SUMMARY

1. Recent literature suggests that thyrotropic exophthalmos commonly follows thyroidectomy.
2. To investigate the true incidence of this as a complication, a questionnaire was submitted in regard to 1,001 patients admitted to the Royal Free Hospital for thyroidectomy from 1940-1944.
3. Satisfactory information was obtained in 584 cases.
4. Three cases, only, of thyrotropic exophthalmos of a mild degree were found.
5. No gross cases of the condition occurred.
6. The condition is rare as sequel to thyroidectomy.

This study was undertaken at the suggestion of Miss Ida Mann and I am much indebted to her for her help and guidance. I wish also to thank Dr. Elizabeth Everitt, formerly of the Royal Free Hospital, for her abstracts of case histories, and Miss Saunders for help with the clerical aspects. Acknowledgments are also due to the Medical Committee of the Royal Free Hospital for their permission to use the notes of the late Mr. Cecil Joll. The secretarial expenses for this investigation have been met by Moorfields Eye Hospital, who made the necessary allocation of funds from the Royal London Ophthalmic Hospital Research Fund.

REFERENCES

- BENEDICT, W. L. and KNIGHT, M. S. (1923).—*Amer. J. Ophthalm.*, **52**, 656.
 BRAIN, W. RUSSELL (1944-45).—*Proc. Roy. Soc. Med.*, **38**, 666.
 CHEVALLEREAU and OFFRET (1913).—*Annales d'oculistique*, **150**, 1. Quoted by Naffziger.
 DUNHILL, T. P. (1930).—*Brit. J. Surg.* **67**, 424.
 MANN I. (1946).—*Amer. J. Ophthalm.*, **29**, 6, 654.
 NAFFZIGER, H. C. (1933).—*Arch. Ophthalm.*, **9**, 1, 1.
 ROBERTSON, C. (1945).—*Aust. N. Z. J. Surg.*, **14**, 262.
 ZIMMERMAN, L. M. (1929).—*Amer. J. Med. Science.*, **178**, 92.

THE GLASS ROD TEST IN GLAUCOMATOUS EYES*

BY

T. L. THOMASSEN

(From The Institute of Ophthalmology, London,
 Director of Research, Sir Stewart Duke-Elder)

IN his first paper on the aqueous veins Ascher described the so-called "glass rod phenomenon"¹. This phenomenon is produced by compressing the recipient vessel just beyond the meeting-point of an aqueous vein and a blood vein. There are two possible results. The aqueous may push away and replace the blood in the recipient vein so that it enters the vein previously filled with

* Received for publication, September 2, 1949.

blood. This is called a *positive glass rod test* or *aqueous influx phenomenon*. Alternatively, blood may flow backwards into the aqueous vein, filling it wholly or in part. This is called a *negative glass rod test* or *blood influx phenomenon*.

In normal eyes Ascher has shown^{1, 2} that this test can be positive or negative in different aqueous veins. According to his law of constancy⁴, however, the test will always give the same result, positive or negative, when performed on the same aqueous vein even after an interval of years. If more than one aqueous vein is present in the same eye, one may show a positive and the other a negative glass rod test. He has also found that aqueous veins situated on the temporal side of the globe show a positive test more often than those on the nasal side. In his first paper on this subject (¹ p. 32 and ² p. 1192) Ascher says that the ratio of aqueous veins with a positive glass rod test to those with a negative test is about seven to five. In a later paper (⁴ p. 1084) he has found statistically that the glass rod test is positive only in two-fifths of all eyes with aqueous veins.

In eyes suffering from simple glaucoma Ascher has made the remarkable finding^{1, 2, 3} that the glass rod test is invariably negative except when the pressure is controlled by either miotics or surgery. Goldmann⁸ has confirmed this and so does de Vries¹². The latter has, however, found that the test can be positive even if the ocular pressure is increased, provided the intra-ocular pressure is in the decreasing phase.

Clinical Investigations.

Twenty-four patients with 35 eyes suffering from simple glaucoma and with an aqueous vein suitable for the glass rod test were examined. The glass rod test was applied to each of these eyes many times. Observations were usually made half-hourly through a large part of the day and in most cases for more than one day, sometimes up to five. As the ocular tension was expected to influence the result of the test, the tension was measured with a Schiötz X-tonometer after each test. Before tonometry a drop of 1 per cent. pantocaine was instilled into the eye. The drops and the manipulations irritated the eye and produced a state of hyperæmia which usually disappeared in half an hour. If the hyperæmia persisted, a further delay in testing was necessary. The eyes examined had not been operated on, and usually not treated with miotics for 24 hours. The tension in most of the eyes oscillated considerably during the period of observation and it could be seen that the result of the test varied with the height of the ocular tension and with the phase of its oscillations.

