

COMMUNICATIONS

OCULAR TENSION IN GLAUCOMA SIMPLEX*†

BY

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THE variations and level of tension in normal and glaucomatous eyes have been studied by many observers. Maslenikow (1904) recorded the tension twice daily in twelve patients with glaucoma of unspecified type and found the tension higher in the morning. Grönholm (1910) considered the morning rise to be due to mydriasis while lying awake in dim illumination, an observation discounted by Köllner (1916, 1918) who recorded parallel changes in tension in unilateral aniridia and iridectomy, and when the eyes were under the influence of miotics. Köllner, following the tension in glaucomatous eyes, found it higher in the morning, and falling after 10 a.m. throughout the day, with sometimes a slight rise at 7 p.m. Thiel (1923, 1925) recorded the tension in cases of glaucoma simplex frequently during the night as well as during the day, and described a nocturnal rise beginning slowly between midnight and 3 a.m., with a sharper rise between 3 a.m. and the morning maximum. The tension was highest in the early morning with a steep fall on rising from bed, followed by a more gradual decline until the late evening. Thiel explains his findings as being due to the filling and emptying of the vessels of the head and neck occasioned by changes in posture. Hagen (1924) also found the tension in glaucoma simplex to be higher in the morning in most cases and considered the variations to be due to defective drainage. He found that miotics produced a fall in tension without decreasing the variations. Sallmann and Deutsch (1930) consider that a tension of 26 mm. Hg Schiötz or more is significant of glaucoma. They also found the tension higher in the morning, except in 5 per cent. of cases, and postulated that cessation of ocular movements was responsible for a rise of tension during the night. Cordes (1937) has stated that variations in tension of 10 mm. Hg Schiötz or more in the unaffected eye in unilateral glaucoma, are indicative of latent disease in this eye, and Downey (1945) regards a difference of more than 4 mm. Hg between the two eyes as a pre-glaucomatous state. Bloomfield and Kellerman (1947) found only 6 per cent. of glaucomatous eyes to have variations of more than 10 mm. Hg. Reese (1948) stated that the base pressure

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in glaucoma approximates to the peak pressure as the disease advances, indicating a decrease in amplitude of the variations with progression of the disease.

The following paper presents an analysis of 36 cases of chronic simple glaucoma, in which the tension variations over 24 hrs are described and discussed in relation to the field changes, blood pressure, provocative tests, and other relevant factors. In addition, our findings are compared with those of other workers. During the investigations, two of our patients were found to be suffering from low-grade cyclitis with all the features of glaucoma simplex, and are included for purposes of comparison.

METHODS

The patients were admitted to hospital in the afternoon, having ceased to use miotics for the previous 24 hours. The tension was recorded at approximately two-hourly intervals until 11 p.m. or midnight, using the same Schiötz tonometer preceded by gutt. pantocaine 1 per cent. for all cases. The readings were resumed at 5 a.m. and carried on at the same intervals until the evening. The systemic blood pressure was recorded in 23 patients at the same intervals.

The results in each patient were recorded graphically as a curve, with the tension in mm. Hg Schiötz as ordinate and the time as abscissa. Full clinical investigations, including gonioscopy and provocative tests, were carried out in the Glaucoma Clinic at the Institute of Ophthalmology.

RESULTS

SHAPE OF CURVE.—It was found that the curves fell into four types according to their shape, which we have named “double-variation”, “rising”, “falling”, and “flat”. The number of cases showing each type of curve is given in Table I, where the “double-variation” type is seen to be the most common.

In the double-variation type, the tension was at a low phase at 5 a.m. and rose to a maximum at approximately 9 a.m. (extremes of 7 to 11 a.m.), after which there was a fall to a low level in the afternoon, usually at about 2 p.m., followed by a second rise between 4 p.m. and 6 p.m. with a steady fall throughout the evening until the last reading.

TABLE I
NUMBER OF CASES OF EACH TYPE OF CURVE

Type of Curve	Cases	
	No.	Per cent.
Double-variation	19	56
Rising	8	23.5
Falling	6	17.6
Flat	1	2.9

In the rising type, the tension was low in the early morning, and climbed steadily, with minor fluctuations, to reach a maximum between 4 p.m. and 6 p.m., after which there was a steady fall until the last reading.

In the falling type, the tension was highest on waking, or rose to its maximum at 7 a.m. from a slightly lower level, after which there was a steady fall, with minor fluctuations, throughout the day and evening until the last reading.

The flat type, of which there was only one example in a case of doubtful glaucoma, was characterized by a horizontal curve with small irregular variations.

Examples illustrating these four types of curve are given in Figs 1 to 4. For comparison, Fig. 5 is the record of a case with signs and symptoms of glaucoma simplex, in whom signs of active low-grade cyclitis were revealed at a later date.

