General Optical Council Approved CET For Optometrists
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Contact tonometry

Part 2

Dr Michael E Johnson completes his discussion of contact applanation tonometry with a look at the technique and how best to undertake it. Module C13377, one general CET point, suitable for optometrists and dispensing opticians

The first part of this two-part article reviewed the importance of intraocular pressure (IOP) assessment and the theory of contact tonometry, with emphasis on slit-lamp mounted Goldmann applanation tonometry (GAT) (29.01.10). GAT has recently become a core competency of the professional qualifying examinations and so all optometrists should be proficient in this technique. However, many clinicians have not used these methods since qualifying and may be daunted by the prospect of undertaking what can appear to be an invasive and potentially harmful test. The second part of this article adopts a practical 'how to' approach to the technique.

GAT in the context of recent guidelines

NICE guidelines

GAT has been considered the reference standard for measuring IOP for many years, and its importance has been reinforced by the recent NICE guidance on the diagnosis and management of chronic open-angle glaucoma and ocular hypertension.[1] The definition of ocular hypertension in these guidelines requires an untreated IOP above 21 mmHg with GAT confirmed on a separate occasion. Essential components to the diagnosis of ocular hypertension are, therefore, the use of GAT in preference to other methods of tonometry and repeated measurement.

It was the view of the NICE guideline development group that non-contact tonometry (NCT) cannot be relied on for accurate measurements when IOP is high. As such, while NCT may be acceptable as a screening tool for confirming normal IOP, if an optometrist records an IOP above 21 mmHg using these methods then the guidelines dictate this should be considered only an indication of ocular hypertension that requires GAT on two separate occasions for confirmation.

Figure 1 GAT has been considered the reference standard for measuring IOP for many years

However, it should be noted that the evidence referenced for this stance was a single study published in 1992 using largely antiquated technology that is probably not applicable to newer NCT instruments.[2] More recent publications have reported a modest level of agreement, difference typically less than 5 mmHg (which should be compared with an expected difference of less than 3 mmHg for two measurements with GAT), and a low level of average bias.[3-8]

The notion that the variation in the difference between NCT and GAT methods is greater for higher IOP has inconsistent support, but this may reflect insensitivity to such a change in some studies, owing to a relatively restricted range of IOP in their sample. My personal opinion is that NCT is more prone to rogue high measurements than GAT, which I suspect largely reflects a real (but unwanted) rise in IOP above the habitual level caused by an increase in extraocular muscle tone and breath-holding in response to apprehension to the impending puff of air, rather than instrument error. It should be considered that anxious persons are encountered more commonly in clinical practice than in clinical trials because such individuals are less likely to volunteer to participate in tonometry studies. It follows from this reasoning that optometrists using NCT should be expected to record spurious IOP values that are significantly higher than GAT more commonly than is predicted in the literature. Certainly, it is good practice when using an NCT to make every effort to put the patient at ease and to disregard outliers.

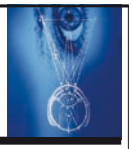
NICE guidelines suggest that Perkins tonometry may be used when GAT is not practicable, but report that evidence for the equivalence of GAT and Perkins is lacking. It was the opinion of the NICE guideline development group that GAT is preferable to Perkins tonometry, and that at the current time the two methods should not be considered interchangeable.

College of Optometrists' and College of Ophthalmologists' guidelines

The NICE guidance is only intended to assist clinicians directly involved in determining the suitability for treatment. The guidelines explicitly state that screening/case-finding for glaucoma and ocular hypertension lie outside its scope and so they are not directly applicable to optometrists in traditional community practice. In response to the uncertainty as to how NICE guidelines should impact the referral practices of optometrists working in community, the College of Optometrists and the College of Ophthalmologists jointly published guidance that specifically addresses this issue.[9] It should be appreciated that these two guidelines were developed separately. One inconsistency between the two guidelines is that in contrast to NICE, the guidance issued by the College of Optometrists and the College of Ophthalmologists implies that GAT and Perkins tonometry are equivalent in accuracy.

