Original Article

Comparison of Intraocular Pressure Measurement by Goldmann Applanation Tonometer and Non-Contact Airpuff Tonometer

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ABSTRACT

Purpose: To compare between the intra-ocular pressures (IOP) measured by Goldmann applanation tonometer (GAT) and non-contact air-puff tonometer (APT) considering GAT as gold standard.

Study Design: Comparative analytical study.

Place and Duration of Study: Al-Shifa trust eye Hospital, Rawalpindi from January 2018 to June 2018.

Methods: Five hundred individuals, 223 glaucoma patients and 277 non glaucoma control subjects were recruited. After taking a detailed history, slit-lamp examination and fundoscopy was performed to check glaucoma status of the eyes. Retinal nerve fiber layer (RNFL) was checked with optical coherence tomography. Non-contact air-puff tonometry of both eyes were performed. Using a drop of local anesthetic and small amount of fluorescein, intra-ocular pressure was measured with GAT (Haag Streit Diagnostics).Central corneal thickness was measured for correction of IOP measurement with GAT. Paired sample correlations were performed to compare the mean IOP with APT and GAT with and without correction factor. Sensitivity and specificity for measurement of IOP by APT was calculated considering GAT as gold standard.

Results: Mean age of the male and female participants was 49.87 ± 18.70 years and 45.53 ± 16.91 years respectively. Mean IOP in glaucomatous eyes measured by GAT (after applying correction factor) and APT was 16.01 ± 5.57 mmHg and 17.31 ± 7.22 mmHg respectively. The sensitivity and specificity of APT for measuring IOP in glaucomatous eyes were 84.04% and 73.53% respectively.

Conclusion: Non-contact air-puff tonometer has good sensitivity and specificity and can be used reliably for measurement of IOP in out-patient department and for mass screening of the population.

Key Words: Glaucoma, Intraocular Pressure, Tonometer, Goldmann Applanation tonometer, Non-contact air-puff tonometer.

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INTRODUCTION

Glaucoma is a group of optic neuropathies of multivariate etiology and is characterized by progressive degeneration of ganglion cells at the optic nerve head.[1] According to the latest report of World Health Organization, more than 2 billion people around the world have some form of visual impairment and at least half of the them have visual impairment due to preventable causes.[2] Prevalence of glaucoma is very high and an estimated 3% of the people over 40 years have glaucoma.[3] According to American Academy of ophthalmology, global prevalence of glaucoma in people between 40 – 80 years is 3.54%.[4] Number of people suffering from glaucoma is 64.3 million which is projected to be 95.4

million by 2030 and by 2040 the projected estimate of people suffering from glaucoma is 111.8 million.[4] Glaucoma is also one of the leading causes of blindness in Pakistan.[5]

Raised intra-ocular pressure (IOP) is the most important and modifiable risk factor of glaucoma which leads to loss of visual field. Normal intra-ocular pressure ranges from 10 – 21 mmHg and is maintained by dynamic equilibrium of aqueous humor production by ciliary body and drainage at trabecular meshwork, sclera, the collector channels and the aqueous veins and anterior surface of the ciliary body.[6] In addition to age related changes, intra-ocular pressure is affected by time of the day, respiratory rate, heartbeat, fluid intake, coughing, straining, vomiting and use of systemic and topical medications.[7] IOP of more than 21 mmHg is associated with Glaucoma however studies have reported no damage to the eye even with IOP of more than 30 mmHg, as seen in cases with ocular hypertension.[8] On the other hand, glaucomatous damage has been observed with IOP below 21 mmHg, as in case of normal tension glaucoma.[9,10]

A review of the literature suggests that early detection of raised IOP and its management can significantly decrease associated morbidity.[11] Measurement of IOP is influenced by many factors including central corneal thickness (CCT), expertise of the measuring doctor, technique used for measurement and corneal curvature.[12] Different types of tonometers are commercially available and have specific advantages and disadvantages. Commonly used tonometers include Goldmann Applanation tonometer, dynamic contour tonometer, pneumo-tonometer, Perkins's applanation tonometer and rebound tonometer.[13]

