The Role of 24-Hour IOP Monitoring in Glaucoma

Continuous monitoring would allow clinicians to develop a more complete IOP profile on which to base long-term treatment goals for patients.

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Imagine the occurence of the following scenario in your clinic. Mr. Jones, a glaucoma patient, comes in for a routine IOP check and visual field testing. The IOP is 15 mm Hg in his treated right eye, a pressure that you have determined to be appropriate based on his prior IOP history and visual fields, the optic nerve's appearance, and corneal thickness. This time, however, there is possible progressive visual field loss and a small disc hemorrhage in the right eye. Is the IOP that you are measuring representative of the patient's 24-hour IOP? Is he truly adherent to prescribed medical therapy? Does he have significant variation in his IOP and experience nocturnal spikes? Is your target IOP simply inadequate? How aggressive should treatment be?

Continuous IOP monitoring would greatly inform clinicians' decisions for treating glaucoma patients. I thank this month's authors for submitting their update on this important area of research in glaucoma.

—Barbara Smit, MD, PhD, section editor

The role of IOP in the pathogenesis and treatment of glaucoma is undisputed. Although IOP is absent from the current definition of glaucoma, it remains the only modifiable risk factor for the disease. Currently, all commercially available medical, laser, and surgical treatments target a reduction of IOP to slow or halt worsening of glaucomatous optic neuropathy. With clinicians' reliance on this single metric, it is critical that they obtain an accurate, precise, and complete assessment of IOP in all glaucoma patients. Goldmann applanation tonometry (GAT) is the standard method in clinical practice. Although GAT has some inherent limitations, an often-overlooked shortcoming is its static nature; GAT provides a single, momentary measure of a patient's IOP in the upright position. Depending on the severity of disease, a patient is typically seen every 3 to 4 months, yielding a handful of IOP snapshots from which the clinician must decide long-term treatment goals and prescribe or modify therapy. These singular readings fail to provide any information on nocturnal IOP or diurnal IOP fluctuation, and they can miss true peak IOP levels over 60% of the time.[1]

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Currently, the diurnal tension curve (DTC) is the most common method for assessing a patient's IOP variation throughout the day. The DTC involves multiple daytime IOP readings by GAT, usually with the patient in an upright position, and he or she remains in the clinic during the process. Although DTC provides a rough pattern of an individual's IOP during clinic hours, it fails to provide data from the evening and overnight periods. These data require the admission of patients to an inpatient hospital or sleep laboratory with measurements taken repeatedly throughout the nocturnal period. This protocol has several limitations, including poor reflection of physiological IOP in a patient's usual environment, lim-

(Courtesy of iCare.)

Figure 1. The iCare Home tonometer.

ited access to inpatient services, the need for specialized equipment, significant cost, and prolonged time requirements of patients. Drawbacks such as these have limited the use of a DTC or 24-hour inpatient session to research protocols or atypical cases.

HOME TONOMETRY

One method by which to avoid an inpatient stay and minimize disruption of patients' normal daily routines is home IOP monitoring. This approach has long been the norm for diabetic patients who monitor blood glucose and patients with hypertension who track blood pressure. The field of glaucoma has lagged far behind in developing a reliable, safe, and economical method for self-tonometry. A few attempts include the Ocuton S (EPSa), which is based on the principles of applanation, and the Proview Eye Pressure phosphene tonometer (Bausch + Lomb), which is based on the induction of the sensation of light from external eye pressure.[2,3] Both instruments were found to be uniformly inaccurate when compared to the standard of GAT, and patients also expressed concern over the requirements of the Ocuton S for topical anesthesia and corneal contact.

More recently, the iCare Home (iCare; Figure 1) has shown promise as a more accurate and user-friendly method for home tonometry.[4] The device determines IOP based on rebound tonometry principles and uses a probe so small that topical anesthesia is not required. The clinic version of the iCare TAO1i is now FDA approved. Comparative studies have shown that IOP readings correlate well with GAT,[5] and approximately 75% of patients were able to correctly perform self-tonometry, with readings that were reasonably similar to those obtained with GAT.[6] Unfortunately, no devices are currently FDA approved for self-tonometry.

