Correlation of iCare ic100 tonometry with iCare TA01i in screening of unselected population in Northern Finland Birth Cohort Eye study

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ABSTRACT

Purpose: iCare tonometers are easy-to-use and portable devices for measuring the intraocular pressure (IOP). Purpose was to evaluate the IOP values measured by both novel iCare ic100 and conventional model TA01i devices in unselected population.

Methods: IOP was measured with iCare ic100 and TA01i tonometers in 149 participants aged 32 to 33 years (born in 1985 or 1986) of the Northern Finland Birth Cohort Eye 2 study. The right eye of each participant was selected for analysis. We also collected data on axial length, corneal curvature and central corneal thickness (CCT). Bland-Altman plot was used for comparing the values obtained by these devices.

Results:

Mean IOP measured with the ic100 device was 13.8 (3.4) mmHg, with TA01i it was 12.5 (3.0) mmHg. The mean difference between these devices was 1.30 mmHg ($p<0.001$) and R^2 was 0.694. In Bland-Altman analysis, the agreement between the two tonometers ic100 and TA01i was constantly good (mean difference -1.30, ic100 device showing higher measures). There was a correlation between IOP and CCT ($r=0.269$, $p<0.001$ for ic100 and $r=0.255$, $p=0.002$ for TA01i), but not with IOP and corneal curvature or IOP and axial length.

Conclusion: In summary, we found ic100 rebound tonometry to be both reliable and effective, although CCT may influence IOP measurements with ic100 and TA01i. Therefore, iCare ic100 is suitable for IOP measurement in large cohort studies.

INTRODUCTION

The accurate determination of intraocular pressure (IOP) is essential for the diagnosis and treatment of glaucoma. For decades, the Goldmann applanation tonometer (GAT) has been considered as (and still is) the gold standard for the measurement of IOP mainly due to its relatively low intra- and inter-observer variability (1)(2). However, determining IOP with GAT requires a trained nurse or doctor to use a biomicroscope and the measurement can only be performed with the subject in the sitting position after instillation of anesthetic eyedrops. Furthermore, the patient must be relatively co-operative (3).

Several devices have been developed in order to make the determination of IOP easier while still retaining the precision of the measurement. The Icare rebound tonometer (RT) is one of these innovations; this device is now in world-wide use. Its features include no need for topical anesthesia or staining with fluorescein, no need for slit-lamp mounting, or any infection risk due to its disposable probe (4). The correlation between the RT and GAT measurements has been examined (5–8). The majority of these studies have reported that RT overestimates IOP in comparison with GAT (5,9)(3).

In the current study, we compared iCare ic100 and TA01i tonometers in unselected healthy population for IOP screening purposes. iCare ic100 is an updated model of iCare TA01i having a position sensor in order to increase the device's accuracy. Nonetheless, the probe must be kept in a horizontal position close to the corneal center because if not correctly positioned, the probe cannot be launched by the position sensor. In our previous study, we compared TA01i with GAT and found that measurements with TA01i were comparable with GAT(3) and 75% of cases were within 2 mmHg of GAT measurements.

METHODS

Subjects

We included subjects of The Northern Finland Birth Cohort (NFBC) 1986, which is a longitudinal one-year birth cohort study of unselected healthy population. The cohort included all of the mothers (N = 9 362) with children whose expected date of birth between July 1st 1985 - June 30th 1986 in the two northernmost provinces on Finland (Oulu and Lapland). The number of deliveries in the cohort was 9 362, which was 99% of all deliveries occurring in the target period. Altogether 9 479 children were born into the cohort, 9 432 of them being live-born. The original data have been supplemented by data collected with postal questionnaires at the ages of 7, 8 and 15 / 16 years and various hospital records and statistical register data (10). The whole cohort has been evaluated regularly by means of health questionnaires and clinical examinations and represents a homogenous population in terms of age, ethnicity and living environment (10). The study has received approval from the Ethical Committee of the Northern Ostrobothnia Hospital District. The study adhered to the Declaration of Helsinki. We obtained written informed consent from all patients. Included subjects had no eye diseases, such as glaucoma or corneal diseases, which would affect the measurements. Exclusion criteria was missing ic100 measurements, missing TA01 measurements or missing CCT measurements or high refractive disorders (mean spherical equivalent < -6 D in myopia or > +6 D in hyperopia). Altogether data was analyzed of 149 individuals in this cross-sectional study.

