Intraocular Pressure in Ophthalmological Practice

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Abstract

Objective: To determine whether we are able to obtain the same values of intraocular pressure using three different non-contact devices.

Patients and methods of examination: The study included 100 eyes of 50 people, of whom 25 were women (25-82 years) and 25 men (21-81 years). The first group included 12 glaucoma patients (6 on prostaglandins) and 13 healthy individuals. The second group included 8 glaucoma patients (3 on prostaglandins) and 17 healthy subjects. Intraocular pressure (IOP) was measured by three devices: non-contact Tonometer TX-F, non-contact Tonometer TX-20P (Canon) incorporating optical pachymeter, and Ocular Response Analyser II (Reichert). To eliminate the role of corneal thickness on IOP, the Tomey Handy Pachymeter SP100 was used with the non-contact Tonometer TX-F. The time difference between individual measurements was 15-30 minutes.

Results: CCT US (central corneal thickness measured by ultrasound) values were statistically significantly higher than CCT OB (central corneal thickness measured by optical biometer) values ($p = 0.000$). The average CCT US value is 560.04; the average CCT OB value is 545.15 (a difference of 14.88). When translated to IOP (intraocular pressure) results, this difference (0.83 mmHg) is clinically insignificant. IOP values were processed by Repeated Measure ANOVA method, $p = 0.007$. This means that, between measurements of IOP-NCT, IOP-C, ORA and IOPcNCT were pairs with statistically significant differences. Subsequent processing by Scheffe's Post Hoc Test showed that the difference between the IOP-NCT and ORA is statistically significant (0.854 mmHg, $p = 0.039$) and the difference between IOPcNCT and ORA is also statistically significant (0.886 mmHg, $p = 0.036$). Again, it should be noted that this small difference in IOP is not clinically significant.

Conclusion: Although we found statistically significant differences between values measured by various NCT devices, these differences have no significant clinical relevance. However, many years of clinical practice have resulted in our use of the Ocular Response Analyser to measure IOP in suspicious cases.

Keywords: intraocular pressure, central corneal thickness, non-contact tonometry, ocular response analyser

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Introduction

Measurement of intraocular pressure is an everyday routine in any regular Ophthalmological practice. Because it is not measured directly, the real values are affected by many factors [5]. The aim of our study was to determine whether it is possible to measure similar IOP values on the same eye within a short time interval with various non-contact devices.

Materials and methods

100 eyes of 50 people, of whom 25 were women (25-82 years) and 25 men (21-81 years) were randomly included. The first group included 12 glaucoma patients (6 on prostaglandins) and 13 healthy individuals. The second group included 8 glaucoma patients (3 on prostaglandins) and 17 healthy subjects. Intraocular pressure (IOP) was measured by 3 devices:

1. Non-contact Tonometer Canon Full Auto Tonometer TX-F (Canon Inc., Tokyo, Japan);
2. Non-contact Tonometer Canon Full Auto Tonometer TX-20P (Canon Inc., Tokyo, Japan) with incorporated optic pachymeter; and
3. Ocular Response Analyser II (Reichert Technologies).

To eliminate the role of corneal thickness on IOP, the Tomey Handy Pachymeter SP100 was used with the non-contact Tonometer TX-F (Nishi-ku, Nagoya, Japan). The time difference between individual measurements was 15-30 minutes. To eliminate the influence of pulse wave on IOP, the highest value of the 3 measurements was eliminated and the remaining values were averaged. For the measurement of corneal pachymetry, the results of 10 measurements were averaged. Investigations were always carried out by the same doctor.

Results

A summary table shows all measured values: Table 1.

To convert IOP measured with the Full Auto Tonometer Canon TX-F non-contact Tonometer, we used the coefficient of 5.6 mmHg/100 μm of CCT [2].

Each patient had the corneal thickness as well as the optical biometer measured by ultrasound. A paired t-test was used to compare these values. The comparison showed that the CCT US values were significantly higher than CCT OB values ($p = 0.000$). The average CCT US value was 560.04; the average CCT OB value was 545.15 (a difference of 14.88). If we look at the value of intraocular pressure, then the difference

in measured values equals 0.83 mmHg, which is a statistically significant difference which, however, has no clinical relevance.

