Evaluation of intraocular pressure in eyes of clinically normal llamas and alpacas

A. Michelle Willis, DVM; David E. Anderson, DVM, MS; Anne J. Gemensky, DVM; David A. Wilkie, DVM, MS; Fernando Silveira, MV

Objective—To estimate intraocular pressure (IOP) in eyes of healthy camelids, using applanation tonometry.

Animals—The eyes of 34 camelids (16 llamas [*Lama glama*] and 18 alpacas [*L pacos*]) that did not have major abnormalities of the ocular surface or intraocular abnormalities.

Procedure—Tonometry measurements were obtained from each eye 3 times during a 24-hour period. Each measurement was the mean of several corneal applanations obtained by use of an applanation tonometer. Data were analyzed, using an ANOVA for a repeated-measures design.

Results—Mean (± SEM) IOP of llamas and alpacas was 13.10 ± 0.35 and 14.85 ± 0.45 mm Hg, respectively. Range of IOP was 7 to 18 mm Hg for llamas and 11 to 21 mm Hg for alpacas. Mean IOP of llamas was significantly less than the mean IOP of alpacas. Significant differences in IOP were not detected between the right and left eye of animals. Significant differences in IOP were not attributed to sex, age, or time of measurement within llamas or alpacas.

Conclusions and Clinical Relevance—Establishing the mean and range of IOP of clinically normal llamas and alpacas provides a frame of reference that is important for use in a complete ophthalmic examination of camelids, which can assist clinicians in the diagnosis of glaucoma and uveitis. Reasons for the difference in mean IOP between llamas and alpacas are unknown. Although the difference may be unimportant clinically, this finding reiterates the fact that caution must be used when extrapolating IOP among species. (*Am J Vet Res* 2000;61:1542–1544)

It is critical for clinicians to have an accurate and reliable method of assessing **intraocular pressure (IOP)** for evaluation of ocular disorders in all species. A decrease in IOP may accompany uveitis, whereas an increase in IOP is a primary risk factor for the development of glaucomatous ocular changes.[1] Certain clinical signs of glaucoma, such as corneal edema, also may be caused by other ocular diseases. Therefore, clinical signs alone have a low diagnostic value for glaucoma. Tonometry is the method of choice for estimating IOP in a clinical setting. Variations exist in IOP among the species in which IOP has been investigated[2-14]; therefore, for tonometry to be of diagnostic value, clinicians must be familiar with the IOP typical of the species being examined. Characteristics of the ophthalmic examination of llamas have been reviewed,[15] and the mean IOP in that study was 14 mm Hg. The authors did not explain how this value was obtained, nor did they report the reference range of IOP in llamas. The purpose of the study reported here was to estimate mean and range of IOP, using applanation tonometry, in eyes of clinically normal llamas and alpacas and to determine the effects of age, sex, eye (left vs right), and time of day on IOP.

Received Oct 21, 1999.
Accepted Jan 14, 2000.
From the Department of Veterinary Clinical Sciences, College of Veterinary Medicine, The Ohio State University, Columbus, OH 43210.
The authors thank Kelley Norris and Bill Cox for technical assistance.

Materials and Methods

Animals—Sixteen llamas (*Lama glama*; 8 sexually intact females, 1 spayed female, 4 sexually intact males, and 3 castrated males) and 18 alpacas (*L pacos*; 11 sexually intact females; 7 sexually intact males) housed at a university research farm were included in the study. Camelids ranged from 5 months to 17 years old. Camelids were transported to our veterinary teaching hospital for the study.

Study design—Llamas and alpacas were allowed to acclimate to the hospital setting for approximately 24 hours. Animals had ad libitum access to water and hay. Animals were considered clinically normal on the basis of results of a physical examination. Species, age, weight, and sex were recorded for each animal. Each animal was manually restrained, and biomicroscopy and indirect ophthalmoscopy were performed. Thirty-four animals without abnormalities of the ocular surface or intraocular abnormalities were selected as the study population.

After ocular examination, 0.5% proparacaine hydrochloride,[a] a topical anesthetic, was applied to the cornea, and IOP was estimated by tonometry, using a commercially available applanation tonometer.[b] Animals were gently restrained by placing a hand around the muzzle or beneath the mandible, with care taken to avoid compressing the jugular veins. Three tonometric measurements were obtained from the axial cornea of each eye in sequence, with each measurement being the mean of 4 to 6 corneal applanations that had a variance of ≤ 5%. Estimations of IOP were performed 3 times within a 24-hour period (7 AM, 1 PM, 7 PM), using the same tonometer, which was considered to be within current calibration specifications of the manufacturer.

