

REVIEW ARTICLE

GOLDMANN APPLANATION TONOMETERS AND ITS CALIBRATION ERRORS.

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ABSTRACT

Aim and Objective: To study the prevalence and variability of calibration errors in Goldmann applanation Tonometer's.

Methods: 53 Goldmann applanation tonometers were checked with standard calibration error check weight bar, by two independent observers and classified into 6 categories of $\pm 0.5, \pm 1, \pm 1.5, \pm 2, \pm 2.5$ and $> \pm 2.5$ mmHg.

Results: There were 30(57%), 17(32%), 1(2%), 3(5%), 0(0%) and 2(4%) with calibration errors of $\pm 0.5, \pm 1, \pm 1.5, \pm 2, \pm 2.5$ and $> \pm 2.5$ mmHg respectively with good agreement between observers.

Conclusion: Study showed significant calibration error prevalence & variability in tonometers. Further studies required to establish the frequency of calibration, and to evaluate the relationship between calibration errors and clinical errors in IOP measurement.

INTRODUCTION:

Intraocular pressure (IOP) is a fundamental parameter in conditions of ocular health and disease.¹ Despite the introduction of several new instruments for IOP measurement, the Goldmann applanation device remains the gold standard for tonometry worldwide.^{2,3}

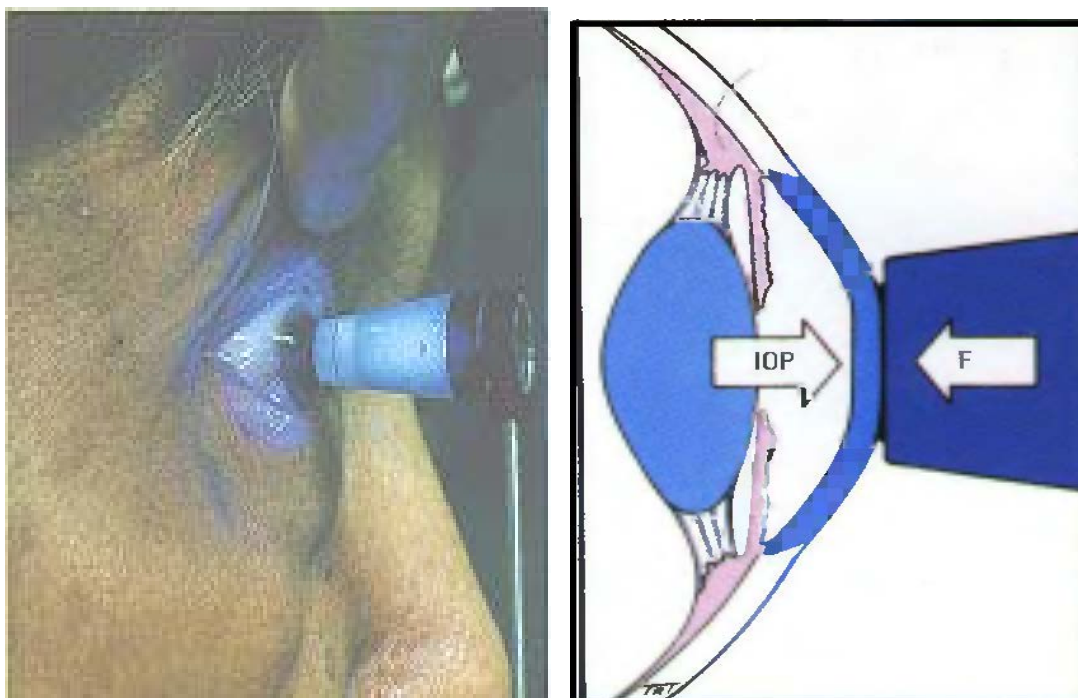


Figure 1:

AREA OF APPLANATION:

The diameter of the circular zone of applanation is 3.06 mm. Hence, one can calculate the area of that circular zone of applanation.

$$\text{Area} = (\pi r^2) = 3.1416 \times (1.53)^2 = 7.3542 \text{ mm}^2$$

This is the minimal area of applanation needed to give accurate results, causing only an increase of 2.5 percent in intraocular pressure. Example: 20 mmHg, which is just 1 mmHg below the suspect reading of 21 mmHg (20 mmHg x 2.5% = 0.5 mmHg). Accordingly, the intraocular measurements should be accurate to within + or - 0.5 mmHg for intraocular pressures of 20 mmHg or less.