The GAT is the most commonly used instrument for measurement of IOP in clinical settings. It works on the principle of Imbert-Fick, which states that "force needed to flatten a known area of a perfect square is directly proportional to internal pressure of the sphere". Measurement of IOP by GAT is affected by variations in corneal curvature, corneal thickness, surface tension of the film causing the plane to adhere to cornea and resistance of the cornea to deformation.[14] Although GAT has historically been used for measurement of IOP but due to requirement of local anesthetic, fluorescein dye, Slit-limp arrangement, precise calibration and trained person to operate, it is less suitable to be used in busy out-patient settings, pediatric age group, elderly people and people with disabilities. Moreover, corneal thickness can also lead to over and under-estimation of the IOP and needs to be corrected.[15]

Contrary to GAT, APT is a non-contact tonometer, which uses column of air to flatten the corneal surface. The APT has advantage over GAT, as it does not require anesthetic, fluorescein dye and is easy to operate. It also reduces the risk of injury and corneal abrasion. Kadu and his colleagues reported comparable results for measurements of IOP by non-contact tonometry in comparison with GAT for both eyes.[16] Although, it can give false measurements when IOP is too high or too low.

Although variations exist between measurements of IOP by GAT and APT but both the methods have their own advantages and disadvantages. The beneficial effect of lowering IOP in progression of glaucoma necessitates a reliable, cost-effective and easy to use screening method for accurate measurement of intra-ocular pressure in out-patient department.

Keeping in view the availability of limited data on the subject matter in our region, the present study was designed to evaluate the sensitivity, specificity and diagnostic accuracy of non-contact air-puff tonometer for measurement of Intra-ocular pressure keeping GAT as gold standard.

METHODS

This was a comparative analytical study conducted at Al-Shifa trust eye Hospital, Rawalpindi from January 2018 to June 2018. The approval of the study was taken from institutional review board. Sample Size was calculated using Raosoft sample size calculator. Keeping margin of error at 6.5%, confidence level 95% and estimated prevalence of glaucoma as 3% a minimum sample size of 223 glaucoma patients was set. For comparison 277 non glaucomatous control subjects were also recruited. Patients with corneal disease, for example ulcer, scarring, ectasia, descemetocele or bullae were excluded. Moreover, subjects with recent history of eye surgery, acute infection and any ocular emergency were also not considered for the study. After getting demographic information, visual acuity and refraction of all the patients was done by an ophthalmologist. Slip-lamp examination with fundoscopy was performed to check glaucoma status of the eyes and was confirmed by retinal nerve fiber layer scan through optical coherence

tomography (OCT RNFL) on Heidelberg Spectralis. An eye was labeled as glaucomatous if there was an evidence of typical glaucomatous changes in optic disc, difference between the eyes in cup to disc ratio > 0.2, rim notching, and peripapillary atrophy or splinter haemorrhage. The diagnosis was further confirmed on OCT to document the thinning of RNFL. Any possible cause of RNFL loss other than glaucoma was also considered on the basis of history and examination. Non-contact air-puff tonometry of both eyes of the subjects was performed on Cannon TX-20P airpuff tonometer. After this a drop of local anesthetic and small amount of fluorescein were instilled in both the eyes for measurement of intra-ocular pressure using GAT (Haag Streit Diagnostics).

For this purpose, the patient was asked to look straight with both the eyes wide open, fixed gaze and perfectly still. Filters were then moved to produce blue beam and the tonometer was forwarded slowly until the prism rested on the center of the patient's cornea. With the other hand, the calibrated dial on the tonometer was dialed clockwise until the two fluorescein semi-circles in the prism head were seen to meet. The reading was noted and after wiping off the tip of the prism, the same procedure was repeated with other eye. Central corneal thickness was measured by pachymetry for correction of IOP measurement with GAT.

