COMPARISON OF INTRAOCULAR PRESSURE MEASUREMENT WITH NON-CONTACT TONOMETRY AND APPLANATION TONOMETRY AMONG VARIOUS CENTRAL CORNEAL THICKNESS GROUPS

Radhakrishnan B[1], Hemapriya S[2], Nazeem Farzana Ghouse[3], Aparna Rajagopalan[4]

[1]Professor and HOD, Department of Ophthalmology, Government Stanley Medical College and Hospital, Chennai.
[2]Assistant Professor, Department of Ophthalmology, Government Stanley Medical College and Hospital, Chennai.
[3]Postgraduate Student, Department of Ophthalmology, Government Stanley Medical College and Hospital, Chennai.
[4]Postgraduate Student, Department of Ophthalmology, Government Stanley Medical College and Hospital, Chennai.

ABSTRACT

BACKGROUND

Glaucoma is the second leading cause of blindness worldwide. Intraocular Pressure (IOP) is the only known modifiable risk factor that has been shown to delay progression in both ocular hypertension and glaucoma patients. Clinical measurement of IOP has undergone several technical advances from the initial digital tension measurements, through indentation tonometry, to applanation tonometry and non-contact tonometry. This study was done to compare the intraocular pressure (IOP) measurements with Non Contact Tonometry (NCT) and Goldmann Applanation tonometry (GAT) and to compare NCT IOP and GAT IOP among various central corneal thickness (CCT) groups.

MATERIALS AND METHODS

IOP measurements were done by NCT and then by GAT followed by CCT. All IOP readings were taken in the sitting position over fifteen minutes. NCT was performed before the GAT to avoid the known mild reduction of IOP by anterior chamber compression with GAT.

RESULTS

The study included 200 eyes of 100 patients. Mean age of the patients was 58.14 ± 11.7 years (range 35- 81 years). The study population consisted of 58 males and 42 females. The mean ± SD intraocular pressure measurements were 23.39 ± 4.6 mmHg and 22.41 ± 5.9 mmHg for NCT and GAT, respectively. The difference between the NCT and GAT IOP was 0.98 ± 4.7 mm Hg. Mean CCT of the study group was 545.74 ± 38.23 microns. The IOP measured with both GAT and NCT showed no significant change with increasing CCT. The difference between the means increases with increasing CCT upto 600 microns. At lower IOPs ≤ 20 mm Hg, GAT measures are higher than NCT and this relationship is reversed at high IOPs.

CONCLUSION

Intraocular pressure measurement by NCT was consistently higher than GAT. There was a tendency for NCT to underestimate IOP at lower ranges and overestimates IOP at higher ranges. By applying appropriate correction factor for CCT, Noncontact tonometry could be used as a good screening tool for glaucoma evaluation.

KEYWORDS

Non- Contact Tonometer, Applanation Tonometry, Central Corneal Thickness, IOP, Glaucoma.

HOW TO CITE THIS ARTICLE: Radhakrishnan B, Hemapriya S, Ghouse NF, et al. Comparison of intraocular pressure measurement with non- contact tonometry and applanation tonometry among various central corneal thickness groups. J. Evid. Based Med. Healthc. 2018; 5(6), 531-536. DOI: 10.18410/jebmh/2018/108

BACKGROUND

Glaucoma is the second leading cause of blindness worldwide. Intraocular Pressure (IOP) is the only known modifiable risk factor that has been shown to delay progression in both ocular hypertension and glaucoma patients.

The middle to late 19th century saw several indentation tonometers which measured the amount of indentation of the sclera produced by a given force.

Von Graefe (1863) developed the first instrument to measure IOP. This device measured the eye pressure using a weight-loaded plunger that measured indentation of the sclera.

Donders (1865) invented a spring-loaded scleral indentation tonometer.

Adolph Weber (1867) introduced the first applanation tonometer which was not accepted as late as 1872, as digital palpation was stated to be the best method of determining IOP (Snellen and Landolt).

Financial or Other, Competing Interest: None.
Submission 17-01-2018, Peer Review 21-01-2018,
Acceptance 03-02-2018, Published 05-02-2018.
Corresponding Author:
Dr. Hemapriya S,
#B1, Geetanjali apartments, 282,
Avvai Shanmugam Road (Lloyd's Road),
Gopalapuram, Chennai- 600086.
E-mail: hemapriya.siva@gmail.com
DOI: 10.18410/jebmh/2018/108

Maklakov (1885) introduced the first applanation tonometer in which IOP was measured by flattening a variable area of cornea by a known weight.

