

An Update on Tonometry

A look at new technology and at many of the commercially available devices for measuring IOP.

BY STEVEN R. SARKISIAN, JR, MD

Goldmann applanation tonometry has been well studied since Dr. Goldmann's definitive article in 1957,¹ and it is still considered the gold standard for measuring IOP. Although Dr. Goldmann described variability in IOP readings based on central corneal thickness (CCT), he did not consider these differences to be common. With advances in pachymetry, and especially with the results of the Ocular Hypertension Treatment Study,² much debate has arisen about whether Goldmann applanation tonometry should remain the standard method of determining IOP. Although some of the newer technologies discussed in this article may point to future trends in clinical practice, the purpose of this article is simply to provide a brief review of some of the newer tonometers and the role they may play in caring for patients. Table 1 provides concise details about these and several other devices.

PICK YOUR PURPOSE

When selecting a tonometer, consider how you will use it. For example, clinicians rarely rely on Goldmann applanation tonometry for very young children who cannot sit still at the slit lamp but instead favor a portable device such as the Tono-Pen XL (Medtronic Xomed Ophthalmics, Inc., Minneapolis, MN). For measuring patients' IOPs in the OR, you might consider the Tono-Pen, the Perkins tonometer (Veatch Ophthalmic Instruments, Tempe, AZ), or a pneumotonometer, because they all may be used on someone who is supine and the first two are portable.

Are you measuring IOP for screening or for the purpose of determining a diagnosis, treatment options, and the progression of disease? If screening in a nontraditional setting such as a community health fair, a portable device with a minimal learning curve (eg, the Tono-Pen or perhaps one of the newer transpalpebral

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tonometers) is preferred. Although not regularly used by ophthalmologists, noncontact "air puff" tonometers may be appropriate for screening when a Tono-Pen is not available, so the units are included in Table 1.

In the traditional office environment, in which you are following disease, Goldmann applanation tonometry has the advantage, because it is predictable, reproducible, and familiar. As mentioned earlier, however, deviations from the true IOP may occur and are predicated on a variety of factors, including the CCT, corneal curvature, and corneal stiffness. Since manometric IOP is not an option when following patients, perhaps some of the methods mentioned later that do not depend on CCT may be helpful.

NEW TECHNOLOGY

The Pascal Dynamic Contour Tonometer

Commercially available since 2004, the Pascal Dynamic Contour Tonometer (DCT; Zeimer Ophthalmic Systems AG, Port, Switzerland) may address variability in corneal thickness. The DCT does not measure IOP by the force applied to a fixed area. Rather, it directly calculates the dynamic pulsatile fluctuations in IOP using a piezoelectric pressure sensor embedded in the device's tip, a calculation the manufacturer says is independent of variations in corneal curvature, thickness, or rigidity. Early in vitro manometric studies seem to validate these claims.³ Recent work, however, by Francis et al demonstrated that, when adjusted for CCT,

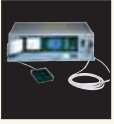
TABLE 1. AN OVERVIEW OF TONOMETERS*

Manufacturer	Device (Name and Model)	Portable?	Contact?	Most Appropriate Use	Comments†
	Goldmann	No	Yes	Routine office setting	Gold standard
Bausch & Lomb (800) 338-2020 www.bausch.com	 Proview Eye Pressure Monitor	Yes	Transpalpebral	Home use	Inexpensive but does not correlate well with GAT‡
BiCom, Inc. (877) 342-8667 www.tonometerdiaton.com	 Diaton	Yes	Transpalpebral	Screening	No anesthesia needed but high learning curve. Uncertain if correlates with GAT. May be useful for glaucoma screenings
Canon U.S.A., Inc. (800) 652-2666 www.usa.canon.com (A)  (B) 	TX-F (A)	No	No	Screening	One-touch technology
	TX-10 (B)	No	No	Screening	Automatic alignment system
EPsA GmbH +49 (0)3671 595 112 www.epsa.de	 Ocuton-S self tonometer	Yes	Yes	Home use	Can be used in any position and any location. Automated disinfection of the measuring prism. Not available in the US.
Keeler Instruments (800) 523-5620 www.keelerusa.com	 Pulsair EasyEye	Yes	No	Screening	
Medtronic Ophthalmics, Inc. (800) 874-7978 www.medtronicophthalmics.com	 Tono-Pen XL	Yes	Yes	Children/EUA§ screening, routine office setting	
Nidek Incorporated (800) 223-9044 www.nidek.com (A)  (B) 	NT-4000 (A)	No	No	Screening	
	NT-2000 (B)	No	No	Screening	
Paradigm Medical Industries (801) 977-8970 www.paradigm-medical.com	 Blood Flow Analyzer	No	Yes	Research/perhaps routine office setting	Possibly a useful adjunct to GAT

*Not a complete list of available devices. †Remarks from Steven R. Sarkisian, Jr, MD.

