BASICS OF CORNEAL BIOMECHANICS

by

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Disclosure

No financial interest

Introduction to Corneal Hysteresis

- **The elastic response:**

- The deformation is proportional to the force applied.

- The reformation is immediately upon unloading.

- The stress-strain relationship would be a straight line.

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Introduction to Corneal Hysteresis

- **Viscous response**:

- The deformation rate is faster than the reformation rate.

- The slow reformation is due to configurationally rearrangement of the material during deformation.

- **Resistance response**: which is the capacity of a material to hold stress without deformation.

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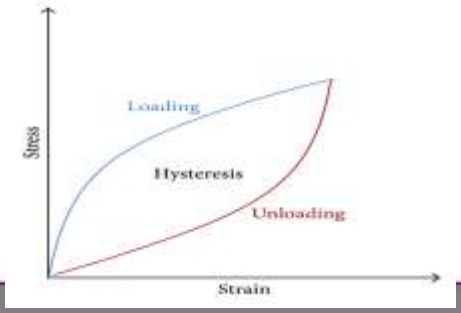
Introduction to Corneal Hysteresis

- **Hysteresis:** in viscoelastic materials, under periodic loading and unloading, the stress-strain relationship are not equal with each other; the gap between them is called hysteresis.



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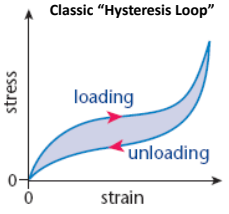
Introduction to Corneal Hysteresis

Hysteresis: Not a New Concept

Sir James Alfred Ewing
Identified the phenomenon of hysteresis and coined the term in 1890



- A measurement that characterizes response to application and removal of force (load/unload)
  - Found in materials or systems that do not follow forces applied to them but react slowly, *or*
  - ***Dissipate a portion of the applied energy.***

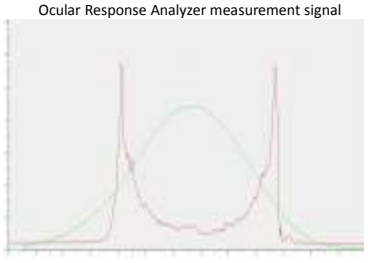
Introduction to Corneal Hysteresis

What is Corneal Hysteresis (CH)

- Corneal hysteresis: is a measure of biomechanical properties of the cornea and it is related to the viscoelastic properties of the corneal tissue.

- The visco-elasticity of the cornea: is the ability of the corneal tissue to absorb and dissipate energy.

Ocular Response Analyzer measurement signal



David Luce, PhD
Invented the concept
of Corneal Hysteresis

ASSESSMENT OF CORNEAL HYSTERESIS

Ocular Response Analyzer Technology

- **2002: Clinical research with ORA commences**
- **2005: The 1st generation ORA was made commercially available**
- **2012: Generation II ORA was launched**
- **3rd Generation "ORA G3" introduced September 2015**

Measures:

- Corneal Hysteresis (CH)
- Corneeal resistant factor (CRF)
- Goldmann-correlated IOP (IOP_g)
- Corneal compensated IOP (IOP_{CC})

