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Comparative Study of Intraocular Pressure Measurements by Goldmann Applanation Tonometer, Noncontact Tonometer and TonoPen

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SUMMARY

Comparative Study of Intraocular Pressure Measurements by Goldmann Applanation Tonometer, Noncontact Tonometer and TonoPen

The purpose of the study was to compare the levels of the intraocular pressure (NOT) measured in one eye at the same moment by three different methods: by Goldmann applanation tonometer (AT), non-contact tonometer (BT) and Tono-Pen (TP). It was further set the average variability of the performed measurements for particular tonometric methods.
Methods: NOT was assessed in 106 eyes of 106 subjects aged 7-77 years (average 34.3 ± 17.1 years). NOT was measured at the same moment with BT, TP and AT. The obtained data were statistically analyzed.
Results: The average NOT was 16.55 ± 2.95, 17.95 ± 4.47 and 16.13 ± 3.4mmHg when AT, BT and TP were applied. Average variability of three measurements for AT, BT and TP was 1.51 ± 0.96, 1.78 ± 1.08 and 1.47 ± 0.9 mmHg. Average NOT levels of the measured AT and TP were almost identical with a difference of 0.42 mmHg (p = 0.236). Average level of the intraocular pressure measured by BT was higher by 1.40 mmHg and 1.82 mmHg in comparison with AT and TP (p = 0.00002), respectively.
Conclusion: NOT measurement produced almost identical average levels at AT and TP, whereas at BT the levels were much higher. Average variability of the three subsequent NOT measurements was the highest at BT, whereas at AT and TP the average variability was lower and nearly identical.

Key words: malignant uveal melanoma, metastasis, prognostic factors

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INTRODUCTION

The aim of this prospective study is to provide a mutual comparison of the values of intraocular pressure (IOP) measured in one eye at the same time by three different methods: Goldmann applanation tonometry (AT), noncontact tonometry (BT) and TonoPen (TP), and to determine the range of the 3 conducted measurements in the individual tonometric methods.
The evaluation of intraocular pressure is a routine component of eye examination, and despite the improvement of possibilities in the diagnosis and monitoring of glaucoma, determining the value of intraocular pressure remains one of the most important parameters. Intraocular pressure is also still the sole parameter which we are able to influence therapeutically in the case of complex pathogenesis of glaucoma damage, and our therapeutic endeavour is directed to attaining the target pressure. Goldmann applanation tonometry is considered the "gold standard" for measurement of intraocular pressure [6]. Noncontact tonometry is a very widespread method especially in outpatient practice, used for screening of glaucoma disease and for subsequent monitoring of patients with glaucoma. With regard to the automatic regime, this examination can be conducted also by trained, non-medical healthcare personnel [15], and can also be used for determination of IOP in children [8, 22]. Measurement of intraocular pressure using TonoPen is advantageous due to the mobility of the instrument, its independence of the position of the patient [21] and the possibility of measurement also in the case of non-standard ratios on the cornea [9]. It is especially suitable for use on small children and patients with a lower capability of co-operating [7, 9, 22].

METHOD

Adult and child patients, and if applicable their parents, from the Adult and Child Eye Clinic at the 2nd Medical Faculty of Charles University and the Motol University Hospital, were included in the study as well as volunteers from the ranks of staff, after signing an informed consent form. The study protocol was approved by the ethical commission of the University Hospital in Motol, Prague.
A total of 106 eyes were analysed (44 left and 62 right) of 106 subjects with an age range of 7-77 years (average 34.3 ± 17.1 years), 68 women and 38 men.
The selection of eyes for analysis was conducted depending on central corneal thickness in such a manner that an eye with a deviation of central corneal

thickness (CCT) larger than 550 µm was evaluated, so that we were also able to evaluate the correlation of tonometry to CCT [2].

A personal anamnesis was taken, refraction was determined and an examination was conducted on the anterior and posterior segment of the eye. Only persons with a normal finding on the anterior segment of the eye were included in the study. Wearing of contact lenses or eye operations were not present in the anamnesis. Six patients had diabetes mellitus, one patient had dry form age-related macular degeneration, six patients had compensated primary open angle glaucoma, nineteen subjects were examined with a suspicion of glaucoma or ocular hypertension and others were examined upon prescription for glasses.

The individual measurements were conducted on all subjects using the same instruments in the same order: determination of refraction and IOP with noncontact tonometer (Tonoref II, Nidek Co. Ltd., Japan), designation of CCT using ultrasound pachymetry (Echoscan US-1800, Nidek Co. Ltd., Japan), on the eye with a CCT deviation larger than 550 µm further measurements of intraocular pressure continued with TonoPen (Tono-Pen Avia®, Reichert Technologies, NY, USA) and applanation tonometry (Haag-Streit Goldmann tonometer, Germany). The time interval between the first and last measurement was 5-10 minutes.

