

Comparison of Intraocular Pressure Measurement by Goldmann Applanation Tonometer, Air Puff Tonometer and Tonopen in Vitrectomized Eyes

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ABSTRACT

Objective: To compare Goldmann applanation tonometer, air puff tonometer, and tonopen measured IOP Readings in vitrectomized eyes filled with temponading oils and gasses.

Study Design: Comparative cross-sectional study.

Place and Duration of Study: Armed Forces Institute of Ophthalmology (AFIO), Rawalpindi Pakistan, from Aug 2021 to Feb 2022.

Methodology: A total of 50 eyes were included in our study. Intraocular pressure was measured by an experienced ophthalmologist between 10am to 4pm on the 7th postoperative day by three devices, Goldmann applanation tonometer (GAT), air puff tonometer, and tonopen. Pearson's correlation and paired samples t-test was applied to determine correlation and any significant difference between the mean of intraocular pressure measured by three different devices.

Results: Out of the 50 people included in study 31(62%) were males and 19(38%) were females. The mean age of study participants was 50.10±11.61 years. Mean intraocular (IOP) pressure measured by the GAT applanation tonometer was 14.59±1.13 mmHg. Mean IOP as calculated by the airpuff tonometer was 15.93±1.88 mmHg, whereas mean IOP as calculated by tonopen was 15.85±1.86 mmHg. All three instrument values showed significant difference as p -value < 0.001.

Conclusions: The air puff tonometer overestimates IOP as compared to GAT. Tonopen and air puff tonometer produce IOP measurements that are similar and consistent to each other but not to GAT.

Keywords: Air puff tonometer, Goldmann applanation tonometer (GAT), Intraocular pressure, Temponading oils gasses, Tonopen and Vitrectomized eyes.

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INTRODUCTION

Vitreous humor in human eye is made up of a frame of collagen and hyaluronic acid with abundant water (99%). The hyaluronic acid coils and swells in the network of collagen creating internal tension through the Donnan effect.¹ The vitreous humour is soft and viscoelastic so can hold the lens and retina in place. This keeps the eye-safe from physical insults providing the cushioning effect. Vitreous humour also maintains an oxygen gradient between the lens and retina. Usually metabolically active pigmented epithelial cells of the retina need a high concentration of oxygen which is maintained by vitreous humour by limiting the transport of oxygen by convection. The presence of antioxidant vitamin-C in vitreous humour creates a low oxygen concentration near lens epithelial cells. So vitreous humour plays an important role in both the biochemical and physical properties of the eye.² In vitrectomy; this viscous fluid is removed and replaced

with a vitreous-like substance e.g., saline, oil, gas, or air bubble. Vitrectomy is used for treating various diseases of the retina, vitreous or vitreoretinal interface.³ Common indications for vitrectomy are major eye trauma, retinal detachment, hemorrhage, trauma or injury during cataract surgery or glaucoma surgery, swelling of central retinal tissue, macular degeneration, injury from infected, dislodged intraocular lens, scars on the retina or endophthalmitis.⁴

Intraocular pressure is determined by the production and drainage of aqueous humour by trabecular meshwork and uveoscleral outflow. The normal eye has intraocular pressure of 10-21 mmHg.⁵ Normally vitreous humour has fixed volume and it doesn't affect intraocular pressure. But after a vitrec-tomy when the vitreous is replaced by saline, oil or gas then changes in intraocular pressure occur. Usually, elevated pressures are noted.⁶ Other complications of vitrectomy apart from elevated pressure include iatrogenic new retinal tears/detachment, lenticular damage, increased rate of cataract formation, extraocular motility disorders, and changes in refractive index (often after combined Scleral Buckling surgery). Sudden changes

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in intraocular pressure after vitrectomy may lead to microbubbles that lead to multiple emboli, hypoxia, ischemia, and damage to retinal microstructures.⁷ Silicone oils when used as tamponing agents lead to higher elevations of intraocular pressures so proper monitoring of intraocular pressure and treatment is required.⁸ Tonometry is the method used to determine intraocular pressure. Most tonometers are calibrated to measure pressures in mmHg. Tonometry has evolved over centuries to look for the ideal instrument which can accurately and precisely measure intraocular pressure. Goldmann applanation tonometer (GAT) is considered the gold standard tonometer.⁹ This method involves the use of a slit lamp and measures the force required to flatten the cornea temporarily. Thus, high intraocular pressure requires higher force and greater IOP reading, and vice versa. It is the most commonly used applanation device for measuring intraocular pressure, but it measures pressure indirectly. With time, new devices have been introduced which require no anesthesia, dye, or require minimal contact but are not superior to GAT.¹⁰ Air puff tonometer measures intraocular pressure by using a jet of air to flatten the cornea. The returning airjet touches a membrane. The force of this membrane movement gives the value of intraocular pressure. Tonopen is the latest handheld easy to use, with minimal contact applanation device.¹¹ We planned this study to compare intraocular pressure values using these three applanation devices in vitrectomized eyes.

