

# Air-Puff Tonometry in population research – a comparison with Goldmann tonometer in individuals with suspected ocular hypertension

## *Uso da tonometria de ar em pesquisas populacionais – comparação com o tonômetro de Goldmann em indivíduos com suspeita de hipertensão ocular*

Luiz Augusto Tolomei<sup>1</sup>, Mitsuo Hashimoto<sup>1</sup>, Caroline Ferreira da Silva Mazeto<sup>1</sup>, Augusto Tomimatsu Shimauti<sup>1</sup>, Maria Rosa Bet de Moraes Silva<sup>1</sup>, Carlos Roberto Padovani<sup>2</sup>, Silvana Artioli Schellini<sup>1</sup>

### ABSTRACT

**Purpose:** to evaluate the use of air tonometer (TA) in population studies in individuals suspected of ocular hypertension, comparing values with those provided by the Goldmann Tonometer (GT). **Methods:** a cross-sectional study was done using a probabilistic sample consisting of 11,452 individuals  $\geq 20$  years old. A subsample composed by the individuals with IOP values obtained with TA  $\geq 20$  mmHg was selected, in which IOP was repeated with the GT. The results of both tonometers were compared considering gender, referred color of skin, laterality, cup-to-disc ratio ( $\leq 0.6$ ;  $\geq 0.6$  and  $< 0.8$ ;  $\geq 0.8$ ) and diagnosis, considering three situations: without glaucoma (NG), suspected glaucoma (SG) and patients with glaucoma (CG). The Student t test was used for paired samples and the Pearson correlation test to evaluate the association between IOP, age and tonometry. **Results:** we identified 198 individuals (339 eyes) with IOP  $\geq 20$  mmHg with the TA, who had the measures repeated with the GT. Two hundred and thirty-three eyes were considered as NG, 47 eyes as SG and 19 eyes as CG. In eyes with cup-to-disc ratio  $\geq 0.8$ , the TA and GT measurements were similar. In NG and SG, the TA overestimated values. There was an association between increased IOP and increasing age with both tonometers. **Conclusion:** IOP values are higher with TA compared to GT, especially when IOP is normal. There is agreement between the methods when IOP is high and the optic nerve excavation is increased, which validates the application of TA in population campaigns.

**Keywords:** Tonometry, ocular/methods; Glaucoma; Ocular hypertension/epidemiology

### RESUMO

**Objetivo:** Avaliar a utilidade do tonômetro de ar (TA) em estudos populacionais em indivíduos suspeitos de hipertensão ocular, comparando os valores com os fornecidos pelo tonômetro de aplanção de Goldmann (TG). **Métodos:** Estudo transversal, de amostra probabilística, composta por 11.452 indivíduos  $\geq 20$  anos, compondo-se uma subamostra dos que apresentaram valores de pressão intraocular (PIO) obtidos com o TA  $\geq 20$  mmHg, nos quais a PIO foi repetida com o TG. Os resultados dos dois tonômetros foram comparados considerando sexo, cor da pele referida, lateralidade, relação escavação/disco ( $\leq 0,6$ ; entre  $\geq 0,6$  e  $< 0,8$ ;  $\geq 0,8$ ) e diagnóstico. Foram consideradas três situações: não-portadores de glaucoma (NG), suspeitos (SG) e portadores de glaucoma (CG). Para comparação entre as medidas foi utilizado o teste t de Student para amostras pareadas e o teste de correlação de Pearson para avaliar a associação entre PIO, idade e tonometria. **Resultados:** Foram detectados 198 indivíduos (339 olhos) com PIO  $\geq 20$  mmHg com o TA, que tiveram a medida repetida com o TG. Foram considerados 233 olhos como NG, 47 olhos como SG e 19 olhos como CG. Em olhos com escavação  $\geq 0,8$ , a medida com TA e TG foram semelhantes. Nos NG e SG, o TA superestimou os valores. Houve associação entre aumento da PIO e aumento da idade com os dois tonômetros. **Conclusão:** Valores de PIO são superiores com TA comparados ao TG, principalmente quando a PIO é normal. Há concordância entre os métodos quando a PIO é alta e a escavação do nervo óptico é aumentada, o que valida a aplicação do TA em campanhas populacionais.