Measurements

The screening protocol in Oulu University Hospital, Department of Ophthalmology included automated and manifest refraction, best corrected visual acuity, central corneal thickness, Humphrey 24–2 perimetry, stereoscopic optic nerve head and retinal nerve fiber layer (RNFL) photography and imaging with Scanning Laser Ophthalmoscopy, Scanning Laser Polarimetry and Optical Coherence Tomography (OCT) (11).

Intraocular pressure was first measured with iCare ic100 tonometry and subsequently with iCare TA01i from both eyes by one person according to the Instruction manual of these two devices. Briefly, after loading the probe, the patient was instructed to relax and look straight ahead. IOP was measured with six measurements from the center of the cornea along the central corneal axis. The measurements were obtained in sitting position according to the manufacturer's instructions and the probe was kept in a horizontal position close to the corneal center at 4 to 8 mm distance. According to the manufacturer's instructions, topical anesthesia was not used. Mean IOP values were automatically calculated by the device and measurement was considered as as invalid and they were repeated when an error bar was high in TA01i model or if repeated measurements were indicated by ic100 model. The measurements from the right eye only were used in this analysis.

Axial length and corneal curvature were determined with IOLMaster 700 (Carl Zeiss Meditec, Jena, Germany), and the mean of 5 measurements was used in the analyses of the axial length. Corneal curvature was defined as the average of horizontal (K1) and vertical (K2) corneal curvatures.

Central corneal thickness (CCT) was measured using Zeiss Cirrus 5000 HD-OCT (Carl Zeiss Meditec, Jena, Germany). The cornea lens attachment was used to obtain a pachymetry map, which consisted of 24 radial B-scan lines (1024 samples per B-scan) with a scan depth of 2 mm. A color-coded thickness map of the cornea was generated after image acquisition and CCT from the 0-2 mm sector was selected for subsequent CCT analysis. The thickness was defined as the distance from a point on the anterior corneal surface to the closest point on the posterior corneal surface as previously described (12). The pachymetry analysis tool delivered an automated cornea thickness measurement in seventeen sectors. The measurements were taken by a single examiner after 14:00 to minimize the effect of diurnal variations on CCT readings. No topical anesthesia or lubricating eye drops were used. In order to achieve optimal scan quality, the volunteers were asked to blink twice before each measurement to form a smooth tear film on the cornea.

Statistical analysis

The statistical analyses were performed with IBM SPSS (version 25.0. Armonk, NY: IBM Corp). The values in the tables are expressed as mean ± standard deviation (range of values). A P-value of 0.05 or lower was chosen to be a statistically significant. In the comparison of the mean difference between ic100 and TA01i, Student's T-test was used. The 95% confidence intervals around Pearson's correlation coefficients were computed by using Fisher's Z-transformation. For the Bland-Altman analysis, an assumption of normality in measurement differences was checked visually from a histogram. Limits of Agreement, LOA were defined as mean ± 1.96 SD.

RESULTS

We included 149 patients with mean age of 33 years (range 32 to 33 years, all born between July 1st 1985 - June 30th 1986). The majority, 69% (n=103) were female and 31% (n=46) were male. Mean axial length was 23.5 mm (1.1 mm), central corneal thickness 537.9 um (33.9 um) and corneal curvature 43.4 (1.6). Demographic characteristics are depicted in Table 1.

Mean IOP measured with the ic100 device was 13.8 (3.4) mmHg (range 6 to 24) and with TA01i 12.5 (3.0) mmHg (range 6 to 20) as depicted in Figure 1, panel A. The mean difference between these devices was 1.30 mmHg ($p<0.001$) and R^2 was 0.694 (Figure 1, panel B).

[insert Figure 1.]

There was a correlation between central corneal thickness and IOP with both devices, which was statistically significant (p=0.001 for ic100 and p=0.002 for TA01i) (Table 2). No correlation was found between IOP and axial length or IOP and corneal curvature (Table 2).