Imbert (1885) and Fick (1888) developed the principle on which modern applanation tonometers are based.[1]

Goldman (1954) introduced the applanation tonometer, the 'constant corneal area' applanation method.[1]

Grolman (1972) introduced the prototype non contact tonometer while Grant combined the concept of schiotz tonometry with continuous electronic monitoring to create the electronic Indentation tonometer. Handheld tonometers were designed by Halberg (1967) as refinements of the Maklakov and Posner (1964) tonometer.[1]

Clinical measurement of IOP has undergone several technical advances from the initial digital tension measurements, through indentation tonometry, to applanation tonometry and non-contact tonometry. Although there are various instruments available for IOP measurement, Goldmann applanation tonometer (GAT) is still considered to be the 'gold standard'.

This study was done to compare the intraocular pressure (IOP) measurements with Non Contact Tonometry (NCT) and Goldmann Applanation tonometry (GAT) and to compare NCT IOP and GAT IOP among various central corneal thickness (CCT) groups.

Aims and Objectives- This study was done

1. To compare the intraocular pressure (IOP) measurements with Non Contact Tonometry (NCT) and Goldmann Applanation tonometry (GAT) and
2. To compare NCT IOP and GAT IOP among various central corneal thickness (CCT) groups.

Inclusion Criteria

- Age above 30 years
- IOP within 10-50 mm Hg measured by NCT
- Astigmatism ≤3D cylinder.

Exclusion Criteria

- Known Glaucoma patient
- Previous history of ocular surgery
- Corneal pathology.

MATERIALS AND METHODS

This study comprised of two hundred eyes of 100 patients aged between 35-81 years. A cross sectional, observational study was done over a period of 1 year.

After getting informed consent, participants underwent a complete ophthalmic examination including visual acuity using Snellen's chart, refraction, slit lamp examination, IOP and CCT measurement.

IOP measurements were done by NCT and then by GAT followed by CCT. All IOP readings were taken in the sitting position over fifteen minutes. NCT was performed before the GAT to avoid the known mild reduction of IOP by anterior chamber compression with GAT.[2,3]

Noncontact Tonometry- An average of three readings of IOP measured using non contact tonometer was taken.

Goldmann Applanation Tonometer- After instillation of topical proparacaine drops, fluorescein strip was applied to the respective eye and IOP was recorded using Goldmann applanation tonometer mounted on a slit lamp. The first GAT measurement recorded was taken. All GAT measurements were taken by the same ophthalmologist.

Central Corneal Thickness- CCT was measured with the help of a pachymeter and an average of 5 readings were noted

The data was compiled on a Microsoft Excel spreadsheet and the statistical analysis was done using SPSS version 16.0.

Descriptive analysis including mean values and standard deviation were performed.

The chi square test was applied to compare the proportions between the groups.

The paired t-test was used to find the statistical significance between the methods of same group of patients. To compare more than two groups of means the analysis of variance (ANOVA) was employed. To examine the linear relationship among the methods the Pearson correlation coefficient (r) was computed.

All analyses were two tailed and p <0.05 was considered for statistical significance.

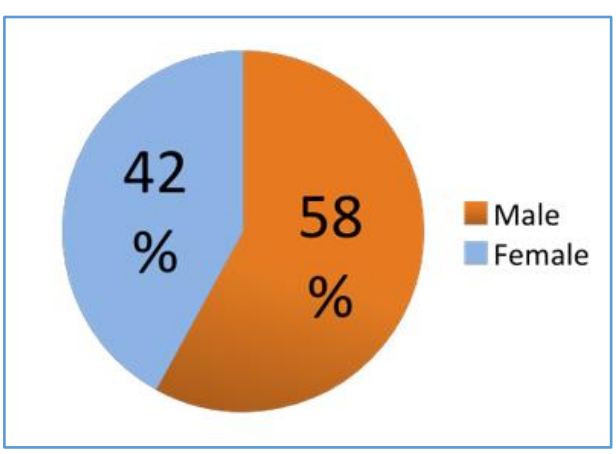
The Bland and Altman graph was done by considering average value of the two method in the X-axis and the value of difference between the method on Y-axis.

RESULTS

The study included 200 eyes of 100 patients. Mean age of the patients was 58.14 ± 11.7 years (range 35- 81 years).

The study population consisted of 58 males and 42 females.

