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**Measurement of venous outflow pressure
in the central retinal vein to evaluate
intraorbital pressure in Graves'
ophthalmopathy: a preliminary report**

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Abstract

PURPOSE To evaluate the intraorbital pressure in patients with Graves' ophthalmopathy (GO) in relation to the intraocular pressure (IOP) and proptosis and to find out whether optic nerve compression is predictable.

METHODS The venous outflow pressure (VOP) in the central retinal vein was measured by the perviously described technique of oculodynamometry.¹ Since the central retinal vein passes through the orbit, the VOP cannot be lower than the intraorbital pressure if outflow is to be guaranteed. The IOP was measured either in primary position or with slight chin elevation to avoid restriction of the globe. Fifty-seven patients underwent a complete ophthalmologic examination, including VOP measurements, Hertel exophthalmometry and visual fields.

RESULTS The IOP in primary position ranged between 10 and 29 mmHg and in most (n=54) cases the VOP was 0-4 mmHg higher than the IOP. These patients had neither scotomas nor visual deterioration during an observation period of up to 2 years. In those cases (n=3) where the difference between IOP and VOP was ≥ 5 mmHg, the patients developed scotomas and visual deterioration and had to be treated (high-dose steroids or orbital decompression). The elevation in VOP did not correlate with the degree of proptosis. In one unilateral case, treatment of high IOP (32 mmHg) with dorzolamide drops led to a decrease in visual acuity of two lines, inferior field depression and relative afferent pupillary defect. The difference between IOP and VOP was 10 mmHg. Stopping treatment normalized visual function, the IOP rose to its original level and the difference between IOP and VOP was 4 mmHg.

CONCLUSION The increased IOP in GO is not caused by primary glaucoma but by elevated intraorbital pressure. The difference between IOP

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and VOP must be <5 mmHg to guarantee normal perfusion. We interpret these findings to suggest that loss of visual acuity and visual field defects may not only be caused by optic nerve compression at the apex but also by deterioration of optic nerve head perfusion.

Key words Venous outflow pressure; intraorbital pressure; Graves' ophthalmopathy; intraocular pressure; oculodynamometry; optic nerve compression

Introduction The central retinal vein passes through the optic nerve when it leaves the globe. Hayreh² demonstrated that the central retinal vein in human beings generally runs a long course through the intervaginal space of the optic nerve sheath, where it is subjected to the cerebrospinal fluid pressure. After the vein leaves the optic nerve sheath it passes through the orbit and drains into the superior ophthalmic vein, which is connected to the cavernous sinus and to the angular veins.

In 1925, Baurmann³ developed a model of the central retinal vein pressure and demonstrated that the intraocular portion of the central retinal vein collapses with pulsating movements when the intraocular pressure is higher than the pressure in the extraocular part of the vein. As the extraocular part of the vein passes through the intervaginal space of the optic nerve sheath, the intraocular venous pressure cannot be lower than the pressure within the optic nerve sheath and within the orbital venous system. If the cerebrospinal fluid pressure or the intraorbital venous outflow pressure is higher than the intraocular pressure, the collapse phenomenon of the central retinal vein disappears. Baurmann increased the intraocular pressure in patients with elevated intracranial pressure until the vein began to collapse and was the first to measure the cerebrospinal fluid pressure by measuring the outflow pressure of the central retinal vein. He was even able to quantify his measurements by using the Bailliart dynamometer and he compared his measurements with invasive investigations of the intracranial pressure and found a good correlation. He discussed the clinical diagnostic relevance, but little attention has been paid to this phenomenon since.⁴

Meyer-Schwickerath¹ developed a technical model that allows analysis of the conditions for the collapse of the central retinal vein. The pressure of the central retinal vein was measured *in vivo* by oculodynamometry. After measuring baseline intraocular pressure (IOP) with an applanation tonometer, a suction cup was applied to the eye and the IOP was increased in a stepwise fashion. The exact IOP at which the central retinal vein, seen by funduscopy, collapsed was recorded. Firsching, Meyer-Schwickerath and Motschmann⁵ analyzed the venous outflow pressure (VOP) in patients who underwent invasive measurement of their intracranial pressure. The results showed a linear correlation between central retinal vein pressure and intracranial pressure with a coefficient of correlation of 0.977. Normal values of venous outflow pressure were below 15 mmHg in this study and readings above 20 mmHg were clearly associated with increased intracranial pressure. In papilledema, the venous outflow pressure was slightly higher than the intracranial pressure. The authors demonstrated that measurement of the venous outflow pressure was a simple and non-invasive way to assess intracranial pressure.

