· Original article ·

Effect of corneal thickness on readings of three different tonometers

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Abstract

• AIM: To compare the intraocular pressure (IOP) measured by Goldmann applanation tonometer (GAT), non-contact tonometer (NCT) and Schiotz tonometer (ST), and to evaluate the effect of central corneal thickness(CCT) on the readings.

• METHODS: IOP measurements were obtained in right eyes of all patients using GAT, NCT and ST. CCT was determinated by ultrasound pachymetry. All IOP and CCT measurements were performed by the same ophthalmologist. Percentile 25%(Q1) and percentile 75%(Q3) values of the CCT were calculated and by this way, the group was divided into thin, medium, and thick cornea subdivisions. Statistical analysis were performed with Statplus software.

• RESULTS: For the entire series of 144 eyes, the mean IOPs measured were 17.4 ± 4.9mmHg with GAT, 16.0 ± 5.8mmHg with NCT, 14.0 ± 4.0 with ST ($P < 0.01$ Friedman ANOVA). Correlation coefficient between IOP level and CCT was 0.787 ($P < 0.01$) with NCT, 0.630 ($P < 0.01$) with GAT, and 0.565 ($P < 0.01$) with ST readings. Correlation between deviation from corrected IOP level and CCT was remarkably weaker in thick corneas with ST measurements ($r = 0.381$, $P = 0.022$).

• CONCLUSION: NCT is the most susceptible device to the effects of varying CCT. ST readings seem to be less affected than GAT and NCT readings. Particularly in thick corneas, ST can be defined as a more reliable instrument as compared to NCT and GAT.

• KEYWORDS: tonometry; Goldmann; Schiotz; non-contact tonometer; pachymetry

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INTRODUCTION

Precise determination of intraocular pressure(IOP) is of great importance because IOP level is the essential risk factor for the development and progression of glaucoma disease and efficacy assessment of treatment[1]. Measurement of IOP can be carried out by several tonometry methods. Tonometry is the objective measurement of IOP, based most commonly on the force required to flatten the cornea, or the degree of corneal indentation produced by a fixed force. Since 1950's, Goldmann applanation tonometer (GAT) is the most commonly used device for the assessment of IOP. As in the case of other devices, GAT measurements are affected from such variables as ocular rigidity, axial length, corneal thickness and curvature[2]. Among these variables, central corneal thickness (CCT) has been predominantly investigated and some correction formulas according to CCT have been reported[3]. Another type of tonometer is non-contact tonometer (NCT), which works on the same principle as the GAT. The air puff hits the cornea on a given and reproducible area for the purpose of flattening the cornea. The moment of applanation is determined by an optical sensor to assess IOP level. NCT is prevalently used for screening purposes because of its practical use. IOP measured by NCT is highly correlated with those of GAT particularly in normal IOP range and seems affected from CCT[4,5]. Newly designed NCT devices are manufactured with correction formula softwares. Schiotz tonometer, which works with indentation principle, has been used since the beginning of 20th century. Since GAT has been the golden standard for IOP assessment, and NCT has been used widely because of its practical use, ST has been losing its prevalence. In parallel to this course, there hasn't been enough data interpreting the effect of CCT on ST measure outcomes. This study is to compare the effect of CCT on GAT, NCT and ST measurements.

MATERIALS AND METHODS

Materials A total of 144 eyes of 144 patients were included in this cross sectional study. Patients were enrolled consecutively from the outpatient clinic of Nisa Hospital Ophthalmology Department. Exclusion criteria were corneal abnormality, corneal astigmatism >2 dioptres, active ocular infection or inflammation, history of ocular surgery or trauma. According to the tenets of the Declaration of Helsinki, informed consent was obtained from each patient.

Methods All IOP and CCT measurements were performed by the same ophthalmologist who was masked to the readings obtained. NCT (Topcon CT80, Topcon Corp., Tokyo, Japan), GAT, Schiotz measurements were performed respectively by 10 minutes intervals. After IOP measurements, CCT measurements were performed. Mean value of three consecutive measurements was used for statistical analysis for IOP and CCT measurements.

