Comparison of Goldmann tonometry, pneumotonometry and the effect of the central corneal thickness

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ABSTRACT

Purpose: To compare the intraocular pressure (IOP) measurements using the Goldmann applanation tonometer (GAT) and contact pneumotonometer (NTC), and to evaluate the effects of central corneal thickness (CCT) on the readings.

Methods: This was a prospective, observational clinical study, which included 96 eyes of 49 patients, 40 glaucomatous, 29 ocular hypertensive and 27 normal subjects. The IOP measurements were performed with each tonometer. The CCT was also measured.

Results: A strong correlation coefficient between GAT and the NTC was found (Pearson=0.922, p<0.001). The mean of paired differences between GAT and NTC was 0.72±2.82 mmHg. The mean difference between GAT and NTC was low at lower levels of PIO and higher at higher levels of IOP. Readings with the GAT showed a mean increase in IOP of 0.47 mmHg for every 10µm of CCT, and the NTC 0.34 mmHg for every 10µm, the difference was not statistically significant.

Conclusions: The contact pneumotonometer is a reliable method in diagnosis and follow up of our population. The effect of the central corneal thickness was more important for the Goldmann applanation tonometer.

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Comparación del tonómetro de Goldmann, neumotonómetro de contacto y el efecto del grosor corneal

Resumen

Propósito: Comparar la medición de la presión intraocular (PIO) usando el tonómetro de aplanación de Goldmann (GAT) y el neumotonómetro de contacto (NTC), y evaluar el efecto del grosor corneal central (CCT) en las mediciones.

Método: Estudio prospectivo, clínico observacional. Se incluyeron 96 ojos de 49 pacientes 40 glaucomatosos, 29 hipertensos oculares y 27 controles. La PIO se midió con cada uno de los tonómetros. Además se midió el CCT.
Introduction

Intraocular pressure (IOP) measurements are an important procedure for diagnosing and following up patients with glaucoma. There are several factors that influence the measurement of IOP, including central corneal thickness (CCT), corneal curvature and the method used for measuring.1-7 The most common technique, which is a reference for measuring IOP, is Goldman applanation tonometry (GAT). However, one of the main limitations of this technique is the influence of CCT in the values it provides.1,2 GAT was gauged for a CCT of 520 µm and therefore gives rise to an underestimation and over estimation of IOP in thin or thick corneas, respectively.3

The contact pneumotonometer (CPT) uses the applanation principle which has the theoretical advantage of delivering a digital value and is a mean of several measurements taken in a short period of time. In addition, in some cases, it is better tolerated and would not be affected by surface problems. Prior to that, a good correlation between CPT and GAT had been demonstrated.3-7

The CPT values would be hardly affected by the CCT, although recent studies have refuted this statement and even demonstrated greater influence of CCT over CPT than over GAT.5

The objective of this study is to compare the IOP values obtained by means of GAT and CPT, the influence of CCT, in glaucomatous and ocular hypertensive patients as well as controls visited in our service.

Subjects, material and method

The patients were recruited in the Glaucoma Dept. of our institution. All were over 18 years of age. Accepted patients had open angle glaucoma, chronic closed angle glaucoma, glaucoma with normal IOP, ocular hypertension and controls. Excluded patients had keratoplasty, LASIK or other surgical procedures on the cornea. The total number of prospective eyes included were 96, 40 of them glaucomatous, 29 hypertense and 27 controls out of 49 patients visited in our services. Of these, 18 belonged to men and 31 to women. Both eyes were included due to the type of the design and objectives of the study.

The measurements were made by three ophthalmologists of the Glaucoma Dept. Three consecutive measurements were taken with Goldmann tonometer by one of said ophthalmologists. The mean values were recorded. Ten minutes later a second ophthalmologist carried out measurements with the pneumotonometer (Model 30 Classic™ Pneumotonometer, Reichert® Ophthalmic Instruments, New York, USA). 10 minutes after that, the CCT was measured with an ultrasonic pachymeter (Ocuscan® RxP Ophthalmic Ultrasound System, Alcon®, Forth Worth, USA). In the case that any of the three measurements with both tonometers exhibited a difference exceeding 2 mmHg (confidence interval 95%), the measurement was repeated.

The match between both tests was analyzed utilizing Pearson’s correlation method. In addition, the values obtained by both methods were compared utilizing the t for Student for paired data. The effect of the CCT was assessed for both methods are utilizing a linear regression analysis. Said analysis was also carried out in subgroups. The data were analyzed with the SPSS® for Windows® software version 13.0 (SPSS Inc. Chicago, Illinois. USA.)

Results

The mean age was of 65.5±11.49 years (range: 37-83 years). Table 1 illustrates the mean IOP values for both methods and the CCT for all patients and subgroups.

