COMMUNICATIONS

EVALUATION OF THE POSNER-INGLIMA APPLANOMETER*

BY

J. GLOSTER AND B. MARTIN

Department of Experimental Ophthalmology, Institute of Ophthalmology, London

Introduction

APPLANATION tonometry is based on the principle embodied in the Imbert-Fick law which states that when a flat weight (W) is lowered on to a spherical container having an internal pressure (P) the area of flattening so produced (A) is related to W and P in the following way: $A = \frac{W}{P}$

This relationship, however, holds only when the membrane bounding the container is flexible and elastic, dry, and infinitely thin; the cornea meets none of these requirements fully, but it has been shown (Gloster and Perkins, 1963) that the Imbert-Fick law does apply to applanation tonometry when the diameter of the area applanated is in the region of 3 mm.

Applanation tonometry may be performed in one of two ways:

(1) In the first method the area of applanation is maintained at a constant value by using a variable weight, which is increased with rising intra-ocular pressures. This is the principle of the Goldmann method.

(2) Alternatively, the weight is kept constant while the area of applanation varies with the intra-ocular pressure, increasing at lower pressures and decreasing with higher ones. The Maklakoff tonometer and its modifications operate in this way.

Maklakoff first described his tonometer in 1885, but it was not until 1892 that he gave some indication of how he used it to determine whether intra-ocular tension was low, normal, or raised. No calibration relating diameters of applanation to pressure was attempted, but from numerous readings he chose a mean diameter to indicate a normal pressure and a smaller diameter indicated a raised pressure. Subsequently, Golowin, in 1895, calibrated the Maklakoff tonometer using the Imbert-Fick principle, but it was not until 1928 that Apin found experimentally that this principle was not an adequate basis for the calibration. Using the previous calibration tables he discovered that the tonometer tended to overestimate at low pressures and to underestimate at high pressures.

Schmidt (1962) pointed out that the Imbert-Fick law was applicable only for diameters of applanation between 2.5 mm. and 4.0 mm. and he considered that the Maklakoff tonometer would only give accurate results if due attention was paid to individual variations in scleral rigidity and corneal curvature.

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In 1962 Posner and Inglima first introduced their modification of the Maklakoff tonometer, which, under the name of the Posner–Inglima applanometer, is the subject of this paper (Posner, 1962a).

Method

The applanometer comprises a magnetic handle, to one end of which may be attached stainless steel tonometer heads of 5.0 g., 7.5 g., and 10.0 g., by means of a metal tab and a ring which slides up and down the head. The end-plates of the head (one at either end) are the applanating surfaces and are made of a flame-resistant ceramic material which, before tonometry is performed, are stained with a homogeneous suspension in glycerine and water of mild silver protein (N.F.) in equal parts (2 g. each.)

A cotton-wool swab is used to apply a spot of stain to the end-plates, and this is then spread over the applanating surface with a clean tissue paper until a uniform light tan colour is produced. The makers suggest also using the swab to spread the stain, but it was found that this resulted in small fragments of cotton becoming stuck to the argyrol on the end-plate.

The patient, who should be lying down, is prepared in the same way as for Schiötz tonometry using Novesine drops 1 per cent. as an anaesthetic. At least one minute should be allowed to elapse between the instillation of the drops and the application of the tonometer to permit excess tears and fluid to drain away. The applanometer is then gently lowered on to the centre of the cornea, while the patient's lids are retracted, and its full weight is allowed to rest on the globe by permitting the ring of the metal tab to move about half-way down the tonometer shaft. The instrument is then lifted vertically off the eye, having been in contact with it for not more than half a second.

Interpretation of Results

The imprint formed on the tonometer end-plate consists, ideally, of a circular white area in which there is a central spot of stain. The diameter of the unstained area is said to correspond to the diameter of the area applanated.

A transparent scale is supplied with the applanometer and is claimed to be accurate to within ± 0.1 mm., which corresponds to ± 1 mm. Hg in the normal or border-line ranges of intra-ocular pressure. The tonometer end-plate is held closely beneath the scale and the imprint is centred between the guide lines and moved into such a position that these lines are tangential to the edges of the applanated area. The pressure may then be read directly from the scale. Alternatively, a magnifier incorporating a millimetre scale in 0.1 mm. divisions may be used to measure the diameter and the scale then referred to in order to obtain the pressure (Inglima, 1963). This second method was used in the experimental and clinical work to be described.

