INTRAOCULAR PRESSURE MEASUREMENT BY GOLDMANN APPLANATION TONOMETER AND NONCONTACT TONOMETERS TAKING CONSIDERATION OF CENTRAL CORNEAL THICKNESS- A COMPARATIVE CROSS-SECTIONAL STUDY
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ABSTRACT

BACKGROUND
Intraocular Pressure (IOP) is one of the key physiological factors, which can regulate the ocular health and homeostasis. Accurate measurement of IOP depends on several factors among which instrument factor plays significant role. Considering Goldmann Applanation Tonometer (GAT) as a “GOLD” standard, we have compared Noncontact Tonometers (NCT) with GAT taking Central Corneal Thickness (CCT) into consideration.

MATERIALS AND METHODS
In this comparative cross-sectional study in a tertiary care hospital, after inclusion and exclusion, patients were thoroughly examined clinically and GAT, NCT and CCT tests are performed using standard technique by single competent ophthalmologist on the same day. Values are tabulated in excel sheet and statistical calculations done using SPSS version 20.

RESULTS
In the study population, 57.7% were males and 42.3% females (M:F = 187:137). The mean age of the population is 45.16 ± 19.58 years (SD) and mean intraocular pressure of males was found to be 16.63 ± 3.72 (SD) mm of Hg by GAT method and 16.75 ± 3.53 (SD) mm of Hg by NCT, and in females, it was found to be 16.12 ± 3.51 (SD) mm of Hg by GAT method and 16.29 ± 3.28 (SD) mm of Hg by NCT. The difference between methods was statistically significant (P <0.05). Mean central corneal thickness of the study population was found to be 546.10 ± 34.87 (SD) µm, whereas central corneal thickness of males 547.11 ± 33.93 (SD) µm and females were 544.71 ± 36.13 (SD) µm. The difference in IOP measurement between methods was statistically significant (P<0.05) for the entire group and in the subgroup with central corneal thickness more than 575 µm. The reliability indices for the noncontact tonometer considering the Goldmann application tonometer as gold standard are highly correlating as coefficient of correlation is near to +1 in all the subgroups in respect to central corneal thickness.

CONCLUSION
The difference in measurements by noncontact tonometer and the Goldmann application method was statistically significant. The measurements by noncontact tonometer were reasonably accurate (coefficient of correlation is near to +1).

KEYWORDS
Goldmann Applanation Tonometer (GAT), Noncontact Tonometers (NCT), Central Corneal Thickness (CCT), Coefficient of Correlation.

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corneal thickness and the development of a new noncontact technique, we have compared the IOP measured by the two techniques in selected healthy-eyed subjects.

Aims and Objectives
- To assess to what extent the central corneal thickness affects measurements of IOP by different methods.
- To assess whether there is a significant difference in IOP measurements between noncontact and contact tonometry by Goldmann applanation method.
- To assess whether the noncontact tonometer can be used for mass screening purposes.

Study Design- Observational, cross-sectional study.
Parameters to be studied- Following parameters will be utilised for the specific objectives- Age, gender (demographic variables), intraocular pressure measured by two different techniques (1. Goldmann applanation tonometer; 2. Keeler Pulsair 3000 noncontact tonometer) and central corneal thickness.

Study Tools- Keeler Pulsair 3000 noncontact tonometer, ultrasonic pachymeter, slit lamp with Goldmann applanation tonometer (Haag-Streit, Bern AT900 model), proparacaine 0.5% ophthalmic solution, fluorescein strips, antibiotic eye drop (moxifloxacin 0.5%).

Inclusion Criteria
- Age 15-80 yrs.
- Patients not having any corneal disease like corneal ulcer scarring or keratitis or corneal oedema.
- The patient must be able to verbalise a basic understanding of the study after it is explained to the patient as determined by physician/examiner.
- Patients who gave an appropriate written consent.

