

ASSESSING CORNEAL BIOMECHANICS

The importance of these properties rests primarily with their effects on IOP measurement.

BY LEON W. HERNDON, MD



Glaucoma can be defined as a progressive optic neuropathy, with characteristic morphologic changes of the optic nerve head and nerve fiber layer. Elevated IOP is the major modifiable risk factor for the development¹ and progression² of the disease. The Goldmann applanation tonometer is currently the gold standard

for measuring IOP. In first describing their applanation tonometer, Goldmann and Schmidt discussed the effect of central corneal thickness (CCT) on IOP as measured by the new device.³ They felt that variations in corneal thickness occurred rarely in the absence of corneal disease but acknowledged that, at least theoretically, CCT might influence applanation readings. It has since become apparent that CCT is more variable among clinically healthy patients than Goldmann and Schmidt ever realized.

Studies by Von Bahr showed large variations in CCT within a healthy population,^{4,5} and research by Ehlers and coworkers demonstrated that this variation in CCT had an effect on applanation-measured IOP.² Many studies have since looked at the influence of CCT on IOP measurement, with most agreeing that measured IOP rises as CCT increases.⁶ CCT alone, however, accounts for only a small proportion of the interindividual variation in measured IOP.

CORNEAL HYSTERESIS

Goldmann applanation tonometry measures IOP by flattening the cornea, which is not neutral in this measurement. Liu and Roberts showed that factors affecting corneal resistance include structural considerations such as the amount of rigidity produced by the way the collagen beams in the tissue line up.⁷ The “bendability” of corneal tissue can also be affected by short-term factors such as the presence of corneal edema.

The Ocular Response Analyzer (ORA; Reichert) measures the corneal response to indentation by a rapid air pulse. The principles of the instrument are based on those of noncontact tonometry: the IOP is determined by the air pressure required to applanate the central cornea. The

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ORA takes two measurements of the corneal response to the pulse of air: the force required to flatten the cornea as the air pressure rises (force-in applanation, P1) and the force at which the cornea becomes flat again as the air pressure falls (force-out applanation, P2). The difference between the two pressures is termed *corneal hysteresis* (CH).

CH is a direct measure of the cornea’s biomechanical properties and may more completely describe the



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“It has only recently become possible to measure the biomechanical properties of the cornea in vivo.”

contribution of corneal resistance to IOP measurements than CCT alone.⁸ There are now several hundred publications on the subject, many of which validate and support the use of CH in glaucoma care. Among the first studies to demonstrate the clinical utility of CH as a risk factor for glaucoma was a retrospective report of 230 glaucoma patients and suspects.⁹ The goal of the research was to identify associations with progression. A lower CH was more associated with progressive visual field loss in this study than was a lower CCT.

CH has also been associated with the risk of progression in patients with normal-tension glaucoma (NTG). A retrospective study of 82 eyes being treated for NTG included an assessment of CH.¹⁰ The study sample was then divided into two groups: those with CH higher than the mean and those with CH lower than the mean. The risk of NTG progression was 67% in the eyes with low CH and only 35% in the eyes with high CH. In a multivariate model of visual field progression, CH was highly predictive, whereas CCT was not significantly predictive at all. This study demonstrated that CH can be used independently of IOP and CCT as a prognostic factor for glaucomatous progression.

Asymmetry in primary open-angle glaucoma may also be explained, at least in part, by CH. In a prospective crossover study, investigators observed 117 patients with asymmetric primary open-angle glaucoma.¹¹ Among several factors evaluated as having a potential association with asymmetry of glaucoma severity, CH offered the best discriminative power for discerning the worse eye.

STRUCTURAL DIFFERENCES

It is possible that differences in corneal biomechanics indicate more generalized structural differences between eyes. Wells et al assessed healthy and glaucomatous eyes for the relationship between (1) acute IOP-induced optic nerve head deformation and (2) CH and CCT.¹² The investigators found that, in glaucoma patients, CH but not CCT was associated with increased deformation of the optic nerve's surface during transient elevations in IOP. That this finding did not hold true in control patients suggests that glaucoma may modify the biomechanical properties of tissues supporting the optic nerve head.



AT A GLANCE

- Corneal hysteresis (CH) is a direct measure of the cornea's biomechanical properties and may more completely describe the contribution of corneal resistance to IOP measurements than central corneal thickness alone.
- Researchers found that a lower CH was more associated with progressive visual field loss than was a lower central corneal thickness. In another study, CH was associated with the risk of progression in patients with normal-tension glaucoma.
- A prospective crossover study suggested that CH may at least partly explain asymmetry in primary open-angle glaucoma.
- Differences in corneal biomechanics may indicate more generalized structural differences between eyes.

CONCLUSION

It has only recently become possible to measure the biomechanical properties of the cornea in vivo, and the importance of these properties rests primarily with their effects on IOP measurement. Corneal biomechanics, however, may provide an indication of the structural integrity of the optic nerve head. Further work is required to determine precisely how clinicians may be able to risk stratify glaucoma patients based on their biomechanical properties. ■

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