

## EVALUATION OF THE WATER-DRINKING TEST\*†

BY

WOLFGANG LEYDHECKER

*From the University Eye Clinic, Bonn.*

DIFFERENT degrees of reliability of the water-drinking test for glaucoma have been reported in the literature. This may partly be explained by the fact that an insufficient number of tests have been carried out on healthy subjects, so that the physiological limits of the response to the test were not clear. Furthermore, the incidence of positive results in glaucomatous eyes with a normal initial tension has generally not been kept apart from those found in eyes with initially high tension. Both criticisms apply to an earlier paper in this Journal (Leydhecker, 1950), and the present re-consideration of the subject has been stimulated by the work of Agarwal and Sharma (1953), in which similar errors seem to be contained.

### Previous Investigations

(A) *Effect of the Test on Normal Eyes.*—Decker (1929) examined fifteen subjects and found no rise of tension above the limits of error of tonometry. Poos (1930) saw "in many cases" rises of 5 or 8 mm. Hg Schiötz. Wegner (1930) mentioned rises of "several" mm. Hg. Heegaard and Larsen (1931) obtained maximal rises of 4 mm. Hg. Ohm (1936) gave the increase of tension as a percentage of the initial tension so that his results are difficult to compare. Meves (1940) injected pituitary hormone (hypophysin), in addition to the ingestion of 1,000 ml. water, and observed a maximal rise of tension of 8 mm. Hg Schiötz in six healthy eyes. Sugar (1948) who was the first to do a large number of tests on healthy subjects, found in 143 eyes a maximal rise of 9 mm. Hg or a ceiling of 32 mm. Hg. Honig-mund (1951) examined seventy eyes of non-glaucomatous subjects after the ingestion of 1,000 ml. water; in vegetative dystonia she observed rises of 10 or even 12 mm. Hg Schiötz in four eyes. Rohrschneider (1952) examined forty healthy students: in 30 per cent rises of 6 to 12 mm. Hg occurred; in six cases the ceiling was 30 or 32 mm. Hg, in three the rise was 10 mm. Hg, and in one 12 mm. Hg. Agarwal and Sharma (1953) obtained rises of 2 to 6 mm. Hg in fifty healthy eyes, but in one considered to be pre-glaucomatous a rise of 10 mm. Hg occurred.

(B) *Incidence of Pathological Results in Glaucomatous Eyes.*—The results of Schmidt (1929, 1931), Wegner (1930), Ohm (1936), and Sugar (1948) are difficult to evaluate, since the increase of tension in their cases is not fully stated. Majorova and Glinika (1939) did 44 tests on 23 patients and obtained a rise of 6 mm. Hg Schiötz or more in four out of twelve eyes. Bloomfield and Kellermann (1947) observed rises of 10 mm. Hg or more in twelve out of 22 eyes with simple glaucoma. Schmidt (1950) reported a ceiling of 30 mm. Hg or more in 60·8 per cent of 250 glaucomatous eyes; amongst 33 tension curves of glaucomatous eyes with an initial tension below 30 mm. Hg there were eight with rises of 10 mm. Hg or more. Sugar (1948, 1951) observed rises of over 9 mm. Hg in 44 per cent. of 112 unoperated eyes with simple glaucoma; he points out (1951) that "with increasing levels of initial tension

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†Most of these experiments were undertaken at the University Eye Clinic, Mainz (Director, Prof. A. Jess), and others at the Institute of Ophthalmology, University of London (Director of Research, Sir Stewart Duke-Elder), and at the University Eye Clinic, Bonn (Director, Prof. H. K. Müller).

there is proportionately a greater increment in the pressure increase". Agarwal and Sharma (1953) regarded rises of 7 mm. Hg or more, or a ceiling of over 30 mm. Hg Schiötz, as pathological, and found them in 54 out of 57 eyes with primary glaucoma.

#### Present Experiments

**Methods.**—In this paper only drinking tests with 1,000 ml. water are discussed. The patient drank the water in the morning within 5 minutes in a state of fasting. The tension was taken with the Schiötz tonometer 30 minutes and immediately before the test, and 15, 30, 45 and 60 minutes after the patient began to drink. The test was started only if the tension during the preceding 30 minutes had not changed by more than 3 mm. Hg Schiötz. All measurements were done by the author. Treatment with miotics was discontinued 12 hours before the test. Only eyes with primary glaucoma, which had not been operated upon, are used in this paper, besides the normals.

**Normal Eyes.**—The effect of 318 water-drinking tests was studied in 264 healthy eyes. In this number are included 48 tests which were repeated on another day 15 to 25 min. after the intramuscular injection of 6 Vögtlin-units pituitary hormone (hypophysin). When these results were compared with those obtained in the same eyes without such injections no significant difference was found. Amongst the 318 tests are twelve in which a rise in tension of 6 mm. Hg Schiötz occurred, two with a rise of 7 mm. Hg, one with a rise of 8 mm. Hg, and one with a rise of 10 mm. Hg. A ceiling of 30 mm. Hg Schiötz was reached by five eyes with normal elasticity of the sclera. In all these eyes glaucoma had been excluded by careful examinations.