Ocular Response Analyzer Technology
The instrument

Patient positioning

Measurement Screen

Ocular Response Analyzer Technology
Interpretation of measurement values

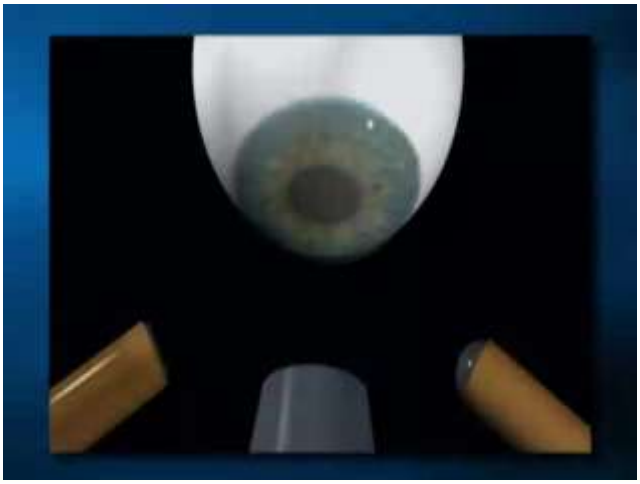
Corneal Compensated IOP: An IOP measurement that is less influenced by corneal properties than Goldmann or other tonometers. This value is closer to the "true pressure" and has been shown to be a better indicator of glaucoma than Goldmann.

Corneal Hysteresis: An indication of corneal biomechanical properties that has been show to be *independently* predictive of future glaucoma progression.
Typical average value is 10.5. Typical Range is 8-14. Low is bad

IOPg: A Goldmann-correlated IOP measurement for reference purposes so that clinicians can appreciate what a Goldmann would read simultaneously with the IOPcc value above.

Waveform Score: A signal analysis algorithm that rates the "quality" of the measurement signal on a scale of 0-10. The higher the value, the more reliable the IOP and CH values are. 6-10 is excellent. 4-5 is not so good. 3 or below is poor.

Ocular Response Analyzer Technology
How does it work?

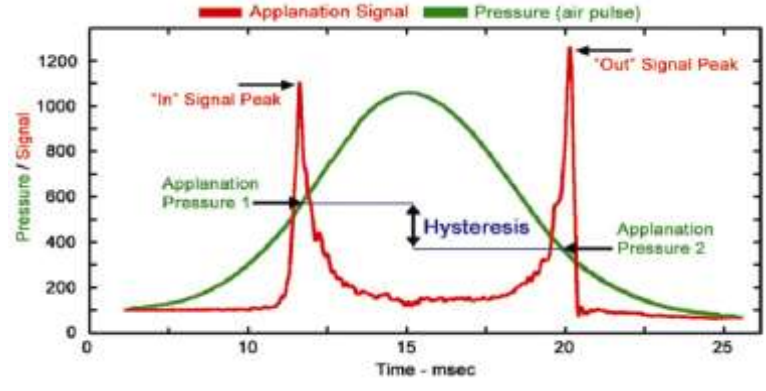


Ocular Response Analyzer Technology

Corneal Deformation

Ocular Response Analyzer Technology

Bi-direction Applanation Signal



Introduction to Corneal Hysteresis

CH: Average Values in Normal Subjects

CH Values in Normals around the world	N	CH*
Brazil	105	10.1 ± 1.8
UK	272 pairs	10.2 ± 1.2
China	125	10.9 ± 1.5
Japan	204	10.2 ± 1.3
Spain	88	10.8 ± 1.5
USA	44	10.5 ± 1.2

*CH units are mmHg

Factors Affecting Corneal Biomechanical Properties

- AGE.
- Central Corneal Thickness .
- Refractive Error and Axial Length.
- Intraocular Pressure .
- Glaucoma.
- Keratoconus.
- Fuchs Corneal Dystrophy.
- Diabetes.
- Soft Contact Lens Wear.
- Orthokeratology.
- Cross-Linking.
- Keratoplasty.
- Intrastromal Corneal Ring Segments.
- Refractive Surgical Treatments(LASIK ,PRK).

Indications of CH

- Indicator for glaucoma progression risk and how much damage we have.

