THE BRITISH JOURNAL OF OPHTHALMOLOGY

APRIL, 1925

COMMUNICATIONS

TONOMETRY*

BY

PROFESSOR HJ. SCHIÖTZ

OSLO, NORWAY

Fresh Corrected Graphs

IN my previous treatise on tonometry in THE BRITISH JOURNAL OF OPTHALMOLOGY for May and June, 1920, I gave an account of measurements made on ten dead eyes *in situ*. These measurements coincided fairly well with those made by Mr. Priestley Smith with the 5.5 gm. weight on twelve dead eyes *in situ*, published in the *Ophthalmic Review*, March, 1915. A graph drawn up according to these last-named measurements stood about 4 mm. Hg. higher than the graph hitherto applying to that weight which was based on measurements of eight enucleated eyes.

Priestley Smith's measurements, and later my own, proved that the graphs hitherto used stand too low and ought to be amended; my opinion, however, was that a considerably larger number of measurements should be made prior to constructing and publishing fresh graphs for clinical use. This I have now done. During the last year I have measured thirty dead eyes *in situ*, and on this basis I have compiled the fresh graphs now published.

For these measurements I used my old standard tonometer, which had been used for all my previous measurements, and which is always used as the standard for the adjustment of other tonometers.

*This article is an abridgment, by Professor Schiötz, of a more detailed paper which was published in *Acta Ophthalmologica*, Vol. II, fasc. I. Table III is now added.

In all the later measurements the canula was carried into the anterior chamber, as indicated in the above-named treatise (p. 255, 1920), being inserted a couple of millimetres outward from the edge of the cornea and pushed forward through the iris and into the region of the pupil without injuring the lens, the opening of the canula being forward. The outside diameter of the hollow needle was 1 mm., that of its lumen 0.5 mm. On raising and lowering the manometer, the fluid (normal saline) flows with ease in and out of the anterior chamber, and not once was there any stoppage of the canula or irregularity in the pressure-variations.

Of the thirty eyes, twenty were in individuals who had been dead from 8 to 48 hours prior to the measuring; on the remaining ten the measurements were made one to two hours after death. Several measurements were taken for each pressure-height. In the following table are entered the maximum, minimum, and average values for all the pressures, and the two groups mentioned above are separated.

TABLE I
THE OPEN EYE—*i. e.* TAP BETWEEN EYE AND
MANOMETER OPEN

Pressure H ₂ O.	Group of 20 eyes measured 8 to 48 hours after death. Deflection of Pointer.			Group of 10 eyes measured 1 to 2 hours after death. Deflection of pointer.		
	Maximum	Minimum	Average	Average	Maximum	Minimum
	5.5 gm. weight					
20 cm.	23.5	15.3	18.98	19.2	22	17
30 "	13.5	7.47	10.27	10.93	12.3	9.5
40 "	7.2	3.87	5.79	6.25	7	5.33
50 "	4.2	2	3.27	3.57	4.48	2.5
60 "	2.3	0.6	1.55	1.63	2.2	1
70 "	1	0.1	0.37	0.2	0.6	0
	7.5 gm. weight					
30 "	19.5	13	15.5	15.1	18	13.75
50 "	7.75	5.3	6.53	6.77	8	5.5
70 "	3.8	2	2.85	2.8	3.5	2
90 "	1.5	0	0.7	0.7	1.75	0.2
100 "	0.7	0	0.3	0.33	—	—
	10 gm. weight					
50 "	13	9	10.5	10.28	11.7	9.5
70 "	6.7	5	5.9	5.48	7	5
90 "	3.8	2	3.12	3.06	4.5	2.5
110 "	1.5	0.5	1.1	1.2	2	0.9
120 "	—	—	0.3	0.44	0.5	0.1
	15 gm. weight					
50 "	20	16	18.45	17.39	20	15
70 "	14	10	11.74	10.8	14	9
90 "	8.5	6.5	7.65	7.08	7.9	6.2
110 "	6	3.5	5.2	4.74	5.8	3.8
130 "	4	2.1	3.47	3	3.75	2.2
146 "	—	—	2.7	2.2	—	—