I. LABORATORY STUDIES

The apparatus used consisted of a perspex chamber, into which corneas excised from enucleated human eyes could be clamped. The chamber was connected to a reservoir of saline by means of a graduated tube.

Method

The cornea, which was excised together with a rim of sclera, was secured in the perspex chamber and then immersed in a solution of dextran to reduce its thickness to a value corresponding to that of the living human cornea.

With the chamber connected to the graduated tube, and using the open stop-cock technique, the pressure in the system was set at the desired levels while readings were taken with the applanometer, using the 5.0 g. and 10.0 g. weights at manometer pressures ranging from 10 mm. Hg to 65 mm. Hg. Readings were taken at intervals of 2.5 mm. Hg from 10 mm. Hg to 32.5 mm. Hg and then at 5 mm. Hg intervals up to the maximum, so that paired readings with the two weights could be obtained, the manometer pressure for the 10.0 g. weight always being twice that used for the 5.0 g. weight in any given pair of readings; thus the fraction W/P was kept constant in each pair of results.

The diameter of applanation obtained was measured with the $\times 8$ magnifying measure.

Results

The results obtained are illustrated graphically in Fig. 1, which shows the areas of applanation, obtained at different manometer pressures, plotted against the corresponding W/P values. The continuous line represents the relationship that would have resulted had the Imbert-Fick law held, the area being calculated from the expression $A = W/P$, where W is the weight of the tonometer and P is the manometer pressure.

FIG. 1.—Relationship between A and W/P for thinned human cornea. The continuous line represents the relationship expected from the Imbert-Fick law. Points A and B relate to a thick human cornea.

FIG. 2.—Calculation of volume of fluid displaced by applanation. (Reproduced from *Experimental Eye Research*.)

The manometer pressure in an open stop-cock circuit is at all times a P_t value, but the P_o necessary to have given this P_t during tonometry can be calculated by applying the formula:

$$\text{Log } P_o = \text{Log } P_t - \Delta VK$$

K is Friedenwald's constant for eyes of average scleral rigidity, 0.0215, while ΔV is the volume change occurring during tonometry. This may be calculated from the theoretical relationship shown in Fig. 2, and the values obtained in this way have been shown by Gloster and Perkins (1963) to approximate closely to the measured volume changes. In this way the diameters of applanation could be related to the P_o 's and could be compared with the Posner-Inglima calibration.

Discussion

Fig. 1 shows that the results obtained do not conform to those that would have been obtained had the Imbert-Fick principle been applicable, for at high pressures (i.e., low values of W/P) areas of appplanation are overestimated by the applanometer while at lower pressures they are underestimated.

The abnormally large areas of appplanation obtained at higher pressures are probably contributed to in two ways. First, the actual area of corneal flattening is surrounded by a fluid meniscus between the tonometer end-plate and the cornea, and this will increase the unstained area on the end-plate, thus increasing the apparent area of appplanation (Apin, 1928). Secondly, this meniscus, by the surface tension it exerts, will tend to attract the tonometer on to the cornea and thus produce an additional appplanating force (Gloster and Perkins, 1963).

The relative decrease in areas of appplanation recorded at low pressures (i.e., high values of W/P) was thought by Gloster and Perkins (1963) to be due to a decrease in the effectiveness of the appplanating force, some of it being expended in bending the corneal tissue at the circumference of the flattened area. This bending effect is necessarily more marked with larger areas of appplanation. Also the appplanating force of the 5.0 g. weight is reduced relatively more than that of the 10.0 g. weight, the same force being required for bending in each case.

This explanation is strengthened by the fact that, using a cornea with a central thickness of 0.9 mm., the areas of appplanation were even further reduced at the lower pressures, i.e., a greater part of the appplanating force was expended in bending the cornea. Also the points for the 5 g. and 10 g. weights were further apart, indicating the relatively greater effect this phenomenon has on the smaller weights. These facts are illustrated by the points A and B in Fig. 1.

For each diameter of appplanation obtained experimentally the corresponding P_0 pressure was calculated as explained above. For a given diameter in the range of larger areas, the P_0 pressure obtained by this calculation was lower than that indicated by the Posner-Inglima calibration chart. This discrepancy gradually diminished until at diameters of less than 3.8 mm. the reverse was true. In other words, using the calibration supplied with the instrument there was an overestimation of pressures with the larger appplanating areas and vice versa.

II. CLINICAL TRIAL

Following this experimental work a clinical trial was undertaken to evaluate the accuracy of the applanometer as compared with the Goldmann appplanation technique and indentation tonometry, as carried out with the Schwarzer electronic tonometer. The head of the Schwarzer instrument has the same physical characteristics as the Schiötz tonometer.

