CORRELATION BETWEEN INTRAOCULAR PRESSURE, PAQUIMETRY AND KERATOMETRY IN A NORMAL POPULATION

ABSTRACT

Purpose: To study the intraocular pressure (IOP), the corneal thickness and the corneal curvature distribution in a normal population. To investigate the relation between these variables, and to determine if the IOP and the paquimetry will be modified by the refractive error and age.

Methods: A population of 273 subjects, 545 eyes, without ocular pathology was selected. The refractive error, the corneal curvature, the corneal thickness and the IOP [with a non-contact tonometer (NCT) and with a Goldmann tonometer (GT)] were evaluated.

Results: The average age of the population was 49.34 (SD 7.23) years (27-68). The average corneal thickness was 544.3 (SD 33) mm in females and 543.1 (SD 29) mm in males. An inverse correlation was found between corneal thickness and age but this was not significant statistically. A mildly statistically significant correlation was found between corneal thickness and intraocular pressure with both methods of measurement of IOP: r = 0.316 (p < 0.001) and r = 0.264 (p < 0.001), with NCT and GT respectively. No correlation was found between the IOP and the refractive error.

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INTRODUCTION

Variability is inherent to human beings in many measurable aspects. The eye globe is no exception, and subsequently there are different parameters which may potentially exhibit wide differences within a given population, such as the axial length, the corneal diameter and depth of the anterior chamber. Furthermore, each individual may show certain variations with respect to a number of age-dependent parameters (1). Likewise, the instruments used may be influenced in terms of results by the use of physical principles which assume ex-ante certain constant ocular variables (2,3). Even the fact of belonging to one race or another could influence decisively many of these measurements, as several studies have shown in the past (4-6).

Some authors have reported this link in patients with previous eye pathology (2). Therefore, it is advisable to know the distribution of certain ocular variables and the existing relationships between them in populations not suffering from ocular pathologies (6,7). This would allow later on for comparison with groups with different pathologies in our environment.

This study has a double aim. First, to determine the average and distribution of intraocular pressure (IOP), central corneal thickness (CCT) and corneal curvature radius (CR) were measured in a normal Caucasian population. And, secondly, to find the correlation between these variables, as well as the influence exerted by age and their refractive condition.

SUBJECT, MATERIAL AND METHODOLOGY

In total, the study surveyed the eyes belonging to 273 individuals who worked in our hospital. All of them were subjected to ophthalmic examination including: biomicroscopy of the anterior segment in order to discard corneal pathologies, IOP measurement via Goldmann tonometer (GT) and non-contact tonometer (NCT) (neumotonometer TX-10, Canon Inc, Japan), central pachymetry (OLCR pachymeter, Haag-Streit AG, Switzerland), keratometry and refractometry (Keratorefractometer RK-3, Canon Inc., Japan). Anamnesis included: age, gender, and body mass index (BMI) by means of a formula based on height and weight; BMI = weight/height in square meters, family history of glaucoma and personal history of diabetes and/or high blood pressure.

When analyzing relationships between the subject’s non-intrinsic variables, central corneal thickness, IOP, corneal curvature, the two eyes for each subject were taken as independent data, whereas only the right eye was taken into account when dealing with variables such as gender or age. Individuals with a history of past ocular trauma or eye surgery were excluded, together with those patients already diagnosed and/or treated for ocular hypertension or optic neuropathy of glaucoma.

Non-medical health personnel performed a non-contact tonometry, refractometry (the spherical equivalent was defined as the spherical error plus...
half of the cylindrical error) and keratometry. Medical personnel performed anamnesis, pachymetry and applanation tonometry. A Goldmann tonometry was performed fifteen minutes after the non-contact tonometry without knowing the corresponding IOP result. Three IOP and corneal thickness measurements were undertaken for each eye, using the arithmetic mean for statistical estimations.

The principle of non-contact tonometers, and among them the one used herein, is to achieve the corneal applanation via a known force. The force is achieved using an air stream and the corneal applanation is verified with an electronic system which casts a beam of collimated light and detects the parallel rays reflected on the cornea when the same is flattened.

