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Corneal Hysteresis:

An Essential Factor for Glaucoma Diagnosis & Management

Glaucoma is a leading cause of irreversible blindness worldwide. The number of people with glaucoma will increase to approximately 112 million by 2040.¹ Despite advancements in diagnosis and treatment, glaucoma is frequently undetected or diagnosed too late. Many treated patients continue to lose vision, despite apparent disease control, according to traditional risk factors.²

Traditional risk factors include: age, race, elevated IOP, family history, and optic nerve characteristics revealed via fundus photograph, optical coherence tomography (OCT) exams, etc.³ The landmark Ocular Hypertension Treatment Study (OHTS), published in 2001, precipitated a paradigm shift with the finding that central corneal thickness (CCT) was a very important risk factor for development of the disease.⁴ Other studies since have confirmed this and established CCT as a glaucoma vital.^{5,6} It should be noted that these studies did not find that CCT-based IOP corrections added value to glaucoma decision making, but that the cornea itself was associated with glaucoma.⁷

Glaucoma diagnosis and treatment requires accurate risk stratification so that resources can be allocated to the proper patients. Since glaucoma is progressive in nature, identification of its onset is essentially impossible. As such, patients with risk factors are monitored, sometimes for years, before a definitive diagnosis can be made.^{8,9} Unfortunately, despite advancements in our understanding of glaucoma risk, all the

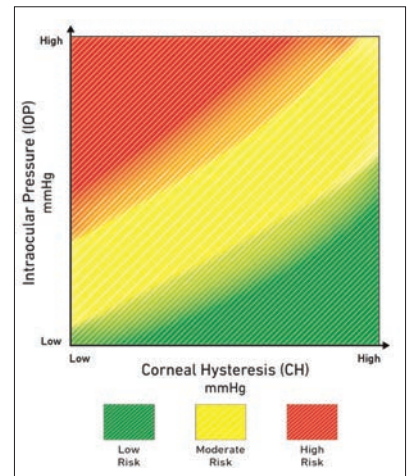
factors noted have relatively poor sensitivity and specificity.¹⁰ Once diagnosed, accurately predicting which patients are likely to progress more rapidly remains difficult. The good news is that a newer parameter, **corneal hysteresis (CH) can help us more accurately identify risk of developing glaucoma and risk of more rapid visual field loss from the disease.**

Hysteresis, a Greek term meaning “delay,” is a property of materials or systems that have a viscous component. Corneal hysteresis, measured by the Reichert Ocular Response Analyzer (ORA), is a biomechanical parameter related to the cornea’s ability to absorb and dissipate energy. In addition to providing CH, the ORA also provides IOP-cc: an IOP measurement that is less affected by corneal properties than other tonometers, including Goldmann applanation tonometry (GAT). Since the operation of the ORA was first described by David Luce in 2005, nearly 700 publications have established evidence for the usefulness of the parameter.¹¹ A substantial number of these publications have focused on glaucoma risk and progression. Several early publications found that CH was associated with the visual field (VF) loss. Eyes with

When compared to other risk factors, CH had two times greater association to glaucoma progression than IOP and three times greater than CCT.

Rate of glaucoma progression per year¹

1. Weinreb RN, Brandt JD, Radcliffe NM, et al. Taking glaucoma risk assessment to the next level: the role of corneal hysteresis. *Rev Optom.* 2015 July; 15(7) Suppl.



worse VF damage tended to have lower CH than normal eyes, or glaucomatous eyes with higher CH. This association seems to be independent from CCT and IOP and was evident even in cases of asymmetric glaucoma progression when IOP and CCT were essentially identical in both eyes of the same patient.¹²⁻¹⁵ Numerous studies have provided us with a better understanding why CH is related to glaucoma, suggesting that corneal biomechanics are related to deformability of the optic nerve and structural changes consistent with the development and progression of glaucoma.¹⁶⁻¹⁸

The aforementioned studies were retrospective and found evidence of an association between CH and glaucoma. To determine if the CH measurement is predictive of glaucoma progression, a series of prospective longitudinal stud-

Every 1 mmHg lower CH was associated with a 21% increase in the risk of developing glaucoma.

ies were conducted. In the first study, a group of 68 glaucoma patients were followed over a four-year period. Researchers demonstrated that the baseline CH measurements were significantly predictive of the rate of future glaucoma progression. When compared to other risk factors, CH had three times greater association with glaucoma progression than CCT. Importantly, investigators showed that a combination of CH and IOP was fundamental in explaining rates of progression. Patients with a high IOP and low CH were particularly at risk for rapid progression. Yet, patients with high IOP and high CH did not progress rapidly.¹⁹ This revelation should fundamentally change the way we stratify risk, and determine efficacy of treatment, in glaucoma patients.

