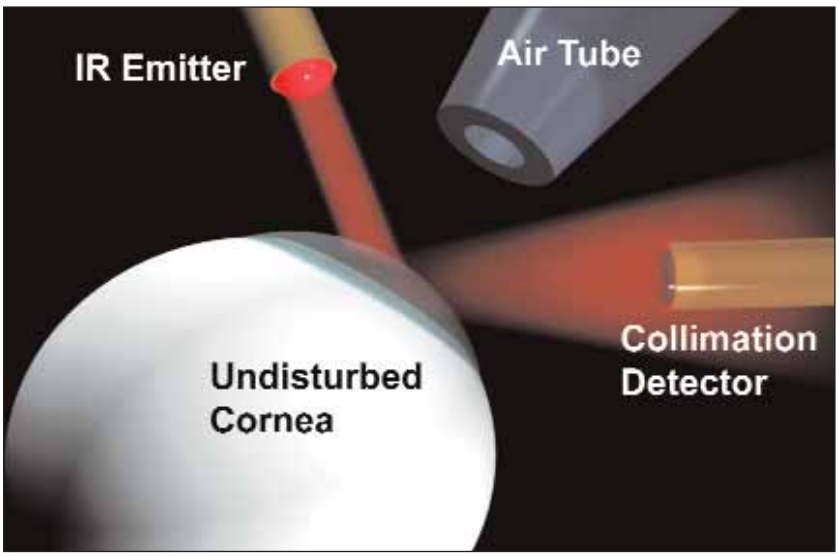
The Ocular Response Analyzer

Measuring the biomechanical properties of the cornea might provide insight into the pathophysiology of glaucoma.

BY TONY REALINI, MD

Glaucoma specialists have long recognized that central corneal thickness (CCT) influences the accuracy of applanation tonometry, but the clinical relevance of this relationship was confirmed only after several landmark studies established that thin corneas are an independent risk factor for glaucomatous progression.[1,2] Based on this research, clinicians not only began to incorporate CCT into risk models, but they also started using pachymetry as a surrogate measurement of corneal biomechanics.

In 2004, Reichert Ophthalmic Instruments, Inc. (Depew, NY), introduced the Ocular Response Analyzer (ORA). In addition to providing information about corneal thickness and IOP, this instrument measures corneal hysteresis and the corneal resistance factor, two newly defined parameters that describe the cornea's viscoelastic properties.



(All images courtesy of Reichert Ophthalmic Instruments, Inc.)

Figure 1. The ORA's sensor consists of an infrared light emitter, a light detector, and a pneumatic tonometer.

Refractive surgeons have used the ORA to detect degenerative corneal disease (eg, keratoconus and Fuchs' dystrophy) and, in some cases, to predict the risk of ectasia after corneal refractive surgery.[3-5] Preliminary research suggests that this instrument may also help clinicians to understand the relationship between corneal biomechanics and the pathophysiology of glaucoma.[6-11] This article describes how I use the ORA in my practice and what I hope to learn by measuring corneal hysteresis.

OPERATING THE ORA

The ORA is easy to use, because its built-in eye tracking software automatically positions the instrument's sensor (Figure 1) over patients' eyes. Once the ORA is in place, it directs a stream of air toward the eye that first flattens (applanates) and then indents the cornea. At the moment of applanation, the infrared light reflected by the cornea aligns with the detector. This event is recorded as peak (P1) on the ORA's signal plot (Figure 2).

As the device continues to direct air toward the eye, the cornea becomes concave, the light disperses, and the applanation signal decreases. The light realigns with the infrared detector after the air pulse is discontinued and the cornea passes through a second applanation event (recorded as P2 on the signal plot). At the end of the test, the cornea returns to its baseline convex shape.

