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PATHOGENESIS OF INTRAOCULAR HYPERTENSION IN CASES OF ARTERIOVENOUS ANEURYSM

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INTRAOCULAR hypertension is a fairly constant symptom in patients with aneurysm of the cavernous sinus and the internal carotid artery. We have found it in each of five patients recently examined. Three times it was unilateral and affected only the eye on the same side as the lesion; twice it was bilateral.

The present work is the report of a new case of arteriovenous aneurysm complicated by intraocular hypertension. The use of recent techniques—measurement of the episcleral venous pressure, measurement of the resistance to the aqueous flow, and calculation of the volume of this flow—has thrown some light on the mechanism of intraocular hypertension.

REPORT OF A CASE

M. J., aged 17 years, was wounded in June, 1950, in a road accident. He sustained a fracture of the skull, with depression of the right frontotemporal region. His condition steadily improved in the weeks following the accident. Recovery seemed complete, but at the end of 1951 a swelling appeared in the superior inner angle of the right orbit. It increased progressively and was complicated by exophthalmos.

Ocular Examination (Nov. 29, 1951).—Examination showed a large swelling on the inner border of the right orbit (Fig. 1). A thrill could be felt, and a continuous murmur could be heard, becoming stronger during systole. The veins of the right upper lid were dilated. The exophthalmos of the right eye measured 9 mm.; it was axial, reducible, and pulsatile. The veins of the palpebral and bulbar conjunctiva were dilated (Fig. 2). No aqueous veins were visible. The iridocorneal angle was normal. The dilated right pupil reacted poorly to direct light stimulation and during convergence, but responded well to consensual stimulation. The optic disk was pale. The retinal veins were larger in the right eye than in the left. The central artery of the retina was under normal tension in each eye. Intraocular tension was 8 mm. Hg higher in the right eye than in the left eye (right eye, 28 mm. Hg; left eye, 20 mm. Hg).

Vision in the right eye was reduced to 2/10, with narrowing of the temporal field (Fig. 3).

Cerebral Arteriography.—An arteriovenous aneurysm between the internal carotid artery and the cavernous sinus caused a prominent dilatation of the ophthalmic vein. The blood entering the internal carotid artery passed directly into the venous system at the level of the aneurysm, never reaching the cerebral arteries above the lesion (Fig. 4).

STUDY OF THE MECHANISM OF INTRAOCULAR HYPERTENSION

According to the hypothesis that the flow of the aqueous humor (F), the resistance to the aqueous flow (R), and the venous pressure where the aqueous

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veins join the conjunctival and episcleral vessels (Pv) are the main factors in ocular pressure (Poc), as expressed in the formula

$$Poc = (F \times R) + Pv$$

intraocular hypertension can result from (a) increased aqueous flow, (b) increased resistance to the flow, or (c) increased conjunctival and episcleral pressure.

In the case reported in this paper, we measured the venous pressure and the resistance to the aqueous flow, and from these values we calculated the intraocular flow.

A. Measurement of Venous Pressure.—Measurement of the venous pressure was made by a small transparent chamber attached to a water manometer, similar to that used by Thomassen.[1] We determined, with the slit lamp, the minimum pressure which collapsed the conjunctival vessels, visibly dilated in Figure 2.[2]

Fig. 1.—Swelling on the inner border of the right orbit due to dilatation of the ophthalmic vein.

B. Measurement of Resistance to Aqueous Flow.—Measurement of resistance to the flow was made with the electronic tonometer and the tonometric tables of Friedenwald, published by Moses and Bruno [3] and Grant.[4] Our method is the same as the one used by Grant.[4]

Normally the ocular tension varies but slightly. This observation signifies that the volume of fluid which penetrates the eye in a given time is equal to the volume of fluid which flows out during the same time. The placing of a tonometer on the

1. Thomassen, T. L.: Acta ophth. **27**:1, 1947.

2. Generally we use for measuring the episcleral venous pressure the manometric apparatus made from a mouse bladder, as described by Goldmann. We prefer this instrument to the transparent manometer used in this case. But the measurement of the venous pressure by using the mouse bladder is possible only if a laminar vein is detected with the slit lamp or if red blood corpuscles are visible in one of the vessels. One then finds the minimum pressure which produces the aqueous inflow, the blood inflow, or the arrest of the flow of red blood corpuscles. The absence of laminar vessel and strong conjunctival hyperemia forced us in the present case to use the transparent manometer.

