

SLIT-LAMP STUDIES ON THE FLOW OF AQUEOUS HUMOUR*†‡

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IN the intriguing problem of the dynamics of aqueous humour there has recently been a shift in emphasis from what one might call the strictly biochemical approach, to a consideration of the bulk flow of aqueous humour utilizing electronic devices and tracer substances. This study is based on direct observation of the rate of flow of aqueous humour on 88 glaucomatous and normal patients.

Since the time of Ehrlich (1882) it has been known that fluorescein, instilled into the conjunctival sac, readily permeates the cornea and appears in the anterior chamber. Here its concentration may be measured by means of a slit lamp after the method of Amsler and Huber (1946). Use of these two observations has formed the basis for observing fluctuations in the rate of flow of aqueous humour wherein fluorescein is utilized as a tracer substance (Langley and MacDonald, 1952).

Technique

One drop of 5 per cent. fluorescein is instilled into the conjunctival sac. If no staining of the cornea is present after 5 minutes, one drop of 20 per cent. fluorescein is instilled. If, after an additional 5 minutes, there is still no staining, a drop of 0.5 per cent. pantocaine is instilled and the cornea is exposed to air for one minute, or until the corneal light reflex loses its lustre when another 20 per cent. drop is instilled. This is frequently necessary in young people or if tearing is excessive.

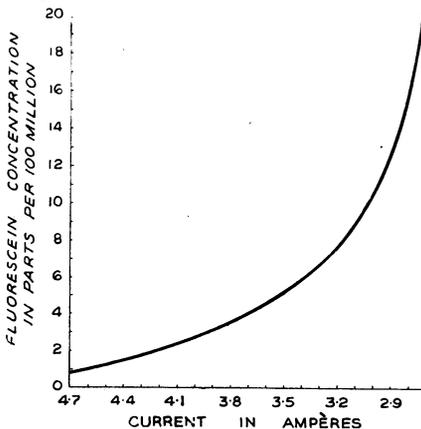


FIG. 1.—Conversion curve, showing relation of ampères to concentration of fluorescein.

practice. Filament illumination is controlled by a variable rheostat in series with an ammeter. Ampère readings, the measurement of current strength, are then converted into approximate fluorescein concentration in parts per 100 million (Fig. 1).

Apparatus

The intensity of the resultant green flare in the aqueous observed with the Haag-Streit slit lamp is taken as an index of fluorescein concentration. The measurement is made by determining the minimal slit-lamp illumination necessary for the observer to recognize threshold green. By the use of this principle, accuracy is quickly attained with

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For greater accuracy in our present work, only one ocular of the slit-lamp is used. The latter is coupled to a control so that the observer has a monocular view of the fluorescein aqueous ray directly beside a control green (Fig. 2).

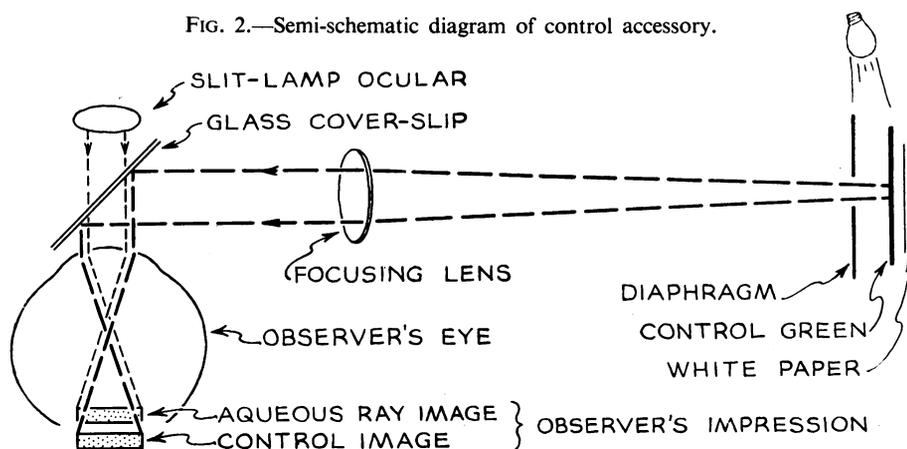
The control consists of a Wratten green (B -58) filter, mounted between glass cover-slips, lying on a white background and illuminated by a 6-watt lamp. The control lamp and the slit-lamp filament are on separate circuits, but are powered by the same main, so that small power fluctuations will affect each simultaneously.

The control is mounted on the end of a 15" arm fixed by clamps to the slit-lamp ocular support. Mounted at 45° to the front of the ocular eyepiece is a glass cover-slip which reflects the rays of light from the control into the observer's eye. The control, illuminated at threshold green, is masked by a black diaphragm. A suitable slot is cut in the latter making the control resemble the aqueous ray under low power in size and shape.