**Descritores:** Tonometria ocular/métodos; Glaucoma; Hipertensão ocular/epidemiologia

<sup>1</sup> Departamento de Oftalmologia, Faculdade de Medicina de Botucatu, Universidade Estadual Paulista "Júlio de Mesquita Filho", Botucatu, São Paulo, SP, Brasil.

<sup>2</sup> Departamento de Bioestatística, Instituto de Biociências de Botucatu, Universidade Estadual Paulista "Júlio de Mesquita Filho", Botucatu, São Paulo, SP, Brasil.

Study carried out out Faculdade de Medicina de Botucatu –UNESP and funded by FAPESP – Fundação de Amparo a Pesquisa do Estado de São Paulo.

**The authors declare no conflicts of interests.**

Received for publication 03/12/2015 - Accepted for publication 31/03/2016

## INTRODUCTION

**G**laucoma is the world's leading cause of irreversible blindness, with worldwide prevalence for the year 2013 estimated at 3.54% among individuals aged 40 to 80 years old<sup>(1)</sup>.

Although it is well established that glaucoma is a multifactorial disease, intraocular pressure (IOP) is still considered the main risk factor for the development of the disease<sup>(2)</sup>. The glaucoma treatment is based solely on IOP reduction because at present there is little evidence to support alternative therapies.

The IOP can be estimated by many types of tonometers, such as the Goldmann applanation (TG), the non-contact air puff tonometer (TA) laptop or desktop, the Perkins tonometer, the Tono-Pen, the Pascal tonometer (dynamic contour tonometry), the ORA (Ocular Response Analyzer) and transpalpebral tonometers<sup>(3)</sup>.

The IOP measured by applanation of the cornea is based on the Imbert-Fick principle, wherein an ideal sphere with a very thin wall will have its internal pressure determined by the force (in grams) required to flatten its surface divided by the applanation area (in mm)<sup>(4)</sup>. However, the cornea is not a perfect sphere, and its thickness and elasticity can interfere with the strength necessary for the flattening. Thus, the IOP may be underestimated in thin corneas and overestimated in thick corneas<sup>(5)</sup>.

Nevertheless, the TG is considered the gold standard for measuring IOP<sup>(6)</sup>. This method determines the intraocular pressure by using a cylindrical part formed by two prisms with a fixed contact area (7.35 mm<sup>2</sup>), and only the force to flatten the cornea is variable. This area was chosen because when in contact with the corneal surface it can zero or get close to zero the result of two opposing forces: the attraction force generated by the surface tension of the tear film and the repulsion force generated by corneal elasticity.

An objective method also based on the principle of applanation is the tonometry of non-contact puff or air puff tonometer (TA). The principle of obtaining the measure is similar to TG, i.e., the force of the air puff generated by a pneumatic system deforms the cornea, leading to flattening of the spot. The system detects the application through a collimated light beam emitted on the cornea. The receiver then detects coaxial and parallel light rays reflected by the cornea. The reduction of the corneal curvature by the air puff increases the number of rays that are detected by the receptor until a peak of light reception. When the air puff begins to produce a concavity in the cornea, the amount of light rays received on the receptor decreases again, the emission of air is disabled, and the IOP is then determined<sup>(7)</sup>.

The reliability of the IOP measures with TG and TA is knowingly influenced by the curvature and the central corneal thickness. These parameters could influence more measures with TA<sup>(8)</sup>, but there is no consensus about it<sup>(9)</sup>.

The TA helps the examination of children in field projects or in population studies due to the relative speed and convenience during the exam, since there is no use of fluorescein eyedrops and topical anesthetic, required when using TG. In addition, the TA does not need positioning in slit lamp which reduces the risk of contamination with secretions, and the measure effected is not dependent on the examiner. However, the values obtained are considered less accurate than those provided by TG, and there are still doubts about the effectiveness of its use.

The aim of the present study was to evaluate whether a type of TA is efficient and reliable for the assessment of IOP in population studies and identification of individuals with increased IOP compared to the values obtained with the gold standard, the TG.