The data was entered and analyzed using SPSS software version 21.0. Paired sample correlations was performed to compare the mean IOP with APT and GAT with and without correction factor. Moreover, sensitivity and specificity for measurement of IOP by APT was calculated considering GAT as gold standard.

RESULTS

During the study period, a total of 500 participants fulfilling the inclusion criteria were recruited. Among the participants 221 (44.2%) were male while 279 (55.8%) were female. Mean age of the male and female participants was 49.87 ± 18.70 and 45.53 ± 16.91 respectively and the difference was not statistically significant ($p > 0.05$). Descriptive statistics of the study participants is provided in Table 1.

The study sample comprised of 500 patients (1000 eyes) out of which, 446 (44.6%) eyes were glaucomatous and 554 (55.4%) eyes were normal. Air-puff tonometry was not reliable in two patients so a total of 4 eyes were excluded from inferential statistics. The details of IOP measurement with GAT, GAT with correction factor and APT in glaucomatous and non-glaucomatous patients is given in Table 2.

Table 1: *Descriptive statistics of the study subjects.*

Variable	Minimum	Maximum	Mean	Standard Deviation
Glaucomatous (444 eyes)				
Age	21	90	52.07	17.72
Central Corneal Thickness	342	681	507.59	38.69
Correction factor	0	7	2.95	2.01
Non-Glaucomatous (552 eyes)				
Age	21	82	43.90	17.15
Central Corneal Thickness	412	627	518.38	32.56
Correction factor	0	7	2.36	1.74

Table 2: *Intra-ocular pressure measurement with GAT and APT.*

Variable	IOP Range	Mean	Standard Deviation
Glaucomatous (444 eyes)			
GAT	4 – 40	13.49	6.66
GAT with correction	6 – 41	16.01	5.57
APT	5 – 51	17.31	7.22
Non-Glaucomatous (552 eyes)			
GAT	6 – 23	13.49	2.82
GAT with correction	5 – 21	15.32	3.13
APT	6 – 37	16.36	4.01

IOP: Intra-ocular pressure, GAT: Goldmann Applanation tonometer, APT: Air-puff tonometer

Table 3: *Co-relations of IOP measurements in glaucomatous and non-glaucomatous patients.*

Paired-sample co-relations	Co-relation	Significance	df
Glaucomatous (444 eyes)			
IOP with GAT without correction factor & IOP with APT	0.761	< 0.001	443
IOP with GAT with correction factor & IOP with APT	0.700	< 0.001	
Non-Glaucomatous (552 eyes)			
IOP with GAT without correction factor & IOP with APT	0.379	< 0.001	551
IOP with GAT with correction factor & IOP with APT	0.258	< 0.001	

Table 4: *Single table analysis of IOP measurements.*

		Glaucomatous		Total	Chi-square Analysis
		≤ 20 mmHg	≥ 21 mmHg		
IOP measured by APT	≤ 20 mmHg	316	18	334	< 0.001
	≥ 21mmHg	60	50	110	
Total		376	68	444	
		Non-Glaucomatous		Total	
		≤ 20 mmHg	≥ 21 mmHg		
IOP measured by APT	≤ 20mmHg	467	19	486	
	≥ 21mmHg	56	10	66	0.001
Total		523	29	552	
		Glaucomatous		Non-Glaucomatous	
Sensitivity		84.04%		89.29%	
Specificity		73.53%		34.48%	
Positive Predictive Value		94.61%		96.09%	
Negative Predictive Value		45.45%		15.15%	
Diagnostic Accuracy		82.43%		86.41%	

Mean difference between IOP measurements with APT and GAT was 3.82 ± 4.59 mmHg and GAT with correction factor was 1.30 ± 5.19 mmHg in glaucomatous eyes. Mean difference between IOP measurements with APT and GAT was 2.87 ± 3.93 mmHg and GAT with correction factor was 1.03 ± 4.40 mmHg in normal eyes.

Paired sample correlation showed that IOP measurements with APT and GAT with and without correction factor significantly correlated in both glaucomatous and non-glaucomatous patients (Table 3). Sensitivity and diagnostic accuracy for measurement of IOP by APT was high in both groups but specificity was low in non-glaucomatous group keeping GAT as gold standard (Table 4).