One hundred consecutive patients attending the Glaucoma Clinic at the High Holborn branch of Moorfields Eye Hospital were the subject of this part of the investigation.

Method

First of all, Goldmann appplanation tonometries were performed by the regular staff of the Glaucoma Clinic, followed 5 to 15 minutes later by an estimation of the intra-ocular

pressure by one of the authors (B.M.) using the Posner-Inglima applanometer. Finally, the tension was estimated by a third person using the Schwarzer electronic tonometer. The author was not told the results of the Goldmann measurements until the applanometer readings had been calculated.

Results

The results obtained were submitted to statistical analysis and correlation coefficients calculated for (1) Goldmann applanation and Posner-Inglima applanation; (2) Schwarzer tonometry and Posner-Inglima applanation; and (3) Goldmann applanation and Schwarzer tonometry.

All correlation coefficients showed that the results obtained were statistically significant ($0.01 > P$). In addition, there was a higher correlation between the Goldmann applanation method and the indentation method ($r = 0.88$) than between the Schwarzer and Posner-Inglima applanation techniques ($r = 0.83$), and the correlation between the Goldmann applanation results and the applanometer results was slightly worse ($r = 0.80$).

Scattergrams were constructed, comparing the results obtained with the applanometer with those given by (1) the Goldmann method, and (2) Schwarzer tonometry, and the Goldmann applanation results were also compared with the results given by the Schwarzer tonometer.

FIG. 3.—A scattergram showing pressures recorded on 100 eyes by the Goldmann method plotted against values obtained by the applanometer. The continuous line is the calculated regression line, assuming the Goldmann measurements to have been made without error.

Discussion

Fig. 3 illustrates pressures measured by the Goldmann method plotted against those obtained with the applanometer, and suggests that the applanometer tends to overestimate the intra-ocular pressure at pressures of less than 26 mm. Hg (Goldmann applanation) and that it underestimates pressures above this value.

Fig. 4, showing the Schwarzer electronic tonometer results plotted against those obtained with the applanometer, has a regression line calculated on the assumption that the Schwarzer is the more accurate of the two, for there is a closer correlation between the Schwarzer and Goldmann methods than between the Goldmann and applanometer methods. Assuming that the Goldmann applanation technique gives a true estimate of the pressure, the results obtained by the Schwarzer tonometer will be a more accurate reflection of the tension than those obtained by the applanometer. On this basis it appears that the applanometer again tends to overestimate at low pressures and underestimate at high pressures, and this impression is strengthened by the distribution of the points in the scattergram.

Finally, Fig. 5 shows that the pressures as measured by the indentation technique, although showing a good deal of scatter, correlate well with the Goldmann values, but tend to be approximately 1.5 mm. Hg higher.

It should be noted here that the Goldmann applanation measurements were carried out in the usual way with the patients seated, but in the other two methods they were lying down.

FIG. 4.—A scattergram showing pressures recorded in 100 eyes by the Schwarzer electronic tonometer plotted against values obtained by the applanometer. The continuous line is the calculated regression line, assuming the Schwarzer measurements to have been made without error.

FIG. 5.—A scattergram showing pressures recorded in 100 eyes by the Goldmann method, plotted against values obtained by the Schwarzer tonometer. The continuous line is the calculated regression line, assuming the Goldmann measurements to have been made without error.

Conclusions and Comments

Both the clinical and experimental results confirm the opinion, gained when using the applanometer clinically, that it overestimates the intra-ocular pressure at low pressures and underestimates it at high pressures. The values at which the change-over from reading high to reading low occur are 31 mm. Hg experimentally and 26.0 mm. Hg (Goldmann) clinically.

The scattergrams (Figs 3 and 5) show a similar or slightly more marked degree of scatter for the applanometer than for the Schwarzer tonometer as compared with the Goldmann applanation readings. Further graphs have been constructed showing

Goldmann and Schwarzer pressures superimposed upon the maker's calibration curve which serve to emphasize the two points just mentioned (Figs 6 and 7).

Posner (1962b) states that "the readings obtained with the 5 g. and 7.5 g. Maklakoff tonometer will correlate well with those obtained either with the Goldmann or with the 5.5 g. Schiötz tonometer", but the results obtained here do not appear to support this statement.

