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Tonometry in glaucomatous globes. KIRK N. GELATT, GLENWOOD G. GUM, AND KATHLEEN P. BARRIE.

The Mackay-Marg, pneumatonograph, and EMT-20 tonometers were evaluated in the eyes of glaucomatous beagles. Tonometric scale readings were compared to the manometric recordings from the anterior chamber. Tonometry was performed with the manometric system closed and open to the reservoir column. The Mackay-Marg tonometer evaluated in the closed and open manometric systems was highly reliable (goodness of fit [r^2] = 0.852 and 0.816, respectively) with intraocular pressures up to 50 mm Hg and somewhat lower (r^2 = 0.818 and 0.740, respectively) with intraocular pressures up to 100 mm Hg. The pneumatonograph also exhibited high reliability (r^2 = 0.892 [closed] and 0.806 [open]) at pressures up to 50 mm Hg and (r^2 = 0.796 [closed] and 0.75 [open]) at pressures up to 100 mm Hg. The EMT-20 to-

nometer was the least satisfactory for the glaucomatous globe, with r^2 ranging from 0.235 to 0.654.

The validity of tonometers is influenced by animal species, age, ocular rigidity, corneal edema, corneal scarring, corneal irregularities, and previous corneal and intraocular surgery. Studies of rabbits and dogs have indicated that Schiøtz tonometry required calibration in the respective species.¹⁻² The rabbit differs from man in ocular volumes and corneal radius and exhibits a variable ocular rigidity. In both rabbits and dogs, use of human-derived calibration tables results in gross underestimation of intraocular pressure (IOP). In edematous corneas in humans, rabbits, and owl monkeys (*Aotes trivirgatus*), the Mackay-Marg tonometer was superior to other types studied.³⁻⁵ IOPs in humans after penetrating keratoplasty were most accurately estimated by the Mackay-Marg tonometer.⁶⁻⁷

Inherited glaucoma in beagles represents a potentially useful animal model for open- and closed-angle glaucoma in man.⁸ In the study of this spontaneous glaucoma model the validity of several tonometers must be ascertained in the diseased eye. Accurate estimation of IOP during the disease course as well as for pharmacologic trials necessitates reliable tonometric results. This study evaluates the validity of the Mackay-Marg, pneumatonograph, and EMT-20 tonometers for the glaucomatous beagle.

Materials and methods. The tonometers evaluated were the Mackay-Marg (Model 12; Biotronics, Redding, Calif.), pneumatonograph (Alcon Laboratories, Ft. Worth, Texas), and the EMT-20 (Electro-Medical Technology, Redding, Calif.). The three tonometers were evaluated in 12 eyes of beagles with moderate to advanced glaucoma. All globes exhibited partial corneal edema and 1 to 2 mm buphthalmia (as estimated by a-scan ultrasonography—Model 7100MA; Kretz-Technik, Zipf, Austria). Inherited glaucoma has been present 24 to 48 months.

After subcutaneous atropinization (0.05 mg/kg), general anesthesia was induced with intravenous sodium thiopental (Pentothal; Abbott Laboratories, North Chicago, Ill.) and maintained by halothane (Halocarbon Laboratories, Hackensack, N. J.). After intubation the dog was placed in dorsal recumbency. The eye was prepared with a lateral canthotomy, retraction of the eyelids by speculum, and placement of fixation 4-0 silk sutures in the dorsal episclera and conjunctiva and the nictitating membrane. The cornea was intermittently moistened with 0.5% methylcellulose.

The anterior chamber was carefully cannulated

Table I. Comparison of the intercept scale readings, slope, and goodness of fit (r^2) for the MacKay-Marg (Model 12), pneumatonograph, and EMT-20 tonometers

Tonometer (system)	Number of observations		Intercept scale reading		Slope		Goodness of fit (r^2)	
	50 mm Hg	100 mm Hg	50 mm Hg	100 mm Hg	50 mm Hg	100 mm Hg	50 mm Hg	100 mm Hg
MacKay-Marg (closed)	120	180	2.372	4.436	0.845	0.883	0.852	0.816
MacKay-Marg (open)	120	180	2.059	7.641	0.858	0.820	0.818	0.740
Pneumatograph (closed)	120	180	2.524	5.178	0.829	0.832	0.892	0.796
Pneumatograph (open)	120	180	3.496	6.701	0.798	0.800	0.806	0.750
EMT-20 (closed)	120	180	10.353	9.339	0.490	0.597	0.342	0.654
EMT-20 (open)	120	180	13.080	13.620	0.431	0.522	0.235	0.467

1 mm posterior to the lateral limbus with a 21-gauge hypodermic needle connected by polyethylene tubing to a transducer (Model P-23B; Statham Laboratories, Hato Rey, Puerto Rico). The transducer was connected by polyethylene tubing and stopcock to a microliter delivery system (Hamilton Co., Reno, Nev.) with a calibrated 0.1 ml pipette and a graduated column reservoir. An adjustable stopcock could isolate the transducer, tubing, and globe from the calibrated pipette and saline column. Heparinized physiologic saline filled the system. The transducer recordings were transmitted into an amplifier (Model 7; Grass Instrument Co., Quincy, Mass.) and were recorded.