These same investigators sought to determine if these findings were also relevant to glaucoma suspects. They followed 199 patients suspected of having glaucoma over a four-year period. In this study, the baseline CH was predictive of development of visual field loss. Even after adjusting for age, intraocular pressure, central corneal thickness, pattern standard deviation (PSD) and treatment, CH was still highly predictive of glaucoma development. **Every 1 mmHg lower CH was associated with a 21% increase in the risk of developing glaucoma.** These finding support the role of corneal hysteresis as an important factor to be considered in the assessment of glaucoma risk.²⁰

Beyond CH, numerous studies have demonstrated the usefulness of the ORA IOPcc measurement. These studies have shown that the IOPcc measurement agrees with GAT on average, but is not affected by CCT, corneal curvature and corneal biomechanical parameters like Goldmann and other tonometers are.²¹ This would seem to indicate that IOPcc is closer to the true IOP. To validate this theory, a prospective observational study compared IOP measurements from three tonometers (GAT, iCare and IOPcc) in glaucoma patients

followed over time. The results showed that the IOPcc measurement was significantly more associated with glaucoma progression than estimates of IOP provided by GAT and iCare.²²

In conclusion, the corneal hysteresis measurement is no longer novel. A wealth of evidence confirms the usefulness of this parameter in the diagnosis and management of glaucoma. In every instance where CH has been compared to other parameters, including CCT and IOP, the corneal hysteresis measurement is significantly more associated with glaucoma risk. In addition, the IOPcc measurement appears to be a clinically useful tool for the accurate assessment of IOP. The time is now to incorporate this valuable information into routine clinical practice.

Implementing New Technology in Clinical Practice

When deciding to incorporate new technology such as the ORA G3 into clinical practice, several practical matters need to be considered. Ease of use, space required, patient flow, patient friendliness, cost and reimbursement are among the most common concerns.

Dr. Medeiros: My experience with the ORA is more in the laboratory than in the clinic. But I know both of you use the ORA daily in your practices. Where do you put the device, and how does it affect patient flow?

Dr. Radcliffe: I'm at a high-volume surgery center where we see about 250 patients per day. Our ORA is located in a room with OCTs, cameras, perimeters and the like. I obtain a measurement on every new patient or anytime a treatment change or surgery has occurred. I measure my glaucoma patients on the ORA at each visit. My techs run the device, which is done before the patient comes into the lane. It is a very fast test, so I have not seen a negative impact on patient throughput.

Dr. Thimons: We have the ORA in our pre-screening room next to the auto-refractor. Patients simply slide over from the auto-refractor to the ORA. We find that the ORA enhances patient throughput because we rely less on

Goldmann tonometry. I don't use GAT on a large percentage of my patients anymore, since I find the ORA IOP to be better than GAT.

Dr. Thimons: Dr. Radcliffe, do you have the same confidence in the ORA IOPcc?

Dr. Radcliffe: I do. I consider the ORA IOP value to be interchangeable with GAT. In fact, and we have published on this, the evidence suggests it is superior. Colleagues ask me if I would perform surgery based on the IOP value provided by the ORA and my answer is a definitive yes. And it also saves the entire office money on Goldmann prisms, fluorescein drops and the time associated with sterilization.

Dr. Medeiros: How do your patients respond to the air puff?

Dr. Thimons: When we incorporated the ORA, we had some concerns because we had moved away from puff tonometry and told our patients we didn't use it anymore. Now I explain to my patients that this is not the same old puff test. Yes, it uses air, but it provides important information that was not possible before. I tell patients this is measuring strength characteristics of the eye, which helps me to better understand their glaucoma risk. That seems to resonate very well with them. I do not get many complaints about the test.

Dr. Radcliffe: We did not have an air puff device before the ORA. The techs and doctors were worried about patient pushback at first, but this has not been a problem. A few patients express concerns, but after the test they usually say, 'that wasn't bad'. Most of my glaucoma patients are happy to better understand their true pressure. To be fair, I'd say that we get an equal number of patients who express concerns about other methods of tonometry.

