COMMUNICATIONS

BULBAR PRESSURE TEST IN GLAUCOMA*

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THIS paper describes a relatively simple clinical test devised to estimate the facility of outflow of aqueous from an eye while external pressure is being applied to the globe; such a test is obviously of value in the investigation of cases of glaucoma.

The fact that it is possible to reduce the tension in the eye by massage has been known for many years, and interest in the subject was revived during the latter part of the 19th century, when the invention of the tonometer enabled changes in the intra-ocular pressure to be measured with some degree of accuracy. Schiötz (1908) himself noted that if the tonometer were left too long on the eye the tension was reduced, and Polak-van Gelder (1911) stated that this fall in tension was due to the expression of aqueous from the eye, and that its magnitude depended on the ease with which the aqueous could escape. She also stated that a greater amount of massage was necessary to produce the same fall in tension in glaucomatous as in normal eyes, and she appears, in fact, to have been the first person to use massage with a tonometer as a diagnostic test. Since then numerous attempts have been made to develop the potentialities of this technique, but, though many workers agreed that in general the pressure did not fall so much in glaucomatous eyes, especially those which were already in a state of increased tension, they were unable to produce a standard minimal fall in tension below which limit an eye can be considered abnormal.

Thomassen (1946) studied the effects of compressing the eye with various weights. Although he found that eyes with advanced glaucoma were not so easily compressed, he came to the conclusion that it was not possible by this method to detect any significant difference between the fall produced in normal eyes and that in glaucomatous eyes with normal tension. Consequently, most of his work was devoted to the study of the secondary rise in tension that occurs after compression. His monograph includes a very comprehensive review of all the previous work done on this subject.

Moses and Bruno (1950) studied the fall in tension produced by leaving an electric tonometer on the eye for 2 minutes, and stated that the rate of

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flow as calculated from this fall was less in glaucomatous than in normal eyes. Grant (1950), in his first paper on the clinical estimation of aqueous outflow, described how, by using an especially adapted tonometer and calculations based on the work of Friedenwald, he was able to produce in normal eyes a figure for the "co-efficient of resistance" by which the facility of aqueous outflow could be compared. Grant (1951) applied this method of tonography to glaucomatous eyes and was able to state that in chronic simple glaucoma there was a marked obstruction to outflow which alone sufficed to account for all the tension changes occurring in this disease. He has also applied this method to congestive glaucoma and cases undergoing treatment. Weekers and Prijot (1952) have used the method with similar results.

Suda and Kamao (1951) stated that the best provocative test for glaucoma was a pressure on the globe of 50 g. for 4 minutes.

So far it seems that tonography has been the one instance when the massage test can produce reliable clinical results, and an increasing use of this technique can be anticipated in the diagnosis of glaucoma. It does, however, demand expensive apparatus and elaborate calculations. In the test to be described these are not required, though the test is clinically satisfactory, and also gives a higher percentage of positive results in early cases.

Principle of the Test

To understand the meaning of this test it is first necessary to consider briefly the principles of massage tests in general.

Normally the volume of fluid entering the eye is approximately equal to that which escapes during a given time, and the intra-ocular pressure shows only minor variations. When external pressure is applied to the globe the intra-ocular pressure is increased by an amount depending on the degree of compression, the elasticity of the sclera, and the initial tension of the eye, less an amount due to the volume of blood and aqueous humour expressed from the eye. Fig. 1 shows the varying results obtained by application of 50-g. pressure in fifty individual eyes. If the compression is maintained, the persistent fall in tension is due to the fact that aqueous is continually forced out of the eye at a rate which exceeds its rate of formation.

Evidence for the assumption that the fall in tension is due to an increased rate of outflow of aqueous, which has been fully described by Thomassen, Grant, and others, is based on the following facts:

- (1) It is possible to see an increased rate of flow in the aqueous veins when pressure is applied to the globe (Goldmann, 1946; de Vries, 1947).
- (2) After the first few seconds, when blood is being expressed from the globe, the fall in tension is gradual (Fig. 2).
- (3) When tonography is performed on cadaver eyes with no circulation or secretion the fall in pressure is greater than in normal eyes (Grant, 1950).

It is of course possible that, in addition to the expression of fluid from the globe, the application of external pressure depresses the rate of formation of aqueous, a factor which would tend to increase the fall in intra-ocular pressure; the importance

FIG. 1.—Increase in ocular tension produced when eyes of varying initial tension are compressed by 50 g.

