Prevalence of Calibration Errors in Goldmann Applanation Tonometers

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Purpose: To determine the prevalence of calibration errors in Goldmann applanation tonometers at Farabi Eye Hospital.
Methods: This cross-sectional study was performed on all tonometers in use at Farabi Eye Hospital. All Haag-Streit Goldmann applanation tonometers were checked according to the manufacturer's method by two independent observers and by a third observer in case of mismatched results. Calibration errors were classified into 6 categories of ±0.5, ±1, ±1.5, ±2, ±2.5 and more than ±2.5 mmHg.
Results: Overall, 43 Goldmann tonometers were evaluated. There were 3 (7%), 10 (24.3%), 16 (38.3%), 24 (56.9%), 31 (72.1%) and 12 (27.9%) tonometers within calibration errors of ±0.5, ±1, ±1.5, ±2, ±2.5 and more than ±2.5 mmHg respectively.
Conclusion: Goldmann tonometers were not within the manufacturer's recommended range (±0.5 mmHg) in 93%, and not within the acceptable range of ±2.5 mmHg in 28% of checked devices. Further study is needed to demonstrate the correlation between calibration errors and clinical errors.

Key words: Goldmann Tonometers; Calibration Error; Intraocular Pressure

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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] 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] Well-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] ±2.0[10] or ±2.5[4] 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]

The aim of this study was to determine the prevalence of calibration errors in Goldmann applanation tonometers at a tertiary eye center.

METHODS

This cross-sectional study was performed on all Goldmann applanation tonometers currently in use at Farabi Eye Hospital, Tehran, Iran. All tonometers were of Goldmann r-type, manufactured by Haag-Streit (Koeniz-Berne, Switzerland) of different models (AT 900, 29 devices and H 03, 14 devices). The tonometers were checked according to the Haag-Streit method using a standard calibration check weight bar provided with each slitlamp and tonometer.

For accurate checking of calibration errors the biprism of the tonometer must be 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.

RESULTS

Overall, 43 slit-mounted (r type) Haag-Streit Goldmann applanation tonometers were checked. The tonometers were within the manufacturer's recommended calibration range of ±0.5 mmHg in 11.6%, 9.3% and 6.9% of tonometers at 0, 20 and 60 mmHg, respectively. The frequency of calibration errors are presented in Table 1.

Considering the highest calibration error at all three IOP levels, 3 (7%) tonometers were within the manufacturer's recommended range and 31 (72.1%) tonometers were within ±2.5 mmHg; therefore 12 (27.9%) tonometers were outside calibration by more than ±2.5 mmHg. Considering ±2.0 mmHg as an acceptable error range, 24 (55.8%) tonometers were acceptably calibrated and the remaining 19 (44.2%) were outside calibration (Table 2).

Table 1 Ranges of tonometer calibration errors at different levels of intraocular pressure

IOP Level	Ranges of calibration errors: No (%)					
	±0.5 mmHg	±1 mmHg	±1.5 mmHg	± 2.0 mmHg	±2.5 mmHg	>±2.5 mmHg
0 mmHg	5 (11.6)	12 (27.9)	23 (53.4)	31 (72.0)	33 (76.9)	43 (100)
20 mmHg	4 (9.3)	11 (25.5)	18 (41.8)	27 (62.7)	32 (74.7)	43 (100)
60 mmHg	3 (6.9)	10 (23.3)	18 (41.8)	28 (65.1)	33 (76.7)	43 (100)

Table 2 Ranges of highest tonometer calibration errors measured at 0, 20 or 60 mmHg

	No	No (Cumulative)
≤±0.5 mmHg	3 (6.9%)	3 (6.9%)
±1 mmHg	7 (16.2%)	10 (23.3%)
±1.5 mmHg	6 (13.9%)	16 (37.2%)
±2 mmHg	8 (18.6%)	24 (55.8%)
±2.5 mmHg	7 (16.2%)	31 (72.0%)
≥±2.5 mmHg	12 (27.9%)	43 (100%)

DISCUSSION

Only 3 (7%) tonometers at our center were calibrated within the manufacturer's range of ±0.5 mmHg. The corresponding figure has been reported 0% by Sandhu et al,[3] 56% by Chuo et al[11] and 76% by Wessels et al.[5] The results of our study are therefore comparable to the lowest rate reported in previous reports. One

reason might be that checking for Goldmann tonometer calibration and replacement of out of range devices is not performed routinely at our center. Another reason for the higher rate of calibration errors in our study might be the frequent use of these instruments at our busy hospital with more than 1000 ophthalmologic visits per day.

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] However, there is no consensus on the frequency of checking for this purpose. 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] We did not evaluate the frequency of tonometer calibration checking but we know that calibration checking is routinely performed only at our glaucoma clinic.

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] In clinical practice however, some authors believe that the manufacturer's tolerance is too strict and therefore suggest that a balance between this tolerance and clinical accuracy should be achieved. Calibration errors within ranges of ±1.0,[11] ±2.0[10] or ±2.5[4] mmHg have been described as clinically acceptable. Tonometer calibration errors within ±1.0 mmHg have been reported in 76% of devices by Chuo et al[11] and in 81% by Wessels et al.[5] The prevalence of tonometer calibration errors within this range was much lower (23.3%) in our study and more than half of the tonometers were outside the range of ±2.0 mmHg. The latter figure was 25% in a study by Costa in Brazil.[10]

Recently, in a well-designed study, Sandhu et al[3] 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. Our study demonstrated that 12 tonometers (27.9%) were outside ±2.5 mmHg of calibration error and should be returned for recalibration as suggested by Sandhu et al.[3]

In summary, approximately 90% and 30% of tonometers in our center were outside the tolerance ranges of ±0.5 and ±2.5 mmHg, respectively. For achieving more accurate IOP measurement in eye care centers in our country we suggest regular checking of Goldmann tonometers for calibration and excluding faulty tonometers until recalibration. Further study is required to evaluate the relationship between tonometer calibration errors and clinical errors in IOP measurement.

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