Data analysis—Data were analyzed by use of a repeated-measures ANOVA, using the least-squares means procedure.[c] Differences were considered significant at $P \leq 0.05$. Correlation analysis was used to evaluate the association of age and body weight with IOP within each species.[c]

Results

Mean (± SEM) IOP of 32 eyes of 16 llamas and 36 eyes of 18 alpacas was 13.10 ± 0.35 and 14.85 ± 0.45 mm Hg, respectively (**Table 1**). Mean IOP differed significantly ($P = 0.001$) between species. Range of IOP was 7–18 mm Hg for llamas and 11–21 mm Hg for alpacas. Significant differences were not detected between the right and left eyes of animals within

Table 1—Mean and range (95% confidence interval) of intraocular pressure (IOP) for 32 eyes in 16 llamas and 36 eyes in 18 alpacas measured 3 times during a 24-hour period

	Mean IOP (mm Hg)								
	7 AM		1 PM		7 PM				
Species	Right	Left	Right	Left	Right	Left	Range	95% CI	Overall mean (± SEM)
Llama	14.08	13.04	13.78	13.69	13.15	12.19	7–18	12.5–13.9	13.10 ± 0.35*
Alpaca	16.23	15.14	15.01	14.90	14.17	14.97	11–21	14.1–16.0	14.85 ± 0.45*

*Values are significantly ($P < 0.001$) different.

species (llamas, $P = 0.428$; alpacas, $P = 0.352$) or between males and females of animals within species (llamas, $P = 0.253$; alpacas, $P = 0.454$). Additionally, age of animal or body weight did not have a significant effect on IOP of animals within species. We were unable to detect a significant difference in IOP among animals in various age groups in either species (alpacas: $r^2 = -0.35$, $P = 0.964$; llamas: $r^2 = -0.016$, $P = 0.969$). The IOP was lower, but not significantly ($P = 0.076$), for llamas and alpacas at the 7 PM measurement.

Discussion

The popularity of South American camelids as show, breeding, and companion animals continues to increase throughout North America, and camelids are economically important in their native continent. Familiarity with ocular anatomy and ranges for objective measurements in clinically normal camelids is essential for the diagnosis and management of ophthalmic diseases. Tonometry is most useful in the diagnosis and management of glaucoma. The incidence of glaucoma in llamas was low in a recent study that used a database review of camelids examined at veterinary teaching hospitals.[16] However, the authors of that report speculated that the true incidence of glaucoma actually may be higher than reported, because tonometry is not routinely performed on camelids examined for conditions not associated with ophthalmic diseases. Detailed descriptions of glaucoma in camelids are lacking, although unilateral buphthalmia with lens displacement and cataract formation has been reported in an alpaca,[17] and congenital glaucoma has been described in a llama cria.[18] Whereas primary glaucoma may be relatively uncommon in camelids, other intraocular diseases such as cataracts, lens luxation, uveitis, or hyphema can predispose an eye to secondary glaucoma. Additionally, camelids appear to be susceptible to corneal endothelial damage, which can result in corneal edema and may mimic glaucoma in a clinical setting.[19-21] Accurate assessment of IOP becomes invaluable in such cases, because it allows clinicians to avoid an erroneous diagnosis of glaucoma, which may result in inappropriate management of the condition.

Applanation tonometry provides a relatively simple means of indirectly estimating IOP in a clinical setting. The applanation tonometer used in the study reported here is used commonly in clinical settings to perform ophthalmologic examinations on animals. It is readily available, portable, and suitable for use in most species with laterally positioned globes. The instrument determines the force necessary to flatten a measured area of cornea, with pressure equal to force per unit area.[22] Applanation tonometry measurements are affected by variations in corneal anatomy and physiology (rigidity, curvature, thickness).[23] Because of the variation and the fact that this applanation tonometer is calibrated by the manufacturer for use in humans, extrapolation of a range of typical IOP among species is inappropriate.

