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**Original Research Article**

# Non contact tonometer & applanation tonometer as a screening tool for glaucoma in general population

**Smita Kishor Kadu**, Hrishabh Manish Jaiswal, Nilesh Balaji Giri* and Santosh Yadawrao Ingle

*Department of Ophthalmology, Dr. Panjabrao Deshmukh Memorial Medical College, Amravati, Maharashtra 444602 India*

**QR Code**

***Correspondence Info:**
Dr. Nilesh Balaji Giri
Junior Resident,
M.S. Ophthalmology,
Department of Ophthalmology,
Dr. Panjabrao Deshmukh Memorial Medical College,
Amravati, Maharashtra 444602 India

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## Abstract

**Purpose:** To study how the non contact tonometer faired against the gold standard - Goldmann applanation tonometer for measuring the intraocular pressure, and to assess if the non contact tonometer was reliable as a mass screening tool for glaucoma detection.

**Method:** Patients in age group of 40 to 60 years coming to OPD were subjected to two method of tonometry: applanation tonometer and non contact tonometer on both eyes, after obtaining the informed consents from them. Three recording were obtained with each method and arithmetic mean of all three reading taken as an intraocular pressure. The data were statistically analyzed using (appropriate test of significance using SPSS software version16.0)

**Results:** The statistical parameter used to analyze the data and the correlation of the study tonometer to the gold standard was the pearson correlation. In this study, the non contact tonometer on the right eyes, compared favorably with the Goldmann applanation tonometer as evidenced by pearson correlation with value of 0.921, with $p<0.001$ being highly significant. Similarly, on the left eyes of the subjects, tonometers was also highly comparable with a p value of <0.001. Readings of non contact tonometry were almost perfect agreement with the Goldmann applanation tonometer.

**Conclusion:** The current study shows that the non contact tonometer compares favorably with the Goldmann applanation tonometer showing excellent agreement with it. The non contact tonometer can be used as a reliable screening tool in general population.

**Keywords:** Glaucoma, Intra ocular pressure, non contact tonometry, Goldmann applanation tonometry, screening tool.

## 1. Introduction

Globally, there are an estimated 60.5 million people with glaucomatous optic neuropathy and an estimated 8.4 million people who are blind as a result of glaucoma. These numbers are set to increase to 80 million. Glaucoma is the second leading cause of blindness globally. [1]

Approximately 11.2 million Indians above age 40 suffer from glaucoma with over 90% of the cases being diagnosed only after significant vision loss has occurred. [2]

Glaucoma previously defined as a state of raised intraocular pressure, is today better understood to be an irreversible and progressive optic neuropathy resulting from a variety of risk factors, the most prominent among is the raised intraocular pressure and it is the only risk factor[3,4] amenable to treatment provided if it is detected early.[5,6]

Thus blindness resulting from glaucoma is largely preventable if adequate measures to control level of intraocular pressure are taken early enough in pathogenesis of disease. Along with the examination of the optic nerve head and an assessment of the visual fields by ophthalmologist, measurement of intraocular pressure at the primary health care level can go a long way in detecting cases as well as screening suspects from the general population. [7]

With the advances in the field of glaucoma management, numerous tonometers have been developed.

One such tonometer is non contact tonometer which does not touch the corneal surface and the problem of disinfection does not arise. It is not operator dependent as it records automatically and can thus be used by non ophthalmologists.[8,9] Applanation tonometry is considered to be the gold standard test and most widely accepted method[10,11], the intraocular pressure is inferred from the force required to flattened (applanate) a constant area of the cornea, fort the Imbert-Fick law.[12]

**1.1 Non contact tonometry:**

**Advantages:**

1) Non invasive.
2) No anaesthesia required.
3) Less time required.
4) No chance of infection.
5) Can be performed by paramedical personnel.

**Disadvantages:**

1) Less reliable in patient with raised intraocular pressure.
2) Inappropriate results in abnormal cornea and poor fixation.
3) Less portable.
4) More expensive.

