AQUEOUS FLOW MEASUREMENTS IN MAN BY THE PERILIMBAL SUCTION CUP TECHNIQUE*

I. OBSERVATIONS IN NORMAL SUBJECTS AND CASES OF GLAUCOMA

BY

MARGARET R. CHANDLER†

Department of Ophthalmology, The Victoria General Hospital, and Dalhousie University, Halifax, Nova Scotia, Canada

OCCCLUSION of the anterior chamber outflow pathways by means of a perilimbally placed suction cup leads to an obvious rise in intra-ocular pressure (Rosengren, 1934, 1956). From this increment in intra-ocular pressure, various investigators (Ericson, 1958; Linnér, 1959; Weekers, Prijot, Feron, and Verrier, 1960; Galin, Baras, and Mandell, 1961; Langham, 1962) have estimated the rate of aqueous formation by expressing the observed pressure difference as a volume change (Friedenwald, 1954). It was assumed that in the normal eye the rise in intra-ocular pressure during the application of the cup was proportional to the continued formation and accumulation of aqueous.

The normal rate of aqueous formation in man obtained in this manner by Ericson (1958) was $0.8 \mu\text{l./min.}$, which contrasts sharply with the $1.9 \mu\text{l./min.}$ measured by Goldmann (1950) using the fluorescein technique, and the $1.3 \mu\text{l./min.}$ found by Grant (1950) employing tonography. This comparatively low estimate of the rate of aqueous formation was explained by the fact that the pressure of the cup itself causes a rise of 4 mm. Hg in the intra-ocular pressure and that the continuous rise in intra-ocular pressure during cup application tends to slow down aqueous inflow. Ericson did not correct for these factors since he was concerned with comparisons only.

Langham (1962) has shown that aqueous outflow can be largely if not completely prevented by a negative pressure of 50 mm. Hg, provided that the intra-ocular pressure does not exceed 30 mm. Hg. At higher intra-ocular pressures leaks of aqueous do occur and the rate of formation of aqueous may be underestimated. In normal subjects this would seem improbable and the assumption can be made that the low estimate of the rate of aqueous formation is in fact related to the application of the cup, and that suppression of aqueous inflow attends the rise of intra-ocular pressure during the procedure. Langham and Eisenlohr (1963) have demonstrated manometrically in living human eyes that analysis of pressure decay curves indicated an approximately linear relationship between pressure and flow over pressure ranges of 10–25 mm. Hg above the normal, yielding a total mean aqueous formation rate of $2.26 \mu\text{l./min.}$ These considerably higher values prompted, therefore, an analysis of the rate of aqueous outflow from the decay curves of intra-ocular pressure to resting levels following the removal of the suction cup. In this report the measurements of aqueous inflow obtained from the increments of intra-ocular pressure during the application of the cup will be contrasted with those which were calculated from the intra-ocular pressure decay curve subsequent to cup removal. The observations

* Received for publication December 20, 1963.

† In receipt of Public Health Research Grant #602.7.36. The National Health Grant Programme, Canada.

from normal individuals are also compared with those found in patients suffering from chronic simple wide-angle glaucoma.

Material

Control observations were derived from 24 'normal subjects' (mean age 49.6 years) who attended the eye clinics with refractive errors. They showed no other evidence of eye disease and did not suffer from diabetes, hypertension, or cardio-respiratory disorders.

Measurements in 24 glaucomatous patients (mean age 56.7 yrs) were carried out at the Glaucoma Clinic, Victoria General Hospital, before treatment and after the establishment of the diagnosis of chronic simple wide-angle glaucoma clinically, as well as by tonometry, gonioscopy, scotometry, and tonography.

Methods

Throughout this study the standard suction cup of Ericson (1958) was used. This plastic cup weighs 1.8 g., has an inner diameter of 12 mm. and an outer diameter of 20 mm. The contact surface measures 5.3 mm. and the radius of curvature of this surface is 12.7 mm.

All patients were studied in recumbency and at the same time of day, usually between 11 and 12 a.m. Both eyes were anaesthetized with 0.4 per cent. Dorsacaine applied topically, and the steady-state pressure was determined with a Mueller electronic tonometer.* The mean of three readings, taken at 1-minute intervals, was used as resting intra-ocular pressure (P_0).