The average IOP values are shown in Table 2 and in Figure 1. The last value (IOPcNCT) is the adjusted IOP value measured by Non-contact Canon Full Auto Tonometer.

Variable	Descriptive statistical values							
	Number of measurements	Average	Confidence interval -95.000%	Confidence interval 95.000%	Median	Minimum	Maximum	Standard deviation
IOP-NCT	100	16.70500	15.84251	17.56749	17.00000	8.00000	27.00000	4.346771
IOP-C	100	17.21500	16.49996	17.93004	17.00000	10.00000	25.00000	3.603628
ORA	100	17.55900	16.66533	18.45267	17.55000	8.50000	30.90000	4.503895
IOPcNCT	100	16.69600	15.88673	17.50527	16.55000	7.20000	27.90000	4.078520

Table 2
IOP-NCP = intraocular pressure uncorrected to CCT (measured by NCT Canon TX-F)
IOP-C = intraocular pressure corrected to CCT (measured by NCT Canon TX-20P)
ORA = intraocular pressure unaffected by CCT (ORA II)
IOPcNCT = intraocular pressure corrected to CCT (measured by NCT Canon TX-F and Tomey Handy Pachymeter SP 100).

Three IOP values were obtained for each eye. The fourth value was obtained after CCT US correction (IOPcNCT). We have therefore used the Repeated Measure ANOVA method for comparison of values. This method tests whether the values differ for the same patient in the 3 or more individual measurements. This method tests the null hypothesis that there is no difference between measurements versus the alternative hypothesis that some pairs of measurements differ significantly. A value of significance (Sign) of less than 0.05 is considered a statistically significant difference between measurements. Subsequent comparison of what particular pairs of measurement were mutually significantly different was performed using Scheffe's Post Hoc Test.

The resulting P value of the Repeated Measure ANOVA statistical analysis was 0.007. This means that, between measurements of IOP-NCT, IOP-C, ORA and IOPcNCT were pairs with a statistically significant difference. Scheffe's Post Hoc Test showed that the difference between IOP-NCT and ORA is statistically significant (0.854 mmHg, p = 0.039) and the difference between IOPcNCT and ORA is also statistically significant (0.886 mmHg, p = 0.036). Again, it should be noted that this small difference in IOP is not clinically significant.