Exclusion Criteria
- Myopia (-3D/more) or hypermetropia (+3D/more) or astigmatism (-2D/more).
- Age less than 15 yrs. or more than 80 yrs.
- Patients diagnosed previously as glaucoma.
- Patients on antiglaucoma medications.
- Postoperative patients.
- Previous contact lens use.
- Connective tissue disorder.
- Previous penetrating keratoplasty in the same eye.
- Any active, infective or inflammatory condition of eyes.
- Not willing to participate.

MATERIALS AND METHODS

After documenting patient particulars, thorough ophthalmic examination was done including refraction. One drop of a topical anaesthetic (0.5% proparacaine) is placed in each eye and the tip of a moistened fluorescein strip is touched to the tear layer on the inner surface of each lower lid. The tonometer tip (after proper calibration) is cleaned with a sterilising solution and the tip and prism are set in correct position on the slit lamp. The tension knob is set at 1 g. The cobalt filter was used with the slit beam opened maximally. The angle between the illumination and the microscope was kept approximately 60°. The room illumination was reduced. The patient was seated in a comfortable relaxed position on an adjustable stool facing the slit lamp. The heights of the slit lamp, chair and chin rest were adjusted properly so that neck is relaxed and without tightening of collar. The patient’s chin is supported by the chin rest and the forehead by the forehead bar. The examiner sat opposite to the patient in position to look through the microscope and the assembly was advanced toward the patient with the tester observing from the side until the limbal zone had a bluish hue. The tension knob was rotated until the inner borders of the fluorescein rings just touched each other. IOP was measured in the right eye until three successive readings are within 1 mmHg. IOP was then measured in the left eye. The readings obtained in grams were multiplied by 10 to give the IOP in millimetres of mercury. This value is recorded along with the date and time of day. Same procedure was performed in each eye five times and the most frequently appeared reading was recorded.

For noncontact tonometry, Keeler Pulsair 3000 noncontact tonometer is used. After adopting a comfortable working position, the patient’s head was supported against a wall. At approximately 25 cm from the patient, looking through the eyepiece, once the examiner could see the patient’s eye, the Pulsair was moved closer (to within 5 cm of the patient), keeping the cornea in the central view. Looking through the eyepiece, two green dots were seen on two ends of limbus on three and nine clock hours, which on moving closer, two red bars were seen within the green dots. Then, finally a bow-tie structure appeared within the red bars. Maintaining the cornea as centre, the Pulsair was fired at this position keeping the hands steady and the reading was noted. The procedure was repeated five times and was performed approximately 10 to 15 minutes apart, which is a safe interval for repeated tonometry and the most frequent reading was taken as final. An interval of 30 minutes was maintained between the contact and noncontact tonometry.

For central corneal thickness was measured by ultrasonic pachymeter. After positioning the patient in a comfortable posture, patient was asked to look straight into the eyes of examiner after instilling 0.5% proparacaine ophthalmic solution in both eyes. The probe of the pachymeter was gently placed on the mid-pupillary axis and the 10 (ten) readings were noted and the average was done. This was done either 1 hr. after IOP measurements or on the next visit, but on the same time of the day. The IOP adjustment was made according to the manufacturer’s logarithm based on a study done by Ehlers et al. 4

RESULTS AND ANALYSIS

In the study population, 57.7% (n=187) were males and 42.3% (n=137) were females. The mean age of the population is 45.16 ± 19.58 years (SD) was ranging from...
15 to 80 years. Mean intraocular pressure of the study population was found to be 16.42 ± 3.64 (SD) mm of Hg by Goldmann applanation tonometry method and 16.55 ± 3.43 (SD) mm of Hg by noncontact tonometer.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Number of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>15-29</td>
<td>52</td>
</tr>
<tr>
<td>30-44</td>
<td>20</td>
</tr>
<tr>
<td>45-59</td>
<td>61</td>
</tr>
<tr>
<td>60-74</td>
<td>38</td>
</tr>
<tr>
<td>75-80</td>
<td>16</td>
</tr>
<tr>
<td>Entire Group</td>
<td>187</td>
</tr>
</tbody>
</table>

