Intraocular pressure- old, new and yet to come
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Disclosure
- Equipment support from Ziemer Ophthalmology
  Pascal tonometer
- Equipment support Reichert Ocular Response Analyzer

Intraocular pressure

Factors affecting IOP: Long-term
- Genetics
- Age
  - Increase of IOP with age
- Gender
  - M=F 20-40 yrs of age
  - Females greater increase in IOP post 40 yrs of age
- Refractive error?

Factors affecting IOP: Short-term
- Diurnal variations
- Postural variations: Supine cause increase
- Exercise: Decrease in IOP
- Blinking and forceful closure causes increase
- Wearing tight neck tie

Factors affecting IOP: Short-term-2
- Food and drugs
  - Alcohol
  - Caffeine
  - Tobacco
  - Heroin and Marijuana
Intraocular pressure

- Sustained elevated IOP causes optic nerve damage in POAG
- Furthermore decrease in IOP lessens the risk of visual field progression and optic nerve head damage

![Intraocular pressure graph](image)

**Figure 1.** Prevalence of primary open-angle glaucoma in relation to screening IOP. Note: The curve is smoothed using a running mean with window width of 7 mm Hg. Caucasian American subjects. (n = 5,706 eyes [open circles]; African American subjects. (n = 3,937 eyes [closed circles].)

Probability of POAG relative to IOP

At IOP of 30 there is about 80% probability of primary open angle glaucoma

Intraocular pressure

- Diagnosis- not helpful
- Treatment- only proven method
- Progression- very closely associated with IOP
- Risk factor- without a doubt most important risk factor
- In fact only alterable risk factor!

Types of tonometry

- Applanation –
  - Goldmann, Perkins
  - Mackay-Marg-Tonopen
  - Pneumotonometer
  - Non-contact
- Others
  - Dynamic Contour Tonometer
  - Ocular Response Analyzer
  - γCR
  - Diaton
  - Rebound tonometer
**Conditions for Imbert-Fick Law**
- Perfect sphere
- Dry
- Infinitely thin
- \( W = P_1 \times A \)

**Applanation tonometry-2**
**Modified Imbert-Fick law**
\[ W + S = P \times A + B \]
**Where**
1. \( S \) = Surface tension
2. \( B \) = Force required to bend the cornea

**Understanding biomechanics of cornea**

**Corneal parameters and IOP**
- Geometric
- Stiffness
- Material
- Corneal thickness
- Radius of curvature
- Shape
- Size
- Age
- Hydration
- Medical history
- Refractive surgery

**Tonometric correction factors**

**IOP correction factors**
- Corrected IOP was calculated using:
  - Ehlers model (1975)
  - Manometry and simultaneous tonometry
  - Table for correction factors
  - Orsengo and Pye model (1999)
  - Finite element analysis
  - Calculates stress and strain on cornea
  - Does not assume linearity
Ehlers correction factor
- 5 mmHg for 70 micron change in CCT.

Orssengo and Pye equation

Study participants
- Total n = 324 subjects
  - Normal = 175
  - OAG or OHT = 149

Normal GAT and CCT

CCT and IOP in OAG & OHT Group

Effect, correction and over-correction
There is a statistically significant residual effect of CCT after correcting IOP.

There is a negative residual slope after correction indicating overcorrection.

Correcting IOP may be a

Summary of scatter plots


Pascal – Dynamic Contour Tonometer

Dynamic contour tonometer

Dynamic contour tonometer (cont 2)

- Minimal corneal deformation, allowing transducer to measure IOP directly
- Digital output
- Continuous recording of IOP waveform
Dynamic contour tonometer (cont 3)

- The corneal biomechanical contribution to IOP measurement is largely removed when the cornea takes up the shape of the tip.
- Tip radius of curvature is 10.5mm.
- Pressure sensor is 1.5 mm.

The PASCAL SensorTip:

- Contour-matched concave tip surface
- Built-in pressure sensor
- Transparent tip permits view of cornea interface for centering and control.