<table>
<thead>
<tr>
<th>Group (µm)</th>
<th>Goldmann (mm Hg) (mean±SD)</th>
<th>Pneumotonometer (mmHg) (mean±SD)</th>
<th>CCT (mean±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>17.79±7.16</td>
<td>17.06±6.08</td>
<td>550.05±42.27</td>
</tr>
<tr>
<td>Glaucoma</td>
<td>19.23±8.58</td>
<td>17.74±7.67</td>
<td>533.98±37.17</td>
</tr>
<tr>
<td>OH</td>
<td>19.96±6.10</td>
<td>18.89±4.51</td>
<td>576.69±42.92</td>
</tr>
<tr>
<td>Control</td>
<td>13.33±2.81</td>
<td>14.11±3.42</td>
<td>545.26±47.09</td>
</tr>
</tbody>
</table>

OH: ocular hypertensive.
When comparing GAT against CPT a significant correlation was obtained with a Pearson correlation coefficient of 0.922 (p<0.001) (fig. 1). The analysis of the t for Student for paired data exhibited a mean difference of 0.72±2.82 mmHg. The analysis per patient subgroups maintained a good correlation between both methods, albeit with a low correlation coefficient in the case of the control group (table 2).

The mean difference according to the t for Student analysis for paired data is summarized in table 3. The same subgroup analysis according to 3 different IOP levels, 5-18 mmHg (n=64), between 19-25 mmHg (n=21) and >25 mmHg (n=11), is summarized in table 4.

A positive correlation was found between GAT and CCT (\(b=0.047, R=0.294\)) and between CPT and CCT (\(b=0.034, R=0.251\)). That is, each 10 µm of CCT produces an increase of 0.47 mmHg, and of 0.34 mmHg when measuring with GAT and/or CPT respectively. The difference in the effect of CCT over GAT-CPT was not statistically significant.

### Discussion

In our population, which includes patients with glaucoma, ocular hypertension and controls, the IOP values obtained with the CPT exhibited a good correlation with the values obtained with GAT. This correlation was maintained at the subgroup level. The poorest correlation in the control group could be explained by the smaller number of patients.

The mean difference obtained between both methods matches the results obtained by previous studies and fall within clinically acceptable ranges.\(^6,7\) Said difference is lower with lower IOP levels and increases with higher IOP levels, which means that the CPT slightly overestimated the IOP at lower levels and underestimated the higher values, compared to GAT. Said difference is also lower in the control eyes, intermediate in ocular hypertensive and higher in controls.

### Table 2 – Pearson’s correlation coefficient for Goldmann tonometry and pneumotonometer per subgroup

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of eyes</th>
<th>Pearson’s correlation coefficient for GAT-CPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>96</td>
<td>0.922</td>
</tr>
<tr>
<td>Glaucoma</td>
<td>40</td>
<td>0.951</td>
</tr>
<tr>
<td>OH</td>
<td>29</td>
<td>0.875</td>
</tr>
<tr>
<td>Control</td>
<td>27</td>
<td>0.772</td>
</tr>
</tbody>
</table>

OH: ocular hypertensive; \(p=0.01\).

### Table 3 – Mean differences between both methods per subgroup patients

<table>
<thead>
<tr>
<th>Group</th>
<th>Controls</th>
<th>OH</th>
<th>Glaucoma</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAT-NCT (mmHg)</td>
<td>0.77±2.19</td>
<td>1.06±3.06</td>
<td>1.49±2.69</td>
</tr>
</tbody>
</table>

OH: ocular hypertensive.

### Table 4 – Mean differences between both methods per different IOP levels

<table>
<thead>
<tr>
<th>Group</th>
<th>5 - 18 mmHg</th>
<th>19 - 25 mmHg</th>
<th>&gt; 25 mmHg</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAT-NCT (mmHg)</td>
<td>-0.25±2.53</td>
<td>2.23±2.21</td>
<td>2.40±3.54</td>
</tr>
</tbody>
</table>

Figure 1 – Regression line for Goldmann tonometer and pneumotonometer.
glaucomatous patients. This is partly explained by the different IOP levels in each subgroup of patients, although other factors cannot be discarded.

Our study exhibits a positive correlation between the IOP measured with both methods and the CCT. The effect of CCT is greater for GAT but also exists for CPT. Previous studies observed similar values.1-7

The subgroup analysis also emphasizes the presence of higher mean CCT values in ocular hypertensive patients. As the CCT is essential for a correct interpretation of IOP values obtained by GAT, it is possible that the IOP of some of these patients was overestimated.

It is also important to emphasize that CPT seems to be better tolerated by some patients, to the extent that in some cases it was only possible to measure IOP with the said instrument. This could not be quantified and could be the object of future studies.

The possible limitations of this study are that the majority of patients are glaucomatous. In addition, the use of both eyes in the analysis could involve a dependence bias although we consider that, due to the design of the study, said bias would not invalidate the obtained results.

In this work as well as in the references, the CPT exhibits a good correlation with GAT. Compared to GAT, the pneumotonometer tends to increase the IOP value at lower levels and reduce it at higher levels. The effect of CCT is greater in the case of GAT than on CPT.

REFERENCES