# Correlation of Central Corneal Thickness with Schiotz and Goldmann Tonometry

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**Purpose**: To investigate the correlation between central corneal thickness (CCT) and intraocular pressure (IOP) measured by Schiotz and Goldmann tonometers.
**Methods:** CCT and IOP were determined by ultrasonic pachymetry and with the Goldmann and Schiotz tonometers, respectively. The correlation between IOP measured by Goldmann and Schiotz tonometers on one hand and CCT on the other, was determined by regression analysis.
**Results**: Overall, 168 eyes of 168 glaucoma patients including 85 male (50.6%) and 83 female (49.4%) subjects with mean age of 54.6±19.8 (range 7-85) years were evaluated. Mean CCT was 547.6±53.02 (range: 446-848) μm without any significant difference between men and women (P=0.811). IOP was correlated with CCT with both types of tonometry: every 20 μm change in CCT was associated with 1.9±1.4 mmHg and 1.54±0.95 mmHg change in IOP as measured by the Goldmann and Schiotz tonometers respectively with no statistically significant difference between the two devices (P=0.6).
**Conclusion:** IOP measurement by Schiotz tonometry is affected by CCT to the same extent as Goldmann applanation tonometry.

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## INTRODUCTION

Glaucoma is a neurodegenerative disorder of the optic nerve and one of the leading causes of blindness worldwide.[1] The most important risk factor for glaucoma is elevated intraocular pressure (IOP) making its accurate measurement essential for disease detection and patient follow-up.[2,3] Although tonometry alone is insufficient for glaucoma screening, it is still useful in case finding.[4] The Goldmann applanation tonometer (GAT) has been universally accepted as the gold standard because of its validity and reproducibility.[5,6] However, the accuracy of GAT depends on central corneal thickness (CCT).[5-7] The importance of CCT and its effect on IOP measurement is going to increase in near future; widespread performance of laser refractive surgery and the resulting decrease in corneal thickness will affect the reliability of IOP measurements.

General practitioners are in a favorable position to detect glaucoma and at present, the Schiotz indentation tonometer is the predominant method of tonometery in general practice.[8] This tonometer is also still used by some ophthalmologists in certain circumstances such as examination of children.[9,10] The aim of this

study was to evaluate the effect of CCT on Schiotz tonometry which to the best of our knowledge, has not been reported previously.

## METHODS

Subjects in this prospective study were recruited from the glaucoma service of the ophthalmology department at Shiraz University of Medical Sciences, Shiraz, Iran. The study was approved by the local ethics committee and included 168 glaucoma patients enrolled from April 2005 to January 2006. Although CCT and IOP were measured in both eyes, only data from left eyes were analyzed. Patients were excluded if they had any corneal pathology (corneal scar, edema, keratoconus), previous penetrating keratoplasty or refractive surgery and if suspected of harboring ocular surface infections.

The examinations were performed in the following order: biomicroscopy, Goldmann applanation and Schiotz tonometry followed by central corneal thickness measurement. The subjects were given 10 minutes of rest throughout the series of IOP measurements. Care was taken to keep the patients comfortable and they were encouraged not to squeeze their eyelids or hold their breath. IOP was measured in the right followed by the left eye, with GAT mounted on a slitlamp and then with a Schiotz tonometer using the 5.5 gram weight and if needed the 7.5 and 10 gram weights. Measurements were converted to mmHg based on the 1955 Friedenwald conversion table. One investigator (M.R.) performed all measurements. Before each measurement with the Goldmann tonometer, a nurse adjusted the tonometer gauge to 15 mmHg. The nurse recorded the measured IOP without informing the investigator of the result. Next, the investigator measured IOP by Schiotz tonometry and recorded the scale readings.

All subjects underwent CCT measurement by one experienced technician at least 30 minutes after IOP measurements with an ultrasonic pachymeter (Paxis, Biovision Inc., Clermont-Ferrand, France). Ten measurements were performed in the center of the cornea and the lowest reading was recorded as CCT. The lowest reading is the most likely to reflect a perpendicular placement of the pachymeter probe and therefore reflects the most accurate measurement.[11]

First of all, outlier analysis was conducted on the collected data. Thereafter we used linear mixed model analysis considering age as a covariate to eliminate its confounding effect. Non-linear regression analysis was conducted for modeling the correlation of Goldmann and Schiotz tonometers with CCT. P values <0.05 were considered statistically significant.

## RESULTS

This study was conducted on 168 glaucoma patients including 85 (50.6%) male and 83 (49.4%) female subjects with mean age of 54.6±19.8 (range 7-85) years. Mean age in male and female subjects was 56.4±20.2 and 51.7±19.1 years, respectively (P=0.114). Mean CCT was 547.6±53.02 (range 446-848) μm overall, and 548.6±50.04 μm and 546.6±55.9 μm in male and female subjects respectively (P=0.811). Mean CCT in different types of glaucoma are shown in table 1.

