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What Do We Measure with Various Techniques When Assessing IOP?

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Abstract. This article reviews briefly three important aspects of tonometry: physics, physiology, and glaucoma. With respect to the physical principles of tonometry, deformation of the globe is a key component: force tonometers measure intraocular pressure (IOP) by deforming the globe whereas pressure tonometers do not. Pressure tonometers can provide measurements that are closer to absolute pressure than force tonometers. Tonometry is a physiological measurement that evaluates IOP over time by assessing pulsation in consideration of the pressure gradient from the cornea to the optic nerve. It seems that the outflow characteristics of the trabecular meshwork also modify the pulse amplitude. When diagnosing glaucoma, tonometry alone does not adequately discriminate between normal and diseased eyes. A long-term measurement may be desirable but this, in turn, evokes new problems. Finally, lowering the IOP improves the blood flow in the optic nerve head. (**Surv Ophthalmol 52**:S105–S108, 2007. © 2007 Elsevier Inc. All rights reserved.)

Key words. deformation • dynamic contour tonometry • force • glaucoma • pressure • tonometry

What do we measure with various techniques when assessing intraocular pressure (IOP)? This question is best answered considering three fundamental aspects of tonometry: physics, physiology, and glaucoma.

Physics

Blaise Pascal established the fundamentals of pressure (known as Pascal's Law of Hydrostatic Pressure), which says: "For freely flowing molecules in liquids and gases, pressure is defined as a uniform force distribution acting perpendicular to all boundaries." Pressure is not defined between rigid and semi-rigid materials, such as the tonometer tip and the cornea. The IOP is the force distribution of the fluids inside the eye acting perpendicular to the sclera and the cornea. It is measured according to the formula: $\Delta p = \Delta F/A$. It has a value with a given fluctuation, called the ocular pulse amplitude (OPA).

The methods of measurement may be classified into three categories. The first method involves measuring the force necessary for a given deformation of the globe, and the second measures the pressure in the eye directly. The third category comprises several procedures that are not directly based on the above-mentioned pressure fundamentals. They include transpalpebral tonometers, psychophysical tonometers, and tonometers that measure the elasticity of the eye walls (e.g., the vibration tonometer). These will not be discussed in this article.

In order to obtain the most accurate reading, IOP is best measured directly over the center of the cornea, where the cornea is thinnest.

FORCE TONOMETERS

Indentation

The globe is deformed and the force necessary for causing that deformation is measured. The deformation is the indentation or impression of the cornea evoked by a plunger of a fixed weight. The shift of the plunger corresponds to the degree of deformation and, hence, inversely to the IOP.[1,10]

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Applanation

There is much less globe deformation with applanation than with indentation. With applanation, the deformation simply involves the flattening of the cornea at its center.[3,8] This means the force is also much less than with indentation, and the value is thus closer to the true value. In both indentation and applanation, the counterforces of the cornea have to be considered. In the case of applanation, the law of Imbert-Fick is valid when the elastic properties of the cornea and the suction of the tear film at the instrument cancel each other.[2,4] In the case of the Goldmann tonometer, the applanated area (7.354 mm^2) shows a constant diameter of 3.06 mm. The displaced volume is 0.44 mm^3, and it is always the same, regardless of the IOP, and thus that is the force necessary for its measurement.[13] The advantages and disadvantages of force tonometers are cited in Table 1.

PRESSURE TONOMETERS

Manometry

Manometry is the invasive measurement of the pressure inside the eye. It gives the true value of p_0, irrespective of the wall characteristics, that is, the cornea and the sclera. One alternative is to perform the measurement within the vitreous. In daily practice, its invasive character does not justify its use.

Dynamic Contour Tonometry (DCT)

The cornea, like any other tissue, keeps its mechanical stability through interstitial forces in all three spatial directions. When the tangential forces of the cornea are cancelled (e.g., by a concave tip gently pressed against the cornea), then the pressure inside the eye is directly transmitted to the sensor in that tip.[5] This fundamental is realized in the Pascal dynamic contour tonometer (Ziemer Group, Port, Switzerland). The concave radius of the tip is standardized, which means that the cornea has to smooth itself intimately to the tip. Theoretically, the contrary is conceivable, in that the contour of the tip may smooth to the curvature of the cornea. In this case, pressure would be measured directly, and, therefore, it would remain uninfluenced by the mechanical properties of the eye. The advantages and disadvantages of pressure tonometers are cited in Table 2.

Physiology

The three elements composing the physiologic aspects of pressure and its modification include the following tenets:

1. The IOP is the time-related fluctuation of pressure; it is dependent on vascular and respiratory properties of the body and the eye. It is clear, therefore, that the pulse also modifies the eye pressure, and thus the pressure is only correctly measured when assessed over time.[6]
2. There is a pressure gradient from the cornea to the cerebrospinal fluid. Physical considerations lead to the assumption that the IOP measured at the corneal apex must be lower than in the posterior chamber. This assumption is supported by the convex curvature of the iris in most patients. We do not know the IOP difference between the anterior chamber and the vitreous next to the nerve head, but the translaminar pressure gradient (TLPG) seems to be of even more interest,[9] although its determination poses the greatest difficulty. Knowledge of this gradient would probably contribute to resolving the glaucoma problem,

TABLE 1

Pros and Cons of Force Tonometers

Indentation Tonometry		Applanation Tonometry	
Pro	Con	Pro	Con
The OPA is shown	The OPA is distorted	Widely accepted throughout the world	Shows no OPA
The measurement is feasible in both sitting and supine body positions	The instrument needs regular calibration, otherwise its accuracy diminishes	The measurement is feasible in both body positions	No temporal measurement
Measurement procedure is straightforward	Deformation is considerable	Relatively accurate; slight deformation	Deformation still enough to act on the mechanical properties of the cornea
No preparation of the eye is necessary	Anesthetic drops	Rapid measurement	Anesthetic drops