Relationships between ocular dimensions and the effects of provocative tests

Water drinking

Homatropine eye drops

Water drinking and homatropine eye drops

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Weekers, Lavergne, and Prijot (1958), Davenport (1959), and Perkins and Jay (1960) have all commented on a high incidence of myopia in open-angle glaucoma.

Abdalla and Hamdi (1970) showed that myopic eyes have higher ocular tensions than emmetropic eyes in most age groups. The findings of Tomlinson and Phillips (1970) agreed with this, but showed that ocular tension correlated more closely with the axial length of the eye (*i.e.* high axial length was associated with higher ocular tension than low axial length) than with the refraction.

Tomlinson and Phillips (1969) have reported a correlation between high cup-to-disc area ratio and high axial length of the eye. Armaly (1969) has suggested that the cup/disc ratio may be a factor determining the susceptibility of eyes with high intraocular pressure to visual field defects. A tendency to high ocular tension and large cup/disc ratio in eyes of long axial length may partly explain the high prevalence of open-angle glaucoma in myopic eyes.

A very clear association between shallowness of the anterior chamber and closed-angle glaucoma is known (Rosengren, 1931; Törnquist, 1956; Lowe, 1969). In open-angle glaucoma also, a shallower than normal anterior chamber has been observed (Rosengren, 1931; Törnquist and Brodén, 1958; Tomlinson and Leighton, in preparation, *i.e.* unpublished data).

Object of present investigation

To find out whether the effects of provocative agents used in the diagnosis of open-angle glaucoma were influenced by dimensions of the eyeball.

Methods

PROVOCATIVE TESTS

38 subjects had 96 provocative tests of four different types. Table I (overleaf) gives the number of provocative tests and the types of subjects who had them.

Table I   *Particulars of 38 subjects tested, showing numbers of tests given to each category of patient*

Provocative tests done	Open-angle glaucoma		Low tension glaucoma cases	Relatives of open-angle glaucoma patients	Normal subjects	Total	
	Suspects	Cases				Patients	Tests
a, b, c	18	1	1	0	0	20	60
c, d	12	0	1	4	1	18	36
a, b, c, d	30	1	2	4	1	38	96

(a)	water-drinking tonography test		(c)	water-drinking homatropine tonography test
(b)	homatropine tonography test		(d)	water-drinking homatropine applanation test

(1)   Twenty subjects had three outflow tests:

(a)   a water-drinking tonography test

(b)   a homatropine tonography test

(c)   a water-drinking homatropine tonography test (Leighton, Phillips, and Gibbs, 1970).

In these tests, the effects on aqueous outflow and applanation tension of water drinking (20 ml./kg. body weight) and/or gutt. homatropine 2 per cent. in randomized order were estimated from the differences between tonographic and tonometric readings immediately before and 45 minutes after provocation.

(2)   Eighteen other subjects had two tests:

(c)   a water-drinking homatropine tonography test as above

(d)   a water-drinking homatropine applanation test (Leighton and Phillips, 1971).

The effect of the provocation (d) was measured from the difference between applanation tensions taken immediately before and 45 minutes after provocation.

OCULAR RIGIDITY

This was measured from Friedenwald's Nomogram (1955 calibration) by applanation and 5·5 g. Schiötz readings in sixty subjects. These comprised the 38 patients shown in Table I with the addition of 22 patients who did not have the provocative tests:

Open-angle glaucoma suspects	4	
Cases of open-angle glaucoma	1	
Cases of low tension glaucoma	1	22
Relatives of open-angle glaucoma patients	2	
Relatives of closed-angle glaucoma patients	14*	

OCULAR DIMENSIONS

The following were measured in the 38 subjects from the eye which received the provocative tests, and from one eye of each of the 22 additional subjects mentioned above:

