Comparison of Intraocular Pressure Measured by Non-Contact Air Puff *versus* Goldmann Applanation Tonometers in Gas-Filled Vitrectomized Eyes†

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Abstract

Objective : To compare intraocular pressure (IOP) measured by two different instruments, air puff tonometer (APT) *versus* Goldmann applanation tonometer (GAT), in gas-filled vitrectomized eyes.

Design : Three-month, prospective, comparative trial.

Participants : Thirty-eight patients (38 eyes), who underwent a pars plana vitrectomy (PPV) with gas injection, were enrolled in the study.

Intervention : The IOP was measured by an APT, followed by GAT within 10 minutes by two different, masked investigators.

Main outcome measures : IOPs were measured by two methods and then were compared.

Results : Overall, there was a high correlation between both measurements ($r = 0.908$, $p < 0.05$). Using the paired *t*-test, IOPs measured by the APT (21.69 ± 9.28 mmHg) and GAT (22.84 ± 9.84) were not significantly different ($p > 0.05$). By a subgroup analysis of 17 eyes with IOP measured by a GAT of 21 mmHg or less, the APT readings (15.28 ± 4.81) and GAT readings (14.47 ± 3.89) were not significantly different ($p > 0.05$). Of 21 eyes, with IOP measured by a GAT of 22 mmHg or more, the APT readings (26.88 ± 8.81) were significantly lower than those obtained by the GAT (29.62 ± 7.69) ($p < 0.05$).

Conclusion : In gas-filled vitrectomized eyes, IOP measurements obtained by an APT correlated well with those obtained by GAT, especially when the IOP was within normal range. However, in eyes with elevated IOP, the APT significantly underestimated the IOP measurement when compared to the gold standard, GAT.

Key word : Intraocular Pressure, Goldmann Applanation Tonometer, Air Puff Tonometer, Non-Contact Tonometer

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Up to one-third of eyes, which undergo a pars plana vitrectomy procedure, can have post-operative elevation of intraocular pressure (IOP) that if undetected, could result in permanent damage of the optic nerve[1]. Generally, the Goldmann applanation tonometer (GAT) is known as the clinical standard for measuring IOP[2]. However, it is a contact instrument, requiring instillation of a topical anesthetic/fluorescein combination prior to contact with the globe[2].

The air puff tonometer (APT), a non-contact instrument, has some advantages when compared to the GAT and Tonopen. Corneal anesthesia and staining are not required. As there is no direct contact, the possibility of damaging the corneal epithelium is very minimal[3]. The measurement is operator independent, as the air puff is released automatically only when proper alignment is reached. Repeated measurements do not reduce IOP due to the "massage effect"[4, 5]. Disadvantages include the necessity of the patient to be capable of fixation, and the corneal surface being regular and smooth[6]. Also a brief pulse of pressurized air can lead to some degree of tear film dehiscence and dispersing microaerosol formation, thus resulting in a potentially small risk of spreading infection[7]. The machine is sensitive to a quick fluctuation of IOP, as a result of cardiac and respiratory cycles. As suggested by Meyers et al[8], this is neutralized by some degree when calculating an average of three measurements.

The XPERT® non-contact APT has been compared with the GAT with fairly good agreement [5, 8-11]. To the authors' knowledge, there has been no information on the APT in gas-filled eyes. The presence of a compressible intraocular gas bubble in the eye can result in an underestimation of IOP by an indentation tonometry[12] and the degree of underestimation depends upon the volume of intraocular gas[12]. Since the APT instrument has been introduced in many ophthalmic practices for IOP screening, the authors have evaluated the use of an APT in measuring the IOP in gas-containing eyes in comparison with GAT.

MATERIAL AND METHOD

Patients were recruited from the retina service, Maharaj Nakorn Chiang Mai Hospital, Chiang Mai. A series of 38 patients (38 eyes) were enrolled in the study. All patients underwent pars plana vitrectomy with fluid-air exchange and a long-acting gas injection of either sulfur hexafluoride or perfluoropropane gas, between May and August 2002 in Maharaj Nakorn Chiang Mai Hospital. Patients, who had swollen eyelids, corneal epithelial irregularity or a defect that was thought to interfere with the reliability of the IOP measurement, and those who could not be examined in an upright, seated position, were excluded from the study. Institutional review board approval for experimentation on human subjects and written consent from each patient prior to the examination were obtained.