FIG. 2.—Water manometer recording of the intra-ocular pressure in the anterior chamber of a rabbit's eye whilst the eye was compressed with 50 g. for 4 min.

of this is uncertain but that it cannot be very great is clear from the experiments on cadaver eyes already referred to. It would seem clear that, after the initial expression of blood, the alterations in intra-ocular pressure which occur during compression of the globe are due to a change in the volume of aqueous humour.

External pressure will also tend to distort the contents of the globe in a way which will depend on the method and site of application of the pressure. This will be referred to again in considering the results obtained from the bulbar pressure test when performed on cases of congestive glaucoma.

The principle of the bulbar pressure test depends on the fact that, if an eye is compressed and the change in intra-ocular pressure recorded at the same time, information is obtained from which a figure can be calculated which is directly dependent on the change of aqueous volume. This figure, which has been termed the *outflow fraction* (O.F.), has been found to differ significantly in normal eyes and in eyes in which the outflow of aqueous is restricted.

The fact that it is necessary to record the changes in pressure whilst the eye is being compressed and not after the compression has been removed, when other factors such as reflux of blood into the eye can interfere with the reading, has made it

FIG. 3.—Application of bulbar pressure test.

FIG. 5.—Diagram of bulbar pressure test performed on a normal eye.

$$\begin{array}{l} B-C=18 \text{ mm. Hg;} \quad A-D=9 \text{ mm. Hg.} \\ \frac{100(B-C)}{B}=35\% \quad \frac{100(A-D)}{A}=53\% \end{array}$$

FIG. 4.—Principle of bulbar pressure test.

necessary to use two instruments on the eye, a Schiötz X tonometer (weightless) to record the changing tension, and a dynamometer to apply the additional compression required.

Method

The eyes are anaesthetized with panto-caine 1 per cent. and a drop of Paroleine is placed in the conjunctival sac to prevent corneal damage. The patient lies on a couch and fixes an object suspended above his head with the eye not being tested.

To perform the test on the right eye the tonometer is applied to the centre of the cornea with the left hand, and the first reading (A) is taken. The Bailliart dynamometer is held in the right hand, and its foot applied to the lateral side of the globe behind the insertion of the lateral rectus muscle, the position varying a little according to the width of the palpebral aperture (Figs 3 and 4). A pressure of 50 g. is applied, and after allowing 10–15 seconds for the intra-ocular pressure to become stable, the reading B is noted. This position is maintained for 4 minutes, after which the reading C is taken. The dynamometer is then removed to give the reading D (Fig. 5). The position of the hands is reversed when the left eye is tested.

Result in Normal Eyes.—Fig. 5 shows the changes in intra-ocular pressure, as recorded on the Schiötz tonometer, that occur when the eye is compressed in this way. The initial pressure A rises to B when the dynamometer is applied. Whilst the compression is maintained the pressure falls steadily, until after 4 minutes it reaches C; finally, on removing the dynamometer, the reading D is obtained. This last reading depends on the amount of fluid that has been expressed less the amount of blood that flows back into the eye when the compression is removed. Its value is therefore influenced by this latter factor, the effect of which is unknown, and consequently it cannot be used to calculate the outflow fraction; it is the difference between B and C (B-C), the change in pressure whilst the compression is being applied, which is significant.

It is unfortunately not sufficient to compare the tension produced by compressing different eyes in absolute values (B-C mm. Hg) because the effect, in terms of pressure, of removing a given volume of fluid from an eye depends on the initial pressure of that eye; the loss of a given volume of fluid would produce a greater fall in tension in an eye with high initial pressure as compared with one in which the initial pressure was low. In the bulbar pressure test we are concerned with the volume of fluid expressed in a given time from eyes with variable initial tensions; to produce a basis of comparison, the fall in tension is therefore represented as a percentage of the initial tension $\frac{B-C}{B} (100)$, and it is this figure that has been termed the *outflow fraction* (O.F.).

By compressing the eye and calculating the O.F., an estimation can be made of the reserve capacity for drainage through the canal of Schlemm. External pressure forces aqueous out of the eye and at the same time places an additional strain on the drainage mechanism. When sufficient compression is used to force aqueous through all the possible exit channels by utilizing them to their maximum extent, the drainage system is working to its full potential and the value for O.F. is at its highest. In this event, however, the reserve has become exhausted, so that, if greater compression is used, although the rate of flow is accelerated, the resistance increases, the efficiency of the drainage mechanism is diminished, and the value for O.F. becomes less, until with a pressure of about 80 g. only a relatively slight fall in tension can be recorded whilst the pressure is being applied (Fig. 6). We cannot at present be sure what happens with still higher pressures, as they produce a value for B which is beyond the range of the tonometer. The weight that produces the maximum value for O.F. is termed the *optimum compression* and its value in

FIG. 6.—Diagram of bulbar pressure test for normal eye, using 80 g. dynamometer weight.