Since the central retinal vein passes through the orbit, the outflow pres-

sure of the central retinal vein cannot be lower than the intraorbital pressure if outflow is to be guaranteed. It is *not* possible to measure normal intraorbital pressure values by measuring the venous outflow pressure because, under physiological conditions, the intracranial pressure is higher than the intraorbital tissue pressure. But if the intraorbital pressure increases and exceeds the intracranial pressure, it is possible to assess the intraorbital pressure by measuring venous outflow pressure.

We wished to investigate the level of the intraorbital pressure in patients with Graves' ophthalmopathy (GO) and to discover something about the relation between intraocular pressure, intraorbital pressure and the degree of proptosis. Is a level of intraorbital pressure definable that can be tolerated without optic nerve damage?

The increased IOP in GO is generally not caused by trabecular dysfunction with reduced facility of aqueous outflow but by elevated intraorbital pressure. Is it possible to lower the IOP with topical antiglaucomatous drugs under these circumstances and what happens if the IOP elevation in GO is altered?

Material and methods Between 1997 and 1999, 57 patients with Graves' ophthalmopathy underwent about four complete ophthalmologic and strabologic examinations, including Hertel exophthalmometry, visual fields, measurements of intraocular pressure (applanation tonometry) in the primary position, upgaze and with a slight chin elevation and VOP-measurements. The venous outflow pressure was measured by the method described by Meyer-Schwickerath et al.¹ To avoid restriction of the globe by a fibrotic inferior rectus muscle, IOP and VOP were measured in the primary position. Few patients had a higher IOP in primary position than with slight chin elevation. In those cases, IOP and VOP were measured in the latter position. Nine men and 48 women (26-84 years old, mean: 47) were investigated.

Results The intraocular pressure in primary position ranged from 10 to 29 mmHg, mean: 16.6 ± 3.2 mmHg (218 single investigations). The intraocular pressure in upgaze ranged from 12 to 38 mmHg, mean: 20.4 ± 5.2 mmHg. The VOP ranged from 12 to 38 mmHg, mean: 18.3 ± 4.6 mmHg.

In Fig. 1, the IOP in primary position is shown in relation to the level of the venous outflow pressure. The absolute levels of VOP are not decisive for the prediction of disturbance of visual function; it is the difference between VOP and IOP that is essential. When this difference was less than 5 mmHg (dots between the lines), the patients developed neither scotomas nor visual deterioration during an observation period of up to 2 years, regardless of the absolute levels (n=54). When the difference between intraorbital pressure and intraocular pressure exceeded 5 mmHg (dots above the upper line), the patients developed scotomas and visual deterioration and had to be treated with high-dose steroids, irradiation or orbital decompression.

The intraocular pressure in primary position in relation to the intraocular pressure in upgaze is shown in Fig. 2. The higher IOP in upgaze indicates restriction of the globe by a fibrotic inferior rectus muscle. It is important to avoid this influence during measurements of VOP by controlling gaze direction.

Fig. 1. IOP in primary position in relation to the VOP.

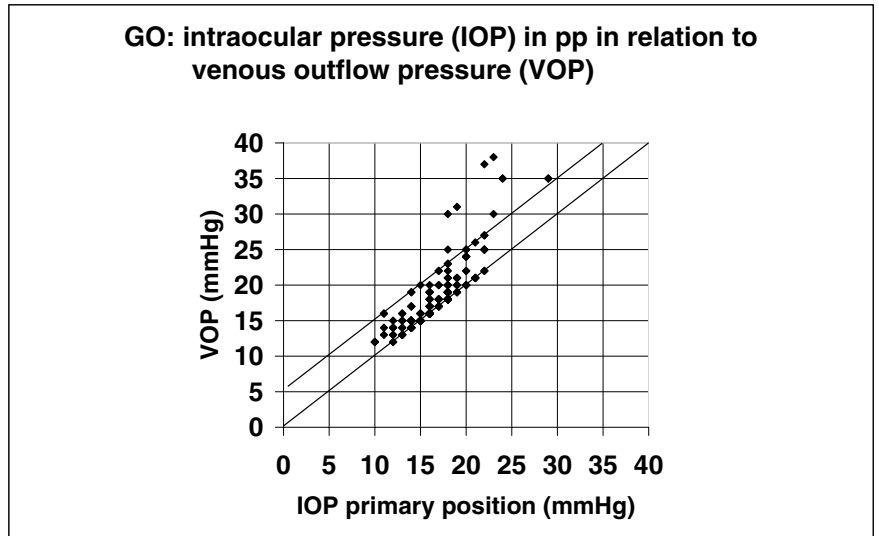
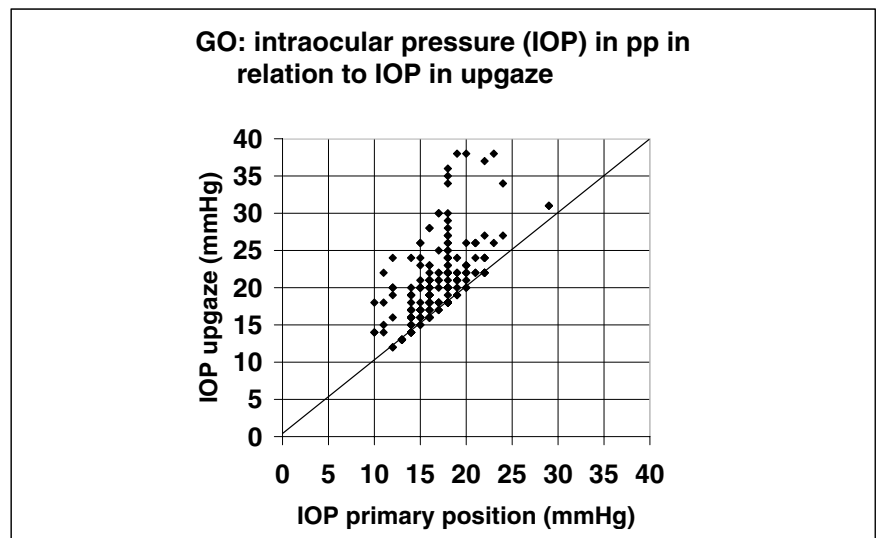


