Factors affecting intraocular pressure measured by noncontact tonometer

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PURPOSE. *To investigate the mean values of intraocular pressure (IOP) measured with noncontact tonometer (NCT) and evaluate the factors that may affect IOP.*
METHODS. *A total of 850 subjects who were admitted to our clinic between March 2005 and February 2006 were recruited for the study. Subjects having blepharitis, conjunctivitis, corneal diseases, glaucoma suspicion, or glaucoma were not accepted to the study. All subjects were questioned about systemic diseases. IOP measurement with NCT and central corneal thickness (CCT) with ultrasound pachymetry were performed for each patient between 9 and 11 AM.*
RESULTS. *The mean ages of 367 (43.2%) male subjects and 483 (56.8%) female subjects were 43.9±18.1 and 40.7±18.0 years ± SD, respectively. Since right and left eye IOP, CCT, and keratometric values were significantly correlated, right eye values were used for statistical purposes. Mean IOP values in males and females were 13.2±3.0 and 13.5±2.9 mmHg, respectively. Mean CCT values were 552.5±34.7 µm for males and 550.1±34.3 µm for females. In multiple regression analysis, IOP was found to be associated with gender, refractive error, CCT, and the presence of diabetes mellitus (DM).*
CONCLUSIONS. *Gender, CCT, the presence of DM, and refractive error may be significantly associated with IOP in this particular population. (Eur J Ophthalmol 2009; 19: 61-5)*

KEY WORDS. *Intraocular pressure, Age, Central corneal thickness, Keratometry, Refraction*

Accepted: May 14, 2008

INTRODUCTION

Glaucoma is one of the leading causes of blindness worldwide. When the disease is detected early and treated properly, blindness from glaucoma may be preventable. Several factors, many of which still unknown, increase the probability of glaucoma development. Increased intraocular pressure (IOP) and advanced age are the well known and important risk factors for glaucoma development. Thus the screening of IOP is crucial especially in subjects above 40 years of age (1-3).
Factors that may affect IOP measurements have already been studied in different nations and ethnicities (4-6). Most of these previous studies investigated the influence of age on IOP and revealed controversial results (5-9). In these studies, IOP measurements were performed with applanation tonometry which is based on Imbert-Fick principle. When using applanation method to measure IOP, central corneal thickness (CCT) is an important source of error (10-12). Both CCT and IOP have been reported to show variation in different nations and ethnicities (2, 3, 5, 12). Although Goldmann applanation tonometer (GAT) is the gold standard method, the noncontact tonometer (NCT) seems to be easier and more comfortable in mass screening of IOP (13).
The present study aimed to discover a mean value of IOP and evaluate ocular and systemic factors that may influence IOP readings in a Turkish population.

1120-6721/061-05$25.00/0

METHODS

A total of 850 subjects admitted to our clinic between March 2005 and February 2006 were recruited for the study. Subjects having blepharitis, conjunctivitis, or corneal diseases were excluded. Patients in whom glaucoma is suspected (cup/disc ratio ≥0.5, asymmetric cupping, neuroretinal rim loss) or diagnosed (glaucomatous visual field defect, documented retinal nerve fiber loss) were referred to glaucoma section and excluded from the study. All subjects were informed about the study and their informed consents were taken. Each measurement was performed between 9 and 11 AM by the same technicians. Intraocular pressure was measured by noncontact tonometer (Reichert AT-555; Reichert Ophthalmic Instruments, NY) without any topical anesthetic and an average of four readings was recorded. CCT was measured by ultrasound pachymeter (Tomey Bio-pachymeter AL-1000; Tomey Corporation, Nagoya, Japan) under topical anesthesia and again the average of four consecutive readings was recorded. Refraction and keratometry readings were made by AutoRef-keratometer (MRK-3100 premium; Huvitz Company, Gyeonggi-do, Korea). All subjects were questioned about demographic data and history of systemic diseases such as diabetes mellitus (DM), hypertension (HT), hyperlipidemia, asthma, and cardiac diseases.

The upper limit of normal IOP value was calculated as mean +2 SD. The differences between mean values of CCT, age, IOP, keratometer horizontal (Kh), keratometer vertical (Kv), and comparison of CCT values for left and right eyes with respect to sex were analyzed by Student *t*-test. Pearson correlation analysis was performed to evaluate the relation between IOP and age, CCT, Kh, and Kv and Spearman correlation analysis was used to evaluate the relation between IOP and refractive status. The possible factors that may affect the IOP values including age, sex, CCT, keratometry readings, refractive status, the presence of DM, HT, and hyperlipidemia were reanalyzed by multivariate regression model. The p values less than 0.05 were accepted as statistically significant. All statistical analysis was performed with SPSS 13.0 version.

