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Is pulse synchronized pneumotonometry more reproducible than routine pneumotonometry and more in agreement with Goldmann applanation tonometry?

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PURPOSE. *This study compared the variability of intraocular pressure (IOP) measurements taken with pulse synchronized pneumotonometry (PNT) and with routine PNT (without pulse synchronization) and evaluated the agreement between PNT and Goldmann applanation tonometry (GAT).*

METHODS. *In this prospective study, 148 eyes from 78 patients were enrolled. Patients were randomized into two groups. In the first group (A), the sequence of measurements was pulse synchronized PNT, routine PNT, and GAT. In the second group (B), the sequence of measurements was routine PNT, pulse synchronized PNT, and GAT. The mean of three measurements was averaged for PNT and GAT. All the measurements were performed by the same investigator, who was masked to GAT measurements. The mean IOP measurements and intrapatient standard deviations among the three tonometers were compared using analysis of variance measurement. Bland & Altman plots were used to assess the agreement between PNT and GAT.*

RESULTS. *The variability of IOP measurements taken with pulse synchronized PNT was significantly lower than with routine PNT in both groups (1.2±0.7 vs 1.3±0.7 mmHg in group A and 1.1±0.9 vs 1.3±1.0 mmHg in group B [$p<0.001$], respectively). PNT measurements with and without pulse synchronization were on average ±2 mmHg higher than GAT measurements in both groups ($p<0.001$). The 95% limits of agreement between PNT and GAT varied between –3.8 and 8.5 mmHg.*

CONCLUSIONS. *Pulse synchronized PNT gives more reproducible measurements than routine PNT. The agreement between PNT and GAT is poor. (Eur J Ophthalmol 2007; 17: 178-82)*

KEY WORDS. *Nidek NT-4000, Pneumotonometer, Pneumotonometry, Pulse synchronized system*

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INTRODUCTION

The gold standard for measuring intraocular pressure (IOP) is the Goldmann applanation tonometer (GAT). The applanation technique, however, has some disadvantages. It requires corneal contact after topical anesthesia, thereby exposing the patient to the risk of corneal abrasion and infection, and is investigator dependent (1). This has led to the development of noncontact pneumotonometry (PNT). However, substantial variations can occur when measuring IOP with PNT compared to GAT (1, 2), and may, in part, be caused by the effect of the cardiac pulse.

The pulse synchronized system of the Nidek NT-4000 noncontact pneumotonometer has been developed to reduce the fluctuations in the measurements of PNT.

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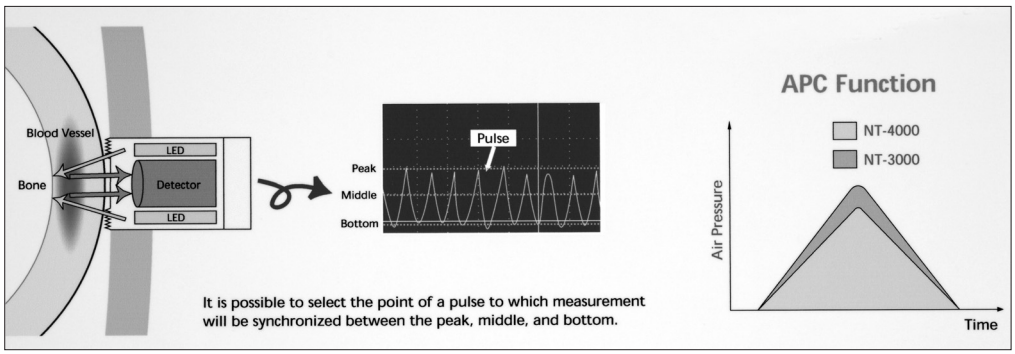

Fig. 1 - *Working of the pulse detection mode from the Nidek NT-4000.*

IOP can be measured by synchronizing the peak, middle, or bottom of the pulse (i.e., different modes of measurement). It has been shown previously that the peak modus from the pulse synchronized PNT is closest to the GAT (3).

In this study the reproducibility precision of IOP measurements between pulse synchronized PNT and routine PNT and the agreement accuracy between pulse synchronized (peak of the pulse) PNT, routine PNT, and GAT were assessed.