Table 1. Showing Age-Sex Distribution

<table>
<thead>
<tr>
<th>Category</th>
<th>GAT (mm of Hg) (Mean ± SD)</th>
<th>NCT (mm of Hg) (Mean ± SD)</th>
<th>“p” value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>16.63 ± 3.72</td>
<td>16.75 ± 3.53</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Female</td>
<td>16.12 ± 3.51</td>
<td>16.29 ± 3.28</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Overall</td>
<td>16.42 ± 3.64</td>
<td>16.55 ± 3.43</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

Table 2. Variation in IOP in Males and Females

<table>
<thead>
<tr>
<th>Category</th>
<th>CCT (µm) (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>547.11 ± 33.93</td>
</tr>
<tr>
<td>Female</td>
<td>544.71 ± 36.13</td>
</tr>
<tr>
<td>Overall</td>
<td>546.10 ± 34.87</td>
</tr>
</tbody>
</table>

Table 3. Variation in CCT in Males and Females

The difference in IOP measurement between methods was statistically significant (P<0.05) for the entire group and in the subgroup with central corneal thickness more than 575 µm. The reliability indices for the noncontact tonometer considering the Goldmann applanation tonometer as gold standard are highly correlating as coefficient of correlation is near to +1 in all the subgroups in respect to central corneal thickness. In the study, we have found that in the group of <513 µm CCT, the measured IOP is more than the groups of CCT >513 µm. There is positive correlation between CCT and IOP (as the CCT increases, IOP measured by GAT and NCT increases) in the groups of >513 µm CCT.

DISCUSSION

As IOP is one of the parameters to monitor glaucoma, a clinician should be aware of the agreement between the different instruments used routinely to monitor IOP for different purposes. Large variation in central corneal thickness may cause false estimation in IOP resulting in misinterpretation. Therefore, for higher accuracy, quantitative effect of central corneal thickness on different IOP measuring techniques is important, so that, we can make appropriate allowances.

In the present comparative study of intraocular pressure measurement by Goldmann applanation tonometer and noncontact tonometer taking consideration of central corneal thickness had been conducted in the OPD of RIO, Kolkata.

In the study population, number of male patients is more than female patients. These pictures signify the socioeconomic condition of our country because of which male patients seek medical attention more than females.

In our study, mean central corneal thickness was found to be 546.10 ± 34.87 (SD) µm, whereas central corneal thickness of males 547.11 ± 33.93 (SD) µm and females were 544.71 ± 36.13 (SD) µm. The group was divided into 4 groups according to the median corneal thickness.

Mean intraocular pressure of males was found to be 16.63 ± 3.72 (SD) mm of Hg by Goldmann applanation tonometry method and 16.75 ± 3.53 (SD) mm of Hg by noncontact tonometer. Mean intraocular pressure of females was found to be 16.12 ± 3.51 (SD) mm of Hg by Goldmann applanation tonometry method and 16.29 ± 3.28 (SD) mm of Hg by noncontact tonometer. 99 noncontact readings and 73 applanation readings were equal to or greater than 21 mmHg. The difference between methods was statistically significant (P <0.05).

Mean central corneal thickness of the study population was found to be 546.10 ± 34.87 (SD) µm, whereas central corneal thickness of males 547.11 ± 33.93 (SD) µm and females were 544.71 ± 36.13 (SD) µm. The group was divided into 4 groups according to the median corneal thickness.

<table>
<thead>
<tr>
<th>Age Group (Years)</th>
<th>GAT IOP (mm of Hg)</th>
<th>NCT IOP (mm of Hg)</th>
<th>CCT (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-29</td>
<td>16.29 ± 3.54</td>
<td>16.45 ± 3.43</td>
<td>544.84 ± 49.78</td>
</tr>
<tr>
<td>30-44</td>
<td>15.81 ± 3.55</td>
<td>15.82 ± 3.63</td>
<td>539.85 ± 74.44</td>
</tr>
<tr>
<td>45-59</td>
<td>16.92 ± 4.30</td>
<td>17.04 ± 4.04</td>
<td>544.26 ± 49.39</td>
</tr>
<tr>
<td>60-74</td>
<td>15.85 ± 3.16</td>
<td>15.85 ± 3.04</td>
<td>537.56 ± 57.13</td>
</tr>
<tr>
<td>75-80</td>
<td>15.83 ± 3.88</td>
<td>16.08 ± 3.25</td>
<td>538.03 ± 74.94</td>
</tr>
</tbody>
</table>