Figure 1 shows that IOP measured by GAT tends to be correlated with CCT and is lower in eyes with thinner corneas and higher in eyes with thicker corneas. Age as a covariate was excluded from the models by mixed model analysis. By performing non-linear regression analysis we found that the equation relating IOP measured by GAT and CCT is: IOP (GAT) $=55.82-(0.179\times CCT)+(0.0002\times CCT^2)$, $R^2= 0.262$, $P<0.001$ ($R^2$ is the variance and CCT is central corneal thickness in microns); standard error (SE) of the slope for IOP against CCT was 0.07.

Figure 2 shows that IOP measured by Schiotz tonometry also tends to vary with CCT and is lower in the eyes with thinner corneas and higher in eyes with thicker corneas. Age as a covariate was excluded from the models by mixed model analysis. Non-linear regression analysis revealed that the equation correlating IOP measured by Schiotz

tonometry and CCT is: IOP (Schiotz) =85.27-(0.289×CCT)+(0.0003×CCT²), $R^2$=0.355, P<0.001 ($R^2$ is the variance and CCT is central corneal thickness in microns); standard error (SE) of the slope was 0.21.

The amount of change in IOP per 20 μm change in CCT was 1.9±1.4 mmHg with Goldmann and 1.54±0.95 mmHg with Schiotz tonometers (P=0.6).

**Table 1** Central corneal thickness (CCT) in different types of glaucoma

| Diagnosis | Number of Patients (%) | CCT (μm) Mean ±SD (Range) |
|---|---|---|
| Primary open angle glaucoma | 43 (25.6) | 535.6±33.1 (450-539) |
| Chronic angle closure glaucoma | 40 (23.8) | 542.7±50.2 (451-685) |
| Glaucoma suspect | 26 (15.5) | 547.8±41.9 (455-628) |
| Pseudoexfoliative glaucoma | 22 (13.1) | 529.2±37.1 (470-642) |
| Aphakia secondary to congenital cataract | 12 (7.1) | 632.6±80.3 (535-848) |
| Normal tension glaucoma | 7 (4.2) | 522±10.1 (508-537) |
| Juvenile open angle glaucoma | 6 (3.6) | 538.1±17.1 (512-559) |
| Weill–Marchesani syndrome | 5 (3.0) | 614±38.7 (554-662) |
| Pigmentary glaucoma | 3 (1.8) | 569±21 (552-593) |
| Aniridia | 2 (1.2) | 511.5±92.6 (446-577) |
| Primary congenital glaucoma | 2 (1.2) | 510±11.3 (502-518) |
| **Total** | **168 (100)** | |

SD, standard deviation

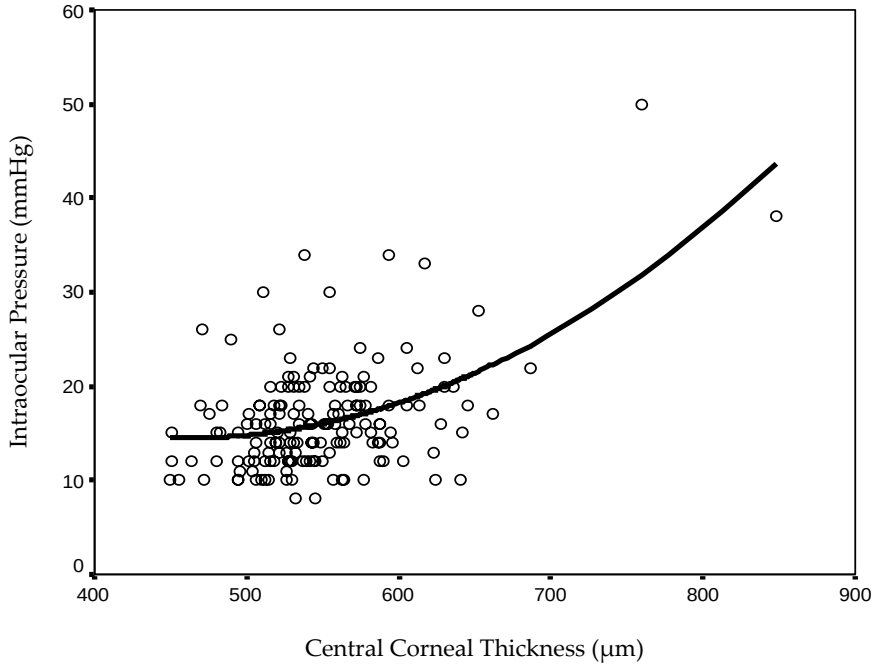


**Figure 1** Scatter plot depicting the correlation of central corneal thickness and intraocular pressure measured by Goldmann applanation tonometry.