As a significant amount of gas bubble in the eye was required, each patient had undergone IOP measurement within 72 hours after the vitrectomy procedure. Eyes with a gas bubble size of less than 50 per cent in the vitreous cavity were not included in the study. The average of three IOP readings was first obtained with a non-contact air puff tonometer (Canon model TX-10, Canon, Tochigiken, Japan) by one of the investigators (SN). Within 10 minutes of IOP measurement by the APT, the measurement was repeated by another investigator (ST) using a calibrated Haag-Streit GAT.

Using SPSS software (SPSS Inc; Chicago, IL), data were analyzed by the *t*-test for pair measurements and Pearson's coefficient of correlation. A p-value of less than 0.05 was considered to be statistically significant. The data were also divided into two groups (21 mmHg or less, and 22 mmHg or more).

RESULTS

Thirty-eight patients, 38 eyes, were enrolled in the study. IOP measurement was performed on day 1 in 13 eyes (33.3%), day 2 in 18 eyes (46.2%), and day 3 in 7 eyes (17.9%). Scattergram of IOP measurements between the GAT and APT are shown in Fig. 1. Overall, there was a linear relationship and a high correlation between both measurements ($r = 0.908$, $p < 0.05$) (Table 1). With linear regression analysis, the equation describing the linear relationship was $y = 0.96x+1.96$, when y was the GAT and x was the APT (95% confidence intervals for the slope, 0.81 to 1.11; and 95% confidence intervals for the y-intercept, -1.57 and 5.49).

For all 38 eyes, the mean IOP measured by the APT was 21.69 ± 9.28 mmHg and that measured by the GAT was 22.84 ± 9.84. Using the paired *t*-test, the IOP obtained by the APT was slightly less than that obtained by the GAT, with the mean difference being -1.15 ± 4.13 (95% confidence intervals, -0.21 to 2.51; $p > 0.05$) (Table 1 and 2).

In a subgroup analysis of 17 eyes, with the IOP measured by a GAT of 21 mmHg or less, the mean IOP measured by the APT was 15.28 ± 4.81 and that

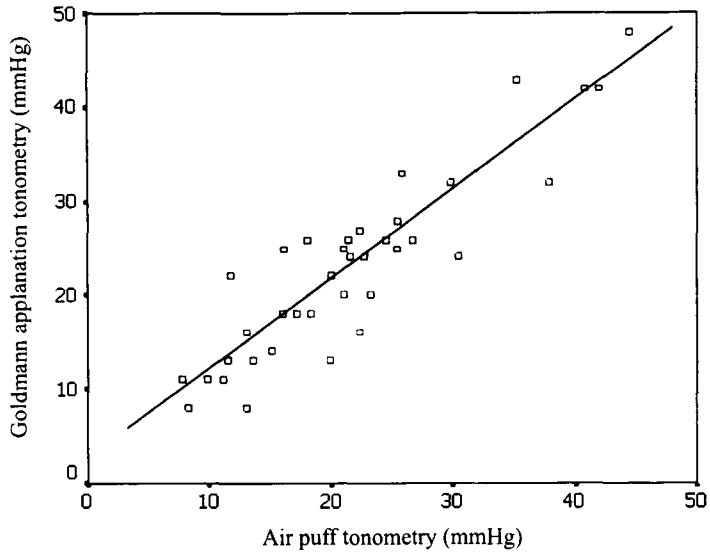

Fig. 1. Significant corrrelation between air puff tonometer and Goldmann applanation tonometer readings (Pearson correlation coefficient, r = 0.908, p < 0.05).

measured by the GAT was 14.47 ± 3.89, as seen in Table 1. The mean difference of IOP measured by APT and GAT was 0.81 ± 2.99 mmHg, which was not statistically significant (95% confidence intervals, -0.73 to 2.35; $p > 0.05$) (Table 2). Of 21 eyes, with the IOP measured by a GAT of 22 mmHg or more, the mean IOP measured by APT was 26.88 ± 8.81 and that measured by the GAT was 29.62 ± 7.69. However, the paired analysis showed a statistically significant difference of mean IOP measured by APT and GAT (-2.74 ± 4.30 mmHg) (95% confidence intervals, -4.70 to -0.79; $p < 0.05$) (Table 1 and 2).

From Table 1 in the present report, Pearson' s correlation coefficient showed a high correlation between two IOP measurement methods in eyes both normal ($r = 0.784$, $p < 0.01$) and elevated IOP ($r = 0.873$, $p < 0.01$).