Conversion to mmHg:

Density of mercury (Hg) which is 13.6 gm/cm³. 1 gram equals 10 mmHg while each small mark in between is equal to 2 mmHg.

$$\text{Pressure} = \text{Force}/\text{Area}$$

$$\text{Pressure} = 1 \text{ gm} / .073541714 \text{ cm}^2 \times 13.6 \text{ gm/cm}^3 \text{ of Hg}$$

$$\text{Pressure} = 1 \text{ cm of Hg} = 10 \text{ mmHg}$$

Recent studies suggest that Goldmann applanation tonometers are not as accurate as the manufacturer states they should be based on calibration error (CE) tolerance.¹⁻⁶ Tonometers with CE greater than ±0.5 mmHg are considered faulty based on Haag-Streit recommendations. Any tonometer outside this standard must be returned to the manufacturer for recalibration.⁷ Other documented sources of tonometric errors include: corneal thickness, eyelid squeezing, tight neckties, fluorescein and tear film volume, poor illumination, corneal astigmatism, inter-observer error, number of tonometer contacts

and calibration errors.^{4,5,7-10} Some authors believe that the manufacturer's tolerance is too strict and calibration errors within ±1.0,¹¹ ±2.0¹⁰ or ±2.5⁴ mmHg may be considered acceptable as a compromise between

tolerance and accuracy.³ There are no set guidelines or protocols regarding the frequency of calibration checking; current literature suggests annual checking as a normal practice.⁴⁻⁶ Tonometer Calibration Errors; The aim of this study was to determine the prevalence of calibration errors in Goldmann applanation tonometers at a multiple tertiary eye centers.

METHODOLOGY:

This study was performed on Goldmann applanation tonometers currently in use at five eye care Hospital's of Aravind Eye care system, Tamil Nadu, India. All tonometers were manufactured by Haag-Streit (Switzerland model AT 900). The tonometers were checked according to the Haag-Streit method using a standard calibration check weight bar provided with each tonometer. For accurate checking of calibration errors the biprism of the tonometer were inserted into the feeler arm in the correct working position pointing toward the patient. There are 5 circles on the weight bar: the middle is marked for checking calibration at 0 mmHg, the two intermediates for checking at 20 mmHg and the two outers for checking at 60 mmHg. The drum is rotated to the aforementioned IOP reading positions. When the drum is rotated toward the patient, the feeler arm freely rocks forward which is positive error. When the drum is rotated away from the patient, the feeler arm will rock backwards which is minus error.⁷

Tonometer performance was checked at 0, 20 and 60 mmHg positions independently by two observers. If the two observers' readings were not compatible, a third observer would recheck the calibration process. Calibration errors were classified into 6 categories of ±0.5, ±1.0, ±1.5, ±2.0, ±2.5 and more than ±2.5 mmHg. The highest error was considered as the calibration error for each instrument.

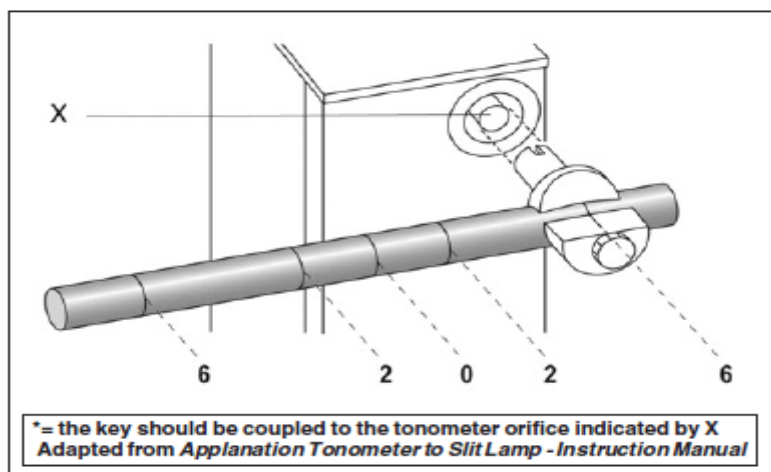


Figure 2 Key for calibration check of Goldmann's applanation tonometer with 0 (0 mmHg), 2 (20 mmHg) e 6 (60 mmHg) markers*