DISCUSSION

To date, GAT is the most reliable and accurate tonometer and is current gold standard for measurement of IOP. The results indicate that IOP measurements with APT were more in agreement with measurements made by GAT with correction factor although the difference was still statistically significant. The results of our study are in line with most of the other studies where researchers have reported over-estimation of IOP with non-contact tonometers.[17]

In a study carried out in Iraq, Farhood QK reported that APT overestimated IOP measurements in more than three quarters of the patients and mean IOP difference between measurements with APT and GAT was 2.72 ± 2.34 mmHg which was statistically significant.[18] Kim et al. also reported significant differences between IOP measurements taken in normal, ocular hypertensive and glaucomatous eyes using Goldmann, TonoPen XL and non-contact tonometer. The researchers concluded that IOP measurements by all tonometers are affected by age, type of glaucoma, central corneal thickness and intra-ocular pressure.[19]

A study carried out in Turkey reported similar trend in IOP measurement by two devices however, the mean difference (0.6 ± 2.3 mmHg) between measurements of two instruments was not significant statistically.[20] Mohan et al. reported lower IOP readings with non-contact tonometer (NCT) compared to GAT. The researchers reported a positive correlation between measurements taken by two instruments but the difference of mean IOP

measurements taken by two instruments were not significant statistically.[21] Another study from Saudi Arabia reported little difference among IOP measurements taken by GAT, APT and TonoPen XL.[17]

Results of the current study demonstrates good agreement between measurements of IOP in normal range in glaucomatous as well non-glaucomatous patients. Moderate positive co-relations were observed between IOP measurement by GAT and APT in glaucomatous eyes and a weak positive co-relation in non-glaucomatous eyes. APT over-estimated the IOP as compared to GAT with and without correction in both groups.

In a study estimating influence of soft contact lenses on IOP measurement, the values measured by dynamic contour tonometry (DCT) were greatly influenced compared to non-contact tonometer.[22] Significant positive correlations were also reported between IOP values measured by GAT and different non-contact tonometers in non-glaucomatous subjects and IOP measurement using both types of instruments was affected by central corneal thickness.[23]

In our study, the sensitivity and specificity for accurately measuring intra-ocular pressure by APT was 84.04% and 73.53% for glaucomatous eyes and 89.29% and 34.48% for normal eyes respectively taking GAT as gold standard. The results indicate that APT has good sensitivity for measuring IOP in both groups but low specificity for measurement of IOP in normal eyes. Comparable sensitivity and specificity of APT has also been reported in other studies from various regions. In a study from Madrid, the sensitivity and specificity of APT was reported to be 86% and 84% respectively in patients with raised IOP.[24] Another study reported 90% sensitivity and 95% specificity for pneumo-tonometry for measuring IOP $\geq$ 21.[25] The reported sensitivity and specificity of APT for measuring IOP from India is 71.42% & 95.31%.[19]

CONCLUSION

Precise measurement of IOP is important for diagnosis, management and prognosis of glaucoma. Each of the commercially available tonometer has its own advantages and disadvantages and can be used in different clinical settings. Although GAT is the most accurate, reliable and current gold standard for IOP measurement, air-puff tonometer can be used for mass-screening of the population as well as in out-patient department for initial measurement of IOP.

Conflict of Interest: Authors declared no conflict of interest.

Ethical Approval

The study was approved by the Institutional review board/ Ethical review board **(ERC-09/AST-18).**

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Authors' Designation and Contribution

Sidra Shaheen; Optometrist: *Concepts, Design, Literature search, Manuscript preparation.*

Mahmood Ali; Professor: *Concepts, Data acquisition, Manuscript preparation.*

Afshan Ali; Senior Registrar: *Literature search, Data acquisition.*

Hina Sharif; Senior Registrar: *Data analysis, Statistical analysis.*

Tayyab Afghani; Professor: *Data analysis, Statistical analysis.*