‡GAT indicates Goldmann applanation tonometry. §EUA indicates evaluation under anesthesia.

TABLE 1. AN OVERVIEW OF TONOMETERS* (CONTINUED)

Manufacturer	Device (Name and Model)	Portable?	Contact?	Most Appropriate Use	Comments†
Precision Instruments www.precision-instruments.net	 Perkins Tonometer	Yes	Yes	EUA/routine office setting	Portable GAT
Reichert, Inc. Fax: (716) 686-4545 www.reichertoi.com	Reichert Tonopen (A)	Yes	Yes	Children/EUA, screening, routine office setting	
(A) 	Ocular Response Analyzer (B)	No	No	Diagnosis of corneal pathology and glaucoma	Measurement of corneal biomechanical properties, which enables corneal-compensated IOP measurements
(B) 	PT100 (C)	Yes	No	Screening	User-friendly icon-based operating system, up to three IOP measurements
(C)  (D) 	AT550 (D)	No	No	Screening	Soft air puff
(E)  (F) 	AT555 (E)	No	No	Screening	Automatic alignment system
	Model 30 Classic Pneumatonometer (F)	No	Yes	EUA/routine office setting in patient with corneal disease	
Tiolat +358 9 8775 1150 www.tiolat.fi	 iCare	Yes	Yes	Children, screening, perhaps routine office setting	No anesthesia needed. Not available in the US.
Topcon Medical Systems, Inc. (800) 223-1130 www.topcon.com	Computerized Tonometer CT-20	No	No	Screening	
	Topcon CT-80	No	No	Screening	Interval time between measurements reduced to see more patients
Zieler Ophthalmic Systems, AG +41 32 332 70 50 www.zieler-ophthalmics.com	 Pascal Dynamic Contour Tonometer	No	Yes	Routine office setting	Possibly useful adjunct to GAT

the mean IOP on DCT increases with rising corneal curvature, whereas it does not with Goldmann applanation tonometry.⁴

The DCT digital display also shows the ocular pulse amplitude. If you add this amount to the diastolic IOP, the sum is the systolic IOP. Although the relevance of the ocular pulse amplitude is unclear, it has been suggested that a low measurement correlates with poor ocular perfusion and is perhaps a risk factor for visual field progression.⁵ Conversely, the ocular pulse amplitude has been shown to decrease after trabeculectomy, which may be a useful prognostic parameter for the successful long-term control of IOP.⁶ Future studies concerning the ocular pulse amplitude are likely going to be of great interest to the glaucoma community, perhaps even more so than the possible benefit of removing the corneal biomechanical variables from the equation in determining IOP.

From a practical standpoint, the DCT has disposable covers that must be replaced after each use. Although some operators may find this upkeep inconvenient, it should be noted that proper care requires the cleaning of the Goldmann applanation tonometer's tip after each use.

The final reading on the DCT's digital display is the Q-value, which is a number from one through five indicating the quality of the data. One is optimal, two and three are acceptable, and four and five are unacceptable and need to be discarded. In my experience with this tonometer, there is a considerable learning curve involved in consistently achieving a Q-value below four, and it is best to train on a patient who is able to sit still and fixate well. Although I do not believe that the DCT replaces Goldmann applanation tonometry, the former may prove to be an important adjunct in caring for patients with glaucoma.⁷

The iCare

Not yet commercially available in the US, the iCare rebound tonometer (Tiolat, Helsinki, Finland) is portable and handheld. The unit does not require anesthesia and may prove most useful for measuring IOP in children or adults who are uncooperative with Goldmann applanation tonometry. The iCare features a small, single-use, disposable probe. According to the manufacturer's Web site, the unit is "based on a new measuring principle in which a very light probe is used to make momentary contact with the cornea ... and often does not even cause corneal reflex."⁸ Brusini et al found that the iCare tonometer provides readings that are similar to Goldmann applanation tonometry, but they are influenced by variations in the CCT.⁹