In order to bring the aqueous ray and control to the same focus, a lens suited to the observer's refractive error is placed between the reflecting cover-slip and the control. It is important that the fluorescein aqueous ray be in sharp focus and that the observer's eye be centred properly behind the eye piece before a reading is taken.

The control image is brought into contact with the aqueous-ray image by rotation of the ocular with its fixed cover-slip. The width of the slit-lamp beam is determined at the beginning of the test by photo-electric cell calibration. Fluorescein readings are taken over the pupillary area of the patient's eye.

FIG. 2.—Semi-schematic diagram of control accessory.



Procedure

Altogether 117 eyes, 32 of which were normal, were examined. At the beginning of the test a careful search was made for aqueous veins and the most suitable ones were selected and observed throughout the test. The patients were allowed to read, drink fluids, and eat as desired. Fluorescein was instilled in the morning and the resulting concentration in the aqueous and the intra-ocular tension were recorded at frequent intervals throughout the day. The intra-ocular tensions were taken with a Schiötz tonometer after the instillation of a drop of 0.5 per cent. pantocaine solution. After the concentration of fluorescein in the aqueous had been observed for about 4 hrs, a miotic was instilled and its effect on the concentration of fluorescein was observed.

Results

In the Normal Eye.—The typical curve obtained from the study of 32 normal eyes is shown in Fig. 3. As reported in earlier work (Langley and MacDonalD, 1952) the concentration of fluorescein in the aqueous humour gradually increased over the first 2½ hrs after instillation. At the end of this time a state was reached at which the amount of fluorescein entering the aqueous from the cornea was balanced by that leaving *via* Schlemm's canal, and other escape channels. After the "steady state" has been reached, the concentration of fluorescein gradually falls during the next 18 to 24 hrs until no traces are visible. In almost all cases this steady state was little influenced by the instillation of miotics.

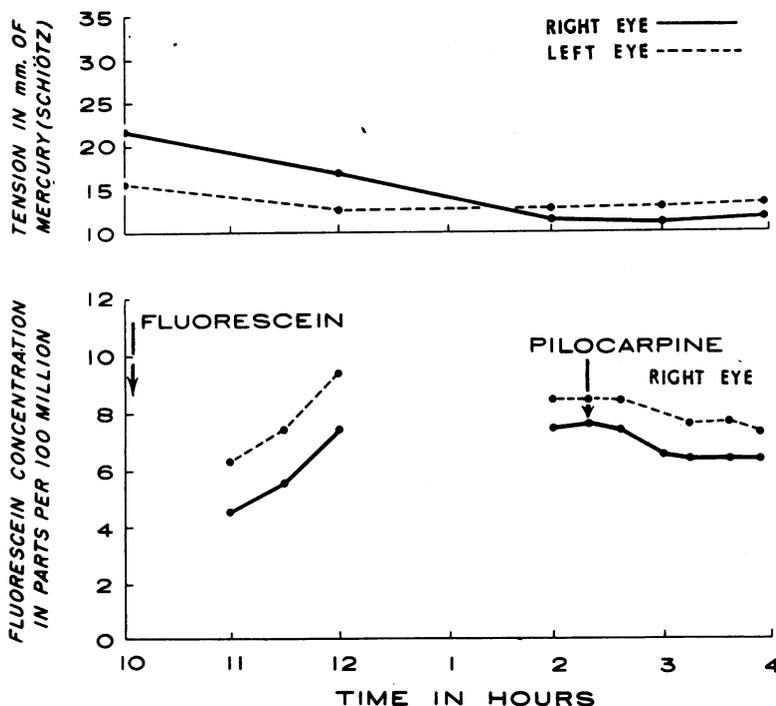


FIG. 3.—Concentration curve in normal subject.

In Glaucoma.—Concentration curves were observed in a total of 85 eyes. Most of the patients were referred from the glaucoma clinic of the Toronto General Hospital; the remainder from physicians interested in this investigation.

In 34 of the eyes studied after the instillation of 4 per cent. pilocarpine the curve shown in Fig. 4 (opposite) was obtained. Here it will be seen that there was a sharp drop in the concentration of fluorescein associated with a gradually falling tension. In sixteen eyes there was a similar drop in concentration without change in tension and in seventeen eyes the tension actually rose while the concentration of fluorescein fell (Fig. 5, opposite).