The IOP result in mmHg is estimated based on the time it takes to flatten the cornea (9). All functions are automated. The device itself discards erroneous measurements and points out the less reliable ones. Two measurement ranges may be used, 0-30 mmHg or 0-60 mmHg, depending on the strength of the air stream used by the device, either 30 mmHg or 60 mmHg (usually, the first range is used; if IOP exceeds 30 mmHg, it switches automatically to the following range). Measurement increments are set at 1 mmHg. In order to mitigate the effects associated with IOP measurements at different points in time during the cardiac cycle, manufacturers recommend performing three valid measurements and the average obtained is the IOP result provided by the device.

The pachymeter used, mounted on a slit lamp, resorts to an optical low-coherence reflectometry to obtain these measurements. To do so, two .1 mm guide laser beams, color red, one perpendicular to the corneal surface and the other lower, in the center of the cornea. The measurement head detects through the reflection of light from an infrared laser changes in the reflection speed between the rear and anterior surface of the cornea.

In order to manage keratometric measurements, the mean K was obtained ex-ante using the K1 and K2 figures provided by the refractometer.

For the statistical study, an SPSS 12.0 software for Windows (SPSS Inc, Chicago, Illinois, USA) was used. Statistical differences were assessed for the different IOP subgroups based on the pachymetry or age, using non-parametric tests such as the Kruskal-Wallis and U-Mann Whitney tests. Correlations were determined between variables using the Spearman correlation test and IOP predictions were assessed via a multiple linear regression study with respect to those factors showing a significant association in correlation tests: corneal thickness, age, corneal curvature and refractive status. A statistical significance was considered for p < .05 bilateral.

RESULTS

IOP and Pachymetry Relation with Age

Table I shows the distribution by age of pachymetries and IOP for our study group. The average age was 49.34 SD 7.23 years (range 27-68). 92.7 percent were female. The mean pachymetry among women was 544.3 SD 33 µm and among men 543.1 SD 29 µm. The mean IOP among women was 15.5 SD 3 mmHg and 15.5 SD 3 mmHg with the non-contact tonometer and Goldmann, respectively. Among men, it scored 15.2 SD 3 mmHg and 14.6 SD 3 mmHg. No significant differences were found in either group nor through the pachymetry and IOP obtained using both methods. No relevant correlation exists between corneal thickness and age r=−.131 (p= .003). In the study by groups two to two, significant differences were found between the age group between 30-43 with respect to the 54-75 range (p= .05) and in the 44-53 group with respect to the 54-75 group (p= .008) (table I). No significant

Table I. Distribution by age for the Pachymetry and IOP, NCT (Non-Contact Tonometer), GT (Goldmann Tonometer)

<table>
<thead>
<tr>
<th>Age</th>
<th>Pachymetry (µm)</th>
<th>NCT (mmHg)</th>
<th>GT (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-43 a</td>
<td>547.3 SD 31</td>
<td>15.2 SD 2</td>
<td>15.2 SD 2</td>
</tr>
<tr>
<td>44-53 a</td>
<td>546.7 SD 31</td>
<td>15.4 SD 3</td>
<td>15.4 SD 3</td>
</tr>
<tr>
<td>54-75 a</td>
<td>536.4 SD 36</td>
<td>15.5 SD 3</td>
<td>15.4 SD 3</td>
</tr>
<tr>
<td>p value*</td>
<td>.026</td>
<td>.779</td>
<td>.894</td>
</tr>
</tbody>
</table>

* Kruskal-Wallis for the study of differences in all groups. SD: Standard Deviation.
differences were found at the IOP level among the different age groups.

**Relation between IOP and Pachymetry**

There is a significant correlation between corneal thickness and IOP levels, both through the non-contact tonometer and Goldmann tonometer, $r = .316$ (p < .001) and $r = .264$ (p < .001), respectively.

Table II shows IOP measurements by corneal thickness groups and the existence of statistically significant differences among the different groups.

There is a tendency to the increase of corneal thickness with the increase of IOP, so that the average pachymetry increases from 532.3 SD. 30 µm for the IOP group < 13 mmHg to 545.6 SD. 34 µm for the IOP group between 14-17 mmHg and 555.3 SD 28 µm in the IOP group > 17 mmHg.

These differences are significant both with respect to total numbers in both groups and inter-groups (p<.001).

### Relation of IOP and Pachymetry with Refractive Status

The mean spherical equivalent was $-0.66$ SD 3 diopters. No significant correlation was found between IOP and refractive error. As for IOP with neuromonometer and Goldmann, it was $r=-.037$ (p=.402); $r=-.068$ (p=.120), respectively.