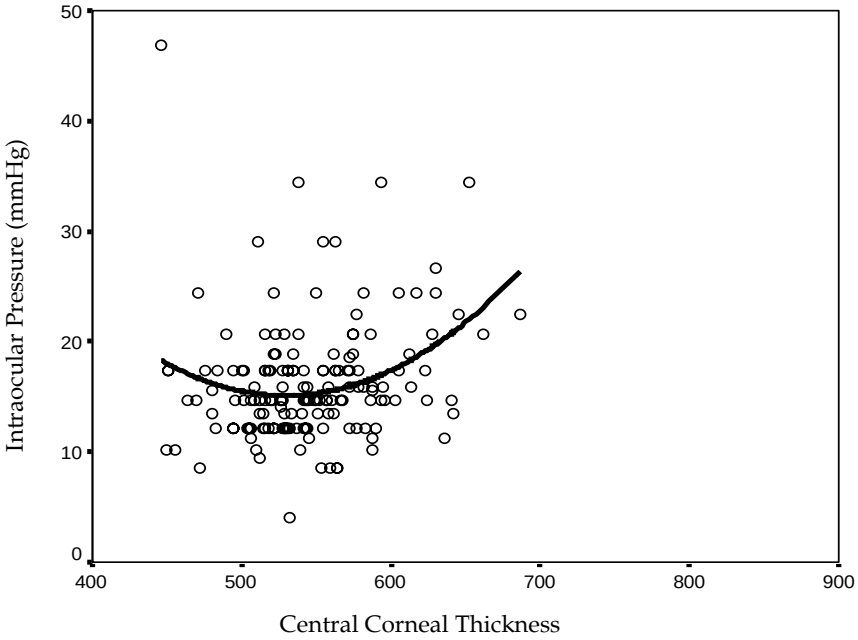


**Figure 2** Scatter plot depicting the correlation of central corneal thickness and intraocular pressure measured by Schiotz tonometry.

## DISCUSSION

This study revealed that both Goldmann and Schiotz tonometers tend to overestimate and underestimate IOP in thick and thin corneas, respectively and that CCT affected IOP measurements obtained by Schiotz and GAT to the same amount. To the best of our knowledge, this is the first study demonstrating a correlation between CCT and IOP measurement by Schiotz tonometry, although in a case report by Johnson et al[12] high Schiotz readings were related to a thick cornea. These authors reported a 17-year-old girl who had IOP of 35 and 34 mmHg measured with Perkins and Schiotz tonometers, respectively, without any glaucomatous optic nerve damage and normal visual fields. Medical treatment was unsuccessful in substantially lowering IOP. CCT was 900 μm in both eyes. Cannulation of the anterior chamber in the left eye revealed an IOP of 11 mmHg.

The literature suggests IOP errors by GAT ranging from 0.22 to 1.42 mmHg for every 20 μm of deviation from a normal CCT of 520 μm.[5,13-16] In our study the amount of change of IOP measured by GAT for every 20 μm change in CCT was 1.9 mmHg, but there is no data to compare the results of Schiotz tonometry (1.54 mmHg for every 20 μm difference in CCT). The difference in the amount obtained for GAT with other studies seems to be related to the inclusion of corneas with CCT greater than 675 μm. In all of the above-mentioned studies the maximum CCT was 675 μm.

One limitation of the present study is that all participants were glaucomatous; conversely this can be the strength of this study which provided a wide range of IOPs and CCTs. We did not measure corneal astigmatism before measuring IOP and this may have some impact on the results obtained from the Goldmann tonometer. However, the large number of patients sampled in the study is likely to mitigate the potential effect of this variable.

Although IOP measurement is insufficient as a screening tool for glaucoma, it is still useful in glaucoma case finding. With the increasing

number of patients with iatrogenically thinned cornea by laser refractive surgery, the measured IOP in these patients is lower than the true value. Most individuals who undergo laser refractive surgery are myopic who are at a 2-6 fold increased risk of developing glaucoma, the risk being proportionate to the degree of myopia. This is of particular concern with higher myopic corrections in which laser refractive surgery is associated with more severe corneal thinning and greater IOP underestimation.[17]

The trend after laser refractive surgery is a mean decrease of 0.63 mmHg in IOP measured by GAT per one diopter of correction.[17] According to the results of our study, IOP will be underestimated using the Schiotz tonometer similar to GAT. This fact may be of concern in the referral of subjects for suspected glaucoma by general practitioners who predominantly use the Schiotz device. On the other hand, IOP is overestimated in the presence of a thick cornea; many individuals with elevated Schiotz readings but no other findings suggestive of glaucoma probably have normal IOP and do not need treatment.

As noted the Schiotz tonometer is used by some ophthalmologists in pediatric patients. Measurement of IOP by this tonometer may be misleading in eyes with thicker or thinner CCT such as patients with previous congenital cataract surgery[18] and congenital glaucoma[19] respectively. In our series, we detected relatively thick corneas in patients with Weill-Marchesani syndrome and aphakic patients following congenital cataract surgery which is compatible with previous reports.[18,20,21] Due to the limited number of patients in other types of glaucoma, it would not be proper to compare our findings with previous reports.

In summary CCT seems to affect IOP measurements by Schiotz tonometry and the correlation is similar to that well known for GAT. This finding may be of particular importance in glaucoma case finding by general practitioners who use the Schiotz tonometer especially in myopic patients with previous laser refractive surgery.

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