Comparison of Intraocular Pressure (IOP) Measured by Non-Contact (Air –Puff) Tonometer Compared with Goldmann Applanation Tonometer

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Abstract

Background: Measurement of intraocular pressure is one of the most important examination procedures in ophthalmic clinics; IOP is an important parameter in the diagnosis of glaucoma. There are numerous types of tonometers available, it is important to evaluate the differences in readings between different tonometers. Goldmann Applanation Tonometers and non-contact Air-Puff Tonometers are largely available in ophthalmic clinics. **Aim:** The purpose of this study is to evaluate the difference between IOP measurements taken by a GAT and those taken by an Air Puff Tonometer and to observe the reliability of Air Puff to be a screening tool. **Material and Methods:** This study was performed on 200 eyes from 100 study participants (including: Relatives of patients, medical students, nurses and patients complaining from errors of refraction). attending an ophthalmic outpatient clinic. visual acuity, Refraction, fundus examination, corneal thickness were assessed for each participant; Also, each patient's IOP was measured using both GAT and Air-Puff tonometry, the difference in readings between the two methods were calculated. **Result:** The mean IOP measured by GAT was 14.48±2.29 mmHg, while that measured by Air Puff tonometer was 16.34±2.3 mmHg. The mean difference between the two methods of measurement was 1.855 mmHg. The readings obtained by Air Puff tonometer were higher than those obtained by GAT and highly statistically significant. **Conclusion:** The non-contact, air puff, tonometer produces IOP measurements which are similar & consistent to that of gold standard GAT. Our study indicated that there is a good consistency between the non-contact Air-Puff tonometer and GAT.

Keywords: IOP, non-contact tonometry, Goldmann Applanation tonometer.

Introduction

Fluid pressure inside the eye is responsible for maintaining the shape of the globe known as intraocular pressure (IOP). IOP has been regarded as a vital parameter of the eye. Accurate measurement of IOP with proper technique is crucial in diagnosis and management of glaucoma.(1)

Glaucoma has been established as the second leading cause of blindness. The treatment of glaucoma focuses mainly on lowering intraocular pressure (IOP). The different methods of tonometry are: Goldmann Applanation Tonometry, Non-contact (Air-Puff) tonometry, Perkins Tonometry, Tonopen Tonometry, Transpalpebral Tonometry.(2)

The most accurate technique for the measurement of IOP is manometry but this is an invasive procedure and is not a method of choice. The method of choice in the optometric and ophthalmological clinical settings is the Goldmann Applanation Tonometer (GAT); which based on the principle of the Imbert-Fick law, which assesses the intraocular pressure by measuring the force necessary to applanate a fixed area of the cornea. Goldmann Tonometry, while being minimally invasive, still requires the instillation of fluorescein, topical anesthesia and corneal contact.(3)

Air-puff tonometry is an applanation method using a standardized puff of air to flatten the cornea. This method has the advantage of no topical anesthesia or risk of corneal abrasion.(4)

Central corneal thickness (CCT) is known to affect the accuracy of intraocular pressure (IOP) measurements by applanation tonometry and Non-Contact Tonometer. A thicker cornea requires greater force to applanate and, conversely, a thinner cornea is more easily flattened. (5)

Patients and methods:

This was a cross sectional observational comparative study between IOP measured by Air puff and Goldmann Applanation tonometry the study included 200 eyes of 100 study participants(including relatives of patients, medical students, nurses and patients complaining from errors of refraction). They were selected from the out-patient clinic of Ophthalmology Department, Benha Faculty of Medicine with age ranged from 18:80 years old. The study was conducted from July 2018 to December 2018.The study had acceptance from scientific ethical committee.

Exclusion criteria*:* patients with corneal opacity, inflammation or infection and edema. Also thin cornea < 500μm thick cornea > 600μm, Corneal astigmatism >

3Diopter and any Previous corneal surgeries like LASIK or PRK were excluded.

Method*:* All patients in this study underwent Full history and full ophthalmic examination and assessment of visual acuity: Uncorrected visual acuity (U.C.V.A.), best corrected visual acuity (B.C.V.A.), Refraction using NIDEK Auto-Refractometer-Keratometer, anterior segment examination by slit-lamp biomicroscopy, Intraocular pressure (IOP) measurement using Goldman Applanation Tonometer (Haag – Streit At 900˚ Swiss Made) and air- puff Tonometer (Topcon Japan CT-80), fundus examination (including posterior vitreous, disc and macular examination) done, measurement of corneal thickness and corneal topography obtained with the Orbscan II Topographic System (Bausch & Lomb).