MATERIALS AND METHODS

Patient population

This prospective randomised study was performed at one center and included 78 patients who were due to attend the general or glaucoma clinic. They were included at the discretion of the ophthalmologist after giving their informed consent. All patients were free from corneal diseases. The patients were randomly divided into two groups (A and B) and one eye per subject was randomly selected for IOP measurements.

Procedures

IOP was taken using the GAT and the Nidek NT-4000 pneumotonometer with or without the pulse synchronized system.

The Nidek NT-4000 has a pulse detection mode in which the pulse signal obtained from the forehead rest can be used to synchronize the IOP measurement. There are three different modes by which an investigator can decide to synchronize the IOP: the peak of the pulse signal (P), the middle of the pulse signal (M), or the bottom of the pulse signal (B). The P signal synchronizes to the contraction of the heart (systole), the B signal synchronizes to the expansion of the heart (diastole) (Fig. 1). In this study we used the P signal.

For GAT, one drop of Unicaine 0.4% and fluorescein was used to prepare the cornea for measurement. The mean of two measurements was used for analysis.

The sequence of the measurements in group A was pulse synchronized PNT, routine PNT, then GAT. The sequence of the measurements in group B was routine PNT, pulse synchronized PNT, then GAT. Once a pulse wave was detected with the pneumotonometer, three consecutive readings were taken. The subject was then required to sit back and move again toward the instrument for taking another three readings with the routine PNT (i.e., without sensor). The automatic puff control (APC) was used with both PNTs to give the closest agreement with the GAT (2). The GAT was always used last because of the instillation of local anesthetic agents. The mean of the three measurements was used for analysis. For each set of IOPs

TABLE I - MEAN INTRAOCULAR PRESSURE MEASUREMENTS (mmHg) OBTAINED WITH THE THREE TONOMETERS

Group	PNT+	PNT–	GAT	p
A (PNT+ → PNT– → GAT)	19.7±5.2	19.0±4.8	17.1±3.6	<0.0001
B (PNT– → PNT+ → GAT)	19.0±5.6	18.7±5.3	17.0±5.1	<0.0001

PNT+ = Pulse synchronized pneumotonometer; PNT– = Routine pneumotonometer; GAT = Goldmann applanation tonometer