The suction cup was then placed perilimbally and a negative pressure of 50 mm. Hg was applied to the cup by a mercury manometer, providing a contact pressure of 28.7 mm. Hg. After 15 min. the vacuum was reduced and the cup removed from the eye. The intra-ocular pressures were then recorded at 1-min. intervals for the first 5 min. and thereafter at 2-min. intervals until the resting steady-state value was once again approached. The pressure calculated by extrapolation to zero time is designated P_1 . The calculations of aqueous flow were conducted in two different ways:

(1) By this method, introduced by Ericson (1958), it is assumed that the pressure increment during the 15 min. of suction corresponds to a constant accumulation of aqueous, the volume of which, according to Friedenwald (1954), would vary with the ratio of the logarithms of the pressure change and scleral rigidity. In this study the pressure-volume tables of Langham and Eisenlohr (1963) have been used instead, as these are based on living human eyes and have been expressed as the volume of fluid required to change the intra-ocular pressure from a value of 10 mm. Hg. The volume increment (mF) thus calculated gives the minimal rate of aqueous humour formation ($mF \mu\text{l./min.}$) and a scleral rigidity correction is eliminated.

(2) For the second calculations it is assumed that the rate at which the intra-ocular pressure returns to its steady-state level, after the removal of the cup, should be considered as a measure of aqueous outflow. The pressure decay is plotted against time, and a curve of best fit is constructed by eye. This curve is divided into segments of 2-min. intervals and the volume change for each segment is calculated from the Langham-Eisenlohr pressure-volume tables. The pressure gradient for each segment is expressed as the difference between initial and final pressures of that time segment minus the steady state resting pressure (P_0). A second plot is then constructed in which the rate of change in flow (ΔF) is placed as ordinate against the pressure decrement (ΔP) as abscissa. The assumption is made that the pressure-flow relationship is linear and that its slope is a measure of the outflow facility (C) for the total length of the pressure decay curve. If the outflow facility slope gives a positive intercept on the ΔF ordinate, it is expressed as the intercept constant (k) in $\mu\text{l./min.}$ and must be added to the minimal flow ($mF \mu\text{l./min.}$) to give the total flow ($tF \mu\text{l./min.}$). The outflow venous pressure (Vp) is calculated for each patient from the formula $F = C(P_0 - Vp)$, which is rearranged to read

$$Vp = P_0 - \frac{F}{C}.$$

The rate of aqueous outflow ($oFD \mu\text{l./min.}$) is derived from the total decay curve divided by the total time of the curve. The difference between the rates of minimal aqueous formation and aqueous outflow is expressed as Δf ($\Delta f = oFD - mF$).

* V. Mueller and Company, Chicago, Illinois, U.S.A.

Results

Normal Studies

Table I gives a summary of observations obtained from 24 normal subjects (aged 34 to 76 years). It indicates that the mean steady-state resting pressure (P_0) was 14.39 ± 3.4 mm. Hg. The mean intra-ocular pressure after removal of the cup (P_1) was 23.74 ± 6.8 mm. Hg, thus showing a mean total rise over the 15 min. of 8.35 mm. Hg, or a mean minute rise of 0.629 ± 0.26 mm. Hg/min.