The system was calibrated before and immediately after the examination of each eye to the column of saline, converted to millimeters of mercury. Each tonometer was also calibrated according to the manufacturer's instructions.

IOP was varied from 5 to 100 mm Hg by 3 to 5 mm Hg increments by varying the height of saline in the reservoir column. Each tonometer was placed vertically on the center of the cornea and three recordings were taken and averaged. The EMT-20 recordings selected were the two lowest identical or repeatable readings. All tonometers were evaluated with the system closed as well as open to the reservoir column. In the closed system, IOP was recorded from the transducer immediately before the tonometer was applied to the cornea.

The averages for each tonometer recordings were compared to the manometric results with the use of the regression model by the method of least squares. Goodness of fit (r^2) was determined for each tonometer, i.e., the proportion of the variance of the tonometric recordings attributed to its linear regression with the manometric results.

Results. The scale readings of the Mackay-Marg

tonometer in the closed and open manometric systems are shown in Fig. 1. The tonometer in both systems exhibited an essentially linear response. The scale readings of the pneumatonograph in the closed and open manometric systems are depicted in Fig. 2. This tonometer provided a linear response to about 50 mm Hg and then indicated pressures that were progressively less than actual manometric IOP. Scale readings of the EMT-20 tonometer in the closed and open manometric systems are shown in Fig. 3. The scale readings of this tonometer varied to a greater extent from the manometric IOP and progressively underestimated actual IOP.

The intercept scale readings, slope, and goodness of fit are indicated for the closed and open manometric systems for the Mackay-Marg, pneumatonograph, and EMT-20 tonometers in Table I. Both Mackay-Marg and pneumatonograph tonometers had superior goodness of fit compared with the EMT-20 instrument. The goodness of fit for the Mackay-Marg and pneumatonograph was highest when evaluated at 0 to 50 mm Hg than at 0 to 100 mm Hg. The goodness of fit for the EMT-20 tonometer in the closed and open manometric systems for pressures up to 50 and 100 mm Hg was much lower than that of the other two tonometers.

Discussion. Tonometric studies in laboratory animals require calibration for each species and experimental condition. Studies in tonometry have been reported in several animal species, including rabbits, certain species of monkeys, cats, and dogs.^{1, 2, 4, 5} Applanation tonometers have been compared in rabbits with corneal edema and irregularities after penetrating keratoplasty.⁴ In the owl monkey corneal edema was induced by topical applications of 10% sodium hydroxide and scarification of the endothelium with a needle.⁵ In

