ESSENTIALS OF GLAUCOMA
1- Tonometry

by
Prof. Dr Ali Khalifa
Al Azhar University

- Ophthalmology owes much of its status as a specialty to its early association with the science of optics.

- Helmholtz work on optics in 1856 on measuring the refraction, accustomed ophthalmologists to the idea of quantifying observations.

- The recognition that hardness of the eye is linked to cupping. Atrophy of optic nerve in the condition known as glaucoma, led to the search for a better method of measuring IOP than palpation.

- The first practical instruments were made by Von Graefe (1863) and by Donders (1863).

- All tonometers in current use rely on deforming the globe and :-

a) Measure the deformation produced by a known force.

b) Measure the force required to produce a known deformation.

It has been suggested by :-

1- Vogelsang 1927 – Ballistic Tonometer in which the rebound of a small metal ball from the eye is measured and this depends to a large extent on the physical properties of the coats of the eye.

2- Maurice 1958 – Indentation tonometer in which the amount of indentation is kept constant and we measure the force required indentation.

3- Roth & Blake 1963- Vibration tonometer cause minimal deformation by oscillating force by a probe, which also functions as a sensor and measures the resonant frequency of the eye. Other physical characteristics can also alter resonant frequency.

4. Gutman et. Al., 1963- Puff of air against cornea cause very small deformation. Good correlation between corneal deflection and IOP.

5. Gloster 1966- Variation in velocity of sound waves with pressure without deforming the globe.

6- Collins and Laoghborough 1966 – As suggested by Prof. Perkins, a pressure sensitive transmitter with miniture radio-transmitter implanted inside the eye in experimental animals.

It causes small volume displacement and is useful in continuous recording of IOP, but it is complicated for clinical use.

Tonometers in clinical use:

1. Indentation Tonometer (Schiotz)

Measures amount of deformation by a fixed force.
Indentation produced by a weighted plunger; the movement of the plunger being amplified mechanically by a lever system with a scale and pointer, or electronically by making part of the plunger the core of a deferential transformer.

It is capable of measuring movement up to 0.05mm and the electronic type can give continuous reading.

Its disadvantage is the force applied to the eye is large - 16.5 gm (whole Schiotz) which causes distortion of globe and increased tension on coats of eye, therefore increasing IOP.

It is this artificially elevated pressure (Pt.) which is recorded and not the pressure in the undisturbed eye (Po).

If difference between Pt and Po was very small, this would not matter but, in range of pressure, we are interested in the difference if over 50%.

Friedenwald 1954, derived a mathematical expression relating Pt, Po, dv (volume of corneal indentation), and a constant K (coefficient of ocular rigidity).

Long Pt – Log Po=dv. K

This relationship provides the basis for the calibration of Indentation tonometers. Pt. & volume are derived experimentally. A value is assumed for K (0.005 to 0.045 $\simeq$ 0.0215). If coefficiency of ocular rigidity of that eye is near K value, therefore the readings will be accurate. If coefficient is not near K, therefore, under or over estimate of true IOP, for example, high ocular rigidity in hyperopes, gives false increase IOP and low ocular rigidity in myopes give false decrease IOP.

A conversion table using average value fork (coefficient of ocular rigidity) converts reading on Schiotz tonometer to IOP in mmHg.

Potential errors In Indentation Schiotz Tonometer

Low ocular Rigidity:

- Elevated IOP
- Old Age
- Strong miotics
- Vasodilators
- Previous cryopexy
- Scleral buckling
- Intravitreal injection of compressible gas

High Ocular Rigidity

- Long standing glaucoma
- ARMD
- Vasoconstrictors
- Steep or thick cornea
- Lid pressure
- Tension of EOM

Technique of Indentation Schiotz tonometer

- ☒ Sit in reclining chair or lie in supine position with head and eyes vertical.
- ☒ Topical anesthesia, benoxinate in conjunctival sac.
- ☒ Check tonometer by placing it on block supplied.
- ☒ The test block permits the plunger to extend 0.05 mm below the concave footplate.
- ☒ Open lids gently so as not to press on globe nor to open lids excessively.
- ☒ By fixating his thumbnail with the other eye.
- ☒ Lower instrument until it touches the eye.
- ☒ Hesitate a few seconds to allow relaxation of patient and to commence normal breathing.
- ☒ Full weight of tonometer (16.5 gm) when 5.5 plunger is used rests on the cornea.
- ☒ Center the instrument on cornea with the scale easily seen.
- ☒ Scale is marked in mm. from 0 to 20mm, representing plunger protrusion from 0.05 to 1.05mm.
- ☒ Estimate reading to nearest 0.25 mm.
- ☒ Proper coupling by observing cardiac pulsation on pointer.
- ☒ Remove instrument, allow patient to blink and repeat one or two times.
- ☒ Take average reading.
- ☒ Value of Po which correspondends to scale reading and weight used is read from 1955 scale.
- ☒ If scale reading is 3 or less, one of the additional weights should be added to plunger to improve accuracy. If same, scleral rigidity is normal, but if there is a discrepancy there is scleral rigidity.

Sterilization:

- Disassemble tonometer
- Clean with water or alcohol or sterilize, then dry by lint.

II. Applantation Tonometers:

If the deformation of the eye and hence corneal indentation is small, variations in K (ocular rigidity) is as unimportant .

This is the advantage of applanation tonometery over indentation tonometers.