When the bulbar tension was in an increasing phase the test was never positive. It is, however, often difficult or even impossible to judge the result of the test in this phase as the aqueous veins are usually filled spontaneously with blood. When the bulbar tension was in a decreasing phase de Vries' findings were confirmed in so far as the test was sometimes found to be positive even when the bulbar tension was increased. It was, however, by no means invariably so. In this connection it does not seem to matter whether the decreasing phase is spontaneous or produced by pilocarpine. When the tension remained on a steady but increased level the test was usually negative. In a few cases, however, it was positive in spite of a tension up to 45 mm. Hg.

Ascher's finding that the glass rod test is always negative in glaucomatous eyes when the bulbar tension is increased was thus not confirmed here. The test is definitely more often negative in glaucomatous eyes. Nor was Ascher's law of constancy found to apply to glaucomatous eyes. Repeated examinations of the same aqueous vein very often gave different results. In 21 of the glaucomatous eyes examined, an inconstancy of the glass rod test was found. In one case for instance the glass rod test was applied to the same aqueous vein 14 times, 9 of which were positive and 5 negative. The bulbar tension oscillated between 15 and 25 mm. Hg during the three days' observation. In this case no direct relationship between the height of the tension and the results of the tests could be observed, although it is probable that the phases in the oscillations of tension determined the variations. The bulbar tension went up and down so quickly that it was impossible to be sure whether the test was carried out during an increasing or decreasing phase.

DISCUSSION.

Some hydrodynamic principles of the aqueous veins will first be explained.

According to Theobald⁹ there are 20 to 30 outlets from the canal of Schlemm. Most of them join the veins within the sclera, but one or a few may appear on the bulbar surface before they join a blood vein; the latter are known as aqueous veins. The total amount of fluid emptied through all the outlets in a normal eye must be just as much as is necessary to keep the production and escape of aqueous humour in equilibrium. The outlets, however, differ in size, length and course. Both the amount of fluid which has to be emptied through each of them and their pressures at the point where they join the blood vein must therefore vary from one outlet to another. On the other hand, the pressure in the blood

veins is not uniform. Inside the globe the venous pressure is high but it starts decreasing as soon as the vein enters the sclera. The pressure in the vein just at the meeting point with an aqueous outlet vein may therefore vary considerably.

From this, it is clear that the amount of fluid which normally passes through an aqueous vein, will be specific for each individual vein. Both the aqueous vein and the blood vein will discharge their contents into the recipient vein even if their pressures, within certain limits, are unequal. The ratio between the amount of outflow from the two vessels will depend, among other things, on the ratio between their end-pressures. Some aqueous veins will therefore normally have a higher pressure and others a lower pressure than that of the joining blood vein.

When the recipient vein is compressed the flow through the vessels will be stopped for a while and that vessel which now has the higher pressure will push its contents up into the vessel with the lower pressure. If, for instance the pressure in the aqueous vein is the higher, the glass rod test will be positive. In accordance with hydrodynamic laws, however, the pressure in both vessels will change until the pressure at the first branching higher up the stream is attained. In other words, the final new pressures not only depend on the previous pressures at the meeting point but also on the fall of pressure which takes place in the respective vessels from the most proximal branching. Now, this fall of pressure will be different for each aqueous vein and blood vein and will depend among other things on the distance from the proximal branching to the meeting point. This new local factor is thus of importance in determining the result of the test.

These facts readily explain Ascher's findings as to the glass rod test in normal eyes. The local circumstances are indeed so different for each aqueous vein that the test applied to some veins will be positive, and to other veins negative. It also explains his law of constancy.

The findings in glaucomatous eyes are, however, not so easy to understand. Both Goldmann and Ascher have tried to explain why the glass rod test is negative when the bulbar pressure is increased. Goldmann emphasises⁸ that it is due to an increased resistance in the permeable membrane between the anterior chamber and Schlemm's canal. This should result in a low pressure in Schlemm's canal and in its outlets, including the aqueous veins; on the other hand it could cause the increased bulbar tension. If, however, the rate of production of aqueous humour is unchanged, the bulbar pressure and therefore the pressure in the aqueous veins will rise until the outflow is the same as before. A constant decreased pressure in the aqueous veins is therefore only

possible if the production of aqueous humour decreases when the bulbar pressure increases. This may or may not be so, but Bárány's findings⁷ seem to indicate that production of aqueous humour is independent of the bulbar pressure.