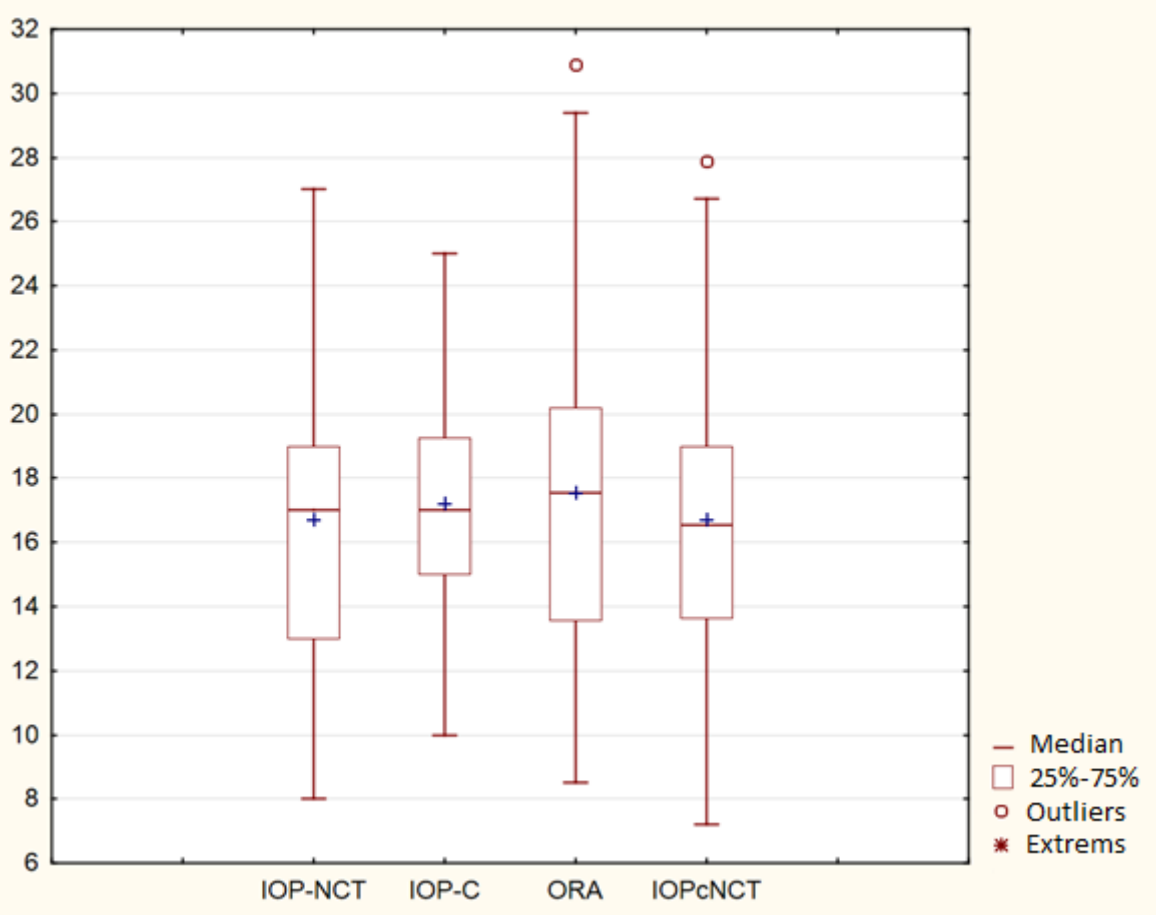

Figure 1
Box plot shows the IOP values measured by various techniques.
IOP-NCP = intraocular pressure uncorrected to CCT (measured by NCT Canon TX-F)
IOP-C = intraocular pressure corrected to CCT (measured by NCT Canon TX-20P)
ORA = intraocular pressure unaffected by CCT (ORA II)
IOPcNCT = intraocular pressure corrected to CCT (measured by NCT Canon TX-F and Tomey Handy Pachymeter SP 100).

Discussion

Central corneal thickness measurement shows different results for different methods. Ultrasonic measurement gives a higher value than measurement by optical devices [1,6]. Our measurements are consistent with the conclusions of the authors.

Although Goldmann Applanation Tonometry (GAT) remains the gold standard even 60 years after its introduction, it still has its drawbacks. In their original study, the inventors explicitly pointed out several limitations in their design [4]. They based their design on what they believed was a relatively constant CCT of 500 um among otherwise normal individuals. They acknowledged that the accuracy of their device

would be affected if CCT deviated from this value. Even our work shows that the average CCT value is not 500 µm but, if measured by US, it is 560.04 and, if measured by OB, it is 545.15 µm.
The theoretical effects of CCT on GAT were confirmed in 1975 when Ehlers *et al.* cannulated otherwise normal eyes undergoing cataract surgery and correlated thickness with errors in GAT [3]. They found that GAT most accurately reflected true intracameral IOP when the CCT was 520 um.

Other sources of error affecting GAT include the Valsalva Manoeuvre, astigmatisms, corneal curvature, inappropriate amount of fluorescein, eyelid squeezing, and indirect pressure on the globe [7]. As applanation devices, however, NCTs are also influenced by biomedical factors such as CCT and ocular rigidity. Tonnu *et al.* (2005) compared NCT to GAT and several other Tonometers, and found that NCT is affected by CCT significantly more than GAT is. Our measurements showed that the mean IOP NCT after CCT adjustment differed by only 0.01 mmHg. Such a value is insignificant in clinical Ophthalmology.