TONOMETRY

THE CLOSED EYE—i.e., TAP BETWEEN EYE AND
MANOMETER CLOSED

5.5 gm. weight.						
20 Cm.	12.6	5.6	8.41	7.67	9.47	6.2
30 "	7	3.7	5	4.79	5.75	4.1
40 "	4.1	1.86	2.93	3.1	4.25	2.4
50 "	2.6	0.85	1.56	1.8	2.97	1.1
60 "	1.2	0.10	0.43	0.55	1	0.17
70 "	—	—	0	0	—	—
7.5 gm. weight.						
30 "	9.5	5.5	7.3	7.1	8.67	6.55
50 "	5	2.7	3.82	3.8	4.5	3
70 "	2.5	0.87	1.63	1.55	2.3	1
90 "	1	0	0.32	0.22	1.1	0.2
100 "	—	—	0	0	—	—
10 gm. weight.						
50 "	7	4.87	5.86	5.47	6.4	4.2
70 "	4.6	3	3.74	3.43	4.6	2.9
90 "	2.9	1	2.12	1.97	3	1.5
110 "	—	—	0.3	0.55	0.9	0.2
120 "	—	—	0	0	—	—
15 gm. weight.						
50 "	11.3	8.23	9.96	9.3	10	8.3
70 "	8.5	5.9	6.85	7.1	8	6.1
90 "	5.83	4	5.16	4.53	6.1	4.1
110 "	4.4	2.5	3.63	3.38	4	3
130 "	3.15	1.5	2.56	2.21	3	1.6
146 "	—	—	2.1	—	—	—

TABLE II
AVERAGES OF THE TWO GROUPS COMBINED.

Pressure H ₂ O	5.5 gm. weight.		7.5 gm. weight.		10 gm. weight.		15 gm. weight.	
	Open	Closed	Open	Closed	Open	Closed	Open	Closed
20 cm.	19.09 (19.58)	8.4 (8)						
30 "	10.6 (10.51)	4.89 (4.9)	15.3 (15.73)	7.2 (7.2)				
40 "	6.02	3.01 (3)						
50 "	3.42 (3.26)	1.68 (1.67)	6.65	3.81 (3.8)	10.39 (10.59)	5.66 (5.9)	17.92 (18.8)	9.63 (8.47)
60 "	1.59 (1.45)	0.49 (0.5)						
70 "	0.28 (0.13)	0	2.82 (2.74)	1.59 (1.6)	5.68	3.58 (3.6)	11.27 (11.26)	6.97 (6.3)
90 "			0.7 (0.6)	0.27 (0.1)	3.09 (2.94)	2.04 (1.96)	7.36	4.84 (4.73)
100 "			0.31	0				
110 "					1.15 (1.2)	0.42 (0.71)	4.97 (4.87)	3.5 (3.5)
120 "					0.37 (0.54)	0		
130 "							3.23 (3.15)	2.38 (2.38)
140 "							2.45 (2.45)	1.9 (1.9)
145 "							2.45 (2.17)	2.1 ? (1.65)

It will be noticed that there is no important difference between the two groups as regards the deflections, I have therefore put

Deflections of the pointer. Water Pressures

FIG. 1

them together, and in Table II, I have combined their averages. These values can be checked partly by means of special graphs and partly by calculation. By these means I have been able to correct somewhat the figures obtained by measurement; the corrected values are put in brackets below the measured values.

The four curves for the closed eye, given in Fig. 1, are constructed on the basis of these corrected values. The small crosses indicate the measured values entered in Table 2, and as will be seen they mostly appear on or near to the graph line; only the two bottom values for the 15 gm. graph deviate somewhat more than desirable. Notice that these are water-pressure graphs. Below the 5.5 gm. line is a broken line drawn according to the old measurements. These lines run quite parallel. There is also a dotted line which crosses the new graph line between the deflections 4.5 and 5; lower down it lies a little over the new

FIG. 2

graph, whereas above it slants across to the 0 point of the old graph. This line is drawn according to Priestley Smith's measurements. The discrepancy is undoubtedly owing to the tonometer which he used not measuring exactly in accordance with my standard tonometer.

When graphs are drawn for the "open eye" and compared with the old ones, one notes that at the upper ends (deflection 0) they nearly coincide, but in their downward course they diverge, the fresh ones passing somewhat below the old ones. This struck me very much, but as the divergence is the same in all the four graphs, the cause must be one and the same; undoubtedly it is owing to the fact that for the last measurements I made use of a comparatively fine hollow needle, whereas for the old ones I used

a canula of very large bore. This would influence the curves for the "open eye," but of course not those for the "closed." In Fig. 2 the continuous line is the new graph for the 5.5 gm. weight. The broken lines above and below it are the maximum and minimum graphs for the same weight; they show the range of deflection which may occur with each degree of pressure; they were obtained by averaging the majority of the largest deflections, and of the smallest deflections, in the whole series of thirty eyes, and by correcting the curves in accordance with the main curve.

We may safely assume that for each degree of pressure the maximum and minimum deflections in living eyes will be about the same as we have found on dead eyes. Notice that the interval between the maximum and minimum graphs is not small; thus, with 29 mm. Hg. one may have, in different eyes, deflections varying from 2.2 mm. to 4 mm.; with 15 mm. Hg. one may have deflections from 6.2 mm. right up to 9.4 mm. Consequently with a deflection of 3 mm. (5.5 gm. weight) the pressure will as a rule no doubt be about 29 mm. Hg., but that deflection might be properly referable to the minimum graph and to an intraocular pressure of 26 mm. Hg., or to the maximum graph and a pressure of 33 mm. Hg. This should absolutely be borne in mind when using a tonometer; the deflection of the pointer does not indicate a precise pressure but a pressure-range, which for the 5.5 gm. weight is about 6 to 8 mm. Hg., for the 7.5 gm. weight 8 to 10 mm. Hg., for the 10 gm. weight about 13 mm. Hg., and for the 15 gm. weight about 15 mm. Hg., nor can it be otherwise when we take into consideration the individual peculiarities in the size of the eyes and in the thickness and elasticity of their walls.