## METHODS

**Design of the study:** cross-sectional study, comparative, observational, probabilistic sample which was attended by 11,452 people living in 12 cities in the Midwest region of the State of São Paulo between the years 2005 to 2009. The individuals were invited to participate and attended voluntarily the joint efforts of eye care. All were informed about the purpose of the study and signed a form agreeing to participate.

**Exam technique:** all individuals underwent ocular exam following standardized sequence, starting with anamnesis, visual acuity assessment, IOP, biomicroscopy, funduscopy, and finally, automated objective refraction (NIDEK -ARK 700, Japan) and subjective in manual refractor (Refractor Greens Nidek Rt 600, Japan). Examiners were trained in order to standardize the tests and reduce interpersonal variations in the assessments.

Individuals aged  $\geq 20$  years and who had IOP values  $>20$  mmHg obtained with TA (NIDEK - Model SL3000, Japan) were a subsample with assessment of IOP also by TG. For the accomplishment of the measure with TG, one droplet of anesthetic eyedrops proximetacaine 0.5% (Anestalcon® - Alcon, SP, Brazil) was instilled, followed by one droplet of sodium fluorescein eyedrops 1% (Allergan, SP, Brazil), with the subject being positioned in a slit lamp (Topcon SL1E, Japan) for the measurement with TG (aT-900, Haag Streit, Switzerland).

Participants with IOP  $\geq 20$  mmHg, younger than 20 years old, using anti-glaucoma medication, and those who did not agree to take the exams were excluded.

The average IOP and the standard deviation were studied with respect to laterality, gender, color of the skin, excavation of the optic nerve and age. According to the IOP values obtained with TG and the exam of the optic disc, which ranked the excavation / disc ratio (E/D) vertically as  $<0.6$ , between  $\geq 0.6$  and  $<0.8$ , and  $\geq 0.8$ , the individuals were classified as patients without glaucoma (NG), suspected glaucoma (SG) and patients with glaucoma (CG).

**Statistical analysis:** the results were compared within each group using the Student t test (MS Excel 2007) for paired samples, and the correlation between the measures obtained and the study parameters was taken by the linear correlation method of Pearson. The logistic regression analysis was performed to assess the relationship between the methods.

## RESULTS

198 individuals (339 eyes) were detected showing IOP  $\geq 20$  mmHg on measurement made by TA in at least one eye, which had the IOP measured again by TG. Of these, 59.5% were female, aged from 20 to 88 years ( $51.6 \pm 14.6$  years).

The average IOP obtained with TA was  $22.77 \pm 2.05$  mmHg, and TG was  $17.79 \pm 3.78$  mmHg. The minimum value considered for inclusion in the TA was 20 mmHg, and the maximum observed during the exams was 30 mmHg. The minimum TGO was 9 mmHg, and the maximum was 35 mmHg.

The distribution of individuals according to the classification criteria adopted resulted in: 233 eyes NG, 47 eyes SG and 19 eyes CG. In 40 eyes it was not possible to determine the clinical diagnosis due to lack of data in the ration E / D.

The average values and standard deviation for the IOP obtained by TA were different and higher than the values obtained by TG both for females and males, with statistical difference (Table 1).

**Table 1**

**Distribution mean and standard deviation of IOP values obtained by the TA and TG according to sex**

Gender	Methods		
	TA	TG	P value
Female	22.69 (2.05)	17.70 (3.55)	p<0.001
Male	22.86 (2.05)	17.89 (4.01)	p<0.001

Regarding the color of that skin, white, black or brown, the mean IOP obtained with TA were different and higher than the values obtained with TG, with significant difference (Table 2).

**Table 2**

**Mean and standard deviation of the distribution of IOP values obtained by the TA and TG according to the color of said skin**

Color	Método		
	TA	TG	P value
White	22.85 (2.11)	17.65 (3.93)	p<0.001
Black	22.38 (0.77)	19.54 (3.91)	p<0.05
Brown	22.30 (1.79)	17.63 (2.53)	p<0.001

The values obtained for the right and left eyes were higher and significantly different from TA when compared to TG (Table 3).