TABLE I
NORMAL SUBJECTS

Case No.	P_0 (mm. Hg)	P_1 (mm. Hg)	Mean Rise (mm./ Hg/ min.)	mF (μ l./ min.)	Return Time to P_0 (min.)	C μ l./ min./ mm./ Hg)	k (μ l./ min.)	tF ($mF + k$)	V_p (mm. Hg)	oFD (μ l./ min.)	Δf (oFD - mF)
1	13.0	22.2	0.6	1.20	10	0.23	+0.45	1.65	7.80	1.80	0.6
2	16.5	26.8	0.7	1.10	12	0.11	+0.52	1.62	6.50	1.40	0.3
3	18.0	30.2	0.8	1.20	14	0.15	+1.20	2.40	17.20	1.30	0.1
4	18.0	36.5	1.2	1.70	12	0.20	+0.25	1.95	9.50	2.10	0.4
5	16.0	22.0	0.4	0.70	8	0.25	+0.60	1.30	13.00	1.30	0.5
6	16.0	28.0	0.8	1.30	12	0.20	+0.30	1.60	9.5	1.60	0.3
7	19.0	37.4	1.2	1.70	14	0.25	+0.70	2.40	12.2	1.80	0.1
8	11.7	17.3	0.4	1.20	11	0.23	+0.60	1.80	6.4	1.60	0.4
9	12.8	17.9	0.3	1.10	16	0.18	+0.50	1.60	6.7	1.00	-0.1
10	11.2	18.0	0.5	1.50	12	0.29	+0.40	1.90	6.0	1.90	0.4
11	20.0	29.2	0.6	1.60	15	0.18	+0.20	1.80	9.4	1.60	0.0
12	15.8	31.0	1.0	1.50	14	0.11	+0.10	1.70	2.2	1.60	0.1
13	11.2	17.0	0.5	0.90	9	0.11	+0.20	1.10	3.2	1.50	0.6
14	16.0	21.8	0.4	0.70	7	0.40	+1.50	2.20	14.3	1.50	0.8
15	11.2	18.2	0.5	1.20	14	0.33	+0.50	1.70	6.6	1.30	0.1
16	18.4	30.5	0.8	1.20	16	0.15	+0.30	1.50	10.6	1.10	0.1
17	12.8	17.3	0.3	1.00	9	0.27	+0.60	1.60	9.2	1.70	0.7
18	11.2	19.5	0.6	1.20	10	0.37	+0.30	1.50	8.0	1.80	0.6
19	20.6	35.0	1.0	1.90	14	0.14	0.0	1.90	7.1	2.00	-0.1
20	11.2	20.5	0.6	1.30	12	0.22	+0.10	1.40	5.5	1.60	0.3
21	8.5	14.6	0.4	1.90	11	0.36	+0.50	2.40	3.2	2.60	0.7
22	11.2	19.6	0.6	1.80	10	0.20	+0.50	2.30	2.0	2.70	0.9
23	14.0	18.8	0.3	1.10	16	0.14	+0.20	1.20	7.0	0.90	-0.1
24	11.2	20.5	0.6	1.30	15	0.22	+0.10	1.40	5.5	1.30	0.0
Mean	14.39	23.74	0.629	1.30	12.21	0.22	+0.44	1.75	7.86	1.62	+0.38

($\bar{x}$ oFD and $\bar{x}$ mF ; $P < 0.01$)

The mean minimal rate of aqueous humour formation (mF) derived from the pressure increment and the pressure-volume tables of Langham and Eisenlohr (personal communication) was 1.3 ± 0.34 μ l./min.

The mean time of return of intra-ocular pressure to resting steady-state level after cup removal (P_1 to P_0) was 12.21 ± 2.6 min. The mean of the coefficient of outflow facility (C) derived from the total pressure decay curve was 0.22 ± 0.082 μ l./min./mm. Hg. The mean of the intercept constant (k) was $+0.44 \pm 0.34$ μ l./min. Thus, in this group of normal controls, the true rate of aqueous formation (tF) is derived from the sum of the means of $mF + k$, i.e. $1.3 + 0.44 = 1.74$ μ l./min., which continues to be less than that obtained by Goldmann (1950), namely 1.9 μ l./min.

The mean rate of aqueous outflow (oFD) calculated from the total pressure decay curve, *i.e.* P_1 to P_0 , was $1.62 \pm 0.43 \mu\text{l./min.}$ This provides a difference between the means of the rates of inflow and outflow ($\bar{x} oFD$ and $\bar{x} mF$) which is statistically significant ($P < 0.01$).

The mean outflow venous pressure (Vp) for this group was 7.86 ± 3.75 mm. Hg. This value is much smaller than the 10–11 mm. Hg episcleral venous pressure accepted by Ericson (1958).

Figure 1A represents a normal pressure decay curve with an exponential decrease in pressure to resting levels in less time than that used for the procedure. Only in three of the 24 control patients did this return time exceed the 15 min. of pressure build-up, and in these three instances the return time was 16 min., or well within two standard deviations of the statistical mean return time of this group.

FIG. 1A.—Normal subject 6. Pressure decay curve after removal of cup with return time to P_0 in 12 min.