Figure 2 shows the Bland-Altman analysis of the agreement between the two tonometers ic100 and TA01i. The agreement between these was constantly good, since the mean of difference between two measurements was -1.30, with the ic100 device recording higher values. The width of 95% LOA was 7.29 mmHg. There was some linear increase in the difference, since Pearson's correlation coefficient was r=0.252 (p=0.002).

[insert Figure 2.]

Figure 3 shows the effect of CCT and corneal curvature on the IOP measurements. There was a correlation between ic100 and CCT, but not with corneal curvature and ic100 (r=0.269, p<0.001 and r=-0.088, p=0.284, respectively). For TA01i there was correlation with CCT as well, but not with corneal curvature (r=0.255, p=0.002 and r=-0.107, p=0.193, respectively).

[insert Figure 3.]

DISCUSSION

In the current study, we show that there is a good agreement between the new model iCare ic100 with TA01i; the measurements obtained with ic100 were somewhat higher than with TA01i. A correlation between central corneal thickness and IOP measurement was found with both devices, but there was no correlation evident between IOP and corneal curvature or axial length.

Comparison with similar studies

Similar results to ours have been reported in previous studies ; for example, in a study by Nakakura et al (4) the agreement between TA01i and ic100 models was good and the mean difference between methods low was (-0.466 mmHg TA01i vs. ic100). The repeatibility (intraclass correlation coefficient of three measurements) with ic100 model in this study was very good (0.936). Furthermore, Molero-Senosiain et al. compared iCare ic100 and iCare Pro against Perkins tonometry (13). The reproducibility of ic100 instrument was good, although ic100 underestimated the IOP as compared to Perkins applanation tonometry at normal values while it overestimated it at high intraocular pressure values (13). Current results show that IOP measured with ic100 was somewhat higher (mean 1.32 mmHg higher) than with TA01i device. Furthermore, in our previous study TA01i was mean of 0.11 mmHg higher than GAT. It seems that ic100 somewhat overestimates the IOP. However, Murdoch and Johnston have shown that in clinical decision making, a 4 mmHg increase or decrease is not significant (14).

Advantages and disadvantages of the two iCare

The speed and portability of RT is a clear advantage in large volume cohort studies and in glaucoma screening. Both these RT devices ic100 and TA01 function in a similar way bouncing a long probe against cornea and measuring subsequent deceleration of the probe. However, it seems that the probe difference in rebound tonometers might have some influence on the accuracy of IOP measurements: those models with long probes (such as TA01i and ic100) are influenced more by ocular biometry and rigidity, such as central corneal thickness (15–19).

There are some differences, although not many, between ic100 and TA01i models. The usefulness of the older iCare model TA01i, especially in measuring IOP in patients, with whom low co-operation may be expected such as children, is fairly good. TA01it gives at least some measurements also in cases with difficulties in co-operation. However, the position sensor in ic100 model is a clear advantage for this model. In addition to position sensor, the ic100 also controls for the distance between the device and the cornea

and therefore, it is possible that it makes more reliable measurements than can be performed with the TA01i model, at least if measurements are performed by inexpierienced persons. In a study by Molero-Senosiain et al. the discomfort with ic100 was minimal and most of the subjects preferred ic100 tonometer over Perkins (13).

Comparison with GAT

Previously, our group has reported that there is a good correlation between IOP measurements taken with TA01i and GAT and although IOP values determined with TA01 were 0.11 mmHg higher than with GAT, these measurements were within 3 mmHg in 88% of cases, within 2 mmHg in 75% and within 1 mmHg in 53% of cases (3). Therefore, it seems that the IOP measurement with RT is reliable enough for clinical decision making, especially in glaucoma screening and population-based studies. It should be borne in mind, however, that the exact IOP value can only be determined invasively using an intracameral manometer. The speed of RT is a clear advantage in utilizing ic100 instead of GAT in large volume cohort studies and in glaucoma screening. Suprisingly, Nakakura et al showed that Icare ic100 almost invariably exhibited IOP lower values (mean -4.2 mmHg) than GAT. However, the discrepancy with our study may be due to differencies in study subjects, since we had no glaucoma cases in our study. In the study by Nakakura the difference in measurements was affected by thinner CCT, small corneal curvature, and glaucoma (4).