GAT calibration

Before a tonometer is used to measure IOP a clinician must be confident that it is calibrated. The manual for the GAT



recommends that this instrument should have its calibration checked at least once a month.[10] Calibration should also be checked after it has carelessly been knocked onto the floor or when a series of unexpected results are encountered. GAT calibration is checked at 0, 20 and 60mmHg. A calibration rod is used to provide a standard weight against which to test the accuracy of GAT at 20 and 60mmHg. This rod has five engraved rings, one centrally, and the others symmetrically offset about the middle. The two rings closest to the centre represent the 2g settings and the two rings closest to the ends represent the 6g settings.

It is important that the GAT is calibrated with the prism in place. There is a small bump on the bottom of the GAT to allow it to be secured into a base-plate on the slit lamp, and this causes the instrument to be unlevel and invalidates calibration results if it is simply be placed on a table. The GAT should, therefore, either be placed on the corner of a table so the bump overhangs or, preferably, set up on the slit lamp in its measurement position. This will normally be on the base-plate of the slit lamp, although with superiorly mounted versions it should be swung in front of the slit lamp microscope.

The dial of the GAT should initially be set at about 5mmHg, which should cause the head to lean forwards, away from the examiner. The dial is turned downwards and the head should rock back when the dial reads between 0-2mmHg. Turning the dial the other way will cause the head to rock forwards, and this should also be between 0-2mmHg. A calibration rod and holding bracket is then attached to the body of the GAT. With most Goldmann tonometers (AT900 range) the rod is slid towards the examiner more than halfway along its length until the 2g ring on the rod is aligned with the mark on the holding bracket (long part of rod points towards examiner). Rarely a variant is encountered (AT870) where the prism is held from above, rather than below, and with this instrument the rod is slid the other way (long part of rod points away from examiner). The tipping point of the head should now be between 20-23mmHg as the dial reading is increased, and between 17-20mmHg as the dial reading is decreased. The calibration rod is then slid further away from the examiner until its 6g ring is aligned with the mark on the holding bracket. The tipping point of the head should now be between 60-64mmHg as the dial reading is increased, and between 56-60mmHg as the dial reading is decreased. It will be noticed that the tolerance increases with the pressure that is being checked: 0mmHg (± 2mmHg), 20mmHg (± 3mmHg), 60mmHg (± 4mmHg).

Measurement with GAT

Timing in examination

GAT often results in mild disturbance to the corneal epithelium that may reduce the sharpness of vision, and so should be undertaken after refraction and other clinical tests demanding high levels of acuity. The cornea should be assessed before GAT so it is possible to differentiate between pre-test epitheliopathy and epithelial trauma caused by the technique.

GAT should be carried out before gonioscopy or any technique that requires the use of a contact lens, because pressure on the eye during these investigations can displace aqueous from the eye and reduce IOP from its normal level. As with all tonometry techniques, GAT should be undertaken prior to pupil dilation because in some individuals, particularly those with narrow anterior-chamber angles, changes to the habitual angle configuration and ciliary body tone can alter aqueous dynamics. Additionally, in patients with pigment dispersion syndrome or pseudoexfoliation syndrome, pupillary dilation can trigger a release of pigment that causes a transient elevation of IOP.

The issue of whether to routinely repeat tonometry soon after pupil dilation to identify angle-closure glaucoma is contentious. It is my personal opinion that traditional optometric teaching on this issue is misinformed. Angle-closure invariably occurs in the setting of a mid-dilated pupil in an anatomically predisposed eye when the backward pressure of the iris against the lens is maximal, leading to a relative increase in resistance to aqueous flow and subsequent billowing forward of the iris mid-periphery. The pupil dilates quickly and returns to its normal size much more slowly. A drug-induced angle-closure event is thus most likely to occur several hours after the instillation of mydriatic eyedrops, and, therefore, a considerable time after the patient has left the practice. It follows that it is more appropriate for patients recording grade 2 or less with Van Herrick, or with angles deemed closable by gonioscopy, to be advised of the symptoms of angle-closure and necessary action following dilation, rather than for the clinician to misguidedly reassure themselves with an ill-timed post-dilation check. It is also important to appreciate that angle-closure following dilation is very rare, and this small risk is invariably less than the risk of eye disease being missed by not dilating. As a caveat, in the absence of symptoms that demand immediate dilation, patients with anterior chamber angles narrow enough to cause concern on the safety of dilation are best served by referral to a specialist who can decide on the appropriateness of a prophylactic peripheral iridotomy or, in the presence of an accompanying opacity of the crystalline lens, cataract extraction.

