Indentation vs. Applanation
- Concept of Scleral Rigidity:
  - “Stretchiness” or the lack of rigidity allows for tissues to be elastic, not firm
  - Decreased measurement accuracy

Goldmann Applanation Tonometry
- Based on 520 micron thick cornea
- 7.354 mm² area at tip (3.06 mm circle diam.)
- Area was chosen so the force at the tonometer tip (in decigrams or millinewtons) could be directly converted to the pressure (in millimeters of Hg)
- It has long been put forward whether any of the available instruments accurately states IOP in scarred or abnormal corneas

Goldmann Applanation Tonometry
- Scleral Rigidity can be largely ignored
  - The prism tip, when flattening the corneal surface for an accurate measurement, will only displace 0.56 mm³
  - This will only have an average error increase of about 2.5% (according to Haag-Streit)
  - There is little or no “massage effect” from repeated measurements

Goldmann Applanation Tonometry
- Based on Imbert-Fick principle:
  - Pressure in liquid-filled sphere can be measured by determining the force required to flatten a known area on the surface.
  - Originally calculated (for the eye) with the formula for the cornea to be infinitely thin & ignored surface tension factors
**Goldmann Applanation Tonometry**

- Goldmann had to incorporate Rigidity and Surface Tension factors into his formula/instrument
- \( P + E = \frac{W}{A} - S \)
  - \( P \)= pressure, \( E \)= mod. of elasticity (corneal deformation), \( W \)= force acting on tip, \( A \)= area of contact, \( S \)= surface tension

**Goldmann Applanation Tonometry**

- Prism Tip is designed to have a diameter 3.06 mm because at that diameter ("the known area" in the Imbert-Fick principle) the opposing forces of corneal rigidity and surface tension cancel each other out, allowing 0.1 g (or 0.981 mN) of force (what the instrument applies) to correspond to 1 mm Hg IOP

**Goldmann Applanation Tonometry**

- Ehlers estimated through regression analysis that Goldmann tonometry:
  - under-est. IOP by 5.2 mm if pachy=450 microns
  - over-est. IOP by 4.7 mm if pachy=590 microns
  - OHT = thicker corneas
  - LTG = thinner corneas

**Ocular Hypertension**

- It has been published (but widely ignored until recently) that many OHT pts. have thicker than average corneas.
  - Do you measure pachymetry in OHT pts.?

**Ocular Hypertension**

- The change in IOP due to increased thickness has been postulated to produce from 2-6 mm Hg instrument error - reading falsely HIGHER than pts. actual IOP

**“Low Tension” Glaucoma**

- Thinner corneas under-estimate true IOP because less resistance
- This has been verified manometrically by comparing “internal” IOP vs. “externally” measured IOP
Refractive Surgery

- Laser refractive surgery does not ADD tissue, so removal of tissue will change the parameters upon which IOP is based.
- Can the change in thickness be correlated with the type of correction and the amount of pachymetric change in the cornea?

Corneal thickness and IOP

- If high corneal thickness results in higher numbers for IOP (artificially higher), can lower pachymetric readings be correlated with low IOP number (artificially lower)?
- What does a change in thickness of “X” microns mean to IOPs in our patients?
  - AND if surgically altered; does the type of ablation (myopic, astigmatic, hyperopic), or optical zone have an effect? How much?

Laser Refractive Surgery and IOP Measurement

- How do we know what the “real” IOP is?
  - Some studies suggest 0.5 mm Hg per 25 micron change in central pachymetry.
  - Others have suggested no change, some as high as 2 mm Hg per 25 micron pachymetric change.
- What does that mean? One study sug.:
  - 4 diopter myope @ 12 microns/diopter change in pachymetry = 48 microns change in thickness, therefore 1-4 mm “artificial” lowering.

Laser Refractive Surgery and IOP Measurement

- How do we know what the “real” IOP is?
  - Using 12 microns/diopter as benchmark, a D myope has 96 microns of pachymetric change, or about 2-8 mm “artificial” lowering.
- Suppose the pre-op thickness was 600 microns, and post-operatively is 520 microns? (520 is our supposed “norm” for Goldmann Applanation)? What then?