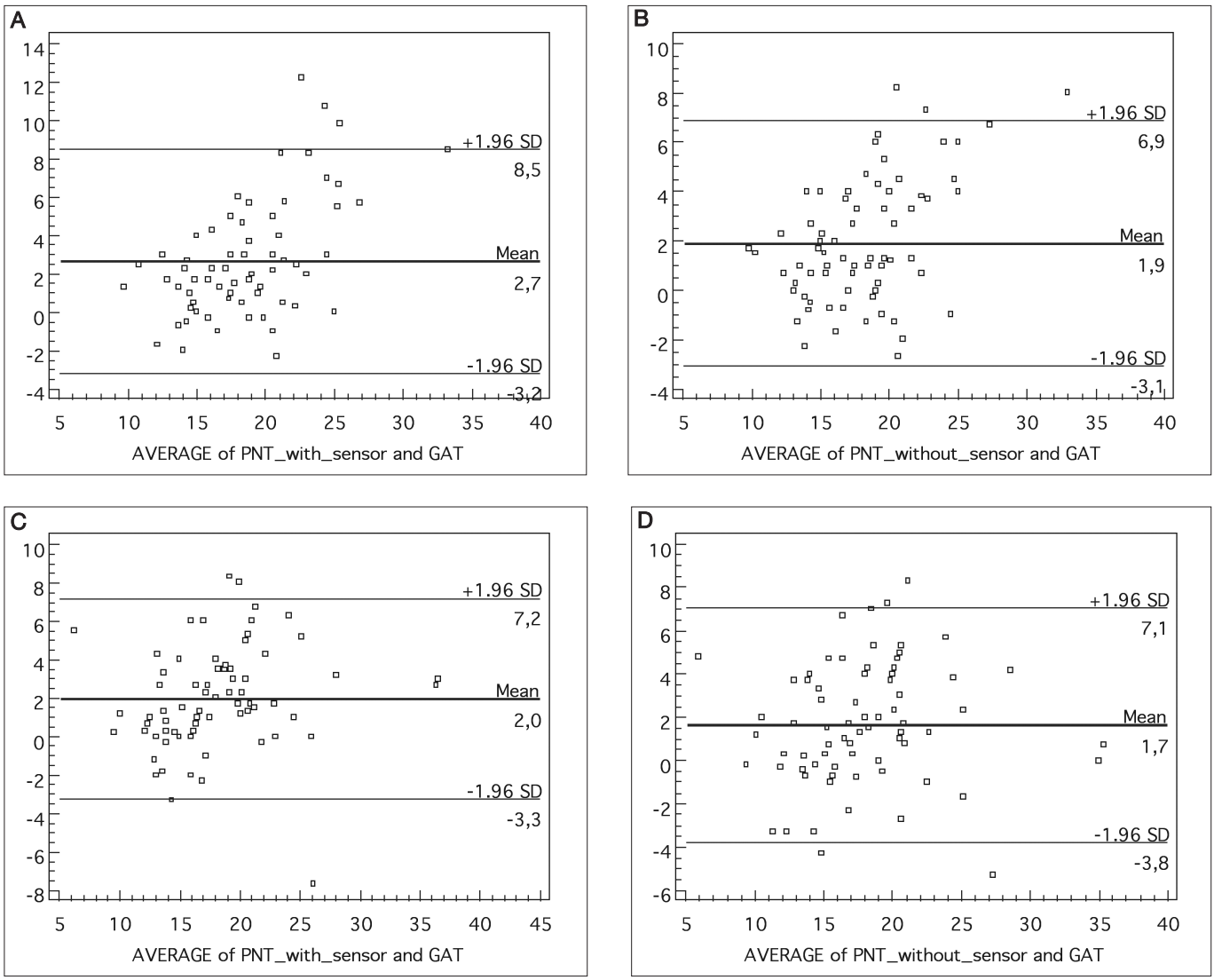

Fig. 2 - *Bland & Altman graphs of the differences in intraocular pressure between the pulse synchronized pneumotonometer and the Goldmann applanation tonometer as a function of their means. (Group A= A and B; Group B = C and D).*

the standard deviation (SD) was calculated and compared. The agreement between the PNT and the GAT was calculated using the Bland & Altman graphs. The GAT was considered as the gold standard.
All measurements were performed by the same investigator, who was masked to GAT measurements.

Statistical analysis

A repeated measures analysis of variance was used to compare the mean of the IOP measurements and the mean intrapatient SD values among the three tonometers. p Values of the pairwise comparisons were two-sided and the alpha level was set at 5%. A square root transformation was used for the SD values to meet the normality assumptions of the statistical model. Plots of the differences against their means and the 95% limits of agreement (Bland & Altman graphs) were made to assess the agreements between the PNT and GAT.

RESULTS

Seventy-eight patients (148 eyes) participated in the study. The mean age was 53.5 years (range 24 to 83

years). The mean IOP measurements with the three tonometers are shown in Table I. There was no difference between the overall results obtained in groups A and B (p=0.12). In both groups, pulse synchronized PNT was slightly higher than routine PNT. The measurements taken with PNT (with and without pulse synchronization) were ±2 mm Hg higher than GAT. The mean intrapatient SD values obtained with the three tonometers are shown in Table II. There was no difference between the overall results obtained in groups A and B (p=0.16). However, the variability of measurements taken with pulse synchronized PNT was significantly lower than with routine PNT. GAT measurements had the lowest variability.

Figure 2 shows the Bland & Altman graphs of the differences in IOP between PNT and GAT as a function of their means. The 95% limits of agreement vary between –3.2 to +8.5 mmHg and –3.3 to +7.2 mmHg for pulse synchronized PNT and GAT in groups A and B, respectively. The 95% limits of agreement vary between –3.1 to +6.9 and –3.8 to +7.1 mmHg for routine PNT and GAT in groups A and B, respectively.

DISCUSSION

Routine noncontact PNT records the IOP with variation in the cardiac pulse. The purpose of pulse synchronized PNT is to reduce the variability to provide more precise measurements. In this study the peak modus of pulse synchronized PNT was used, so that IOP was always measured at the time of systole. The reason the peak modus of pulse synchronized PNT was chosen was because it has been shown to be closest to the GAT (3).