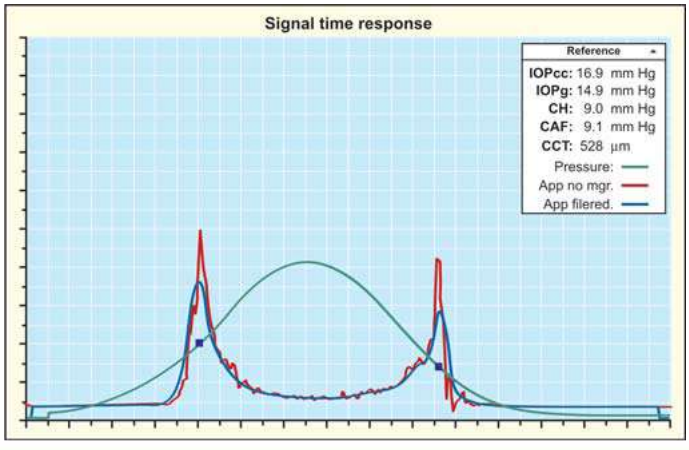
  -Low CH Strongly associated with glaucoma progression.

- Tissue properties indicator in refractive surgeries.

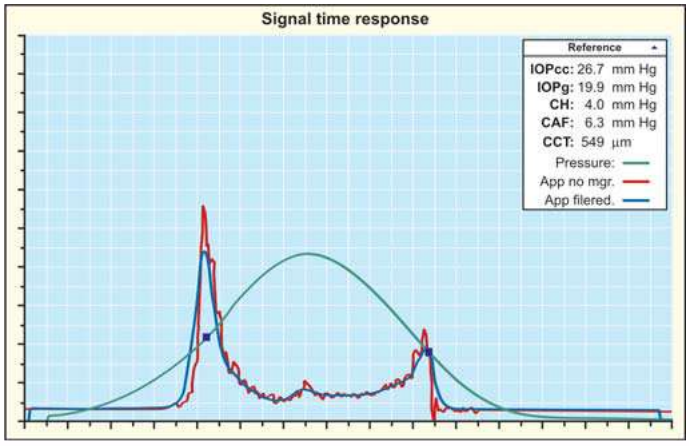
  - Low CH means weak cornea

  - High CH means taught cornea.

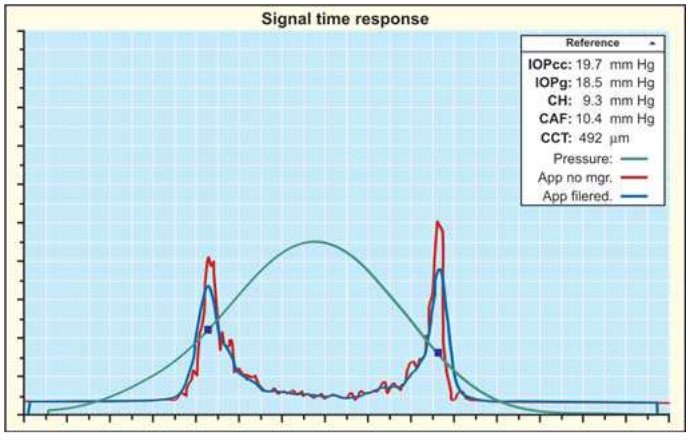
Normal-IOPcc and IOPg close and in normal range
CH and CRF close and in normal range



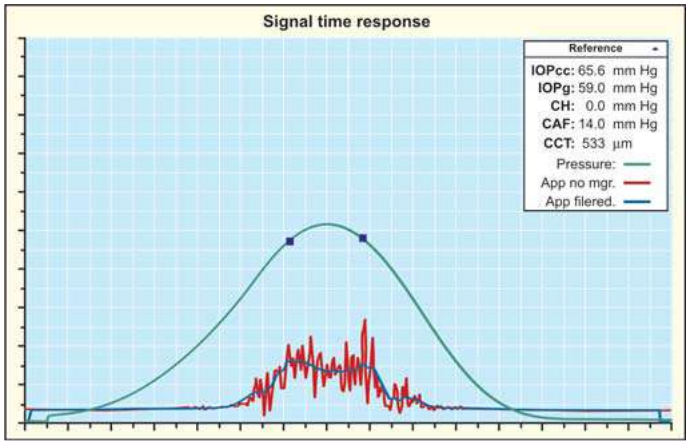
NTG—IOPcc greater than IOPg, low CH and CRF low amplitude peaks



