Retrospective Audit of Goldmann Applanation Tonometry Measurements in a Consultant-Led Glaucoma Clinic

Debra Gleeson AssocDipAppSc(Orth)[1]
Meri Vukicevic BOrth PGDipHlthResMeth PhD[2]
Michael Jamieson MBBS BMedSc FRANZCO[1]

[1]The Royal Victorian Eye and Ear Hospital, Melbourne, Australia
[2]Discipline of Orthoptics, School of Allied Health, La Trobe University, Melbourne Australia

ABSTRACT

Goldmann applanation tonometry is the gold standard for measuring intraocular pressure by indenting or flattening the corneal apex. Accuracy in performing Goldmann applanation tonometry is of high importance as changes to glaucoma treatment are often made based on this measurement. Clinical audits of Goldmann applanation tonometry are crucial for identifying variance within clinics and ensuring quality control. This study reports the finding of three routine clinical audits on a consultant-led glaucoma clinic, comparing measurements taken by orthoptists and medically trained ophthalmologists or registrars. Sixty-six percent of tonometry readings were within acceptable range (±2mmHg) at Audit 1 and this improved to 71% at Audit 3 ($p = 0.03$). Many factors affect applanation tonometry measurement and the findings of this audit suggest that hands-on training of orthoptic clinicians would be useful to ensure best practice in the technique and thereby reduce the number of erroneous measurements.

Keywords: applanation, tonometry, glaucoma, intraocular pressure

INTRODUCTION

Glaucoma is a group of ocular conditions whereby the defining feature is optic neuropathy, caused by increased intraocular pressure (IOP). Diagnosis is made based on numerous factors, including optic nerve head appearance and visual field loss, and may vary depending upon the glaucoma classification.[1] Raised IOP has been shown to be a significant risk factor for glaucomatous damage to the optic nerve and progression of the disease. The goal of glaucoma treatment is to lower the IOP to a targeted pressure at which there is a reduction in the risk of further damage to the optic nerve and therefore decreased impact on the visual field. This is particularly important as the prevalence of glaucoma is increasing and once diagnosed, requires lifelong monitoring.[2,3]

Goldmann applanation tonometry (GAT) is the gold standard for measuring IOP by indenting or flattening the corneal apex. It was described by Goldmann and Schmidt, based on the Imbert-Fick principle that the internal pressure of a sphere can be approximated by the measuring the force required to flatten a given wall area.[4] Major forces involved in IOP measurement with applanation include corneal rigidity, tear meniscus, IOP and tonometer force.[4] The GAT has a diameter of 3.06 mm and surface area of 7.35 mm^2 to neutralise confounding forces and expose the relationship between tonometer force and IOP.

Accuracy in performing GAT is of high importance as changes to glaucoma treatment are often made on the basis of this measurement.[5] Measurement variation arises due to many factors that are either clinician, instrument, or patient dependent. Patient-dependent factors include corneal thickness, corneal irregularity, direct or indirect globe pressure, eyelid squeezing, valsalva manoeuvres (patient holding their breath or having tight neckwear), ciliary muscle contracture occurring during prolonged accommodation, dilation of the pupil, excessive tear film and caffeine or water intake.[5-10] Technical factors include tonometer head wear and tear, instrument calibration, measurement interpretation, positioning of the tonometer head, variable fluorescein application, prolonged contact time and inter-observer variability. Repeated indentation of the cornea by one or different observers is also thought to lower IOP.8 Repeated IOP measurement by different observers can occur in multi-disciplinary ophthalmic clinics. The interobserver variability has been reported as low as 0.4 mmHg,[5] but more commonly between 1.2 and 2.3 mmHg.[7,8,11]

Due to the importance of accurate GAT measurements for the treatment and monitoring of glaucoma and the likelihood that variance can occur, clinical audits are an important method for ensuring quality control and

Corresponding author: **Meri Vukicevic**
Discipline of Orthoptics, School of Allied Health,
La Trobe University, Victoria, 3086, Australia
Email: m.vukicevic@latrobe.edu.au

the outcomes benefit both patients and clinical staff. Identifying discrepancies that may affect treatment outcomes is particularly relevant in shared-care clinics to ensure appropriate patient care.

