Do ophthalmology residents know how to check the calibration of a Goldmann applanation tonometer?

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Conclusions Most ophthalmology residents were unable to correctly check GAT calibration. Although better than previously published results, this observational study shows that further training and assessment is required for ophthalmology residents to learn the technique of checking GAT calibration.

Keywords Goldmann · Applanation · Tonometer · Calibration · Residents

Abstract Purpose The purpose of this observational study was to determine whether ophthalmology residents know how to check Goldmann applanation tonometer (GAT) calibration.

Methods The step-by-step technique for checking the calibration of a GAT was taken from the manufacturer’s manual and developed into a mark sheet. Ophthalmology residents in years 2–8 of training from 11 hospitals were individually observed and assessed checking calibration of a GAT. Participation was voluntary. Contact between participants was minimised to prevent communication about the study.

Results Sixty-eight per cent (n = 30) of eligible ophthalmology residents (years 2–8) from 11 hospitals (three teaching hospitals and eight local general hospitals) were observed checking GAT calibration. Only 33% (n = 10; 95% CI: 16–50%) of ophthalmology residents were able to correctly check GAT calibration. Those participants who were previously taught (p = 0.046) or assessed (p = 0.015) were more likely to be successful in GAT calibration.

Introduction Intraocular pressure (IOP) measurement is fundamental in the assessment of glaucoma since it is the only modifiable risk factor. Precise readings are paramount since large clinical trials have associated IOP thresholds with progression risk. The early manifest glaucoma trial showed that a reduction in IOP by 1 mmHg led to a 10% reduction in progressive nerve damage [1]. The Goldmann applanation tonometer (GAT; Haag-Streit Diagnostics, Köniz, Switzerland) is the gold standard for IOP measurement and is used in most hospital eye services. However, it is subject to errors of which calibration error is common, the most variable and often unnoticed [2].

A questionnaire survey showed that only 15% of ophthalmology residents in the UK checked GAT calibration in their current practice [3]. Another study revealed that less than 15% of ophthalmic practitioners knew how to check the calibration of a GAT [4].
This previous research has relied on self-reporting, with no published information on direct observation of skill.

The purpose of this novel observational study was to determine whether ophthalmology residents know how to check GAT calibration by direct observation and assessment of this clinical skill.

Methods

Participants were recruited from ophthalmology residents in years 2–8 of training in the East of England and the Northern Ireland deaneries, in the UK. The study gained favourable approval from the clinical audit departments of Norfolk and Norwich University Hospital (study number: OPH-15–16-13) and the Royal Victoria Hospital, Belfast (reference number: 6760). Participants excluded from this study were: (i) consultants, (ii) specialty and associate specialists (SAS), (iii) fellows, (iv) ophthalmology residents in year 1 and (v) medical ophthalmologists.

All available ophthalmology residents from the East of England and the Northern Ireland deaneries (from years 2 to 8) were recruited on two days of assessment in each of the regions. Participation was voluntary. Ophthalmology residents were led to individual testing areas shielded from other participants, and participants were asked to keep the study confidential. Informed consent was obtained. Ophthalmology residents were then asked to check GAT calibration. All necessary equipment was available, and no confabulatory equipment was present. Multiple attempts were allowed, and no time limit was applied. Technique was assessed against a mark sheet. Criteria for checking GAT calibration were taken from the Haag-Streit applanation tonometer AT 900/870 Instructions for Use (Haag-Streit Diagnostics, Switzerland) [2]. The mark sheet assessed the placement of the Goldmann prism to balance the instrument, correct calibration check at position 0 with or without the calibration rod, and correct calibration check at positions 2 and 6 with the calibration rod. Technique was recorded as correct if all steps were performed correctly and incorrect if any one step was performed incorrectly. Trial and error was allowed. Fluent technique is described as following all the steps in the correct order and inserting the calibration bar correctly. Examples of trial and error would include attaching the calibration bar to the tonometer and trying to check calibration, then realising that they needed to balance the tonometer with the prism or moving the calibration rod in the wrong direction and then correcting the direction of movement. The assessor was marking all the steps and whether they were performed in the correct order. The results were anonymised.

Participants were invited to respond to a Likert scale for the importance of the GAT calibration as a competency [5]. The Likert scale ranged from 1 to 5 (1: not very important, 5: very important).

This was a small observational study. The adjusted Wald test was used to generate 95% confidence intervals. The Fisher’s exact test was used to test statistical significance in the analysis of contingency tables. Statistical significance was determined at a \( p \) value < 0.05.