**Table 3**

**Distribution of the mean and standard deviation of IOP values obtained by the TA and TG according to the rated eye**

Eye	Methods		
	TA	TG	P value
Right	22.72 (1.99)	17.75 (3.74)	p<0.001
Left	22.78 (2.10)	17.83 (3.72)	P<0.001

Analyzing the IOP obtained with both tonometers related to the excavation of the optic disc, for excavations <0.6 and between e"0.6 and <0.8 the values expressed by the TA were significantly higher than the TG. When the excavation was e"0.8, the average IOP values obtained with TA and TG matched (Table 4).

In matching the methods of assessment of IOP by TA and TG according to the diagnosis established and taking into account the IOP and the excavation - disc ratio, there was agreement between TA and TG in individuals with data compatible with glaucoma. When there was suspected glaucoma or when there was no glaucoma, the average values obtained with TA were higher than those obtained with TG (Table 5).

**Table 4**

**Distribution of the mean and standard deviation values IOP obtained by the TA and TG according to optical pupil morphology**

Eye	Methods		
	TA	TG	P value
Excavation < 0.6	22.88 (2.14)	18.13 (3.53)	p<0.001
Excavation ≥ 0.6 e < 0.8	23.29 (2.07)	19.58 (5.40)	p<0.001
Excavation ≥ 0.8	23.82 (2.71)	23.91 (4.21)	p<0.05

**Table 5**

**Distribution of the mean and standard deviation of IOP values obtained by the TA and TG second clinical diagnosis**

Diagnostic	Methods		
	TA	TG	P value
Glaucoma	24.26 (2.60)	24.68 (4.92)	p<0.05
No Glaucoma	22.46 (1.82)	16.48 (2.53)	p<0.001
Suspected Glaucoma	23.49 (2.39)	20.19 (4.17)	p<0.001
Undetermined	22.88 (2.05)	19.23 (2.87)	p<0.001

The linear association measured between IOP and age showed that with increasing age there was an increase in IOP obtained with TA, and the same occurred with TG. Also, when IOP was increased with TA, there was an association between increased IOP and TG (Table 6).

**Table 6**

**linear association between variables measured of interest , comparing IOP and age**

Association	Methods	
	Linear correlation coefficient	P value
X PIO age	0.160	p<0.01
X PIO Goldmann Age	0.164	p<0.01
PIO X PIO Goldmann	0.296	p<0.001

Considering the diagnostic hypotheses from the data obtained, the prevalence of CG and SG was 0.07% and 0.2%, respectively.

TG excluded 53.53% of eyes from the abnormality range (IOP e" 20 mm Hg) previously indicated by TA.

## DISCUSSION

The main reason for conducting the present study was to determine whether there are significant differences between the IOP measurements obtained with the TA and TG and which influence the clinical practice, especially during field work, in which case the TA is very useful and all the propaedeutic arsenal necessary for definitive diagnosis is not available and is necessary to separate the possible patients of high IOP in which to perform all armed propaedeutics.

Although the two tonometers follow the same principle, the use of TA for IOP assessment is much simpler and with advantages over the TG, since it can be used without the use of eyedrops and there is no contact with the eyeball, which you gives less chance of infection transmission. It can be used without the need for special positioning in individuals with allergy to the eyedrops required for the use of TG, in patients with difficulties to cooperate with the examiner and keep the eyes stoped, those with corneal edema and postoperative surgery of the eye's anterior segment.<sup>(10)</sup>

The participants of the present study did not necessarily have ophthalmological complaints, having been randomly chosen and invited to participate. Using the elevated IOP criterion, a prevalence of 1.72% of individuals with initial suspicion of glaucoma was observed, and they were reassessed with TG and analysis of the ratio E / D. After this reassessment, the prevalence of SG was 0.2% and CG 0.07%. There are few Brazilian population studies, mostly involving non-institutionalized individuals, and there is no regional epidemiological data on the prevalence of glaucoma. In general, the literature data was obtained in ambulatories of university hospitals or targeted campaigns, consisting of 7.3% of glaucoma patients in the city of São Paulo in a population sample of other age group (40 to 87 years, average age  $58.24 \pm 10.88$  years)<sup>(11)</sup>, data much higher the stated in the present study. A population study in southern Brazil found a prevalence of 3.4% of glaucoma patients in individuals above 40 years, an age group in which the prevalence of glaucoma is higher<sup>(12)</sup>. The prevalence of IOP  $\geq 21$ mmHg in a population of Eastern Europe was even higher, about 30.8%, and the morphological signs consistent with neuropathy were observed in 0.92% of the individuals examined<sup>(13)</sup>. Our values are much lower, probably due to the fact that our population has been selected at random, with the inclusion of young people, and it is not a convenience sample.