**Glaucomatous Eyes.**—The results obtained in eyes with primary glaucoma which had not been operated upon are summarized in the Table.

TABLE  
RELIABILITY OF THE WATER-DRINKING TEST IN PRIMARY GLAUCOMA

Initial Tension (mm. Hg Schiötz)	Clinical Form of Glaucoma	No. of Tests	No. of Eyes	Pathological Reactions*			
				Tests		Eyes	
				No.	%	No.	%
30 or Below	Simple	185	106	36	19	28	26
	Chronic congestive	82	53	10	12	10	19
	Acute	19	9	4		4	
	Total	286	168	50	17	42	25
Above 30	Simple	19	16	9	47	9	56
	Chronic congestive	24	21	16	67	14	67
	Altogether	43	37	25	58	23	62

\*In this series only rises in tension of 10 mm. Hg Schiötz or more were regarded as pathological. Recent research has shown that "probable pathological results" (rises of 8 or 9 mm. Hg Schiötz) may be differentiated from "definitely pathological results" (rises of 10 mm. Hg Schiötz or more). When both are taken together we find pathological reactions in 32.9 per cent. of the eyes with initial tension below 30 mm. Hg, and 77 per cent. in the group with initial tension above 30 mm. Hg Schiötz.

**I. Initial Tension 30 mm. Hg Schiötz or Below.**—The Table shows that 286 water-drinking tests were done in 168 eyes. The incidence of positive results was as low as 17 per cent. The percentage of eyes which at one time gave a pathological response after repeated applications of the test was 25 per cent. In another small series of 53 eyes (Leydhecker, 1953), in which as many as 132 drinking tests were done, the incidence of pathological results was 40 per cent. after frequent applications. This seems to be the limit of the reliability of the test if applied to the same patient on different days. These 53 eyes are

included in the numbers given in the Table. As in normal eyes, the injection of pituitary hormone did not influence the results of the test.

II. *Initial Tension above 30 mm. Hg Schiötz.*—43 tests were done on 37 unoperated eyes with primary chronic glaucoma. Although the test was not repeated nearly so often on the same patient as in the previous group and the chance of obtaining a positive result was thus much smaller, the percentage of pathological results was 62 per cent. No selection of cases was made.

III. *Influence of Initial Tension.*—The importance of the initial tension, which is evident from the comparison between the two preceding paragraphs, is further demonstrated in Figs 1 and 2. Both show water-drinking tests done on the same patient within a fortnight but in Fig. 1 the initial tension was low, while in Fig. 2 it was high in the left eye. A pathological result was obtained only in the second case. No anatomical factors account for the different results in this case, only the physical factor of the initial tension being of importance.

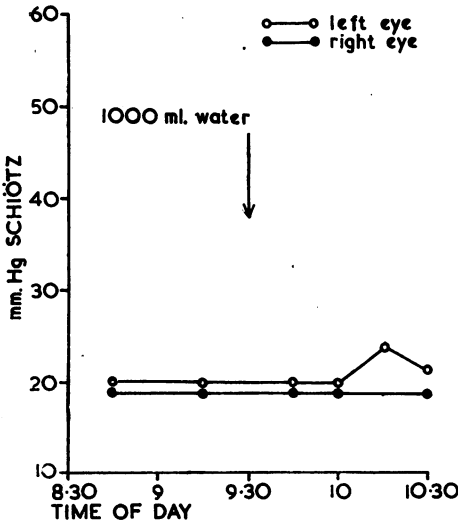


FIG. 1.—Drinking test with 1,000 ml. water. Simple glaucoma.

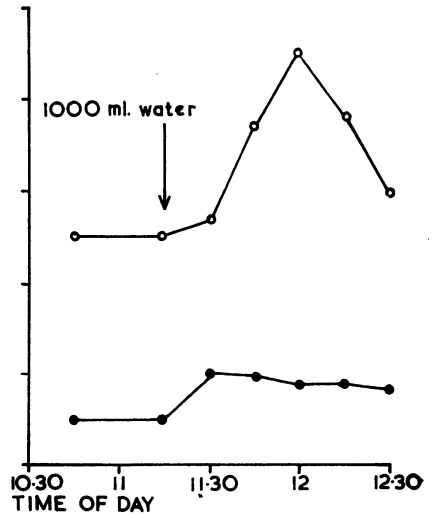


FIG. 2.—Same test with same patient as shown in Fig. 1 on another day.

Fig. 3 shows the results in a patient suffering from bilateral chronic congestive glaucoma of long standing. The chamber angle was wide in both eyes, and in the left there were a few narrow anterior synechiae. The tension in the right eye was normal; in the left it was 35 mm. Hg at the beginning of the test. The water-drinking test was positive in the left eye only. This indicates that the different rise of tension in each eye is not due to the systemic response, as Figs 1 and 2 might lead one to suspect, but that the initial tension is decisive.

The initial tension cannot, however, be the only important factor in the water-drinking test. The tests were negative in glaucomatous eyes when tested in a period of a normal initial tension and again when tension was high. The Table shows that not all eyes with a high tension gave a positive result, whereas there were pathological results in 25-40 per cent. of the eyes with a normal tension.