GAT preliminaries

Wash hands

As with all clinical procedures both hands should be washed. More conveniently, when visibly clean, hands may be disinfected with an alcohol gel.

Tonometer set up

The GAT is usually mounted on a base-plate on the slit lamp. There is a choice of two location holes that minimally alter the angle of the probe relative to the viewing system, and simply determine whether the right or left eye of the observer will be used during the monocular technique. For most clinicians either position can be used for measurement in both of the patient's eyes, but the option is non-trivial for those with a preferred viewing eye. With some variants the GAT is permanently mounted to the slit lamp and is swung in place from the side. With these models there may not be a choice of what ocular of the microscope is used for the procedure.

The tension knob is set just below the anticipated IOP level, based on previous test results, or at 1g (equivalent to 10mmHg) when there is no expectation. If the knob is set at zero the prism head may vibrate or jerk forwards when it touches the cornea. As a rule, it is considered more accurate to measure IOP by increasing, rather than decreasing, the force of applanation. This is to avoid indentation, and thus the potential for a tonographic effect that would cause an underestimation of IOP.

A bi-prismatic head is attached to the GAT. The orientation of the prism does not matter for most eyes, but is conventionally done so that its dividing line is horizontal. In the presence of regular corneal astigmatism the area applanated is elliptical, rather than circular. This leads to an underestimation of IOP for with-the-rule astigmatism and an overestimation for against-the-rule astigmatism, by about 1mmHg for ▶

every 3 DC. It has been calculated that to avoid this error the dividing line of the bi-prism should be rotated by an amount determined by the direction and magnitude of corneal astigmatism, varying between 40° and 50° relative to the flattest meridian of the cornea, usually coincident with the minus cylinder axis of the eye's refraction.[11] At this angle the radius of the applanated meridian will produce an imaginary circle whose area equals the area of the elliptical tonometer-cornea contact (Figure 2). It was suggested that 43° to the flattest meridian of the corneal astigmatism provided minimal error at commonly found ranges of corneal curvature. The probe carrier of the GAT has two marks, a white mark at 180 degrees and a red mark, or the inscription 'A', at 43°. The original non-disposable tonometer heads have a scale running around their curved surface that enables the adjustment for astigmatism to be made by rotating the probe within its carrier until the angle of the flattest corneal meridian and astigmatism mark are aligned. As an alternative, GAT readings in horizontal and vertical meridians can be averaged. The latter technique is not only simpler, through elimination of the need for keratometry and reorienting the tonometer head to differing angles, but on the basis of theoretical calculations has been purported to marginally better compensate for corneal astigmatism than a fixed angular displacement of the measuring meridian.[12]

A cobalt blue filter is selected, along with a high light intensity and the beam width opened maximally, to give good fluorescence. It is generally taught that the angle of the illumination system is shone obliquely from the temporal side at an angle approximating 60°. This is done to avoid shining light directly at the eye and so improve patient comfort, and perhaps to reduce distracting reflections, not because it is critical to achieving an accurate result, in contrast to the Van Herrick or Smith techniques that assess the peripheral and central anterior chamber configuration, respectively. It should be recognised that the angle of illumination has no effect on the force needed to applanate or the width of the menisci, and thus it would introduce no error if both the observation and illumination systems were directed straight ahead to avoid the need to swing the illumination system between eyes. Certainly, a specific angle of illumination is not essential, although at some angles between straight-ahead and 60° its housing can obstruct viewing through the microscope.