Compensation Factor

- Most MD’s now accept the following:
  - ADD 1 mm Hg to measured IOP for every 20 microns of “thinner” below 545 microns.
  - SUBTRACT 1 mm Hg from measured IOP for every 20 microns of “thicker” over 545 microns.
- Recent literature suggests a slightly “non-linear” relationship between thickness and IOP – especially at “thick” or “thin” corneal measurements.

Compensation Factor

<table>
<thead>
<tr>
<th>Pachymetric thickness (measured):</th>
<th>No change</th>
<th>Add 1 to measurement</th>
<th>Add 2 to measurement</th>
<th>Subtract 1 from meas.</th>
<th>Subtract 2 from meas.</th>
</tr>
</thead>
<tbody>
<tr>
<td>545</td>
<td>525</td>
<td>505</td>
<td>565</td>
<td>585</td>
<td></td>
</tr>
</tbody>
</table>

FOR EXAMPLE:

- Pachymetric thickness (measured): 545 = No change
- Pachymetric thickness (measured): 525 = add 1 to measurement
- Pachymetric thickness (measured): 505 = add 2 to measurement
- Pachymetric thickness (measured): 565 = subtract 1 from meas.
- Pachymetric thickness (measured): 585 = subtract 2 from meas.
Compensation Factor
Let MD convert!
We should record only our ACTUAL reading in charts.
Pachymetry should be noted in an easily located chart area since it will be referenced many times over years in “suspect patients”.
I take to have a small conversion chart on the back of each tonometer body – for reference.

Cylinder Compensation
• In order to keep the AREA (of contact) on the cornea of the prism tip (3.06 mm diameter) at the desired area (7.354 mm²), we cannot just leave the axis of the prism in the “usual” 180 degree position!
• Must be corneal cylinder, not just refractive
  – Example:
    • K’s: 44.00/46.00 X 90
    • Refraction: -2.00 +4.00 X 180
    • Anterior CORNEA has +2.00 @ 180, remainder of EYE (lens, post. Cornea) has +2.00 more @ 180

Cylinder Compensation
• We only need to worry if the Corneal Cylinder if 5.00 D or greater
• K’s and Topo only are anterior corneal measurement (But MOST cylinder is located here!)
  – How would (could we?) we measure posterior corneal cylinder?

Cylinder Compensation
• Method:
  – Verify the Corneal Cylinder > 5.00 D
  – Convert to MINUS Cylinder notation
  – Measure as usual (even though the image may be “slanted”) and record as usual!

Other Measurement Tips
• Most of you are aware of the problems patients can give us which affect IOP measurement:
  – Breath Holding (IOP measured too high)
  – Lid Squeezing (IOP measured too high)
  – Tight Collars (IOP measured too high)
  – Difficult Body Positions for patients (usually measured too high)
  – Closing Other Eye (Not centering on cornea)
**When NOT to measure?**

- Possible infection (relative contraindication)
- History of Recent Orbital or Globe Trauma (let MD measure!)
- Significant Corneal Scarring (relative contraind. – accuracy significantly less)

**Disinfection**

- CDC currently recommends 10 min. soak
  - 10% bleach solution
  - 3% H2O2 (OTC Hydrogen Peroxide)
- Alcohol wipe OK but not truly disinfected, and DOES act harshly on the tip
- Haag-Streit sells “Pantasept” – be sure to rinse with sterile saline and dry
- Gas (Ethylene Oxide) sterilization also OK
  - ensure proper ventilation and aeration

**What do we do if measured IOP isn’t accurate?**

- So, how then do providers decide if a patient has glaucoma of some form if you can’t rely on IOP?
  - Visual Fields
  - Stereo Disc Photo Changes over time
  - Nerve Fiber Layer Analysis (HRT, OCT, or NFA/GDX)
  - In the future? “Cup/Disc” Volumetric Analysis? (soon?)

**Questions?**

- I’ll stay after if you have specific questions

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