Dr. Medeiros: How do technicians handle the device?

Dr. Thimons: I think the techs initially didn't want to learn a new device. But the instrument is so easy to use, the learning curve is short. You just put the patient's head against the headrest and push a button. It doesn't get much sim-

pler. There is a quality score that helps the tech know it was a good scan. If they get a low score, they re-measure.

Dr. Medeiros: How did you justify the purchase of yet another instrument?

Dr. Radcliffe: Like you, I have been using the ORA in the research environment for more than 10 years. In my private practice, there was already an older generation ORA in place. When the newer model G3 came out, it was an easy decision to upgrade. The device is smaller, faster and integrates with EMR better. We do get reimbursement for the corneal hysteresis measurement for our Medicare patients and some of our private insurance patients, which helps offset the cost.

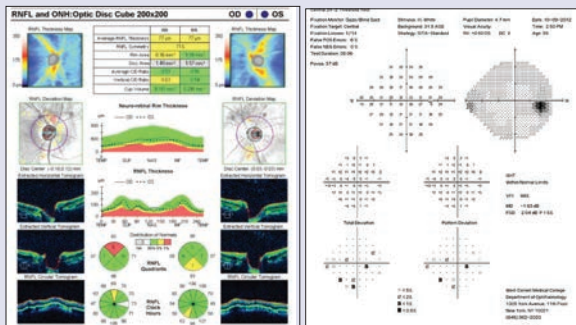
Dr. Thimons: The instrument is not very expensive compared with many other 'toys' we need. We get some reimbursement in our state too. Regardless, I find that so many patients who are glaucoma suspects want to use this device that it will pay for itself just in the increase in other tests we do—and we are finding more glaucoma earlier. I really consider it to be a dual-purpose device: The corneal hysteresis measurement makes the device a worthy addition to my practice, but the IOPcc measurement is the icing on the cake.

Dr. Medeiros: How do you take what we have learned from the clinical studies and apply the ORA results to real-world glaucoma decision making?

Dr. Thimons: With regards to the IOPcc measurement, I simply treat it like a Goldmann number without the fear of corneal artifact. I consider the corneal hysteresis measurement to be the A1C of glaucoma. In diabetes, A1C tells us the status of the disease and the potential for future worsening of the disease. Corneal hysteresis does this for glaucoma. In my patients with high hysteresis, I will tolerate a higher IOP and monitor them less frequently because they are less likely to progress. Conversely, in my low hysteresis patients, I will attempt to lower the IOP more than I previously would have. I pay closer attention to fluctuations in IOP or the occasional high

CASE 1

Age: 70-year old man presents in 2007
IOP (GAT): 28 mmHg OU
CCT: 545 microns
VF: Full (PSD 1.4)
OCT: Borderline, some thinning
VCDR: 0.7
Corneal hysteresis: Not available at the time.



Five Years Later:

Patient has been on three topical agents (PGA, b-blocker and CAI).
IOP (GAT): Still 24 mmHg
VF: No progression in 5 years
ORA data: CH=13 mmHg (2 standard deviations higher than average)
IOPcc=19 mmHg
Conclusion: This patient is low risk. The IOP is lower than we thought, and the high CH is protective against glaucoma progression. We decide to continue medical therapy with annual monitoring of VF and OCT.

CASE 2

59-year old woman presents in 2016 at another practice
IOP: 21 mmHg OU
CCT: 560 microns
VF: Mostly full, but questionable
OCT: Normal, with cupping
VCDR: 0.8
Corneal hysteresis: Not available at the time.
Clinical decision in 2016: No major risk factors for progression. We decide to monitor without treatment.



2017:

OD: Rapid progression at modestly elevated IOP (PSD 6.11)
ORA data: CH=6.8 (3 standard deviations lower than normal)
Conclusion: Low CH, particularly with a moderately elevated IOP and a thicker CCT, suggests that treatment should have been considered earlier. We initiate IOP lowering therapy immediately.

reading. These patients may get referred to surgery much earlier than I would have in years past, especially if they are younger, because I know the low CH puts them in a high-risk category.

Dr. Radcliffe: I agree. I think I can best explain how I use the information with the two case examples in this piece. ■

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