METHODS

Between 2014 and 2016, three audits were conducted as part of routine clinical care, on a consultant-led glaucoma clinic at the Royal Victorian Eye and Ear Hospital (RVEEH). The focus of the audits were GAT measurements where applanation tonometry was conducted using Haag-Streit instrumentation (Bern, Switzerland). In the period between audits, orthoptic clinic staff were offered a non-mandatory professional development training opportunity.

Figure 1 shows the sequence of audits and training opportunities. The training session included information relating to common factors which cause over or underestimation of IOP, both patient-dependent and clinician-dependent reasons.

The patient cohort included new patients, short-term and long-term reviews and postoperative patients. The disparity in GAT readings between the medically trained ophthalmologists (consultants, fellows and registrars) and orthoptic clinicians was investigated. In addition, an attempt was made to understand the possible reasons why the IOP was re-tested by the ophthalmologists. The possible reasons may have been that IOP differed from the previous visit; IOP was higher than the set target pressure; or a possible treatment change was needed based on the IOP. Intraocular pressure recordings were classified as either within acceptable range (±2 mmHg) or outside acceptable range.

The professional development training opportunity was part of the regular pre-clinical teaching session and the GAT component was presented to orthoptic clinic staff after Audits 1 and 2, conducted by a senior orthoptic clinician. During training, orthoptic clinicians were shown the findings of the audits. The primary aim of the professional development was to highlight the factors which affect IOP measurement, with a specific focus on the factors that can be controlled by orthoptists. These included patient positioning, corneal biomechanical factors, correct technique and specific reasons for over or underestimation of IOP. Prior to the second professional development session, orthoptic clinicians undertook a self-test task to assess whether they were applying these factors when performing IOP measurements. Statistical analysis was performed using IBM Corp SPSS version 24.0 (Armonk, NY). As data were not normally distributed, the non-parametric Wilcoxon Signed-Rank test was used for analysis.

RESULTS

Audit 1 was completed by examining patient histories over three clinics in November 2014, involving 11 orthoptists and 7 ophthalmology consultants. The total number of patient histories examined was 174. During the audit period, the IOP of 94 eyes were re-tested by ophthalmology consultants. Sixty-six percent (n = 62) of IOP measurements were within acceptable range; 30% (n = 28) were the same, 36% (n = 34) were within ±2 mmHg. Thirty-four percent of measurements (n = 32) were outside the acceptable range. Of the orthoptists' measurements that did not fall within the acceptable range, most were lower than that measured by the ophthalmologist as shown in Figure 2. The mean difference between orthoptist and ophthalmologist IOP was 1.4 mmHg, a statistically significant difference (ophthalmologist higher, 95%CI -0.78 to 1.94 mmHg, $p < 0.01$).

Retrospective Audit 2 was conducted over six clinics in June 2015, six months after the first professional development session, and 437 patient histories were examined. This audit involved 11 orthoptists and 8 ophthalmologists. During the audit period, the IOP measurements of 122 eyes were re-tested by an ophthalmologist and the differences in IOP ranged from -11 to +5 mmHg (Figure 3). Sixty-four percent (n = 78) of IOP measurements were within acceptable range; 21% (n = 26) were the same and 43% (n = 52) were within ±2 mmHg. Thirty-six percent of measurements (n = 44) were outside the acceptable range. The mean difference between orthoptist and ophthalmologist IOP of 0.4 mmHg was not statistically significant (ophthalmologist higher, 95%CI -1.00 to 0.92 mmHg, p = 0.08).