Classically, the assessment of IOP using the TA shows less reliable results than those obtained with TG<sup>(14)</sup>. Thus, the verification of IOP using TA is justified by screening evaluations, as it was done in the present study, when the first evaluation was made by TA, and confirmed by TG in cases where the IOP was suspected ( $\geq 20$ mmHg) and the individuals were targeted for armed propaedeutics at the university hospital.

The average IOP in individuals who had IOP above 20 mmHg with TA was  $22.77 \pm 2.05$  mmHg, and with TG was  $17.79 \pm 3.78$  mmHg, also showing that the variability using the TG was higher than that obtained with TA. Our results confirm that TA overestimates the IOP in about 4 to 5 mmHg. The comparison between the no contact tonometer XPERT NCT air-puff with TG also showed variation similar to that obtained with the NIDEK used herein, with superiority range of values provided by XPERT NCT of 4.0 to 5.85 mmHg.<sup>(15)</sup>

The present study showed statistical difference between TG and TA, which is in line with the vast majority of research comparing the two types of tonometers. The IOP levels seem to be determinant for matching the methods. A study evaluating the IOP ranging from 6 to 40 mmHg with different tonometers found variable concordances according to the blood pressure levels, with overestimated or underestimated values<sup>(14)</sup>. According to other authors, the difference between the methods is more important when the IOP exceeds 24 mmHg with TG, and the matching between the methods is seen especially when IOP values are below 20 mmHg<sup>(16)</sup>. The results of the present study are in line with the literature findings, which show that the values

obtained with TA are higher than those obtained with TG. However, an important aspect of the present study was to compare the values obtained by TA and TG in patients with glaucoma, which clearly showed a greater association between the methods. In these individuals, TA showed an increased accuracy when dealing with individuals with really high IOP, confirmed by TG.

A limiting factor of the study was the lack of assessment of corneal thickness, since there are differences between the methods dependent on the corneal thickness and curvature<sup>(8,9)</sup>. Recent research found that corneal resistance to applanation is the main predictive factor for matching the measurements obtained with different tonometers<sup>(17)</sup>, and the values obtained with TG and TA suffer the same type of variation due to both tonometers being dependent on the same mechanism of IOP measurement<sup>(9)</sup>. However, because it is a populational and screening study, pachymetry of the cornea was not part of the propaedeutics.

The data obtained indicate that values with TG and TA tonometers can be comparable, although the values obtained with both methods are not identical<sup>(18)</sup>.

Other factors not considered in the comparative analysis of tonometers of the present study, such as refractive errors, do not influence the IOP levels obtained with TA and TG<sup>(19)</sup>.

TAs must be considered for their efficiency in the detection of elevated IOP indicating glaucoma. There are many positive points in favor of the use of TAs in populational studies, such as a simpler use, faster service, needless to use anesthetic eyedrops and fluorescein, reduced contamination risk by contact of secretions from different patients, lack of corneal abrasion, more comfort and possibility of use by assistants of ophthalmologists<sup>(16)</sup>. Although the confirmation of the measure with TG is necessary when the IOP exceeds the limits deemed normal values, TA is very useful as a screening method.

## CONCLUSION

TA was an efficient method to point out individuals with elevated IOP. Despite the overestimated values in individuals with normal IOP, this method should be considered for population examination, with the proviso that there is the need to repeat the measures that go beyond the values considered normal.