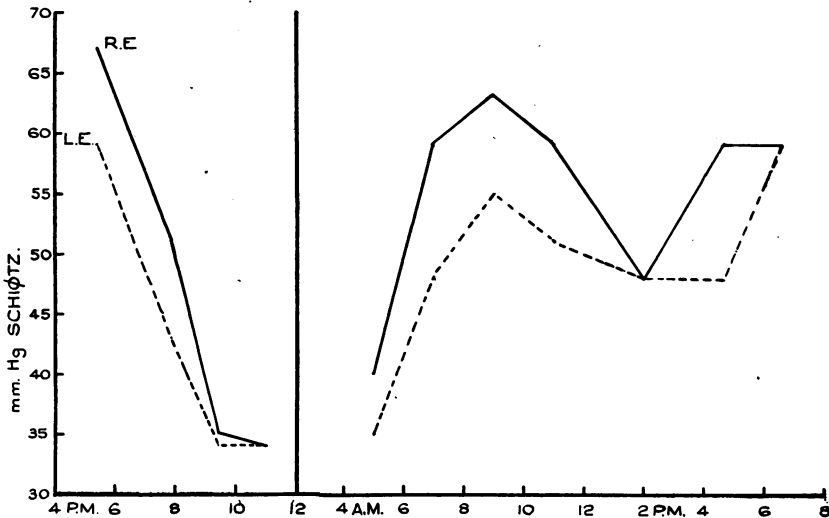


FIG. 1.—Double-variation type of curve.

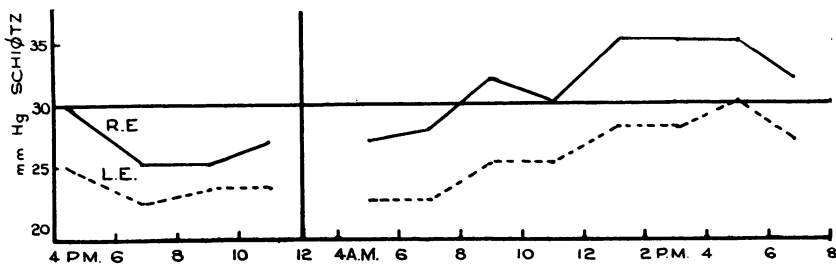


FIG. 2.—Rising type of curve.

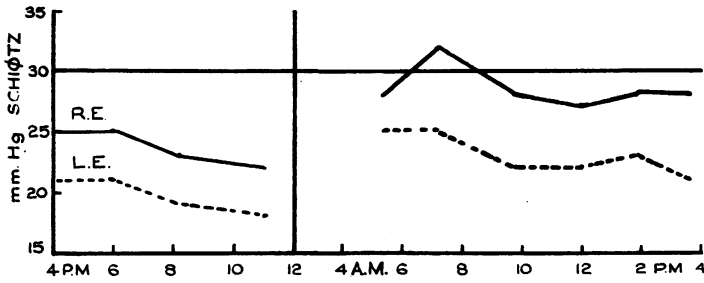


FIG. 3.—Falling type of curve.

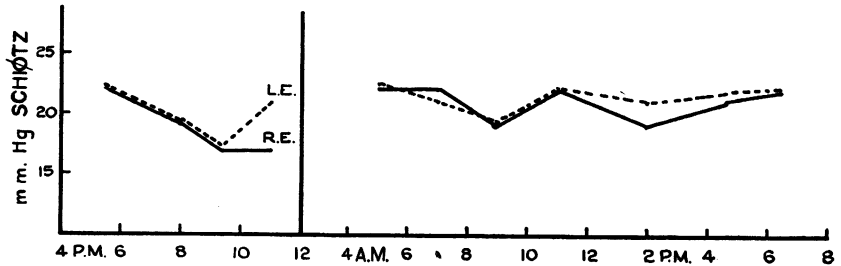


FIG. 4.—Flat type of curve.

In order to establish whether the shape of the curve was fortuitous or whether it represented a constant rhythm in a given individual, the procedure was repeated in sixteen patients, five of whom had undergone an operation on one eye since the first examination. The second record was made several months after the first and was conducted under similar conditions. The results in the 27 eyes recorded on two occasions. (Table II) indicate that the shape of the curve is characteristic of the individual in the majority.

