DISTENSIBILITY OF THE HUMAN EYE*

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THE relationship between changes in pressure and changes in volume within the eye is of practical importance in the calibration of tonometers and in tonographic calculations, and the coefficient of ocular rigidity, K , proposed by Friedenwald (1937) has been employed generally for these purposes. Contrary to Friedenwald's assertion, it has been found that this coefficient is not a constant, but varies with intra-ocular pressure in the eyes of rabbits (Perkins and Gloster, 1957a, b) and of cats (Macri, Wanko, Grimes, and von Sallmann, 1957). In both species, the values of K increased markedly as the intra-ocular pressure increased. In view of these findings, it is of considerable importance to determine whether the coefficient of rigidity of human eyes is similarly dependent upon the intra-ocular pressure. Little attention has been given to this matter, although MacDonald (1955) produced some tonometric evidence which suggested that scleral rigidity was inversely related to intra-ocular pressure in living human eyes, and McBain (1957) reported that the rigidity of enucleated human eyes decreased as the intra-ocular pressure increased. Our observations, which have already been described briefly (Gloster, 1957), are in general agreement with the above findings and this paper gives a fuller account of our results.

Methods

Two methods for determining ocular rigidity were used—the “volumetric” method (Perkins and Gloster, 1957a) and the tonometric method (Perkins and Gloster, 1957b), the latter being quite distinct from the usual differential tonometric method using two weights, which was found to be completely unreliable. Only dead human eyes have been studied, as both methods necessitate the introduction of a needle into the anterior chamber. Some of the measurements were made on eyes which had been rejected for use in corneal grafting and stored at 4° C. for 5 to 15 days after enucleation. Other determinations were carried out on cadaver eyes, *in situ*, between 8 and 14 hours after death.

The experiments may be divided into three groups:

- (A) Enucleated eyes (three); studied by the volumetric method.
- (B) Enucleated eyes (four); rigidity determined by the tonometric method.
- (C) Dead eyes *in situ* (four); studied by the tonometric method.

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Results

The coefficient of ocular rigidity was calculated from the formula

$$K = \frac{\log_{10} P_2 - \log_{10} P_1}{\Delta V}$$

where P_1 was the initial intra-ocular pressure (cm. saline) and P_2 the pressure after a change in intra-ocular volume of $\Delta V \mu l$.

The values for K in each eye were plotted against intra-ocular pressure, and curves were drawn to fit the points as closely as possible. From these curves the values of the coefficient of ocular rigidity at 25 cm. saline and at 50 cm. saline were obtained, and these are presented in the Table.

TABLE
VARIATION OF THE COEFFICIENT OF OCULAR RIGIDITY K , WITH
INTRA-OCULAR PRESSURE IN DEAD HUMAN EYES

Group	Method	Eye	Coefficient of Ocular Rigidity, <i>K</i>	
			At 25 cm. Saline	At 50 cm. Saline
A Enucleated Eyes	Volumetric	1	0.012	0.009
		2	0.019	0.015
		3	0.013	0.010
B Enucleated Eyes	Tonometric	4	0.018	0.014
		5	0.017	0.015
		6	0.020	0.011
		7	0.017	0.013
C Dead Eyes <i>in situ</i> *	Tonometric	8	0.014	0.009
		9	0.027	0.016
		10	0.018	0.022
		11	0.018	0.012
Means			0.018	0.013
Ranges			0.012–0.027	0.009–0.022

* Eye 8 was examined 14 hours after death, Eye 9, 10 hours, Eye 10, 8 hours, and Eye 11, 13 hours after death.

The two main facts to be noted from these results are:

- (1) There was a wide individual variation in the values for K at both pressures;
- (2) In all eyes, except one (Eye 10), K was lower at 50 cm. saline than at 25 cm. saline.

The results for one eye (Eye 9) are shown in Fig. 1 (opposite).