No statistical difference was noted between measuring first with or without the pulse synchronized sensor. The mean IOP was slightly higher with pulse synchronized PNT than with routine PNT. This difference (<1 mmHg), however, was not clinically significant. Both pneumotonometers gave mean IOPs that were approximately 2 mm Hg higher than that measured with the GAT. The variability of pulse synchronized PNT was significantly lower than the variability of routine PNT. However, the lowest variability from consecutive readings was obtained with the GAT. This was in accordance with Lam et al (3). They found mean intrapatient SD of 0.6, 0.7, and 0.8 mmHg, respectively, with GAT, pulse synchronized PNT, and routine PNT. Our mean intrapatient SD with GAT was even lower. This may have been because the GAT measurements were not masked in our study (by concealing the tonometer drum). The mean IOP measured with PNT was higher than the mean IOP measured with GAT in both studies. The mean difference between PNT and GAT in the study of Lam et al was lower than in our study probably because their mean IOP was also lower. This is in accordance with what was observed by Rao et al (4) and Van de Velde et al (1), who showed that IOP measurements are higher with PNT than with GAT when the IOP is >21 mmHg. On the other hand, the difference between PNT and GAT measurements can be reduced artificially by adjusting the calibration of the pneumotonometer to the values obtained with a particular GAT (1). Our results were also in accordance with those of Yaoeda et al (5), who also found a lower variability with pulse synchronized PNT than with routine PNT.

It has been reported that repeated contact tonometry can reduce the IOP by a mean of <0.5 mmHg (6, 7). Whether noncontact PNT, without corneal touch and with short air-puff duration, could have a similar massaging effect is unknown. In our study GAT measurements were always performed last, and the mean GAT IOP was lower than the mean PNT IOP. On the other hand, the average difference between PNT and GAT in our study was 2 mmHg, which is much more than the 0.5 mmHg reported. It seems unlikely that repeated noncontact PNT can have a massaging effect on the eye resulting in lower GAT measurements. One shortcoming of our study is that we did not measure the corneal thickness. It has been proven that

TABLE II - MEAN INTRAPATIENT STANDARD DEVIATIONS OBTAINED WITH THE THREE TONOMETERS

	PNT+	PNT–	GAT	p
A (PNT+ → PNT– → GAT)	1.2±0.7	1.3±0.7	0.1±0.2	<0.0001
B (PNT– → PNT+ → GAT)	1.1±0.9	1.3±1.0	0.1±0.3	<0.0001

Values are mmHg. PNT+ = Pulse synchronized pneumotonometer; PNT– = Routine pneumotonometer; GAT = Goldmann applanation tonometer

corneal thickness has an influence on IOP measurements taken by PNT (8-10). Bhan et al (8) demonstrated that PNT was more affected by variation in the central corneal thickness than GAT. In the case of PNT, it is the resistance offered to the gas that is measured as the IOP. This resistance is determined by the IOP and the corneal elastic forces, including the central corneal thickness. IOP with noncontact PNT is also measured over a wider area than with GAT (9).

A potential bias in our study is that the measurements with GAT were not masked, e.g., by concealing the tonometer drum. On the other hand, this did not influence the variability of the measurements with PNT, the main outcome of our study.

One potential advantage of pulse synchronized PNT is that it could be an indirect measurement of ocular blood flow in patients without arrhythmia. The ocular pulse amplitude represents the pulsatile component of the intraocular blood flow and could therefore be used to measure the ocular perfusion (3, 11). This was not explored here, since it was not the scope of our study.

It is usually accepted that an agreement within 3 mmHg from GAT is clinically acceptable (4, 12, 13). The Bland & Altman graphs (Fig. 2) showed disagreement between PNT and GAT measurements, with a 95% confidence interval varying between –3.8 and +8.5 mmHg. This confirms that, although PNT can be helpful for screening purposes, it cannot replace GAT for the follow-up of patients with glaucoma (9).

In conclusion, we found that the pulse synchronized pneumotonometer gave more reproducible measurements than the routine pneumotonometer (without pulse synchronization). However, there was disagreement between PNT and GAT measurements.

Proprietary interest: None.

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