Sex Distribution of the Study Population



Graph 1. Sex Distribution of the Study Population

	Mean ± SD	Median (Range)
Age (Years)	58.14 ± 11.6	58 (35-81)
Gender		
Male	58.57 ± 11.13	60 (37-81)
Female	57.55 ± 12.28	56 (35-79)
GAT (mm Hg)	22.41 ± 5.9	22.00 (12-47)
NCT (mm Hg)	23.39 ± 4.6	23.00 (12-47)
Difference of GAT- NCT	-0.98 ± 4.7	-1 (-14 to +14)
CCT (microns)	545.74 ± 38.23	546 (460- 633)

Table 1. Demographic Characteristics and Summary Statistics

GAT- Goldmann Applanation Tonometer; NCT- Noncontact Tonometer; SD- Standard deviation; CCT- Central Corneal Thickness.

The mean ± SD intraocular pressure measurements were 23.39 ± 4.6 mmHg and 22.41 ± 5.9 mmHg for NCT and GAT, respectively (p=0.004).

The difference between the NCT and GAT IOP was 0.98 ± 4.7 mm Hg (p=0.265).

Mean CCT of the study group was 545.74 ± 38.23 microns.

The mean GAT and NCT measured IOP stratified into 4 different CCT categories (CCT ≤ 500 microns, 501- 550 microns, 551-600 microns, >600 microns) are shown below-

CCT Groups (Microns)	≤ 500 (n = 26)	501- 550 (n= 84)	551- 600 (n= 77)	>600 (n = 13)	P Value
GAT (mm Hg)					0.265
Mean (SD)	21.38 (5.6)	23.33 (6.5)	21.99 (5.6)	21 (3.1)	
Median (Range)	20 (12-30)	22 (12-52)	22 (14-40)	20 (16-26)	
NCT (mm Hg)					0.107
Mean (SD)	21.77 (3.6)	24.14 (5.1)	23.32 (4.7)	22.23 (1.8)	
Median (Range)	22 (16-30)	23 (12-46)	22 (16-47)	22 (18-26)	
GAT-NCT (mm Hg)					0.809
Mean (SD)	-0.38 (6.9)	-0.81 (5)	-1.33 (3.8)	-1.23 (2.3)	
Median (Range)	-1 (-14 to 14)	-1 (-14 to 12)	-1 (-13 to 7)	-2 (-5 to 3)	

Table 2. Comparison for Goldmann Applanation Tonometry (GAT), Non Contact Tonometry (NCT) and GAT minus NCT among Central Corneal Thickness (CCT) groups

The IOP measured with both GAT (p=0.265) and NCT (p=0.107) showed no significant change with increasing CCT.

Although mean and median GAT IOP was lower than the NCT IOP across all CCT groups, the difference between the means increases with increasing CCT upto 600 microns (p=0.809).

NCT Levels (mm Hg)	≤ 20 (n= 41)	21- 30 (n = 145)	>30 (n = 14)	P value
GAT (mm Hg)				0.265
Mean (SD)	20.56 (3.7)	21.80 (3.7)	34.14 (8.8)	
Median (range)	20 (14-30)	22 (12-34)	36 (20-52)	
GAT-NCT (mm Hg)				0.809
Mean (SD)	1.97 (3.9)	-1.74 (4.35)	-1.72 (7.6)	
Median (range)	2 (-5 – 14)	-2 (-14 – 12)	0.5 (-14 – 6)	

Table 3. Comparison for Goldmann Applanation Tonometer (GAT) and GAT minus Noncontact Tonometry (NCT) among NCT Groups

The difference in GAT and NCT IOP were also analysed with respect to IOP levels (≤ 20, 21-30, > 30 mm Hg) determined by NCT as shown in Table 3.

At lower IOPs ≤ 20 mm Hg, GAT measures are higher than NCT and this relationship is reversed at high IOPs.

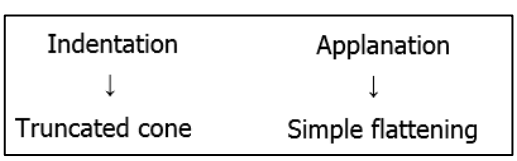
This suggests that NCT tends to underestimate IOP compared to GAT in lower range and overestimates it in higher ranges.

DISCUSSION

Glaucoma is an optic neuropathy of multivariate aetiology wherein intraocular pressure (IOP) is the most important and only modifiable risk factor.[4] The accurate IOP measurement has a very important role in diagnosis as well as management of glaucoma.

Methods of Measuring IOP

1. Direct- By insertion of needle into anterior chamber through paracentesis site
2. Indirect- Based on amount of external force causing deformation.



Classification of Tonometers

➢ Indentation
- Shape of deformation is truncated cone
- Displace large intraocular volume

- Applanation
  - Shape of deformation is simple flattening
  - Based on variable measured
  - Variable force
    Measures the force required to applanate a standard area of the corneal surface (Goldmann)
  - Variable area
    Measures the area of the cornea that is flattened by a known force (Maklakov)
- Non-contact
  Uses a puff of air to deform the cornea and measures the time or force of the air puff that is required to create a standard amount of corneal deformation (Grolman)

Goldmann Applanation Tonometry- Goldmann applanation tonometry was introduced by Hans Goldmann and Theo Schmidt and it is the gold standard for IOP measurement.