Technique

IOP was measured in all patients using both a GAT and an Air Puff tonometer, and the difference in readings between the two methods was calculated. For the assessment of IOP by Air puff tonometer, three readings were averaged to get the IOP values for an eye. The IOP assessment with the GAT was always subsequent to that with the noncontact tonometer; this was done to prevent bias due to a reduction of measured IOP caused by applanation. For the measurement by GAT, the eyes were anesthetized using Benox (Benoxinate hydrochloride) (Egyptian Int. Pharmaceutical Industries CO.) 0.4% Sterile Ophthalmic Solution 10 ml and a fluorescein strip was applied to the inferior conjunctival fornix for a few seconds. The period of contact with the applanation probe was kept under 5 seconds to minimize the IOP reducing effect of aqueous massage on repeated applanation readings. All readings of IOP were taken between 8 am and1 pm.

Statistical analysis:

The collected data were described in terms of mean ± Standard Deviation (SD) and range for quantitative data and frequency and percentage for qualitative data., Comparisons between the different study groups were carried out using the independent t-test and the Mann-Whitney test and The degree of agreement in the measurement of IOP by Air-puff and Goldmann methods was examined using the Bland Altman test and scatter plotting.

Statistical significance was accepted at $P<0.05$. A P value <0.001 was considered highly significant (HS) while a P value >0.05 was considered non-significant. All statistical analyses were carried out in STATA/SE version 11.2 for Windows (STATA Corporation, College Station, Texas).

Result:

200 eyes of 100 participants were enrolled in this study. The age of patients ranged between 18 and 80 years with a mean age (34.93±14.25). Sex distribution among the patient of the studied group showed male to female percentage 44% and 56% respectively. As shown in Table (1)

Table 1: Age and sex distribution of the studied group

Variable No.=100		No.	%
Gender	**Females**	56	56.0
	Males	44	44.0
		Mean ±SD	Range
Age (years)		34.93±14.25	18-80

Table 2: Comparison of IOP measured by air puff and Goldmann applanation tonometers in total eyes

variables	Total (no.=200) Mean ±SD; (range)
IOP air puff (mm Hg)	16.34±2.3; (12-22)
IOP Goldmann (mm Hg)	14.48±2.29; (10-21)
Paired t-test	21.63
P	<0.001 (HS)

Table 2: shows that there were highly significant differences between IOP measurements taken by Air Puff and IOP measurements taken by Goldmann Applanation Tonometer; the mean IOP measured by air puff (16.34±2.3) was significantly higher than the mean IOP measured by Goldmann (14.48±2.29).

Table 3: Bland Altman scatter plot comparing IOP measurements obtained by air puff and Goldmann methods

Total eyes (no.=200)	
Limits of agreement	-0.571 to 4.281
Mean difference (95% CI)	1.855 (1.686 to 2.024)
Range	11.00 to 21.00
Pitman's test of difference in variance	r= 0.016
	p= 0.824
RT eyes (no.=100)	
Limits of agreement	-0.502 to 4.042
Mean difference (95% CI)	1.77 (1.545 to 1.995)
Range	11.00 to 21.00
Pitman's test of difference in variance	r= 0.084
	p= 0.042 (S)
LT eyes (no.=100)	
Limits of agreement	-0.631 to 4.511
Mean difference (95% CI)	1.94 (1.685 to 2.195)
Range	12.00 to 20.50
Pitman's test of difference in variance	r=-0.043
	p= 0.669

Table 3: shows that there was a narrow limit of agreement LOA (which reflected to the difference between measurements of IOP taken by Air-puff Applanation Tonometer and by Goldmann Applanation Tonometer in each eye); since it is narrow so the two devices of IOP measurements were closely related and similar to each other

Discussion:

Intraocular pressure (IOP) is a measurement involving the magnitude of the force exerted by the aqueous humor on the internal surface area of the anterior eye.(6)

Given this importance of IOP as a core vital sign of the eye, the measurement of IOP (tonometry) in a consistent and reliable manner is fundamental to the diagnosis and management of glaucoma and similar disorders. Goldmann applanation tonometry is the most widely used method of tonometry (7)

On the other hand, noncontact (Familial known as 'air puff') tonometry is a form of applanation tonometry that employs a calibrated column of compressed air to briefly flatten the corneal apex. Recently, a growing body of evidence showed that modern NCT devices are correlate well with Goldmann Applanation tonometry (8).

We conducted the present cross sectional observational comparative study in order to evaluate the difference between IOP measurements taken by a Goldmann Applanation tonometer and those taken by an air puff tonometer and to observe the reliability of air puff to be a screening tool.

