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Episcleral venous pressure in normotensive and glaucomatous beagles. KIRK N. GELATT, GLENWOOD C. GUM, REUBEN E. MERIDETH, AND NANCY BROMBERG.

*Episcleral venous pressure was measured by a noninvasive method with a modified force-displacement transducer in six laboratory-quality normotensive and 12 glaucomatous beagles. The dogs were anesthetized by ketamine-xylazine, acepromazine-ketamine, and halothane. Simultaneous intraocular pressure (IOP) and blood pressure were recorded. The mean episcleral venous pressures in normotensive beagles were 11.4 to 11.6 mm Hg with the three methods of anesthesia; in the glaucomatous beagles the mean episcleral pressures were 10.6 to 12.5 mm Hg. There were no significant differences in episcleral venous pressure ($p < 0.19$ and greater) and blood pressure ($p < 0.53$ and greater) between the normotensive and glaucomatous beagles. IOP was significantly different between the normotensive and glaucomatous beagles anesthetized with acepromazine-ketamine (mean IOP, 23.4 and 34.2 mm Hg, respectively; $p < 0.02$) and halothane (mean IOP, 19.9 and 27.4 mm Hg, respectively; $p < 0.001$) but not significant with anesthesia with ketamine-xylazine (mean IOP, 26.0 and 37.8 mm Hg, respectively; $p < 0.12$). Episcleral venous pressure is unchanged as the disease progresses in the glaucomatous beagle. (*INVEST OPHTHALMOL VIS SCI* 23:131-135, 1982.)*

Noninvasive measurements of episcleral venous pressure in man and animals have used direct pressure to temporarily blanch and collapse the vessel by various devices and a stream of air.¹⁻⁴ These methods have employed a torsion balance, pressure chamber with transparent membranes, and force-displacement transducer. Measurement of episcleral venous pressures in rabbits and cats by direct cannulation under general anesthesia yielded highly reproducible results and had a distinct end point but was an invasive procedure.⁵⁻⁸ Pressure-chamber methods using various membranes provided values similar to direct cannulation.⁵ The torsion-balance system, evaluated in



Fig. 1A. Isometric force-displacement transducer with applanating lucite cone and 20 diopter lens for the measurement of episcleral venous pressure.

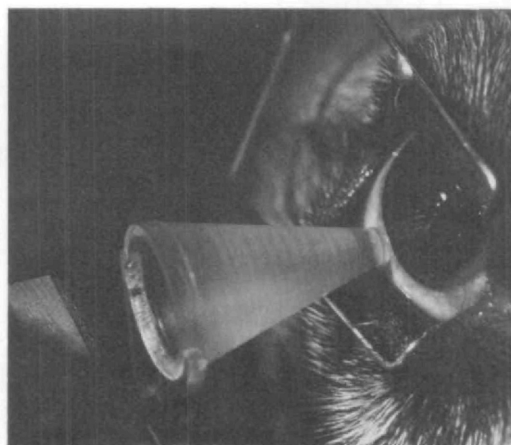


Fig. 1B. Position of the episcleral venous pressure measuring system on the dog's eye.

man and rabbits, resulted in greater difficulty in obtaining an end point and provided higher values.⁵ With an isometric force-displacement system, episcleral venous pressures of normotensive and glaucomatous humans were not significantly different.² However, in one family with glaucoma, episcleral venous pressure was elevated.⁹ The episcleral venous pressure in persons with ocular hypertension was significantly lower than that in subjects with normal levels of intraocular pressure (IOP) and glaucoma.⁴

Normal episcleral venous pressures in rabbits, cats, and man range from 5 to 15 mm Hg. Pressure chamber measurements of the episcleral venous pressure in the dog yielded a range of 10 to 18 mm Hg.⁸ The values in these species are remarkably similar in spite of the different venous pathways of the anterior segment.

Table I. Mean blood pressure, IOP, and episcleral venous pressure in laboratory-quality normotensive beagles

Anesthesia	Blood pressure		IOP	Episcleral venous pressure
	Systolic	Diastolic		
Ketamine HCl (20 mg/kg) and xylazine HCl (2 mg/kg) IV	205.0* (10.6)	177.7 (8.0)	26.0 (2.1)	11.4 (0.7)
Acepromazine maleate (0.5 mg/kg IV) and ketamine HCl (10 mg/kg IM)	126.3 (7.3)	104.3 (5.7)	23.4 (1.5)	11.7 (0.3)
Halothane	132.3 (5.9)	93.9 (3.6)	19.9 (0.6)	11.6 (0.4)

IV = intravenous; IM = intramuscular.

*Data expressed as mean mm Hg, with S.E.M. in parentheses.