METHODOLOGY

Our study was a comparative cross-sectional study conducted at the Armed Forces Institute of Ophthalmology, Rawalpindi Pakistan, from August 2021 to February 2022. A total of 50 eyes of 50 patients were included in our study.

After a thorough literature search, a sample size of 13 in each group was calculated using OpenEpi Online calculator, keeping two sided confidence level 95%, power of 80, and combined odds ratio of 25.7 (risk of retinal detachment in myopic patients).¹² Sampling was done using the nonprobability consecutive sampling technique and maximum number of available participants fulfilling inclusion and exclusion criteria i.e. total 50 patients, were recruited. IOP from only 1 vitrectomized eye from a single patient was recorded and documented for the study purpose.

Inclusion Criteria: Patients who underwent pars plana vitrectomy due to rhegmatogenous retinal detachment along with Silicone Oil as tamponading agent, in either eye, had age ≥ 18 years, and belonged to either gender

were included. Patients also had optically clear cornea, astigmatism < 2.5 diopters with no history of any recent eye infection or use of contact lenses were included.

Exclusion Criteria:

Patients with, corneal opacity, corneal edema, vascularization or corneal surgery or glaucoma surgery, or diagnosed cases of glaucoma or hypotony were excluded.

All patients included in our study had given their written informed consent voluntarily and were examined on the 7th post-operative day. Ethical approval was obtained from the hospital ethical review committee vide AFIO letter dated 22 Dec 2020. All devices used were calibrated as per the manufacturer's instructions. Measurements of intraocular pressure were taken by ophthalmologists with more than 5 years of experience. A 30-minute time interval was given in-between measurements and an average of 6 readings with each method is documented. All intraocular pressure measurements were taken between 10am and 4pm thus to avoid any early-morning changes in corneal thickness as a result of overnight edema. Air puff tonometer (Computerized Tonometer CT-80 by Topcon healthcare®, Tokyo, Japan) was the first instrument to be used for the measurement of intraocular pressure. The eye under study was then anesthetized by using topical Proparacaine 0.5% eye drops and a second ophthalmologist then measured intraocular pressure with the Tonopen (Reichert TONO-PEN AVIA by HAAG-STREIT®, Zug, Switzerland). Then after a gap of 30 minutes topical proparacaine 0.5% eye drop was instilled again and a fluorescein strip was applied to the inferior conjunctival fornix and a third ophthalmologist took GAT measurements (Goldmann applanation tonometer AT-900 by HAAG-STREIT®, Zug, Switzerland) through the use of biomicroscope (cobalt blue filter). All three investigators were blind of the IOP readings of their patients measured by other 2 instruments to reduce the bias.

All data was entered in Microsoft excel and then shifted to Statistical Package for the social sciences (SPSS) version 23.00 which was used for analyzing data later on. Pearson's correlation and Anova test were applied to determine any significant difference and association between the mean of intraocular pressure measured by three different techniques. A p-value of < 0.05 was considered statistically significant.

RESULTS

Out of the 50 people included in study 31(62%) were males and 19(38%) were females. The mean age

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of study participants was 50.10 ± 11.61 years. Mean intraocular (IOP) pressure measured by the GAT applanation tonometer was 14.59 ± 1.13 mmHg. Mean IOP as calculated by the airpuff tonometer was 15.93 ± 1.88 mmHg, whereas mean IOP as calculated by tonopen was 15.85 ± 1.86 mmHg. All three instrument values showed significant difference as p -value < 0.001 shown in Table-I. Goldman Applanation Tonometer had significant difference in IOP measurement with Airpuff and tonopen (p -value < 0.001) while Airpuff and tonopen had not significant difference in IOP measurement p -value $= 0.157$ shown in Table-II. There was positive correlation between Goldman Applanation Tonometer and Airpuff r -value $= 0.886$ with significant p -value < 0.001 shown in Figure-1. There was positive correlation between Goldman Applanation Tonometer and Tonopen r -value $= 0.808$ with significant p -value < 0.001 shown in Figure-2. There was positive correlation between Airpuff and Tonopen r -value $= 0.927$ with significant p -value < 0.001 shown in Figure-3.