In Fig. 3 are the four new graphs for the respective weights of 5.5 gm., 7.5 gm., 10 gm., and 15 gm., the ordinates indicating the height of the pressure in mm. Hg. and the abscissae the deflection of the pointer.

These graphs of 1924 are the final ones for my tonometer with a concave surface at the lower end of the plunger.

In my previous treatise I drew attention to the fact that the position of the graphs does not make any difference in the use of the tonometer. A deflection of 3 mm. will now as previously be the approximate limit for the normal intraocular pressure, but its mercury value is about 4 mm. Hg. higher than previously assumed. For anyone who has recorded the deflections as the measure of the intraocular pressure, which is really the only correct method, the change in the graphs makes no difference, whereas those who have translated the deflection values into mm. Hg. must now rectify these according to the fresh graphs.

Improvement of the Instrument

I have made several attempts at improving the tonometer with the result that I have in principle retained the old model, whereas the appearance has been somewhat altered as is proved by the adjoining drawing. A small simplification, which may be considered an improvement is, that only the 5.5 gm. weight is

Fresh corrected graphs for the Schiötz Tonometer, 1924

FIG. 3

now made to screw on and off; the other weights are placed directly on to the 5.5 gm. weight, so that the troublesome screwing on and off of fresh weights for higher pressures is avoided. Further, the sliding cylinder with the small round discs is replaced by a cylinder with ball-bearings; this makes the cylinder more solid, and the tonometer is better balanced.

Accurate Adjustment

It is essential, however, not only that the graphs be accurate, but, more important still, that all tonometers act alike. At present, unfortunately, this is far from being the case, nor will

it be attained unless one or more centres be established for the adjustment of tonometers. In case there are several there must be co-operation between them so that all adjusted tonometers shall measure exactly alike, that is to say like the standard tonometer used by myself, with which the graphs were made. The firm of A. Tandberg has now, in co-operation with myself⁽¹⁾, established such a centre to which tonometers may be sent for adjustment; it also negotiates the sale of adjusted tonometers⁽²⁾.

In the *Klinische Monatsblätter für Augenheilkunde*, volume 71, page 603 (1923), Messrs. Arnold and Karpow in Tübingen published a treatise "Ueber Aichungsverfahren (gauging process) für das Tonometer von Schiötz." They find such large deviations

1. Professor Hj. Schiötz, Dr. Med. I. Schiötz and Diplom Engineer Tandberg.
2. Applications to be made to Engineer Arnt Tandberg, Akersgaten, Oslo, Norway.

in the deflections of the various tonometers that they recommend simply an adjustment of all instruments to the 3 mm. deflection of the standard tonometer, that is to the assumed limit for the normal intraocular pressure; for when this has been done all smaller deflections will be pathological and will indicate too high an intraocular pressure. This is quite a practical suggestion, but it will not give a really ideal adjustment. Most of the tonometers of various manufacture can be made correct by minor alterations, but to this end exact comparison with a reliable standard tonometer is essential.

TABLE III
THE SCHIÖTZ TONOMETER
DEFLECTIONS OF POINTER AND INTRAOCULAR PRESSURES
CORRESPONDING APPROXIMATELY THEREWITH
N.B.—Mercury pressures are in heavy figures

Deflections.	Weight 5.5 gm.		Weight 7.5 gm.		Weight 10 gm.		Weight 15 gm.	
	Pressure		Pressure		Pressure		Pressure	
	cm. H ₂ O.	mm. Hg.	cm. H ₂ O.	mm. Hg.	cm. H ₂ O.	mm. Hg.	cm. H ₂ O.	mm. Hg.
0	65	48	91	67	123	91	188	139
0.5	60	44	84	62	114	84	174	128
1	55	41	77	57	105	77	160	118
2	47	35	66	49	90	66	137	101
3	40	30	56	41	76	56	117	86
4	34	25	48	36	66	49	101	75
5	29	22	41	31	56	41	86	64
6	26	19	36	26	48	36	73	53
7	23	17	31	23	41	31	62	46
8	20	15	27	20	36	26	53	39
9	18	13	24	17	31	23	46	34
10	15	11	20	15	27	20	40	29
11	13	10	18	13	23	17	34	25
14	10	7	13	9	16	12	23	17
20	6	4	7	5	8	6	11	8