(i)	Corneal diameter	from a colour photograph of the anterior surface of the eye
(ii)	Corneal thickness	by the No. I attachment for the Haag-Streit 900 slit lamp
(iii)	Central corneal radius	} by the Zeiss keratometer
(iv)	Corneal astigmatism	
(v)	Anterior chamber depth	by the No. II attachment for the Haag-Streit 900 slit lamp
(vi)	Lens thickness	} from an antero-posterior axis trace of the eye obtained by
(vii)	Length of vitreous body	A-scan ultrasonography
(viii)	Axial length of the eyeball	from the addition of (v), (vi), and (vii)

* Relatives of closed-angle glaucoma patients were used in this part of the survey to extend the range of ocular dimensions measured

None of the patients was having treatment for glaucoma at the time that the above dimensions were taken. If treatment with gutt. pilocarpine had been started beforehand this was discontinued 48hrs before the measurements were made. Wilkie, Drance, and Schulzer (1969) demonstrated reduction in anterior chamber depth in patients on miotic eye drops.

Results and discussion

OCULAR DIMENSIONS AND PROVOCATION

Correlation coefficients (r_s) are recorded in Tables II and III for twenty patients who had three outflow tests, and in Table IV for eighteen patients who had an outflow test and an applanation test. The Spearman rank correlation method (Siegel, 1956) was used. Analysis of the ages of the subjects and correlations of these with lens thickness and corneal astigmatism are given in Table V.

THREE PROVOCATIVE TESTS IN EACH OF TWENTY SUBJECTS

The rise in applanation tension found in the three outflow tests 45 minutes after provocation would have been affected by the fall in ocular tension due to the initial tonography which had been done after the initial applanation tension and before provocation.

No significant correlations were found between ocular dimensions and rise in Po/C in any of the three provocative outflow tests on twenty patients.

Test (a)   Water-drinking tonography test

No significant correlations between the dimensions and rise in outflow resistance were found. The small non-significant rise in outflow resistance which occurred might have explained this. However, the rise in applanation tension correlated significantly with corneal diameter, length of vitreous body, and lens thickness (see Table II)—$0 \cdot 01 < P < 0 \cdot 05$ in each case. Thus water loading induced a greater rise in ocular tension in eyes with small corneal diameters than in those with large diameters. Presumably such eyes have only a small circumference of filtration angle and perhaps also small total amount of trabecular meshwork, which is less able to allow the passage of the extra aqueous formed after water drinking.

The correlation between the rise in applanation tension and the length of the vitreous body suggests that water loading becomes less effective as a provocative agent in large eyes. A small rise in applanation tension tended to be associated with large axial length but this trend did not reach significance.

It is difficult to understand why variation in lens thickness correlated directly with rise in applanation tension due to water drinking. The explanation was presumably an indirect one. The rise in applanation tension after water was age-dependent (Armaly, 1970, has also shown this) as was lens thickness, $(r_s = +0 \cdot 471; +0 \cdot 384$ respectively; $0 \cdot 01 < P < 0 \cdot 05$ in each case) so the significant correlation between lens thickness and rise in applanation tension presumably reflected the age-dependence of each. A significant inverse correlation between lens thickness and anterior chamber depth was found $(r_s = -0 \cdot 440; 0 \cdot 01 < P < 0 \cdot 05)$. Shallowness of the anterior chamber, which François, Rabaey, Neetens, and Evens (1958) have shown experimentally to be associated with a high outflow resistance, tended to be associated with a high rise in applanation tension $(r_s = -0 \cdot 103; P > 0 \cdot 05)$ though not significantly so. The expected association of a shallow anterior chamber in an eye with a thick lens might therefore have contributed to the rise in applanation tension found, and thus to the correlation between lens thickness and effect on applanation tension of the water drinking.

The effect of water drinking on outflow resistance was slight compared with its effect on applanation tension (Tables II and III). Accordingly, the rise in applanation tension found was probably related more to an increase in aqueous production than to an increase in outflow resistance. The higher rise in applanation tension after water drinking found in older subjects could have been due to various factors, including greater haemodilution after easier absorption from the gut, less effective diuresis because of poorer renal function, or to an easier passage of water across the blood–aqueous barrier.

