SCHIÖTZ TONOMETERS AN ASSESSMENT OF THEIR USEFULNESS*

BY

C. R. S. JACKSON

Edinburgh†

THERE is no doubt that applanation tonometry gives more accurate information about the level of intra-ocular pressure than does indentation tonometry. This increased accuracy is due to the fact that applanation readings approach very closely to the levels of pressure in the undisturbed eye (P_o), owing to the small volume of fluid displaced by the application of the tonometer (Goldmann, 1957).

An indentation tonometer, on the other hand, which compresses the eye with a considerable weight (16.5 G in the case of a standard Schiötz tonometer), raises the intra-ocular pressure considerably and the level of P_o can only be obtained by reference to conversion tables which assume that the eye responds in a standard way to the application of the tonometer (Grant, 1951).

It is now recognized that the effect of the application of a Schiötz tonometer may vary, not only from eye to eye, but also in the same eye from time to time. This variability of effect is related to what we call "scleral rigidity", a complex of factors which includes not only the resistance of the ocular coats to deformation, but also the compressibility of the vascular contents of the eye, and the ease with which fluid is expressed through the drainage channels, both of aqueous and blood (Perkins and Gloster, 1957).

The currently accepted conversion charts for Schiötz tonometers (the 1955 scale) are based on Friedenwald's work and assume an average scleral rigidity (Friedenwald, 1957). When the scleral rigidity is within the normal range, Schiötz tonometers (provided that they are of standard construction) may be expected to give readings of intra-ocular pressure which are of an acceptable standard of accuracy.

The purpose of this present paper is to attempt to assess the relationship between the readings of applanation and Schiötz tonometers. Before doing so, however, it seems necessary to draw attention to certain established facts about Schiötz tonometers, and in particular, tonometers of the mechanical type. Some of these considerations do not apply to electronic tonometers.

Schiötz "Range"

When Schiötz (1920) and later Friedenwald (1957) constructed their conversion charts for Schiötz tonometers, the results were obtained under laboratory con-

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ditions and the readings were expressed to a considerable degree of accuracy. Thus we read in Friedenwald's tables that a reading of 3.0 scale divisions with a 5.5 G plunger load represents an intra-ocular pressure of 24.38 mm. Hg. An attempt to carry this type of accuracy into clinical work persists in hospitals and elsewhere and is, I believe, a major cause of the perpetuation of misconcept about Schiötz tonometers. The recorded intra-ocular pressure continues to be noted as being "24.4", "17.3", or whatever the case may be.

An interesting corollary of this method of recording intra-ocular pressure is the fact that Schiötz tonometers are almost invariably read to the nearest whole scale division. A scale reading of "5" may therefore represent any reading between 4.5 and 5.5, and yet our faithful house-surgeons continue to note patients' intra-ocular pressures in terms of mm. Hg expressed to one or more places of decimals!

In the ever-increasing atmosphere of doubt surrounding the accuracy of indentation tonometers, a case could certainly be made out for recording the results obtained with them in terms of actual scale divisions, rather than by attempting to convert these readings into mm. Hg intra-ocular pressure. This is not a novel suggestion, for Priestley Smith (1915) wrote: "It is the reading and not the supposed equivalent in mm. Hg which should be recorded. The reading is a fact; the other is an inference which may be correct or incorrect."

If a comparison is to be made between the results of Schiötz tonometry and of those obtained by applanation, then the readings must be taken under clinical conditions and the expressed results, in the case of Schiötz tonometers, must take account of the fact that each reading actually represents a "range" within which the true pressure may or may not lie.

For example, in the case of the conversion scale for the 5.5 G weight, a clinical reading of 4 scale divisions may represent anything between 3.5 and 4.5 scale divisions, and thus a level of intra-ocular pressure between 19 and 22 mm. Hg. A table of what we may call the "Schiötz range" can then be constructed (*see Table*).

TABLE
SCHIÖTZ RANGE OF CONVERSION VALUES

Scale	Original Model		X-Tonometer mm. Hg
	5.5 G mm. Hg	10 G mm. Hg	
1	32-38	64-75	41-49 35-41 31-35 27-31 23-27 20-23 17-20 14-17 12-14 10-12
2	27-32	55-64	
3	22-27	47-55	
4	19-22	40-47	
5	16-19	34-40	
6	13-16	29-34	
7	11-13	25-29	
8	9-11	21-25	
9	8-9	18-21	
10	6-8	15-18	
11	5-6	13-15	
12			
13			
14			

Method

The method used was similar to that previously described in the comparison of original Schiötz and Schiötz X-tonometers (Jackson, 1957; 1959). Readings, collected in the course of routine out-patient clinics, were taken from a number of eyes in patients, some of whom were known sufferers from glaucoma, and some of whom showed no clinical evidence of glaucoma. For the purpose of the present comparison, no distinction is made between the "glaucoma" and the "no glaucoma" groups.

The same tonometers were used throughout:

- (1) Goldmann applanation tonometer, which was repeatedly checked for accuracy.
- (2) Schiötz tonometer, made by Meyrowitz and certified as a standard tonometer by the American Testing Station. (This tonometer was kindly made available to me by the late Dr. Friedenwald, and its performance has been checked at intervals at the Tonometer Testing Station in Edinburgh.)
- (3) Schiötz X-tonometer, complying with the provisional specification for X-tonometers (Jackson, 1959).