3. Moses, R. A., and Bruno, M.: Am. J. Ophth. **33**:389, 1950.

4. Grant, W. M.: Arch. Ophth. **44**:204, 1950; **46**:113, 1951.

cornea changes this equilibrium, the foot of the tonometer raising the intraocular pressure and distending the sclerotic.

If the tonometer is kept in place for a prolonged period, the escape of fluid becomes greater than its formation, and the intraocular pressure falls progressively. Several observations by Grant [4] and studies by one of us (R. W.) in collaboration with Prijot [5] have shown that the decrease in tension is due mainly to a reduction in the volume of the aqueous humor.

According to Goldmann,[6] the flow of the aqueous humor from the anterior segment of the eye obeys relatively simple physical laws. Poiseuille's law may be applied: $F = \frac{Pf}{R}$

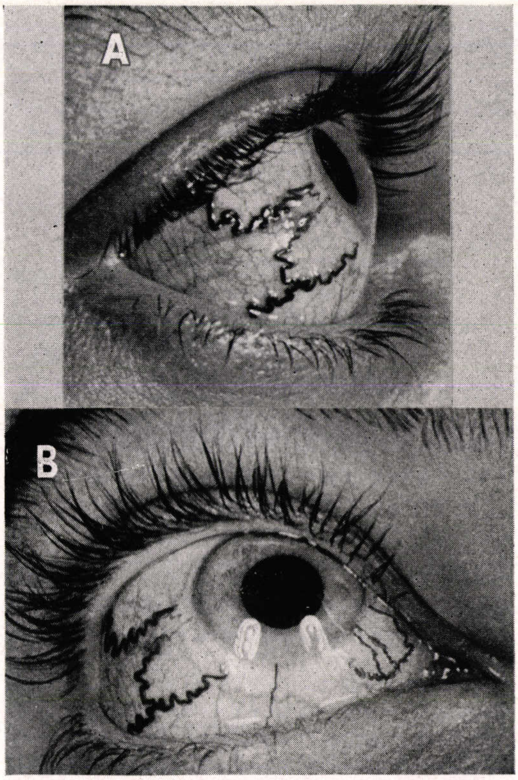

Fig. 2.—Exophthalmos and dilatation of the veins of the bulbar conjunctiva.

where F is the flow of aqueous humor, expressed in cubic millimeters per minute; Pf is the outflow pressure of the aqueous humor, that is, the intraocular pressure (Poc) minus the venous pressure at the point where the aqueous joins the blood (Pv), and R is the resistance offered to the passage of aqueous humor from the anterior chamber to the point where Pv is measured.

From this formula, we infer that $R = \frac{Pf}{F}$.

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5. Weekers, R., and Prijot, E.: Ophthalmologica **123**:1 and 114, 1952.
6. Goldmann, H.: Docum. ophth. **5-6**:278, 1951.

When the tonometer is placed on the globe, the intraocular pressure and the rate of flow of the aqueous are increased. In other experiments we have shown that, on the contrary, the resistance remains constant (Weekers and Prijot [5]).

Friedenwald's tables published by Moses and Bruno [3] make possible the calculation of the increase of *Poc* during the compression test. Tonometric pressure (*Pt*) is the pressure of the globe when the tonometer is placed on the cornea. Pt_1 is the tonometric pressure at the beginning of the test, and Pt_2, the tonometric pressure at the end of the test, i. e., after five minutes. The average tonometric

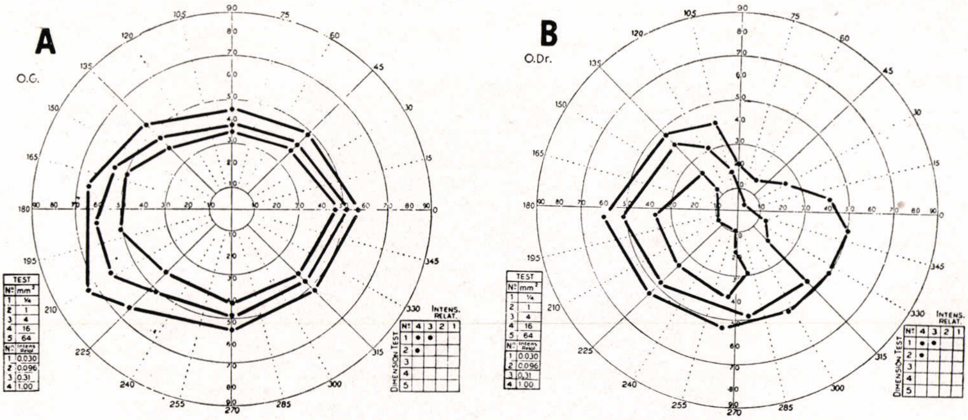

Fig. 3.—Reduced visual field caused by compression of the optic nerve.