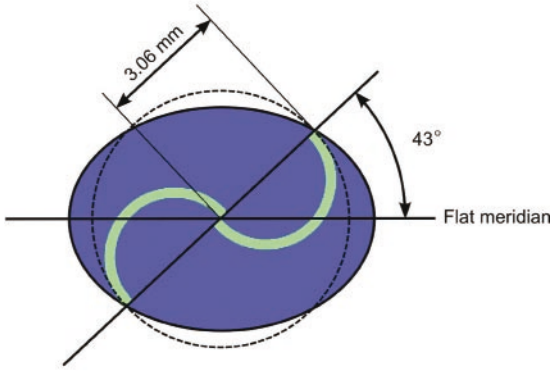


Figure 2 The applanated area is elliptical in the presence of corneal astigmatism. By orientating the tonometer head at an angle of 43° to the flattest corneal meridian the radius of the applanated meridian will produce an imaginary circle whose area almost equals the area of the elliptical tonometer-corneal contact

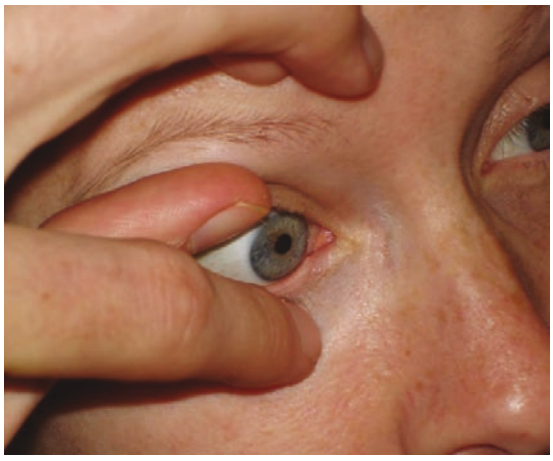


Figure 3 Holding the eyelids open in patient with twitchy lids, using the thumb to support the upper eyelid

It is not critical to dim the room lights. A darkened room is, however, useful for nervous patients because it reduces awareness that the tonometer is approaching the eye and so lessens the blink reflex.

Explanation of procedure

As a matter of courtesy, patients should be told why IOP assessment is considered necessary. When non-contact tonometry has been used before it may be shrewd to tell patients that GAT is an alternative to the 'air puff' test. This is to avoid the misperception of receiving a less than complete examination. It can also reduce patient tension and so assist in the appraisal of habitual IOP. All patients need to be told that an numbing eyedrop will be instilled to allow a probe to come close to and lightly touch the tear film, after which it is reasonable to assume implicit consent. It is helpful to inform patients that the eyedrops will sting for a few seconds but reassure them that during measurement they will not feel any discomfort.

Instil anaesthetic and fluorescein

A topical anaesthetic and fluorescein are required for GAT. This is most conveniently achieved with a combination eyedrop. This may also have the advantage of better standardising the volume and surface tension of fluid in the eye during the technique, versus relative difficulty in achieving a constant volume and concentration of fluorescein with wetted paper strips. Proxymetacaine is preferred by many clinicians because it stings less than other topical anaesthetics. A potential drawback is the requirement for refrigerated storage, although the manufacturers suggest that it may be kept at room temperature before use for up to 28 days. Also, it is slightly more likely than amide-linked anaesthetics, such as lidocaine, to cause hypersensitive epithelial toxicity. With practice, eyedrops can usually be instilled at the slit lamp, although in apprehensive patients it is helpful to stand almost behind them and ask them to look away so that they do not see the looming dropper, which invites a reflex withdrawal and blink. Sometimes a finger from both hands is needed to separate the eyelids to create a gap at the lateral canthus. An additional tip is to have the drop most of the way out of the dispenser before approaching the eye so there is no unnecessary wait, which reduces the opportunity for the patient to break free and clamp the lids shut.