Nakamura et al also found relative agreement between the iCare and other applanation tonometers, but they reported that, as the CCT increased, the iCare tonometer overestimated the IOP compared with Goldmann applanation tonometry and the Tono-Pen.¹⁰ Finally, Davies et al demonstrated a positive bias when measuring IOP with the iCare versus Goldmann applanation tonometry. Moreover, they showed that the intersession repeatability of IOP measurements taken with the iCare was poorer than with Goldmann applanation tonometry.¹¹

Seemingly, the iCare tonometer would be useful in similar situations as the Tono-Pen, because they are both portable, have a disposable tip or cover, and are easy to use. The fact that the former does not require anesthesia is a clear advantage over the latter. If and when the iCare becomes more broadly available and more studies demonstrate reasonable agreement with Goldmann applanation tonometry, it may become the preferred tonometer for screening and for patients who may be difficult to examine such as children. Finally, although it has not been studied, patients may be able to use the iCare to monitor their own IOPs at home.

The Diaton Transpalpebral Tonometer

There are limited data on the Diaton transpalpebral tonometer (BiCom Inc., Long Beach, NY), which was recently approved by the FDA. This device resembles the Tono-Pen, and there is a rod at its tip that the operator depresses against the patient's eyelid. The portable Diaton provides a digital readout and does not require anesthesia or sterilization. The manufacturer's Web site specifies a measurement error of ± 2 mm Hg if the IOP is between 5 and 20 mm Hg and $\pm 10\%$ if the IOP is from 20 to 60 mm Hg.¹² According to BiCom Inc., the device uses the ballistic principle of tonometry, which is based on measuring an elastic reaction during the momentary influence on the eye of a free-falling object with a definite weight.

Clearly, more data are needed to assess the device. Based on the company's reports of the Diaton's accuracy, however, it will likely be used only as a screening tool by experienced users. Moreover, the company's Web site explains that the "reliability of IOP measuring with the [Diaton] tonometer is provided with ... perfect technique of transpalpebral tonometry and sufficient practical experience in application (not less than 50 people during a month)."¹³ The Diaton tonometer is not being marketed for home-monitoring by patients.

The Proview Eye Pressure Monitor

An interesting device marketed for use at home by patients is the Proview Eye Pressure Monitor (Bausch &

Lomb, Rochester, NY). Users press the device against their partially closed eyelids until they see a pressure phosphene, a dark circle with a ring of light around the outer circumference. The force to create this phenomenon is supposed to correlate with the IOP. Significant discrepancies with this device have been demonstrated compared with Goldmann applanation tonometry.^{14,15} Nevertheless, many patients have probably purchased the Proview Eye Pressure Monitor to reduce their anxiety about their glaucoma.

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The Ocuton S

Although not a transpalpebral device, the Ocuton S (not available in the US; EPSa GmbH, Saalfeld, Germany) is another handheld self-tonometer. After applying topical anesthesia, a patient may hold the tonometer and apply the measuring prism directly to his cornea. The device provides a digital display of his IOP. Sacu et al, however, have demonstrated that the reliability of the Ocuton S is not comparable to that of Goldmann applanation tonometry.¹⁶

CONCLUSION

The ideal tonometer would be easy to use, comfortable for the patient and physician, portable, and reliable. It would also have low inter- and intraoperator variability and would provide an IOP reading that was as close to manometric IOP as possible. To date, no such tonometer exists. Still, the gold standard for measurements of the IOP—Goldmann applanation tonometry—is accurate but not precise. In the future, clinicians may need to use more than one tonometer to measure the IOP accurately.

The DCT needs further study and may be a useful adjunct in many patients. A better understanding of the ocular pulse amplitude would be helpful. Although the reliability of IOP measurements at community screenings is questionable, many of the devices mentioned in Table 1 may be useful in that setting. Moreover, at-home IOP monitors are attractive in some respects, provided that clinicians educate their patients about the devices' limitations. For example, the units are not replacements for regular visits to a

physician, but self-tonometers may help assuage patients' anxiety by providing them with some control over their ocular health and thus may even bolster their compliance with prescribed therapy. Conversely, the devices may also decrease compliance if IOP measurements are inaccurately shown to be under the targeted level. The units may also create unnecessary phone calls to the office regarding the interpretation of the results.

Finally, in young children, in the OR, or in bedridden patients, several portable devices have shown reasonable agreement with and may be more appropriate and/or practicable than Goldmann applanation tonometry.^{15,17} □

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