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BLOOD IN THE CANAL OF SCHLEMM*

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THE APPEARANCE of blood in the canal of Schlemm was described by Salzmann (1914) and has been reported since by many workers. It has been suggested, furthermore, that this gonioscopical appearance is seen less commonly in glaucomatous as compared with normal eyes (Kronfeld, McGarry, and Smith, 1942; François, 1948). Ascher and Spurgeon (1949) interpreted this as a sign of a relative obstruction in the depths of the sclera, since a blood regurgitation into the aqueous veins is said to occur more commonly in glaucomatous eyes. Hobbs (1950) cast doubt, however, on the validity of the evidence that blood was less commonly seen in the canal in glaucoma, and it was therefore decided to investigate this problem by Hobbs's method.

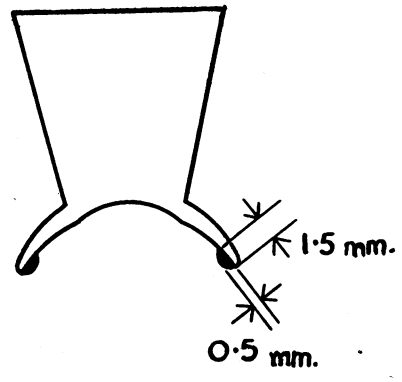

FIG. 1.—Hobbs's modification of Goldmann's gonioscopy lens.

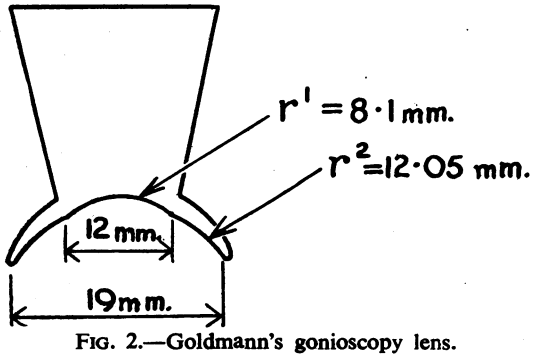

FIG. 2.—Goldmann's gonioscopy lens.

Material and Method

Gonioscopic examination was carried out by the use of modified Goldmann lenses. The first was a conventional lens, from which the scleral part had been entirely removed, the lens thus making contact with the cornea only. The second was Hobbs's modification of Goldmann's lens (Figs 1 and 2). It will be seen from the figure that a ridge, 1·5 mm. broad and 0·5 mm. thick, is added to the inner aspect of the edge of the lens. This ridge tends to press on the eye and produces congestion of the episclera and conjunctiva.

Two groups of patients were examined with this lens, the examinations being made in the usual way, that is with the patient seated before the Haag-Streit slit lamp and corneal

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microscope, the eye having been anaesthetized with a drop of 1 per cent. amethocaine hydrochloride. The lens was allowed to remain in position for two minutes and the presence of blood in all or part of the canal of Schlemm at any time during this period was noted. The ocular tension (Schiötz) was then measured.

At the conclusion of the investigation, it was found that a significant difference was present between the glaucomatous and the normal series but it was feared that this might be due to bias on the part of the examiner, since in some cases it is a little difficult to be certain of the presence of blood. In many cases, indeed, it was impossible to see, because of pigmentation of the trabeculae, and these cases were excluded. In order to avoid bias, a second investigation was arranged in which the examiner was kept unaware of whether the case under examination was normal or glaucomatous. The controls in the first investigation were persons who had attended Moorfields for minor conditions of the eye, such as corneal foreign bodies or who were being refracted (high refractive errors were excluded), and the controls in the second series were similar patients who were written to and asked to attend the Institute of Ophthalmology as volunteers for this research. The glaucomatous patients were all fully authenticated, unoperated cases of chronic simple glaucoma, investigated previously in the Glaucoma Clinic at the Institute of Ophthalmology.

In order to subject the controls to the minimum of interference it was decided to examine only the right eye. This seemed justified in view of a preliminary observation on the glaucomatous cases that no great difference appeared to exist between the two eyes of an individual in this respect, and it had the additional advantage of avoiding certain statistical difficulties in the analysis of results.

Findings

Corneal Lens.—Blood was only seen in the canal of Schlemm in one case out of fifty when using the purely corneal lens. All following data, therefore, refer to work with the ridged lens.