If Goldmann's conception is correct, the following three facts would suggest that the resistance in the permeable membrane alters very often and quickly and at times is even less than normal.

1. The occurrence of large oscillations in the bulbar tension which usually take place in glaucomatous eyes.
2. The extraordinarily great outflow of clear liquid seen when the bulbar pressure is in a decreasing phase¹¹.
3. The fact that the glass rod test does not show the same constancy as in normal eyes.

It follows then, that Goldmann's theory can only be accepted if a rapid alteration in the resistance of the permeable membrane can take place and if the production of aqueous humour decreases when the ocular pressure increases. The first of these conditions is improbable and the second doubtful.

Ascher has also explained the negative glass rod test by postulating a decreased pressure in the aqueous veins^{4, 5, 6}. He finds it more likely, however, that the hampering of the outflow is caused by a narrowing of the outlets from Schlemm's canal. It is perhaps more credible that such a narrowing may be reversible but Ascher's explanation, like Goldmann's, is entirely dependent on a decreased production of aqueous humour when the bulbar pressure is increased.

The aqueous veins are usually, as Goldmann emphasises⁸ direct branches from Schlemm's canal. This is, however, not always the case. When they are direct branches it is impossible that their constriction can cause a negative glass rod test. Such a narrowing would cause an unusually high pressure in the canal of Schlemm and as the glass rod test depends on the pressure at the first branching higher up the stream, the test would tend to be more positive than ever.

In my opinion the cause of the phenomena appearing in glaucomatous eyes must be sought not in the aqueous veins, but in the blood veins. Ascher has also mentioned this possibility³ but he has not followed it up.

There are two circumstances concerning the venous pressure that will play a part in the determination of the direction of flow. The higher the bulbar pressure, the higher must be the intra-bulbar venous pressure. On the other hand, the general venous pressure in the orbit will be the same. The pressure gradient in the veins when they pass through the sclera and along the epi-

sciera must therefore be steeper if the bulbar pressure is high. The fall of pressure from the proximal branching to the point of meeting with an aqueous vein must therefore also be greater, thus tending to cause a negative glass rod test. On the other hand, it has been shown¹⁰ that the venous pressure is high in proportion to the bulbar pressure when the latter is in an increasing phase. This fact also tends to cause a negative glass rod test. When the bulbar pressure is in a decreasing phase, however, the venous pressure is low compared with the bulbar pressure and thus tends to make the test positive. The combination of these facts can explain the irregular findings with the glass rod test in glaucomatous eyes. One has, however, also to take into account the fact that the result of the test is normally vigorous in some veins while in others it is feeble. The fact that it must be easier to change a feeble test than a vigorous one probably explains why the test is sometimes positive even when the bulbar tension is increased and why, in other eyes, the result of the test frequently changes in response to minor oscillation in the tension.

SUMMARY

The glass rod test was applied to 35 eyes suffering from simple glaucoma.

When the bulbar tension was increased the test was usually found to be negative. It was, however, found to be positive when the ocular tension was in a decreasing phase and sometimes when it was on a steady, but increased level. The most striking difference between normal and glaucomatous eyes is that Ascher's law of constancy does not apply to glaucomatous eyes. Early investigators' explanations as to the cause of the negative glass rod test in glaucomatous eyes are discussed. The author emphasises that the state of the venous pressure provides the most rational explanation of the findings.

REFERENCES

1. ASCHER (1942).—*Amer. J. Ophthalm.*, **25**, 31.
2. ——— *Ibid.*, 1174.
3. ——— *Ibid.*, 1301.
4. ——— (1944).—*Ibid.*, **27**, 1024.
5. ——— (1946).—*Ibid.*, **29**, 1373.
6. ——— (1949).—*Ibid.*, **32**, No. 6, Part 2, 239.
7. BARÁNY, E. H. (1947).—*Brit. J. Ophthalm.*, **31**, 160.
8. GOLDMANN (1948).—*Ophthalmologica*, **116**, 199.
9. THEOBALD (1934).—*Trans. Amer. Ophthalm. Soc.*, **32**, 593.
10. THOMASSEN (1947).—*Acta Ophthalm.*, **25**, 221.
11. ——— *Ibid.*, 369.
12. VRIES, S. DE.—*Die Zichtbare Afvoer van het Kamerwater*. Amsterdam, 1947.