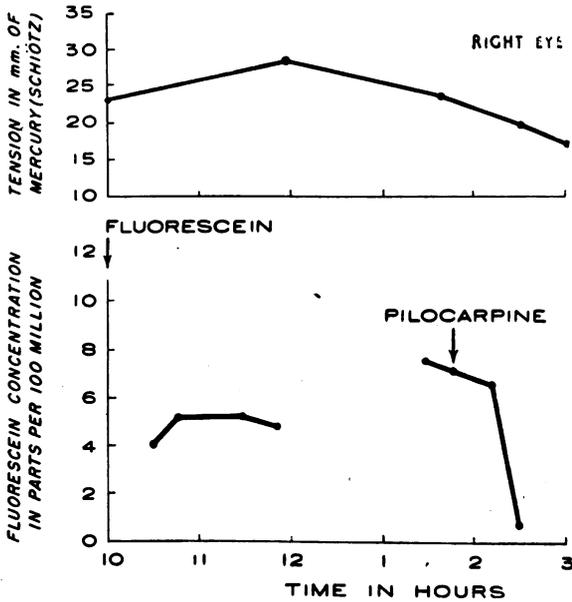


FIG. 4.—Effect of pilocarpine in glaucoma, showing fall in concentration and ocular tension.

Similar findings were observed after the instillation of 0.5 per cent. eserine. In four of the eyes treated a fall in the concentration of fluorescein was associated with a fall in the ocular tension. In three eyes a drop in concentration occurred without any change whatsoever in ocular tension, and in three eyes a drop in concentration was associated with a significant elevation in tension (Fig. 6, overleaf).

In eight eyes a marked drop in tension occurred after the instillation of

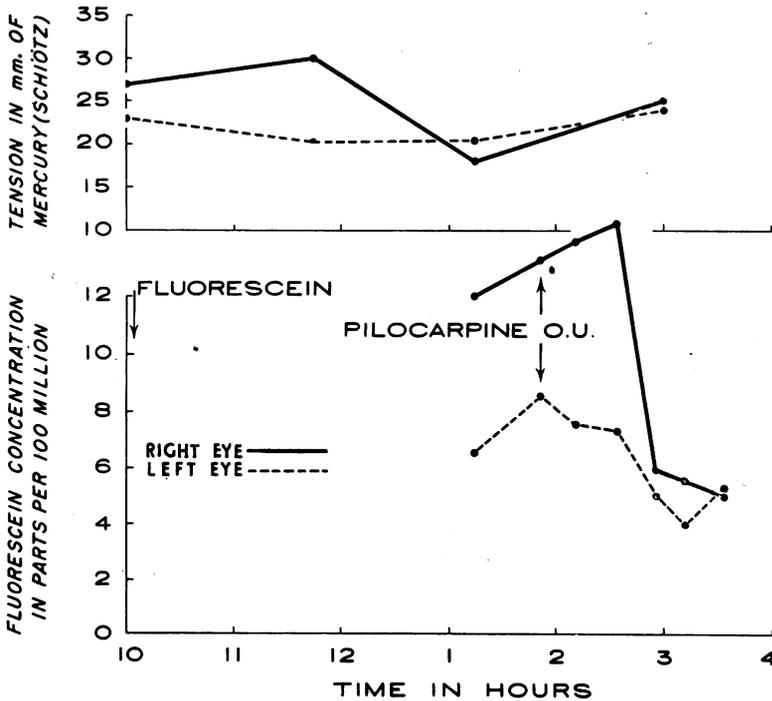


FIG. 5.—Curve in glaucoma, showing drop in concentration with rise in tension, after instillation of pilocarpine.

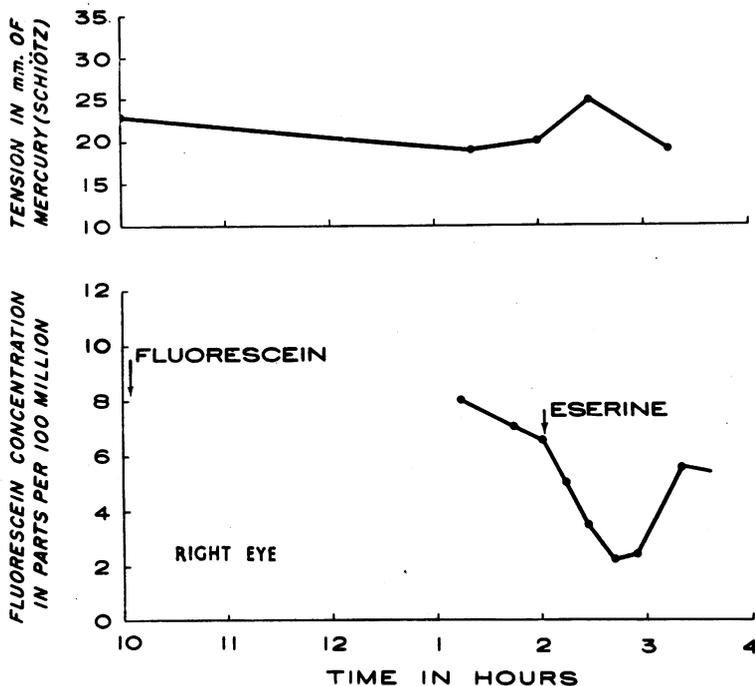


FIG. 6.—Curve in glaucoma, showing drop in concentration with rise in tension, after instillation of eserine.

miotics without any significant change in the level of fluorescein.