Fig. 2. IOP in primary position in relation to the IOP in upgaze.



Case report A 58-year-old male patient with GO presented with a right-sided optic nerve compression with right-sided visual deterioration and proptosis (at least on the right side) at the first visit. The VOP was 12 mmHg higher than the IOP on the more affected right side. The visual field of the right eye showed an inferior field accentuated depression. As the patient refused orbital decompression, we put him on high-dose steroids and reduced them over 4 months in combination with irradiation.

Five months later the visual acuity and the visual field of the right eye had recovered and the intraorbital pressure had returned to values less than 5 mmHg higher than the IOP.

This patient was *the only one* in whom the IOP was reduced by topical application of antiglaucomatous drops. The findings in the course of treatment are shown in Table 1.

Due to the high IOP, dorzolamide drops were administered. In the course of this treatment a decrease in visual acuity of two lines occurred (17.06.1997). After stopping local treatment the visual function of the right

eye normalized and the IOP rose to its original level of 31 mmHg. The difference between VOP and IOP was reduced to 4 mmHg, the VOP being 35 mmHg. Dorzolamide drops were administered again. The IOP decreased to a level of 24 mmHg, the difference between VOP and IOP increased to a “pathological” level of 11 mmHg and the visual acuity again decreased by 2 lines. At this point we stopped treatment with dorzolamide drops. The remaining treatment was not modified during the observation period. The patient had no other problems during the observation period such as infections or drops in blood pressure.

Discussion Since the central retinal vein passes through the intervaginal space of the optic nerve and through the orbit, the outflow pressure of the central retinal vein cannot be lower than the cerebrospinal fluid pressure and the intraorbital pressure if outflow is to be guaranteed. The venous collapse phenomenon enables us to determine the venous outflow pressure.¹ It is possible to assess elevated cerebrospinal fluid pressure by measuring the venous outflow pressure in a non-invasive way.^{1,3,5,6}

It is *not* possible to measure normal intraorbital pressure values by measuring venous outflow pressure because, under physiological circumstances, the intracranial pressure exceeds the intraorbital pressure. However, if the intraorbital pressure is increased and higher than the intracranial pressure, it is possible to assess the intraorbital pressure by measuring venous outflow pressure.

Graves’ ophthalmopathy is characterized by orbital congestion and proptosis of variable degrees. The eye muscles are enlarged and the fat surrounding the globe is swollen. The volume of tissue behind and surrounding the globe is increased and this can lead to compression of intraorbital structures and optic nerve “damage”. Morphologically, the optic nerve can be encroached upon by swollen muscles at the tight orbital apex. We investigated patients with Graves’ ophthalmopathy to gather information about the level of intraorbital pressure and the relation between intraocular pressure and intraorbital pressure. The mean value of the intraorbital pressure in patients with GO was about 18 mmHg. When the difference between VOP and IOP was less than 5 mmHg the patients developed neither scotomas nor visual deterioration, regardless of the absolute levels. It seems that normal perfusion gradients are still guaranteed under these circumstances. When the difference between VOP and IOP exceeded 5 mmHg, optic nerve “damage” with visual deterioration and visual field defects developed. The deterioration of visual function is thus not caused by a mere compression of the optic nerve. We suppose, therefore, that loss of visual acuity and visual field defects may not only be caused by optic nerve compression at the