The final audit (Audit 3) of 370 patient histories was conducted two months after the second professional development session and the differences in IOP measurement are shown in Figure 4. This audit involved 9 orthoptists and 12 ophthalmologists. During the audit period, the IOP of 78 eyes were re-tested by an ophthalmology consultant. Seventy-one percent of IOP measurements (n = 55) were within the acceptable

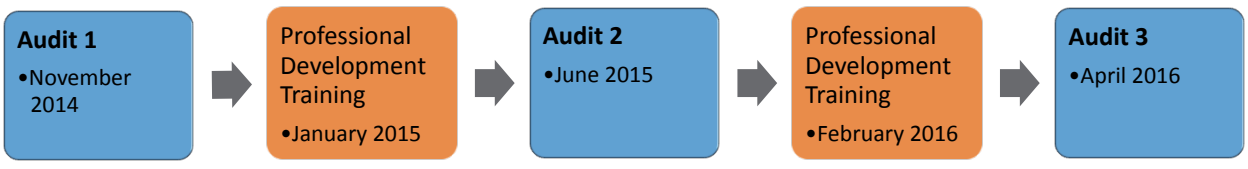

Figure 1. Sequence of audits and training opportunities.

range; 32% (n = 25) were the same, 39% (n = 30) were within ±2 mmHg. Twenty-nine percent of measurements (n = 23) were outside the acceptable range. The mean difference between orthoptist and ophthalmologist IOP of 0.4 mmHg was not statistically significant (ophthalmologist higher, 95% CI -0.30 to 1.14 mmHg, p = 0.09).

Figure 5 shows the proportion of IOP measurements which were either identical, within tolerance or outside tolerance when comparing orthoptists and ophthalmology consultants across all three audit periods. The number of IOP measurements which were within acceptable range improved from 66% to 70.5% from Audit 1 to Audit 3, a statistically significant difference (p = 0.03)

DISCUSSION

This collection of real-world clinical audits suggests that there is no clinically significant difference between IOP measurements by orthoptists and ophthalmologists using GAT in a sub-specialty glaucoma clinic. There was a trend towards lower readings by orthoptists, however there were outliers in both directions with several patients having IOPs recorded 10 mmHg higher or lower when re-tested by an ophthalmologist. It must be noted that a population statistics approach in analysing the findings of the audit hides individual cases where marked differences in IOP measurement are important and would affect treatment decisions.

This retrospective collection of audits contrasts with previous studies that have been prospective and controlled. Previous clinical studies have used a very limited number of observers, the same instrumentation and compliant, healthy patients. The audit findings are highly pertinent to actual clinical situations. In this study, the initial GAT measurement could have been taken by five different orthoptists and the second reading repeated by seven different ophthalmologists, ophthalmology fellows and registrars. The audited GAT measurements used one reading from each observer, whereas in controlled studies a number of measurements are usually taken and the mean or median value is used. It has been shown that using the median value of three consecutive GAT readings reduces inter-observer variability by 11% compared with one single observer measurement, which could account for some variability seen in our audits.[7] Garway-Heath[12] reported that two GAT measurements taken by the same observer on the same patient, using the same instrument under the same conditions in a short period of time, yielded a difference between 2.2 and 5.5 mmHg. Our real-world results suggest that similar results can be achieved by different observers using different equipment.

Other studies have repeated GAT measurements within a very short time-period (minutes) and the time intervals have been consistent. For the patients in this audit, the interval between readings could vary from 10 minutes to over an hour. This duration could impact the patient's IOP if for example they have had caffeine intake, been reading for prolonged periods in the waiting area causing ciliary muscle contracture, or have been exposed to environments affecting moisture content of the cornea, as well as possible short-term diurnal variation. Some of the patients in this audit may have had pupil dilation after the first GAT measurement, thereby affecting the second measurement. This information was not recorded as part of the data gathering process.