By comparing IOP and measured NCT, with and without CCT adjustment (Canon Full Auto Tonometer TX-F and Canon Full Auto Tonometer TX-20P), we obtained an average IOP difference of only 0.5 mmHg. (Table 2). Even this value is without great significance in clinical practice. We also tried to eliminate corneal hysteresis and corneal response factor during non-contact measurements of IOP (Ocular Response Analyser II). Using Scheffe's Post Hoc Test, it was found that the difference between IOP-NCT and ORA is statistically significant (difference of 0.854 mmHg, $p = 0.039$) and the difference between IOPcNCT and ORA is also statistically significant (difference of 0.886 mmHg, $p = 0.036$). Again, it should be noted that this small difference is not clinically significant.

We must however emphasise that, despite the above-mentioned findings associated with non-contact measurement of IOP, we have repeatedly encountered cases in our clinical practice where the IOP in glaucoma patients was normal even after CCT adjustment, but there still was progression of functional and organic glaucoma changes. After measuring IOP with ORA II, values significantly higher than 21 mmHg were found. Table 2 shows the maximum values measured with the first two devices of 27 and 25 mmHg respectively. For ORA, the maximum value was 30.9 mmHg. Therefore, today, IOP is measured using ORA II for almost every patient.

Conclusion

Non-contact Tonometry is now one of the routine methods of IOP measurement. Although we found statistically significant differences between values measured by various NCT devices, these differences have no significant clinical relevance. However,

many years of clinical practice have resulted in our use of the Ocular Response Analyser to measure IOP in suspicious cases.

The study protocol was approved by the local Ethics Committee and the study was performed in accordance with Good Clinical Practice and the Declaration of Helsinki.

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Conflict of interest statement

The authors state that there are no conflicts of interest regarding the publication of this article.

References

1. Amano S, Honda N, Amano Y, Yamagami S, Miyai T, Samejima T, Ogata M, Miyata K. Comparison of central corneal thickness measurements by rotating Scheimpflug camera, ultrasonic pachymetry, and scanning-slit corneal topography. Ophthalmology. 2006 Jun;113:937-941.

2. Burdova MC, Ferrova K, Filous A, Oskorypova K, Lezatkova P, Sedlackova P. Correlation of intraocular pressure measured by applanation tonometry, noncontact tonometry and TonoPen with central corneal thickness. Cesk Slov Oftalmol 2011;67:154-157.

3. Ehlers N, Bramsen T, Sperling S. Applanation tonometry and central corneal thickness. Acta Ophthalmol (Copenh). 1975;53:34-43.

4. Goldmann H, Smith T. Über applanationstonometrie. Ophthalmologica 1957;134:221-242.

5. Okafor KC and Brandt JD. Measuring intraocular pressure. Curr Opin Ophthalmol 2015; 26:103-109.

6. Prospero Ponce CM, Rocha KM, Smith SD, Krueger RR. Central and peripheral corneal thickness measured with optical coherence tomography, Scheimpflug imaging, and ultrasound pachymetry in normal, keratoconus-suspect, and post-laser in situ keratomileusis eyes. J Cataract Refract Surg 2009;35:1055-1062.