FIG. 1B.—Normal subject No. 6. Pressure-volume relationship with positive intercept at $0.3 \mu\text{l./min.}$ The slope represents the facility of outflow (C) of $0.20 \mu\text{l./min./mm. Hg.}$

Fig. 1B depicts a normal pressure-flow relationship derived from the decay curve of Fig. 1A. The pressure-flow relationship is approximately linear over the pressure range studied, and backward extrapolation of the mean provides a positive intercept on the ΔF axis for a zero pressure. This positive intercept appears to be a cardinal characteristic of all but one of the normal subjects studied and, according to Langham and Eisenlohr (1963), indicates the suppression of aqueous humour formation with rising intra-ocular pressures.

The positive intercept constant (k) has thus to be added to the mean rate of aqueous formation in order to obtain the total inflow. The slope of the curve, which is nearly linear, represents the facility of aqueous outflow over the total range plotted. Fig. 2 (opposite) indicates the variations in slope and intercept noted in some of the group of normal subjects.

Glaucoma Studies

Table II (opposite) provides the results in 24 patients with chronic simple wide-angle glaucoma (ages 43 to 79 years). The mean resting steady-state intra-ocular pressure (P_0) was 20.33 ± 2.9 mm. Hg, and this is significantly higher than that of the

FIG. 2.—Mean normal outflow facility represented by slope of A, showing positive intercept at 0.44 $\mu\text{l./min.}$ and facility of outflow of 0.22 $\mu\text{l./min./mm. Hg.}$ Additional lines indicate the variations found in nine of the normal subjects.

TABLE II
GLAUCOMA PATIENTS

Case No.	P_0 (mm. Hg)	P_1 (mm. Hg)	Mean Rise (mm. Hg./min.)	mF ($\mu\text{l./min.}$)	Return Time to P_0 (min.)	C ($\mu\text{l./min./mm./Hg}$)	k ($\mu\text{l./min.}$)	V_p (mm. Hg)	oFD ($\mu\text{l./min.}$)	Δf ($oFD - mF$)
1	18.0	28.4	0.70	1.00	30	0.08	-0.18	5.5	0.5	-0.5
2	17.0	27.0	0.67	1.10	18	0.20	-1.05	11.7	0.9	-0.2
3	22.0	36.0	0.93	1.20	27	0.21	-0.90	16.3	0.7	-0.5
4	20.0	33.4	0.89	1.20	18	0.25	-1.20	15.2	1.0	-0.2
5	23.0	27.6	0.30	0.40	16	0.40	-0.40	22.0	0.4	0.0
6	19.0	30.0	0.73	1.10	25	0.35	-1.28	16.0	0.7	-0.4
7	24.0	34.0	0.67	0.8	20	0.20	-0.13	19.8	0.6	-0.2
8	18.0	30.6	0.84	1.20	30	0.11	-0.20	7.1	0.6	-0.6
9	19.0	34.4	1.20	1.40	35	0.07	-0.03	-1.0	0.6	-0.8
10	21.0	32.2	0.75	1.00	40	0.08	-0.05	8.5	0.4	-0.6
11	17.0	25.8	0.59	1.00	25	0.17	-0.10	11.2	0.6	-0.4
12	17.0	26.4	0.62	1.00	35	0.07	0.0	2.5	0.4	-0.6
13	20.0	32.0	0.80	1.10	25	0.10	-0.50	9.4	0.7	-0.4
14	24.0	38.4	0.96	1.10	25	0.12	-1.00	14.9	0.7	-0.4
15	20.0	30.4	0.69	1.00	18	0.25	-0.10	16.0	0.8	-0.2
16	23.0	34.0	0.73	0.90	20	0.25	-1.15	19.3	0.7	-0.2
17	25.0	29.8	0.32	0.40	16	0.18	-0.01	22.8	0.4	-0.0
18	25.0	34.2	0.61	0.80	18	0.30	-0.30	22.4	0.7	-0.1
19	18.0	31.8	0.92	1.30	25	0.15	-0.57	9.4	0.8	-0.5
20	23.0	32.0	0.60	0.80	20	0.28	-0.28	20.6	0.6	-0.2
21	18.0	28.4	0.70	1.10	35	0.18	-1.00	3.0	0.5	-0.6
22	16.0	24.8	0.59	1.00	24	0.20	0.0	11.0	0.6	-0.4
23	24.0	30.6	0.44	0.50	18	0.15	-0.08	15.0	0.4	-0.1
24	17.0	26.8	0.65	1.10	24	0.20	-0.05	11.7	0.7	-0.4
Mean	20.33	30.79	0.70	0.98	24.46	0.19	-0.44	13.01	0.62	-0.35