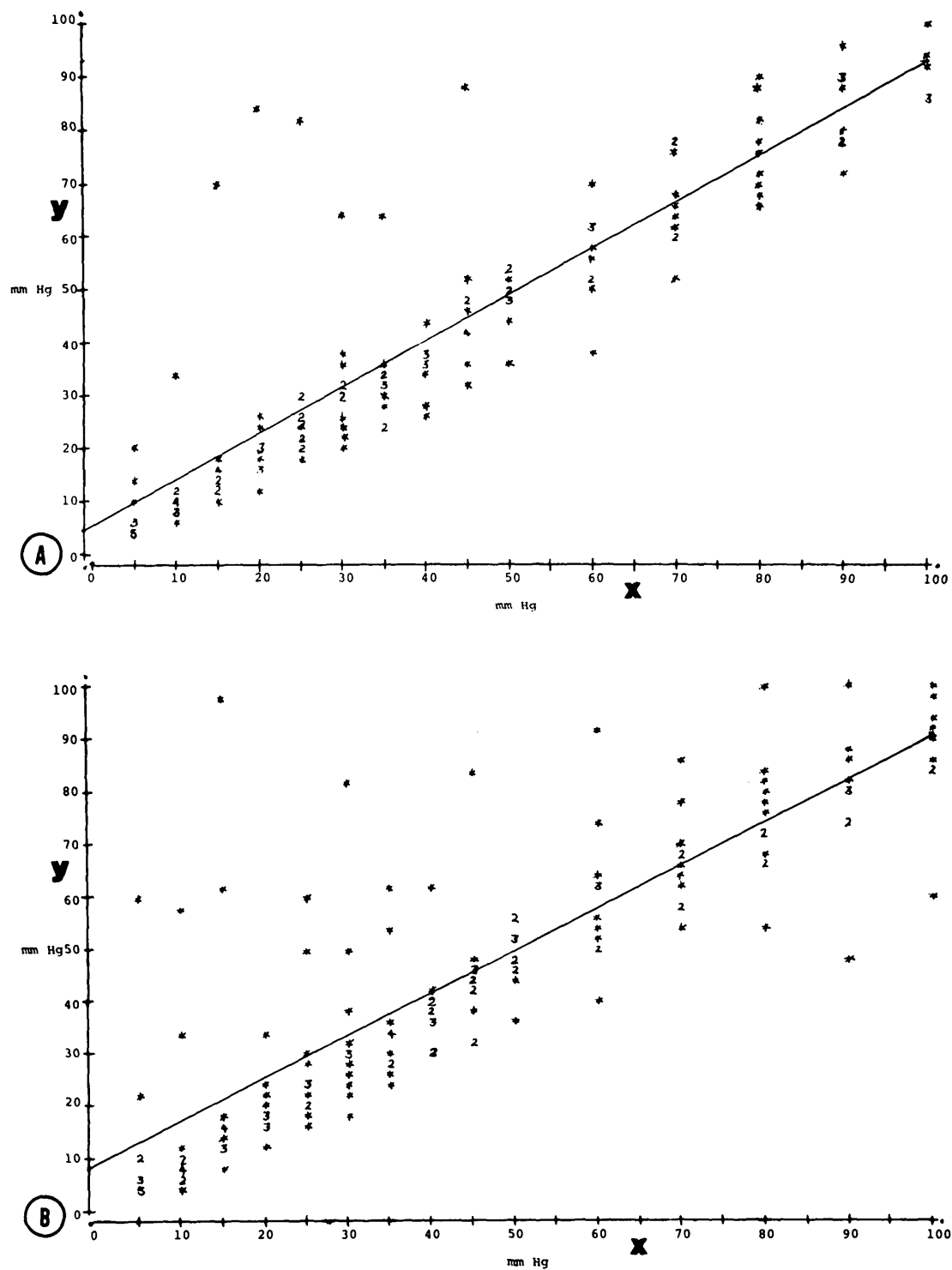


Fig. 1. A, Relationship of the scale reading (y) of the Mackay-Marg tonometer to the closed manometer pressure (x). B, Relationship of the scale reading (y) of the Mackay-Marg tonometer to the open manometer pressure (x). The continuous line is the calculated regression.

