

# A Practical Venomanometer

## Measurement of Episcleral Venous Pressure and Assessment of the Normal Range

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● **Glaucomatous damage develops in certain patients because of elevated episcleral venous pressure (EVP). To measure the EVP in typical clinical settings, a practical and reliable instrument is needed. We have developed such an instrument, the venomanometer, and present tests of its reproducibility. The intraobserver reproducibility was 0.7 mm Hg, and the mean difference between the readings of two observers was  $0.7 \pm 1.2$  mm Hg. We then used the venomanometer to study the EVP in 122 eyes of 68 normal subjects distributed in seven age groups between 10 and 80 years. The EVP did not vary with age (mean,  $7.6 \pm 1.3$  mm Hg). This value is compared with those obtained with other instruments.**

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The episcleral veins serve as collector channels for the outflow of aqueous humor from the eye. Increased pressure in these veins may cause an elevation of intraocular pressure that may lead to glaucomatous damage. Increased episcleral venous pressure (EVP) may occur rarely on an idiopathic basis, but may be associated with specific abnormalities such as encephalotrigeminal angiomas or venous outflow obstruction (eg, arteriovenous malformation or cavernous sinus fistula).<sup>1-4</sup>

Engorged episcleral vessels and blood in Schlemm's canal may indi-

cate increased venous pressure. Clinical measurement, however, is needed to verify and quantitate the level of EVP. The major obstacle to frequent evaluations of EVP is the lack of a practical instrument. Although good results have been obtained previously with a number of experimental instruments,<sup>1,5-8</sup> their impracticality in the clinical environment has limited their routine use. The ingenious non-contact air jet instrument developed by Krakau and co-workers<sup>6</sup> is cumbersome and may require calibration. The different versions of the air chamber necessitate either an assistant to read the pressure or the presence of equipment that may be in the way of the clinician when not in use. Moreover, most of the membranes used on these instruments are not translucent enough to permit clear visualization of the eye during the measurement. Also, instruments made with hard tips and a torsion transducer produce less reproducible measurements.<sup>7</sup>

For an instrument to be practical in the clinical environment, it should be easily operated by one observer, require little calibration, be of compact size, be mounted quickly on the slit lamp, permit stereopsis before and during the measurement, and provide good reproducibility. We describe herein a venomanometer that appears to meet these requirements and use it to report on the EVP in normal subjects distributed over a large age range.

### METHODS

The venomanometer (Fig 1) incorporates elements found separately in different devices. Basically, it consists of a flexible transparent tip connected to an air chamber. Specifically, the threaded shaft of the

rotating dial controls the position of an air-sealed piston. The position of this piston determines the volume of the air chamber and, therefore, its pressure. The dial is graduated in millimeters of mercury with a range up to 32 mm Hg. When the dial is at position 0, the piston uncovers an opening within the air chamber that allows it to communicate with the outside. This equalizes the zero pressure in the instrument with ambient pressure, thereby compensating for variations in atmospheric pressure. At other positions above zero this opening is sealed.

The flexible transparent tip is molded out of silicone rubber (General Electric RTV 615A). It is prepared by pouring the material on a mold under controlled conditions. The desired area of contact with the eye is marked by an indicator ring 3 mm in diameter formed during the molding of the material. The translucent membrane is very thin and flexible around the area that contacts with the eye. On the other hand, the periphery of the membrane is reinforced and acts as a seal when stretched over the viewing port. The membrane is secured in place by a protrusion in its seal that fits into a matching groove on the viewing port. This arrangement permits replacement of the membrane whenever necessary and assures its accurate positioning.

The instrument is mounted directly on a slit-lamp microscope (Haag-Streit 900) in a manner similar to the applanation tonometer. For slit-lamp microscopes manufactured by Zeiss, it is fitted with an adaptor to the common shaft of the microscope and illumination source.

A drop of topical anesthetic is instilled in the eye to be tested. The observer then adjusts the fixation light so the tested eye is adducted, permitting the axis of the flexible tip to be as closely perpendicular to the temporal surface of the eye as possible. While viewing stereoscopically, the operator adjusts the microscope so that the flexible tip just touches the conjunctival surface. The microscope is then finely adjusted until correctly aligned, that is, until the area of contact is exactly super-

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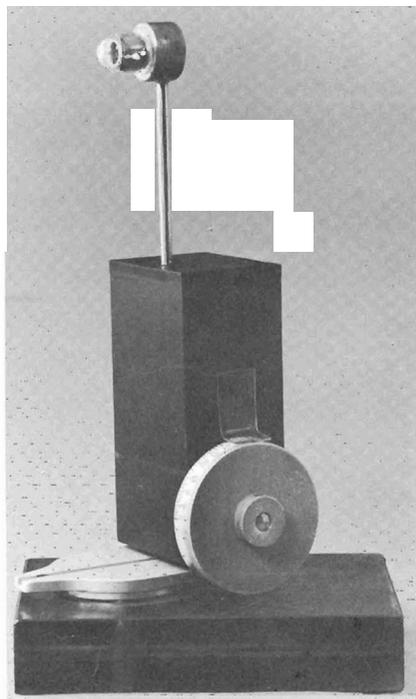


Fig 1.—General view of venomanometer.

imposed on the indicator ring of the flexible membrane and both are in focus, as in Figs 2, top, and 3, top.