($\bar{x}$ oFD and $\bar{x}$ mF ; $P < 0.01$)

control group ($P < 0.01$). After 15 min. of application of the suction cup the intraocular pressure rose to a mean of 30.79 ± 1.1 mm. Hg (P_1) which was also significantly greater than in the normal subjects ($P < 0.01$). The mean rate of aqueous

inflow (mF) of $0.98 \pm 0.25 \mu\text{l./min.}$ was significantly less than in the normal group ($P < 0.01$). The mean return time from P_1 to P_0 after removal of the cup was significantly prolonged ($P < 0.01$) to 24.46 ± 6.8 min. The mean of the coefficient of facility of outflow (C), although smaller at $0.19 \pm 0.087 \mu\text{l./min./mm. Hg}$ is statistically not significantly different from the controls ($P > 0.1$). In all but two instances, a negative intercept upon the ΔF ordinate was found, providing a mean k factor of $-0.44 \pm 0.45 \mu\text{l./min.}$, which precludes a correction to be made for the minimal rate of aqueous inflow. The mean rate of aqueous outflow oFD was $0.62 \pm 0.16 \mu\text{l./min.}$, which is significantly smaller than that of the controls ($P < 0.01$) as well as that for aqueous inflow in this group ($\bar{x} oFD$ and $\bar{x} mF$) ($P < 0.01$).

The outflow venous pressure (Vp) of this group, derived in the same manner as in the control patients, yields a mean of 13.01 ± 6.03 mm. Hg, which is significantly higher than in the normal patients ($P < 0.01$).

Table III summarizes the means and the statistical differences between the two groups of patients.

Fig. 3A shows a representative pressure decay curve from P_1 to P_0 in a glaucoma patient. The curve appears to be unstable with a tendency to plateau formation and is typically slow in returning to the steady-state level. Fig. 3B provides the plot of the pressure-flow relationship from the decay curve of the glaucoma patient in Fig. 3A. The slope of this curve, as in all but two patients with glaucoma, shows a low negative intercept upon the ΔF ordinate.

FIG. 3A.—Glaucoma Patient 1. Pressure decay curve after removal of cup shows considerable instability and a delay of 30 min. before returning to P_0 .

FIG. 3B.—Glaucoma Patient 1. Pressure-volume relationship with negative intercept of $0.18 \mu\text{l./min.}$ and facility of outflow of $0.08 \mu\text{l./min./mm. Hg}$.

Fig. 4 (opposite) represents a number of these slopes in glaucoma illustrating the negative intercept, and in many cases the steepness of the slope which gives a false high outflow facility.

TABLE
COMPARISON OF MEANS BETWEEN NORMAL

Group	P_0 (mm. Hg)		P_1 (mm. Hg)		Mean Rise (mm./Hg/min.)		mF ($\mu\text{l./min.}$)	
	N	G	N	G	N	G	N	G
Mean	14.39	20.33	23.74	30.79	0.629	0.70	1.30	0.98
S.D. $\pm$	3.4	2.9	6.8	1.1	0.26	0.197	0.34	0.25
Significance of Difference	$P < 0.01$		$P < 0.01$		$P > 0.1$		$P < 0.01$

FIG. 4.—Mean outflow facility represented by slope of A, showing a negative intercept at 0.44 $\mu\text{l./min.}$ and a facility of outflow of 0.19 $\mu\text{l./min./mm. Hg.}$ Additional lines indicate the variations found in six glaucoma patients, some showing a very high value for the outflow facility.