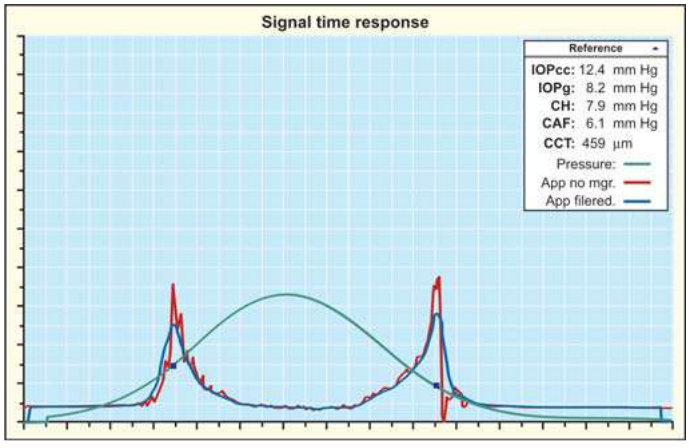
Stable POAG on medications-CH and CRF in normal range IOP well-controlled. Signal is smooth



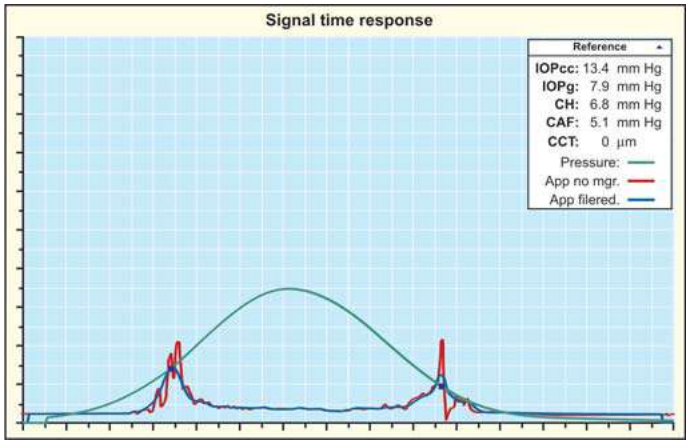
Blind eye - Signals are low amplitude, noisy and lumpy
IOPcc and IOPg are elevated. CH is very low, CRF is elevated



Post LASIK IOPcc higher than IOPg. CH, CRF and CCT low. Low amplitude signals with thin sharp peaks, noisy signals



Keratoconus - IOPcc higher than IOPg, low CH and CRF noisy, low amplitude signals, less repeatable values



New Imaging Techniques to Measure the Corneal Biomechanical Properties

- Corneal Visualization Scheimpflug Technology (Corvis ST; Oculus, Wetzlar, Germany). which is commercially available since 2011. This device is based on:

  - Non-contact air puff tonometer combined with an
  - Ultrahigh Speed Scheimpflug camera, which records
  - 4330 images per second along an 8mm horizontal corneal coverage during corneal deformation under an air puff indentation.

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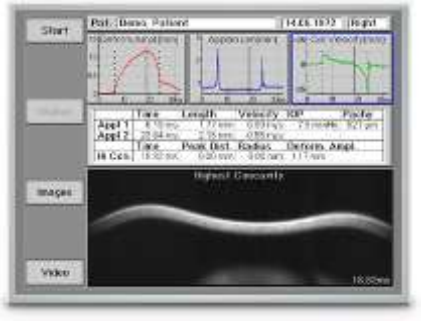

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New Imaging Techniques to Measure the Corneal Biomechanical Properties

- Dynamic Corneal Surface Topography.
- Dynamic Corneal Imaging.
- High speed Swept Source OCT.
- OCT Elasto-graphy.
- Corneal Transient Elasto-graphy.
- Quantitative Ultrasonic Spectroscopy.
- Optical interferometric techniques.

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Thank You!