TABLE II
SIMILARITY OF CURVES

Degree of Similarity on Two Occasions	Eyes	
	No.	Per cent.
Similar	18	66
Somewhat similar	8	30
Not similar	1	4

MAXIMUM TENSION.—In the 68 eyes of our 34 patients, two were clinically normal and three had been trephined before the first examination. The maximum tension in the 63 unoperated glaucomatous eyes was less than 30 mm. Hg Schiötz in eighteen (28.5 per

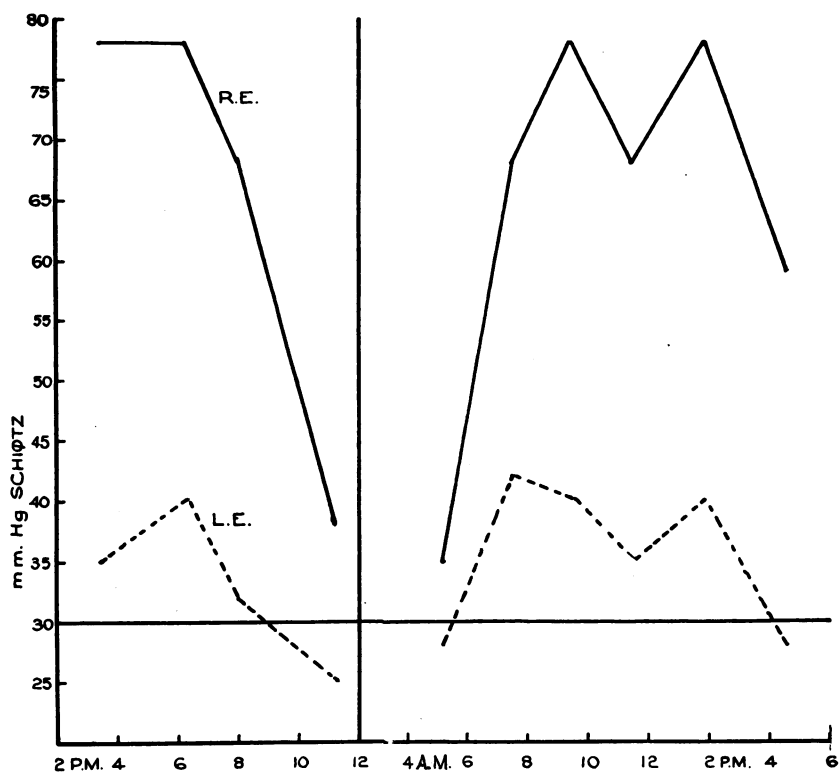


FIG. 5.—Curves in a case of low-grade cyclitis simulating glaucoma simplex.

cent.), and less than 25 mm. Hg in two (3 per cent.). The level generally accepted as the upper limit of normal is 30 mm. Hg Schiötz, but it is evident that many cases of glaucoma simplex occur where the tension does not reach this level. In this respect, the level of 26 mm. Hg put forward by Sallmann and Deutsch (1930) is not unreasonable.

One of our patients, a man of 76 years who had cupping of the optic disks and field defects, was seen to have a maximum tension of 28 mm. Hg Schiötz in both eyes and was originally thought to be a case of pseudo-glaucoma, but a further examination 6 months later revealed a maximum tension of 35 and 32 mm. Hg Schiötz in the two eyes, at 5 a.m. only.

RELATIONSHIP BETWEEN OCULAR TENSION AND VISUAL-FIELD DEFECTS.—It is evident that eyes of different individuals resist damage by raised ocular tension to different degrees, and it is well known that patients with untreated chronic congestive glaucoma

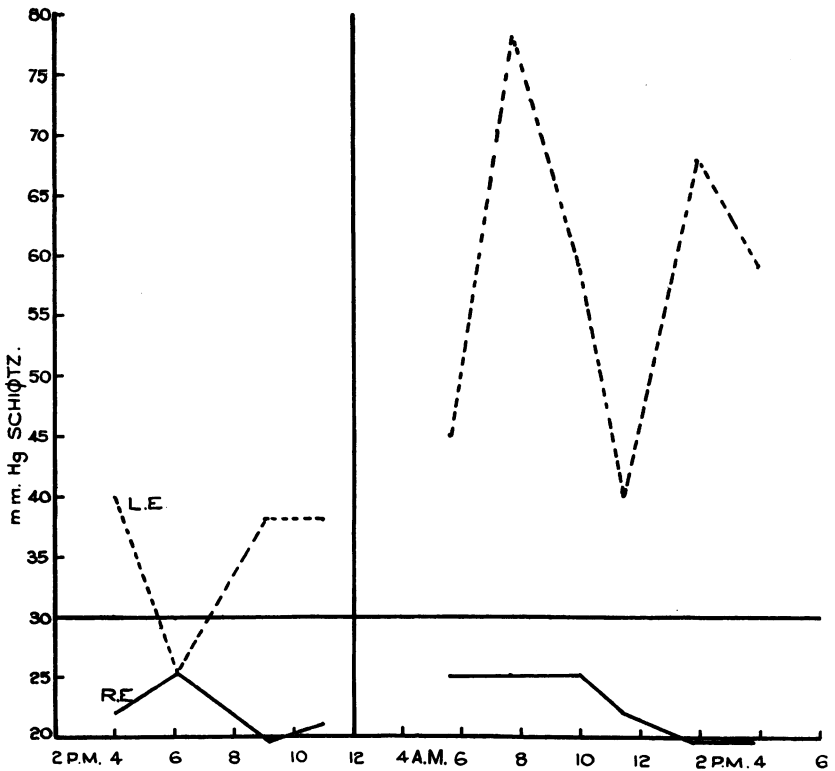


Fig. 6.—Curves in a case of chronic congestive glaucoma affecting the left eye only.