Results of several in vitro studies indicate that the applanation tonometer used in our study, when applied to corneas of animals other than humans and compared with IOP determined manometrically, overestimates or underestimates actual IOP.[2,3,5,7] In cats[5] and horses,[2] this tonometer consistently provides reliable underestimated values for IOP that paralleled actual IOP in a linear fashion. In dogs, this applanation tonometer was reliable for a range of IOP, compared with manometric measurements; however, it consistently overestimated IOP at lower pressures and underestimated IOP at higher pressures.[3] Overestimation or underestimation of IOP observed with this tonometer in nonhuman species is speculated to be attributable to species variation in corneal anatomy and physiology.[2] The objective of the study reported here was to establish a range of IOP for eyes of clinically normal camelids that would provide useful information when making comparisons in a clinical setting, using common instruments. Determination of actual IOP in these camelids would require concurrent manometric measurements to compare actual IOP with the indirect measurement of IOP acquired with the applanation tonometer. Although that would verify the accuracy of this applanation tonometer with respect to the eyes of camelids and make this instrument more useful to researchers, manometry was beyond the scope of this study.

Although the gross appearance of the eyes of llamas and alpacas is remarkably similar, subtle species differences in corneal curvature, rigidity, or thickness may be sufficient to account for the small but significant difference observed in mean IOP between these species. Intraocular pressure is influenced by rate of formation and outflow of aqueous humor, extraocular muscle tone, systemic blood pressure, and alterations in pH of arterial blood induced by changes in respiration.[24] Changes in central venous pressure produce changes in episcleral veins that can lead to rapid changes in IOP.[25] In a study of horses,[2] it was speculated that psychogenic factors such as fear and excitability were involved in short-term alterations in IOP and that horses with more volatile temperaments or those requiring a considerable degree of physical restraint often had widely fluctuating IOP. In our experience, alpacas display more outward signs of stress (vocalization, spitting) and, reportedly, tend to protest more when physically restrained,[26] compared with llamas. However, the animals in our study were not overtly anxious and were accustomed to being handled, and there was not a noticeable difference in the behavior of our alpacas, compared with our llamas.

In one study of American alligators, IOP was negatively correlated with increased body length, and body length increased with age until a plateau value was reached.[10] Length of the neck of llamas is greater than that of alpacas, and it could be speculated that the relative distance from the heart to the eyes is greater in llamas, resulting in hemodynamic differences that alter IOP. If this rationale were true, however, one would expect to observe differences among animals of various age groups within a species, because juvenile llamas are smaller and shorter than their adult counterparts; however, relative eye size among age groups would likely vary as well. We were unable to detect a significant difference in IOP among animals in various age groups in either camelid species.

Camelids in the study reported here were amenable to handling and did not require chemical restraint, nor was it necessary to perform an auriculopalpebral nerve block to enable us to perform tonometry. A study[27] in horses did not reveal differences in IOP between eyes after an auriculopalpebral nerve block and eyes for which an auriculopalpebral nerve block was not performed. The IOP of eyes with and without an auriculopalpebral nerve block in that study was significantly less after IV administration of xylazine. It is not known whether chemical restraint or an auriculopalpebral nerve block would affect IOP in camelids. The camelids in the study reported here were members of a research herd and were accustomed to frequent handling and manipulation. In our experience, camelids admitted to our veterinary teaching hospital are amenable to gentle manual restraint for physical and ophthalmic examinations. Camelids that have had little exposure to humans and human handling, especially when they have a painful physical abnormality, may be more excitable and have greater fluctuations in IOP during a clinical evaluation. These animals may be most effectively examined after administration of chemical restraint and an auriculopalpebral nerve block. Additional studies are required to determine the effect that these procedures may have on the IOP of camelids and to determine comparative aspects of corneal and ocular anatomy in these species.

[a]Alcaine, Alcon Laboratories Inc, Fort Worth, Tex.
[b]Tono-Pen XL, Mentor Ophthalmics Inc, Norwell, Mass.
[c]Systat 6.0 for Windows, SPSS Inc, Chicago, Ill.