Table II *Twenty subjects. Correlations between (1) Effects on applanation tension of water drinkin and/or gutt. homatropine and (2) Ocular dimensions and age*

Tonography test	Rise in applanation tension		Correlation coefficients (r_s) between rise in applanation tension and:							
			Corneal diameter	Horizontal corneal radius	Corneal astigmatism (corneal radii: horizontal minus vertical)	Anterior chamber depth	Lens thickness	Length of vitreous body	Axial length of eyeball	Age
	Mean	SD								
(a) Water-drinking	+3·05	2·68	−0·399	+0·043	−0·230	−0·103	+0·427	−0·420	−0·248	+0·4
	S		S*	NS	NS	NS	S*	S*	NS	S*
(b) Gutt. homatropine	+0·55	2·04	−0·518	+0·276	−0·027	−0·237	+0·046	−0·283	−0·361	+0·2
	NS		S*	NS	NS	NS	NS	NS	NS	NS
(c) Water-drinking and gutt. homatropine	+5·25	5·16	−0·182	−0·105	−0·338	−0·014	−0·049	−0·557	−0·451	+0·3
	S		NS	NS	NS	NS	NS	*S*	S*	NS

S = Significant at P < 0·01
S* = Significant at 0·01 < P < 0·05
NS = Not significant P > 0·05
SD = Standard deviation

Correlation coefficients for $\left.\begin{array}{l} P = 0·05 \\ P = 0·01 \end{array}\right\}$ are $\left\{\begin{array}{l} 0·377 \\ 0·534 \end{array}\right.$

The rise in applanation tension quoted is the difference between an initial applanation reading taken just before a 4-minute tonograph before provocation, and a second applanation reading 45 minutes after provocation

Table III *Twenty subjects. Correlations between (1) Effects on outflow resistance of water drinkin and/or gutt. homatropine and (2) Ocular dimensions and age*

Tonography test	Rise in outflow resistance		Correlation coefficients (r_s) between rise in outflow resistance and:							
			Corneal diameter	Horizontal corneal radius	Corneal astigmatism (corneal radii: horizontal minus vertical)	Anterior chamber depth	Lens thickness	Length of vitreous body	Axial length of eyeball	Age
	Mean	SD								
(a) Water-drinking	+3·28	8·45	−0·127	−0·117	−0·008	+0·164	−0·150	−0·130	−0·043	+0·1
	NS		NS	NS	NS	NS	NS	NS	NS	NS
(b) Gutt. homatropine	+5·20	10·86	−0·447	+0·114	+0·279	−0·268	−0·012	−0·271	−0·265	−0·2
	S		S*	NS	NS	NS	NS	NS	NS	NS
(c) Water-drinking and gutt. homatropine	+5·73	9·68	−0·050	+0·110	−0·190	−0·125	+0·149	+0·189	+0·178	+0·0
	S		NS	NS	NS	NS	NS	NS	NS	NS

S = Significant at P < 0·01
S* = Significant at 0·01 < P < 0·05
NS = Not significant P > 0·05
SD = Standard deviation

Correlation coefficients for $\left.\begin{array}{l} P = 0·05 \\ P = 0·01 \end{array}\right\}$ are $\left\{\begin{array}{l} 0·377 \\ 0·534 \end{array}\right.$

The rise in outflow resistance quoted is obtained from the difference between an initial 4 minute tonography before provocation, and on done 45 minutes after provocation

Test (b) Homatropine tonography test

Significant correlations were found between corneal diameter and both rise in outflow resistance and rise in applanation tension (Fig. 1) (0·01 <P<0·05 in each case). Re-

laxation of tonus in the ciliary body after instillation of gutt. homatropine in an eye with a small corneal diameter therefore resulted in a greater rise in outflow resistance and applanation tension than it did in an eye with a large corneal diameter, perhaps because of the small circumference of filtration angle and hence a relatively small amount of trabecular meshwork in eyes with small corneal diameters.