Specificity: 95% [13]
Sensitivity: 85% [13]

**1.2 Applanation tonometry:**

**Advantages:**

1) Reliable in patient with raised intra ocular pressure.
2) Less expensive.

**Disadvantages:**

1) Invasive.
2) Topical anaesthesia required.
3) Chances of infection are possible.
4) More time required.
5) Only skilled person can perform the procedure.

Specificity: 93.9% [14]
Sensitivity: 95.5% [14]

In view of this present study, this study is an effort to study the efficacy of the noncontact tonometer as compared to the applanation tonometer and its feasibility as a screening method.

## 2. Materials and methods

**2.1 Study area:**

Study conducted in department of ophthalmology in atertiary hospital in central India.

**2.2 Study subject:**

Patients in the age group of 40-60 years attending ophthalmology OPD at a tertiary hospital in central India.

**2.3 Study design:**

Hospital based Observational study.

**2.4 Sample size:**

By considering Non contact tonometer sensitivity 85%and prevalence of glaucoma in India 2.65% at 20% absolute precision and 95% confidence interval. The estimated sample size is 462.

Patients were selected according to following criteria:

**a) Inclusion criteria:**

1) All male and female patients, 40 to 60 years of age were included in the study.

**b) Exclusion criteria:**

1) Patients below 40 years and above 60 years.
2) Established case of glaucoma.
3) Any current conjunctival or corneal infection.
4) History of previous corneal surgery including refractive surgery.
5) Microophthalmos.
6) Blepharospasm.
7) Manifest Nystagmus.
8) Keratoconus.
9) Scarred or Hazy cornea.

**2.5 Duration of study:** 18 months.

**2.5 Procedure:**

462 patients in age group of 40 to 60 years coming to OPD were subjected to two method of tonometry: applanation tonometer and non contact tonometer on both eyes.

Informed consent was obtained after informing the study subjects the details of the procedure. Only after obtaining the informed consent from the subject, he/she will be included in the study.

Three recording were obtained with each method and arithmetic mean of all three reading taken as a intraocular pressure.

**2.7 Statistical test used:**

1) Proportion
2) Mean
3) Standard deviation
4) Statistical correlation

**2.8 Procedure for Goldmann applanation tonometry:**

After the instillation of topical proparacaine (0.5%) eye drops, the precorneal tear film was stained with sodium fluorescein (0.6mg) impregnated strips. Any excess of tears were wiped off. The procedure was briefly explained to the patient who was then positioned at the slit lamp. The force knob on the applanation apparatus was adjusted to read 1 on the scale and the cobalt blue filter was turned on. With the patient looking in primary gaze, the applanation head was advanced to just touch the cornea. The semicircles of the fluorescein stained tear film were viewed through the applanation biprism and the force knob adjusted till the inner edges of the semicircles just touched.

The reading on the scale of the force knob was taken and multiplied by ten to give the IOP in mm Hg. The right eye followed by the left eye was subjected to the procedure, three times each and all six readings noted. The readings were rejected if the semicircles were too thick or too thin.

**Figure 1: The Goldmann applanation tonometer and the biprisms**

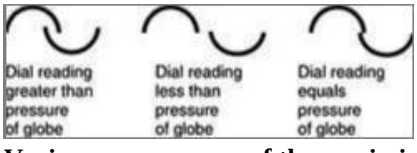


**Figure 2: Various appearances of the menisci and their relationship to the IOP**

Fick in 1888, developed the Goldmann applanation tonometer,[15] a fixed area tonometer which is the most reliable tonometer devised till date and is the standard by which other tonometers are judged.[16] The instrument comprises a slit lamp mounted housing with a plastic biprism as the applanation device. The biprism produces an applanation area of 7.35mm$^2$ on the internal surface of the cornea when it applanates an area with a diameter of 3.06mm on the external surface of the cornea. The beam splitting biprism optically converts the area of applanation into two semicircles, the edges of which overlap when an 3.06mm of the cornea is flattened. [17]

**2.8.1 Procedure:**

The patient is seated comfortably at a slit lamp, after the instillation of topical anesthetic and sodium fluorescein with both eyes in primary gaze. The plastic biprism under cobalt blue light is brought into gentle contact with the cornea and the fluorescein stained tear film meniscus is visualized through the prism as two semicircles.