WHAT THE ORA MEASURES

The ORA provides four distinct measurements: two IOP values and

two corneal biomechanical values. The first IOP value is an estimate of Goldmann IOP (IOPG) and corresponds to the IOP value at the first applanation point in the ORA waveform (P1). The second IOP value, IOPCC, is an estimate of IOP corrected for the biomechanical properties of the cornea. The two biomechanical values provided by the ORA are called *corneal hysteresis* and the *corneal resistance factor*. Corneal hysteresis is a quantification of the cornea's ability to absorb and/or dissipate energy (viscous damping). It is calculated as the difference in pressure between the two corneal applanation events (P1 minus P2) in the waveform. The corneal resistance factor is also derived from these two pressure values but in a more complex calculation that provides a combined estimate of both the viscous and elastic nature of the corneal tissue.

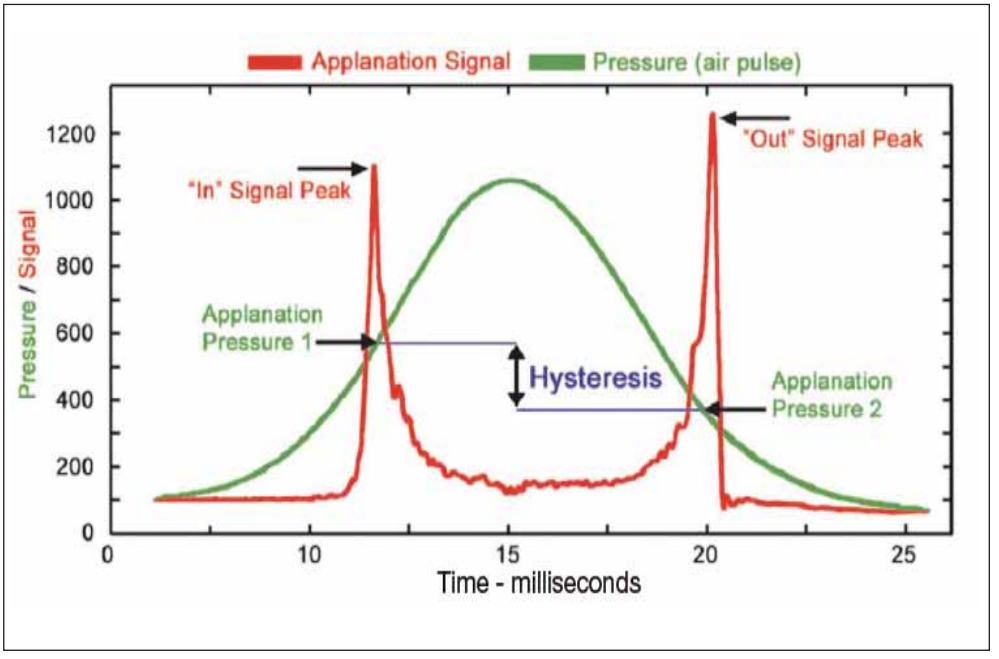


Figure 2. The green line on the ORA signal plot indicates the pressure exerted on the cornea during the applanating events. The red line shows the amplitude of the infrared signal. The first and second peaks occur during the inward and outward applanation events, respectively.

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A convenient feature of the ORA is a built-in ultrasound pachymeter with a probe. Although it requires anesthesia (and the ORA measurements do not), it is handy to have the capacity to measure multiple clinical parameters with one instrument.

THE ORA AND GLAUCOMA

When reviewing the ORA output for a patient, I glance at, but do not give much weight to, the two IOP values. I have Goldmann tonometry readily available and still consider it the clinical standard for IOP assessment, so the ORA's IOPG is of little value to me. In fact, various studies claim that the ORA's IOPG under- or overestimates IOP relative to Goldmann tonometry.[10,12]