7. Whitacre MM, Stein R. Source of error with use of Goldmann-type tonometers. Surv. Ophthalmol 1993;38:1-30.

Sex/Age	CCT US	CCT US	CCT OB	CCT OB	IOP-NCT	IOP-NCT	IOP-C	IOP-C	ORA	ORA	IOPcNCT	IOPcNCT	Diagnosis
	RE	LE	RE	LE	RE	LE	RE	LE	RE	LE	RE	LE	
F/57	606	608	579	575	14	15.5	13	14	14.3	11.6	11.4	12.8	
F/55	567	560	540	545	17	21.5	19	25	22.6	25.4	16.6	21.5	POAG-P
F/61	539	542	529	530	19.5	18.5	19.5	21.5	17.1	18.4	20.7	19.5	POAG
F/27	619	620	595	585	24	22	18	18.5	16.8	15.8	21.7	18.6	
F/54	613	607	585	565	23	24	22	19	19.1	17.7	20	21.4	
F/65	567	570	548	546	14	14	17	17	16.6	11.2	13.6	13.4	
F/72	605	618	588	583	19	19	18	17	14.1	17.8	16.5	15.8	POAG
F/63	551	544	526	524	14	13	15	17	18.2	18.1	14.5	13.9	
F/66	599	606	586	597	18	18.5	18	17	17.3	15.4	15.8	15.9	POAG
F/73	601	603	558	564	18	18	19	19	17.3	15.1	15.7	15.6	
F/56	589	608	574	659	27	24	22	23	25.2	25.2	25.4	21.2	POAG-P
F/75	490	493	474	484	24	20	21	16.5	29.4	22.7	27.9	23.8	POAG-P
F/43	560	559	556	552	19	23	17.5	19.5	18.7	21.5	19	23	
F/46	606	609	600	598	10	11	11	11	10	11.6	7.2	8.3	
F/81	581	607	506	518	15	14	15	15	19.7	17.1	13.8	11.4	POAG-P
F/64	557	576	527	541	20	20	20	21	25.8	23.9	20.2	19.1	
F/45	535	538	527	525	15	16	14	15	18.9	19.7	16.4	17.2	
F/82	527	552	525	534	18	17	22	19	22.8	21.2	19.8	17.4	POAG-P
F/76	653	691	573	584	22	25	19.5	25	19	17.5	16.8	17.7	POAG-P
F/81	562	566	566	555	12	12	16	14	15.5	11.8	11.9	11.7	
F/25	523	514	525	520	16	16	17	18	18.7	17.8	18	18.6	POAG
F/50	565	569	555	535	12	13	13	15	13.3	11.3	11.7	12.5	
F/65	509	522	490	485	14	13	18	17	18.2	17.2	16.9	15.1	POAG
F/79	558	584	561	542	23	24	24	25	25.3	30.9	22.9	24.3	POAG
F/50	585	601	580	570	19	19	22	20	19.8	17.6	17.6	16.7	
M/32	595	588	556	553	14	14	16	16	14	18.5	11.8	13.8	
M/77	512	516	522	510	8	8	11	11	13	11.4	10.7	11	
M/67	572	585	550	561	17	17	21	20	21	20	16.3	15.6	POAG-P
M/44	517	532	542	549	24	17	18	17	23.4	18.4	26.4	18.6	
M/67	529	530	534	533	25	24	25	25	24.5	20.2	26.7	25.7	
M/71	601	579	600	603	19	20	19	17	21.1	24.5	16.7	19	POAG-P
M/58	515	519	521	516	15	15	15	15	20.2	18.9	17.5	17.3	POAG-P
M/68	594	581	612	600	15	16	17	17.5	17.2	19.8	13.1	14.8	
M/53	555	551	565	568	18	18	22	20	20.8	15.7	18.3	18.5	POAG
M/47	578	562	559	550	13	16	15	15	8.5	10.4	12	15.9	
M/36	549	542	532	530	20	18	18	18	12.9	12.9	20.6	19	
M/30	535	532	532	523	12	9	13	13	15.7	16.5	13.4	10.6	
M/36	508	522	510	498	13	16	16	17	13	13	15.9	18.1	
M/30	472	479	476	474	10	11	10	11	12.3	11.4	14.9	15.5	
M/60	554	555	550	545	13	17	14	15	18.5	20.9	13.3	17.3	

M/48	564	553	543	532	16	16	13	13	13.7	12.5	15.8	16.4	
M/26	556	554	539	544	12	11	12	12	12.9	10.7	12.2	11.3	
M/21	550	557	527	528	18	19	18.5	19	16.9	14	18.6	19.2	
M/48	503	511	500	506	10	11	15	17	13	11.4	13.2	13.7	POAG
M/81	558	554	558	554	11	13	12	12	13.4	13.1	11.1	13.3	POAG
M/81	553	549	538	540	19	17	19	19	21	17.7	19.4	17.6	POAG
M/71	565	567	537	542	19	19	20	18	21.4	23.4	18.7	18.6	
M/71	507	514	503	522	11	12	15	15	17	16.2	14	14.6	
M/73	535	550	528	542	13	12	13	12	17.4	12.6	13.8	12.6	POAG
M/61	620	557	587	542	21	21	19	21	23.3	18.5	17.6	21.2	

Table 1