DISCUSSION

The authors found that among all eyes in the present study the GAT and APT measurements showed a good correlation ($r = 0.908$) and the slope of the linear relationship (0.963, 95% confidence interval 0.81 to 1.11) did not differ significantly from 1.0. The mean difference between both measurements of 1.15 mmHg was not statistically significant ($p > 0.05$). The standard deviation of difference (4.13 mmHg) was larger than earlier reports that compared the GAT and APT in eyes with normal corneas (1.5-2.93 mmHg)[5, 8-10]. This is not surprising because the measurement of the GAT is sometimes not easy to obtain in eyes that have undergone pars plana vitrectomy with gas injection. The eyelid can be edematous, due to prone positioning, and the eye can become greatly irritated with tearing during the first few days after the vitrectomy procedure. Patients may have some difficulty in aligning the eye for a good IOP reading by either the GAT or APT method, and may be aware of the eye being touched when using the Goldmann applanation tonometer. However, the APT can reduce this awareness, thus improving the patient's co-operation. By using the APT, trauma to the post-operative and unhealthy corneal epithelium can be minimized. The standard variation of the difference represents the total variability of the study, including variability due to operator, instruments, and physiologically related factors, such as time dependent IOP fluctuations and the possible effect of one measurement on the next[13].

Fig. 1 shows that, as IOP increased, there was a tendency for the APT measurement to be underestimated when compared to the GAT measurement. This was confirmed by subgroup analysis. Among 21 eyes, the IOP measured by APT was significantly

Table 1. Comparison of GAT* and APT readings in gas-filled eyes.**

Variable	All eyes	IOP by GAT (mmHg)	
		≤ 21	> 21
Number of eyes	38	17	21
Mean ± SD (mmHg) by GAT	22.84 ± 9.84	14.47 ± 3.89	29.62 ± 7.69
Mean ± SD (mmHg) by APT	21.69 ± 9.28	15.28 ± 4.81	26.88 ± 8.81
Correlation coefficient (r)	0.908	0.784	0.873
P-value for r	0.000	0.000	0.000

* GAT = Goldmann applanation tonometer
** APT = air puff tonometer

Table 2. Difference between GAT* *versus* APT.**

APT minus GAT	All eyes	IOP by GAT (mmHg)	
		≤ 21	> 21
Number of eyes	38	17	21
Mean ± SD (mmHg)	-1.15 ± 4.13	0.81 ± 2.99	-2.74 ± 4.30
Range (mmHg)	-10.20 to 6.90	-3.20 to 6.90	-10.20 to 6.50
95% Confidence intervals	-2.51 to 0.21	-0.73 to 2.35	-4.70 to -0.79
Paired *t*-test	1.720	-1.12	2.93
P-value (two-tailed)	0.094	0.280	0.008

* GAT = Goldmann applanation tonometer
** APT = air puff tonometer

lower than that measured by GAT of 22 mmHg or more, but both methods were not significantly different for eyes with GAT reading of 21 mmHg or less.

Repeated measurement by the GAT was shown to decrease the IOP, but not when the APT was used[4]. Therefore, the authors measured the IOP by the APT first and followed that by using the GAT. As the IOP can quickly fluctuate, as a result of cardiac and respiratory cycles, this effect has been compensated by calculating an average of three measurements[8].

The ideal measurement of the IOP would be a manometric study of the pressure by indwelling a catheter from the anterior chamber, but this method is not feasible in a clinical setting[13,14]. One can question whether the use of the GAT, as the control measurement, is inappropriate. However, the GAT is generally considered the most reliable method in a clinical setting, and at this time there are no other clinically available methods that are more accurate[13].

The Tonopen, another contact instrument based on the Mackay Marg principle, is small, portable and convenient, and the reading is quick. Additionally, it is relatively independent of surface irregularity[15]. Compared to the GAT, however, the Tonopen requires direct contact to the cornea, thus necessitating instillation of topical anesthetic drops, and it creates a possibility of corneal epithelial damage in post-operative eyes[13]. Hines et al found that measurements from the Tonopen correlated well with those made by the GAT at both normal and elevated ocular pressure levels[16]. Lim et al studied intraocular pressure measurement in vitrectomized gas-filled eyes. They concluded that Tonopen readings were highly correlated with those of the manometer. However, the Tonopen underestimated IOP as it increased above 30 mmHg[14].

The present study showed that in gas-filled vitrectomized eyes, the non-contact APT correlates well with those obtained by a GAT when the IOP level is normal. However, care must be taken, since the APT significantly underestimates when the IOP is elevated above normal range. Although this underestimation by the APT is not extreme, with an average of -2.74 ± 4.30 mmHg (95% confidence intervals, -0.79 and -4.70), undetection of the elevated IOP could lead to some optic nerve damage, especially in eyes with pre-existing optic nerve pathology or ischemic

retinopathy. Therefore, if a non-contact APT tonometer is used for IOP screening in eyes containing a gas bubble, it is wise to recheck the IOP by the GAT if the APT measurement is found to be increased.