Similarly, I tend not to place much weight on IOPCC. This may seem counterintuitive, as the device was reportedly developed to provide a truer estimate of IOP. I do not believe, however, that it is clinically useful to correct IOP based on corneal biomechanical properties. I do not correct IOP based on corneal thickness, either, because the relationship between CCT and IOP is likely too complex to allow simple corrections. More importantly, I am not convinced that the relevance of corneal biomechanical properties is limited to their effect on IOP. I suspect that corneal biomechanics provides insight into ocular biomechanics, which in turn may provide insight into an eye's susceptibility to glaucomatous optic neuropathy. For instance, a thicker or stiffer cornea may reflect greater ocular rigidity in a given eye, and such an eye may be better able to withstand elevated IOP without damage. Dismissing corneal biomechanics as merely a source of inaccurate IOP measurements may deprive us of this more important information about ocular biomechanics.

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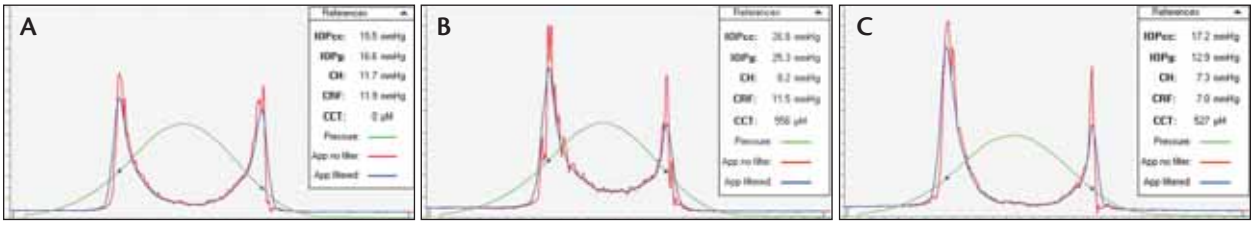

Figure 3. These waveforms were obtained from a healthy patient (A), a patient with newly diagnosed primary open-angle glaucoma (B), and a patient whose primary open-angle glaucoma is progressing on medical therapy. Note the difference in corneal hysteresis between the healthy (11.7 mm Hg) and the glaucomatous eyes (8.2 and 7.3 mm Hg).

biomechanical properties than CCT. Preliminary research suggests that the corneal hysteresis of glaucomatous eyes is lower than that of their healthy counterparts[6-11] (Figure 3). These findings suggest that glaucoma (or its treatment) alters the cornea's biomechanical properties, or that eyes with lower hysteresis values are more susceptible to glaucoma.

CLINICAL UTILITY

More research is needed to clarify the relationship between corneal biomechanics and glaucoma. In the meantime, I have begun incorporating ORA assessments into my clinical practice.

I currently use the information collected by the ORA to supplement the data provided by tonometry, pachymetry, perimetry, and examination/imaging of the optic nerve and retinal nerve fiber layer. When considering corneal hysteresis values, my approach is similar to the way I incorporate CCT values into individual risk assessments. A low CCT or hysteresis value in a patient with well-controlled and stable glaucoma does not warrant a change in management. In a patient with apparently well-controlled but progressing disease, however, or in a newly diagnosed patient, a low value might warrant the consideration of a lower target IOP. Conversely, just as a high CCT value is reassuring in a patient with elevated IOP but normal optic nerves and visual fields, so, too, does a high hysteresis value provide some insight into the ocular hypertension phenotype and support my decision not to treat many of these patients.

FUTURE DIRECTIONS

As with any new technology, the ORA's role in the clinical management of glaucoma is currently limited by a lack of quality data. What does the ORA tell us about our patients? We do not fully know yet, because we have never before had access to this sort of biomechanical information, and we have no established technologies against which to validate the new instrument. The same was once true of tonometry, automated perimetry, and optic nerve imaging early in their respective development. To optimize the ORA's use in clinical practice, we will need prospective longitudinal studies in which corneal hysteresis values are correlated to the risk of developing glaucoma or its progression, just as recent major clinical trials have provided these data for CCT.

> "Preliminary research suggests that the corneal hysteresis of glaucomatous eyes is lower than that of their healthy counterparts."