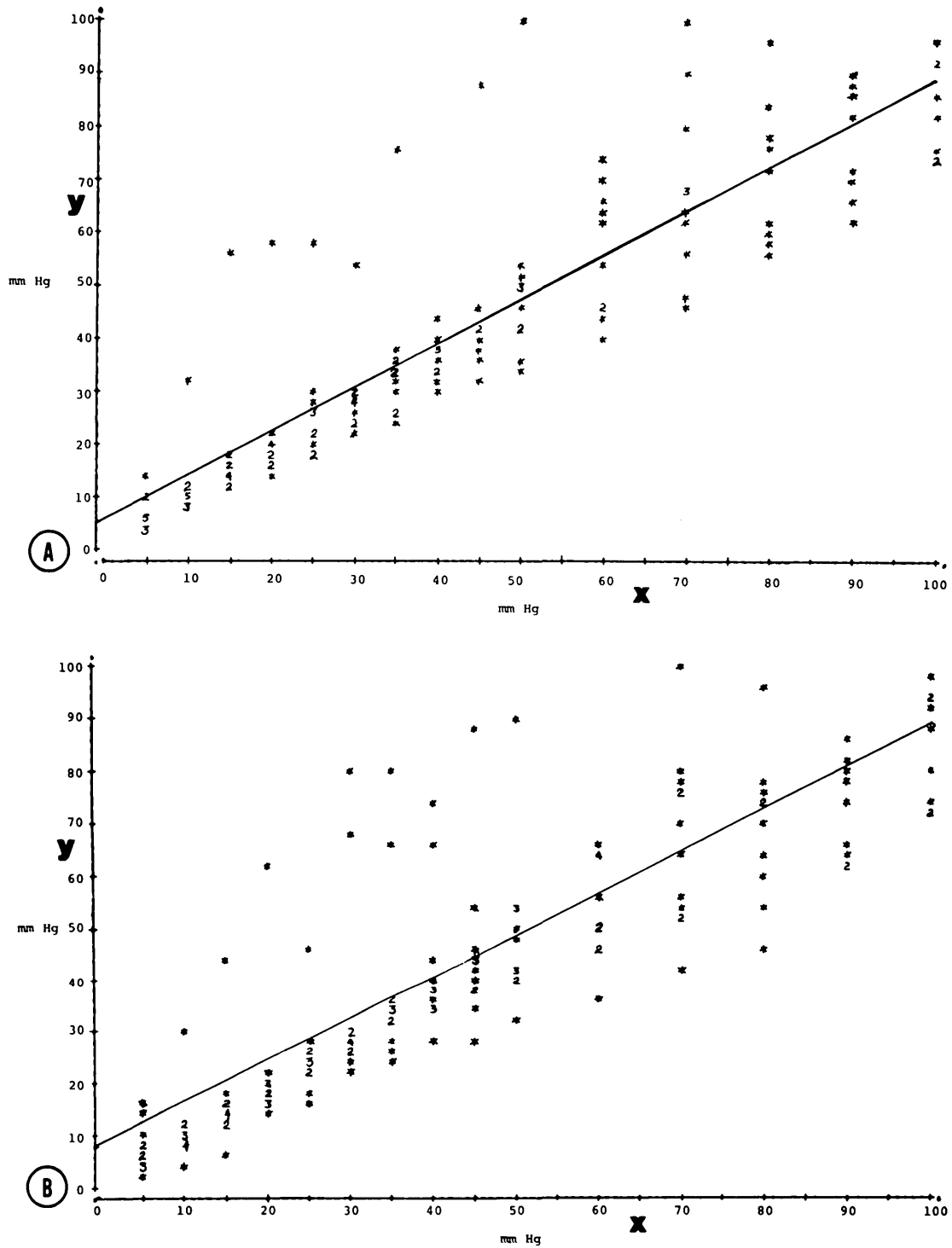


Fig. 2. A, Relationship of the scale reading (y) of the pneumatonograph tonometer to the closed manometer pressure (x). B, Relationship of the scale reading (y) of the pneumatonograph tonometer to the open manometer pressure (x). The continuous line is the calculated regression.

