



Original Research Article

Comparison of intra-ocular pressure measurement with four different methods of tonometry

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ABSTRACT

Aim: The aim of this study was to measure the intraocular pressure (IOP) by Perkins hand held tonometer, non contact tonometer(NCT) and rebound tonometer with the Gold standard GAT and to analyse their correlation with varied CCT.

Materials and Methods: Cross-sectional, hospital- based study that included 200 patients from the glaucoma department. After complete eye evaluation, the IOP measurement was performed sequentially in the same order- NCT, RT, Perkin's and GAT. CCT was then measured for all the patients. The intra-ocular pressure within the eyes was compared by paired "t" test and between the right and left eyes were compared by the independent "t" test.

Results: Mean age of the patients was 54.5±13.5 years. The mean IOP of Right and Left eyes measured with GAT were 15.9±6.2 and 16.3±7.0 mm/Hg, that with Perkins were 15.7±6.2 and 16.3±7.0 mm/Hg respectively. Both eyes' mean IOP were 15.4±6.7 and 15.9±7.4 mm/Hg by Icare. The mean IOP measured by NCT were 16.4±6.7 and 16.9±8.0 mm/Hg. The mean CCT of right eye was 528.9± 29.6 and left eye was 530.6±29.6 microns. All the four instruments namely GAT, Perkin's, Icare ic100 and NCT were influenced by CCT.

Conclusions: IOP remains the only alterable factor in the management of glaucoma patients. Numerous methods have been devised to measure IOP accurately. The IOP measured with Perkin's, NCT and Icare are comparable but GAT remains the gold standard.

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1. Introduction

Glaucoma is the leading cause of irreversible blindness worldwide and is second only to cataract as the most common cause of blindness overall.¹ Glaucoma describes a group of ocular disorders of multifactorial aetiology, characterized by progressive loss of retinal ganglion cells, which leads to structural damage to optic nerve head, retinal nerve fibre layer and consequent visual field defects.^{2,3} Although it no longer forms part of the definition, elevated intraocular pressure (IOP) is the principal modifiable risk factor for the development and progression of the disease⁴ and forms the mainstay of treatment. Thus, the

need for accurate measurement of IOP cannot be over-emphasised.

Although, the Goldmann applanation tonometer (GAT) is considered the 'gold standard' for measuring IOP in the clinical setting for several decades, some limitations associated with the instrument including the influence of central corneal thickness (CCT) on IOP readings, use of anaesthetic drops and fluorescein dye, difficulty in irregular corneal surface, non-utility for patients who cannot be examined by slit-lamp biomicroscope, recently there has been a growing interest in developing new technology to measure a more accurate IOP.^{5,6}

Based on Imbert Fick law, GAT assesses the intra-ocular pressure by measuring the force necessary to appanate a fixed area of cornea.⁷ The Perkins tonometer works on

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the same principle as the Goldmann with the advantage of being hand-held, portable and does not require a slit lamp, allowing measurement in supine patient also. Noncontact tonometer (NCT) has a pneumatic system that generates a puff of air directed against the cornea and a detector device that estimates the IOP based on reflections from flattened cornea. NCT has the advantage of elimination of risk of cross-infection or abrasion of cornea. Rebound tonometer (RT) measures intraocular pressure by bouncing a small plastic tipped metal probe against the cornea. As the probe bounces against the cornea and back into the device, it creates an induction current from which the IOP is calculated. Easy to handle, does not require anaesthetic drops it is particularly suitable for children and non-cooperative patients.⁸ As already established in various studies, thickness of cornea affects IOP measurement.⁹

The aim of this study was to compare the IOP measured by Perkins, NCT and rebound tonometer with the Gold standard GAT and to analyse their correlation with varied CCT.

2. Materials and Methods

This was a cross-sectional, non-interventional hospital-based study conducted in the Glaucoma department of a tertiary eye centre. Total of 200 patients were enrolled in this study from December 2018 to February 2019 selected by convenience sampling method. Based on detailed explanation of the procedures, the patients were voluntarily recruited after taking consent. All measurements were taken between the office hours.