GAT measurement technique

The patient is instructed to put their chin on the chinrest and press their forehead against the headrest. It should be ensured that the patient is sitting comfortably at a height that allows for some fine-tuning of vertical alignment during measurement. If the patient is wearing a tight necktie it should be loosened. The GAT should meet the cornea perpendicularly, or very nearly so, and so normally the tonometer should be directed forwards and the patient asked to look straight ahead and relax. It is useful to refer to an object behind you to act as a fixation target. In the presence of very poor unaided vision or a marked strabismus, wiggling fingers at the required angle of gaze to achieve correct ocular orientation, and then asking them to hold still, is crude but effective. In patients who are difficult to position properly at the slit lamp, or in those with a strabismus where it is difficult to get the eye looking ahead, it may be beneficial to rotate the viewing system of the microscope, and thus the attached tonometer, to facilitate a perpendicular approach.

Patients should be asked to keep their eyes open. The choice of whether to immobilise eyelids is dependent on patient factors and a decision should be made on an individual basis. If the lids come in contact with the tonometer probe then tears are drawn from the lid menisci, and possibly from under the eyelids, which results in a flood of fluorescein and necessitates withdrawal and drying of the probe. It is also an unpleasant experience for patients because the eyelids are not anesthetised, and can increase apprehension for the next attempt and may diminish their confidence in the practitioner. However, an artifactual increase in IOP can be induced by pressure exerted unintentionally on the globe when holding the eyelids. It is my preference to routinely support the eyelids against the bony rims of the orbit using as little force as possible, pushing upwards against bone rather than downwards against the globe. Then, if no resistance is felt, after a reading has been taken, with the probe remaining in contact with the eye, digital pressure is gently released to see if the IOP reduces. Holding the eyelids open can be difficult in deep-set eyes and when reflexes are strong. It is advantageous to ensure that the lids are dry to improve grip, and in challenging cases it may be helpful to switch the usual roles of the thumb and index finger, using the more dextrous thumb to tackle the more problematic upper lid (Figure 3). On the issue of holding eyelids, it is important to appreciate that regardless of any apparent success in preventing blinking, if the patient continues to forcefully squeeze their eyes, which through increased tone of the extraocular and orbicularis muscles compress the globe and so raise IOP, the test results will be of little value. Putting the patient at ease and gaining their cooperation is vastly preferable to brute force. Some apprehensive patients, and others trying to be helpful, need to be reminded to breathe to avoid IOP elevation through Valsalva's manoeuvre.

The GAT should be advanced towards the centre of the cornea, while the clinician looks from the side. This movement is initially relatively quick, but slows significantly as the eye is approached. At the beginning of the approach it is preferable to push the slit lamp forward using the heel of a hand with the joystick pulled back, and then in the final stages fine-tune positioning by easing the joystick forward. A common mistake made by novices is to initially push the joystick forward, realise that they are some way short in distance, and then jerk the tonometer against the eye with a poorly controlled shove. The oculars of the biomicroscope are only used at the end when the probe just touches the eye, or is nearly touching, so as to help judge the speed of approach and because otherwise clinicians are unaware of large patient movements that would cause them to miss the target. Another common fault in technique is not moving the GAT forward enough to contact the eye fully, usually owing to a misguided concern that it will cause serious eye injury. The GAT continues to apply the dialled force as the probe is pushed back for some distance, and because subtle patient movement during the technique is commonplace it follows that the tonometer should be advanced so that the probe is displaced backwards into the mid-portion of this range, not at the very start where any drifting back of the patient's head from the headrest would cause the probe to bounce off the eye. Hesitant clinicians should be reassured by the truth that the cornea, while exquisitely sensitive, is quite tough, and penetration of Bowman's membrane with a GAT is

nearly impossible, and would certainly require a malicious determination.

When the tonometer prism is on the eye the clinician should look through the eyepieces of the biomicroscope. The fluorescein rings should be approximately 0.3 mm wide, or about a tenth the diameter of the semicircles. The width of the rings is important and can be refined by either blotting with tissue or topping-up the level of fluorescein. It is my preference to err on the side of instilling too little fluorescein initially because this is simpler to remedy and lessens the risk of leaving the patient with unattractive orange stained eyelids and cheeks.