The force knob on the housing is adjusted till the inner edges of the semicircles just touch and the IOP read off the scale on the tonometer housing.[16,17] In some instances, the pulse pressure causes oscillation of the mires, in which case the excursions must be averaged to give the desired endpoint.

**2.8.2 Sources of error**

The tonometer was initially calibrated assuming the corneal thickness to be 0.5mm. Studies have since shown that corneal thickness influences the IOP reading with thicker corneas resulting in falsely higher readings of IOP with IOP increasing by around 0.19 mmHg per 10µm increase in central corneal thickness.[18] Corneas post refractive surgery undergo significant thinning and consequently result in underestimation of IOP.[17]

The thickness of the menisci also alters the IOP reading with wider menisci causing the read IOP to be falsely higher.[17,19] Vertical mal alignment of the semicircles also causes false elevation of the IOP value.[17,20]

High corneal astigmatism beyond 3 diopters also induces significant errors in IOP estimation. In these cases, the area of corneal contact is elliptical and the biprism in the usual orientation results in underestimation of IOP for with the rule astigmatism and overestimation of IOP for against-the-rule astigmatism. [21] Therefore in such cases the prism should be rotated to an angle of 45 degrees from the major axis of astigmatism measured in the minus cylinder, to give a more accurate estimate of IOP. Alternately, the average of the readings taken with the prism horizontally and vertically can be used. [17,20,21]

**2.9 Procedure of non contact tonometry**

The Keeler Pulsair Desktop non contact tonometer was used. The patient was seated in a comfortable position and before the actual reading of the IOP; He/she was instructed to blink normally and avoid squeezing the eyelids. Then, the patient was asked to fix at the internal red light on the tonometer with his/her right eye. Looking through the eyepiece of the tonometer, the observer moved the tonometer close to the eye keeping the cornea in view all the time till the image of a vertical bar with a bowtie became well defined on the cornea. At this point the machine would automatically blast an air puff and record a reading. The procedure was performed three times on the right eye followed by three times on the left eye, and all six readings were noted.

**2.9.1 The non contact tonometer**

**Figure 3: The Keeler Pulsair Easy Eye non contact tonometer**

This tonometer works on the same principle as the Goldmann tonometer and uses a puff of air to applanate a known and reproducible area of the cornea. At the point of flattening, the cornea acts as a plane mirror and reflects light which is recorded by a receiver. A microcomputer then calculates the IOP from the force required to applanate the cornea and the area applanated and gives a digital display of the IOP.

The instrument comprises an alignment system which optically aligns the cornea vertically, horizontally and axially; a pneumatic system which generates a puff of room air and a monitoring system which transmits light onto the cornea and receives parallel light rays reflected from the cornea.[16,17]

Non contact tonometers are available in a table mounted form as in the Nidek and Reichert AT tonometers and a portable form as in the Pulsair Easy Eye tonometers.

**2.9.2 Procedure:**

The procedure is performed with the patient seated and observing an internal target. The operator aligns the cornea by superimposing a reflection of the target on the patient's cornea with a stationary ring. When the cornea is accurately aligned, the operator presses a button which triggers a puff of air onto the cornea. In the X-pert NCT and the Keeler Pulsair Easy Eye Tonometer, the air puff is automatically triggered once the alignment is centered.