maintain full fields of vision, normal disks, and good visual acuity for long periods, even though the tension may reach high levels at times. Fig. 6 illustrates an untreated case of chronic congestive glaucoma in a woman aged 51 who had had attacks of haloes and blurred vision for 18 months. Her optic disks, visual fields, and corrected visual acuity were normal. The curve reveals extreme limits of 25 mm. Hg and 78 mm. Hg in 24 hrs, with large fluctuations occurring in a short time.

In glaucoma simplex, however, cupping of the disks and para-caecal field defects may be evident even though the tension does not rise above 30 mm. Hg, and in this disease, the eyes of individual patients show different degrees of field loss in association with a given level of tension. Individually, however, we have found that the eye with the greater maximum tension has the greater field defect in the majority of cases. Thus in 33 patients, 26 (79 per cent.) conformed to this observation. The seven exceptions included three in whom the differences in tension and field defects were small, and one who had greater field loss in an eye with high degenerative myopia.

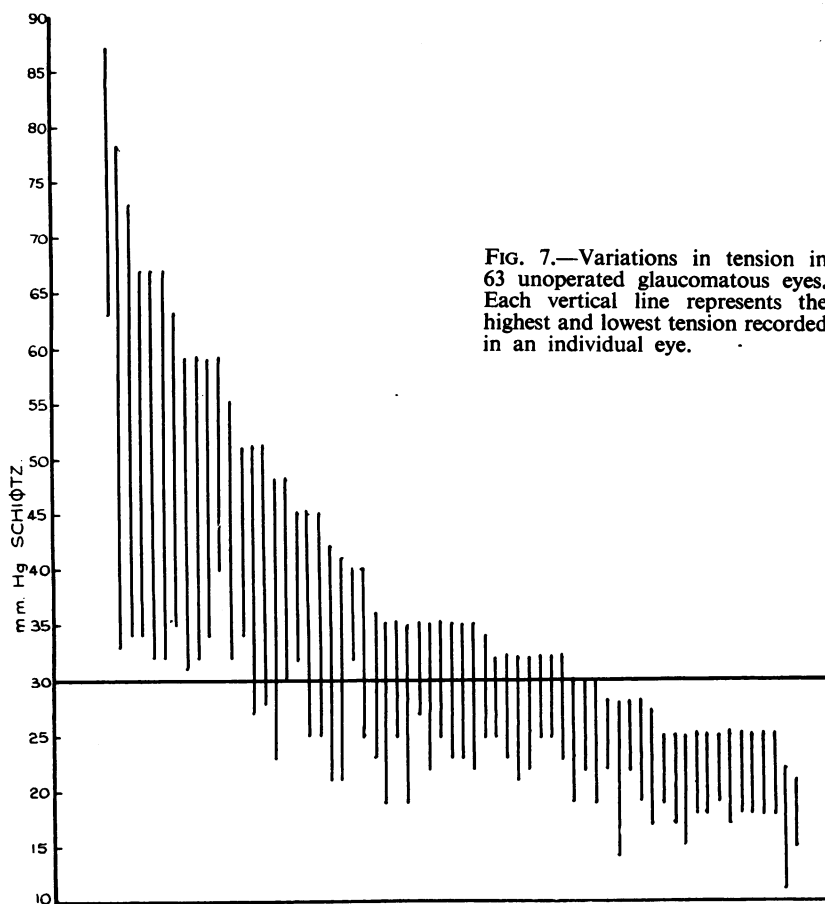


FIG. 7.—Variations in tension in 63 unoperated glaucomatous eyes. Each vertical line represents the highest and lowest tension recorded in an individual eye.

VARIATIONS IN OCULAR TENSION.—Fig. 7 illustrates the variations in tension over 24 hrs in 63 unoperated glaucomatous eyes, where each vertical line represents the highest and lowest tension recorded in an individual eye.

In general, it is seen that the higher the tension, the greater the variations. This observation, first pointed out by Köllner (1918), is opposite in effect to the views of Reese (1948) in glaucoma simplex, although Reese's views may hold in chronic congestive glaucoma.