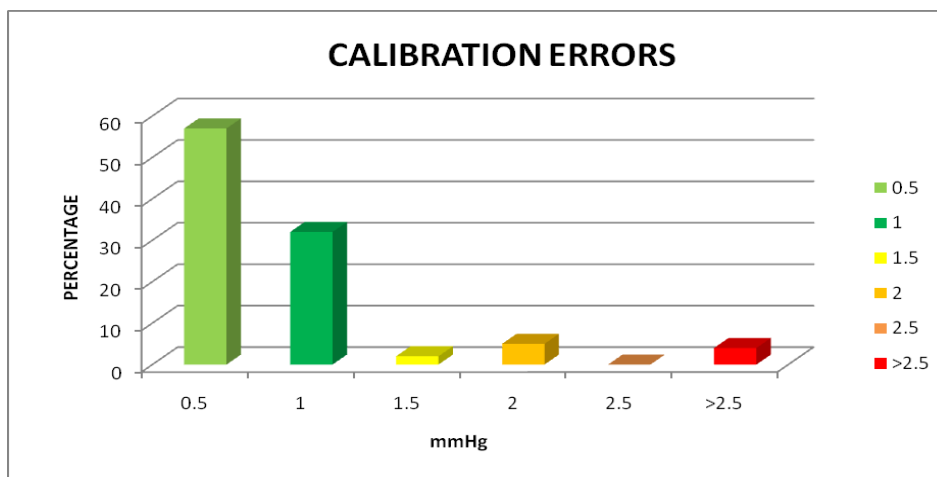
RESULTS:

Overall, 53 slit-mounted Haag-Streit Goldmann applanation tonometers were checked. The tonometers were within the manufacturer’s recommended calibration range of 30(57%), 17(32%), 1(2%), 3(5%), 0(0%) and 2(4%) with calibration errors of ± 0.5 , ± 1 , ± 1.5 , ± 2 , ± 2.5 and $> \pm 2.5$ mmHg respectively. The frequency of

calibration errors are presented in Table 1. Considering the highest calibration error at all three IOP levels, 30 (57%) tonometers were within the manufacturer’s recommended range of ± 0.5 mmHg and 51(96%) tonometers were within ± 2.5 mmHg; and therefore 2 (4%) tonometers were outside calibration by more than ± 2.5 mmHg.

Table 1:

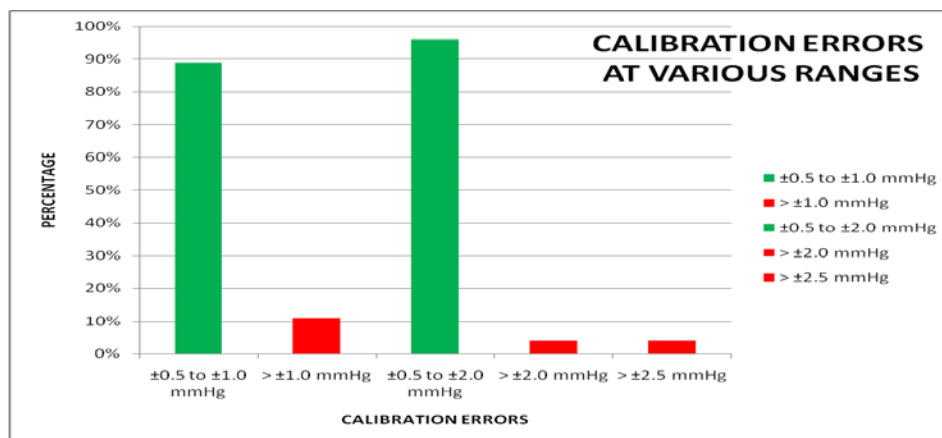
IOP Level	Frequency of calibration errors: No (%)					
	± 0.5 mmHg	± 1.0 mmHg	± 1.5 mmHg	± 2.0 mmHg	± 2.5 mmHg	$> \pm 2.5$ mmHg
Total	30(57%)	17(32%)	1(2%)	3(5%)	0(0%)	2(4%)



Considering ± 1.0 mmHg as an acceptable error range, 47(89%) tonometers were acceptably calibrated and the remaining 6 (11%) were outside calibration (Table 2). Considering ± 2.0 mmHg as an acceptable error range, 51(96%) tonometers were acceptably calibrated and the remaining 2 (4%) totally were outside calibration (Table 2).

Table 2:

Ranges of calibration errors	Number	Percentage
± 0.5 to ± 1.0 mmHg	47	89 %
$> \pm 1.0$ mmHg	06	11 %
± 0.5 to ± 2.0 mmHg	51	96 %
$> \pm 2.0$ mmHg	02	04 %
$> \pm 2.5$ mmHg	02	04 %



DISCUSSION:

J. Y. Chuo, MD; F. S. Mikelberg, MD. Can J ophthalmol 2007;42:712-4.¹¹

Results : calibration errors of 68 % in $< \pm 0.5$ mmHg and 32 % in $> \pm 0.5$ mmHg

calibration errors of 76 % in $< \pm 1.0$ mmHg and 24 % in $> \pm 1.0$ mmHg

Our results : calibration errors of 57 % in $< \pm 0.5$ mmHg and 43 % in $> \pm 0.5$ mmHg calibration errors of 89 % in $< \pm 1.0$ mmHg and 11 % in $> \pm 1.0$ mmHg

Results of two studies comparable and their study shows frequent calibration is the reason and key to reduce errors.