Bárány and Christensen (1967) demonstrated a greater increase in outflow resistance after gutt. homatropine 5 per cent. in (open-angle) glaucomatous eyes than in normal eyes. This difference in effect might, in part, have been due to variation in corneal size, although a small cornea is not a conspicuous feature of eyes with open-angle glaucoma.

Test (c)   Water-drinking homatropine tonography test

The rise in applanation tension in this tonography test correlated inversely with both length of the vitreous body and axial length of the eyeball ($P < 0.01$ and $0.01 < P < 0.05$ respectively). The effect of the provocation was therefore significantly less in large than in small eyeballs. No significant correlations between the ocular dimensions and rise in outflow resistance were found.
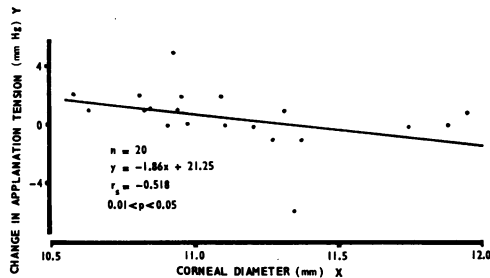

FIG. 1 *Change in applanation tension and corneal diameter in homatropine tonography test. Corneal diameter also correlated significantly with rise in outflow resistance ($r_s = -0.477$; $0.01 < P < 0.05$)*
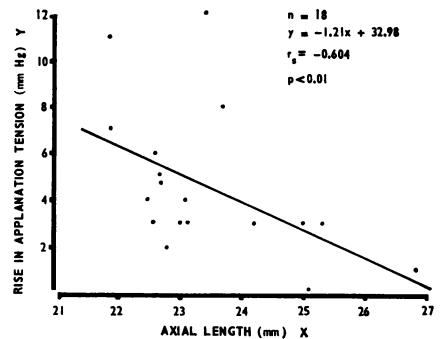
FIG. 2 *Rise in applanation tension and axial length of eyeball in a water-drinking homatropine tonography test*

TWO PROVOCATIVE TESTS IN EACH OF EIGHTEEN SUBJECTS

Correlations between ocular dimensions and the effects of these provocative tests on applanation tension and outflow resistance are recorded in Table IV (overleaf).

Test (c) continued   Water-drinking homatropine tonography test

Significant correlations were found between the rise in applanation tension and both the depth of the anterior chamber and the axial length of the eyeball (Fig. 2) ($r_s = -0.632$ and -0.604 respectively; $P < 0.01$ in each case). Eyes with shallow anterior chambers and short axial lengths therefore showed a greater rise in applanation tension after the provocation than eyes with deep anterior chambers and large axial lengths. The same trends were found between rise in Po/C, and both depth of anterior chamber ($r_s = -0.461$; $0.01 < P < 0.05$) and axial length of eyeball ($r_s = -0.395$; $P > 0.05$; the correlation coefficient for $P = 0.05$ is 0.399).

When this same test was done on twenty patients (see paragraph (c) above), no correlation between rise in applanation tension and anterior chamber depth was found ($r_s = -0.014$; $P < 0.05$). The reason for the wide discrepancy between the samples of twenty and eighteen subjects in the correlations of anterior chamber depth with rise in

Table IV *Eighteen subjects. Correlations between (1) Effects on outflow resistance and applanation tension of water drinking and gutt. homatropine and (2) Ocular dimensions and age*

| | Rise in | | | | Correlation coefficients (r_s) between rise in applanation tension or outflow resistance and: | | | | | | | |
| | Applanation tension | | Outflow resistance | | Corneal diameter | Horizontal corneal radius | Corneal astigmatism (corneal radii: horizontal vertical) | Anterior chamber depth | Lens thickness | Length of vitreous body | Axial length of eyeball | Age |
Test	Mean	SD	Mean	SD								
(c) (i) Water-drinking homatropine tonography			+8·30 *S**	10·88	−0·088 NS	−0·190 NS	−0·084 NS	−0·112 NS	+0·503 S*	−0·296 NS	−0·250 NS	+0·309 NS
(ii) Water-drinking homatropine tonography	+4·61 *S**	3·18			−0·111 NS	+0·273 NS	−0·490 S*	−0·632 *S*	+0·278 NS	−0·354 NS	−0·604 *S*	+0·040 NS
(d) Water-drinking homatropine applanation	+5·17 *S**	3·58			−0·369 NS	+0·150 NS	−0·482 S*	−0·150 NS	−0·232 NS	−0·031 NS	−0·232 NS	−0·276 NS