The episcleral veins are identified as vessels that are less mobile and deeper than conjunctival vessels and straighter, slightly darker, and often more narrow than the episcleral arteries. The measurement of the EVP is taken approximately 3 mm from the limbus; care is taken to avoid intrascleral veins. The observer slowly increases the pressure by turning the knob until the selected vessel is half blanched (Figs 2, bottom, and 3, bottom). At this point the slit lamp is moved back, the pressure is read off the scale, and the knob is reset to zero. To reduce interference with natural hemodynamics, three rapid measurements half a minute apart are recommended. This is preferable to prolonged contact when attempting to vary pressure around the blanching point. In some cases, the clearance between the eyelids is inadequate, and the lids are separated by an assistant.

The *in vitro* accuracy of the venomanometer was tested by cannulating the view port to an electronic manometer (Hewlett Packard No. 7819A). Successive runs were performed with increasing pressure, and the absolute difference (expressed in percent) between the readings of the venomanometer and those of the manometer were recorded. The reproducibility of the venomanometer was obtained from the SD of ten consecutive measurements. The reproducibility of the electronic manometer was obtained by creating a repetitive change of volume in an air chamber.

The intraobserver reproducibility, that is, the reproducibility of measurement obtained by one observer, was evaluated by two observers. Each observer performed

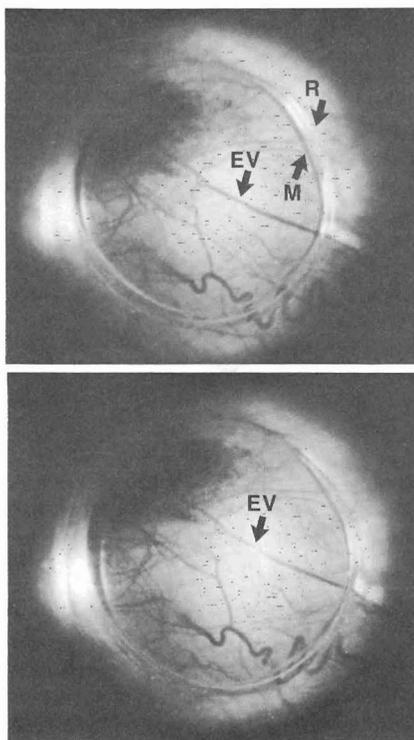


Fig 2.—Example of episcleral venous pressure measurement. Top, Area of interest at atmospheric pressure. R indicates aiming ring embedded in membrane; M, meniscus of tear film coaxial with ring; and EV, episcleral vein. Limbus is to left. Dark area is due to congenital conjunctival melanosis. Bottom, Same area at end point pressure. EV is now half blanched.

five consecutive measurements on each of 30 eyes. The interobserver reproducibility, that is, the reproducibility of measurements obtained by two observers, was assessed by two clinicians who performed separate independent measurements on 16 eyes.

To assess the normal values of EVP, the pressure was measured in 122 eyes of 68 subjects from whom we obtained informed consent. Only subjects known to be free of ocular disease at the time of examination were included. The fellow eye was not tested if there was a history of ocular surgery or trauma or if optimal cooperation was not obtained. Subjects were divided according to age as follows: eight subjects, 10 to 19 years old; 11 subjects, 20 to 29 years old; ten subjects, 30 to 39 years old; 11 subjects, 40 to 49 years old; ten subjects, 50 to 59 years old; ten subjects, 60 to 69 years old; and eight subjects 70 to 79 years old.

No significant difference between right and left eyes was noted either within each age group or when all eyes were studied as a single population; therefore, the results of both eyes were analyzed together.

#### RESULTS

The *in vitro* accuracy was 2.4% for pressures between 4 and 23 mm Hg. For the same range the reproducibility

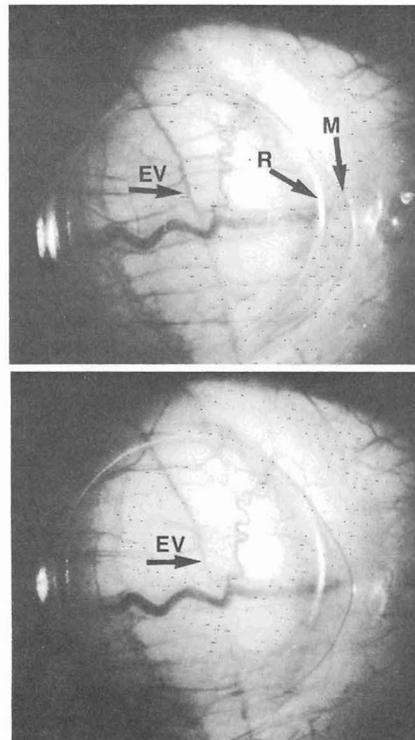


Fig 3.—Example of episcleral venous pressure measurement. Top, Area of interest at atmospheric pressure. R indicates aiming ring embedded in membrane; M, meniscus of tear film coaxial with ring; and EV, episcleral vein. Limbus is to left. Bottom, Same area at end point pressure. EV is now half blanched.

was better than 1.6%. This estimate included a variability of 1.1% for the electronic manometer alone.