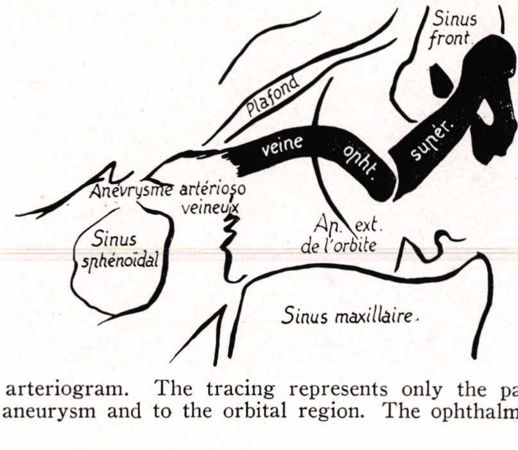

Fig. 4.—Cerebral arteriogram. The tracing represents only the part of the arteriogram corresponding to the aneurysm and to the orbital region. The ophthalmic vein is considerably enlarged.

pressure during the course of the test is calculated accurately enough by the arithmetic mean: $\frac{Pt_1 + Pt_2}{2}$.

The average increase in pressure during the test is calculated from the formula $\frac{Pt_1 + Pt_2}{2} - Poc$.

On the other hand, Friedenwald's tables published by Grant [4] show the increase in flow of the aqueous humor during the compression test. V_1 is the reduction in volume of the globe at the beginning of the test, and V_2 the reduction in volume at the end of the test. Friedenwald's tables take into account the indentation of the cornea and the retraction of the sclera.

The volume of liquid expressed from the globe during the five minutes of the test is $V_2 - V_1$. The quantity of liquid expressed per minute is $\frac{V_2 - V_1}{5}$.

During the compression test $R = \dfrac{Pf + \left(\frac{Pt_1 + Pt_2}{2} - Poc\right)}{F + \left(\frac{V_2 - V_1}{5}\right)}$.

Since R is not modified during the test, and since Poiseuille's law postulates that $R = \frac{Pf}{F}$

$$R = \frac{\frac{Pt_1 + Pt_2}{2} - Poc}{\frac{V_2 - V_1}{5}}.$$

Consequently, the compression test performed with the electronic tonometer allows direct measurement of the resistance to the aqueous flow outside the globe.

C. Calculation of Rate of Aqueous Flow.—According to Poiseuille's law, $F = \frac{Pf}{R}$ the ocular pressure minus the episcleral venous pressure gives the outflow pressure: $Pf = Poc - Pv$.

The compression test with the electronic tonometer, on the other hand, gives the value of the resistance, thus allowing the calculation of the rate of flow.

Average Values for Five Measurements Made During One Week's Hospitalization

	R. E.	L. E.
Ocular pressure (mm. Hg)	26.7	18.5
Episcleral venous pressure (mm. Hg)	20.0	12.0
Outflow pressure (mm. Hg)	6.7	6.5
Resistance to flow	5.6	6.7
Rate of flow (cu. mm./min.)	1.1	1.0

Goldmann's fluorometer allows direct measurement of the aqueous flow. The value of the flow calculated by the compression method and the value measured by Goldmann's method are approximately the same (Goldmann [6]; Grant [4]; Weekers and Prijot [5]).

In applying these methods to the present case, we have obtained the average values shown in the Table (average of five measurements made during one week's hospitalization).

COMMENT

From our experiment, ocular hypertension in cases of aneurysm of the internal carotid artery and cavernous sinus results essentially from the increased blood pressure in the episcleral and conjunctival veins. In this particular case, the pressure in these veins was increased by 8 mm. Hg (right eye, 20 mm. Hg; left eye, 12 mm. Hg), and the ocular pressure was increased by 8.2 mm. Hg (right eye, 26.7 mm. Hg; left eye, 18.5 mm. Hg). The resistance offered to the flow of the aqueous humor was not increased (right eye, 5.6 and left eye, 6.7). Consequently, the calculation of the flow of the aqueous humor shows no alteration on the side of the lesion (right eye, 1.1 cu. mm. per minute, and left eye, 1.0 cu. mm. per minute).

SUMMARY

Measurements of (*a*) the resistance to the aqueous flow, (*b*) the rate of aqueous flow, and (*c*) the episcleral venous pressure in a case of aneurysm of the internal carotid artery and cavernous sinus with unilateral intraocular hypertension show that the intraocular hypertension was due to increased episcleral venous pressure.

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