BENCH TO BEDSIDE

TONOMETRY DEBATE

Industry weighs in on the IOP measurement discussion.

BY DAVID A. TAYLOR AND DAN EISENBERG, MD

The following reader-author exchange refers to the article "What Is the Real IOP?" by Dan Eisenberg, MD, that ran in GT's July/August edition. (Read it at bit.ly/bench1116.) This was the second installment of a three-part series on the subject in our "Bench to Bedside" column.

It remains frustrating to measure IOP with devices that give us variable readings in the same patient. Which measurement is the real pressure? Most ophthalmologists still use the Goldmann tonometer, but both Nathan Radcliffe, MD, and Dan Eisenberg, MD, point out the many limitations of Goldmann tonometry. These limitations may make a difference in visual outcome over the lifetime of some glaucoma patients. It is thought that the biomechanics of the eye likely account for some of the inaccuracies and that methods to evaluate "ocular biomechanics" might give us insight into glaucomatous disease. This discussion led to the response from David A. Taylor of Reichert Technologies concerning Dr. Eisenberg's article on identifying the "real" IOP. We think *GT*'s readers wills obtain a better understanding of ocular biomechanics by reading the comments from Mr. Taylor and Dr. Eisenberg's response.

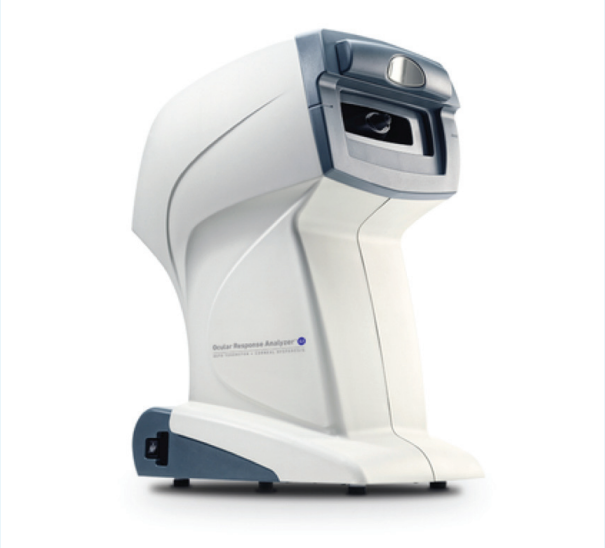
—Ronald L. Fellman, MD, and Davinder S. Grover, MD, MPH, section editors

DAVID A. TAYLOR

I applaud Dr. Eisenberg's efforts to educate readers about the flaws of Goldmann tonometry. I have numerous concerns, however, about inaccurate statements and the exclusion of important information in his article related to corneal hysteresis and the Ocular Response Analzer (ORA; Reichert).

Dr. Eisenberg stated that hysteresis is used in electronics to describe the difference between activation and deactivation of a switch and claims ORA's corneal hysteresis is merely "a thematic analog."

Hysteresis was identified by Ewing in 1890 and is common in physics, engineering, and medicine (my PubMed search pulled up 9,162 publications related to hysteresis). Hysteresis is the output of a measurement involving stress/strain response. It is identified as a lag between making a change, such as increasing and then decreasing applied



Ocular Response Analyzer.

> "Penetrating manometry studies are plagued by numerous confounding factors. As such, conclusuons are questionable."

force, and the response to that change, and it is usually related to dissipation of energy (damping).[1] The ORA rapidly deforms the cornea in a load/unload manner in order to provide the corneal hysteresis measurement, which is a function of viscoelastic damping in the corneal tissue.[2] As such, using the term *hysteresis* to describe the ORA measurement output is appropriate.

There are over 600 peer-reviewed publications on ORA, but Dr. Eisenberg referenced only one that found "corneal hysteresis is influenced by age, corneal thickness, and IOP," which he asserted "presents a problem for interpreting the results." Dozens of similar studies show that such relationships exist but are weak and that the corneal hysteresis measurement provides independent information related to corneal biomechanics.[3-6]

Dr. Eisenberg stated that "the theory is that this hysteresis value somehow relates to intrinsic corneal structure and this may also be related to the risk of glaucomatous progression." The conclusions from published articles are based on observations from human eye measurements, not theory. He remains "unconvinced … that hysteresis is of value in the management of glaucoma." He failed to mention dozens of articles, including longitudinal studies, that show corneal hysteresis is independently and more powerfully predictive of glaucomatous progression than parameters such as IOP or central corneal thickness.[7-11] Numerous studies provide evidence that corneal hysteresis is related to ocular biomechanics and optic nerve characteristics such as deformability and rate of retinal nerve fiber loss, explaining the link between corneal hysteresis and glaucoma susceptibility.[12-16]