S = Significant at P < 0·01
S* = Significant at 0·01 < P < 0·05
NS = Not significant P > 0·05
SD = Standard deviation

Correlation coefficients for P = 0·05 and P = 0·01 are { 0·399 / 0·564 }

The rise in outflow resistance in (c) (i) and rise in applanation tension in (c) (ii) above are the differences between tonographic and tonometric readings taken immediately before, and 45 minutes after provocation. (c) (i) and (c) (ii) relate to the same visit. The rise in applanation tension in (d) is the difference between applanation tension taken immediately before and 45 minutes after provocation

applanation tension is probably as follows. In the eighteen subjects, in whom both shallow anterior chamber and short axial length correlated with a high rise in applanation tension, a correlation between shallow anterior chamber and short axial length almost reached significance ($r_s = +0.375$; P>0.05; r_s for P = 0.05, the borderline of significance, is 0.399). An explanation for a high rise in applanation tension could therefore have been either a shallow anterior chamber or short axial length, or both. In the twenty subjects short axial length correlated with a high rise in applanation tension, but very little correlation between axial length and anterior chamber depth was found ($r_s = +0.152$; P>0.05). This probably explains the absence of correlation between anterior chamber depth and rise in applanation tension in the twenty subjects and may well indicate that in the eighteen subjects short axial length was more important than a shallow anterior chamber in producing a high rise in applanation tension.

A greater rise in applanation tension tended to be found in eyes with small corneal diameter, but this trend did not approach significance ($r_s = -0.111$; P>0.05). However, as shallow anterior chamber was associated with small corneal diameter ($r_s = +0.519$; 0.01<P<0.05), the latter could also have contributed to the correlation found between shallow anterior chamber and a high rise in applanation tension after provocation.

A significantly greater rise in applanation tension was found in eyes with a larger horizontal than vertical corneal radius (*i.e.* "with-the-rule" astigmatism) than in those with a greater vertical than horizontal corneal radius (*i.e.* "against-the-rule" astigmatism) ($r_s = -0.490$; 0.01<P<0.05).

Rise in outflow resistance correlated significantly with lens thickness ($r_s = +0.503$; 0.01<P<0.05) as it had done with the rise in applanation tension in test (*a*), the water-drinking tonography test.

Test (d)   Water-drinking homatropine applanation test

The only significant correlation here was between corneal astigmatism and rise in applanation tension ($r_s + -0.482$; 0.01<P<0.05) (Fig. 3). This result agreed very closely with that for the water-drinking homatropine tonography test (see (*c*) continued above and Table IV) in these same eighteen individuals. Marin-Amat (1956) has shown that corneal astigmatism "against-the-rule", *i.e.* greater vertical than horizontal corneal radius, increases with age. This trend was not significant in these eighteen individuals ($r_s = +0.120$; P>0.05). It seems surprising that the rise in applanation tension became
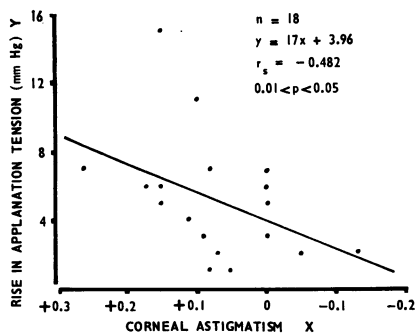

FIG. 3   *Rise in applanation tension and corneal astigmatism in a water-drinking homatropine applanation test*
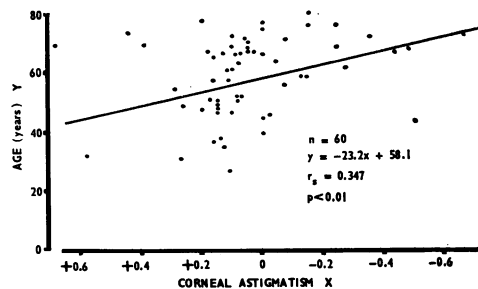
FIG. 4   *Age related to corneal astigmatism*

progressively less with increasing "against-the-rule" corneal astigmatism, which tended, though not significantly, to correlate with increasing age.