No details are given of the methods used to recalibrate the Maklakoff tonometer (Posner, 1962c), but in the calibration curves supplied with the instrument there is a straight line relationship between pressures and diameters of applanation between intra-ocular pressures of 15 mm. Hg and 27 mm. Hg (Figs 6 and 7), which it has not been possible to reproduce experimentally in this study.

FIG. 6.—Graph showing the relationship between Goldmann applanation pressures and diameters of applanation measured with the Posner-Inglima applanometer (5 g. weight). The continuous line is the calibration curve supplied with the instrument.

FIG. 7.—Graph showing relationship between Schwarzer tonometer pressures and diameters of applanation measured with the Posner-Inglima applanometer. The continuous line is the calibration curve supplied with the instrument.

The readings obtained with the applanometer are no more consistent than those obtained with the Schwarzer tonometer and there are numerous factors which may play a part in this.

Scleral rigidity, although less of a problem than in indentation tonometry, because of smaller volume changes occurring with the applanometer, will lead to differences between applanometer and Goldmann readings, while variations in corneal thickness or an abnormally wet eye are factors which will tend to give a false area of applanation. Human errors in measurement of diameters and in application of the tonometer must also be taken into account.

Several small difficulties and potential sources of error were encountered during the work just described and these fall into two categories.

(1) **Application of Tonometer.**—Some difficulty was experienced clinically in placing the applanometer on the centre of the cornea, poor centring resulting in sliding and tilting of the tonometer head with consequent elongation and distortion of the imprint, necessitating a repeat tonometry. However, with practice this difficulty gradually became less of a problem.

An oval imprint is also obtained if the tonometer is not lifted absolutely vertically when it is removed from the cornea. However, unless the elongation of the imprint is excessive, in which case the reading should be repeated, the smaller diameter should be measured. If, however, an oval imprint is caused by corneal astigmatism, measuring the smallest diameter will not give a true estimate of the size of the applanated area, but it will, in fact, give an underestimation of the flattening produced and so an overestimation of the tension.

In addition to being oval the imprint may be blurred at the edges or irregular. These defects are caused by any tremor on the part of the observer or fine eye movements by the patient. This type of imprint cannot be measured satisfactorily and the procedure must be repeated.

(2) **Measurement of Imprint.**—When the transparent scale supplied with the applanometer was used for measuring the applanation diameter in preliminary studies, it was found that it presented several difficulties. With the border-line pressures, using the 5.0 g. weight, a change in pressure of 1 mm. Hg is represented by a change in diameter of 0.1 mm., which with the naked eye is a very small variation. In addition, it was found that it was impossible to be quite certain of the true diameter when using the scale, for a further two reasons.

Firstly, the effects of parallax cannot be completely abolished by bringing the tonometer end-plate into contact with the back of the scale, for any subsequent adjustment of the tonometer head in order to get the converging lines on the scale tangential to the smallest diameter will result in smudging of the edges of the imprint.

Secondly, there is a consistent tendency to overestimate the diameter of the imprint by 0.1 mm. when using the scale, probably due to the fact that the opaque red background of the scale to either side of the transparent measuring segments casts a shadow on to the end-plate, which merges with the opaque part of the scale and gives rise to an apparent decrease in the size of the clear part of the scale. This leads to a somewhat larger diameter being recorded.

However, if the magnifying measure is used the effects of parallax can be abolished by bringing the imprint into contact with the built-in scale, as no movement is necessary once the imprint is centred; no shadow is cast by the fine graticule and it should be possible to obtain readings accurate to within ± 0.1 mm. Errors of ± 0.3 mm. may be made with the plastic scale.

The applanometer appears to be no more accurate or reliable than the Schwarzer tonometer, although it is influenced less by variations in scleral rigidity. However, the applanometer is easier to keep clean and to sterilize, either by flaming or wiping with an alcohol swab, and the absence of moving parts eliminates any errors due to friction. The flat and smooth end-plate of the applanometer is less liable to abrade the cornea than the foot piece and plunger of the Schiötz tonometer.

Apart from its small size, its relatively low cost, and the fact that it may be used on the recumbent patient, the applanometer has no advantages over the Goldmann applanation method.

Summary

The Posner-Inglima modification of the Maklakoff tonometer is described and an account is given of the experimental and clinical work carried out, both of which suggest that, compared with the Goldmann technique the applanometer is about as consistent as the Schwarzer tonometer; it tends to overestimate intra-ocular pressures in the lower pressure ranges and to underestimate them in the higher ranges.

Various difficulties experienced with this instrument and possible sources of error are mentioned.

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