CONTINUOUS IOP MONITORING

Although home tonometry would provide insight into the IOP profile of glaucoma patients outside the clinic,

(Courtesy of Sensimed.)

Figure 2. The Sensimed Triggerfish Sensor in the eye.

it would still leave large gaps in data and fail to provide nighttime IOP measurements. The need for continuous IOP monitoring then becomes paramount for a complete assessment of patients' IOP profiles. Recently, Downs et al developed an implantable pressure transducer system that allowed continuous IOP monitoring for several months.[7] The investigators were able to illustrate multiple fluctuations in IOP that occurred over seconds, hours, and days in nonhuman primates. Although the data were enlightening, this type of invasive implantable system is not likely useful clinically.

A NONINVASIVE APPROACH

Another implantable approach by Todani et al involves a circular pressure transducer embedded in silicone that is placed into the lens capsule.[8] The transducer relays IOP data wirelessly through radiofrequency to an external reader that also powers the device. Preclinical use of the device in rabbits was well tolerated and produced comparable readings to external tonometry and direct manometry. Clinical studies of this implantable device in humans are currently underway. Limitations of implanted devices include the risks associated with invasive surgery, failure of the device, and the need for intervention and revision over time.

The most practical and needed approach for continuous IOP monitoring is a method that is temporary, ambulatory, and noninvasive. The first commercially available device to meet these requirements is the Triggerfish wireless contact lens sensor (CLS) from Sensimed (Figure 2).[9] The device consists of a strain gauge, wireless antenna, and microchip, all embedded in a soft silicone contact lens. Once fitted to the eye, the strain gauge overlies the corneoscleral limbus and

measures very small changes in the ocular circumference, which are assumed to correspond to fluctuations in intraocular volume and IOP. Of note, the CLS measurement of these IOP-related changes also depends on the buffering effects of viscoelastic properties of the cornea and sclera. At present, little is known about the impact of these factors on CLS data, which are wirelessly transmitted to an antenna taped to the orbital rim and then saved in a recorder worn around the patient's torso. A 24-hour IOP-related profile is then plotted with the accompanying software highlighting both rapid changes, as seen with ocular pulsation and blinking, and a patient's peak IOP and fluctuations throughout the day. When analyzed in conjunction with a patient's activity diaries, the clinician can determine how certain activities, positions, and medications may affect the IOP curve.

Initial use of the CLS has revealed good functionality and tolerability.[9,10] The most common adverse effects included blurred vision and conjunctival hyperemia that were mild to moderate in severity and temporary. The device is the first of its kind to provide noninvasive, continuous monitoring of an ocular metric that may directly correlate to IOP in an ambulatory setting but also captures the overnight period without the requirement of repeated sleep disturbance. One notable limitation of the device is the output signal is in arbitrary units of millivolts, which cannot be readily converted to millimeters of mercury.

Several other invasive and noninvasive approaches are currently in preclinical stages and promise to advance the field in the near future. It is also important to mention that, once the stage of obtaining reliable 24-IOP data is achieved, clinicians will be confronted with the bigger challenges of how to analyze and interpret the data and how to apply the new information to the care of patients.

CONCLUSION

The role of 24-hour IOP monitoring in glaucoma continues to evolve. Historically limited by logistical and time constraints, technology is being developed to more easily obtain comprehensive IOP profiles of patients. These data may shed light on the disease process, promote individualized treatments, and improve patients' education and adherence to prescribed therapy. New devices that couple 24-hour IOP monitoring with drug delivery devices might also enhance therapeutic outcomes by eliminating medical adherence from the treatment paradigm. A future prospective study of 24-hour IOP data will be needed to prove its ability to affect long-term outcomes. ■

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