FIG. 7.—Values of outflow fraction obtained when a normal eye is compressed by varying weights, showing optimum compression at about 40 g. and subsequent falling off as pressure is increased.

65 g. = 50 g. (pressure of dynamometer) + 15 g. (weight of tonometer).

normal eyes is approximately 45 g. (Fig. 7). If there is an anatomical constriction to the outflow channels, the capacity of the drainage mechanism is less, and the value for the optimum compression is smaller; conversely, in eyes with a patent trephine in which the outflow channels are supplemented, greater weights can be used before the drainage becomes impaired (Fig. 8).

The bulbar pressure test has been developed with the purpose of accentuating the difference between the facility of outflow in normal and glaucomatous eyes by compressing the eye with a weight that is greater than the optimum compression for a normal eye; it has been

FIG. 8.—Results of compressing normal and glaucomatous eyes with varying weights, showing divergence of curves when weights are used above that producing optimum compression.

found in practice that a pressure of 65 g. (tonometer 15 g. + 50 g. applied with dynamometer) suffices to accentuate this difference.

Clinical Application of the Bulbar Pressure Test

Method.—The eyes are anaesthetized with pantocaine 1 per cent., and a drop of paroline is placed in the conjunctival sac to prevent corneal damage. The patient lies on a couch and fixes an object suspended above his head with the eye not being tested.

(1) As a preliminary, useful information can be obtained by allowing the Schiötz X tonometer to rest on the cornea for 4 minutes, taking the tension at the beginning and at the end of this time. In the normal eye, the value for O.F. obtained by this method should be above 30 per cent. A lower reading indicates a severe obstruction to outflow.

(2) After allowing time for the intra-ocular tension to return to a steady level (about 30 minutes), the bulbar pressure test proper is performed, using the method which has already been described.

In general, patients tolerate this manoeuvre well, although occasionally a patient is found whose continual blinking or squeezing upsets the readings. With patients with only one seeing eye, it is sometimes difficult to perform the test on the good eye due to lack of fixation. No discomfort is felt during the test although there may be a slight discomfort and blurring of vision afterwards. This test has been done on over 800 eyes with no case of corneal abrasion or severe discomfort.

Results

(1) Fig. 9 shows the results obtained by compressing fifty glaucomatous eyes with the Schiötz X tonometer alone. The lowest value for O.F. which can be considered the normal for this method is 30, and on this basis 44 per cent. of the cases show a positive result (O.F. less than 30), but most of these positive results were obtained from cases in an advanced state of the disease or with an abnormally high intra-ocular pressure at the time of the test. The majority of the early cases with normal tension had a normal O.F.

FIG. 9.—Results obtained in fifty cases using Schiötz tonometer alone (normal 30.)

(2) Fig. 10a (overleaf) shows the results of the bulbar pressure test performed on 83 normal eyes. The average value for O.F. was 34, and therefore, in the bulbar pressure test, values below 29 are considered to be indicative of obstruction to the aqueous outflow, and those below 25 to be definitely abnormal.

Fig. 10(b) shows the results when the test was performed on 199 cases of chronic simple glaucoma. In 88 per cent. the value for O.F. was below 29 and in 73 per cent. it was below 25.

Fig. 10(c) shows similar results obtained with 114 cases of congestive glaucoma. In 74 per cent. the value for O.F. was below 29, and in 62 per cent. it was below 25.

FIG. 10 (a-d).—Results of bulbar pressure test performed on normal and glaucomatous eyes.

classifying the cases of glaucoma according to the state of the disease as assessed by clinical examination:

Grade 1 (a) Eyes with no symptoms or signs of glaucoma but where the fellow eye is a known case of glaucoma (*i.e.*, the preglaucomatous state).

(b) Similar cases but with positive provocative tests.

Grade 2 (a) Eyes with early field loss but with normal tension.

(b) Eyes with tension of over 27 mm. Hg at the time of test but with normal discs.

Grade 3 (a) Eyes with gross field loss but normal tension at the time of test.