Table-I: Comparison between IOP Measurements by Different Instruments (n=50)

Parameter	Instrument			p-value
	Goldman Applanation Tonometer	Airpuff	Tonopen	
Intra-Ocular Pressure (mmHg)	14.59 ± 1.13	15.93 ± 1.88	15.85 ± 1.86	< 0.001

Table-II: Inter-group Instruments Measurements for IOP Measurements (n=50)

Parameter	Instrument		
	Goldman Applanation Tonometer Vs Airpuff	Goldman Applanation Tonometer Vs Tonopen	Airpuff vs Tonopen
Intra-Ocular Pressure (mmHg)	< 0.001	< 0.001	0.157

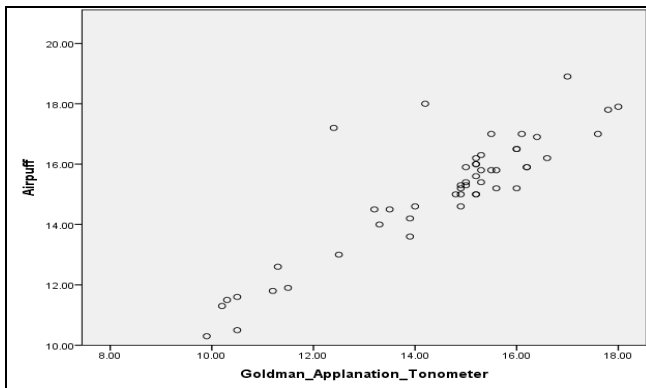


Figure-1: Correlation between Goldman Applanation Tonometer and Airpuff (n=50)

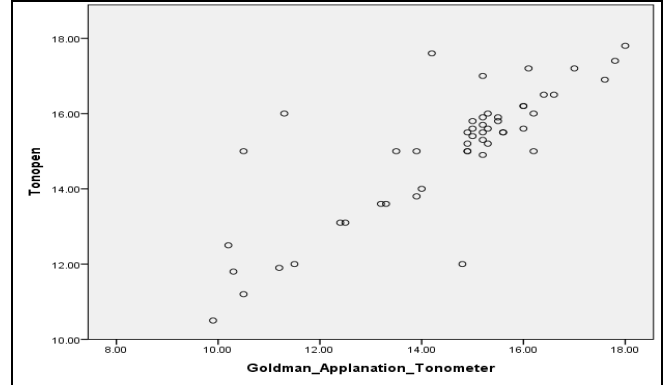


Figure-2: Correlation between Goldman Applanation Tonometer and Tonopen (n=50)

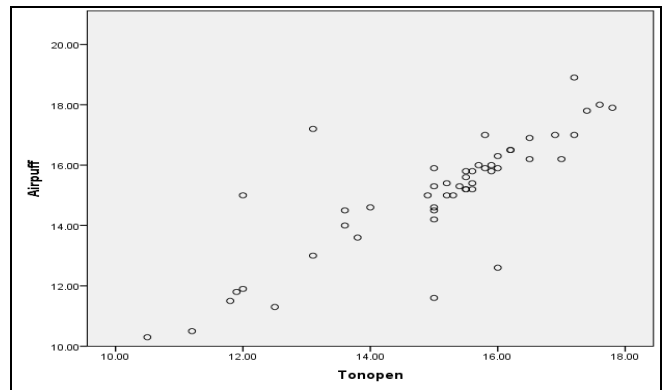


Figure-3: Correlation between Airpuff and Tonopen (n=50)

DISCUSSION

Elevation in intraocular pressure post vitrectomy has been observed in about 9% post vitrectomy cases on the first post-operative day and in 7.9% of cases after one week.¹³ In another study done in Pakistan elevations of Intraocular pressure post vitrectomy were noted in 20% of cases.¹⁴ Measurement of intraocular pressure is one of the important procedures carried out pre and postoperatively in such cases. Measurement is commonly done with GAT and until now it is considered the gold standard non-invasive technique for measurement of intraocular pressure, but it is associated with the risk of contamination and physically damaging the Corneal surface. It cannot be performed by assistant medical staff easily and requires the presence of a trained ophthalmologist for taking measurements. Commonly present conditions like corneal stiffness, thickness, scars, irregularities, steep corneas, thick corneas, and against the rule astigmatism may lead to falsely high values of intraocular pressure when obtained with GAT.¹⁵ Keeping in mind these issues of GAT we planned our study and used recent advances like tonopen and air puff tonometer and

compared the intraocular pressure obtained by these three ways.