Table 1　Correlation between CCT and GAT, NCT, and Schiotz IOP measurements and deviation from corrected IOP

	CCT	GAT	NCT	Schiotz
*vs*GAT, NCT, IOP	Entire group	0.630 (P<0.01)	0.787 (P<0.01)	0.567 (P<0.01)
	>Q3(>583μm)	0.185 (P=0.281)	0.307 (P=0.069)	0.178 (P=0.299)
	<Q1(<503μm)	0.140 (P=0.401)	0.416 (P=0.009)	0.165 (P=0.323)
*vs*deviation from corrected IOP	Entire group	1 (P<0.01)	0.955 (P<0.01)	0.746 (P<0.01)
	>Q3(>583μm)	1 (P<0.01)	0.872 (P<0.01)	0.381 (P=0.022)
	<Q1(<503μm)	1 (P<0.01)	0.784 (P<0.01)	0.757 (P<0.01)

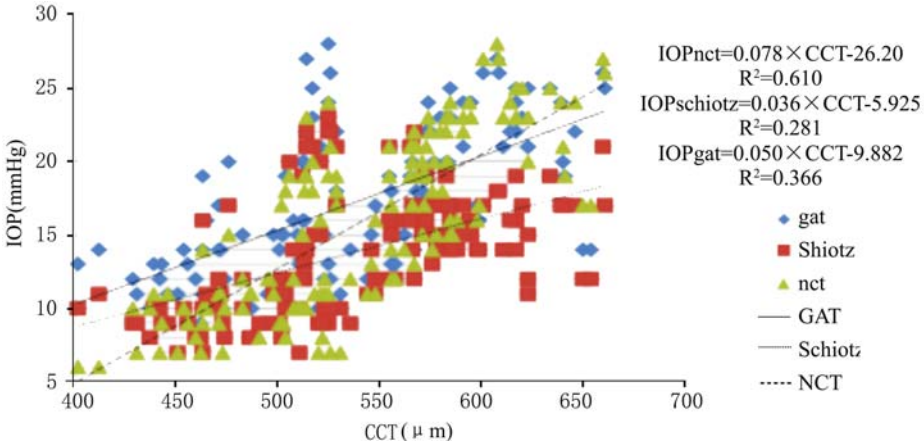

Figure 1 Regression analysis of GAT, NCT, and ST measurements with CCT.

Statistical Analysis　The outcomes were analyzed by Statplus software (Analysoft, USA). Comparisons were made by paired two sample t-test for normal distribution, and Wilcoxon matched pairs test, *vice versa*. Correlation coefficients were calculated with Pearson correlation test for data with normal distribution, and Spearman correlation test for data without normal distribution. Two tailed distribution outcomes were accepted for P values.

RESULTS

All 144 eyes of 144 patients were recruited from outpatient clinic regardless of whether they have glaucoma and ocular hypertension. Measurements were performed on the right eye of each patient. The mean age of the patients was 49.3±16.3 years. Sixty-eight of 144 patients were male. For the entire series of 144 eyes the mean IOP measured were 17.4±4.9mmHg with GAT, 16.0±5.8mmHg with NCT, 14.0±4.0 with ST (P<0.01 Friedman ANOVA). GAT-NCT (P<0.01), GAT-ST(P<0.01), NCT-ST(P<0.01) mean IOP value differences were all statistically significant (Wilcoxon matched pairs).

Mean CCT was 541.06±58.27 (range 401-660)μm. Percentile 25% (Q1) value of CCT was 502.75μm, and percentile 75% (Q3) was 583.25μm. Thirty-six eyes had a higher value of CCT than Q3, and 38 eyes had lower than Q1. CCT and IOP level correlation was calculated in entire group, in eyes with CCT lower than Q1, and higher than Q3. For the entire group, Schiotz measurements showed the least correlation coefficient, and NCT measurements showed greatest coefficient. In eyes with CCT greater than Q3 and less than Q1, correlation coefficients weren't statistically significant. Correlation coefficients between CCT and IOP level are shown in Table 1. Mean deviation from corrected IOP levels according to Ehlers Formula was 1.50±4.16mmHg in GAT, 0.05±6.03mmHg in NCT, and -1.93±4.27mmHg in ST measurements. Correlation coefficients between CCT and deviation from corrected IOP levels are shown in Table 1. ST measurements showed remarkably weaker correlation in thick corneas. (CCT > Q3) as shown in Table 1.

With the linear regression analysis, the NCT measurements showed the greatest regression coefficient (β=0.078, R^2=0.610), while the Schiotz measurements showed the least regression coefficient (β=0.036, R^2=0.281). Regression coefficients and formulas are shown in Figure 1.

DISCUSSION

Tonometers measure the IOP by relating a deformation of the cornea to the force responsible for the deformation. Some tonometers indent the cornea, such as ST, while others applanate the cornea. Within the latter group, some devices measure the force required to flatten a standard area, of which GAT is an example, while others measure the area that is applanated by a standard force[6]. GAT has been the gold standard for IOP measurements for decades. Goldmann assumed an average corneal thickness of 520μm in designing the tonometer[6]. The thickness of the cornea has been shown to influence the pressure estimate, with thin corneas producing falsely low readings. A thick cornea causes a falsely high measurement if the thickness is due to increased collagen fibrils, whereas low readings occur if the thickness is due to edema. Corneal curvature and marked corneal astigmatism have also been shown to influence IOP measurements[7,8]. In this study, regression coefficient between GAT measurements and CCT was found 0.050 (R^2=0.366). Ko *et al*[5] found these values as β=0.037, R^2=0.246. In Babalola's study[9], these values were β=0.04 and R^2=0.05. According to Babalola, every 10μm increase in CCT results in 0.6mmHg

increase of GAT measurement. In this study, every 10μm increase of CCT,causes 0.5mmHg increase of GAT measurements. These findings show convenience between previous studies.