Moving back to the subject of IOP, Dr. Eisenberg stated, since there are "no manometric studies of the IOP measurement provided by the ORA … there cannot be a definite answer regarding its accuracy" and claimed that "studies of tonometer versus tonometer are unacceptable." Penetrating manometry studies are plagued by numerous confounding factors. As such, conclusions are questionable, and results often contradict those of other studies using the same device. So few manometric studies exist that it is impossible to arrive at a clinical consensus based on them. Fortunately, one does not need manometric IOP in order to determine the clinical utility of a tonometer. We can determine if one tonometer outperforms other tonometers in independence from known sources of error (ie, corneal thickness, corneal biomechanics) and, more importantly, in its ability to identify glaucoma or glaucoma risk. Indeed, the IOP measurement provided by the ORA has been shown to be less influenced by corneal properties and to have higher sensitivity and specificity for identifying glaucoma than other methods of tonometry.[17-19]

I hope that Dr. Eisenberg will continue to educate others about the shortcomings of Goldmann tonometry but ask that he provide more accurate explanations of critical concepts regarding device technology and a more fair assessment of the published literature on corneal hysteresis and the ORA.

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DAN EISENBERG, MD

I appreciate Mr. Taylor's detailed response to my impressions of the Ocular Response Analyzer (ORA; Reichert) and the opportunity to further clarify my comments.

With respect to the term *hysteresis*, I hope my comments were not interpreted as a criticism. I intended to inform *GT*'s readers that this term was not native to tonometry measurements and has been adapted to describe one type of dynamic response. Mackay and colleagues first described the dynamic deformation-reformation response of the cornea.[1] They used the term *metrotonometry* to mean the group of properties of corneal deflection such as the rate of change of deflection, the gap between the deformation and reformation pressure (now called *hysteresis*), corneal rigidity, and a form of outflow facility. The *metrotonometry* term never gained popularity, and the phrase "deformation to reformation pressure gap" is lengthy and awkward compared to the breviloquence of *hysteresis*.

They assumed the gap represented a microquantity of aqueous expression during tonometry as opposed to the ORA assumption of a structural corneal property. They also proposed the rate of change of the gap as a form of rapid tonography, which would predict that a lower number would be more associated with glaucoma. Perhaps ORA hysteresis is really a proxy for outflow facility?

Mr. Taylor omitted discussing a major concern regarding the presentation of hysteresis as a single number. As I originally wrote, hysteresis is usually reported as a collection of force-response curves, because the results change based on the initiating conditions. The air jet force can yield different responses for different IOP, corneal thickness, corneal hydration, age, and possibly other factors, just as different rates and magnitudes of air jet can produce different responses for the same IOP. It seems inadequate to compress all of the potential outputs of such a dynamic process into a single number.

The lack of an in vivo manometric study is not trivial and cannot be overcome by any quantity of tonometer-versus-tonometer correlations. Correlation never proves causation and can easily lead to false conclusions.[2] Manometry is the true measurement of IOP and the only way to avoid the confounding factors found in tonometer-versus-tonometer studies. The accuracy of the ORA tonometer remains unknown without an in vivo manometric comparison study.

The volume of correlation studies showing links to hysteresis and glaucoma parameters is also unhelpful. What we clinicians would like to know is what to do with the results. If our patient has borderline IOP but a stable visual field and optical coherence tomography, would a poor hysteresis value alter our clinical decision to change therapy? I answer "no" today but am looking forward to future research. ■

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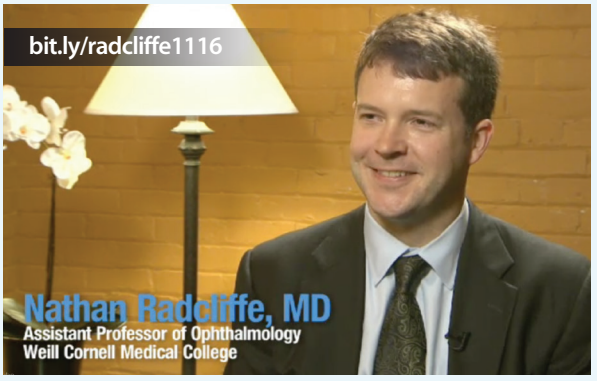
WATCH IT NOW

Nathan Radcliffe, MD, explains why greater understanding of corneal biomechanics may lead to better outcomes for patients.



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