Wessels IF, Oh Y. Arch Ophthalmol. 1990 Dec;108(12):1709-12.⁵

Results : calibration errors of 81 % in $< \pm 1.0$ mmHg and 19 % in $> \pm 1.0$ mmHg

calibration errors of 95.5 % in $< \pm 2.0$ mmHg and 4.5 % in $> \pm 2.0$ mmHg

Our results : calibration errors of 89 % in $< \pm 1.0$ mmHg and 11 % in $> \pm 1.0$ mmHg

calibration errors of 96 % in $< \pm 2.0$ mmHg and 4 % in $> \pm 2.0$ mmHg

results of two studies closely comparable and study says 86% of their tonometers were annually calibrated

Abrão FP, Araújo WA, Vieira GM. Arq Bras Oftalmol. 2009 May-Jun;72(3):346-50.¹²

Results : calibration errors of 53 % in $< \pm 1.0$ mmHg and 47 % in $> \pm 1.0$ mmHg

Our Results : calibration errors of 89 % in $< \pm 1.0$ mmHg and 11 % in $> \pm 1.0$ mmHg

Results of study not much comparable but conclusion of their study agrees with us as they say infrequent calibrations of their tonometers is the main cause of Calibration errors.

Choudhari NS, George R, Baskaran M, Vijaya L, Dudeja N. Ophthalmology. 2009 Jan;116(1):1-2.¹³

Results : calibration errors of 04% in $< \pm 0.5$ mmHg and 96 % in $> \pm 0.5$ mmHg

calibration errors of 28% in $< \pm 2.0$ mmHg and 72 % in $> \pm 2.0$ mmHg

Our results : calibration errors of 57 % in $< \pm 0.5$ mmHg and 43 % in $> \pm 0.5$ mmHg

calibration errors of 96 % in $< \pm 2.0$ mmHg and 4 % in $> \pm 2.0$ mmHg

results of the two studies differ a lot but again their study stress that frequent calibration is needed to reduce the calibration errors.

Heydar Amini, MD; Sasan M, MD; et al J Ophthalmic Vis Res 2009; 4 (3): 147-150.¹⁴

Results : calibration errors of 3% in $< \pm 0.5$ mmHg and 97 % in $> \pm 0.5$ mmHg

calibration errors of 72% in $< \pm 2.5$ mmHg and 28 % in $> \pm 2.5$ mmHg

Our results : calibration errors of 57 % in $< \pm 0.5$ mmHg and 43 % in $> \pm 0.5$ mmHg

calibration errors of 96 % in $< \pm 2.5$ mmHg and 4 % in $> \pm 2.5$ mmHg

results are comparable again suggesting infrequent calibration as cause of high errors.

The Early Manifest Glaucoma Trial demonstrated that IOP reduction by 1 mmHg reduces the risk of progressive nerve damage by 10%.² Therefore correct IOP measurement and control plays a major role in glaucoma management. Ideally, tonometers should be checked for calibration error before each use.⁶ Although it has been reported that annual checking is the normal practice,⁴ a more recent study has recommended monthly checking especially in busy clinics.⁶ However, there is no consensus on the frequency of checking for this purpose.

We did not evaluate the frequency of tonometer calibration checking but we know that calibration checking is routinely performed only at our glaucoma clinics. Manufacturers suggest that calibration errors should be within ± 0.5 mmHg and any tonometer outside this range must be returned for recalibration, as this can only be performed by the manufacturer.¹ Authors say calibration errors within ranges of ± 1.0 ,¹¹ ± 2.0 ¹⁰ or ± 2.5 ⁴ mmHg have been described as clinically acceptable.

Recently, in a well-designed study, Sandhu et al¹³ demonstrated a correlation between calibration error and IOP measurement error which was not a one-to-one relationship. They demonstrated that calibration errors overestimate IOP, a finding which was consistent over a range of IOPs. They recommended that under certain circumstances where resources are limited, it may be clinically acceptable to use tonometers with calibration errors of less than ± 3.0 mmHg, because they do not overestimate IOP by more than 2 mmHg.

CONCLUSION:

In summary we suggest regular once a monthly and also as and when needed checking of Goldmann tonometers for calibration errors and excluding faulty tonometers until recalibration. Further studies are required to establish the relationship between calibration errors and clinical errors in IOP measurement.

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