Venous ophthalmodynamometry: a noninvasive method for assessment of intracranial pressure

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Object. The goal of this study was to examine the potential use of ophthalmodynamometry in the noninvasive assessment of intracranial pressure (ICP). Under normal conditions, pressure within the central retinal vein is equal to or greater than ICP, because the central retinal vein passes through the optic nerve before it drains into the cavernous sinus. The optic nerve sheath is the place where ICP affects retinal venous pressure. Suction ophthalmodynamometry is an established method of investigation in ophthalmology to determine the pressure of the central retinal artery. Although observations of papilledema and lack of venous pulsations are commonly used to provide a vague assessment of ICP, ophthalmodynamometry may be used to determine the pressure of the central retinal vein. This venous pressure has never been compared with ICP.

Methods. In this study the pressure of the central retinal vein was recorded in 22 patients who underwent continuous simultaneous registration of ICP for various reasons, mainly for suspected hydrocephalus. A comparison of the two pressures was made. The results indicated a highly significant linear correlation between central retinal vein pressure and ICP.

These results are of great practical value because up-to-date reliable ICP monitoring has only been possible by using invasive means, by placing a probe extradurally or subdurally into the brain parenchyma or a ventricle.

Conclusions. Ophthalmodynamometry can be relevant for momentary assessment and is not suitable for continuous monitoring. However, this technique can easily be repeated and may be used whenever increased ICP is suspected in a patient suffering from hydrocephalus, brain tumors, or head injury.

Key Words • venous outflow pressure • intracranial pressure • ophthalmodynamometry

Pressure within the optic nerve is exposed to ICP because the optic nerve and nerve sheath have a sleeve of CSF that extends up to the globe. Venous outflow of the entire retina drains through the central vein. It passes through the optic nerve for a variable stretch of some millimeters before it exits from the lower side of the optic nerve. Retinal VOP has to overcome the pressure it encounters within the optic nerve. When the central retinal vein collapses, the pressure of the eye is higher than the VOP, that is, the pressure within the optic nerve. When the vein pulsates, its pressure is approximately equal to the IOP. When it is clearly visible and does not pulsate, the VOP must be higher than the IOP. The first to explain these phenomena was Baumann in 1925. He recommended that the pressure of the central retinal vein be recorded to assess ICP; however, until now his idea has never been verified. Based on his observation, we recorded the pressure of the central retinal vein in more than 50 patients with suspected hydrocephalus or other disorders that cause an increase in ICP. Subsequently, we recorded each patient’s ICP after a variable interval of 1 to 5 days.

Abbreviations used in this paper: CSF = cerebrospinal fluid; ICP = intracranial pressure; IOP = intraocular pressure; VOP = venous outflow pressure.
ter attaching a suction cup to the lateral eye bulb until the collapse of the central retinal vein was noted by funduscopy (Fig. 2). A conversion chart for the ophthalmodynamometry reading was used to determine the IOP. At the end of the procedure, the ocular pressure was recorded and added to the converted pressure applied by ophthalmodynamometry. Measured in millimeters of mercury, the level of IOP at which the vein collapsed was called the VOP. The significance of the correlation was evaluated statistically.

Recordings of ICP and VOP levels that had been obtained simultaneously were compared. In four additional patients with hydrocephalus and obstructed CSF circulation, VOPs were recorded before and after surgery (Fig. 3). Patients with a history of ocular disease or papilledema were excluded from the study.

### Results

The relationship between the simultaneous recordings of ICP and VOP is displayed in Fig. 4. The relationships between ICP, VOP, blood pressure, and IOP are listed in Table 1. There is a close linear relation. Regression analysis revealed the function:

$$ICP = 0.903 \times \text{retinal VOP} - 8.87.$$  

The correlation is highly significant ($r = 0.983; p < 0.001$). In all patients in whom the ICP was greater than 15 mm Hg, the VOP was higher than 30 mm Hg.