Both eyes of the patient were included for the study. Patients more than 18 years of age, male or female presenting to the Glaucoma department for routine eye check-up of IOP, suspected Glaucoma patients or patients coming for cataract surgery were included. Exclusion criteria were patients with corneal pathology, patients with ocular infection/ inflammation or with history of ocular trauma, patients with high refractive errors (> 3 D astigmatism), single eyed patients and uncooperative patients.

The selected patients underwent thorough ophthalmic examination including careful and complete history, refraction, slit-lamp bio microscopy and then IOP measurement. Appropriately calibrated tonometers were used. The IOP measurement was performed sequentially in the same order- NCT, RT, Perkin's and GAT. CCT was then measured for all the patients.

For NCT (NCT- 200, Nippon, Japan) the patient was seated on a chair and asked to look straight. Cornea was aligned by superimposing the reflection of the target from the patient's cornea on a stationary ring. An air puff was automatically triggered when the alignment was satisfactory. The software gave average reading of the IOP. For RT (Icare ic100) patient was asked to look straight

ahead to distance while the tonometer was brought near patient's eye. Tip of the probe was positioned in front of central cornea at a distance of 4-8 mm for measurement. RT software is programmed for 6 readings and automatically gives average IOP value. For Perkin's eye was anaesthetized with Proparacaine (0.5%) and sterile strip of fluorescein was applied to the inferior conjunctival fornix. With the patient in sitting position looking at distance, tip of the Perkin's probe (MK3 tonometer, Haag Streit) was brought into gentle contact with the centre of cornea. The fluorescein semicircles were viewed and the calibration dial was adjusted till the inner edges overlapped and the value was noted. After 10 minutes, eye was again anaesthetized and fluorescein strip applied. GAT (Haag Streit), mounted on the slit lamp was done using cobalt blue filter of biomicroscope to view the semicircles. The point where the inner edge met was the end point. Three readings were taken and the average of IOP was taken for analysis. Bias was controlled by applying standardized technique and by masking the result obtained by other tonometer to the consultant doctor GAT. The IOP readings were divided into three groups- < 12 mmHg, 12-21 mmHg, > 21 mmHg.

CCT of the patients were measured with ultrasonography (Pocket 2 Quantel Medical, France). It was repeated five times. The pachymeter automatically calculated the mean CCT (with SD < 5, was taken for the study). Patients were divided into three groups according to CCT-group 1- comprised patients with CCT <520 microns, group 2- included patients with CCT between 520-570 microns and group 3- comprised patients with CCT > 570 microns.

2.1. Statistical analysis and interpretations

The study subjects' demographical variables were described in terms of averages and percentages. The intra-ocular pressure within the eyes was compared by paired "t" test and between the right and left eyes were compared by the independent "t" test. The IOP of both eyes measured with Perkins, Icare and NCT were compared with GAT and CCT values were tested for the significance by "Z" test of proportions. The above statistical procedures were performed with the help of the statistical package namely IBM SPSS statistics-20. The p- values less than or equal to 0.05 ($P \leq 0.05$) were treated as statistically significant.

3. Results

Description of demographic profile:

The mean age of the subjects was 54.5 ± 13.5 years. The mean age of males being 55.9 ± 14.0 years and the females 51.3 ± 12.1 years.

3.1. Intra ocular pressures (IOP) within the eyes

The IOP measured with GAT and Perkins did not differ statistically ($p > 0.05$) whereas it was statistically significant

Table 1: Description of subject's age and gender

Ages (years)	Males		Females		Total	
	No	%	No	%	No	%
20-59	71	35.5	46	23.0	117	58.5
60+	61	30.5	22	11.0	83	41.5
Total	132	66.0	68	34.0	200	100.0
Mean \pm SD	55.9 \pm 14.0		51.3 \pm 12.1		54.4 \pm 13.5 Range=85-20= 65	
Significance	t=2.306, df=198, P=0.022					

Table 2: Comparison of IOP of right eyes with GAT and others:

Variables	Gold Std	Others		Difference		“t”	df	Sig
		Mean	SD	Mean	SD			
Gold	Others	Mean	SD	Mean	SD	Mean	SD	
GAT	Perkins	15.9	6.2	15.7	6.2	0.2	0.8	1.871
GAT	Icare	15.9	6.2	15.4	6.7	0.5	1.7	3.774
GAT	NCT	15.9	6.2	16.4	6.7	0.5	2.2	3.803

Table 3: Comparison of IOP of left eyes with GAT and others:

Variables	Gold Std	Others		Difference		“t”	df	Sig
		Mean	SD	Mean	SD			
Gold	Others	Mean	SD	Mean	SD	Mean	SD	
GAT	Perkins	16.3	7.0	16.3	7.0	0.05	0.7	0.913
GAT	Icare	16.3	7.0	15.9	7.4	0.4	1.6	3.877
GAT	NCT	16.3	7.0	16.9	8.0	0.6	2.1	3.984

when compared with Icare and NCT ($p < 0.001$).

3.2. Similar results in left eye

IOP between right and left eyes by four methods. The mean IOP of Right and Left eyes measured with GAT were 15.9 \pm 6.2 and 16.3 \pm 7.0 mm/Hg, that with Perkins were 15.7 \pm 6.2 and 16.3 \pm 7.0 mm/Hg respectively. Both eyes' mean IOP were 15.4 \pm 6.7 and 15.9 \pm 7.4 mm/Hg by Icare. The mean IOP measured by NCT were 16.4 \pm 6.7 and 16.9 \pm 8.0 mm/Hg.

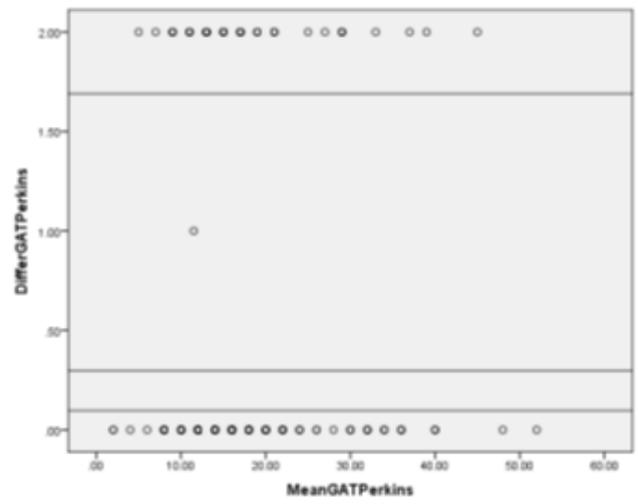
The mean CCT of right eye was 528.9 \pm 29.6 and left eye was 530.6 \pm 29.6 microns. The difference between the means were not statistically significant ($P > 0.05$).

Table 5 states the relationship of CCT with GAT, Perkins, Icare and NCT. The GAT and Perkins did not have any statistically significant relation with CCT ($P > 0.05$). The CCT positively correlated with Icare and NCT. The CCT determined 3.2% of Icare and 3.5% NCT ($p < 0.05$).

The Table 6 states the relationship of CCT with GAT, Perkins, Icare and NCT of left eyes. There were no statistically significant relationships between them in respect of left eyes ($P > 0.05$).

4. Discussion

Glaucoma affects more than 70 million people worldwide with approximately 10% being bilaterally blind, making it the leading cause of irreversible blindness in the world,¹⁰ still, the biological basis of glaucoma is poorly understood and the factors contributing to its progression have not

**Fig. 1:** Agreement between GAT and Perkin's

been fully characterized. Reduction of intraocular pressure is the only proven method to halt glaucoma. Results from several multi-centre “land-mark” clinical trials^{11–14} have demonstrated the benefit of lowering intraocular pressure in preventing the development and slowing the disease's progression.