It has been previously shown that there is a statistically significant relationship between GAT measurement error and age of tonometer prism, the number of times the tonometer is used daily and the range of calibration endpoints.[13] There can be up to 12 tonometers used on any given glaucoma clinic at the RVEEH. It is worth noting that a large number of tonometer prisms were replaced in 2015. As the audit GAT measurements were conducted on different tonometers and factors such as tonometer head wear and tear, repeated use, differences in slit lamp illumination and calibration (tonometers are calibrated on the same day, monthly at the RVEEH) may affect the GAT reading, this may account for some variation in IOP recorded

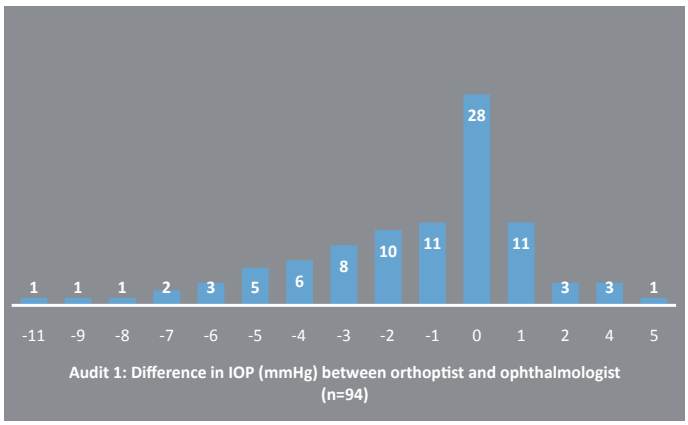

Figure 2. Range of difference in IOP measurement between orthoptists and ophthalmologists (Audit 1).

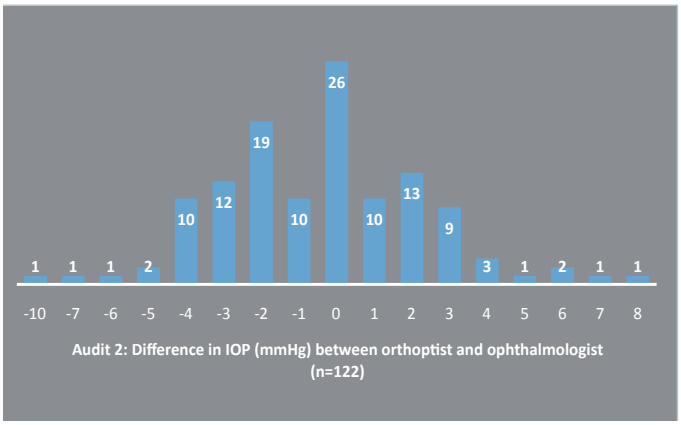

Figure 3. Range of difference in IOP measurement between orthoptists and ophthalmologists (Audit 2).

by orthoptists compared ophthalmologists, ophthalmology fellows and registrars.

The authors acknowledge that operator technique can also be a factor. It is worth noting that there has been a reduction in opportunity for orthoptists on non-glaucoma clinics to perform GAT, as tonometry using iCare rebound tonometry (iCare Finland Oy, Helsinki) is becoming increasingly used in clinics due to ease of use and improved time efficiency. Orthoptists at the RVEEH are performing less GAT measurements than in previous years, particularly since ten general clinics closed. This in turn impacts teaching of final year students who receive less opportunity to practice GAT, thereby affecting some of the new graduate workforce who become employed at the RVEEH. The difference between orthoptist and ophthalmologist IOP was statistically significant only in Audit 1, and it is theorised that orthoptist education and training in improved technique was at least partially responsible for the improved results in Audit 2 and 3. In addition, the number of GAT measurements re-tested fell over time, decreasing to 21% at Audit 3, compared to 54% at Audit 1. It is difficult to postulate the exact reason, however it may be due to improved staff confidence after participating in training.