## REFERENCES

1. Tham YC, Li X, Wong TY, Quigley HA, Aung T, Cheng CY. Global prevalence of glaucoma and projections of glaucoma burden through 2040: a systematic review and meta-analysis. *Ophthalmology*. 2014;121(11):2081-90.
2. American Academy of Ophthalmology. Practicing Ophthalmologists Curriculum: glaucoma, basic and clinical science Course. 2007-2008. San Francisco: AAO; 2007. p.22-5.
3. Torres RJ. Tonometria. In: Alves MR, coordenador. *Semiologia básica em Oftalmologia*. 2ª ed. Rio de Janeiro: Cultura Médica; 2013. p. 111-7.
4. Benjamin WJ. *Borish's Clinical refraction*. 2nd ed. Butterworth-Heinemann; 2006. p. 501-3.
5. Ehlers N, Bramsen T, Sperling S. Applanation tonometry and central corneal thickness. *Acta Ophthalmol*. 1975;53(1):34-43.
6. Whitacre MM, Stein R. Sources of error with use of Goldmann-type tonometers. *Surv Ophthalmol*. 1993;38(1):1-30.
7. Forbes M, Pico Jr G, Grolman B. A noncontact applanation tonometer -description and clinical evaluation. *Arch Ophthalmol*. 1974;91(2):134-40.

8. Tonnu P-A, Ho T, Newson T, Sheikh AEI, Sharma K, Bunce C, et al. The influence of central corneal thickness and age on intraocular pressure measured by pneumotonometry, noncontact tonometry, the Tono-Pen XL, and Goldmann applanation tonometry. *Br J Ophthalmol.* 2005;89(7):851-4.
9. Murase H, Sawada A, Mochizuki K, Yamamoto T. Effects of corneal thickness on intraocular pressure measured with three different tonometers. *Jpn J Ophthalmol.* 2009;53(1):1-6.
10. Yücel AA, Stürmer J, Gloor B. Comparison of tonometry with the Keeler air puff non-contact tonometer “Pulsair” and the Goldmann applanation tonometer. *Klin Monbl Augenheilkd.* 1990;197(4):329-34.
11. Pova CA, Nicolela MT, Valle AL, Gomes LES, Neustein I. Prevalência de glaucoma identificada em campanha de detecção em São Paulo. *Arq Bras Oftalmol.* 2001;64(4):303-7.
12. Sakata K, Sakata LM, Sakata VM, Santini C, Hopker LM, Bernarndes R, et al. Prevalence of glaucoma in a south Brazilian population: projeto glaucoma. *Invest Ophthalmol Vis Sci.* 2007;48(11):4974-9.
13. Turno-Krecicka A, Nizankowska MH, Pacholska D. Results of screening for primary glaucoma from data in materials from the Medical Diagnostic Center DOLMED in Wroclaw. *Klin Oczna.* 1997;99(3):179-83.
14. Brencher HL, Kohl P, Reinke AR, Yolton RL. Clinical comparison of air-puff and Goldmann tonometers. *J Am Optom Assoc.* 1991;62(5):395-402.
15. Hansen MK. Clinical comparison of the XPERT non-contact tonometer and the conventional Goldmann applanation tonometer. *Acta Ophthalmol Scand.* 1995;73(2):176-80.
16. Farhood QK. Comparative evaluation of intraocular pressure with an air-puff tonometer versus a Goldmann applanation tonometer. *Clin Ophthalmol.* 2013;7:23-7.
17. Tranchina L, Lombardo M, Oddone F, Serrao S, Lomoriello DS, Ducoli P. Influence of corneal biomechanical properties on intraocular pressure differences between an air-puff tonometer and the Goldmann applanation tonometer. *J Glaucoma.* 2013;22(5):416-21.
18. Hong J, Xu J, Wei A, Deng SX, Cui X, Yu X, et al. A new tonometer-the Corvis ST tonometer clinical comparison with non-contact, and Goldmann applanation tonometers. *Invest Ophthalmol Vis Sci.* 2013;54(1):659-65.
19. Jara Peñacoba M, López Traynor A, Duce Tello S, Navas Serrano V, González Sanz M, Toledano Fernández N. Comparative study of pneumotonometer and Goldmann tonometer for screening high intraocular pressure in primary care. *Aten Primaria.* 2000;25(7):493-6.

---

**Corresponding author:**

Silvana Artioli Schellini  
 Faculdade de Medicina de Botucatu - UNESP.Campus Universitário – Botucatu, São Paulo, Brasil. CEP: 18618-970  
 E-mail: sartioli@fmb.unesp.br