Principle- It works on the principle of Imbert-Ficks law which states that the external force (W) against a sphere equals the pressure in the sphere (P1) times the area applanated by the external force (A)

$$W = P1_{x} A$$

The validity of the law requires that the sphere be
Perfectly sphere, dry, flexible, infinitely thin

The cornea fails to satisfy any of these requirements, in that it is aspherical and wet, and neither perfectly flexible nor infinitely thin. It is needed for modification of Imbert - Fick law in following manner to account for characteristics of cornea.

$W + S = P_{2\,1}\, A_1 + B$

When A = 7.35 mm; S balances B and $W = P_1$

To achieve this, the extent of corneal applanation is 3.06 mm diameter creating a volume displacement of 0.50 mm^3, and ocular rigidity does not significantly influence the measurement.

Description The instrument is mounted on a standard slit lamp. The biprism is attached by a rod to a housing which contains a coil spring and series of levers that are used to adjust the force of the biprism against the cornea. The examiner view is through the biprism that applanates the cornea. Two beam splitting prisms convert the circular area of corneal contact into two semicircles. Prisms arranged so that inner margins of the semicircles overlap when 3.06 mm (diameter) of cornea is applanated.

Technique- Biprism in the holder – 180° marking aligned with white line on the holder. Cornea is anesthetized with a topical preparation**.** Tear film is stained with sodium fluorescein – paper strip touch tears in the lower cul de sac or fluorescein solution (0.25% - optimum)**.** Patient is seated on slit lamp and lateral canthus is aligned with black band on head rest column. Biprism illuminated with cobalt blue light approximately 60° to biprism, temporal with low magnification and high intensity. Adjusting knob is set at 1**.** Patient is asked to look straight. Examiner hold lids against bony orbit and the biprism is brought near the corneal apex**.** Gentle contact with the corneal apex while observing through the slit lamp by monocular view**.**

Fluorescein of stained tears facilitate visualisation of tear meniscus at the margin of contact between cornea and the biprism. Split into two by biprism knob adjusted till inner edges overlap. Excursions between ocular pulsations are averaged. Reading on the dial multiplied by 10 gives the IOP.

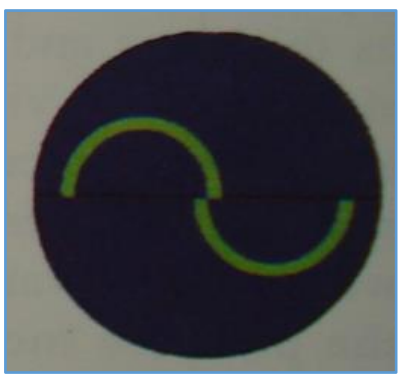


Figure 1. Correct end Point of Measurement of IOP

Potential errors of applanation tonometry:

- Inappropriate fluorescein
- Corneal thickness variation
- Astigmatism more than 3 diopters
- Elevating the eyes more than 15 degree
- Pressing on the globe or eyelids
- Squeezing of eyelids
- Repeated tonometry
- Tonometer out of calibration
- Observer bias.

Inappropriate Fluorescein Pattern

The fluorescein ring is too wide (high IOP) or too narrow. The measuring prism does not touch the cornea or presses with the protection weight on the eye.