(b) Advanced cases with tension above 27 mm. Hg at the time of test, and field loss.

In Fig. 10(d) seven cases of absolute glaucoma are seen to give 100 per cent. positive results.

(3) Fig. 11(a-c), which shows the results obtained from the same cases as are shown in 10(a-c) when O.F. is calculated from A - D, is included for comparison. Not only do the glaucomatous eyes show a much smaller percentage of positive results, but the figures for the normal and glaucomatous eyes vary over a range so wide that they are apparently without significance.

(4) Fig. 12 (opposite) shows the same results further analysed by

FIG. 11 (a-c).—Results from same normal and glaucomatous eyes as shown in 10 a-c when outflow fraction was calculated from A-D.

Discussion

(1) The results obtained when the Schiötz tonometer was used alone show a much smaller percentage of positive results than were obtained with the bulbar pressure test; this is probably due to the fact that the compression (15 g.) is below the optimum compression of a normal eye, and is thus insufficient to accentuate differences in the facility of outflow unless the

FIG. 12.—Results from classified cases of chronic simple and congestive glaucoma.

obstruction is marked. While a negative result is therefore of no significance, a positive result undoubtedly indicates a severe degree of obstruction.

(2) The high percentage of positive results obtained in chronic glaucoma, even in the earliest cases (and the fact that cases with raised tension at the time of the test show 100 per cent. positive results), indicates that obstruction to aqueous outflow is one of the major factors in the aetiology of the disease.

(3) The results from the cases of congestive glaucoma, of which even the early cases with no tension show a fair number of positive readings, are at first a little surprising; it is contrary to what one would expect and to what has been found by other workers. This, however, is probably explained by the nature of the test itself. As will be seen from the diagram (Fig. 3), pressure behind the ciliary body will cause an increase of pressure in the posterior chamber; this will have the effect of pushing the lens and iris forward, and in an eye with a narrow angle this may be sufficient to cause angle-block; for this reason positive results obtained with the bulbar pressure test in cases of narrow angle glaucoma cannot be considered as indicative of an obstruction to outflow and are in fact merely a confirmation of the gonioscopy findings. In such cases, therefore, the test is of little value, although a positive result obtained with the Schiötz X tonometer alone when the pressure is on the front of the eye is indicative of obstructed outflow.

TABLE
EFFECT OF MIOTICS ON BULBAR PRESSURE TEST

Case	Eye	Right		Left	
	Test	Schiötz X Tonometer Alone	Bulbar Pressure Test	Schiötz X Tonometer Alone	Bulbar Pressure Test
A	Before Miotic	13	10	40	28
	After Miotic	32	19	40	29
B	Before Miotic	12	12	30	28
	After Miotic	32	18	35	28

In both cases the Tension of the R.E. was raised before miotic therapy and both tests produced a positive result, but after treatment when the tension was normal a positive result was obtained with the B.P.T., but not with the weightless tonometer alone.

(4) *Effects of Miotics.*—The Table shows the results of the bulbar pressure test performed on two cases of chronic simple glaucoma before and after miotic therapy. In each untreated case the tension in the right eye was raised and a low reading was obtained with the weightless tonometer alone as well as when a 50 g. compression was used. After treatment, however, when the initial tension was normal, although the reading was within the normal limit for the test with a weightless tonometer alone, the bulbar pressure test still showed a low reading.

Moreover, the results of the bulbar pressure test are not greatly influenced by the phase through which the ocular tension is passing, positive results being obtained in a falling phase as well as when the tension is rising or level.

These two facts suggest that in chronic simple glaucoma there are two processes to consider. The first is a permanent structural resistance to outflow which reduces the reserve capacity of the drainage mechanism but does not itself cause a rise of tension, at any rate in the early stages, although it allows the eye to respond less easily to other physiological or abnormal factors which tend to increase the tension. This obstruction exists whatever the phase of the ocular tension and is not overcome by miotics.

The second factor, which is probably vascular in origin and may be overcome by miotics, is probably the cause of the phasic variations in the tension. It is presumably because of the flexibility of this second factor that the tension in the eye is not constantly raised in spite of the permanent obstruction to outflow. It is possible that this factor is also present in normal eyes and that the increased swing of the phasic variations occurring in early simple glaucoma is merely the normal variation being amplified by the permanent obstruction, the tension being normal when the vascular phase is in favour of easy drainage and rising above normal when the vascular element, either by increasing secretion or hindering drainage, would cause a small rise in the normal eye. Miotic therapy is capable of overcoming this vascular element but not the obstructive element.