Table II. Mean blood pressure, IOP, and episcleral venous pressure in glaucomatous beagles

Anesthesia	Blood pressure		IOP	Episcleral venous pressure
	Systolic	Diastolic		
Ketamine HCl (20 mg/kg) and xylazine HCl (2 mg/kg) IV	211.8* (8.2)	183.8 (8.0)	37.8 (4.2)	12.5 (0.5)
Acepromazine maleate (0.5 mg/kg IV) and ketamine HCl (10 mg/kg IM)	122.3 (6.1)	82.2 (7.2)	34.2 (3.7)	10.6 (0.3)
Halothane	130.3 (3.8)	96.9 (3.4)	27.4 (0.4)	12.1 (0.4)

IV = intravenous; IM = intramuscular.

*Data expressed as mean mm Hg, with S.E.M. in parentheses.

Episcleral venous pressure is an important factor in aqueous humor dynamics. This can be expressed in a rearrangement of the familiar Goldmann's classic model of aqueous humor outflow: $P_o = F/C + P_{EVP}$. According to this formula, a rise in episcleral venous pressure (P_{EVP}), unless compensated by a fall in the rate of aqueous humor flow (F) or an increase in outflow facility (C), will produce an equal rise in IOP.

In the development of the spontaneous glaucoma model in the beagle, measurement of episcleral venous pressure is imperative prior to and during the different stages of the disease. This study reports episcleral venous pressure, as measured by a modified force-displacement transducer, in normotensive laboratory-quality beagles and glaucomatous beagles at different stages of the disease.

Materials and methods. Six normotensive and 12 glaucomatous beagles were evaluated by each of three methods of anesthesia. The glaucomatous beagles ranged in age from 13 to 100 months. A transparent cone-shaped lucite applanation head with a 3 mm diameter flat tip was attached to a nearly isometric force-displacement transducer

with a maximum working range of 2 gm and a displacement of 2.5 mm/kg (Model 03; Grass Instruments, Quincy, Mass.). The transducer with applanating cone was mounted on a camera stand with a joystick; magnification was provided by a 20 diopter planoconvex lens positioned 8.0 cm from the applanating tip (Fig. 1A). The system was calibrated for each dog to provide 1 gm of force to produce a 5 cm deflection on the recorder that was equal to 12.5 mm Hg. Changes were displayed on a recorder (Model 7D; Grass Instruments) with a paper speed of 2.5 mm/sec. IOP was measured by Mackay-Marg tonometry (Model 12; Biotronics, Redding, Calif.) and blood pressure was recorded by the doppler ultrasonic pressure transducer (Arteriosonde 1010; Roche Medical Electronics, Cranbury, N. J.) or by recording directly from the femoral artery.

The dogs were maintained in position by three methods: (1) combination of 20 mg/kg ketamine HCl (Ketaset; Bristol Laboratories, Syracuse, N. Y.), 2 mg/kg xylazine HCl (Rompun; Haver-Lockhart Laboratories, Shawnee, Kan.), and 0.5 mg of atropine SO_4 injected slowly intravenously; (2) 0.5 mg/kg acepromazine maleate (Ayerst Lab-