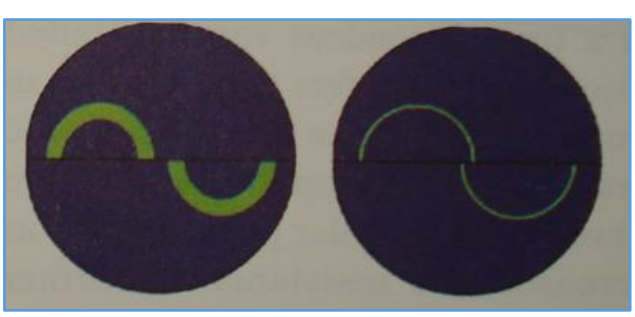


Figure 2. Inappropiate Fluorescein Pattern

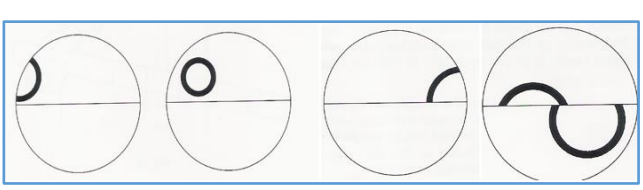


Figure 3. The Two Semi-Circles are not in the Middle of the field of view

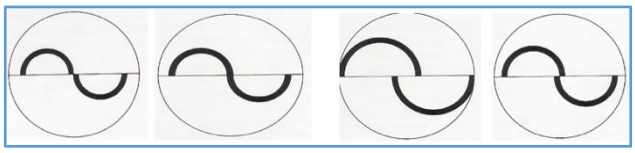


Figure 4. The Inner border of the Fluorescein Rings do not Touch each other

Non Contact Tonometer- Introduced by Grolman in 1972, it has the unique advantage of not touching the eye of the patient.

Principle- Non Contact Tonometers (NCT) flatten the cornea using a puff of air; the time required to flatten the cornea (measured in milliseconds) is then correlated with IOP

The original NCT has three components and is mounted on a table.

i. **Alignment System**- Allows the operator to align the patient's cornea in three dimensions i.e. Axial, vertical and lateral.
ii. **Optoelectronic Applanation Monitoring System** consists of a transmitter which directs a collimated beam of light at the corneal vertex and a receiver and detector which accepts only parallel, coaxial rays reflected from cornea.
iii. **Pneumatic System** which generates a puff of room air.

Handheld NCT – PULSAIR Tonometer

A puff of room air creates a constant force which momentarily deforms the cornea.[1] The central cornea is flattened at the moment the pressure is measured. The time from an internal reference point to the moment of presumed flattening is measured and converted to IOP based on prior comparisons with readings from Goldmann applanation tonometer.

Technique- Patient observes an internal target, operator aligns the cornea by superimposing a reflection of the target from the patient's cornea. When the cornea is properly aligned, the operator depresses a trigger which causes a puff of air to be directed against the cornea.

Central Corneal Thickness (CCT) Central Corneal Thickness (CCT) was measured by Pachymetry.

It was done to adjust the IOP reading in patients with thick or thin cornea which has an effect on IOP measurements.

Goldmann & Schmidt - average CCT is 520µ with mean values from 537 to 554 µ in normal subjects.

- Corneal thickening due to oedema leads to underestimation of true IOP
- Thicker corneas give false high IOP and vice versa
- Refractive surgery for myopia results in corneal thinning gives false underestimation of IOP.

CCT (Microns)	Adjustment for Measured IOP mmHg
445	+7
455	+6
465	+6
475	+5
485	+4
495	+4
505	+3
515	+2
525	+1
535	+1
545	0
555	-1
565	-1
575	-2
585	-3
595	-4
605	-4
615	-5
625	-6
635	-6
645	-7

Table 4. Goldmann IOP Correction Values (mmHg) for Central Corneal Thickness (CCT)

In this study, we compared NCT and GAT across various CCT and IOP ranges.

This study observed that overall IOP as measured by NCT was significantly higher than GAT (p=0.004). However, Salim et al found no significant difference between NCT and GAT measurements (p=0.64). Tonnu et al reported GAT to be greater than NCT.[5]

Most studies showed that NCT overestimates at low pressures and underestimates at high pressure when IOP readings are compared with GAT.[6-9] However, Tonnu et al showed that NCT underestimates IOP at lower ranges and overestimates at higher IOP ranges. Our study showed similar results.

The difference between the two measurements in our study was greatest in patients with thick corneas, gradually lessening as CCT decreased. Although this finding was not significant (p=0.809), CCT may contribute to the relative IOP overestimation at higher IOP levels.

On the contrary, Francis et al and Pache et al found that the difference between two measurements was greatest in participants with thin corneas, gradually lessening as CCT increased.[10]

STUDY	GAT- NCT
Tonnu et al – 2005	0.7 ± 4.8
Gupta et al - 2006	0.9 ± 3.1
Salim et al - 2009	0.3 ± 7.1
Present study	0.98 ± 4.2

Table 5. Comparison of GAT-NCT in Various Studies

Limitation- Sample size was not large enough for better stratification of IOP and CCT.

There were lesser number of eyes with IOP ≤ 20 mm Hg (n-41) and >30 mm Hg (n-14). Similarly, number of eyes with CCT ≤ 500 µ (n-26) and > 600 µ (n-13) were small.

CONCLUSION

In our study, we found that intraocular pressure measurement by NCT was consistently higher than GAT. There was a tendency for NCT to underestimate IOP at lower ranges and overestimate IOP at higher ranges. By applying appropriate correction factor for CCT, it was hence found that Noncontact tonometry could be used as a good screening tool for glaucoma evaluation.

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