Table 4. IOP by Different Methods and Central Corneal Thickness in Different Age Groups

<table>
<thead>
<tr>
<th>Corneal Thickness (µm)</th>
<th>GAT (mm of Hg)</th>
<th>NCT (mm of Hg)</th>
<th>P Value</th>
<th>Coefficient of Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire group</td>
<td>16.42 ± 3.64</td>
<td>16.55 ± 3.43</td>
<td>&lt;0.05</td>
<td>0.939</td>
</tr>
<tr>
<td>&lt;513</td>
<td>16.79 ± 4.22</td>
<td>16.96 ± 4.04</td>
<td>&gt;0.05</td>
<td>0.918</td>
</tr>
<tr>
<td>514-539</td>
<td>15.20 ± 2.69</td>
<td>15.22 ± 2.83</td>
<td>&gt;0.05</td>
<td>0.940</td>
</tr>
<tr>
<td>540-575</td>
<td>16.60 ± 3.51</td>
<td>16.74 ± 3.13</td>
<td>&gt;0.05</td>
<td>0.945</td>
</tr>
<tr>
<td>&gt;575</td>
<td>16.51 ± 3.53</td>
<td>16.68 ± 3.28</td>
<td>&lt;0.05</td>
<td>0.954</td>
</tr>
</tbody>
</table>

Table 5. IOP Measurements with Noncontact and Applanation Methods and the Statistical Significance between Measurements
mmHg. There was no significant difference between the groups according to statistics.7 Moseley et al compared GAT and NCT and they reported that NCT underestimated IOP at low pressures (<10 mmHg), while it tended to overestimate IOP at high pressures (>19 mmHg).8 In our study, the measurements with noncontact tonometer were higher than Goldmann applanation tonometer. The difference between IOP measurements by the methods is statistically significant (p<0.05).

Based on its own principle that GAT measures the force needed to flatten a given area of the cornea, GAT is inevitably affected by Central Corneal Thickness (CCT).9 In the cannulation study by Ehlers et al,8 GAT errors were found to be as large as 5 to 6 mmHg in otherwise normal eyes and GAT appeared to be most accurate with a CCT of 520 μm. Thicker corneas resulted in a higher IOP estimate, while thinner corneas resulted in estimated IOPs lower than the actual value. Because NCT basically uses the same application method (i.e., a standardized puff of air to flatten the cornea), NCT is also affected by CCT.10,11 In a study conducted by Kouchaki B et al, a significant correlation was observed between GAT and NCT (P < 0.001, Pearson correlation coefficient = 0.820). The IOP difference measured by the two methods was not statistically significant (0.3 ± 2.2 mmHg, P = 0.382).12 In our study, though the difference in IOP measurement between the two methods was statistically significant (P<0.05) for the entire group and in the subgroup with central corneal thickness more than 575 μm, the reliability indices for the noncontact tonometer considering the Goldmann applanation tonometer as gold standard are highly correlating as coefficient of correlation is near to +1 in all the subgroups. There we have found a positive correlation between CCT and IOP (as the CCT increases, IOP measured by GAT and NCT increases) in the groups of >513 μm of CCT corroborating with the study done by Johnson M et al.13

We suggest that if the IOP measured with a noncontact tonometer is significantly different from that taken with an applanation tonometer, the patient’s corneal thickness to be measured. Central corneal thickness is indirectly important in the diagnosis and follow up of glaucoma as it may lower the incidence of misdiagnosis. The outcomes of our study might not be the true representative of the parameters of general population as it was conducted in patients attending outpatient department of a tertiary care hospital for seeking medical help for any ocular problem and was satisfying inclusion criteria.

**REFERENCES**