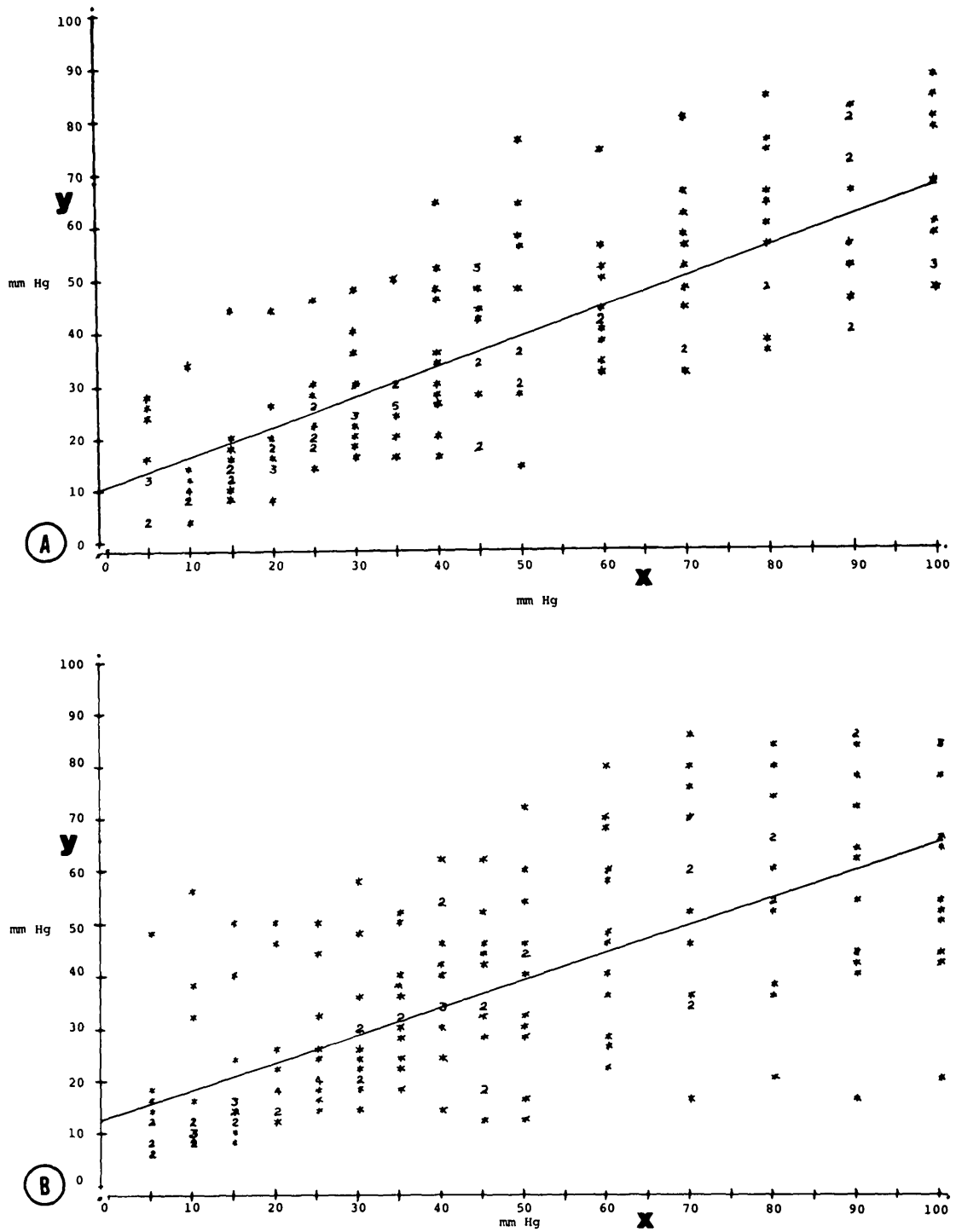


Fig. 3. A, Relationship of the scale reading (y) of the EMT-20 tonometer to the closed manometer pressure (x). B, Relationship of the scale reading (y) of the EMT-20 tonometer to the open manometer pressure (x). The continuous line is the calculated regression.

both studies the Mackay-Marg tonometer was demonstrated superior.

The Mackay-Marg tonometer requires only a brief contact for measurement of IOP in the conscious dog with an intermittently moving eye. The pneumatonograph is more difficult to use in the conscious dog; in addition, the probe sound may distract the animal. Movement of the dog's eye beneath the pneumatonograph probe footplate may cause corneal abrasions.

In a previous study we compared these tonometers in the normal canine eye using the same methodology.⁹ Both the Mackay-Marg and pneumatonograph tonometers were found to be highly reliable. In this study with glaucomatous globes, goodness of fit for the Mackay-Marg and pneumatonograph tonometers decreased about 10% from that of the normal canine eye. Because the Mackay-Marg and pneumatonograph tonometers evaluated in the closed and open manometric systems from 0 to 50 mm Hg exhibited r^2 of 0.8 or above, these tonometers provide readings 95% of the time that are accurate to within ± 2.5 to 3.0 and ± 2.0 to 3.0 mm Hg, respectively. The presence of corneal edema, glaucoma, and possible changes in the corneal surface may account for the differences. The statistical analyses for the glaucomatous eyes were divided into IOP from 0 to 50 mm Hg and 0 to 100 mm Hg. The upper range may have exceeded the limits of these tonometers; however, IOP in glaucomatous beagles may exceed 50 mm Hg in acute exacerbations of the disease and after water loading.¹⁰

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The effect of steroidal and nonsteroidal anti-inflammatory agents on corneal re-epithelialization. B. D. SRINIVASAN, AND P. S. KULKARNI.

Topical 0.5% indomethacin, 0.01% flurbiprofen, 1% prednisolone acetate, 0.1% dexamethasone, or 0.1% fluorometholone pretreatment and daily instillation did not affect the course of re-epithelialization after partial corneal epithelial denudation. However, topical 1% prednisolone acetate, 0.1% dexamethasone, and 0.1% fluorometholone—but not 0.5% indomethacin and 0.01% flurbiprofen—significantly retarded re-epithelialization after complete corneal denudation.

Recent evidence¹ suggests that prostaglandins (PGs) are one of the mediators of certain types of experimental ocular inflammation, including the release of polymorphonuclear leukocytes (PMNs) after partial corneal denudation.² Nonsteroidal anti-inflammatory drugs (NSAID) such as indomethacin, aspirin, and flurbiprofen³⁻⁵ have been used in experimental and clinical ocular inflammatory conditions. Several steroidal drugs (SAID) are also currently in clinical use as anti-inflammatory agents. Indomethacin, aspirin, and flurbiprofen inhibit the cyclooxygenase enzyme, but corticosteroids apparently block the release of arachidonic acid, the precursor of PGs, by inhibition of the phospholipase enzyme.⁶ In this report we compare the effect of anti-inflammatory doses of topical indomethacin (0.5%), flurbiprofen (0.01%), topical prednisolone acetate (1%), dexa-