Cordes (1937) regards a variation in tension of 10 mm. Hg in the unaffected eye in unilateral glaucoma as a sign of latent disease in this eye. Bloomfield and Kellerman (1947) found that in twenty glaucomatous eyes, only six (30 per cent.) had variations of 10 mm. Hg or more. In our series of eyes, 23 (36.5 per cent.) out of

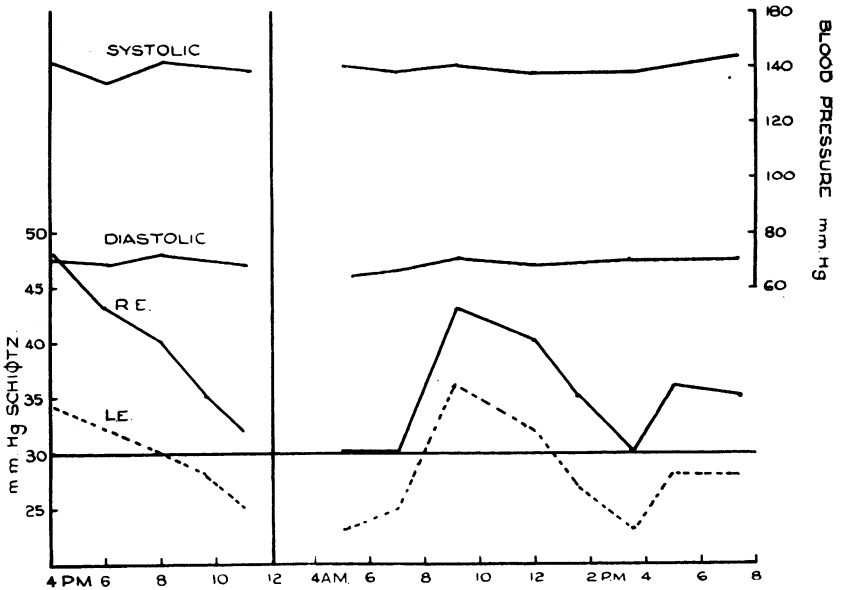


FIG. 8.—Case showing proportionately greater variations in ocular tension as compared with blood pressure.

63 had variations of less than 10 mm. Hg, twenty being cases of early and three of advanced glaucoma.

In the majority of patients, the variations of tension in the two eyes of an individual were remarkably parallel although differing in degree. This observation held in cases where one eye had been successfully operated on, and in cases where one eye was clinically normal. Parallel variations in tension were also observed in a case of bilateral chronic glaucoma secondary to uveitis (Fig. 5).

Downey (1945) regards a difference in tension of more than 4 mm. Hg between the two eyes as a pre-glaucomatous state. We found that in 32 patients the maximum difference was less than 4 mm. Hg in five cases (15.6 per cent.), in two of whom the disease was advanced and in three early. This difference is, therefore, not invariable in glaucoma simplex.

RELATIONSHIP BETWEEN OCULAR TENSION AND BLOOD PRESSURE.—The blood pressure in the brachial artery was recorded by the orthodox method at 2-hourly intervals in 23 cases during the examination.

In only one case (4 per cent.) was there some correlation between blood pressure and ocular-tension changes. A comparison between the two pressures showed the variations in ocular tension to be proportionately greater in fifteen cases (65.2 per cent.), equivalent in four cases (17.8 per cent.), and less in four cases (17.8 per cent.).

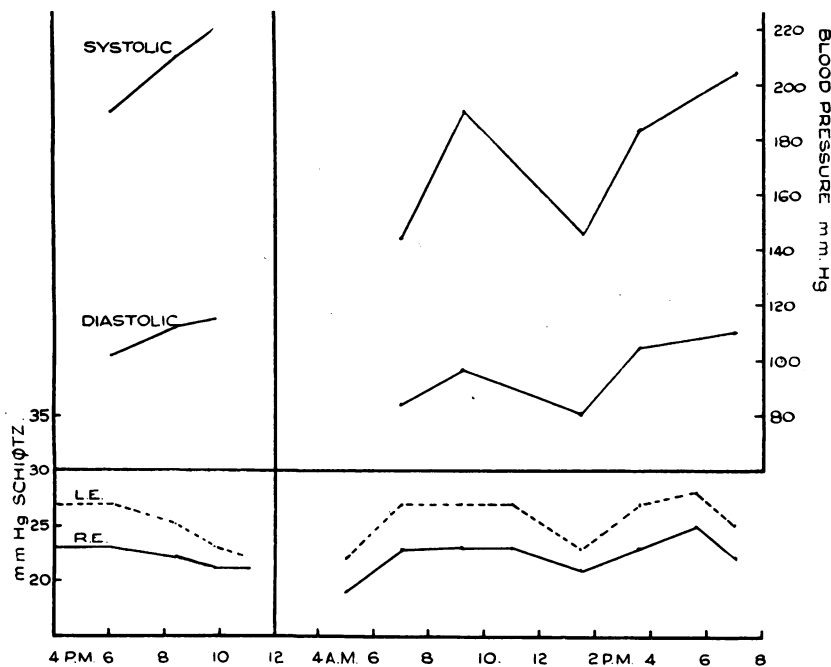


FIG. 9.—Case showing proportionately greater lability of blood pressure compared with ocular tension.