**2.9.3 Sources of error:**

Like with the Goldmann applanation tonometer, noncontact tonometry is also affected by corneal thickness and corneal surface irregularities. The air puff is random with respect to the phases of the cardiac cycle and thus the ocular pulse becomes a significant variable resulting in poor reliability if few readings are taken. It is therefore recommended that a minimum of three readings within 3mm Hg be taken and averaged.

**2.10 Disinfection**

The non contact tonometer is the only tonometer that does not come into contact with the ocular surface, thus disinfection is not a consideration for this tonometer. Nevertheless it has been feared that the part of the instrument facing the patient may get contaminated with tear film dispersed at the time of air impact.

## 3. Observations and results

In this study, 462 patients were subjected to the two methods of tonometry–Goldmann applanation tonometry and non contact tonometry. The analysis of the data obtained showed the following results:

**3.1 Goldmann applanation tonometry:**

**Table 1: Goldmann applanation tonometry on the right eyes of the study population**

| | N | Minimum | Maximum | Mean± SD | Median |
|---|---|---|---|---|---|
| GAT-right eye | 462 | 10 | 28 | 14.12± 3.683 | 13.00 |

The Goldmann applanation tonometer on the right eyes of 462 subjects recorded a minimum IOP of 10 mm Hg and a maximum of 28mm Hg, the mean being 14.12mm Hg (standard deviation =3.683).

**Table 2: Goldmann applanation tonometry on the left eyes of the study population**

| | N | Minimum | Maximum | Mean± SD | Median |
|---|---|---|---|---|---|
| GAT -left eye | 200 | 10 | 28 | 14.76± 3.619 | 14.0 |

On the left eyes of the same subjects, with the Goldmann applanation tonometer, the lowest recorded IOP was 10 mm Hg and the highest reading was 28mmHg with a mean reading being 14.76mm Hg (standard deviation = 3.619)

**3.2 Non contact tonometry**

**Table 3: Non contact tonometry on the right eyes of the study population**

| | No | Minimum | Maximum | Mean± SD | Median |
|---|---|---|---|---|---|
| NCT Right eye | 462 | 10 | 29 | 14.03± 3.731 | 13 |

The non contact tonometer on the right eyes of 462 subjects recorded a minimum IOP of 10 mm Hg and a maximum of 28mm Hg, the mean being 14.12 mm Hg (standard deviation = 3.683)

**Table 4: Non contact tonometry on the left eyes of the study population**

| | No | Minimum | Maximum | Mean± SD | Median |
|---|---|---|---|---|---|
| NCT Left eye | 462 | 10 | 29 | 14.75± 3.500 | 14 |

On the left eyes of the same subjects, with the non contact tonometer, the lowest recorded IOP was 10 mm Hg and the highest reading was 29 mmHg with a mean reading being 14.75mm Hg (standard deviation = 3.500)

**3.3 Comparison of the non contact tonometer to the Goldmann applanation tonometer**

**3.3.1 In the right eye**

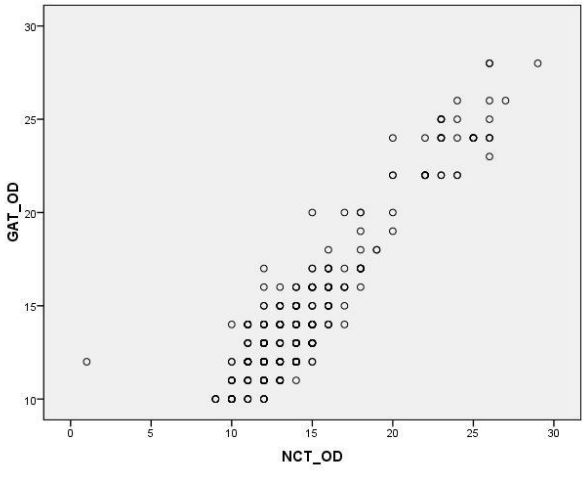


**Figure 4: Noncontact tonometry values versus Goldmann applanation values-right eye**

**Table 5: Correlations of GAT OD and NCT OD**

| | | GAT_OD | NCT_OD |
|---|---|---|---|
| GAT_OD. | Pearson Correlation | 1 | 0.921** |
| | Sig. (2-tailed) | | 0.000 |
| | N | 462 | 462 |
| NCT_OD | Pearson Correlation | 0.921** | 1 |
| | Sig. (2-tailed) | 0.000 | |
| | N | 462 | 462 |