Results

Of the 27 eligible ophthalmology residents (years 2–8) within the East of England School of Ophthalmology, 20 (74%) participated in the study. The remaining seven ophthalmology residents were not available on the study days. Of the 17 eligible ophthalmology residents (years 2–8) within the Northern Ireland Deenery of Ophthalmology, 10 (59%) participated in the study. The remaining seven ophthalmology residents were not available on the assessment days. An average of 68% \((n=30)\) of the total eligible ophthalmology residents were recruited from both deaneries. Representation was from across all ophthalmology residents years 2–8 (Fig. 1). Participants from the East of England cohort were from the two teaching hospitals \((n=9)\), eight of the 11 local general hospitals \((n=8)\) or out of programme \((n=3)\). Participants from the Northern Ireland cohort were from one teaching hospital \((n=10)\).

Only 33% \((n=10; 95\% \text{ CI: 16–50%})\) of ophthalmology residents (years 2–8) were able to correctly check GAT calibration (Table 1). There was no statistical difference in the ability to check GAT calibration between the two deanery regions \((p=0.10)\). Of those participants who were able to correctly check GAT calibration, most \((n=8)\) had a fluent technique with only a few \((n=2)\) using a trial-and-error type technique. Twenty ophthalmology residents \((70\%)\)
were unable to check GAT calibration. Of those participants who were unable to check GAT calibration, 100% (n = 20) did not mount the prism in the prism holder. Four (20%) of these participants who did not mount the prism in the prism holder were otherwise able to use the calibration rod to check calibration at the 0, 2 and 6 positions. Sixteen (53%) participants were unable to use the calibration rod, and all 16 participants also did not mount the prism correctly. Some participants were observed placing the calibration rod in the prism holder (n = 3) or spinning the calibration rod around in its insert (n = 1). There was a tendency for a greater proportion of junior ophthalmology residents (years 2–4) (n = 6; 38%) to be able to check GAT calibration correctly compared with senior ophthalmology residents (years 5–8) (n = 4; 29%); however, this did not reach statistical significance (p = 0.71).

Most ophthalmology residents (years 2–8) (n = 16; 53%) did not recall being taught how to check the calibration of a GAT (Table 2). Fourteen (47%) ophthalmology residents recalled receiving teaching on how to check the calibration of a GAT. Of ophthalmology residents previously taught how to check calibration, seven (50%) ophthalmology residents were observed as having a correct technique and seven (50%) ophthalmology residents were observed as having an incorrect technique. Of ophthalmology residents not previously taught how to check calibration (n = 16), only two ophthalmology residents (13%) were observed as having a correct technique. Previous teaching of the technique of checking GAT calibration increased the likelihood that the correct technique was used (p = 0.046). Since the main error with checking the calibration of a GAT related to failure to mount the prism in the prism holder, the association of prior teaching and correct use of the calibration rod was investigated. Eleven (79%) of the 14 ophthalmology residents who had received previous teaching were able to use the calibration rod correctly, compared with four (25%) of the 16 ophthalmology residents who had no previous teaching (p = 0.009).
In this study, only 37% of ophthalmology residents (years 2–8) \((n=11)\) recalled previously being assessed on how to check the calibration of a GAT (Table 3). Of the 11 ophthalmology residents that had been assessed, seven (64%) ophthalmology residents were able to correctly check GAT calibration. In comparison, only three (16%) ophthalmology residents that had not been assessed were able to check GAT calibration correctly and this reached statistical significance \((p=0.015)\). When allowing for failure to balance the instrument with the prism in the prism mount, nine (82%) ophthalmology residents that had been previously assessed were able to use the calibration rod correctly, compared with six (32%) ophthalmology residents that had not previously been assessed \((p=0.021)\). Of the ophthalmology residents who were previously assessed on this competency, all stated this had occurred during year 1 or year 2 of ophthalmology training. Most ophthalmology residents stated that assessment of the technique of checking GAT calibration had taken place during their general ophthalmology placement \((n=5; 45\%)\) or glaucoma placement \((n=3; 27\%)\) and three \((27\%)\) ophthalmology residents could not remember when.

Most participants \((n=28; 93\%)\) responded to a Likert scale for the importance of this competency. The mean score was 4.3. This indicated they felt it was important to very important.

### Table 2

| Technique                              | Previously taught, \(n=14\) | No prior teaching, \(n=16\) | \(P\)-value |
|--------------------------------------|-----------------------------|-----------------------------|------------|
| Correct technique, \(n\) (%)         | 7 (50)                      | 2 (13)                      | 0.046      |
| Incorrect technique, \(n\) (%)       | 7 (50)                      | 14 (87)                     |            |
| Incorrect technique, \(n\) (%)       | 3 (43)                      | 2 (14)                      |            |
| Only failure to mount prism, \(n\) (%) | 0 (0)                       | 2 (14)                      |            |
| Only improper calibration rod use, \(n\) (%) | 4 (57)                      | 0 (0)                       |            |
| Both prism and calibration rod errors, \(n\) (%) | 12 (86)                    |                             |            |