In all four patients in whom the underlying cause of increased ICP was corrected by surgery, the increased VOP fell to a normal value of less than 13 mm Hg (Fig. 3).

### Discussion

In 1917 Bailliart described the new technique of ophthalmodynamometry based on the premise that a retinal blood vessel will collapse when the ocular pressure is equal to or higher than the pressure of the retinal blood vessels. Since that time ophthalmodynamometry has become an established investigation in the diagnosis of disorders of ocular vessels, mostly the arteries. A relationship between the vein, which drains the retina, and ICP was first suggested by Baurmann who reported early results. His work remained largely unknown; however, a few au-

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<th>Age (yrs)</th>
<th>Sex</th>
<th>Diagnosis</th>
<th>Blood Pressure</th>
<th>Venous Pressure</th>
<th>ICP</th>
<th>VOP</th>
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*Values are expressed in millimeters of mercury. Abbreviations: hem = hemorrhage; SAH = subarachnoid hemorrhage.

3. Patients with a history of ocular disease or papilledema were excluded from the study.

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**TABLE 1**

Clinical characteristics of 22 patients who underwent simultaneous monitoring of retinal VOP and ICP

<table>
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<tr>
<th>Age (yrs)</th>
<th>Sex</th>
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The retinal vein will invariably collapse when its pressure is lower than the IOP. If the IOP were continuously higher than the VOP, the vein would collapse permanently and an exact VOP could not be determined. Because venous ophthalmodynamometry requires mydriasis, it was usually performed in one eye only. Therefore, we presently have no data on any differential effects of a unilateral brain lesion on the ipsilateral or contralateral eye. It is possible that ophthalmodynamometry could be performed without mydriasis in suitable patients; however, we have not yet made an attempt to do that.

Aside from some repeated studies performed in indi-

FIG. 3. Bar graph demonstrating VOP in four patients (I, II, III, IV with identification numbers) with hydrocephalus and increased ICP. The VOP was recorded before and after CSF shunt placement. In all patients VOP was lowered after shunting. These patients are not included in the 22 cases that comprise the present study. White bars = before ventriculoperitoneal shunting; black bars = after ventriculoperitoneal shunting.

FIG. 4. Graph demonstrating relationship between ICP and retinal VOP. In general, ICP levels higher than 15 mm Hg are arbitrarily considered clearly above normal. Thus a VOP higher than 30 mm Hg indicated an increased ICP.
individual patients, which confirmed little variability in the repeated VOP measurements, sequential investigations were not performed routinely in this series.

Up to now, reliable data on ICP have only been available after invasive placement of probes, epidurally or subdurally, into the brain parenchyma or into a ventricle. Therefore, the practical value of ophthalmodynamometry appears to be high and relevant to any physician dealing with suspected elevation of ICP. According to this study, normal values of VOP are lower than 20 mm Hg. Values greater than 30 mm Hg are associated with an ICP higher than 15 mm Hg, which may serve as an arbitrary upper limit for normal values. Registration of VOP is only a momentary assessment and, therefore, the technique is not suitable for continuous monitoring. On the other hand, venous ophthalmodynamometry may be repeated at any time.

Observations of papilledema and the lack of venous pulsations have been reliably used to indicate increased ICP for many years. In addition to these observations, in our experience, the use of ophthalmodynamometry may be helpful in the differential diagnosis of malfunction of ventricular shunts and gastrointestinal disorders (Fig. 1) and hypertensive hydrocephalus and brain atrophy. Because ophthalmodynamometry is a simple and noninvasive method to assess ICP, the neurosurgeon, neurologist, and ophthalmologist should be aware of this option.

Acknowledgments

The authors are grateful to Frau Peters and Prof. Läuter, Institut für Biometrie und Medizinische Informatik der Universität Magdeburg, for the statistical evaluation of our data and to Dr. Meyer Schwickerath, for his advice on the technique of venous ophthalmodynamometry.

References
