

Pitfalls in Intraocular Pressure Measurement by Goldmann-Type Applanation Tonometers

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In recent years, Applanation tonometry using the Goldmann instrument has become the gold standard in the assessment of intraocular pressure. Unfortunately, it is often not recognized that there are numerous sources of error that may significantly influence accuracy of Goldmann-type Applanation tonometers. It is very important that the clinician should be able to keep in mind these potential pitfalls while checking intraocular pressure.

Accuracy of Goldmann-type applanation tonometers

Various experimental studies have shown that Goldmann tonometers give accurate results when patient's central corneal thickness is 0.52 mm¹, thicker cornea lead to an over estimate of IOP and thinner cornea to an under estimation of IOP.

Ehler's et al have calculated that a true IOP of 20mmHg, a central corneal thickness(CCT) of 0.45mm would lead to an error of -5.2mmHg and that a CCT of 0.59 mm would lead to an error of +4.7mmHg. Ehlers has estimated that IOP is affected by ± 5 mmHg for every 0.07mm change in CCT above or below normal.

The Imbert Fick law, the basis of goldmann tonometry

The Imbert Fick law is considered to be the basis for Applanation Tonometry. It states that when a flat

surface is pressed against a spherical surface of a container with a given pressure, an equilibrium will be attained when the force exerted against the spherical surface is balanced by the internal pressure of the sphere exerted over the area of contact between the sphere and the flat surface.

It is assumed that the sphere applanated by the flat surface is thin, perfectly elastic, and perfectly flexible and that the only force acting against it is the pressure of the applanating surface. It is further assumed that the applanated area and subsequently displaced volume is small in relation to the total area and the volume of sphere.

None of the presumptions of Imbert Fick law is true when applied to Applanation Tonometry, since the cornea offers resistance to indentation varying with its curvature and thickness and the presence or absence of corneal epithelial or stromal edema. Tonometer tips do not contact the cornea alone, but also come in contact with precorneal tear film. The precorneal tear film produces capillary attraction, or repulsion, between it and object in contact with its meniscus. The volume displaced by any applanation tonometer will produce rise in IOP varying in degree with ocular rigidity. The dimensions of the Goldmann tonometer head were not determined on the basis of Imbert Fick law, but on the basis of empirical

experimentation by Goldmann². Goldmann found that in the eye preparations he studied. An applanating area of 3mm diameter gave the best results; because with this area the corneal indentation was balanced by the capillary attraction of the precorneal tear film for the tonometer tip. An applanating area of precisely 3.06mm diameter was chosen because at that diameter, a force of 0.1 gram corresponded to an IOP of 1mmHg.

Area of tonometer –tear film contact

If there is adequate fluorescein in the precorneal tear film but there are excessive tears, then the fluorescent rings will be broader than normal. This will cause overestimation of the IOP by about 2 to 4.5 mmHg³.

Performing tonometry without fluorescein

If tonometry is performed without fluorescein then an under estimation of IOP by up to 5.5mmHg may be encountered⁴. If there is inadequate concentration of fluorescein in the tear film the IOP may be significantly underestimated by 1.5 to 9.5mmHg⁵. There is evidence that application of fluorescein from paper strips doesn't produce an adequate concentration of fluorescein in precorneal tear film⁶.

Corneal astigmatism

When regular astigmatism is present, an elliptical contact with tonometer head occurs. This results in an under estimation of IOP in with-the-rule astigmatism and an over estimation with against-the-rule astigmatism, with an error range of about -2.5 to +2.5 mmHg. Two options exist to counteract this source of error:

1. Align tonometer head at 43 degree to axis of astigmatism (in negative cylinder).
2. Average IOP readings at 0 and 90 degrees.
 - a. In regular astigmatism, the IOP reading may be grossly inaccurate⁷.

Effect of corneal curvature

Steeper corneas need to be indented more to produce the standard area of contact, necessitating more force and therefore indicating a higher IOP reading. It has been suggested that over the range of corneal curvature of 40 to 49 diopters, the error in IOP reading is about 3mmHg⁸.

Effect of corneal oedema

Kaufman⁹ reported that Goldmann Applanation Tonometry underestimates the IOP in eyes with

moderate corneal edema with errors in the range of 10 to 30 mmHg.

This underestimation was attributed to the observation that the epithelium of edematous corneas is easier to indent than normal epithelium.

Effect of corneal thickness

As already pointed out, thin corneas tend to produce underestimation and thick corneas produce overestimation of IOP. Clinical implication of this fact in patients with thin corneas may be wrongly diagnosed as normal tension glaucoma and thick corneas wrongly as ocular hypertensives; emphasizing importance of checking central corneal thickness on a routine basis in glaucoma clinics.

Scleral Rigidity

Under physiological condition, scleral rigidity doesn't have significant effect on IOP when using Applanation tonometer¹⁰.

Blepharospasm

Forceful lid closure may lead to a dramatic rise in IOP and this may lead to gross errors in diagnosis and management of glaucoma. Experiments by Coleman and Trokel¹¹ revealed that closure of lids produce an IOP increase of about 5mmHg and blepharospasm increased the IOP to 80mmHg.

Arterial perfusion pressure

Marked reduction in IOP can occur when arterial pressure perfusing the eye decreases. During periods of asystole or transient cardiac arrhythmias, IOP can decrease by 20%. Ipsilateral carotid compression can reduce the IOP by 10 to 20 mmHg¹². This decline is due to loss of choroidal perfusion.

Central venous pressure

Restrictive clothing around the neck can increase IOP. Hence tight collars and ties should be loosened before positioning of the patient at the slit lamp¹².

Eye position

Eye position can affect IOP transiently. This transient rise is thought to be due to rectus muscle tone. The magnitude of effect of globe position on IOP can be exaggerated in patients with restrictive orbital disease, for example thyroid eye disease.

Applanation of paracentral cornea (Off axis)

Applanation of paracentral cornea occurs when the Applanation tip contacts the non-central cornea. Numerous studies have shown that a large change is not produced by having the tonometer tip contact the eccentric cornea.

Effect of Repeated Applanation attempts

When IOP is repeatedly measured in an eye over a short span of time, there is a reduction of IOP and this can vary between -2 to -5 mmHg¹³.

Interobserver Variability

Interobserver variability is an important source of error when the same patient is assessed by multiple individuals.

Calibration of tonometers

This is a frequent but forgotten source of error in IOP assessment with the Goldmann type applanation tonometers. It is therefore recommended that tonometer calibration should be checked at least once a year and preferably twice a year, following the techniques indicated in each tonometer's operator's manual.

Tips to avoid pitfalls

1. Regularly check calibration of your tonometer.
2. If error is suspected, recheck IOP with different machine.
3. Use appropriate mixture of local anaesthetic and fluorescein.
4. Ensure good illumination
5. Eye should be in primary position and ensure correct patient position at the slit lamp.
6. Compensate for corneal astigmatism if astigmatism greater than three diopters.
7. Consider checking central corneal thickness.
8. Do not consider IOP in isolation

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