In addition, I think that Reichert Ophthalmic Instruments, Inc., could improve the clinical utility of the ORA by adding software that automatically rates the quality of individual scans, much in the way of advanced imaging systems. An objective scoring system would increase my confidence in the ORA's measurements, and it would facilitate the acquisition of quality data by my technical staff.

Physicians should be aware that the reimbursement for examinations performed with the ORA is evolving. The American Medical Association's CPT panel committee recently established a category III code (0181T) for the ORA, but Medicare has not issued a National Coverage Determination for the code. I therefore recommend obtaining an Advanced Beneficiary Notice from all patients prior to testing. The introduction of CPT code 0181T precisely mirrors the tracking code for assessing CCT that was issued several years ago. Clinicians who are performing ORA testing are encouraged to submit claims using the new code in order to demonstrate that the procedure is being performed and justifies reimbursement.

CONCLUSION

The relationship between corneal hysteresis and glaucoma is still unknown. As practitioners gain more clini-

cal experience with the ORA, its unique measurements may improve their understanding of ocular biomechanics and, consequently, help them to assess patients' susceptibility to progressive optic nerve damage and visual field loss in the presence of elevated IOP. ❑

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1. Gordon MO, Beiser JA, Brandt JD, et al. The Ocular Hypertension Treatment Study: baseline factors that predict the onset of primary open-angle glaucoma. *Arch Ophthalmol.* 2002;120:714-720.
2. European Glaucoma Prevention Study (EGPS) Group. Results of the European Glaucoma Prevention Study. *Ophthalmology.* 2005;112:366-375.
3. Luce DA. Determining in vivo biomechanical properties of the cornea with an ocular response analyzer. *J Cataract Refract Surg.* 2005;31:156-162.
4. Pepose JS, Feigenbaum SK, Qazi MA, et al. Changes in corneal biomechanics and intraocular pressure following LASIK using static, dynamic, and noncontact tonometry. *Am J Ophthalmol.* 2007;143:39-47.
5. Kerautret J, Colin J, Touboul D, Roberts C. Biomechanical characteristics of the ectatic cornea. *J Cataract Refract Surg.* 2008;34:510-513.
6. Congdon NG, Broman MA, Bandeen-Roche K, et al. Central thickness and hysteresis associated with glaucoma damage. *Am J Ophthalmol.* 2006;141:868-875.
7. Wells AP, Garway-Heath D, Poostchi A, et al. Corneal biomechanics and optic nerve head compliance: corneal hysteresis but not corneal thickness correlates with optic nerve surface deformation in glaucoma patients. *Invest Ophthalmol Vis Sci.* March 3, 2008 [E-pub ahead of print].
8. Bochmann F, Ang GS, Azuara-Blanco A. Lower corneal hysteresis in glaucoma patients with acquired pit of the optic nerve. *Graefs Arch Clin Exp Ophthalmol.* 2008;246:735-738.
9. Ang GS, Bochmann F, Townend J, Azuara-Blanco A. Corneal biomechanical properties in primary open angle glaucoma and normal tension glaucoma. *J Glaucoma.* 2008;17:259-262.
10. Sullivan-Mee M, Billingsley SC, Patel AD, et al. Ocular Response Analyzer in subjects with and without glaucoma. *Optom Vis Sci.* 2008;85:463-470.
11. Wang J, Chagnon M, Bayoumi A, et al. Correlation between glaucoma damage, ocular biomechanical properties, and vasospasm. Poster presented at: The Annual Meeting of the Association for Research In Vision and Ophthalmology; April 30, 2008; Fort Lauderdale, FL.
12. Martinez-de-la-Casa JM, Garcia-Feijoo JG, Fernandez-Vidal A, et al. Ocular Response Analyzer versus Goldmann applanation tonometry for intraocular pressure measurements. *Invest Ophthalmol Vis Sci.* 2006;47:4410-4414.