References

1. Gelatt KN, Brooks DE. The canine glaucomas. In: Gelatt KN, ed. *Veterinary ophthalmology*. 3rd ed. Philadelphia: Lippincott, Williams & Wilkins, 1999; 701–754.
2. Miller PE, Pickett JP, Majors LJ. Evaluation of two applanation tonometers in horses. *Am J Vet Res* 1990;51:935–937.
3. Priehs DR, Gum GG, Whitley D, et al. Evaluation of three applanation tonometers in dogs. *Am J Vet Res* 1990;51:1547–1550.
4. Smith PJ, Gum GG, Whitley RD, et al. Tonometric and tonographic studies in the normal pony eye. *Equine Vet J* 1990; 10(suppl):36–38.
5. Miller PE, Pickett JP, Majors LJ, et al. Evaluation of two applanation tonometers in cats. *Am J Vet Res* 1991;52:1917–1921.
6. Sapienza JS, Porcher D, Collins BR, et al. Tonometry in clinically normal ferrets (*Mustela putorius furo*). *Prog Vet Comp Ophthalmol* 1991;4:291–294.
7. Dziezyc J, Millichamp NJ, Smith WB. Comparison of applanation tonometers in dogs and horses. *J Am Vet Med Assoc* 1992;201: 430–433.
8. Moore CG, Milne ST, Morrison JC. Noninvasive measurement of rat intraocular pressure with the Tono-Pen. *Invest Ophthalmol Vis Sci* 1993;34:363–369.
9. Stiles J, Buyukmihci NC, Farver TB. Tonometry of normal eyes in raptors. *Am J Vet Res* 1994;55:477–479.
10. Whittaker CJG, Heaton-Jones TG, Kubilis PS, et al. Intraocular pressure variation associated with body length in young American alligators (*Alligator mississippiensis*). *Am J Vet Res* 1995;56: 1380–1383.
11. Ofri R, Horowitz IH, Kass PH. Tonometry in three herbivorous wildlife species. *Vet Ophthalmol* 1998;1:21–24.
12. Gum GG, Gelatt KN, Miller DN, et al. Intraocular pressure in normal dairy cattle. *Vet Ophthalmol* 1998;1:159–161.
13. Ofri R, Horowitz IH, Jacobson S, et al. The effects of anesthesia and gender on intraocular pressure in lions (*Panthera leo*). *J Zoo Wildl Med* 1998;29:307–310.
14. Gelatt KN, MacKay EO. Distribution of intraocular pressure in dogs. *Vet Ophthalmol* 1998;1:109–114.
15. Gionfriddo JR, Friedman DS. Ophthalmology of South American camelids: llamas, alpacas, guanacos and vicunas. In: Howard JL, ed. *Current veterinary therapy 4: food animal practice*. Philadelphia: WB Saunders Co, 1999;644–648.
16. Gionfriddo JR, Gionfriddo JP, Krohne SG. Ocular diseases of llamas: 194 cases (1980–1993). *J Am Vet Med Assoc* 1997;210: 1784–1787.
17. Gelatt KN, Otzen Martinic GB, Flaneig JL, et al. Results of ophthalmic examinations of 29 alpacas. *J Am Vet Med Assoc* 1995; 206:1204–1207.
18. Cullen CL, Grahn BH. Congenital glaucoma in a llama (*Lama glama*). *Vet Comp Ophthalmol* 1997;7:253–257.
19. Gionfriddo JR. Update on llama medicine. Ophthalmology. *Vet Clin North Am Food Anim Pract* 1994;10:371–382.
20. Barrie KP, Jacobson E, Peiffer RL Jr. Unilateral cataract with lens coloboma and bilateral corneal edema in a guanaco. *J Am Vet Med Assoc* 1978;173:1251–1252.
21. Ingram KA, Sigler RL. Cataract removal in a young llama, in *Proceedings*. Annu Meet Am Assoc Zoo Vet 1983; 95–97.
22. Hart WM. Intraocular pressure. In: Hart WM, ed. *Adler's physiology of the eye*. 9th ed. St Louis: Mosby-Year Book Inc, 1992;248–267.
23. Moses RA, Marg E, Oechlsi R. Evaluation of the basic validity and clinical usefulness of the Mackay-Marg tonometer. *Invest Ophthalmol Vis Sci* 1962;1:78–85.
24. Benson GJ, Manning JP, Hartsfield SM, et al. Intraocular tension in the horse: effects of succinylcholine and halothane anesthesia. *Am J Vet Res* 1981;42:1831–1832.
25. Tarkkanen A, Leikola J. Postural variations of the intraocular pressure as measured with the Mackay-Marg tonometer. *Acta Ophthalmol (Copenh)*1967;45:569–575.
26. Fowler ME. Restraint and handling. In: Fowler ME, ed. *Medicine and surgery of South American camelids: llama, alpaca, vicuna, guanaco*. 2nd ed. Ames, Iowa: Iowa State University Press, 1998; 49–68.
27. van der Woerdt A, Gilger BC, Wilkie DA, et al. Effect of auriculopalpebral nerve block and intravenous administration of xylazine on intraocular pressure and corneal thickness in horses. *Am J Vet Res* 1995;56:155–158.