Ridged Lens.—Blood was seen frequently, both in normal and glaucomatous eyes, when using the ridged lens, and appeared most commonly in the normal group.

Table I shows the findings in the first series, that in which the identity of the patients was known to the examiner. It will be observed that blood was seen in 31 per cent. of the glaucomatous eyes as compared with 66 per cent. of

TABLE I

Group	+	0	Totals	Per cent. +ve
Glaucoma	16	35	51	31
Control	27	14	41	66

Difference = 35 per cent.
Standard error of the difference = 10
Difference > 3 × Standard error

(Analysis excludes cases not visible due to pigment)

normal eyes. The standard error of the difference is 10 so that the difference is more than three times the standard error.

Table II shows the findings in the second series, when the identity of the patients was not known. Blood was seen in 41 per cent. of the glaucomatous eyes but in 92 per cent. of the controls. The standard error of the difference is 13, so that the difference is four times the standard error.

TABLE II

Group	+	0	Totals	Per cent. +ve
Glaucoma	9	13	22	41
Control	12	1	13	92

Difference=51 per cent.
Standard error of the difference=13
Difference 4× Standard error

(Analysis excludes cases not visible due to pigment)

Table III shows the results of considering Series 1 and 2 together. In the combined series, blood was seen in 34 per cent. of glaucomatous eyes but in 72 per cent. of controls. The difference is statistically significant, taking $P=0{\cdot}05$ as the level of significance, since $P<{\cdot}01$. A footnote to Table III shows the number of cases excluded because of pigmentation of the trabeculae. It will be noted that 17 per cent. of the glaucomatous eyes were rejected (fifteen out of 88) and 11·5 per cent. of control eyes (seven out of 61). Examination of these figures by the χ^2 test shows that $\chi^2=0{\cdot}8$; $N=1$, therefore $P>0{\cdot}3$. The difference in incidence of pigmentation, sufficient to obscure a view of blood, is not therefore greater than would be expected from chance. It is thought unlikely, therefore, that the exclusion of these heavily pigmented eyes affects the conclusions reached in the work.

TABLE III

SUM OF TABLES I AND II

Group	+	0	Totals	Per cent. +ve
Glaucoma	25	48	73	34·2
Control	39	15	54	72·2

Difference=38 per cent.
Standard error of the difference=8·2
Difference 4·5 × Standard error
$\chi^2=19$; $N=1$; $P<0{\cdot}01$

(Analysis excludes cases not visible through pigment)

(N.B.—Cases excluded because of pigment comprise fifteen glaucomatous patients (17·0 per cent.) and seven controls (11·5 per cent.).

Table IV shows the effect of removing from the series all cases of glaucoma in which the tension (mm. Hg Schiötz) was more than 30. This is done as an attempt to eliminate the possibility that the level of the tension might be the cause of the observed difference, rather than some other factor, at present unknown. There is, in fact, a strong suspicion that the actual level of the tension does play a part, since only one of the thirteen glaucomatous eyes with a tension above 30 mm. Hg showed blood. However, even with these cases excluded, blood was seen in only 40 per cent. of glaucomatous eyes but in 72 per cent. of controls. The difference is significant since $P < 0{\cdot}01$.

TABLE IV

TABLE III EXCLUDING CASES WITH TENSION ABOVE 30 mm. Hg SCHIÖTZ

Group	+	0	Totals	Per cent. +ve
Glaucoma	24	36	60	40
Control	39	15	54	72·2

Difference=32·2 per cent.
Standard error=8·8
Difference 3·6× Standard error
$\chi^2=10$; $N=1$; $P<0{\cdot}01$

Table V shows the incidence of blood-filling in the glaucomatous and control groups at various tension levels. It will be seen that no significant difference exists in either group in the incidence of blood-filling at the various levels until a tension of 30 mm. Hg is reached. Above this tension, in the glaucomatous group, a sharp fall in the incidence of blood-filling is seen, 40 per cent. falling to 7·7 per cent. The standard error of the difference between the normotensive and the hypertensive group is 10·5, but the difference is 32·3 per cent., so that the difference is significant ($P < 0{\cdot}01$).