One might question whether the tendency to underestimate the IOP by APT against the GAT in eyes with a high IOP contributed to the absence of vitreous gel or presence of the compressible intraocular gas. Therefore, the effect of vitrectomy on the IOP measurement by the APT in comparison with the GAT remains to be seen.

SUMMARY

Besides the GAT and Tonopen, the air puff tonometer can be used as an alternative method for IOP assessment in gas-filled eyes. Its measurement method is objective, rapid, easy to operate, not unpleasant, and friendly to the delicate epithelium of the post-operative cornea. The APT, however, may be misleading in ascertaining whether the IOP is at an acceptable level or underestimated in gas-containing eyes, thus, insufficient management of the real ocular pressure occurs. This is clinically important in eyes with underlying glaucomatous optic nerve damage or ischemic retinal vasculopathy.

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The authors have no propriety interest in any product investigated.

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การเปรียบเทียบความดันตาที่วัดโดยวิธีแอร์พัฟและวิธีโกลด์แมนในตาที่มีแก๊สภายหลังการผ่าตัดน้ำวุ้นตา†

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วัตถุประสงค์ : เพื่อเปรียบเทียบความดันตาที่วัดโดยวิธีแอร์พัฟและวิธีโกลด์แมนในตาที่มีแก๊สภายหลังการผ่าตัดน้ำวุ้นตา

รูปแบบการศึกษา : เป็นการศึกษาแบบไปข้างหน้า ในช่วงระยะเวลา 3 เดือน

ผู้ป่วย : ผู้ป่วยจำนวน 38 ราย (38 ตา) ที่ได้รับการผ่าตัดน้ำวุ้นตาและใส่แก๊ส

วิธีการ : วัดความดันตาโดยวิธีแอร์พัฟก่อน และวัดซ้ำโดยวิธีโกลด์แมนโดยผู้วัดอีกคน

ตัววัดหลัก : ความดันตาที่วัดโดยวิธีแอร์พัฟและโกลด์แมน

ผลการศึกษา : โดยรวมแล้วพบว่าความดันตาที่วัดโดยวิธีแอร์พัฟและโกลด์แมนมีความสัมพันธ์กันสูง ($r = 0.908$, $p < 0.05$) และความดันตาที่วัดโดยวิธีแอร์พัฟ (21.69 $\pm$ 9.28 มม.ปรอท) ไม่แตกต่างอย่างมีนัยสำคัญทางสถิติจากวิธีโกลด์แมน (22.84 $\pm$ 9.84 มม.ปรอท) และเมื่อวิเคราะห์โดยการแบ่งกลุ่มย่อย พบว่าในกลุ่มที่ความดันตาโกลด์แมนไม่เกิน 21 มม.ปรอท ความดันตาที่วัดโดยวิธีแอร์พัฟ (15.28 $\pm$ 4.81 มม.ปรอท) ไม่แตกต่างอย่างมีนัยสำคัญทางสถิติจากวิธีโกลด์แมน (14.47 $\pm$ 3.89 มม.ปรอท) แต่ในกลุ่มที่ความดันตาโกลด์แมน 22 มม.ปรอทขึ้นไป พบว่าความดันตาที่วัดโดยวิธีแอร์พัฟ (26.88 $\pm$ 8.81 มม.ปรอท) น้อยกว่าวิธีโกลด์แมน (29.62 $\pm$ 7.69 มม.ปรอท) อย่างมีนัยสำคัญทางสถิติ

สรุปการศึกษา : ในตาที่มีแก๊ส ความดันตาที่วัดโดยวิธีแอร์พัฟมีความสัมพันธ์สูงกับความดันตาที่วัดโดยวิธีโกลด์แมน โดยเฉพาะรายที่มีความดันตาปกติ ส่วนตาที่มีความดันตาสูงกว่าปกติ ความดันตาที่วัดโดยวิธีแอร์พัฟมีค่าต่ำกว่าความดันตาที่วัดโดยวิธีมาตรฐานโกลด์แมน

คำสำคัญ : ความดันตา, เครื่องวัดความดันตาแบบโกลด์แมน, เครื่องวัดความดันตาแบบแอร์พัฟ, เครื่องวัดความดันตาแบบใช้ลมเป่า

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