We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research.

RESULTS

The mean ages of 367 (43.2%) male and 483 (56.8%) female subjects as years ± SD (range) were 43.9±18.1 (5–92) and 40.7±18.0 (5–88). Male subjects seemed to have significantly higher mean age than female subjects (Student *t* test, p=0.00).

Right and left eye IOP, CCT, and Kh-Kv values were significantly correlated (Pearson correlation test, r=0.719, p=0.00; r=0.947, p=0.00; r=0.852, p=0.00; r=0.085, p=0.01, respectively). Right eye values were used for statistical purposes. Mean ± SD values of age and right eye CCT, IOP, Kh, and Kv by gender are shown in Table I.

There was no significant difference between IOP values among genders (Student *t* test, p=0.10).

IOP and age was slightly correlated when whole group was investigated (Pearson correlation test, r=0.076, p=0.02). However, this correlation did not appear when male (r=0.078, p=0.14) and female (r=0.085, p=0.06) subjects were analyzed separately. The upper limit of IOP was calculated as 19.4 mmHg for whole group, 20.0 mmHg for subjects >40 years, 20.6 mmHg for subjects >50 years, and 20.4 mmHg for subjects >60 years old.

A moderately significant correlation was observed (Pearson correlation test, r=0.405, p=0.00) between IOP and CCT.

Intraocular pressure was not correlated with Kh and Kv (Pearson correlation test, r=–0.063, p=0.06; r=–0.014, p=0.68, respectively).

There was no statistically significant correlation between spherical equivalence and IOP (Spearman correlation test, for myopia r=–0.056, p=0.20, for hypermetropia r=0.076, p=0.17).

Among all subjects, 43 (5.1%) had DM, 71 (8.4%) had HT, and 33(3.9%) had hyperlipidemia. Since subjects with

TABLE I - MEAN AND STANDARD DEVIATION VALUES OF AGE, CCT, IOP, Kh, AND Kv BY GENDER

	Male	Female	p*
Age ± SD (years)	43.9±18.1	40.7±18.0	0.009
CCT ± SD (µm)	552.5±34.2	550.1±34.3	0.300
IOP ± SD (mmHg)	13.2±3.0	13.5±2.9	0.105
Kh ± SD (D)	43,5±1.7	43.9±1.7	0.003
Kv ± SD (D)	42.9±1.7	43.3±2.2	0.001

*Student t test.
CCT = central corneal thickness; IOP = intraocular pressure; Kh = keratometer horizontal; Kv = keratometer vertical.

TABLE II - MULTIPLE REGRESSION MODEL OF ASSOCIATIONS WITH INTRAOCULAR PRESSURE

Variables	Standardized coefficient	p value
Gender	0.067	0.03
Refractive status*	0.065	0.04
DM*	–0.133	0.00
CCT	0.415	0.00

*Categorical variable: myopia/hypermetropia, yes/no.
DM = diabetes mellitus; CCT = central corneal thickness.

cardiac diseases (10 [1.2%]) or asthma (3 [0.4%]) were very few, these parameters were not studied. Diabetic or hypertensive subjects had statistically significant high IOP readings (Student *t* test, p=0.00 for both) than healthy population. Hyperlipidemia did not seem to affect IOP significantly (Student *t* test, p=0.84).

A multivariate regression analysis which included age, gender, CCT, Kh-Kv, refractive status, the presence of DM, HT, and hyperlipidemia showed a statistically significant relation between IOP and gender, CCT, refractive status, and the presence of DM (Tab. II).