In previous studies, comparisons with GAT showed that the NCT is reliable within the normal IOP range, although the reliability is reduced in the higher pressure ranges. IOP measured by NCT are highly correlated with those of GAT and affected from CCT[4,5]. Advantages of NCT are elimination of infection spread, corneal abrasion and adverse effects of topical anesthetics. Its limitations include poor fixation, corneal abnormality, and higher IOP range. According to Ko's study, regression coefficient between CCT and NCT measurements was 0.063 ($R^2 = 0.42$)[5]. These values were $\beta = 0.078$ and $R^2 = 0.61$ in our study. In this study, every 10μm increase of CCT would increase NCT measurement by 0.78mmHg. Ko *et al*[5] found this increase as 0.65mmHg. These findings show that NCT measurements correlation with CCT is stronger than that of GAT measurements.

ST is one of the pioneer instruments for measuring IOP. Studies indicate that it reads lower than the GAT, even when the postural influence on IOP is eliminated. In this study, lowest mean value of IOP was the mean value of the ST measurements concordant with such previous studies. The ST has been shown to be particularly unsuitable for situations in which ocular rigitidy is known to be significantly altered, such as following retinal detachment surgery or in eyes containing gas[10].

In this study, mean value of ST measurements was lowest and GAT measurements' mean value was highest (GAT:17.45 ± 4.87mmHg, NCT:16.00 ± 5.80mmHg,ST:14.01 ± 4.04mmHg). The difference was statistically significant ($P < 0.01$). According to correlation coefficients between CCT and IOP level, ST was found to be the least affected by CCT, and NCT was found to be the most. Correlation between CCT and deviation from corrected IOP (regarding Ehlers formula) was weaker with ST than with NCT. Particularly, in thick corneas (CCT > Q3 = 583), correlation coefficient was remarkably weak as compared to NCT. While all the coefficients were at the level of 0.7-0.9, correlation coefficient between CCT and deviation from corrected IOP measured with ST was 0.381 ($P = 0.022$). These findings implies that ST isn't affected from higher CCT values as much as other devices.

In conclusion, GAT and NCT have similar behaviors against corneal thickness in normal IOP range. Both of them show significant correlation with CCT. ST has lower readings as compared to NCT and GAT. Particularly in thick corneas, ST seems reliable than NCT and GAT. Although it is known as an old fashioned instrument, it has advantages of being inexpensive, practical and mobile. Also it is being used prevalently[11]. It can still be useful for IOP measurement unless there is an evidence of ocular rigidity alteration.

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角膜厚度对三种不同眼压计测量的影响

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摘要

目的:比较采用 Goldmann 压平眼压计(Goldmann applanation tonometer, GAT)、非接触眼压计(non-contact tonometer, NCT)和 Schiotz 眼压计(Schiotz tonometer, ST)的眼压(intraoeular pressure, IOP)测量,评估角膜中央厚度(central corneal thickness,CCT)对读数的影响。

方法:使用 GAT、NCT 和 ST 对所有患者的右眼进行眼压测量。超声角膜厚度测量法测定 CCT。所有 IOP 及 CCT 测量由同一检查者进行。计算 CCT 25%(Q1)百分位数和 75%(Q3)百分位数值,并通过这种方法将该组分为薄、中、厚角膜亚组。使用 Statplus 软件进行统计分析。

结果:全系列 144 眼,GAT 测量平均 IOP 为 17.4 ± 4.9mmHg, NCT 为 16.0 ± 5.8mmHg,ST 为 14.0 ± 4.0mmHg(Friedman 方差分析 $P < 0.01$)。IOP 水平和 CCT 之间的相关系数 NCT 为 0.787($P < 0.01$),GAT 为 0.630($P < 0.01$),ST 为 0.565($P < 0.01$)。ST 测量中,纠正的 IOP 误差和 CCT 之间的相关性在厚角膜明显弱($r = 0.381$, $P = 0.022$)。

结论:NCT 是最易受不同 CCT 影响的设备。ST 读数似乎比 GAT 和 NCT 读数受 CCT 的影响小。特别是在厚角膜,与 NCT 和 GAT 相比,ST 可以被认为是一个更可靠的仪器。

关键词:眼压测量;Goldmann;Schiotz;非接触眼压计;角膜厚度测量法