Thus the lability of ocular tension in glaucoma simplex is proportionately greater than that of the systemic blood pressure in most cases.

Fig. 8 illustrates a case where the variations in ocular tension are great as compared with those of the blood pressure, and Fig. 9 one showing the opposite relationship.

It is therefore concluded that variations in blood pressure are not responsible for the height of or variations in ocular tension.

RELATIONSHIP TO PROVOCATIVE TESTS.—The venous-congestion test, the water-drinking test, or both, were carried out on 31 patients (62 eyes), and the maximum tension obtained was compared with the spontaneous changes occurring in the 24-hr. curve.

The provoked maximum was less than the spontaneous maximum in 42 eyes (67.7 per cent.). Of the remaining twenty, the spontaneous maximum was more than 30 mm. Hg Schiötz in ten (16 per cent.), and the provocative tests were negative in a further five (8 per cent.).

This means that from the diagnostic point of view, in only five eyes (8 per cent.) did the provocative tests yield more information than the 24-hr. curve, which emphasizes the clinical value of the latter procedure.

EFFECT OF BODY POSTURE.—In our cases, the body posture had an effect opposite to that described by Thiel (1925). In all cases we observed a fall in tension, with minor fluctuations in some individuals, beginning between 6 p.m. and 8 p.m. and continuing up to the last reading about midnight. In those showing a falling type of curve, the decline was a continuation of the fall which had occurred throughout the day. The patients went to bed at approximately 8.30 p.m. and the fall had begun before that time in many cases, which suggests that the posture itself may not have been responsible for the fall. Fig. 10 shows the evening curves of 45 eyes superimposed to illustrate the general trend.

We were unable to confirm the rise in tension during the night as described by Thiel, and it is probable that this worker's results may have been due to the disturbance of frequently waking the patients. In 29 (85 per cent.) of our 34 patients, the tension was approximately the same at 5 a.m. as at the last reading the previous evening. The exceptions all showed the falling type of curve.

Again, rising from bed did not produce a fall in tension. Our patients rose at approximately 8 a.m., and after this time the tension was found to be either unaltered or higher than at the 7 a.m. reading in 26 cases (76 per cent.), five of the eight exceptions having curves of falling type.

These observations also apply to an equal degree to the possibility that ocular movements are responsible for changes in tension. It would appear that neither body posture nor eye movements is responsible for these changes.

RELATIONSHIP TO MEALS.—Köllner (1918) considered that the ingestion of food could influence the ocular tension by altering the blood pressure and modifying the consistency and distribution of the blood.

We were unable to demonstrate any constant alteration in tension after meals. In many cases the tension either rose or fell in the same individual after a meal, and in other cases the trend of the curve was unaltered.

OTHER FACTORS.—There was no correlation between the behaviour of the ocular tension and the age, sex, and refraction of the patient, and it was not possible to evaluate the duration of the disease. Gonioscopy in 33 patients showed broad or medium chamber angles in 55 eyes (83 per cent.), and narrow angles in eleven (17 per cent.).

EFFECTS OF OPERATION

Curves were obtained in five eyes which had been operated on since the first examination, and in three which had been trephined before the first examination.