Accurate measurement of IOP is imperative in the management of glaucoma. GAT, considered the gold standard technique, is the method used by the majority of ophthalmologists. It has proved to be accurate and shows low intra- and interobserver variability.¹⁵ Limitation of

Table 4: Comparison of IOP between the right and left eyes

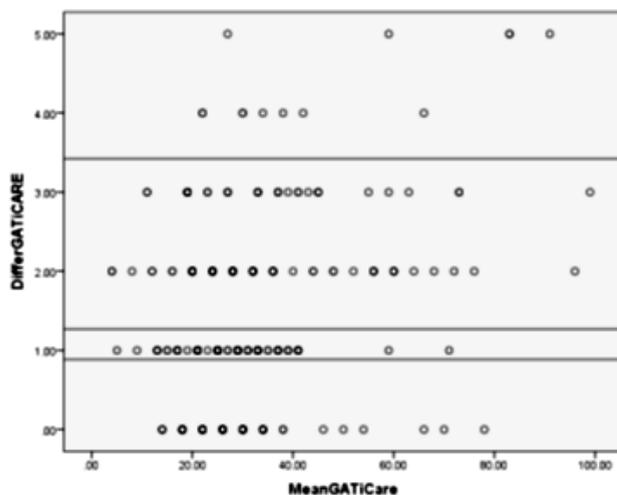
Variables	Right Eyes		Left eyes		Difference b/w means	“t”	df	Sig
	Mean	SD	Mean	SD				
GAT	15.9	6.2	16.3	7.0	0.4	0.714	398	P=0.476
Perkins	15.7	6.2	16.3	7.0	0.6	0.808	398	P=0.808
Icare	15.4	6.7	15.9	7.4	0.5	0.682	398	P=0.682
NCT	16.4	6.7	16.9	8.0	0.5	0.640	398	P=0.523
CCT	528.9	29.6	530.6	29.6	1.7	0.591	398	P=0.555

Table 5: Correlation between tonometry measured IOP with CCT in Rt eyes:

Variables		“r”	Significance	r ²	% of Determination
CCT	GAT	0.030	P=0.678	-	-
	Perkins	0.034	P=0.628	-	-
	Icare	0.178	P=0.017	0.032	CCT determined 3.2%
	NCT	0.188	P=0.007	0.035	CCT determined 3.5%

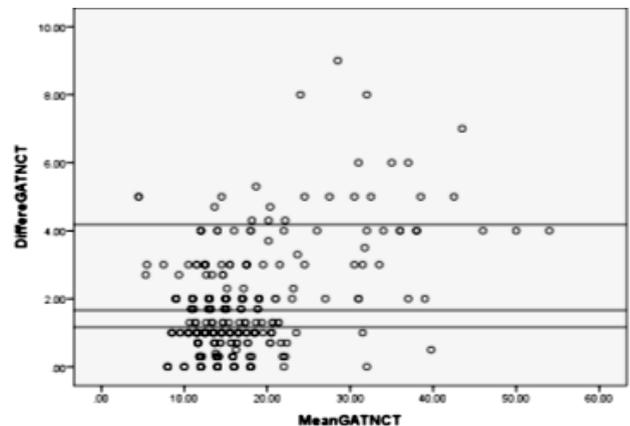
Table 6: Correlation between tonometry measured IOP with CCT in Lt eyes:

Variables		“r”	Significance	r ²	% of Determination
CCT	GAT	-0.027	P=0.708	-	-
	Perkins	-0.019	P=0.791	-	-
	Icare	-0.101	P=0.156	-	-
	NCT	0.084	P=0.094	-	-

**Fig. 2:** Agreement between GAT and Icare

GAT to use topical anaesthetic drops and fluorescein dye which is difficult in cases of children and un-cooperative patients, requirement of slit-lamp and inability to measure IOP in supine position has led to the emergence of other techniques of IOP evaluation. The present study is undertaken to compare the IOP measured by Perkins's, Non-contact tonometer and Rebound tonometer with that of GAT.

The mean age of patients in our study was 54.5 years. Males constituted 66% of the study population whereas females 34%.