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

The pearson correlation applied to the readings showed a value of 0.921, p<.001 which was highly significant

**3.3.2 In the left eye:**

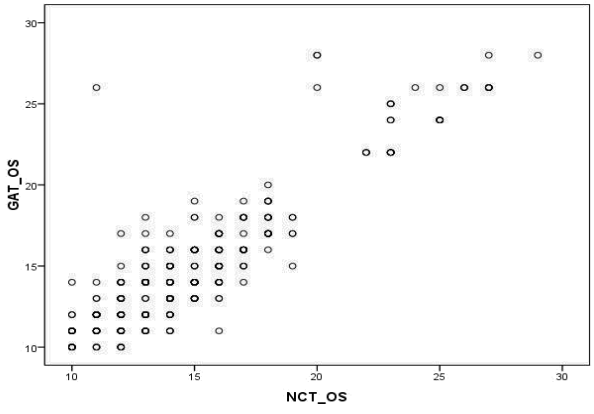


**Figure 5: Noncontact tonometry values versus Goldmann applanation values-left eye**

**Table 6: Correlations of GAT OS and NCT OS**

| | | GAT_OS | NCT_OS |
|---|---|---|---|
| GAT_OS | Pearson | 1 | 0.897** |
| | Correlation | | |
| | Sig. (2-tailed) | | 0.000 |
| | N | 462 | 462 |
| NCT_DS | Pearson | .897** | 1 |
| | Correlation | | |
| | Sig. (2-tailed) | .000 | |
| | N | 462 | 462 |

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

The pearson correlation applied to the readings showed a value of 0.897, p<.001 which was highly significant.

**3.4 Sensitivity and specificity**

The sensitivity and specificity for the non contact tonometer calculated, using an intraocular pressure of more than and less than to 21mmHg with the Goldmann applanation tonometer as the screening criterion. In Goldmann applanation tonometry - Out of 462 patients 11 were diagnosed as glaucoma, 3 were diagnosed as normotensive glaucoma and 22 had ocular hypertension. The results obtained are below.

**Table 7: Goldmann applanation tonometer**

| C | Glaucoma | No Glaucoma | Total |
|---|---|---|---|
| More than 21 | 11 | 22 | 33 |
| mmHg | (a) | (b) | (a+b) |
| | | | |
| Less than | 3 | 426 | 429 |
| 21mmHg | (c) | (d) | (c+d) |
| Total | 14 | 448 | 462 |
| | (a+c) | (b+d) | (a+b+c+d) |

A) Sensitivity = a/(a+c)x100 = 11/14x100 = 78.57%
B) Specificity = d/(b+d)x 100=426/448x100=95.08%

In non contact tonometry - Out of 462 patients 10 were diagnosed as glaucoma, 4 were diagnosed as normotensive glaucoma and 21 had ocular hypertension. The results obtained are below.

**Table: For non contact tonometer**

| IOP | Glaucoma | No Glaucoma | Total |
|---|---|---|---|
| More than 21 | 10 | 21 | 31 |
| mmHg | (a) | (b) | (a+b) |
| Less than 21 | 4 | 427 | 431 |
| mmHg | (c) | (d) | (c+d) |
| Total | 14 | 448 | 462 |
| | (a+c) | (b+d) | (a+b+c+d) |

A) Sensitivity = a/(a+c)x100 = 10/14x100=71.42%
B) Specificity= d/(b+d)x100=427/448x100=95.31%

## 4. Discussion

The current understanding of glaucoma is inclusive of three entities– the optic nerve head, the visual field and intraocular pressure. While optic nerve head damage and a consequent field loss are pre-requisites for the diagnosis of glaucoma, raised intraocular pressure while commonly being associated with glaucoma, is not necessary for designating an eye as glaucomatous. Visual field loss and degenerative optic neuropathy can occur without an elevation in intraocular pressure as seen in the normotensive glaucoma patients. Conversely, a good number of eyes with pressures above the accepted normal of 21mm Hg have failed to demonstrate glaucomatous optic nerve head changes or visual field defects.