Correlations with corneal parameters and their impact in daily practice

In our previous study, the effect of CCT on IOP measurement with TA01i and GAT was evident, and the CCT had an effect on the discrepancy between GAT and RT values. In the current study, however, the effect of CCT on IOP measured with ic100 was also significant. The effect of CCT on IOP with ic100 was also

evaluated by Wong et al. (Wong et al., 2018). In their hands, iCare ic100 displayed a weak positive correlation with CCT, resulting in an overestimation of the IOP value in patients with thicker corneas and an underestimation in those with thinner corneas (20). It seems that the CCT is important in RT as well as in GAT, and therefore measurements of CCT should be included, at least in suspected glaucoma cases.

In addition to CCT, also corneal biomechanical factors, such as corneal resistance factor and corneal hysteresis (CH) has been shown to influence IOP measurement by RT (21,22). CH is reduced after LASIK and in corneal diseases such as keratoconus or Fuchs endothelial dystrophy. In healthy young adults the effect of corneal hysteresis on IOP measurement may be low and in this population the CH has been previously shown to correlate with CCT (23). Furthermore, CH has negative correlation with IOP measured by RT, as shown by Brown at al (24). However, the measurement in current study were performed with two devices using RT, therefore, the bias of CH on our results was most likely minimal.

Strenghts and limitations

The strengths of current study are its well-characterized normotensive, healthy population of similar age, therefore eliminating the effect of age and diseases on IOP measurement. There are also some limitations to our study; although our study population has been well characterized, it was normal, healthy population and we did not detect any extremely high IOP measurements. In the very high IOP ranges, such as those above 40 mmHg, the agreement between the two tonometers may be less impressive. Furthermore, this was a large cohort study, in which we aimed at effective data acquisition rather than undertaking any GAT measurements, which is time-consuming and requires doctor or trained nurse. However, our previous publication had measured IOP with GAT and therefore can be used as reference (3). Theoretically, due to ocular squeezing, there might be some bias resulting in higher IOP values with ic100 when measuring the IOP first with the ic100 and immediately after with TA01i.

In conclusion, we found ic100 rebound tonometry to be both reliable and effective, although CCT may affect IOP measurements made with ic100. The iCare ic100 device is suitable for use in large cohort studies such as the present work.

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CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

Table 1. Characteristics of the subjects examined.

	N=149
Age (years)	33 (32 to 33)
Gender (male)	46 (31 %)
Axial length (mm)	23.5 ± 1.1 (20.7 to 26.9)
CCT (µm)	537.9 ± 33.9 (434 to 605)
Corneal curvature	43.4 ± 1.6 (38.2 to 47.4)

The values are mean ± SD (range) and for gender N (% of total).
CCT refers to central corneal thickness.
Corneal curvature taken as an average of K1 and K2

Table 2. *Correlation Coefficients between IOP measurements and Axial Length, CCT and Corneal Curvature.*

	Axial Length		CCT		Corneal Curvature	
	r (95% CI)	P	r (95% CI)	P	r (95% CI)	P
iCare ic100	0.01 (-0.14 to 0.17)	0.879	0.27 (0.12 to 0.41)	**0.001**	-0.09 (-0.24 to 0.07)	0.284
iCare TA01i	0.08 (-0.08 to 0.24)	0.718	0.26 (0.10 to 0.40)	**0.002**	-0.11 (-0.26 to 0.05)	0.193

The 95% Confidence Intervals computed with Fisher's Z-Transformation.

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FIGURE LEGENDS

Figure 1.

Boxplot of IOP measured with the ic100 and TA01i devices (panel A) and correlation between ic100 and TA01i devices (panel B). In panel A, boxplot shows the median of the measurements as dark line and diamonds indicate the mean.