Refraction was determined in the automatic regime of the instrument. A calibrated noncontact tonometer was used for measurement of intraocular pressure of both eyes in all subjects. 3 measurements were conducted in automatic regime, which were used for statistical analysis on the evaluated eye. After application of 0.4% oxybuprocaine (Benoxi, Unimed Pharma) CCT was determined in both eyes using a calibrated ultrasound pachymeter. After calibration by the manufacturer, TonoPen was used to conduct 3 measurements in the centre of the cornea of the selected eye with maximum validity, and the obtained values were used in the data analysis. After application of local anaesthetic with fluorescein (Thilorbin, Alcon), 3 standard measurements were performed on a calibrated Goldmann applanation tonometer, which were used for further statistical processing.

The gathered data was statistically evaluated using commercially available software SPSS Ver. 10.00 (Chicago, IL). Range analysis with repetition (ANOVA repeated measures) and a Tukey HSD Post hoc test of pair comparison were used for the tests of the difference in measurements.

RESULTS

The average IOP value in 106 eyes determined using noncontact tonometry was 17.95 ± 4.47 mmHg (8.67-30.33 mmHg), using TonoPen 16.13 ± 3.40 mmHg (8.67-27.0 mmHg) and Goldmann applanation tonometry 16.55 ± 2.95 mmHg (8.33-25.33 mmHg). The measured values of the averages of IOP are presented in summary in table 1.

Table 2 presents the results of the tests in the differences of the averages of the three methods. Range analysis with repetition (ANOVA repeated measures) rejects the hypothesis of an accordance of the averages of all three methods ($p < 0.0001$). According to the Tukey HSD Post hoc pair comparison test, a significant statistical difference is demonstrated in BT versus TP and BT versus AT, whilst upon a comparison of TP versus AT the difference is not statistically significant. The average IOP values measured by TonoPen (16.13 mmHg) and applanation tonometry (16.55 mmHg) were virtually identical, with an average difference of -0.42 mmHg, which is statistically and clinically insignificant ($p = 0.236$). The average value measured by noncontact tonometry (17.95 mmHg) was higher than the average difference of 1.82 mmHg and 1.40 mmHg in comparison with TP or AT ($p = 0.00002$), as stated in table 2.

Table 3 presents the average values of variability of the three measurements of intraocular pressure in individual tonometric methods determined by the difference of the maximum and minimum value in the individual methods of measurement. The average variability value was 1.78 ± 1.08 mmHg for BT, for TP 1.47 ± 0.9 mmHg and for AT 1.51 ± 0.96 mmHg.

Table 4 presents the results of the tests of variability of the three measurements for the individual tonometric methods.

Range analysis with repetition (ANOVA repeated measures) rejects the hypothesis of accordance of all three methods ($p = 0.038$).

According to the Tukey HSD Post hoc pair comparison test, there is a statistically significant difference in the variability of the individual measurements upon a comparison of BT and TP, whereas the difference between BT and AT is not significant, as is the case between TP and AT, where the average range of measurement is virtually identical.

The average refraction was -0.21 ± 1.75 D (from -7.0 to +4.5 D of spherical equivalent). The average CCT value was 572 ± 46 µm (455-701 µm).

Table 1. TNM classification of MUM of ciliary muscle and choroid (part "T") according to AJCC. According to Edge et al. 2010

Eye Number N	Method	Average mmHg	SD mmHg	Min. mmHg	Max. mmHg
L N=44	BT	17.70	4.80	8.67	30.33
	TP	15.79	3.88	8.67	27.00
	AT	16.30	3.02	10.0	25.33
P N=62	BT	18.12	4.25	10.0	29.33
	TP	16.37	3.03	10.0	24.67
	AT	16.73	2.92	8.33	22.33
L+P N=106	BT	17.95	4.47	8.67	30.33
	TP	16.13	3.40	8.67	27.00
	AT	16.55	2.95	8.33	25.33

Table 2. Variability and statistical significance of differences in measurements between individual methods of tonometry (mmHg)

Method of tonometry	Average difference (mmHg)	SD	Min.	Max.	Statistical significance
BT-TP	1.82	3.02	-5.33	12.0	P=0.00002
BR-AT	1.4	2.91	-6.0	10.67	P=0.00002
TP-AT	-0.42	2.12	-7.0	7.33	P=0.236

Table 3. Variability of IOP measurement (mmHg) using individual tonometric methods