However, raised intraocular pressure has been demonstrated to cause damage to the optic nerve head and its reduction has consequently retarded the progression of such damage.[22-24] Thus tonometry has gained importance and has become the mainstay of glaucoma screening and monitoring. While an array of tonometers are available today, the tonometer used for screening should be feasible in the screening set up viz. camps and primary eye care providers. The non contact tonometer is portable and has a minimal learning curve for the operator handling it. Moreover, since the reading is taken automatically there is no scope for operator bias or error. Thus it can be used by non ophthalmologists to get reliable measurements of the intraocular pressure.

**In this study:**

The 462 participants of the study were subjected to the two methods of tonometry – first non contact tonometry, followed by applanation tonometry.

Three readings were taken with each of the tonometers, first in the right eyes and then the left eyes and the arithmetic mean obtained. This was done keeping in mind the non contact tonometer which records randomly with respect to the cardiac cycle and at very short intervals. Thus, the scope for fluctuations is higher and it has been recommended that a minimum of three readings be taken and averaged to give the IOP.[25-27] The statistical parameter used to analyze the data and the correlation of

the study tonometer to the gold standard was the pearson correlation.

**The Keeler Pulsair Easy Eye non contact tonometer versus the Goldmann applanation tonometer:**

In this study, the non contact tonometer on the right eyes, compared favorably with the Goldmann applanation tonometer as evidenced by pearson correlation with value of .921, with p<0.001 being highly significant.

On the left eyes of the subjects, the difference between the two tonometers was also highly significant with a p value of <0.001. Almost perfect agreement with the Goldmann applanation tonometer.

Thus the non contact tonometer was found to compare well with the gold standard tonometer and confirmed the finding of previous researchers Hsu *et al*[28] and Ogbuehi and Almubrad.[29] The non contact tonometer was also found to read slightly higher than the Goldmann applanation tonometer as had been previously observed by Parker *et al* and other researchers.[29-33]

**The noncontact tonometer as a screening tool:**

An essential criterion for a good screening test is high specificity and high sensitivity. The non contact tonometer has been shown to be a reliable screening tool by Shields [34] and Moseley *et al*.[35]

In this study, a screening criterion of more than or equal to 21 mm Hg was used to study the sensitivity and specificity. The non contact tonometer, by producing very few false negative results, demonstrated a high sensitivity. It also reliably detected positives without including falsely positive pressures, thus showing good specificity. It is thus proved to be a good screening tool.

The tonometer gains further credentials as a screening tool since it is easy to operate and can be operated by non medical and paramedical personnel without any observer bias since it records pressures automatically. Being a non contact method, the need for disinfection is obviated, thus giving it additional value in mass screening programmers.

Its only drawback is its cost.

## 5. Summary

The study aimed to correlate the non contact tonometer and the Goldmann applanation tonometer – the current gold standard tonometer.

462 participants – 248 women and 214 men between the ages of 40 and 60 were subjected to the above methods of tonometry.

The non contact tonometer showed excellent agreement with the Goldmann applanation tonometer, especially in general population. Its value in monitoring glaucomatous eyes needs to be evaluated further.

The non contact tonometer proved to be an excellent screening tool with near perfect sensitivity and specificity.

## 6. Conclusion

The current study shows that the non contact tonometer compares favorably with the Goldmann applanation tonometer showing excellent agreement with it.

The non contact tonometer can be used as a reliable screening tool in general population.

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