In the two other samples, *i.e.* twenty subjects who had three outflow tests, and sixty subjects in whom ocular rigidity was measured (see Fig. 4 and Table V), the correlations between increasing age and increasing "against-the-rule" astigmatism were both significant.

Table V　*Age, lens thickness, and corneal astigmatism of subjects and correlations between these*

Sample comprised subjects who had	Number of subjects	Lens thickness		Correlation coefficient (r_s) (Lens thickness/age)		Age (yrs)		Correlation coefficient (r_s) (Corneal astigmatism/age)		Corneal astigmatism (corneal radii: horizontal minus vertical)		Correlation coefficients (r_s) for	
		Mean	SD			Mean	SD			Mean	SD	$P = 0.05$	$P = 0.0$
(a), (b), (c)	20	4·72	0·43	+0·384	S*	65·8	9·4	+0·396	S*	+0·054	0·232	0·377	0·534
(c), (d)	18	4·68	0·44	+0·642	*S*	55·4	11·2	+0·120	NS	+0·071	0·157	0·399	0·564
Ocular rigidity	60	4·71	0·41	+0·465	**S*	59·1	13·1	+0·347	*S*	+0·044	0·193	0·255	0·330

(a)　Water-drinking tonography
(b)　Homatropine tonography
(c)　Water-drinking homatropine tonography
(d)　Water-drinking homatropine applanation

SD = Standard deviation
NS = Not significant
S* = 0·01 < P < 0·05
S = P < 0·01
**S* = P < 0·001

OCULAR RIGIDITY AND OCULAR DIMENSIONS

Ocular rigidity and axial length

These correlated significantly ($r_s = -0.322$; N = 60; P<0·02) (Fig. 5), *i.e.* large eyes had low ocular rigidity.

n = 60
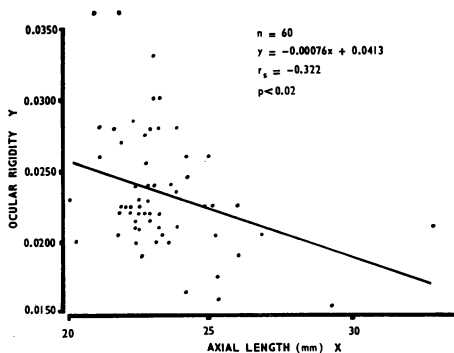y = −0.00076x + 0.0413
r_s = −0.322
p<0.02

FIG. 5　*Ocular rigidity related to axial length of eyeball*

Ytteborg (1960), in experiments on enucleated eyes, noted that ocular rigidity was less in large than in small eyes. Phillips and Quick (1960) and Phillips and Shaw (1970) have shown experimentally that, in impression tonometry on hollow rubber spheres simulating eyeballs, volumes of indentation are dependent on total volume. Luyckx (1967) found, by applanation and 10 g. Schiötz tonometry *in vivo* in seventy subjects, that ocular rigidity was inversely proportional to the square of the axial length. It follows, therefore, that an impression tonometer would sink more easily into a large myopic or buphthalmic eye than into a small eye.

Ocular rigidity as measured here represents a discrepancy between the estimated intraocular pressure measured by applanation and Schiötz tonometry. Factors other

than ocular volume determine ocular rigidity. It is known that corneal radius can affect Schiötz tonometer readings (Friedenwald, 1954) but that the effect of varying corneal radius on applanation tonometer readings is negligible (Schmidt, 1956). As no correlation between ocular rigidity and corneal radius was found, variation in the latter does not appear to have affected readings with the Schiötz tonometer compared with applanation readings.

