Analysis of aqueous humor obtained from normal eyes of llamas and alpacas

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Objective—To evaluate composition of aqueous humor obtained from normal eyes of llamas (*Lama glama)* and alpacas (*Lama pacos).*

Sample Population—Aqueous humor obtained from 10 male llamas and 10 male alpacas.

Procedure—All animals had normal eyes, as determined by ocular examination. Aqueous humor samples were obtained via paracentesis of the anterior chamber of animals that were heavily sedated. Chemical analysis included measurement of concentrations of sodium, potassium, magnesium, chloride, bicarbonate, phosphorus, and glucose as well as osmolality and pH.

Results—With the exception of potassium concentrations, values for aqueous humor composition did not differ significantly between llamas and alpacas. Mean ± SD values for llamas and alpacas, respectively, were: sodium, 154.7 ± 2.1 and 152.7 ± 2.1 mEq/L; potassium, 5.3 ± 0.4 and 4.6 ± 0.4 mEq/L; magnesium, 1.8 ± 0.1 and 1.7 ± 0.1 mg/dl; chloride, 130.0 ± 1.6 and 127.0 ± 3.3 mEq/L; bicarbonate, 19.2 ± 1.5 and 20.2 ± 2.3 mEq/L; phosphorous, 2.7 ± 0.3 and 2.5 ± 0.4 mg/dl; glucose, 80.3 ± 3.9 and 80.8 ± 7.3 mg/dl; total protein, 29.0 ± 8.6 and 31.5 ± 10.1 mg/dl; and osmolality, 305.8 ± 11.8 and 306.2 ± 4.9 mOsm. The pH ranged from 7.5 to 8.0 for both species. Potassium concentrations were significantly higher in llamas than alpacas.

Conclusions and Clinical Relevance—Except for potassium, composition of aqueous humor did not differ significantly between llamas and alpacas. Aqueous humor composition of llamas and alpacas is similar to that of other species that have been examined. (*Am J Vet Res* 2001;62:1060–1062)

South American camelids, particularly llamas (*Lama glama)* and alpacas (*Lama pacos)*, continue to gain popularity as pets and working animals. They are most commonly used as pack animals or sentinels for sheep herds. Good vision is critical to their success as working animals, and information regarding their comparative ocular physiologic characteristics is largely lacking.

Cataracts are the most common disease of the lens in llamas.[1] Often congenital and presumed heritable, cataracts can progress to cause complete blindness.[2-4,a] They also may develop secondary to uveitis,[2,3] particularly in cases of failure of passage transfer.[1,2,5] Recently, lens abnormalities were detected in 39 of 50 (78%) alpacas examined for ocular disease.[b] Successful cataract surgery in captive camelids could mean the difference between the need to euthanatize an animal and the opportunity for it to resume its status as a working animal. In llamas and alpacas, cataract surgery has been largely unsuccessful because of severe corneal edema after surgery, which sometimes leads to corneal ulcers and rupture.[2,5,6,c,d] Cause of the edema is not yet known, but a species-specific variation in corneal endothelial fragility has been hypothesized.[2] Intraocular manipulations including the use of irrigating fluids for phacoemulsification can result in corneal endothelial damage and subsequent corneal edema.[7-9]

Aqueous humor in clinically normal animals provides an optimal environment for function of corneal endothelial cells.[10-12] Knowledge of its composition in normal eyes of llamas and alpacas is the first step to understanding and improving function of endothelial cells during cataract surgery in these species. To our knowledge, analysis of aqueous humor of llamas and alpacas has not been reported. The objective of the study reported here was to determine values for ionic composition, total protein, pH, and osmolality of the aqueous humor in llamas and alpacas and thereby provide a basis for further study involving fluids used for ocular irrigation and corneal perfusion in these species.

Materials and Methods

Ten male llamas and 10 male alpacas were obtained from the resident herd at our institution. Four animals were sexually intact, and the rest were neutered. Animals ranged from 2 to 16 years old. For an animal to be included in the study, it was necessary for results of an ocular examination to be normal. All animals were used in accordance with regulations established by the Animal Care and Use Committee of Colorado State University.

All llamas and alpacas were sedated by intramuscular administration of a combination of xylazine hydrochloride (0.2 mg/kg of body weight), butorphanol tartrate (0.02 mg/kg), and ketamine hydrchloride (2 mg/kg) to affect recumbency. Following topical application of anesthetic,[e] paracentesis of the anterior chamber at the limbal sclera was performed, using a 27-gauge needle attached to a 1-ml tuberculin syringe. A sample (0.3 ml) of aqueous humor was obtained from each eye of each animal and pooled to create 1 sample/animal. Each sample was immediately transferred into evacuated pediatric vials and analyzed within 4 to 6 hours after collection.

All samples were submitted to the clinical pathology laboratory at Colorado State University for analysis. An automated chemical analysis machine[f] was used to determine

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Table 1—Composition of aqueous humor obtained form normal eyes of llamas and alpacas

Variable	Llama Range	Llama Mean ± SD	Llama Median	Alpaca Range	Alpaca Mean ± SD	Alpaca Median
Total protein (mg/dl)	18–43	29.0 ± 8.6	27	19–46	31.5 ± 10.1	33
Glucose (mg/dl)	75–85	80.3 ± 3.9	80	74–97	80.8 ± 7.3	80.5
Phosphorus (mg/dl)	2.7–3.0	2.7 ± 0.3	2.8	2.1–3.3	2.5 ± 0.4	2.4
Magnesium (mg/dl)	1.7–1.9	1.8 ± 0.1	1.8	1.5–1.8	1.7 ± 0.1	1.7
Sodium (mEq/L)	152–158	154.7 ± 2.1	155	150–157	152.7 ± 2.1	152.5
Potassium (mEq/L)	4.6–5.9	5.3 ± 0.4	5.3	3.9–4.9	4.6 ± 0.4	4.7
Chloride (mEq/L)	128–132	130.0 ± 1.6	131	122–133	127.0 ± 3.3	127.5
Bicarbonate (mEq/L)	16.5–21.3	19.2 ± 1.5	19.5	16.1–23	20.2 ± 2.3	21.1
pH	7.0–8.0	NA	NA	7.5–8.0	NA	NA
Osmolality (mOsm)	285–318	305.8 ± 11.0	309.5	295–313	306.2 ± 4.9	306

NA = Not applicable, because only ranges were determined by the method used.