There is a positive significant correlation between the refractive status and age $r=.268$ (p<.001). No correlation exists between corneal thickness and refractive status $r=.021$ (p=.630).

### Relation of IOP and Pachymetry with Corneal Curvature

The mean corneal curvature was $K_1$: 7.8 SD .2 mm, $K_2$: 7.6 SD .2 mm; the range for $K_1$ and $K_2$ was (7.2- 8) and (7-8.5), respectively; average $K$: 7.70 SD .2 mm (fig. 1).

No relevant correlation exists between the different IOP levels and corneal curvature. The average $K$ was $r=-.10$ (p=.04), $r=-.115$ (p=.014) for the neuromonometer and Goldmann, respectively. No correlation was found between the corneal thickness and the value of the average $K$.

The correlation between the corneal curvature and age cannot be considered significant for the average $K$ $r=-.148$ (p=.003).

### Multiple Regression Study

The multivariate linear regression study was performed including the IOP prediction model via a Goldmann tonometer: corneal thickness, age, ave-
rage K and the interaction between pachymetry and age.

The pachymetry and average K were included in the regression model with very good tolerance limits for prediction. The remaining variables showed low significance and tolerance issues. With a r=.304 (p<.001) a regression line is obtained (fig. 2).

IOP Goldman = 18.4 + (.23 x pachymetry) – (1.2 x average K). This means that for each 100 µm increase in the pachymetry, the IOP increases by 2.5 mm. Even though this model only predicts 10 percent of the IOP value, there is an obvious relation between the later and corneal thickness.

Using the IOP resulting from the neumotonometer, results are very similar. R=.341 (p<.001). The line obtained is as follows: IOP neumotonometer = 13.37 + (.30 x pachymetry) – (1.8 x average K).

**DISCUSSION**

The study found a mean corneal thickness of 544.34 µm. This mean is similar to that found in Latin individuals by Hahn et al (9), of 546.9 µm, and is smaller than the one found in the La Rosa’s study on the American Caucasian population (10). Nevertheless, caution is advised when performing comparisons, since minimal differences may respond to distribution based on age or gender, or to the use of different types of pachymeters.

Certain studies found measurement errors and interobserver differences when using optical pachymeters due to a poor eye alignment. Such errors may be rectified using laser pachymeters (11,12), which is the case in the present study.

A relation was found between corneal thickness and age by groups, with older individuals presenting thinner corneas. Hahn et al (9) found among Latins that corneas were thinner in older people and thicker among younger subjects. Similar findings were reported by Foster (11) and La Rosa (10). This may be due to the fact that age leads to a decrease in the density of keratocytes and likely to a rupture of the collagen fibers in older corneas. Nevertheless, Nemesure (4), Shimmyo (5) and the studies by Reykjavik (6) and Rotterdam (13) did not find such relation.

Nemesure (4) found a relation between thickness and age, refractive status and a history of diabetes. In the present study, no relation was found with the refractive status.

In the same fashion as Shimmyo (5), the present study found a statistically significant relation between the IOP and the corneal curvature both in the correlation test and in the multivariate study.

The study authored by Cho and Lui (14) found that IOPs measured with a Goldmann tonometer and the neumotonometer may be comparable.

The present study aimed at using both data in order to assess whether there were any differences between the measurement of IOP with both methods and its relation with the remaining variables.

The IOP measured by the applanation tonometer or the neumotonometer is correlated with the corneal thickness (15). This relation, already described by Goldman and Shimmyo (5), was confirmed in other studies, thus pointing at the need of performing an IOP adjustment in relation with the corneal thickness (5,16).

The study revealed an IOP difference of 2.5 mm for each 100 µm of difference in corneal thickness. Similar findings with IOP variations ranging from 1.1 and 3.2 mm have been described by other authors (6,9,16,17). Although corneal thickness barely accounts for 10 percent of the IOP, it seems to be a relevant factor to be taken into account in the patients’ daily examinations.

The relation between corneal thickness and IOP may have implications in the diagnosis of ocular hypertension, open angle glaucoma or normal-tension glaucoma. The IOP is still a very important factor.
factor when developing glaucoma. Correcting the IOP via the corneal thickness, Copt (18) and Bron (19) found a high percentage of patients suffering from normal-tension glaucoma and ocular hypertension needed to be reclassified.

REFERENCES