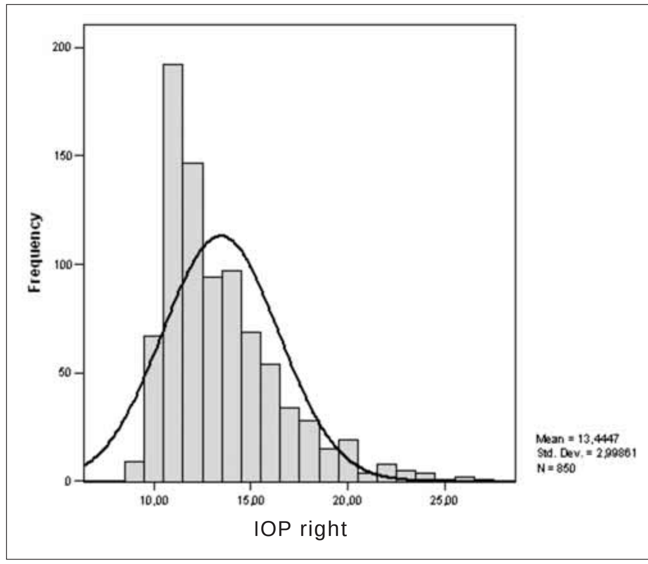

Fig. 1 - *Distribution of intraocular pressure for right eye.*

DISCUSSION

Glaucoma, being a vision-threatening disorder, has to be screened routinely for early detection and treatment. The gold standard method for IOP measurement is GAT. However, since it is easier, cheaper (13), and more appropriate for mass screening as there is no contact to the eye, NCT is also being used widely. Katsushima et al (14) compared GAT and NCT in a glaucoma population study and found no difference between GAT and NCT in detecting glaucoma. Factors that are thought to affect IOP measurements were studied in different nations and ethnicities (6, 15-17). We tried to investigate the factors that might affect the IOP in a Turkish population using NCT.

Figure 1 shows the distribution of IOP for right eye. It was typically Gaussian-like with a little right skewness which is consistent with most studies (16, 18, 19). The upper limit of normal IOP for subjects older than 40 years was 20.0 mmHg. For the subjects older than 40 years Hashemi et al (16) found the upper limit of IOP as 20.8 mmHg in an Iranian population and Carel et al (15) found this cutoff as 20.1 mmHg in an Israelian population. The former study used GAT and the latter was performed with NCT.

In our study there was a slightly significant positive correlation between age and IOP in the whole group but this was not the case when both genders were analyzed separately. In multivariate regression analysis, age was found to not associate with IOP. This is consistent with the literature in which there is a slight tendency for IOP to increase with age in univariate analysis but not in multivariate analysis (5, 15-17). In the Barbados Eye Study (BES) Leske et al (6) have found a significant age-related increase of IOP in multivariate model in a black population. These abovementioned studies were cross-sectional like ours. In a Japanese population, Shiose et al (18) found negative association between age and IOP in a cross-sectional study. Nomura et al (19) performed age-IOP relation both cross-sectionally and longitudinally and found decline in the former and increase in the latter. Hennis et al (20) found positive association in a longitudinal 4-year follow-up in BES black population.

There was no significant difference for IOP values between male and female subjects. However, in multivariate regression model, gender seemed to be an important factor to affect IOP. This is consistent with the 9 year results of BES (21).

Central corneal thickness and IOP relation was statistically significant both in univariate and multivariate models. CCT is accepted to be the primary source of error in IOP measurements with applanation tonometer. Nowadays it is accepted to be an important risk factor in glaucoma development and progression. In the meta-analysis performed by Doughty and Zaman (12) 20 µm CCT variation corresponded to 1 mmHg IOP change. For this reason while evaluating the age-IOP relationship, the age-CCT relationship should also be considered due to the possible effect of aging on CCT. Our results revealed a slight decrease of CCT with age (Pearson correlation test, r=–0.076, p=0.02). This decrease did not change the significant relationship between age and IOP when a partial correlation was performed (r=0.117, p=0.00). In the study of Nomura et al (22) CCT variation did not affect age-IOP relationship, which is consistent with our result.

Kh-Kv values were found to not affect IOP measurements in our study. This finding was coherent with that of Kohlhaas et al's (23) patient population designed study conducted on preoperative cataract patients. However, both Kohlhaas et al (24) and Shimmyo et al (25), while trying to find a formula for real IOP calculation using the data of pre- and postkeratorefractive patients, have found that keratometric values had statistically significant effect in multiple regression analysis. Kohlhaas et al reached different conclusions concerning keratometry and IOP relationship in their studies. They found no correlation of keratometry and IOP in a patient population study (23) similar to our study design but found a significant relationship in an interventional study (24) with pre and postkeratorefractive values. As a result, keratometry and IOP relationship may vary according to the study design.

Spherical equivalence of refraction was found to not correlate with IOP. On the other hand, the presence of myopia or hypermetropia was a significant factor for IOP readings in a multiple regression model in our study. In the literature, regression analysis showed a statistically important relation between spherical equivalent refraction and IOP (4, 5, 15).

Patients having DM or HT had statistically significant higher IOP values. Most studies have found that systolic blood pressure (SBP) was significantly correlated with IOP (15, 17, 26). In our study HT did not have any significant effect in multiple regression analysis. As most of the HT patients were on medication, their SBP values might be within normal limits and this may be the reason why HT was not significantly correlated with IOP in multivariate analysis. On the other hand, we found DM an important factor affecting IOP values, which is consistent with the literature (8, 17).

Since this study is based on noncontact tonometer measurements rather than gold standard Goldmann applanation, literature data to compare our results are limited.

In conclusion, in the present study IOP was not related to age, keratometric values, HT, or hyperlipidemia, but was related to gender, refractive error, DM, and CCT in multiple regression analysis.

Proprietary interest: None.

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