The intraobserver reproducibility was 0.7 and 0.8 mm Hg for the two observers, respectively. The mean interobserver difference was  $0.7 \pm 1.2$  mm Hg, indicating a somewhat higher reading for one observer and a variability of 1.2 mm Hg.

The EVP for seven age groups is summarized in the Table. The mean EVP for the entire population (122 eyes of 68 subjects) was  $7.6 \pm 1.3$  mm Hg. The highest EVP noted was 10.3 mm Hg; the lowest value was 4.8 mm Hg.

#### COMMENT

The venomanometer described herein appears to be a practical clinical tool that meets the requirements enumerated earlier: (1) It is easily operated by one observer in the majority of cases. Only occasionally does an assistant have to hold the eyelids open. (2) It requires no calibration. (3) It is compact and quickly mounted on the slit lamp. (4) The viewing is stereoscopic. The intraob-

Episcleral Venous Pressure (EVP) of Normal Subjects Distributed Over Seven Age Groups			
Age, yr	No. of Subjects	No. of Eyes	EVP, mm Hg (Mean $\pm$ SD)
10-19	8	12	7.9 $\pm$ 1.0
20-29	11	21	7.8 $\pm$ 1.3
30-39	10	14	7.8 $\pm$ 0.9
40-49	11	21	7.9 $\pm$ 1.0
50-59	10	20	7.2 $\pm$ 1.6
60-69	10	18	7.2 $\pm$ 1.4
70-79	8	16	7.6 $\pm$ 1.3
<b>Total Population</b>	<b>68</b>	<b>122</b>	<b>7.6 <math>\pm</math> 1.3</b>

server reproducibility of 0.7 mm Hg compares well with the reproducibilities of 0.6 to 1.0 mm Hg reported for other instruments.<sup>1,4,5,8</sup> The interobserver reproducibility test shows that the results of the two observers may differ by 1.2 mm Hg, and one observer may, on the average, obtain values that are 0.7 mm Hg higher. We realized that rather than being limited by the instrument the interobserver reproducibility was affected mainly by the choice of the vessel being measured and by the determination of the end point.

The major difficulty in measuring the EVP is of an anatomic nature. Different observers may select different blood vessels, which may yield slightly different readings. For example, more deeply seated intrascleral vessels may require higher pressures to collapse than more superficial ones. Such deep-seated vessels are located at the exiting point from the sclera. The ideal point of measurement would be just distal to the junction of aqueous and episcleral veins. However, because of the difficulty in ascertaining this junction in some patients, it is more practical to take all the measurements 3 mm from the limbus.

A second variable is the selection of the end point indicative of EVP. Investigators have demonstrated that the variability of the EVP measurement is affected by the choice of the end point. Like others,<sup>1,5,6,8</sup> we have selected half blanching as the end point. We assume that the tissue compressibility is negligible and that the pressure required to blanch the vessel to the one-half point accurately reflects the intraluminal pressure. When the vessel is compressed beyond the halfway point, the compressibility of the vessel wall itself is more likely to cause a falsely elevated reading. On the other hand, determination of the half blanching point of a vessel may be subject to variability. We believe, however, that with practice, this difference becomes minimal.

The study we have performed on normal subjects is the most extensive so far. By using a large population separated in a wide range of age groups we were able to find that the EVP does not vary with age in eyes of subjects between 10 and 80 years. Our normal values are somewhat lower than those reported by others. The average EVP in 122 eyes examined with our device was  $7.6 \pm 1.3$  mm Hg. Phelps and Armaly,<sup>1</sup> using a similar air chamber technique, reported a mean EVP of  $9.0 \pm 1.6$  mm Hg in 56 eyes; Podos and Minas<sup>7</sup> noted a mean value of  $9.0 \pm 1.4$  mm Hg in 39 eyes using a transparent lucite cone connected to a displacement transducer. Talusan and Schwartz<sup>9</sup> obtained a mean EVP of 9.1 mm Hg in 20 eyes. The difference between our values and those of others may be due in part to the factors mentioned earlier. However, there are two unique features of our instrument that may also account for this difference. The high transparency of the silicone membrane and the stereoscopic viewing may allow the

operator to detect changes in blood flow earlier than was previously possible. If this is so, the detection of the end point would be more rapid and sensitive, thus resulting in a lower EVP reading. In any case, the difference in absolute value is not clinically important, because one uses as a reference the normal values obtained with the same instrument. The reliability of the measurement is determined by the reproducibility that, as mentioned earlier, was found to be very satisfactory.

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