Eye Number N	Method	Average mmHg	SD mmHg	Min. mmHg	Max. mmHg
L N=44	BT	1.64	0.87	1.0	4.0
	TP	1.59	0.92	0.0	4.0
	AT	1.43	0.97	0.0	4.0
P N=62	BT	1.89	1.20	0.0	5.0
	TP	1.39	0.88	0.0	5.0
	AT	1.56	0.95	0.0	4.0
L+P N=106	BT	1.78	1.08	0.0	5.0
	TP	1.47	0.90	0.0	5.0
	AT	1.51	0.96	0.0	4.0

Table 4. Tests of differences in variability of three measurements

Tests of differences in averages of three methods		Statistical significance
ANOVA Repeated measures		p=0.038
Tukey HSD Post hoc test	BT v TP	p=0.048
	BT v AT	p=0.095
	TP v AT	p=0.96

DISCUSSION

Upon selection of subjects for the clinical study, the only exclusion criteria were pathological finding on the cornea and decompensated glaucoma. We know that certain general disorders, just as general or local treatment, may influence both clinically measured IOP and its actual value [5, 6].

However, the primary aim of the study was to provide a mutual comparison of the values of intraocular pressure measured at the same time and in the same eye using three different methods: Goldmann applanation tonometry (AT), noncontact tonometry (BT) and TonoPen (TP). All measurements in the study took place on the same calibrated instrument. Emphasis was placed on the correct measuring technique and repeated tonometry in an endeavour to minimise the factors introducing errors into the measurement results. The order of the individual measurements was configured so as to prevent any influence of tonometry upon handling the eye.

Tonometric methods commonly available in clinical and outpatient practice were used in the study.

From the statistical results it ensues that the hypothesis of accordance of measured averages of IOP values examined by the three methods of tonometry is rejected ($p < 0.0001$).

In our study, the difference in average of IOP measured by TonoPen and applanation tonometry is -0.42 ± 2.12 mmHg ($p = 0.236$), which is similar to the values stated in the majority of other studies at an interval from -0.8 to +0.54 mmHg [1, 3, 4, 11, 12, 15, 20, 21], although Sullivan-Mee et al. state a difference of +1.3 mmHg in a smaller sample of 40 eyes [16].

The average IOP value measured by noncontact tonometry was higher in our study, with an average difference of 1.82 ± 3.02 and 1.40 ± 2.91 mmHg in comparison with TP or AT ($p = 0.00002$), in comparison with the published values which range from -1.1 to 0.6 mmHg [13, 15, 20, 22]. The CCT value, as a factor influencing the precision of IOP measurement [6, 10, 17, 18], contributes to the overvaluation of IOP in the case of thicker corneas [2, 19, 22].

Central corneal thickness stated in clinical studies ranges from 540-560 µm [5, 6], in children aged 7-17 it is 554 ± 33 µm [14]. The average CCT value in our sample was 572 ± 46 µm, which is a higher value in comparison with other studies [2]. Eyes with a higher positive or negative deviation than 550 µm of central corneal thickness were intentionally included in the study, with the aim of creating a sample with the largest possible and if possible homogenous range of CCT values. The sample also included 19 patients who were sent to our clinic with suspicion of glaucoma following measurement of increased intraocular pressure by a noncontact tonometer, and in whom we subsequently measured a thicker cornea. This fact explains the higher average central corneal thickness in our study, which however should not distort the results upon a difference of around 20 µm in comparison with the norm [17].

A further aim of the study was to determine the range of the three conducted measurements using the individual tonometric methods. Here also the hypothesis of the congruity of all three methods was rejected ($p = 0.038$). In our study the determined range of the three measurements of 1.51 mmHg upon use of applanation tonometry is similar to the results stated in other studies at an interval of 0.77-1.49 mmHg [4, 11]. Our determined variability of measurement for TonoPen of 1.47 mmHg is within the stated range of 0.13-2.94 mmHg [4, 11], although we did not confirm such a high fluctuation of IOP values ourselves [4]. The average range of measurement upon comparison of TP and AT is virtually identical ($p = 0.96$).

The age range of the subjects in the study is 7-77 years, with an average of 34.3 years. Children in the Czech Republic aged 7-17 have higher IOP values in comparison with adults [14].

CONCLUSION

In our sample of 106 eyes the average values of intraocular pressure measured by Goldmann applanation tonometer (16.55 mmHg) and TonoPen (16.13 mmHg) were virtually identical, with a difference of 0.42 mmHg, which is clinically and statistically insignificant ($p = 0.236$). The average value of intraocular pressure measured at the same time using a noncontact tonometer (17.95 mmHg) was higher by 1.82 mmHg and 1.40 mmHg in comparison with TonoPen and Goldmann applanation tonometer respectively, with a statistically significant difference in both cases ($p = 0.00002$). The average range of the three subsequent measurements of intraocular pressure was highest in the case of noncontact tonometry (1.78 mmHg) and lower in the case of Goldmann applanation tonometry (1.51 mmHg) and TonoPen (1.47 mmHg).

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