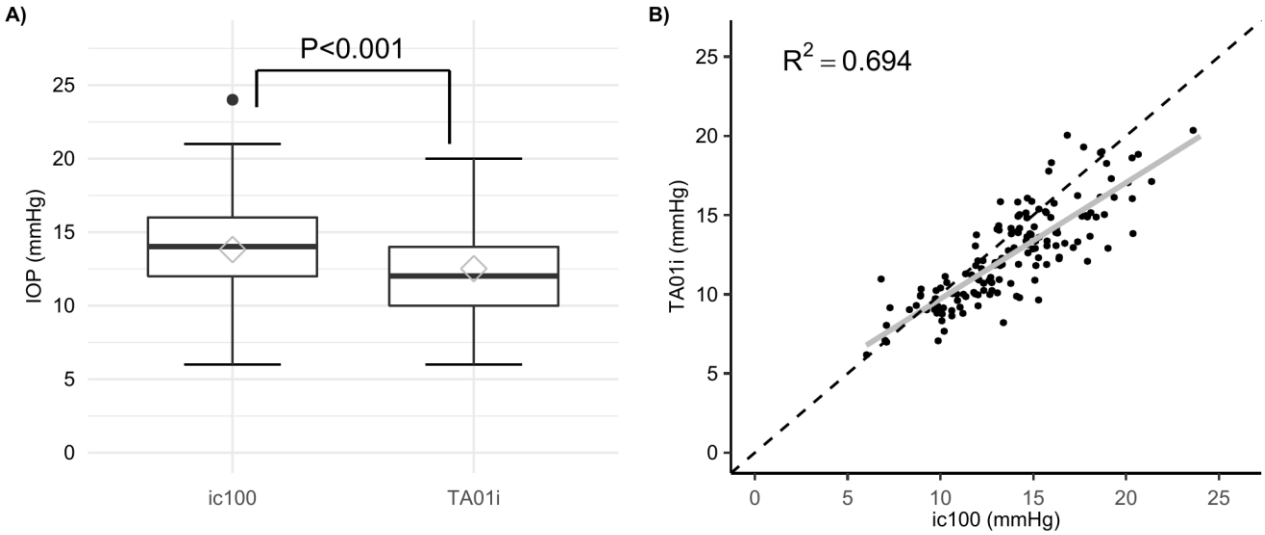

Figure 2.

Bland-Altman analysis of the agreement between the two tonometers ic100 and TA01i.

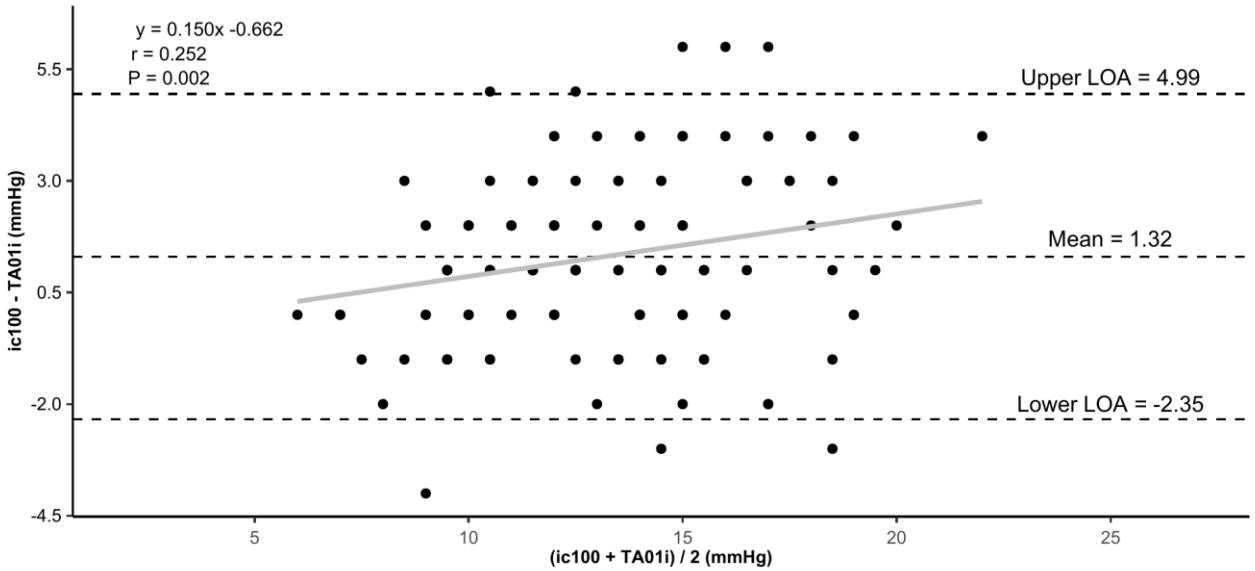

Figure 3.

The effect of CCT and corneal curvature on the IOP measurements with ic100 (panels A and C) and TA01i (panels B and D).