In seventeen of the 85 glaucomatous eyes there was a spontaneous drop in the concentration of fluorescein. Fig. 7 demonstrates the curve in such a case. Further study of this particular curve shows that although the concentration of fluorescein continued to fall after the administration of pilocarpine, the miotic was without effect on the tension.

Aqueous Veins.—A very great individual variation was observed in the prominence and configuration of

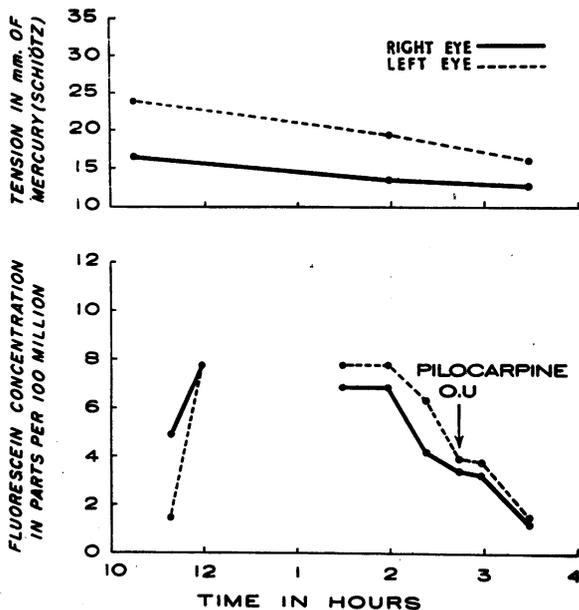


FIG. 7.—Concentration curve, in glaucoma, showing spontaneous drop in concentration, which continued after instillation of pilocarpine, although miotic did not affect tension.

the aqueous veins. Particular attention was paid to the relative rate of flow of clear fluid in these vessels as indicated by the rapidity of movement of occasional blood cells. In glaucomatous eyes, it was noted that the aqueous veins generally appeared to contain more clear fluid flowing at faster speeds at times when the concentration of fluorescein was falling or about to fall. This fall in concentration associated with a more rapid stream in the aqueous veins was taken as an index of increased bulk flow of aqueous humour.

The latter phenomenon in the aqueous veins usually followed the instillation of either pilocarpine or eserine. After the administration of eserine, a temporary constriction of blood vessels was also noted. The blood flow at this stage was reduced to a mere trickle frequently stagnating for several minutes. The flow of clear fluid in the aqueous veins, however, continued unabated.

Generally where there was a filtering bleb, clear sizable aqueous veins were almost impossible to find, but in cases in which the bleb had disappeared, particularly in the face of increased tension, clear aqueous veins were usually readily apparent.

Discussion

This work further demonstrates the inherent instability of the glaucomatous eye as compared to the normal, not only in the tension but also in the flow of aqueous humour.

Miotics temporarily increase the rate of flow, but in only 50 per cent. of the cases studied was there an associated fall in the tension. The remainder were about equally divided between those in which the tension remained unaltered and those showing a slight elevation. This shows that rate of flow and ocular tension (as measured by Schiötz tonometry) do not bear a constant relationship to one another. Moreover in seventeen of our cases there was a spontaneous drop in the concentration of fluorescein without tension change. This was usually a bilateral phenomenon. The degree of increased flow as indicated by a fall in concentration of fluorescein does not indicate the degree or direction of tension change in most cases. Similarly, signs of increased flow of clear fluid in aqueous veins, occurring as they do during periods of falling concentration of fluorescein, must not necessarily be taken as the index of tension change. In other words, changes in the flow of clear fluid in aqueous veins are related to rate of flow of aqueous humour, not necessarily to tension.

In conclusion, although a change in rate of bulk flow of aqueous humour is reflected in a change of flow in the aqueous veins, neither bears a constant parallel relationship to changes in tonometric readings. Although the rate of escape of aqueous humour from the anterior chamber through its exit channels is obviously important, the present findings indicate that it by no means explains all the changes found in tonometric readings and that a much broader concept must be envisaged, to include such factors as uveal tone, changes in scleral rigidity, and rate of formation of aqueous humour.

Summary

An improved method of measuring changes in the concentration of fluorescein in the anterior chamber without disrupting the physiological state of the human eye is described. In these experiments fluorescein was administered by the instillation method. Fluctuations in the bulk rate of flow, either spontaneous or after the instillation of miotics, were reflected in changes in flow of clear fluid in the aqueous veins, but neither the fluctuations nor changes in the aqueous veins bore a constant parallel relationship to the tonometric readings.

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