Discussion

A satisfactory interpretation of the pressure-flow relationship of the normal living human eye required a knowledge of the volume required to effect a unit change in intra-ocular pressure. This relationship has now been determined by several investigators (Prijet, 1959; Ytteborg, 1960; Eisenlohr, Langham, and Maumenee, 1962), with essentially concordant results. These results differ significantly from the pressure-volume relationship of Friedenwald (1937), particularly in respect of the scleral rigidity constant. Eisenlohr and others (1962) showed that scleral rigidity was less than 0.0215 and varied with intra-ocular pressure, which causes the slope of the pressure-volume relationship to become much steeper and more linear over a range of pressures 10 to 50 mm. Hg above normal. It is in this respect that the pressure decay curves following the application of the suction-cup show an obvious similarity, and that the pressure-flow relationship of the decay curve is once more linear and provides by its slope a valid measure of outflow facility.

The outflow facility (C) calculated in this way in the normal subjects was $0.22 \pm 0.082 \mu\text{l./min./mm. Hg}$ and 0.19 ± 0.087 in the glaucoma patients without therefore, yielding a significant difference. The similarity in mean slope is shown in Figs 2 and 4, and indicates that in this respect the method does not distinguish between the two groups.

III

SUBJECTS (N) AND GLAUCOMA PATIENTS (G)

Return Time to P_0 (min.)		C ($\mu\text{l./min./mm./Hg}$)		k ($\mu\text{l./min.}$)		V_p (mm. Hg)		oFD ($\mu\text{l./min.}$)		Δf ($oFD - mF$)	
N	G	N	G	N	G	N	G	N	G	N	G
12.21	24.46	0.22	0.19	+0.44	-0.44	7.86	13.01	1.62	0.62	+0.38	-0.35
2.6	6.8	0.082	0.087	0.34	0.45	3.75	6.03	0.43	0.16	0.275	0.21
$P < 0.01$		$P > 0.1$		$P > 0.1$		$P < 0.01$		$P < 0.01$		$P > 0.1$	

The mean rate of aqueous formation in the normal (tF) of $1.75 \pm 0.37 \mu\text{l./min.}$ continues to be below the figures established by Goldmann (1950) and that established manometrically by Langham and Eisenlohr (1963), and this may be related to the effect of the weight of the cup and the pressure range. Comparison of the uncorrected mean rates of aqueous formation (mF), although at different pressure levels, indicates a significant reduction in glaucoma, namely 1.3 contrasted with $0.98 \mu\text{l./min.}$ The calculated mean rate of aqueous outflow (oFD) of $1.62 \pm 0.43 \mu\text{l./min.}$ in the normal subjects approaches the mean rate of aqueous formation when corrected to tF . It is significantly higher than the uncorrected formation rate as a result of the significant reduction in the return time of the normal decay curve to P_0 . In glaucoma the mean rate of aqueous outflow is significantly lower than that of aqueous formation, $0.62 \pm 0.16 \mu\text{l./min.}$ contrasted with $0.98 \pm 0.25 \mu\text{l./min.}$, and this arises principally from the grossly prolonged return time of the decay curve to steady-state levels.

The total duration of the pressure decay curves furnishes the most important single difference between the control observations and the findings in cases of glaucoma. The mean normal return time to P_0 was 12.21 min. and all normal observations fell within two standard deviations of this mean, whereas in the glaucoma group the mean return time was 24.46 min., only two patients falling within the normal range. It is of interest that, in the pilocarpine-treated glaucoma patients (Chandler, 1964), a restoration of the normal return time could be demonstrated.

It is clear that a higher aqueous outflow venous pressure would have to be calculated in the glaucoma patients in view of the significantly higher mean resting intra-ocular pressure, *i.e.* 20.33 ± 2.9 contrasted with 14.39 ± 3.4 mm. Hg of the normal subjects, and the similar outflow facilities.

The suction cup technique in man provides its most useful information during the decay of intra-ocular pressure to resting levels after cup removal. The instability of this decay curve in glaucoma and glaucoma suspects is strikingly different from the fairly smooth exponential decline in pressure seen in normal eyes. The resultant prolongation of the return time beyond two standard deviations of the mean time of the normal recovery, again offers a most useful additional facet in the diagnosis of glaucoma, and also concerning efficacy of therapy. The positive intercept upon the ΔF ordinate in the pressure-volume plot appears to be a cardinal characteristic of the normal eye and fails to be noted in untreated glaucoma. There, a negative intercept seems to be the rule, and in addition, a significant change in the angle of the facility of outflow slope. Apart from these characteristics, aqueous flow measurements yield values which, although lower in magnitude than those provided by the unpractical fluorescein technique, differ significantly in cases of glaucoma from those found in normal subjects.