PASCAL SensorCaps

- SensorCap protects the patient
- SensorCap protects the tip

Ocular pulse amplitude

<table>
<thead>
<tr>
<th>OPA and NTG</th>
<th>OPA [mm Hg] vs. NTG</th>
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<tbody>
<tr>
<td>[Graph]</td>
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| Table 2: Group comparisons by two samples of PASCAL
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<th>Group</th>
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* Indicates local statistical significance.
Ocular Pulse Amplitude in Normal Tension and Primary Open Angle Glaucoma

Ingeborg Satthuma, MD, PhD,* Alan Harris, PhD,† Veronique Vanhoutteboom, BSc,* Timothy Zeyen, MD, PhD,‡ and Brent Sacks, PhD†

Conclusions: OPA is reduced in normal tension and POAG patients compared with healthy controls. OPA is influenced by IOP, but not by corneal thickness.

CPT code 0198T Effective January 1, 2009

Dynamic Ocular Tonometry

PASCAL®

Ocular Response Analyzer

- IOPl - Goldman Correlated IOP
- IOPcc - Corneal Compensated IOP
- CH - Corneal Hysteresis
- CRF - Corneal Resistance Factor
- CCT - Central Corneal Thickness

Applanation Detection

Applanation Detection II
Applanation Detection III

Applanation Detection IV

Applanation Signal Plot

The Glaucoma Tonometer

Data courtesy New England College of Optometry

IOPcc is not influenced by the thickness of the cornea

Reichert 7 CR

The Glaucoma Tonometer

Corneal Hysteresis but Not Corneal Thickness Correlates with Optic Nerve Surface Compliance in Glaucoma Patients

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1 Department of Ophthalmology, Massachusetts Eye and Ear, Boston, Massachusetts, USA
2 Department of Ophthalmology, New England Eye Center, Tufts University School of Medicine, Boston, Massachusetts, USA
3 Department of Environmental Health, Harvard School of Public Health, Boston, Massachusetts, USA
4 Department of Biomedical Engineering, Tufts University, Boston, Massachusetts, USA
5 Department of Ophthalmology, The Royal Victorian Eye and Ear Hospital, Melbourne, Victoria, Australia

R² = 0.0006

Data courtesy New England College of Optometry
Advantages
- Small area of contact
- Sterile caps
- In scarred and irregular cornea
- In post LASIK and post-operative cornea - peripheral measurements can be obtained
- Portable

Disadvantages
- Expensive over time
- Need anesthetic
- Calibration issues
- Battery
- Fragile

Mackey-Marg devices

Procedure

Advantages
- No anesthetic requirements
- More natural position rather than slitlamp
- Disposable probe
- May have use in screenings
Intra operator repeatability

Inter operator repeatability

Goldmann applanation tonometer versus Rebound tonometer

ORA and Rebound tonometer

Intraocular pressure telemetry

Need of IOP telemetry
- 24-hour IOP measurement not easy
- Uncertain cases of NTG, progression, high risk for progression
- Need to evaluate clinical efficacy of drugs
- New drugs and modalities testing
- May be more accurate than clinical measurements
- Continuous monitoring will help identify spikes in IOP both short and long term
Types of IOP telemetry
- Non invasive - temporary
  - CL's
  - continuous applanation or indentation devices
- Invasive - permanent
  - Subconjunctival
  - anterior chamber implants
    - in AC
    - as IOL haptics
    - scleral buckles
    - scleral fixed sensor
  - Posterior chamber implants - choroidal

Temporary devices contact lenses

Temporary devices
- Advantages
  - Non invasive
  - not permanent
  - can be used on ad-hoc basis
- Disadvantages
  - Eye movement may have greater effect when compared to permanent devices
  - Surface tension, light exposure, temperature
  - Reproducibility

SENSIMED
 Triggerfish

Summary tonometers
- IOP is still important in management of glaucoma.
- New generation tonometers show great promise.
- Pascal and ORA are more accurate than GAT.
- Pascal measurement of OPA may be an indicator of glaucoma.
Summary of tonometer – cont...

- ORA gives a wealth of corneal biomechanical parameters.
- Corneal hysteresis is most interesting parameter.
- Tonopen may have its use of measuring IOP in scarred or damaged cornea
- Rebound tonometer needs more research to make it more accurate
- Contact lens tonometry may give insights into pathogenesis of certain types of glaucoma by 24-hour IOP measurements.