### Discussion

To our knowledge, this is the first study to directly observe whether ophthalmology residents were able to check GAT calibration, and most (67%) were unable to correctly do so. However, a greater proportion of participants (33%) in our study were able to check GAT calibration compared with 15% reported in other studies [3, 4]. It is important to note that previously published studies relied on self-reporting of this skill, but not on direct observation of the skill. Allowing for failure to balance the instrument by mounting the prism in the prism mount, we found that 14 (47%) ophthalmology residents were able to use the calibration rod correctly. With an international perspective, the Royal College of Ophthalmologists’ UK curriculum requires the competency of checking GAT calibration is completed successfully by the end of year 1 and clinical supervisors should formally assess this skill prior to approving it on the e-portfolio [6]. The Accreditation Council for Graduate Medical Education in the USA assesses competencies arranged into milestone levels from novice to expert. It is important to note these levels do not correspond with postgraduate year of education unlike the UK [7]. The Royal Australian and New Zealand College of Ophthalmologists require residents to sit the Ophthalmic Basic Clinical Competencies and Knowledge examination.
which formally assesses GAT calibration between 12 and 18 months and may offer the closest equivalence in training for comparison with UK residents [8]. In the interest of objective comparison, further research may be appropriate to correlate competency outcomes with ophthalmic residents with a similar training structure.

There was good participation of ophthalmology residents from the regions, and each of the training grades had good representation, reflecting the numbers of residents at each stage of training within the two deaneries. There was a trend for junior ophthalmology residents (years 2–4) to be able to check GAT calibration more successfully than senior residents (years 5–8); however, this did not reach statistical significance. Most ophthalmology residents recalled being taught this practical skill in years 1 or 2 of training. It is possible that junior ophthalmology residents appeared to be more successful in checking GAT calibration since they had received teaching and undergone assessment of this competency relatively recently. Additionally, it is possible that the time lapse since senior ophthalmology residents were taught and assessed this competency may have contributed to this skill being lost.

The most common error identified with checking the calibration of the GAT was the failure to balance the instrument by mounting the prism in the prism holder. It may be that this part of checking GAT calibration is not emphasised as important or is easily forgotten. Observation of this practical skill in the present study was not performed in a clinical setting where it may have been more intuitive for the ophthalmology resident to mount the prism in the prism holder.

Having been taught the skill of GAT calibration increased the likelihood of ophthalmology residents being able to correctly check the calibration of a GAT (50%) compared with those that had not been previously taught (13%), and this reached statistical significance ($p = 0.046$). Similarly, having been taught GAT calibration seemed to increase the likelihood of being able to use the calibration rod correctly (79%) compared with those that had not been taught (25%) and this reached statistical significance ($p = 0.009$). Having been assessed on GAT calibration during the residents’ training increased the ability to check GAT calibration correctly (64% previously assessed group vs 16% not previously assessed group), and this reached statistical significance ($p = 0.015$). Likewise, having been assessed GAT calibration seemed to increase the likelihood of being able to use the calibration rod correctly (82% previously assessed group vs 32% not previously assessed group), and this reached statistical significance ($p = 0.021$).

Ophthalmology residents participating in this study identified being able to check GAT calibration as an important practical skill to learn. Previous small studies by other groups have shown that 18–100% of GATs within units are uncalibrated [3, 4, 9–12]. Furthermore, a survey of all hospital eye services in the UK revealed 39% of GATs were never checked or were not regularly checked in an identifiable pattern [3, 13]. To ensure accurate IOP readings, the manufacturer Haag-Streit recommends that the calibration of the tonometer is checked monthly and returned for recalibration if found to be faulty [2]. A multicentre study has suggested newer GATs (<1 year old) could be checked twice yearly, whilst older GATs should be checked monthly [14].

There are limitations to this study; most notably, there was a small sample size, and it was only performed in two deaneries in the UK. Whilst a good proportion of ophthalmology residents participated, some of the smaller eye units were not represented. Additionally, the study was performed in a non-clinical setting and performance may vary within a clinical setting. Participants were asked to not communicate with each other regarding the topic of the study, but they were not completely isolated from each other. Hence, prior knowledge of the study may have increased the success rate due to the participants revising the technique before participating in the study.

Checking the calibration of a GAT is of training significance and of clinical significance since using an uncalibrated GAT could lead to under- or over-estimation of IOP. Under-estimation of IOP has the possible consequences of delay in instigating appropriate interventions and could lead to progression of glaucoma. Over-estimation of IOP has the possible consequence of unnecessary intervention. The recommendations of this study are that ophthalmology residents should be trained in checking GAT calibration and supervisors should observe and assess this skill.
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Declarations

Competing Interests  The authors declare no conflicts of interest.

Ethics approval  The study gained favourable approval from the clinical audit departments of Norfolk and Norwich University Hospital (study number: OPH-15–16–13) and Royal Victoria Hospital (reference number: 6760).

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