Principle

Based on Imbert-Fick law, which states "the pressure within a sphere is equal to the external force needed to flatten a portion of the sphere divided by the area of the sphere that is flattened".

$$P \text{ (Pressure)} = \frac{w \text{ (force)}}{A \text{ (area flattened)}}$$

$$W = P \times A$$

Hence at moment of equilibriun the force will be counter balanced by pressure acting over the area of applanation.

a) Maklakov (1885) Tonometer:

Is a force with the flat end balanced on the cornea. The flat surface was coated with a dye, which was removed on contact with cornea leaving a ring of dye, which could be stamped on the absorbent paper. The diameter of ring correspondends to diameter of applanation.

It is not very accurate, but still used in Eastern Europe. It is a high displacement volume instrument.

b) Goldmann Applanation tonometers:

Invented by Swiss Ophthalmologist Hans Goldmann (1954).

Principle:

An optimal area of cornea 3- 4 mm to be flattened, is kept constant and displaces only 0.5 ml of aqueous (low displacement) and raises IOP only 3%, and to minimize the inward force caused by surface tension of tears and the outward force caused by the elasticity of the cornea.

A fixed diameter 3.06 mm (area 7.35mm^2) was chosen to permit direct conversion of the force in deci gm (x10) to pressure in the eye in mmHg.

Technique

- Local anaesthetic
- FL. Paper or 0.25% Na FL. Solu.
- Cobult blue light (wide open) to illuminate tip of cone and cornea.
- Slit lamp moved towards eye while joy stick held back.
- Initial position interior to visual axis and upper lid lifted to avoid lashes.
- Two equal semicircles (upper and lower) seen through low power ocular, then advance joy stick till touch.
- Dial is rotated until inner edges of semicircles touch.
- Read the dial x 10 mmHg.
- Read twice if difference is 2 or more; read third and take average.

Potential Error in Measurements by Goldman Tonometer

Overestimate readings

- Wide tear meniscus
- Unequal circles
- Thick cornea (increase collagen in cornea)
- Increases corneal curvature (steep). If more that 3 diopters it becomes elleptial, causing increase in IOP - 1mmHg for every 4D. This can be corrected by performing horizontal and vertical reading and divide by two or red line opposite least (flat) corneal curvature.

Underestimate readings:

- Measurement without use of FL.
- In adequate FI. concentration.
- Thin cornea or thick cornea due to epithelial or stromal edema.

- Decreased corneal curvature (flat)
- With rule astigmatism – 1mm for every 4D.

Sterilization:

- Tip wiped with alcohol prep pads and left to dry
- Tip wiped with a clean tissue prior to use

Disadvantage:

- Sitting position
- Mounted on a slit lamp – Expensive
- If Argon laser to follow – wash properly
- If anesthesia causes allergy, warm up prism above body temperature and perform without anesthesia.

Perkin's Applanation Tonometer

- Same principle of Goldman's applanation tonometer
- Prism is counter balanced
- Force is applied by a coiled spring
- It does not have to be held vertically
- It is hand held
- Viewing gives less magnification
- Used for children under general anesthesia, operating rooms and rounds.

Draeger Applanation Tonometer

- Same as any applanation tonometer but with a different prism.
- It is portable but larger
- Less accurate than Goldman

Mackay Marg Tonometer

- Portable electronic tonometer
- Has an action lying between indentation tonometer and applanation
- Utilizes the guard ring principle used in measuring intra-uterine pressure
- Applanating surface consists of a central pressure sensitive plunger 1.5mm (affixed to a rigid spring) extends 10mu. Beyond plane of the surrounding guard ring (displacement small).
- Flat area is pressured until guard ring is in contact and when a corneal area of 1.5mm is flattened.
- Under these conditions, the central area measures the force due to the IOP through the cornea. The pressure transducer connected to central area yields an electrical output, which is recorded on paper strip.

Adv:- The bending force of cornea and surface tension forces act only on the guard ring.

- used in scarred, edematous and irregular corneas.

Disadv:- no consistent readings

- readings are taken by rapid placing and removal of tonometer; these rapid readings are influenced by inherent stiffness of cornea.

Pneumotonometer

- Similar to Mackay-Marg, but instead of electronically controlled plunger, an air pressure is used. (Durham et. al. 1965.)
- Measures the IOP by indenting the cornea by a guarded ring and is activated by an air valve.
- When the central area is leveled with guard ring, the valve closes off a stream of air and the air press required to maintain equilibrium is measured and recorded on moving paper or digital display.
- Gives higher estimates than Goldman tonometer.
- Useful in measuring pressure in eyes with scarred, irregular and/or edematous corneas.

Non-contact Air-Puff Tonometer

- Uses Golden principle.
- But instead of Prism, the central part of the cornea is flattened by a jet of air.
- Light is reflected (parallel) when cornea is flattened to a photoreceptor which is activated to turn the air off.
- The time required to sufficiently flatten the cornea relates directly to the level of IOP.
- Adv: No anesthesia
- No cross infection

Tonography

- Non invasive method for measuring outflow facility.
- Application of electronic Schiotz tonometer to the eye for 4 minutes in supine position while recording the pressure change on galvanometer
- C – is determined by comparing the initial and final pressure reading and then using a special nomogram.
- C-over 0.20-- normal } in healthy and glaucomatous eyes
- C-below 0.11-- pathological}

Tono-pen Tonometer

- It works with a similar principle of Mackay - Mag tonometer
- It is portable battery operated
- It employs a microscopic strain gauge transducer that applanates the cornea, converting IOP into electrical waves, giving audible beep when acceptable measurement.
- A single chip computer in instrument analyses the wave forms obtained from several corneal touches and displays it with an estimate of reliability on a digital read out.
- It correlates well with Goldmann in normal ranges.
- The area of applanation is small, allowing increase accuracy in measuring IOP after keraloplasty, RK, and irregular astigmatism.