If the two rings are different sizes the vertical positioning of the GAT needs to be adjusted. Failure to do this leads to an overestimation in IOP. Large adjustment should not be needed if reasonable care is taken when aiming the GAT at the central cornea, but, in exceptional circumstances, if this is required it is preferable to withdraw the probe and re-approach the eye. Small adjustments in height can be made with the probe on the eye, when any frictional trauma to the epithelium is often less than repeated GAT contacts.

The relative horizontal positioning of the two semicircles is altered using the knob on the body of the GAT. The fluorescein rings usually undergo a rhythmic movement in response to the cardiac cycle. The tension knob is turned until their inner borders just touch each other at the midpoint of their pulsations (Figure 4). The force in grams is read off the dial and multiplied by 10 to give IOP in mmHg. This value is recorded along with the time of day. In contrast to non-contact tonometry, repeated readings in the same eye are not usually necessary because variations caused by the cardiac pulse are inherently considered by the choice of endpoint.

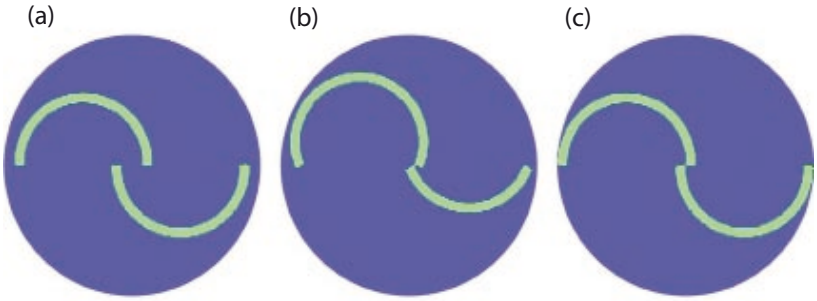


Figure 4 Semicircles seen by examiner during GAT. Applanating force too high (a). Incorrect vertical alignment (b). Correct endpoint with the innermost aspects of the two semicircles touching (c)

The procedure is then carried out in the fellow eye. Not uncommonly a lower pressure is recorded with the second measurement owing to initial patient apprehension and failure to relax. If this is the case or there is any marked IOP asymmetry it is prudent to repeat measurements. If a second measurement is much lower then it is probably this value that should be considered the more reliable and is the one that should be recorded.

GAT post-technique

Check cornea

After GAT the cornea should be examined for epithelial damage. This is usually minor and of no clinical concern (Figure 5). When extensive, with rapid and diffuse penetration of fluorescein into the stroma, some clinicians advocate prescribing an antibiotic to prevent opportunistic infection until the cornea heals and the epithelial barrier is restored, normally within hours. This should occur very rarely, typically only in teaching clinics after repeated and prolonged insult by inexperienced students. However, when indicated, a topical broad spectrum antibiotic is appropriate, and an example prescribing regimen is chloramphenicol 0.5 percent eyedrops two-hourly until bedtime that evening.

Patient information

Possibly after drop instillation, and invariably after GAT has been performed, patients should be offered a tissue and told if they have spillage of fluorescein onto the face. They should also be warned not to rub the eyes for the next half hour because the anaesthetic causes their eyes to be insensitive to any harm.

Disinfection of tonometer prisms

The Medical Devices Agency advise that wherever practicable a device that comes into contact with the ocular surface should not be used on more than one patient, as to do so may expose patients to unnecessary risk through the transmission of disease.[13] This strongly encourages the use of disposable tonometer prisms. Ordinarily, the same prism can be used for the two eyes of