This method fails to show a significant difference between the actual facilities of aqueous outflow in glaucoma and in normal subjects. The other parameters, particularly the curve instability as well as the prolonged return time of the decay curve in glaucoma, are sufficiently specific, however, to render the outflow facility estimate by this technique superfluous. The main limitation of the method seems to lie in the difficulty of plotting a decay curve in some patients with glaucoma, but in this

respect as well as in the aforementioned characteristics much additional diagnostic help is provided, particularly in borderline patients with chronic simple glaucoma.

Summary

The perilimbal suction cup technique was employed in 24 normal subjects and 24 patients with chronic simple wide-angle glaucoma of similar ages in order to compare estimates of mean rates of aqueous inflow (mF $\mu\text{l./min.}$), coefficient of aqueous outflow facility (C), mean rate of aqueous outflow (oFD $\mu\text{l./min.}$), and mean venous outflow pressure.

Significant differences emerged between the groups in respect of resting steady-state intra-ocular pressure (P_0), final intra-ocular pressure after 15 min. of cup-application (P_1), return time of intra-ocular pressure after removal of the cup, and outflow venous pressure (Vp). All these estimates exceeded those which obtained in the normal subjects. In the normal group the mean rate of outflow (oFD $\mu\text{l./min.}$) exceeded the mean rate of inflow (mF $\mu\text{l./min.}$), whereas in the glaucoma group this difference was reversed, principally because of the grossly prolonged return time to P_0 .

The mean rates of aqueous inflow and outflow were significantly smaller in the glaucoma group than in the normal subjects, and no differences were demonstrable in respect of the facility of aqueous outflow (C) and the mean rise in intra-ocular pressure as a result of the application of the suction cup. The mean aqueous suppression constant (k) was $+0.44$ in the normal group and -0.44 in the glaucoma group, but significance between these two means could not be established.

The usefulness and limitation of this technique are discussed.

The discussions and helpful advice from Dr. M. E. Langham, Wilmer Institute, The Johns Hopkins University Medical School, Baltimore, Maryland, are gratefully acknowledged.

REFERENCES

- CHANDLER, M. R. (1964). *Brit. J. Ophthalm.*, **48**, in press.
 EISENLOHR, J. E., LANGHAM, M. E., and MAUMENEE, A. E. (1962). *Ibid.*, **46**, 536.
 ERICSON, L. A. (1958). *Acta ophthalm. (Kbh)*, Suppl. 50.
 FRIEDENWALD, J. S. (1937). *Amer. J. Ophthalm.*, **20**, 985.
 — (1954). "Standardization of Tonometers". Decennial Report of the Committee on Standardization of Tonometers. *Amer. Acad. Ophthalm. Otolaryng.*, chap. 7, p. 94.
 GALIN, M. A., BARAS, I., and MANDELL, G. L. (1961). *Arch. Ophthalm. (Chicago)*, **66**, 65.
 GOLDMANN, H. (1950). *Ophthalmologica (Basel)*, **119**, 65.
 GRANT, W. M. (1950). *Arch. Ophthalm. (Chicago)*, **44**, 204.
 LANGHAM, M. E. (1962). *Invest. Ophthalm.*, **1**, 484.
 — Personal communication.
 — and EISENLOHR, J. E. (1963). *Invest. Ophthalm.*, **2**, 72.
 LINNÉR, E. (1959). *A.M.A. Arch. Ophthalm.*, **61**, 520.
 PRIJOT, E. (1959). *Docum. Ophthalm. (Den Haag)*, **13**, 193.
 ROSENGREN, B. (1934). *Acta ophthalm. (Kbh)*, **12**, 403.
 — (1956). *Trans. ophthalm. Soc. U.K.*, **76**, 65.
 WEEKERS, R., PRIJOT, E., FERON, A., and VERMER, P. (1960). *Acta ophthalm. (Kbh.)*, **38**, 129.
 YTTEBORG, J. (1960). *Ibid.*, **38**, 548.