In the present study, we included 100 male and female subjects with normal IOP who were selected from the ophthalmic outpatient clinic of Benha Faculty Of Medicine. The mean age of the included subjects was 34.93±14.25 years and 56% of them were females. The present study found that there was a statistically significant difference between the mean IOP in males and IOP in females ($P < 0.04$), with higher IOP in females

Similar to our findings, in 2014 a case-control study was performed on 50 males and 50 females subjects above the age of 40 years with normotension patients to study the variation of IOP with age and gender. There was a statistically significant difference between the mean IOP in males and IOP in females, with higher IOP in females ($P < 0.05$). (9)

In addition, some studies demonstrated variability in the IOP distribution among different ethnicities, age groups and gender. In 2015 an observational prospective cross-sectional study was performed (10). The participants were selected by the convenient sampling method.The study sample consisted of 458 healthy Saudi participants, aged 20 years or over and found that there was no sufficient evidence to conclude that intraocular pressure in Saudi participants is

related to gender, age or refractive error. The median IOP in this study is different from that in various studies in other geographical regions. The observations need confirmation by study with larger sample representing Saudi population.(10)

In the present study, we found statistically significant differences between the IOP measurements of Goldmann applanation tonometry and air puff tonometry.The mean IOP was 16.34±2.3 for Air puff and 14.48±2.29 for GAT. As a result of the Bland–Altman plot showed a narrow limit of agreement and high consistency between airpuff and Goldmann applanation measures.

In agreement with our findings, a cross sectional comparative study done in 2012, (11), 73 eyes from 73 patients (did not have glaucoma based on medical history or previous exams) were included in this study and intraocular pressure (IOP) was measured by GAT and PT100 Non-contact tonometer at Sheikh Khalifa Bin Zayed Hospital. The mean intraocular pressure was 16±3.2 mmHg for GAT, and 16.58±2.7 mmHg for PT 100. Mean IOP measurements showed significant differences in measurements performed by the two tonometers ($p<0.05$). Correlation revealed significant relation between PT100 and GAT (Pearson's correlation 0.715, $p<0.01$).(11)

Like our findings, in a study done in 2014, compared the IOP measurements between the Goldmann applanation tonometer and a non-contact air puff tonometer (12). A cross-sectional study of 200 eyes from 200 patients was conducted. Bland–Altman analysis showed that the mean difference between measurements from the Goldmann applanation tonometer and a non-contact airpuff tonometer was 0.6±2.3 mmHg. Thus, the non-contact airpuff tonometer was found to provide IOP measurements similar to those of the gold standard Goldmann applanation tonometer in normotensive eyes (12).

Similarly, another study was conducted to comparing IOP, measured by three different non-contact tonometers and the Goldmann applanation tonometer for non-glaucomatous subjects. Fifty two eyes of 52 non-glaucomatous subjects, 22 were males and 30 were females, with a mean age of 50.56 ± 17.25 years (range: 21–85 years). IOP was measured sequentially with (the Canon TX-20P, the Nidek NT-530P, the Topcon CT-1P) and the Goldmann applanation tonometer at the same time. The mean IOP across all subjects was 17.23 ± 2.94 mmHg (range: 11–21 mmHg) with the Canon TX-20P, 14.87 ± 3.25 mmHg ,with the Nidek NT-530P, 16.33 ± 3.01 mmHg ,with the Topcon CT-1P, and 15.85 ± 3.05 mmHg with the GAT. In conclusion,(the Canon TX-20P, Nidek NT-530P and

Topcon CT-1P) all offer similar accuracy to the GAT. (13)

In addition, a cross sectional study was conducted, in which IOP measurements of 256 patients (500 eyes) (glaucomatous and non-glaucomatous) were performed using GAT and NCT on patients visiting the outpatient clinic of Department of Ophthalmology. The results showed that NCT and GAT measurements showed good agreements for IOP less than 24 mm Hg, proving that both are consistent methods of measuring IOP. (14)

Similarly, a cross sectional study was conducted comparing the IOP measured by the Goldmann applanation tonometer and a Non-contact Air puff tonometer in two groups: 65 glaucoma patients and 46 normal controls. Bland–Altman plots indicated that there was a greater consistency between air puff and Goldman applanation (8).

In contrary to our findings, a cross-sectional study in a private tertiary glaucoma clinic was conducted on 109 glaucoma patients (54 males, 55 females) with a mean age of 65±14 years (range17–88) to compare the IOP readings obtained with the non-contact tonometer with those measured by Goldmann applanation tonometry. The results showed that there were statistically significant differences between the average readings for each tonometer. The non-contact tonometer were lower than the average Goldmann reading for both right ($P < 0.001$) and left ($P > 0.01$) eyes. The authors concluded that the non-contact tonometer measures IOP in fundamentally different ways to the Goldmann applanation tonometer (15).

