SECTION 3 EVALUATION OF GLAUCOMA

10 Tonometry and Intraocular Pressure Fluctuation

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Summary

This chapter describes the mechanisms and theories behind the current instruments used to measure intraocular pressure. The evidence for the significance behind intraocular pressure fluctuations is also discussed.

Introduction

Raised intraocular pressure (IOP) is the most important modifiable risk factor for the development and progression of glaucomatous optic neuropathy. The accurate and precise measurement of IOP is, therefore, of great clinical importance. Several tonometers are in common usage, and an understanding of the principles of IOP measurement and sources of measurement error for each of the tonometers facilitates the correct interpretation of clinical IOP readings. The 'accuracy' of a measurement refers to how close the measurement is to the true value; the 'precision' of a measurement refers to the reproducibility of measurements. All current forms of clinical tonometry measure the IOP through the cornea and the accuracy of their measurements is, therefore, subject to the biomechanical properties of the cornea. This topic is considered in detail in Chapter 18. Measurement precision may be quantified for repeat observations by the same observer (the repeatability coefficient) or by different observers (95% limits of agreement). The repeatability coefficient gives the value within which multiple readings by the same observer will fall for 95% of individuals. Recently, it has been suggested that IOP fluctuation, in addition to raised IOP, may be a risk factor for glaucoma progression. Variation in IOP measurements may arise from measurement error or from true IOP fluctuation. This chapter considers the operating principles of the tonometers in common use, and the sources and clinical significance of IOP measurement variation.

Goldmann Applanation Tonometry

TONOMETER PRINCIPLE

Hans Goldmann and Theo Schmidt introduced the Goldmann applanation tonometer (GAT) in 1957. The IOP is estimated by measuring the force required to flatten a fixed area of the cornea ('applanation' tonometry). The optimal applanation area was derived from empirical experimentation and the Imbert–Fick principle. The Imbert–Fick principle states that the pressure *(P)* of a body of fluid encapsulated within a sphere is directly proportional to the force *(W)* required to applanate an area *(A)* of the sphere:

$$W = PA \tag{10-1}$$

The principle holds provided that the surface encapsulating the fluid is infinitely thin, perfectly elastic, dry, and perfectly flexible and that the only force being exerted upon it is from the applanating surface. However, with respect to the cornea, none of these assumptions is true. Goldmann recognized that the equation would need to be modified to account for certain corneal characteristics (a finite thickness, measurable rigidity, and the capillary attraction forces of the precorneal tear film). An assumption was made that, in the absence of corneal pathology, the central corneal thickness (CCT) did not vary much around 500 µm. The modified equation included factors to account for the resistance of the cornea to applanation and the action of surface tension from the tear meniscus on the tonometer prism:

$$W + s = PA + b \tag{10-2}$$

where W = tonometer force, s = surface tension of precorneal tear film, P = intraocular pressure, A = area of applanation, and b = corneal rigidity/resistance to bending (Fig. 10-1).

The effects of corneal rigidity and tear film surface tension forces (see Fig. 10-1) approximately cancel when the area applanated is 7.35 mm^2. When applanating this area, a force of 0.1 *g* corresponds to an IOP of 1 mmHg.

GAT is the reference standard for tonometry. The GAT is slit-lamp-mounted and is available in a modified hand-held form (the Perkins tonometer). When viewed through the slit lamp, the tonometer biprism splits the image of the fluorescent tear meniscus into two semicircular rings. A dial on the side of the tonometer is adjusted to vary the force applied to the eye, causing a movement of the rings either together or apart. The end point is achieved when the inner edges of the semicircles touch (Fig. 10-2).

A strategy first suggested in 1965 to minimize infection risk from contact tonometry is the use of disposable tonometer prisms.[1] Alternatively, existing GAT prisms may be used with disposable covers. A major consideration for the use of these modifications is their comparative precision and agreement with GAT using the standard prism.

ACCURACY OF INTRAOCULAR PRESSURE MEASUREMENTS AND PRECISION OF TECHNIQUE

Sources of IOP measurement error[2] using this technique are summarized in Table 10-1.