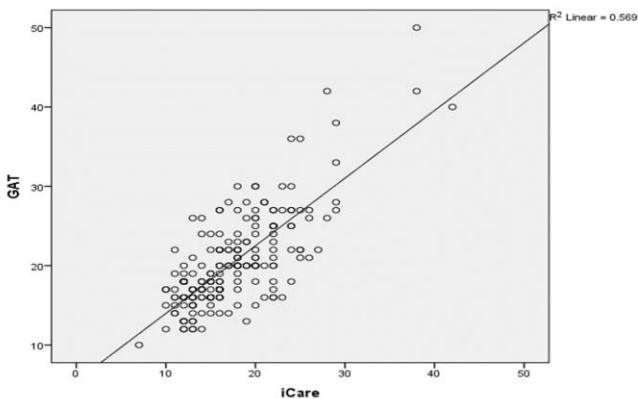
**+NCT vs iCare**

NCT and iCare shows a strong significant positive correlation (Pearson correlation coefficient,  $r = .843$ ,  $p$  value<0.001) and a very strong consistency of interclass correlation coefficient .904(95% CI).



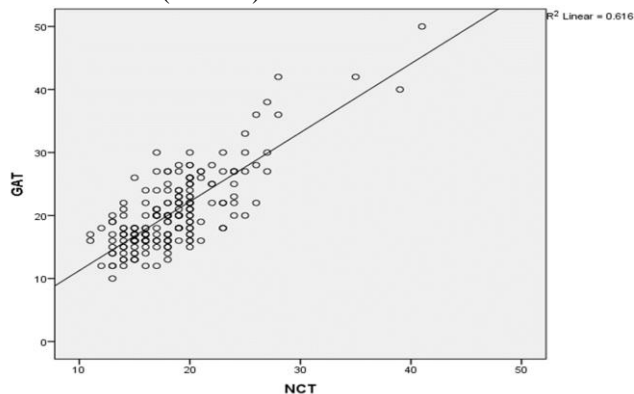
**iCare vs GAT**

iCare and GAT shows a significant positive correlation (Pearson correlation coefficient,  $r = .754$ ,  $p$  value<0.001) and a very strong consistency of interclass correlation coefficient .856 (95% CI).



**NCT vs GAT**

NCT and GAT shows a significant positive correlation (Pearson correlation coefficient,  $r = .785$ ,  $p$  value<0.001) and a very strong consistency of interclass correlation coefficient .853 (95% CI).



	Normal (10-21) mmHg		High IOP ranges (> 21mmHg)	
	NCT vs GAT	iCare vs GAT	NCT vs GAT	iCare vs GAT
r	.437	.522	.770	.690
p	<0.001	<0.001	<0.001	<0.001
icc	.607	.654	.865	.816

In normal IOP ranges iCare shows higher agreement with GAT and in case of higher IOP ranges NCT shows more significant agreement with GAT

**4. Discussion**

Tonometry involves diagnostic testing to measure the pressure inside the eye or intraocular pressure (IOP). Glaucoma is a silent disease that causes irreversible functional peripheral visual field loss that can ultimately lead to blindness in the very late stages of the disease if not treated. Tonometry should be performed during routine ophthalmic examinations to screen for glaucoma and other ocular diseases. An accurate IOP measurement is necessary for ophthalmic evaluation in clinical practice.

Clinical measurement of IOP has undergone several technical advances from initial digital tension measurements, through indentation tonometry, to applanation tonometry and non-contact tonometry. The current gold standard for the measurement of IOP is the Goldmann applanation tonometer. IOP is measured in millimetres of mercury (mm Hg). About 90 percent of people will fall between a pressure range of 10-21 with an average eye pressure is being approximately 15mm Hg with fluctuations of about 2.75mmHg. Elevated intraocular pressure without any glaucomatous changes is ocular hypertension, and IOP below 5mm Hg is termed as ocular hypotony.

In this study we compared the IOP measurements obtained by three methods, NCT, GAT, iCare and confirmed significant correlations and consistency between the IOP measurements. In our study we selected 200 eyes of 101 subjects, measurements performed with the NCT and iCare were in good agreement with the GAT, no significant difference was found in tonometric measurements using non-contact tonometer iCare rebound tonometer and Goldmann applanation tonometer. We didn't made any categorization in subjects with age or IOP level, we evaluated both glaucomatous and non-glaucomatous subjects, we found that non-contact tonometer iCare rebound tonometer and Goldmann applanation tonometer have strong positive correlation ( $p$  value<0.001) with each other and in reliability it poses high consistency among each other. In normal IOP ranges (10-21mm Hg) iCare shows slightly high agreement with GAT and high IOP measurements NCT poses more significant agreement with GAT.

In a study by Goktug Demirci, Sevil Karaman Erdur, Cafer Tanriverdi, Gokhan Gulkilik, and Mustafa Ozsutcu, they selected 180 eyes of 90 healthy subjects. According to the subject's age, the eyes were categorized into three groups: group 1 (age: 7-17 years), group 2 (age: 18-40 years), and group 3 (age: 41-75 years). In their results, the mean corneal thickness was significantly higher in group 1 compared with groups 2 and 3. Non-contact air puff tonometry was significantly higher than both Goldmann applanation

tonometry and rebound tonometry measurements in all groups. No statistical difference between Goldmann applanation tonometry and rebound tonometry measurements was found in group 1, group 2 and group 3. There was a significant positive correlation in the meaning of intraocular pressure measurements between rebound tonometry and non-contact airpuff tonometry; non-contact air puff tonometry and Goldmann applanation tonometry; and Goldmann applanation tonometry and rebound tonometry in all groups.

In a similar study in Chen, Lina Zhang, Jia Xu, Xinyi Chen, Yuxiang Gu, Yuping Ren & Kaijun Wang, they recruited 200 subjects. They categorized the subjects in to 4 different groups, group 1; (IOP<10mm Hg) group 2; (10-21 mmHg) group 3(22-30mmHg) and group 4; (IOP>30mmHg). No significant difference was found between the IOP measured by three methods in IOP < 10 mmHg, IOP 10–21 mmHg, and IOP > 30 mmHg groups. In IOP 22–30 mmHg group, there were significant difference between the three methods. The IOP value measured by NCT was significantly higher than iCare and GAT. However, there was no significant difference in IOP values measure by iCare and GAT.

In another study by Jose M. Martinez-de-la Casa, Maria Jimenez -Santos, Federico Saenz- Frances, Maria Matilla-Rodero, Carmen Mendez-Hernandez, Rocio Herrero-Vanrell, Julian Garcia-Feijoo, their sample was comprised of 108eyes of 108 subjects. In their results a difference with respect to GAT under  $\pm 1$  mmHg was observed in 11.1% of the eyes measured by NCT and 18.5% of eyes measured by RBT. According to the IOP ranges established by the ISO 8612, differences from GAT measurements greater than  $\pm 5$  mmHg were always above the accepted level of 5%. Correlations between IOP and central corneal thickness (CCT) were significant for all three tonometers.

## 5. Conclusion

In conclusion iCare 1C100 and NCT shows high consistency and reliability with GAT in IOP measurements. In normal IOP ranges iCare shows more agreement with GAT and in high IOP ranges NCT is more significant with GAT. As a result, NCT and iCare can be used as alternative to GAT. Without need of anaesthesia, ease of use, portability, and space saving features, rebound tonometry is a good alternative to Goldmann applanation tonometry.

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