Ocular rigidity and lens thickness

A significant correlation was found between these measurements ($r_s = -0\cdot268$; N = 60; $0\cdot01 < P < 0\cdot05$), in that eyes with thicker lenses showed lower ocular rigidities.

As eyes with longer axial lengths usually contain thinner lenses (see Lowe, 1970), a positive correlation between lens thickness and ocular rigidity might have been expected. But as no correlation between lens thickness and axial length was found for this sample ($r_s = -0\cdot056$; N = 60; $P > 0\cdot50$), no inconsistency exists.

Weale (1963) mentioned conflicting reports from various authors on change in ocular rigidity with increasing age, some reporting a fall in ocular rigidity and others an increase. In our sixty subjects, although lens thickness was age-dependent (Table V) ($r_s = +0\cdot465$; $P > 0\cdot001$), ocular rigidity was not ($r_s = 0\cdot149$; $P > 0\cdot05$). The correlation found between lens thickness and ocular rigidity could not therefore be explained in terms of their age dependence.

Conclusions

EYEBALL SIZE AND EFFECTS OF PROVOCATION

Significant correlations were found in outflow tests between a high rise in applanation tension and short length of vitreous body when water was used alone, and between a high rise in applanation tension and short lengths of both vitreous body and eyeball when water was combined with gutt. homatropine (Tables III and IV; Fig. 3). A tendency for small eyeballs to respond to water and homatropine by a high rise in Po/C very nearly reached significance ($r_s = -0\cdot395$; $P > p\cdot05$; correlation coefficient for $P = 0\cdot05$ is $0\cdot399$). This dependence of test effect on eyeball size was not significant in the water-drinking homatropine applanation test, although the correlation approached significance (Table IV). Presumably the dependence of rise in applanation tension on eyeball size in an outflow test was partly due to the fall in ocular tension after the initial tonography, carried out after the first applanation reading but before water or water and homatropine were given. No significant correlation was found between the initial applanation tension and anterior chamber depth or axial length of eyeball, nor between these last two dimensions and the initial outflow resistance. The relatively small test effect in large eyes probably adversely affects the ability of water-drinking and gutt. homatropine to discriminate between glaucoma and normality in such eyes, as large eyeballs are probably more susceptible to open-angle glaucoma than small eyes.

CORNEAL DIAMETER AND ANTERIOR CHAMBER DEPTH

Water drinking or homatropine, each given separately, induced a rise in applanation tension which was greater in eyes with a small corneal diameter than in those with a large diameter. Homatropine alone induced a greater rise in outflow resistance in eyes with small than in those with large corneal diameters.

It is unlikely that correlation of the response to provocation and corneal diameter increases the ability of the provocative agents to differentiate between glaucoma and normality.

The greater effect of water drinking combined with gutt. homatropine on applanation tension found in eyes with shallow anterior chambers in the eighteen subjects (but not in the twenty subjects) might have been regarded as a useful trend because, as has been mentioned above, patients with open-angle glaucoma tend to have shallow anterior chambers. However, unfortunately for this test, the trend probably resulted from a tendency to a high rise in applanation tension in eyes of short axial length, because a fairly close correlation was found between anterior chamber depth and axial length in the eighteen subjects but not in the twenty subjects.

CORNEAL ASTIGMATISM AND EFFECTS OF PROVOCATION

The well-known change from "with-the-rule" to "against-the-rule" refractive astigmatism with increasing age is probably chiefly due to a change in corneal astigmatism. McLena-chan and Loran (1967) have shown that "against-the-rule" refractive astigmatism is commoner in patients with closed-angle glaucoma than in normal subjects. They attributed the greater likelihood of angle closure in "against-the-rule" astigmatism to a greater vertical than horizontal corneal radius. Surprisingly, the greater rise in applan-ation tension after water drinking combined with homatropine was found in "with-the-rule" corneal astigmatism (Fig. 3). This is the reverse of the trend with increasing age, and the trend in closed-angle glaucoma. It is unlikely that a greater horizontal than vertical corneal radius is a feature of eyes with open-angle glaucoma and its correlation with rise in applanation tension may reveal an unreliable feature of the test. It is very difficult to explain this trend.