**Fig. 3:** Agreement between GAT and NCT

The Perkins applanation tonometer works on the same principal of Imbert-Fick law as GAT. It is a portable and handheld tonometer. It has the advantage of being easily transported for screening examinations and can be especially used for those patients for whom the use of a chin rest proves difficult or for determination of IOP in supine position. In our study, the mean IOP of the right eye and the left eye as measured with GAT were 15.9 and 16.3 mmHg, with that of Perkins were 15.7 and 16.3 mmHg respectively. The SD of right eye as measured with GAT and Perkins's was 6.2 and in left eye was 7 mmHg. The mean IOP obtained with Perkins's did not differ with that of GAT significantly (p=0.063 in RE and p= 0.362 in LE). The IOP value varied from 4 mmHg to 52 mmHg in our study group. We divided

the IOP readings into groups of three- <12 mmHg, 12-21, > 21 mmHg. In all the three groups, IOP measured with Perkin's was in close agreement with GAT. This was like the study done by J Leng et al.,¹⁶ Arora et al.,¹⁷ Eriksson et al.,¹⁸

Icare ic100 is the latest addition to the family of rebound tonometer. It is a hand-held, portable device with particular advantage of not requiring anaesthetic drops and is useful in cases of screening, paediatric age group and also in patients in whom chin rest is difficult. The mean IOP of right eye and left eye with Icare ic100 were 15.4 and 15.9 mmHg. The SD of right eye was 6.7 and left eye was 7.4. The IOP measured with Icare ic100 differed with that of GAT significantly ($p < 0.05$). The mean difference in right eye was 0.5 +1.7 and in left eye was 0.4 +1.6. The IOP obtained from Icare ic100 was comparable but slightly on the lower side as compared to GAT in the normal range of pressure (10-21 mmHg) but varied considerably at extremes of IOP (<10 mmHg and >24 mmHg) similar to the studies done by Benny W et al.,¹⁹ Nakakura S et al.,²⁰ For IOPs more than 30 mmHg, the difference between GAT and RT ranged from 1- 5 mmHg. For IOPs less than 10 mmHg difference was 1-3 mmHg.

Non-contact tonometer is a quick method of IOP measurement, requiring less skill especially useful for screening and in post-operative cases. The mean IOP measured by NCT in our study in the right and left eye were 16.4 and 16.9 mmHg. The SD in right eye was 6.7 and left eye was 8.0. The overall difference of IOP measurement between GAT and NCT was statistically significant (<0.05). The IOP measured in the range of 10-21 mmHg correlated well with that of GAT. Both in cases of low IOP (<10 mmHg) and high IOP (>24 mmHg) variation between GAT and NCT was noted. Various other studies such as those done by Tonnu et al.,²¹ Chakrabarty L.,²² Moseley et al.,²³ Lawson Kopp et al.,²⁴ also concluded that NCT is a valuable tool for screening but reliability decreases in outside normal range of IOP. Most studies showed NCT overestimates IOP in higher range and underestimates at lower range.²¹⁻²³ In our study, NCT overestimated IOP in either extremes. For IOP <10 mmHg it varied by 1-2 mmHg and for >24 mmHg the range was in between 2-5 mmHg. The overestimation of IOP in lower range was also noted by Chakrabarty L.²²

The mean CCT of right eye was 528.9 ± 29.6 micron meters and that of left eye was 530.6 ± 29.6 micron meters. All the four instruments namely GAT, Perkin's, Icare ic100 and NCT were influenced by CCT but values positively correlated for Icare ic100 ($r^2=0.032$) and NCT ($r^2=0.035$). This was well in accordance to various published articles.^{21,25,26}

Limitation of the study was we could not keep into consideration other factors such as corneal curvature, axial length, use of anti-glaucoma /steroid eye drops or systemic conditions such as Diabetes that may have influenced the CCT.

5. Conclusion

The IOP measurement obtained by Perkin's is in close agreement with that of GAT at all ranges of pressure. Rebound tonometer and NCT are fair tool for screening purposes in community practices especially paediatric population but their reliability decreases outside the normal range of pressures. Hence, they can be an aid but cannot replace GAT at present.

6. Source of Funding

Nil.

7. Conflict of Interest

Nil.

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