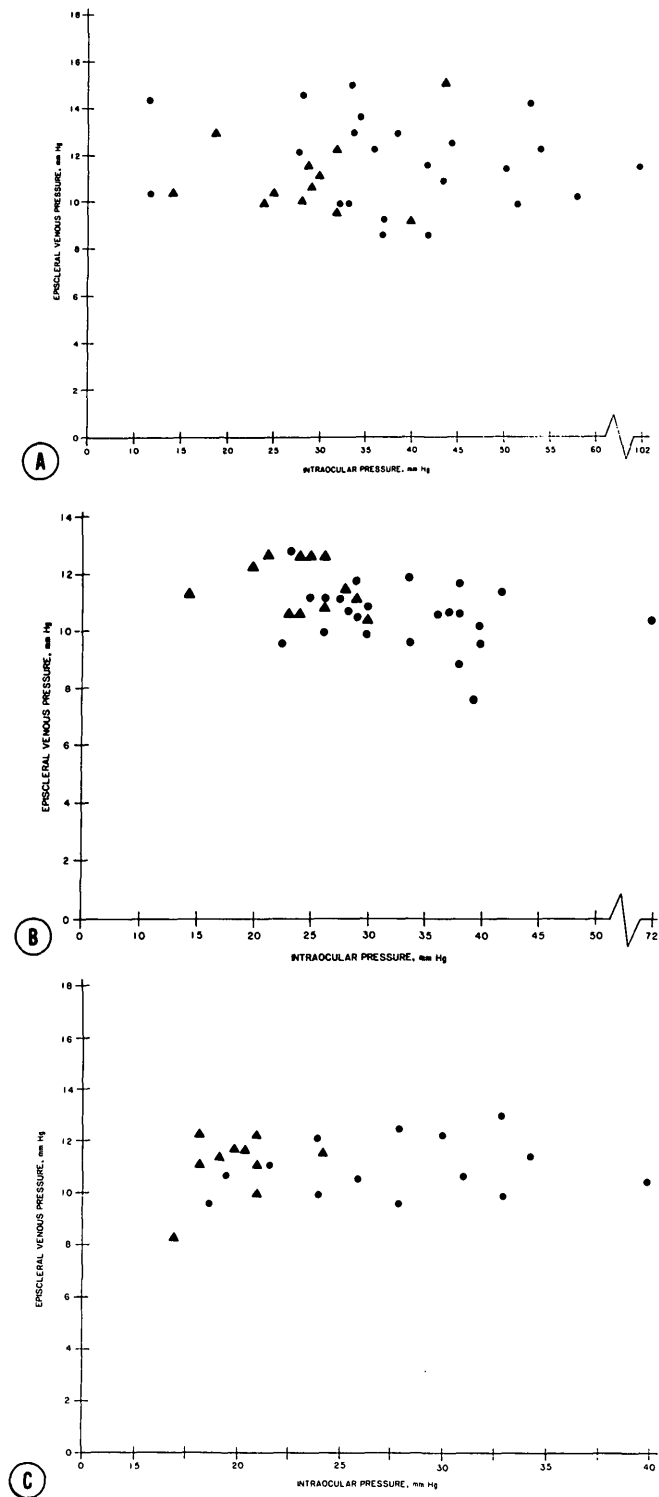


Fig. 2. Distribution of the mean episcleral venous pressure and IOP of each eye of normotensive and glaucomatous beagles anesthetized with ketamine-xylazine (A), acepromazine-ketamine (B), and halothane (C). ▲, Normotensive beagles; ●, glaucomatous beagles.

oratories, New York, N. Y.) intravenously followed 5 min later by 10 mg/kg ketamine HCl intramuscularly; or (3) general anesthesia induced with intravenous thiamylal sodium (Surital; Parke-Davis, Detroit, Mich.) and endotracheal intubation and maintained at a heart rate of 120 beats/min with a mixture of oxygen and halothane (Halocarbon Laboratories, Hackensack, N. J.). The dog was positioned in lateral or dorsolateral recumbency; the eyelids were retracted by wire eyelid speculum. Two to three episcleral veins were selected in the dorsal-to-dorsolateral episclera and their pressures were measured with two to three consecutive readings (Fig. 1B). The applanating cone was applied perpendicularly to each vessel to produce blanching, but not complete collapse of the vein, while simultaneously displaying the event on the recorder. Applanation tonometry was performed immediately before administration of the parenteral drugs as well as before and after episcleral venous pressure measurements.

The six normal beagles were 10 months old (two males, two females) and 59 months old (one male, one female). The 12 beagles with glaucoma were 13 months old (one female), 19 to 24 months old (two males, two females), 25 to 30 months old (one male, one female), 43 to 48 months old (two males, two females), and 55 months old (one male). The glaucoma was divided on the basis of clinical signs into early, moderate, and advanced.¹⁰ Early glaucoma was present in four dogs (ages 13, 19, 20, and 22 months old), moderate glaucoma occurred in four dogs (ages 24, 28, 29, and 43 months), and advanced glaucoma occurred in four dogs (ages 44, 45, 48, and 55 months).

The average pressures for each episcleral vein, IOP, and blood pressure were calculated for each eye. The normotensive and glaucomatous beagles' episcleral venous pressures, IOPs, and blood pressures were compared by the Student's *t* test. Regression analysis and Pearson correlation coefficients were used to determine the relationship between IOP and episcleral venous pressure.

Results. The mean systolic and diastolic blood pressure, IOP, and episcleral venous pressure of the normotensive animals are summarized in Table I. The ranges in episcleral venous pressure were 9.0 to 15.0 mm Hg (ketamine-xylazine), 10.0 to 12.5 mm Hg (acepromazine-ketamine), and 8.0 to 15.5 mm Hg (halothane). Under halothane anesthesia the mean difference in pressure between two episcleral veins in the same normotensive eye was 0.02 mm Hg. The mean difference between pressures of episcleral veins of fellow normotensive eyes was 0.40 mm Hg (ketamine-xylazine),

1.0 mm Hg (acepromazine-ketamine), and 0.82 mm Hg (halothane).