In our study eyes of either gender were included but we noted more males (62%) as compared to females (38%). The mean age of participants in our study was 50.10±11.61 years. In a five-year retrospective cohort study done by Muhammad *et al.*¹⁶ in Pakistan mean age of vitrectomized cases noted was 49±15.8 years which is similar to that noted by us. They noted a higher number of males who underwent vitrectomy 287(67.8%) as noted by us 31(62%). In a retrospective study done on vitrectomized cases by Nursalim *et al.*¹⁷ in the years, 2018 to 2020 more males were noted 59(70%) as compared to females 40.3%. These findings are similar our study results. Most of their cases belonged to the age group 51-60 years. We didn't categorize our cases in age groups but noted mean age of 50.10±11.61 years.

Mean intraocular pressure measured by us by three GAT, air puff tonometer, and tonopen was 14.59±2.13 mmHg, 14.93±1.88 mmHg, and 14.85±1.86 mmHg respectively which is quite comparable to that noted by Mirza *et al.*¹⁸ in a similar study done in Pakistan. They noted a mean IOP of 14.78±2.489 mmHg with GAT, 15.84±2.736 mmHg air puff tonometer, and 14.48±2.435 with tonopen. Statistically significant correlations were noted between three techniques in Pearson's correlation test in our study, air puff tonometer and tonopen ($r=0.982, p<0.001$), GAT and tonopen ($r=0.979, p<0.001$), Air puff tonometer with GAT ($r=0.974, p\text{-value}<0.001$). But on applying paired t-test statistics, statistically, a significant difference in means was observed even between GAT and airpuff tonometer ($p\text{-value}<0.001$) and GAT and tonopen ($p\text{-value}<0.001$). The mean difference between tonopen and airpuff tonometer on t-test analysis was not statistically significant ($p\text{-value}=0.157$). Mirza *et al.*¹⁸ also noted that these three are well correlated in the one-way ANOVA test but on paired t-test difference between mean air puff tonometer and tonopen was statistically significant ($p\text{-value}=0.02$). However, the difference between GAT and tonopen ($p\text{-value}=0.0867$), GAT and air puff wasn't statically significant ($p\text{-value} 0.083$). These results are different from that noted by us. In an international study done by Rowaida Elsayed Basunoy *et al.*¹⁹ the readings obtained by airpuff tonometer were higher than those obtained by GAT and the difference was statistically significant. These findings are similar to that noted by us.

Tonopen and air puff tonometer are easy to use and are faster as compared to GAT. In this study, we

found that the mean IOP measured by either Tonopen or air puff is having statistically significant difference from that measured by using GAT ($p\text{-value}<0.001$). Parker *et al.*²⁰ compared air puff tonometer with GAT and found that IOP measurement by both devices is well correlated. In another study carried out by Tonnu *et al.*²¹ in the year 2005 GAT, Tonopen, and airpuff, all showed homologous results of IOP. However Farhood *et al.*²² noted similar results to that noted in our study which is different from those noted by Mirza *et al.*¹⁸, Parker *et al.*²⁰ and Tonnu *et al.*²¹ Farhood *et al.*²² also documented that the airpuff tonometer and GAT are not well correlated and the air puff tonometer gave higher IOP values which is similar to our results.

This was a single-centered study with time constraints. We studied three techniques, only on vitrectomized eyes. We didn't study the performance of these appliances in cases with low intraocular pressure (hypotony) or cases with high intraocular pressure like those having glaucoma or cataract. Furthermore, central corneal thickness and important influencer of IOP was not measured in these cases. Multicentered diagnostic accuracy studies with an evaluation of three appliances on all ranges of intraocular pressure (low, normal, high) are recommended for more generalization of results.

CONCLUSIONS

To conclude, air puff tonometer over-estimates IOP as compared to GAT. IOP measurements by Tonopen and air puff tonometer were similar and consistent to each other but not to GAT. GAT should be considered a reliable tool for measuring IOP in post-vitrectomized cases as well. If an airpuff tonometer or Tonopen is used then overestimation of IOP should be kept in mind.

Conflict of Interest: None

Author's Contribution

Following authors have made substantial contributions to the manuscript as under:

MUG & MAM: Study design, drafting the manuscript, data interpretation, critical review, approval of the final version to be published.

TAK & MS: Data acquisition, data analysis, data interpretation, critical review, approval of the final version to be published.

AR & IT: Conception, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

conceptualized the study, collected the data, analysed it, written the manuscript and proof read the final document.

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