Discussion

(a) *Individual Variations in Ocular Rigidity.*—The values obtained for the coefficient of ocular rigidity are in broad agreement with those given by Grant and Trotter (1955), who found an average value for K of 0.0163 (range

FIG. 1.—Variation of coefficient of ocular rigidity K with intra-ocular pressure. Dead human eye. (P_{av} = mean of initial and final intra-ocular pressures).

0.0110 to 0.0215) in 29 normal human eyes examined within 24 hours of death. However, these workers did not measure K over a range of pressures, and therefore their results cannot be compared strictly with ours.

It is not known how far these results are applicable to the living human eye, but there is reason to believe that the stretching properties of the eye are not grossly changed *post mortem*. Grant and Trotter (1955) found no correlation between the value of K and the time after enucleation (from 3 to 24 hours), and in one eye which they examined 15 minutes after enucleation K was found to be only slightly above their average value. These observations suggest that any *post mortem* changes in ocular rigidity probably take place rapidly, but in a previous study (Perkins and Gloster, 1957a) we found only small changes in K for the rabbit eye in the first hour after death. Thus, while we are ignorant of the absolute value of K in the living human eye, it seems highly probable that the individual variation in K for dead eyes reflects a similar variation for living eyes. The importance of this is obvious when it is remembered that the usual calibration curves for the Schiötz tonometer are calculated assuming that K is equal to 0.0215, and such calibrations are accurate only for eyes having this coefficient of ocular rigidity.

Moreover, variations in K will have a considerable effect upon determinations of the coefficient of facility of outflow, C , when the latter is calculated from tonographic measurements. The magnitude of this effect is shown in Fig. 2 (overleaf). Here the Tables given by Ballintine (1955) have been used to deduce values for C , assuming that, using a Schiötz tonometer with 5.5 g. weight, the scale reading changed from 5 to 7 in the course of 4 minutes—a

fairly average tonographic result. It is clear from the graph that the coefficient of facility of outflow calculated from tonographic data is most strongly influenced by ocular rigidity over just that range in which values for normal eyes fall.

FIG. 2.—Variation of coefficient of facility of outflow, C , with coefficient of ocular rigidity, K . (AB and CD represent the ranges of K at 25 and 50 cm. saline, respectively, found in the present study).

(b) *Variation of Ocular Rigidity with Intra-ocular Pressure.*—The variation of K with intra-ocular pressure in dead human eyes is of interest from two aspects. First, such a variation would again influence tonometric calibrations and tonographic results. Secondly, the variation is in marked contrast to that found in living and dead rabbit eyes, in which the same methods of determination showed that K increased as the intra-ocular pressure increased, a variation found in only one of the eleven human eyes studied. However, this seemingly great contrast between the human eye and the rabbit eye is due in part to the use of the coefficient of ocular rigidity as an expression of the distensibility of the eye. In Figs 3(a) and 3(b), the distensibility of a rabbit eye is compared with that of a human eye; in Fig. 3(a) the distensibilities are expressed by means of the coefficients of ocular rigidity, while in Fig. 3(b) the distensibilities of the same two eyes are expressed as the increase in pressure for unit increase in intra-ocular volume (opposite). These graphs show that, while there are undoubtedly differences between the two species in the stretching properties of the coats of the eye, there is some similarity of behaviour when the distensibilities are expressed as rises of pressure for unit increases of volume. Therefore, the contrast between the two eyes is

not as great as might be supposed from the opposite variations of K with intra-ocular pressure.

FIG. 3(a and b).—Comparison of distensibility of a human eye with that of a rabbit eye. In Fig. 3(a), the distensibilities are expressed as coefficients of rigidity, K . In Fig. 3(b), the distensibilities are expressed as changes in pressure for unit changes in volume, $\frac{\Delta P}{\Delta V}$.

Summary

The distensibility of dead human eyes has been studied and it has been shown that the coefficient of ocular rigidity, K , decreases as the intra-ocular pressure increases. There was a considerable individual variation in K , values from 0.012 to 0.027 at an intra-ocular pressure of 25 cm. saline being found in a series of 11 eyes. The importance of these findings in relation to tonometry and tonography is discussed.

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