It is convenient at this point to consider the clinical value of the bulbar pressure test in relation to the pressure test with the weightless tonometer alone and with tonography, because the combination of these methods gives a reliable means not only of diagnosing early chronic glaucoma, but also of estimating whether or not a case is likely to be controlled by miotic therapy.

The bulbar pressure test itself places an abnormal strain on the drainage mechanism; this amplifies the effect of the permanent obstruction so that positive results may be obtained whatever the state of the vascular factor. It is in fact independent not only of the phase of ocular tension but also of the effects of miotic therapy, so that, although the value for the outflow fraction for a glaucomatous eye may be higher when repeated after miotic therapy, it is usually not as high as the normal value. Therefore, whilst as a diagnostic method the bulbar pressure test is superior to tonography or the weightless tonometer alone, a positive reading with this test on an eye under the influence of a miotic does not necessarily mean that the tension cannot be controlled in normal conditions by a miotic, although a very low value for the outflow factor suggests that this is probably the case.

Tonography and the pressure test with the weightless tonometer alone are directly comparable. (Grant estimates that the value of 0.1 is the limit for normal eyes, and this is equivalent to an outflow fraction of 25 which is the limit for normal eyes with the bulbar pressure test.)

If an eye gives a positive result with either tonography or the weightless tonometer alone, it is indicative of a fairly high degree of obstruction, but early cases do not produce as high a percentage of positive results as the bulbar pressure test because the strain on the drainage channels is not so great, the compression being well below the optimum compression instead of above it (Fig. 5).

If, however, a positive result is obtained with the tonometer or tonography on an eye under miotic therapy, it indicates that the obstruction is of such a severe degree that it is unlikely that the tension in the eye can be controlled without a filtering operation.

The combination of these methods is the only ready means we have of making a firm diagnosis of chronic glaucoma in the doubtful cases, and of estimating with accuracy in any type of case whether operation (or a second operation) is necessary.

(5) *Use of the Bulbar Pressure Test*

(a) The test is a reliable diagnostic test for doubtful and early cases of chronic simple glaucoma and has, in fact, proved in many cases to be the first positive sign (Figs 13, 14, and 15, overleaf).

(b) The test, combined with a test with the weightless Schiötz alone, yields considerable information about the state of the outflow channels. A positive test with the weightless Schiötz indicates a gross obstruction to outflow

FIG. 13.—Bulbar pressure test in a case of chronic glaucoma (B-C=18 per cent.).

FIG. 14.—Bulbar pressure test in a case of secondary glaucoma (both eyes).

FIG. 15.—Bulbar pressure test in both eyes of two cases of absolute glaucoma. Tension was raised in one case and normal in the other, but both show a gross obstruction (B-C=7 per cent.; b-c=6 per cent.).

FIG. 16.—Bulbar pressure test performed in a case of chronic simple glaucoma before and after right and left trephine.

probably existing all the time. If it is positive in spite of the use of miotics, the indication is that surgery offers the only means of treatment likely to be

successful. A positive result with the bulbar pressure test indicates that the reserve drainage capacity is diminished so that, whilst the tension may still be normal, the eye cannot deal efficiently with factors tending to increase the tension.

(c) The test has also proved valuable in estimating the efficiency of filtering operations (Fig. 16). The results obtained when the test was performed on a series of eyes which had undergone such operations are shown in Fig. 17; these results will be more fully discussed in a further communication.

FIG. 17.—Results of bulbar pressure test performed on 82 operated eyes.

Summary

(1) The principles of the bulbar pressure test and its application are described.

(2) The results indicate that the test is of value in the early diagnosis of chronic simple glaucoma, but is apt to be misleading in congestive glaucoma.

(3) The test is of value in investigating the success of filtering operations.

(4) When combined with tonography, the test enables the examiner to decide whether surgery is necessary in any individual case.

(5) The nature of the results obtained in cases of chronic simple glaucoma suggests that the main factor in this disease is obstruction to aqueous outflow, and that this obstruction has two components: one permanent, anatomical, and sclerotic, and the other variable and vascular in origin.

(6) A scheme for the rapid calculation of results is given in the Appendix overleaf.

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APPENDIX

TABLE FOR THE RAPID CALCULATION OF RESULTS OF BULBAR
PRESSURE TEST OF 4 MIN. DURATION