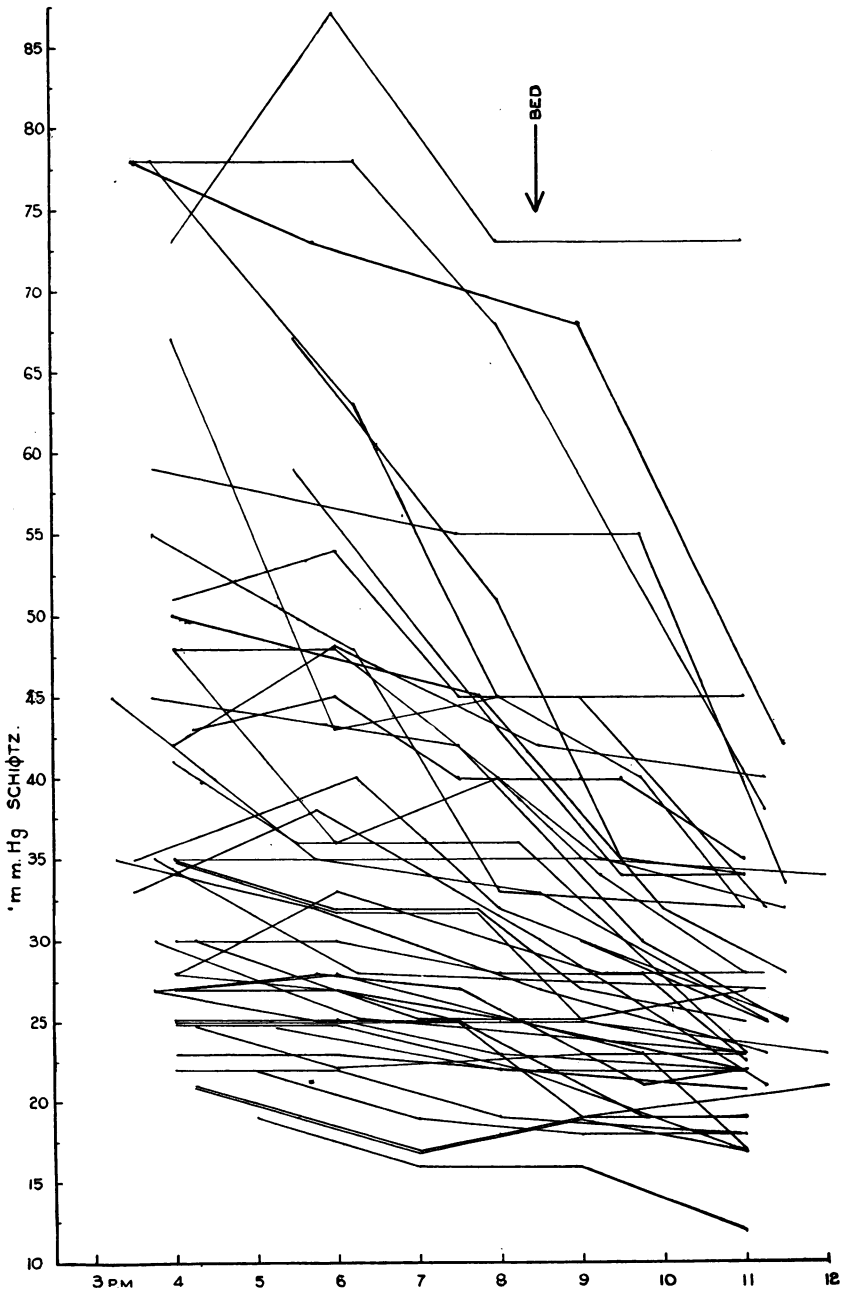


FIG. 10.—Superimposed evening curves of 45 glaucomatous eyes showing the general decline in tension towards the late evening.

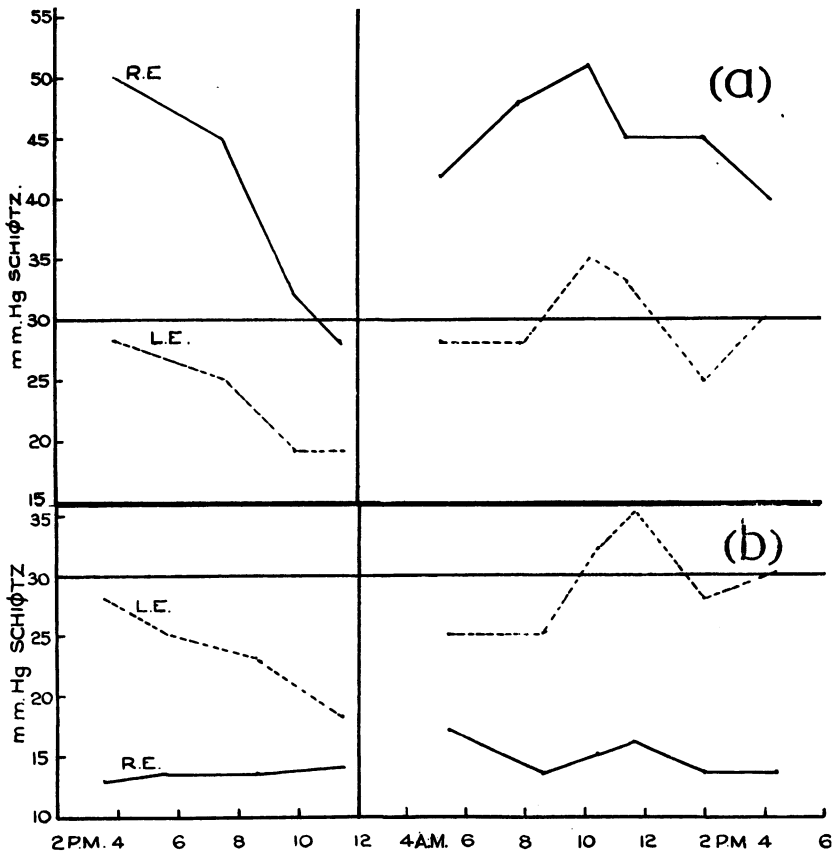


FIG. 11 (a) Curves in a case of bilateral glaucoma simplex taken on December, 5, 1950. (b) Curves of the same patient taken on March 3, 1951, the right eye having had a flap sclerotomy in January, 1951.