Full evaluation of the factors which determine effects of provocation would require more measurements, both ocular and extraocular. Analysis of these data as well as those already considered here would become more complex. The rôle of these dimensions in determining the response to provocation would be uncertain because of the many possible relationships between the dimensions and the effects of provocation, and between the dimensions themselves. The connection between the cause, *i.e.* provocation, and effect of the provocation, therefore becomes increasingly obscure as more dimensions are considered.

Ocular dimensions, such as corneal astigmatism and corneal diameter, which appear to determine the effects of the provocation, seem to have no relevance to open-angle glaucoma, and may explain some unsatisfactory results of provocative tests.

The smaller effect of provocation in eyes of great axial length (or surface area of corneo-scleral envelope: Phillips and Shaw, 1970) is probably a factor which adversely affects the ability of a test to discriminate between glaucoma and normality, and may well account for some false negative results of provocative tests in patients with open-angle glaucoma and high myopia.

Summary

Twenty subjects (eighteen open-angle glaucoma suspects and two cases of definite open-angle glaucoma) had three outflow tests: (a) water-drinking tonography test, (b) a homa-tropine 2 per cent. tonography test, and (c) a water-drinking homatropine 2 per cent. tonography test. A dose of 20 ml./kg. body weight of water was given.

The following significant correlations (P<0·05) were found between ocular dimension^S and rise in applanation tensions and rise in outflow resistance in these three outflow tests:

Test (a) Water-drinking tonography test

A high rise in applanation tension was associated with:

(*i*)   Small corneal diameter,

(*v*)   A thick lens,

(*vii*)   Short length of vitreous body and greater age.

Test (b) Homatropine tonography test

A high rise in applanation tension and outflow resistance was associated with:

(*i*)   Small corneal diameter

Test (c) Water-drinking homatropine tonography test

A high rise in applanation tension was associated with:

(*vii*)   Short length of vitreous body,

(*viii*)   Short axial length of eyeball.

Eighteen subjects (twelve open-angle glaucoma suspects, one case of definite open-angle glaucoma, four relatives of patients with open-angle glaucoma, and one normal subject) had two tests in which water-drinking and gutt. homatropine were given:

(*c*) an outflow test (*i.e.* same as (*c*) above),

and

(*d*) a tonometry (only) test.

The following significant (P<0·05) correlations were found:

Test (c) Water-drinking homatropine tonography test

A high rise in applanation tension was associated with:

(*iv*)   "With-the-rule" corneal astigmatism,

(*v*)   Shallowness of anterior chamber,

(*viii*)   Short axial length of eyeball.

A high rise in Po/C was associated with:

(*v*)   Shallowness of anterior chamber

A high rise in outflow resistance was associated with:

(*vi*)   A thick lens

Test (d) Water-drinking homatropine applanation test

A high rise in applanation tension was associated with:

(*iv*)   "With-the-rule" corneal astigmatism

In the sample of eighteen subjects, eyeballs with shallow anterior chambers tended to have short axial lengths.   The rise in applanation tension found was probably due to a short axial length rather than to a shallow anterior chamber.

Variations in the axial length of the eyeball and the length of the vitreous, which tend

to correlate inversely with the effect of the provocation used, are likely to cause a *reduction* in the ability of the provocative agents used to discriminate between open-angle glaucoma and normality.

In sixty subjects, a significant association between increasing age and a change from "with-the-rule" to "against-the-rule" corneal astigmatism was found.

In the same sixty subjects, a significant tendency for low ocular rigidity to be associated with a high axial length of the eyeball was found, suggesting that Schiötz tonometry gives an erroneously low estimate of intraocular pressure on larger than "normal" eyes and an erroneously high reading in smaller than "normal" eyes.

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