TABLE V

TENSION STUDIES

Group	Tension (mm. Hg Schiötz)	+	0	Totals	Per cent. +ve	Mean Age (yrs)
Glaucoma ...	<21	7	12	19	37	68·4
	21–25	12	17	29	41	66·06
	26–30	5	7	12	41	63·58
	31–35	1	8	9	11	67·1
	>35	0	4	4	0	61·5
Control ...	<21	22	9	31	71	49
	21–25	15	6	21	71	57·3
	>25	1	0	1	(–)	(49)
	Not taken	1	0	1	(–)	(60)

It should be emphasized that in the glaucomatous group below a tension of 31 mm. Hg there is no sign of a progressive decrease in blood-filling as

tension rises, and a similar observation holds for the control group. It may be said, therefore, as far as the present series is concerned, that the actual level of the tension at the time of examination does not appear to influence the results in either group, provided the level of 30 mm. Hg (Schiötz) is not exceeded. Above this level the tension at the time of examination has a profound influence on the results.

The control group does not exactly match the glaucomatous group in respect of age and sex distribution, so that an attempt must be made to assess the influence of these factors on the results.

Furthermore, since a tension of more than 30 mm. Hg clearly inhibits blood-filling *per se*, regardless of any other factor peculiar to the glaucomatous eye, it would be advisable again to exclude such cases. These cases number thirteen, leaving sixty glaucomatous eyes with a mean age of 66·7 years. These eyes may be compared with those of 54 controls with a mean age of 53 years (Table VI).

TABLE VI

AGE STUDIES

Group	Age (yrs)	+	0	Totals	Per cent. +ve	
Glaucoma	Less than 66·7 ...	13	15	28	46	$\chi^2=11$ $N=1$ $P<0{\cdot}01$
	More than 66·7...	11	21	32	34	
Control	Less than 53 ...	23	6	29	80	$\chi^2=4{\cdot}5$ $N=1$ $P<0{\cdot}05$
	More than 53 ...	16	9	25	64	

Mean age of glaucomatous patients with tension less than 31mm. Hg Schiötz =66·7 yrs
Mean age of all controls =53 yrs

Considering all the glaucomatous patients below the mean age of 66·7 years, we find a figure of 46 per cent. blood-filling compared with 34 per cent. for all those above the mean age.

Considering all the controls below the mean age of 53 years, we find a figure of 80 per cent. blood-filling compared with only 64 per cent. for all those above the mean age.

In the glaucomatous patients the difference in incidence of blood-filling between the younger and the older age groups is statistically significant ($P<0{\cdot}01$), and in the controls the difference between the younger and the older groups is also significant but not with such certainty ($P<0{\cdot}05$).

An attempt may now be made to estimate the influence of age on the different incidences of blood-filling in glaucomatous patients as compared with controls (Table VII, opposite). The younger cases of glaucoma (*i.e.* all those below the mean age for all glaucomatous patients, excluding cases with tensions above 30 mm. Hg Schiötz) have a mean age of 59 years and a blood-filling incidence of 46 per cent. The older controls (those above the mean age for

TABLE VII

EFFECT OF AGE

Group	Age (yrs)	+	0	Total	Mean Age (yrs)	Mean Tension (mm. Hg Schiötz)	Per cent. +ve
Glaucoma	Less than 66·7	13	15	28	59	22·68	46
Control	More than 53	17	9	26	66	21·00	65

Difference = 19 per cent.
Standard error of difference = 13·4
Difference $< 2 \times$ Standard error
$\chi^2 = 6{\cdot}6$; $N = 1$; $P = 0{\cdot}01$

controls) have a mean age of 66 years and a blood-filling incidence of 65 per cent. Thus the difference between glaucomatous patients and controls in these groups is nineteen, which is significant (since $P = 0{\cdot}01$). Thus age cannot be said to account completely for the observed difference in the incidence of blood-filling between the glaucomatous patients and the controls.

The influence of sex on the findings may now be examined. In the glaucomatous group (excluding, once more, cases with tension of more than 30 mm. Hg Schiötz), there are 36 males and 24 females: 33 per cent. of the males show blood-filling, while 45·8 per cent. of the females show blood-filling, a difference of 12·8 per cent. The standard error of this difference is, however, exactly 12·8, so that the difference cannot be regarded as significant. In the control group there are sixteen males, of whom 75 per cent. show blood-filling, and 38 females, of whom 71 per cent. show blood-filling. The difference here is clearly not significant.