Table 2—Composition of aqueous humor of various species*

Variable	Llama	Rabbit	Monkey	Dog
Protein (mg/dl)	31.5	25.9	33.3	36.4
Phosphorus (mg/dl)	0.62	0.89	0.14	0.53
Magnesium (mg/dl)	0.70	0.80	0.80	—
Sodium (mEq/L)	152.7	143.0	152.0	149.4
Chloride (mEq/L)	128.0	105.1	125.0	124.8
Bicarbonate (mEq/L)	20.16	33.6	22.5	—
Potassium (mEq/L)	4.6	5.2	3.9	5.0
pH	7.5-8.0†	7.6	7.49	—

*Data represent mean values determined for the llamas of the study reported here, whereas mean values for rabbits, monkeys, and dogs were reported in another study.[10] †Data reported are range values. — = Not determined.

osmolality and concentrations of ionic substances, glucose, and total protein. Colorimetric determination of pH was conducted, using pH paper.[g]

Mean, SD, median, and range values were determined for each variable. A Wilcoxon 2-sample test at a value of $P < 0.01$ was used to determine whether a significant difference existed between llamas and alpacas for each variable.

Results

Mean ± SD and range values for llamas and alpacas were determined (**Table 1**). Colorimetric evaluation of pH conducted by use of pH paper allowed only range values to be obtained, but values for all alpacas and 9 of 10 llamas were within the color scale corresponding to pH 7.5 to 8.0; the value for the remaining llama was in the pH range of 7.0 to 7.5. Significant differences were not detected between llamas and alpacas for any of the variables evaluated, except potassium concentration.

Aqueous humor composition of llamas and alpacas was compared with values obtained in other species (**Table 2**). Aqueous humor of llamas and alpacas is similar in ionic composition, osmolality, pH, and concentration of glucose and total protein to that of other species.

Discussion

Potassium concentration of aqueous humor was the only variable that differed significantly between llamas and alpacas. Llamas had a higher potassium concentration in aqueous humor than alpacas. Although serum concentrations of potassium were not evaluated in this study, it is possible that serum concentrations of potassium were slightly greater in these llamas than the alpacas. A difference in concentrations in aqueous humor could correlate to a difference in serum concentrations via simple diffusion or active transport.[11]

For pH, aqueous humor from all alpacas and 9 of 10 llamas was within the range of 7.5 to 8.0. A more specific determination was not possible given the method used. It is possible that pH of the aqueous humor in these species is slightly more alkaline (closer to pH 8.0) than that of rabbits and primates.[11] A difference in relative alkalinity of the aqueous humor in llamas and alpacas may be of importance. The pH tolerance of human corneal endothelial cells reportedly is between 6.8 and 8.2,[8,9] with irreversible damage to endothelial cells occurring outside a range of 6.5 to 8.5.[9] Studies have documented that intraocular irrigating fluids differing in pH, osmolality, and ionic composition from that of aqueous humor can result in compromise of corneal endothelial cells.[7,10,13-15] Variations among species in tolerance of endothelial cells for exposure to suboptimal environments have been documented.[7,10,13-15] Data regarding pH of aqueous humor in domestic animals is lacking. It may be that endothelial cells of llamas and alpacas would have a slightly different tolerance range for pH if their natural environment were substantially more alkaline than that of fluids used for intraocular perfusion. Further evaluation of pH of the aqueous humor of llamas and alpacas is needed.

Limitations of the study reported here included a relatively small population from which to attempt to establish reference range values and the fact that we did not include female llamas or alpacas among the animals evaluated. In addition, the small volume of sample obtained from each animal precluded the use of a pH meter. Thus, evaluation of pH was limited to use of pH paper, which only enabled us to determine range values. Although each sample of aqueous humor was immediately placed in airtight containers, the delay from collection to analysis (4 to 6 hours) may have altered pH values.

There appears to be little difference between aqueous humor of llamas or alpacas and that of other species. The overall similarities between aqueous humor of llamas or alpacas and that of other species suggests that corneal edema as a sequela to phacoemulsification surgery may be attributable to a species-specific fragility of corneal endothelial cells in llamas and alpacas. This may be a consequence of a relatively low density of endothelial cells or simply a lower tolerance for stresses created by intraocular manipulations.[9] Additional studies on function of endothelial cells in llamas and alpacas, including corneal perfusion studies with various irrigating solutions, are crucial to improving the success of cataract surgery in these species.

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[d]Wilke DA, Department of Clinical Sciences, College of Veterinary Medicine, Ohio State University, Columbus, Ohio: Personal communication, 1999.

[e]Proparacaine Hydrochloride 5%, Bausch & Lomb, Tampa, Fla.

[f]Hitachi Model 911, Boeringer Mannheim, Indianapolis, Ind.

[g]pHydrion, MicroEssential Lab, Brooklyn, NY.

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