The mean systolic and diastolic blood pressure, IOP, and episcleral venous pressure of the glaucomatous beagles are summarized in Table II. The ranges in episcleral venous pressure were 9.0 to 16.0 mm Hg (ketamine-xylazine), 7.5 to 12.5 mm Hg (acepromazine-ketamine), and 9.5 to 17.5 mm Hg (halothane). Under halothane anesthesia the mean difference in pressure between two episcleral veins in the same glaucomatous eye was 0.03 mm Hg. The mean difference between pressures of the episcleral veins of fellow glaucomatous eyes was 1.3 mm Hg (ketamine-xylazine), 0.6 mm Hg (acepromazine-ketamine), and 0.3 mm Hg (halothane).

The episcleral venous pressures of the normotensive and glaucomatous beagles were not significantly different with any of the three methods of anesthesia (ketamine-xylazine, $p < 0.61$; acepromazine-ketamine, $p < 0.19$; halothane, $p < 0.46$). IOPs of the normotensive and glaucomatous beagles were significantly different with two anesthetic methods (acepromazine-ketamine, $p < 0.02$; halothane, $p < 0.001$) but not with the ketamine-xylazine combination ($p < 0.12$). Hence the IOPs of both the normotensive and glaucomatous groups of dogs were influenced by the choice of anesthetic agents. The systolic and diastolic blood pressures of the normotensive and glaucomatous beagles were not significantly different with the three methods of anesthesia (ketamine-xylazine, $p < 0.59$; acepromazine-ketamine, $p < 0.53$; halothane, $p < 0.930$). The systolic and diastolic blood pressures, like IOP, were directly influenced by the anesthetic method.

The distributions of IOP and episcleral venous pressure for the normotensive and glaucomatous beagles are summarized in Fig. 2. There were no significant linear correlations between the right and left eyes, the levels of episcleral venous pressure, and the levels of IOP in the normotensive and glaucomatous dogs.

Discussion. This noninvasive method offers ease, permits multiple recordings, and allows comparison of the results of this study to other reports. The instrumentation is readily available, and the special lucite applanating cone can be easily constructed. Estimation of venous pressure by collapse has inherent errors. The interposition of the conjunctiva and reluctance of the episcleral venous wall may result in slightly higher values. Pressure to produce only blanching of the episcleral vein may minimize this rigidity factor.¹ Movement of the eye negates the procedure,

necessitating sedation or general anesthesia in the dog. Episcleral venous pressure in man is affected by position; the recumbent pressure is at least 1 mm Hg higher than that in the sitting position.³ Regardless of the limitations of this method, differences between the normotensive and glaucomatous beagles, if present, should be detectable.

The episcleral venous pressures in the normotensive dogs, as estimated by this method, were similar to those reported with the pressure-chamber systems.^{7, 8} The range of 10 to 18 mm Hg of the canine episcleral venous pressure is similar to the intrascleral venous pressures measured by direct cannulation in the anesthetized cat of 6.8 mm Hg (S.D. \pm 0.60), with a mean IOP of 20 mm Hg.⁶ In both the cat and dog the episcleral and intrascleral vessels are related, in part, to the venous circle of Hovius, which may also branch with the anterior ciliary and vortex veins. Whether these anatomic differences in the anterior segment venous pathways are important differences to man in relationship to aqueous humor dynamics has not been ascertained; however, it is reasonable to assume the pressures are important considerations.

Variations of the episcleral venous pressures of the normotensive and glaucomatous Beagles under halothane anesthesia between veins within the same eye were not significant ($p < 0.45$ and $p < 0.50$, respectively), supporting the reproducibility of this method. Nor were the changes different between episcleral veins of the fellow eyes in the same dog with all three methods of anesthesia. The lack of a significant difference of episcleral venous pressure between the normal and glaucomatous beagles suggests the trabecular meshwork and/or intrascleral plexus connective tissues are the major site of resistance for the outflow of aqueous humor in inherited glaucoma in the beagle.

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Monocular deprivation in humans: a study of identical twins. CHRIS A. JOHNSON, ROBERT B. POST, LEO M. CHALUPA, AND TIMOTHY J. LEE.

Ultrasonic axial length measurements and psychophysical vernier acuity thresholds were determined for a pair of identical human twins, one of whom had been monocularly deprived since birth with a congenital lens opacity. Axial lengths of both eyes in the normal twin and the nondeprived eye in the other twin differed by less than 0.2 mm, whereas the axial measurement of the deprived eye was approximately 2.0 mm longer. Monocular vernier acuity thresholds in the nondeprived eye of the one twin were not significantly different from those obtained in the normal twin. Our findings are consistent with previous reports of increased axial length after monocular deprivation but do not support the concept of enhanced vernier acuity in the nondeprived eye of monocularly deprived humans. (INVEST OPHTHALMOL VIS SCI 23:135-138, 1982.)

Since the introduction of the monocular deprivation paradigm almost two decades ago by Wiesel and Hubel,¹ a voluminous literature has documented the behavioral, anatomic, and physiologic