### Discussion

**Evaluation of the Test.**—The results in healthy subjects agree closely with those of Sugar (1948) who considers a rise of 10 mm. Hg to be pathological and smaller rises are insignificant. A rise of 10 or 12 mm. Hg is no proof of the existence of glaucoma, as is indicated by the results of Honigsmund (1951),

Rohrschneider (1952), and by my own case with a rise of 10 mm. Hg, but it is very exceptional amongst normal subjects, and requires a thorough search for glaucomatous symptoms and prolonged observation.

The ceiling is, in my opinion, unimportant when the reliability of the test is discussed. The test works by an increased inflow of water into the eye, which cannot be compensated for speedily enough by an increased outflow in glaucomatous eyes, so that the tension piles up for some time (Leydhecker, 1950). Therefore, if the power of the eye to eliminate fluid through Schlemm's canal is to be tested, only the relative increase of tension is indicative of the degree of obstruction, whereas the ceiling depends also on the initial tension. A rise of 6 mm. Hg from 28 to 34 mm. Hg, for example, is within normal limits and, therefore, not indicative of an obstruction of the outflow. As regards the registration of the test for scientific evaluation purposes, this test would be negative but as regards the diagnosis I would suspect glaucoma, because of the ceiling of 34 mm. Hg and the initial tension of 28 mm. Hg.

**Reliability of the Test.**—For the reliability of any provocative test the incidence of positive results in unoperated glaucomatous eyes, with an initial tension below 30 mm. Hg is of decisive significance, for this is the field in which we are searching. When we apply the test to a suspected eye, it will always be an eye with a normal tension, since in cases with elevated tension no test is usually required. The very low incidence of pathological results of the water-drinking test in glaucomatous eyes with a normal initial tension has not been pointed out hitherto. The unreliability of this test has been masked by the strong rises of tension which occur in eyes in which it was initially high. How is this influence of the initial tension to be explained?

If we inject the same amount of liquid into an eye with a low tension and into one with a high tension, the increase of pressure will be considerably greater in the latter. The water-drinking test acts in the same way, and the high incidence of pathological results in eyes with an initially high tension is a further proof of the mechanism of the test (Leydhecker, 1950).

Figs 1–3 show that neither a difference in the systemic response on different days nor anatomical factors alone explain the high incidence of positive results in eyes with a supernormal tension. One decisive factor, the height of the initial tension, is mechanical. We have seen that there is a second

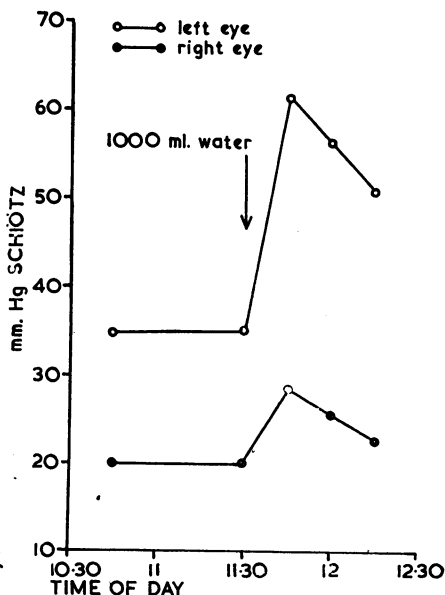


FIG. 3.—Drinking test with 1,000 ml. water. Chronic congestive glaucoma.

important factor, because the initial tension does not explain all the results. This is probably an obstruction of the outflow through Schlemm's canal. In eyes with no hindrance of the outflow, the result is always negative, even when the initial tension is high. A positive result in an eye with normal tension would indicate a great obstruction of the outflow. A pathological result in an eye with a high initial tension does not necessarily indicate a great hindrance of the outflow, since this anatomical factor may not be sufficient to cause a positive result in a period of normal tension (Figs 1 and 2). These conclusions are presented here as a hypothesis, which must be further elucidated by more refined methods of investigation, such as those of Goldmann (1951).

It may be added that the systemic reactions after drinking large quantities of water are very complicated. They by no means consist in a simple hydraemia in exact relation to the ingested quantity of liquid, but the degree of hydraemia which finally causes the increased flow of water into the eye is the reaction that matters (Leydhecker, 1950). It is a serious drawback that the quantity of water flowing into the eye cannot be predicted and depends upon uncontrollable systemic reactions. A negative result, therefore, never indicates a normal outflow mechanism.

### Summary

According to the results of 318 water-drinking tests in normal eyes, only rises of 10 mm. Hg or more may be regarded as pathological. In 168 glaucomatous eyes with an initial tension of 30 mm. Hg Schiötz or less, 286 water-drinking tests were carried out, and the incidence of positive results was as low as 17 per cent. Because of the repeated application of the test to some eyes, the percentage of those which reacted pathologically was 25 per cent. In 37 eyes with primary chronic glaucoma and with an initial tension above 30 mm. Hg Schiötz, the incidence of pathological results was 62 per cent., but this is not important, since these eyes require no diagnostic test. In eyes with suspected glaucoma and a normal tension this test is not reliable.

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