The professional development sessions appear to have made some impact to orthoptist IOP measurement performance, and it is believed that hands-on clinical training is the most effective way to further improve and maintain these results. This will be implemented using a newly acquired teaching arm, connected to the Haag-Streit slit lamp enabling the teaching clinician to observe the mires as they appear to the clinician. This will be useful for both training and quality control purposes in the hospital. A close working relationship between the university and clinic-based elements of orthoptic graduate training is important to ensure that high quality training for orthoptic students leads to positive skill improvements and patient outcomes.

IOP measurement is useful in many situations where orthoptists are involved, including glaucoma diagnosis and monitoring as well as assessment of patients with uveitis, retinal vascular disease or post-surgery. Despite inherent limitations to audit data. such as retrospectivity, lack of controls, incomplete records, instrument and personnel variation, the information yielded is valuable and can be used to inform clinical practice. It was found that GAT performed by orthoptists appears to be similarly reliable to that performed by ophthalmologists in most patients, and agreement can be improved with orthoptist training. It is recommended that individual patients with unexpectedly high or low IOP, or where IOP is particularly critical to a treatment decision, should have the measurement repeated.

CONCLUSION

Our audit results found that orthoptists can achieve similar Goldmann applanation tonometry measurements to ophthalmologists in the majority of patients in a glaucoma sub-specialist clinic. Sources of error and potential benefits from further training were identified. The presence of a few outlier patients with a marked difference between orthoptist and ophthalmologist IOP measurement reinforced the need to re-test unexpectedly high or low readings, and in situations where an important treatment decision is being made. It is important to maintain the skill of Goldmann applanation tonometry through vigilance and care during training and clinical practice.

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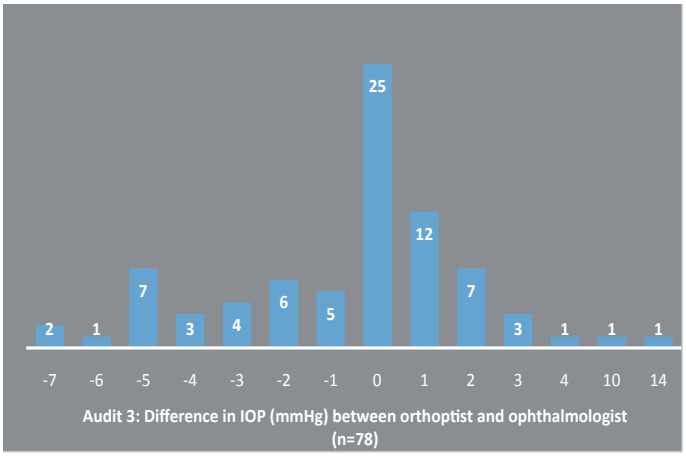

Figure 4. Range of difference in IOP measurement between orthoptists and ophthalmologists (Audit 3).

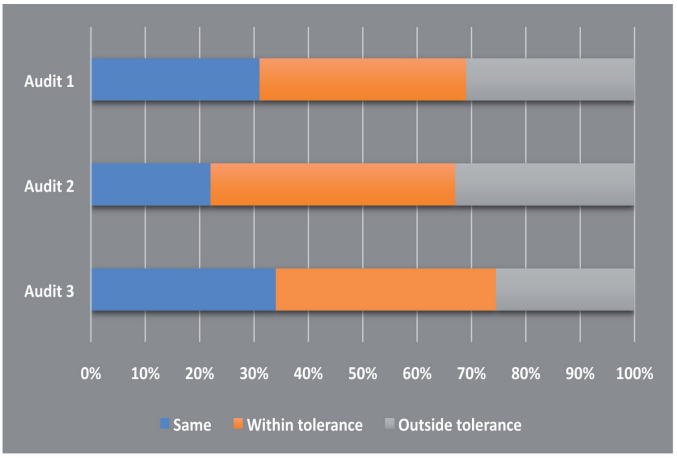

Figure 5. Proportion of IOP measurements within or outside tolerance for all audits.

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