A study was conducted on 55 patients (15 males and 40 females) age between 40 - 80 years with clinical diagnosis of bilateral POAG. The mean age was 64.1 ±8.1 years. The mean IOP values were (14.22±3.42, 14.28±3.29, 14.66±3.49 mmHg) for NCT1, NCT3 and GAT respectively (P=0.291) In conclusion, although IOP values obtained from NCT1 and NCT3 appear to be similar with GAT measurements, wide range of LoA might limit the use of this NCT (both 1-puff and 3-puffs) and GAT interchangeably in POAG patients.(16)

Similarly, a cross-sectional study was conducted on 46 volunteers with normal ophthalmic examination and no history of eye surgery or trauma. The results showed that the limit of agreement between air puff and Goldmann applanation tonometers was relatively large (17).

The exact causes of such heterogeneity between our findings and the above mentioned studies, regarding the accuracy of air puff tonometer, are unclear. However, this difference can be attributed to different populations, whether healthy subjects or glaucomatous patients, were included; Another explanation is the differences in sample size and age groups and ethnicities .

In the present study results showed that the mean IOP measured by air puff (16.34±2.3) was significantly higher than the mean IOP measured by Goldmann(14.48±2.29).

Several studies performed gave the same results like our study; researchers performed a study involving 196 eyes from 98 study participants, all of whom were patients attending an ophthalmic outpatient clinic. Each patient's IOP was measured using both Goldmann applanation tonometry and AP tonometry. The mean IOP measured by GAT was 13.06 ± 4.774 mmHg, while that measured by AP tonometer was 15.91 ± 6.955 mmHg. The mean difference between the two methods of measurement was 2.72±2.34 mmHg. The readings obtained by AP tonometer were higher than those obtained by GAT in 74% of patients (18).

A retrospective cross sectional study was performed on 50 eyes from 50 subjects without glaucoma. The IOP was measured using GAT and NCT and calculated the difference between the two methods. The mean IOP measured by GAT and NCT was (16.7 ± 3.0) and (18.1 ± 3.8) mmHg, respectively. The mean IOP difference was (1.5 ± 1.7) mmHg, and the IOP measured by NCT was (8.4% ± 11.3%) higher than that measured by GAT (19).

This study also agrees with a study performed on 400 eyes of 200 patients, males 125 (250 eyes) and females 75 (150 eyes) with age ranging from 20 to 70 years to compare IOP measured by GAT and Non-Contact Air Puff Tonometer . The mean IOP measured by APT was 16 mm Hg and measured by GAT was 13 mmHg. The calculated difference between APT and GAT was 3± 2.5 mm Hg. The results showed that Air Puff gave slightly higher results (around 3 mm Hg) (20).

The measurement of central corneal thickness (CCT) has emerged as an essential component in the diagnosis of glaucoma. CCT has an influence on the accuracy of intraocular pressure IOP measurements obtained using Goldman applanation tonometry. It has been well established from studies that the IOP is under estimated in thin and over estimated in thick corneas.

The present study showed that the CCT was significantly correlated with the IOP measurements obtained by either air puff or Goldmann applanation tonometer, in both right and left eyes.

In agreement with our findings, it was reported that there was a statistically significant correlation between CCT and air puff measurements. Simple regression model showed that CCT had significant relationship with IOP measured with air puff or Goldmann applanation tonometer (17).

In another study, IOP measurements of 500 eyes (glaucomatous and non-glaucomatous) were performed using GAT and NCT on

patients visiting the outpatient clinic of Department of Ophthalmology at Christian Medical College and Hospital. This was a cross sectional and observational study. Comparison of IOP values was done in different IOP ranges. CCT was measured and analysis of its correlation with GAT and NCT was done and Finding that IOP readings with GAT and NCT positively correlated with CCT (14).

Similarly, in a prospective study done in 2018 on 188 eyes of 94 healthy volunteers; compared the intraocular pressure values measured using non-contact tonometer and Goldmann applanation tonometry, the study was also performed to test whether the values obtained using each technique change in accordance with the central corneal thickness (CCT). The mean CCT was 538.2±34.4 µm, the CCT was positively correlated with a non contact tonometer and Goldmann applanation tonometry (21).

Conclusion

In conclusion, the non-contact air puff tonometer produces IOP measurements which are similar & consistent to that of the gold standard Goldmann Applanation tonometry. Our study indicated that there is a good consistency between the non-contact air puff tonometer and Goldmann Applanation tonometry.

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