It is unlikely, therefore, that the difference in sex distribution between the glaucomatous patients and controls in the present series has any influence on the observations with regard to blood in the canal of Schlemm, since it occurs approximately with equal frequency both in males and females.

A further point of interest which is not suitable for statistical study is that of the morphology of the observed blood-filling. In the glaucoma patients it was often observed that very short filled sectors of the canal alternated with short unfilled sectors in a given case, the filling being patchy and incomplete. In the controls, filling was generally more extensive; it was usually total, but if, for example, only half of the circumference became filled, it was usually filled completely without patches or gaps.

Conclusions

It is concluded from the statistical analysis of the results obtained in this investigation that the appearance of blood in the canal of Schlemm is influenced by at least three factors. The first is the existence of chronic simple glaucoma, the second is the presence of an ocular tension of more than 30 mm. Hg Schiötz at the time of examination, and the third is the age of the patient. It cannot be too strongly emphasized that these factors each have separate influences on the results, since, as has been shown, a significant

difference exists between glaucomatous patients and controls even when the factors of age and tension have been allowed for.

It is thought unlikely that blood failed to be seen in the glaucomatous cases through opacity of the trabeculae. Pigment obscured the view in some normal and some glaucomatous cases but these were all excluded from the series. If blood appeared in an eye with a non-pigmented or moderately pigmented trabecular meshwork it was always obvious, which would not be expected if varying degrees of trabecular opacity were present, to obscure or partially obscure it.

Discussion

Two important questions arise from the present findings; first, what factor is present in glaucoma simplex to inhibit the backflow of blood into the canal in the conditions of the investigation; secondly, of what use might this technique (or a refinement of it) be in the diagnosis of glaucoma simplex?

As far as the first question is concerned, it is felt that the technique itself is so crude and its mechanical effects so incalculable that an estimate of the factor or factors causing the inhibition of blood-filling in glaucoma could only be arrived at by pure guesswork. Many possibilities may be considered, such as partial or total obliteration of the canal of Schlemm, constriction of scleral channels, constriction of episcleral channels, sclerosis of episcleral veins resisting the pressure of the contact lens, high pressure in the episcleral veins giving a like result, low pressure in the intrascleral arteries giving an inadequate blood supply to the deep scleral plexus, the presence of unduly well-developed deep scleral-uveal venous anastomoses (by-passing the compression effect of the contact lens on the episclera), sclerosis and rigidity of the trabeculae (preventing blood backflow into the canal by virtue of converting it into an inexpansible chamber), or the influence of miotic drops. It is clearly necessary, if the above possibilities are to be studied further, to seek a more refined technique.

As far as the second question regarding the value of the test as a diagnostic procedure is concerned, it is worth noting that even in its present crude form it is able to show a difference in response of 35 per cent. as between glaucomatous patients and controls in the presence of a normal tension (Table IV). Considering any individual case in this Table it will be appreciated that if blood-filling is not observed the odds are 1·7 to 1 in favour of the case being glaucomatous and 2·6 to 1 against its being normal. Thus, even in its present form, the test can make a definite contribution to clinical knowledge of an individual case although its value is obviously only slight. It does not seem beyond the bounds of possibility, however, that the technique might be so improved as to accentuate the difference between glaucomatous and normal eyes in this respect.

Summary

An investigation is described in which blood-filling of Schlemm's canal

was observed gonioscopically using Hobbs's modification of Goldmann's contact lens. A statistically significant difference was found in the incidence of blood-filling in a group of patients with unoperated simple glaucoma as compared with normal controls, blood-filling being less frequent in the glaucomatous group.

A high level of ocular tension (above 30 mm. Hg Schiötz) and advancing age were two factors which were found to militate against the appearance of blood, but they were not sufficient to account for the difference between glaucomatous and normal eyes. It is concluded that there is an additional, unknown factor or combination of factors present in a glaucomatous eye which tends to inhibit blood backflow into the canal of Schlemm.

Some of the numerous possibilities which might account for the observed difference are mentioned and it is also suggested that the test in an improved form might prove to have some diagnostic value.

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