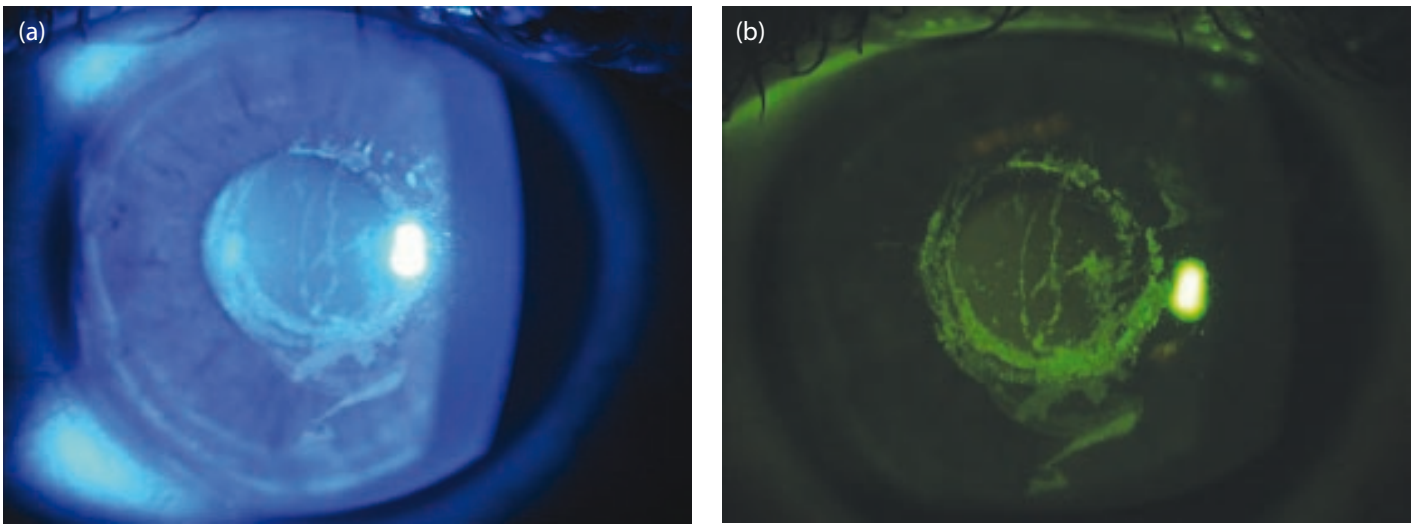


Figure 5 Extensive epithelial damage after GAT seen with cobalt blue alone (a) and with orange absorption filter (b)

the same patient, although it is sensible to use another prism if a uniocular infection is suspected. After use, disposable tonometer prisms should be destroyed by incineration.[14]

It may be acceptable to decontaminate tonometer prisms immediately after contact with the eye using the methods recommended by the Department Health's Advisory Committee on Dangerous Pathogens (ACDP). This advice has been strongly influenced by the theoretical risk of transmitting prions from one patient to another, although there are no known cases of transmission of variant Creutzfeldt-Jakob Disease (vCJD) by ophthalmic devices. Until recently the recommended method for decontaminating ophthalmic devices was soaking in sodium chlorite solution providing 20,000ppm of available chlorine (2 per cent solution) for one hour. However, the latest advice for the decontamination of ophthalmic devices by the ACDP ophthalmology sub-group allows for a lower concentration of sodium hypochlorite of 10,000ppm of available chlorine, and immersion for the shorter time of 10 minutes.[14] This is combined with prior cleaning with soap/detergent and a series of rinses with water for irrigation (not tap water), and then finally storing the device dry. Soap/detergent is recommended because sodium hypochlorite is not effective against spores and cysts of certain microorganisms. Multiple rinsing is recommended to avoid the accidental damage to subsequent patients with caustic sodium hypochlorite. It is recommended that tap water be avoided to avoid the risk of Acanthamoeba spp.

It is noteworthy that this new guidance appears to be inconsistent with other, even more recent, publications by the ACDP, which state that sodium hypochlorite is considered to be effective at reducing infectivity but only at concentrations of 20,000ppm of available chlorine and when used for at least one hour.[15]

Summary

GAT has been the 'gold standard' of IOP measurement for many years. It is important to appreciate that while GAT is the reference standard and gives acceptable accuracy in most eyes, the technique will under- or overestimate IOP by clinically significant amounts in some individuals. Also, IOP is a variable that frequently changes by clinically significant amounts throughout the day and so it is not possible to confidently predict the average or peak IOP that an eye is exposed to with a single measurement, regardless of the accuracy of that technique at measuring IOP at any given moment in time. As such, practitioners must interpret GAT and manage patients in the context of other test results. ●