Applanation readings were taken first in order to limit the massaging effect of the Schiötz tonometer. All Schiötz readings were taken with the patient lying comfortably on a couch. The Schiötz tonometers were used in a random order. For reasons that have already been mentioned, the Schiötz tonometer was read to the nearest whole scale division. There is no doubt that the intra-ocular pressure varies with posture and the extent of this variation is the subject of much debate. It seems certain that the pressure is higher in the recumbent than in the upright position, and estimates of the difference between these two levels vary from 1 to 6 mm. Hg (Armaly and Salamoun, 1963; Roberts and Rogers, 1964). While uncertainty exists as to the true position, and the possibility of individual variation remains, one can only guess as to a suitable correction factor to adopt. A factor of 1 mm. Hg has therefore been added to all readings with the applanation tonometer, and the resulting figures have simply been compared with the scale readings of the Schiötz tonometer.

FIG. 1.—Relationship between Schiötz (5.5 G load) and applanation +1 readings.

FIG. 2.—The varying relationship between Schiötz (5.5 G load) and applanation +1 readings.

Results

The results obtained are set out graphically and diagrammatically in the figures.

(1) *Schiötz 5.5 G* (Figs 1 and 2). 357 eyes.

Percentage of applanation +1 readings:

Within "Schiötz range"		38.6
Within "Schiötz range"	± 3 mm. Hg	81.7
Within "Schiötz range"	± 5 mm. Hg	93.8
Outside "Schiötz range"	± 5 mm. Hg	6.2

(2) *Schiötz 10.0 G* (Figs 3 and 4). 247 eyes.

Percentage of applanation +1 readings:

Within "Schiötz range"		19.4
Within "Schiötz range"	± 3 mm. Hg	60.7
Within "Schiötz range"	± 5 mm. Hg	82.5
Outside "Schiötz range"	± 5 mm. Hg	17.5

FIG. 4.—The varying relationship between Schiötz (10 G load) and applanation +1 readings.

FIG. 3.—Relationship between Schiötz (10 G load) and applanation +1 readings.

(3) *X*-tonometer (Figs 5 and 6). 357 eyes.

Percentage of appplanation +1 readings:

Within "Schiotz range"		25.2
Within "Schiotz range"	± 3 mm. Hg	75.3
Within "Schiotz range"	± 5 mm. Hg	91.4
Outside "Schiotz range"	± 5 mm. Hg	8.6

FIG. 5.—Relationship between Schiötz X-tonsometer and appplanation +1 readings.

FIG. 6.—The varying relationship between Schiötz X-tonsometer and appplanation +1 readings.

In Figs 1, 3, and 5, the Schiötz range of pressures at each scale reading is represented by a solid line, while the dotted boxes above and below the "range" represent 5 mm. Hg above and below respectively. It will be seen that the tendency is for the "Schiötz range" to be relatively high, in terms of mm. Hg, at the lower end of the scale in each case, and to be relatively low as the upper end of the scale is approached, when compared with the readings of the appplanation tonometer.

A similar lack of agreement between appplanation and Schiötz readings has previously been reported by Abrahamson and Abrahamson (1959), Armaly (1960), Armaly and Salamoun (1963), Christiansson (1963), and Cramer and Lamela (1960).

Discussion

A direct comparison of the Goldmann appplanation tonometer against a standardized Schiötz tonometer confirms the impression that the latter is a relatively inaccurate instrument. I believe that these inaccuracies should lead us to an urgent reconsideration of our methods of the recording of intra-ocular pressure when

measured with instruments of the Schiötz type. When a Schiötz tonometer of the mechanical type (as distinct from electrical recording instruments) is used in practice, the readings are almost invariably made to the nearest whole scale division. In fact, on the majority of occasions, the movements of the patient, together with the normal pulsations of the pointer, make more accurate readings impossible. If this contention be accepted, it follows that a recorded reading of, for example, 5, may represent any figure from 4.5 to 5.5 scale divisions, and may, even in eyes of average scleral rigidity, be considered to indicate a pressure reading anywhere between these two levels. This has led to the drawing-up of a conversion table (p. 479) based on the Schiötz 1955 scale, in which each point on the scale is represented, not by a single level of pressure, but by a "range" of values, between which the pressure within the eye in question will probably lie, if the scleral rigidity factor in turn is normal. With a Schiötz tonometer it is, however, very uncertain if useful information with regard to the state of the scleral rigidity can be obtained. In my hands, at least, the use of paired readings to obtain this value has proved to be so uncertain as to be useless.

Having accepted, for the reasons set out above, the relative inaccuracy of tonometers of the Schiötz type, it becomes possible to make a more realistic comparison between the performance of an indentation tonometer and that of an applanation tonometer. The basic need for such a comparison is expressed in the ophthalmologist's desire for an answer to the question: "What reliance can we place on our standardized Schiötz tonometers?"

The figures obtained in the course of the present work indicate that, under ordinary clinical conditions, something of the order of 40 per cent. of readings of the applanation tonometer will fall within the "Schiötz range" of pressure readings obtained with the 5.5 G load. Similarly, again with the same load on the Schiötz tonometer, about 80 per cent. of applanation readings will fall within the "Schiötz range" ± 3 mm. Hg, while almost 95 per cent. of applanation readings will fall within the "Schiötz range" ± 5 mm. Hg.

In the case of the higher loads, the relationship between Schiötz and applanation tensions is even less close while the Schiötz X-tonometer is considerably more accurate than the 10 G load of the weighted instrument.

These figures are published in the belief that, in the absence of a portable tonometer of the applanation type and of an accepted standard of accuracy, there will long be a need for a portable, inexpensive instrument. Schiötz tonometers, provided that they are of standard construction and that their limitations are understood and accepted, can continue to fill this need.

Summary

A proposal is presented for considering the readings of Schiötz tonometers as representing, in each case, a "range" of pressures, rather than a single pressure level, which gives a misleading impression of accuracy.

It is shown that the relationship between Schiötz and applanation tonometers is in no way a close one, but reasons are advanced for continuing to regard the Schiötz tonometer as a useful clinical tool.

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