In only three cases could the operation be considered successful, the maximum tension having been lowered to approximately 20 mm. Hg or less, and the variations reduced to 4 mm. Hg or less.

Fig. 11 illustrates the curves in a successful case before and after an operation of flap-sclerotomy on the right eye. Incidentally, the curves of the left eye are seen to correspond closely although 3 months elapsed between the two examinations.

An unsuccessful case is illustrated in Fig. 12 which shows three curves of the right eye taken at different times. The eye was trephined after the first curve was obtained, but the tension was not lowered nor the variations reduced. Gonioscopy revealed iris tissue obstructing the trephine hole, and accordingly a second trephine was performed, but, as is shown by the third curve, this has been no more

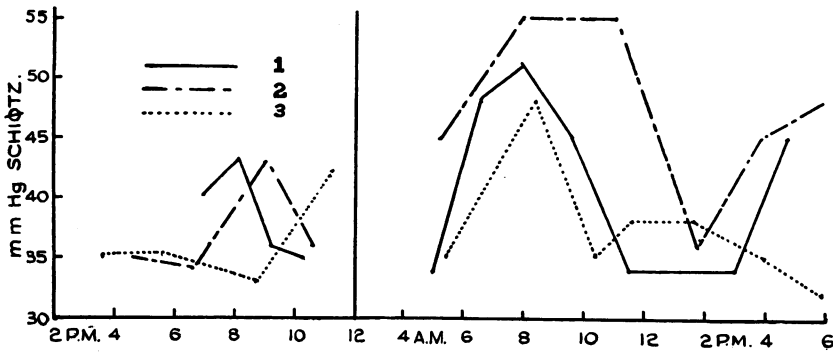


FIG. 12.—Three curves of the right eye only of a case of glaucoma simplex.

- (1) February, 1950.
- (2) November, 1950, 3 months after a trephine operation.
- (3) March, 1951, 3 months after a second trephine operation.

successful, in spite of there being œdematous subconjunctival tissue at the site of operation. A second gonioscopic examination showed that the trephine hole was open with two ciliary processes attached to its edge.

DISCUSSION

The height of the ocular tension is not the only agent by which a glaucomatous eye suffers damage. Patients with untreated chronic congestive glaucoma may observe haloes (indicating phases of high tension) over many years without cupping of the disks, or loss of visual field or visual acuity. Again, obvious cases of hypertensive uveitis often withstand the elevated tension for prolonged periods without evidence of cupping of the disks. In glaucoma simplex, different individuals show varying degrees of ocular damage in association with a given level of tension; in general, though not invariably, the maximum tension rises and the variations increase as the disease advances. In a given case, the eye with the higher maximum tension is most likely to suffer the greater damage.

Both in chronic congestive glaucoma and in the late stages of chronic simple glaucoma, haloes are a feature, and in both these types, large fluctuations of tension occur within short periods of time, and may be responsible for the corneal œdema. In the early stages of simple glaucoma, the changes are smaller in degree and slower in development, so that presumably the fluid content of the cornea is adjusted during the rise. The fact that haloes are so often absent, even in late cases of glaucoma simplex with large fluctuations in tension, may be due to the depression of visual function.

The variations in tension in glaucoma simplex are seen to be habitual and characteristic of the individual in the majority of cases, and are produced by some factor which influences both eyes in a

parallel fashion. In cases of unilateral disease, the affected eye responds to these influences in an exaggerated way. This determining factor is not associated with size of pupils, body posture, massaging effect of ocular movements, ingestion of food, or blood pressure.

The curve is of clinical value diagnostically in that in most cases as much or more information is obtainable as by provocative tests. It also provides a useful index as to the optimum diurnal times for the instillation of miotics, and it is a reliable method of assessing the results of operation, the criteria of success being the reduction of tension to a low level and the smoothing out of variations.

The tension should be followed from 5 a.m. until 7 p.m., and this period should be sufficient to record the maximum tension.

SUMMARY

The ocular tension has been followed at 2-hourly intervals over 24 hrs in 34 cases of glaucoma simplex and repeated after some months in sixteen patients.

The curves obtained are discussed in relation to visual-field defects, blood pressure, body posture, provocative tests, ingestion of food, and other clinical features.

This method of study is of value in diagnosis and in assessing the results of operation.

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