MULTIPLE-CHOICE QUESTIONS – take part at opticianonline.net

1 Which of the following is necessary for a diagnosis of OHT?
A IOP >21mmHg with NCT
B IOP >21mmHg with GAT on one occasion
C IOP >21mmHg with GAT on two separate occasions
D IOP >21mmHg with GAT on two separate occasions and a visual field defect

2 What is the error caused by 6DC non-compensated with-the-rule astigmatism?
A 1 mmHg underestimation
B 2 mmHg underestimation
C 1 mmHg overestimation
D 2 mmHg over estimation

3 Which of the following anaesthetics is least likely to cause a toxicity reaction?
A Lignocaine
B Amethocaine
C Oxybuproaine
D Proparacaine

4 At what pressures is the GAT calibrated?
A 0, 10, 20mmHg
B 0, 20,40mmHg
C 0, 20, 60mmHg
D 0, 30, 60mmHg

5 Which of the following tests should be done after contact tonometry?
A Visual acuity
B Refraction
C Gonioscopy
D Stereopsis

6 What concentration of sodium hypochlorite is recommended by the ACDP for reusable ophthalmic devices?
A 1,000ppm of available chlorine
B 10,000ppm of available chlorine
C 20,000ppm of available chlorine
D 50,000ppm of available chlorine

Successful participation in this module counts as one credit towards the GOC CET scheme administered by Vantage and one towards the Association of Optometrists Ireland's scheme. The deadline for responses is March 25 2010

References

1 The National Institute for Health and Clinical Excellence. Diagnosis and management of chronic open angled glaucoma and ocular hypertension. www.nice.org.uk/CG85, April 2009.

2 Atkinson PL, et al. Deterioration in the accuracy of the pulsair non-contact tonometer with use: need for regular calibration. Eye (Lond). 1992;6:530-4.

3 Mackie SW, et al. Clinical comparison of the Keeler Pulsair 2000, American Optical MkII and Goldmann applanation tonometers. Ophthalmic Physiol Opt, 1996;16:171–7.

4 Parker VA, et al. Clinical comparison of the Keeler Pulsair 3000 with Goldmann applanation tonometry. Br J Ophthalmol, 2001;85:1303-04.

5 Jorge J, et al. Clinical performance of non-contact tonometry by Reichert AT550 in glaucomatous patients. Ophthalmic Physiol Opt, 2003;23:503–6.

6 Tonnu PA, et al. A comparison of four methods of tonometry: method agreement and interobserver variability. Br J Ophthalmol, 2005;89:847–50.

7 Ogbuehi KC, Almubrad TM. Accuracy and reliability of the Keeler Pulsair EasyEye non-contact tonometer. Optom Vis Sci, 2008;85:61-6.

8 Babalola OE, et al. A comparison of the Goldmann applanation and non-contact (Keeler Pulsair EasyEye) tonometers and the effect of central corneal thickness in indigenous African eyes. Ophthalmic Physiol Opt, 2009;29:182-8.

9 The College of Optometrists and The Royal College of Ophthalmologists. Guidance on the referral of Glaucoma suspects by community optometrists. www.college-optometrists.org, December 2009.

10 Goldmann AT900/870 Applanation Tonometer to slit lamp. Instruction manual. www.haag-streit.com.

11 Goldmann H, Schmidt T. Über Applanationstonometrie. Ophthalmologica. 1957;134:221-42.

12 Holladay JT, Allison ME, Prager TC. Goldmann applanation tonometry in patients with regular corneal astigmatism. Am J Ophthalmol, 1983;96:90-3.

13 Medical Devices Agency. MDA AN1994 (04). Single patient use of ophthalmic medical devices: Implications for clinical practice, October 1999.

14 Guidance from the ACDP TSE Working Group: Annex L – Managing CJDvCJD risk in ophthalmology. www.dh.gov.uk/ab/ACDP/TSEguidance/index.htm, September 2009.

15 Guidance from the ACDP TSE Working Group: Annex C - General principles of decontamination and waste disposal. www.dh.gov.uk/ab/ACDP/TSEguidance/index.ht, November 2009.

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