Date	Visual acuity	IOP pp (mmHg)	VOP (mmHg)	Therapy
17.06.1997	0.6 / 0.8	24 / 23	35 / 30	30 mg Decortin <i>Trusopt</i> “off”
26.06.1997	1.0 / 1.0	31 / 29	35 / 30	30 mg Decortin Trusopt “on”
08.07.1997	0.6 / 0.9	24 / 21	35 / 26	30 mg Decortin <i>Trusopt</i> “off”

TABLE 1. Clinical findings in the course of treatment of a 58-year-old male patient with GO.

orbital apex but also by deterioration of optic nerve head perfusion. The elevated pressure gradient between the intraorbital and the intraocular pressure may be followed by deterioration of optic nerve head perfusion. We might predict that a difference between IOP and VOP exceeding 5 mmHg will lead to optic nerve “damage”. This screening seems to be more sensitive than other methods (blue-yellow visual fields, visual acuity, contrast sensitivity, VECP), because the latter tests are based upon deteriorated visual function.

It is difficult to evaluate the VOP in relation to the degree of proptosis, because we had no values of Hertel exophthalmometry before the disease started. We have the impression that the level of VOP does *not* correlate with the degree of proptosis.

It is generally accepted that the increased IOP in GO is not caused by trabecular dysfunction, with reduced facility of aqueous outflow, but by elevated intraorbital pressure.⁷ This causes impaired outflow facility and elevated intraocular pressure. The pathogenesis of elevated IOP in GO is different from that in open-angle glaucoma, but there is much confusion and most ophthalmologists try to treat increased IOP in GO.

In most cases of GO, application of antiglaucomatous drops has no effect. Secretory inhibitors may lower IOP. When antiglaucomatous drops lower the IOP, the difference between IOP and VOP increases. The case report demonstrates that a decreasing IOP caused by an elevated intraorbital pressure leads to a deterioration in visual function. This deterioration in visual function may be caused by a deterioration of the microcirculation at the level of the optic nerve head because of a higher venous outflow pressure degree. It would seem wise to tolerate an elevated IOP in similar cases. The treatment of choice is lowering of the elevated intraorbital pressure by means of steroids or orbital decompression.

The raised IOP in GO seems to interfere with the autoregulation of the optic nerve head. The gradient between IOP and the intraorbital pressure may be of more significance than the isolated intraorbital pressure values in the prediction of visual function disorders. If the difference between IOP and VOP is low, the visual function remains stable. If the difference between these pressures rises, a “breakdown” of optic nerve function develops. It does not matter whether the intraorbital pressure rises and the IOP is unable to follow or if we lower only the IOP with antiglaucomatous drops and thus produce a higher relative venous outflow pressure.

By means of the data described above, we are able to use VOP measurements to predict optic nerve “damage”. We are able to detect those patients who require a close follow-up and we use this method to determine the advisability of high-dose steroids or orbital decompression before irreversible optic nerve damage develops.

It is most surprising that there is evidence that higher pressure gradients not only lead to optic nerve “damage” if the IOP exceeds the intraorbital pressure (i.e., in glaucoma) but also in the inverse situation. The VOP may reflect the intraorbital pressure elevation in GO. Additionally, our data shed light on the problems produced by the pressure gradient between the IOP and the intraorbital pressure as represented by the VOP.

References

- 1 Meyer-Schwickerath R, Kleinwächter T, Firsching R, Papenfuss D. Central retinal venous outflow pressure. Graefe's Arch Clin Exp Ophthalmol 1995; 233:783-8.
- 2 Hayreh SS. Pathogenesis of oedema of the optic disc (papilloedema). A preliminary report. Br J Ophthalmol 1964;48:522-43.
- 3 Baurmann M. Über die Entstehung und klinische Bedeutung des Netzhautvenenpulses. Dtsch Ophthalmol Ges 1925;45:53-9.
- 4 Kukán F. Mit einem selbst konstruierten Apparat ausgeführte Untersuchungen über den Zusammenhang zwischen dem Blutdruck der Retinagefäße und dem Hirndruck (Sitzungsbericht). Klin Monatsbl Augenheilkd 1937;98:680.
- 5 Firsching R, Schütze M, Motschmann M, Behrens-Baumann W, Meyer-Schwickerath R. Non-invasive measurement of intracranial pressure. Lancet 1998;351:523-4.
- 6 Firsching R, Meyer-Schwickerath R. Non-invasive assessment of intracranial pressure by measurement of retinal central venous pressure. Child Nerv Syst 1994;10:415.
- 7 Duke-Elder S, Jay B. Glaucoma and hypotony. In: Duke-Elder S, editor. Diseases of the lens and vitreous. System of Ophthalmology, Vol 11, London: Kimpton, 1969:678-81.

