Brainstem auditory evoked responses and ophthalmic findings in llamas and alpacas in eastern Canada

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Abstract — Seventeen llamas and 23 alpacas of various coat and iris colors were evaluated for: 1) deafness by using brainstem auditory evoked response testing; and 2) for ocular abnormalities via complete ophthalmic examination. No animals were deaf. The most common ocular abnormalities noted were iris-to-iris persistent pupillary membranes and incipient cataracts.

Résumé — Potentiels évoqués auditifs au niveau du tronc cérébral et trouvailles ophtalmiques chez des lamas et des alpagas de l'est du Canada. Dix-sept lamas et 23 alpacas de différents pelages et couleurs d'iris ont été évalués pour : 1) surdité par utilisation de potentiels évoqués auditifs au niveau du tronc cérébral et 2) anomalies oculaires par examen ophtalmique complet. Aucun animal n'était sourd. Les anomalies oculaires les plus fréquentes étaient la persistance de la membrane pupillaire (iris — iris) et des débuts de cataractes.

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South American camelids, including llamas and alpacas, are used as pack animals, for the production of fibre, and for companionship in Canada. The Canadian Llama and Alpaca Association closed the Canadian registry to any newly imported animals in December, 2000 (1). This could potentially have several effects on the Canadian llama and alpaca industry. First, individual registered breeding animals could increase in value. Second, limiting introduction of new breeding stock within the registry could reduce the size of the gene pool, and potentially increase the risk of spread of genetic diseases within the Canadian camelid population. In an attempt to reduce inherited diseases, a list of congenital traits has been drafted and implemented to disqualify animals from being used in breeding programs. Also, to avoid limiting genetic diversity of the Canadian breeding herd of llamas and alpacas, the Canadian Llama and Alpaca Association has recently adopted a breeding-up program whereby nonregistered animals free of congenital anomalies can be bred to "pure-bred" Canadian animals, thereby providing a means by which new genes can be introduced into the breeding population (1). Nevertheless, because of the partially closed genetic population of these species in Canada, inherited ocular conditions may become more prevalent. Additionally, it is known that in other species, animals with particular genes coding for a variety of coat and iris colors are associated with congenital deafness. As llamas and alpacas are often bred for their coat coloring, inadvertent selection for congenital deafness is a potential concern. The purpose of this study was to determine if coat or iris color(s), or both, are related to congenital deafness in llamas and alpacas in eastern Canada. Further, we set out to describe the ocular findings in this group of animals.

Seventeen llamas (17 female) and 23 alpacas (17 female; 4 male; 2 geldings) were examined in Prince Edward Island and Nova Scotia. Age and coat and iris colors were recorded.

Hearing was evaluated by using brainstem auditory evoked response (BAER) testing. Two llamas and 3 alpacas did not undergo BAER testing, because they could not be restrained effectively. For BAER testing, animals were restrained with a halter. Positive, negative, and reference subdermal stainless steel electrodes (UFI, Morro Bay, California, USA) were placed at the vertex of the skull, rostral to the tragus of the ear being tested, and rostral to the tragus of the ear not being tested, respectively. Electrodes were connected to a portable BAER evaluation system (BAERCOM; UFI). Two to three thousand monaural "clicks" were delivered at 80 dB at a rate of approximately 40/s via an earphone that was inserted deep within the external ear canal. The earphone was examined prior to usage to ensure that the end of the earphone was not occluded with any sebum. The BAERs were confirmed by repeating the test and

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Table 1. Number of animals with various coat and iris colors

Species	Coat color	Iris color	Number of animals
Alpaca	Brown	Brown	3
		Heterochromia	3
Alpaca	Brown and white	Brown	4
		Heterochromia	3
Alpaca	Black	Brown	1
		Heterochromia	3
Alpaca	Grey, grey with white face, or blue roan	Heterochromia	3
Alpaca	White	Blue	1
		Heterochromia	2
Llama	Black, brown, or brown with white markings	Brown	2
		Heterochromia	5
Llama	White	Blue	0
		Brown	1
		Heterochromia	2
Llama	White with brown or black spots	Brown	1
		Heterochromia	4
Llama	White with grey	Brown	1
Llama	Appaloosa	Brown	1

Note: heterochromia indicates > 1 iris color between and/or within each eye

ensuring that electrodes were in place both prior to and after testing. Latencies were determined manually for peaks I and V of the BAER.

Ophthalmic examination was completed on all animals; it included neuro-ophthalmic examination and intraocular pressure (IOP) measurements (Tonopen XL; Biorad Ophthalmic Division, Santa Clara, California, USA) prior to pupillary dilation. Slit-lamp biomicroscopic examination (Kowa SL-14; Kowa, Tokyo, Japan) and indirect fundic examination (Keeler All Pupil Indirect; Keeler Instruments, Broomall, Pennsylvania, USA) were performed following pupillary dilation with 1% tropicamide (Mydriacyl; Alcon Canada, Mississauga, Ontario). Paired *t*-test was used to identify differences for IOP between eyes within each species, while Student's *t*-test was used to identify differences for IOP between genders for alpacas and for differences in IOP between species (Sigma-Stat, version 2.03; SPSS Inc., Chicago, Illinois, USA).

The mean age and standard deviation (s) of llamas and alpacas was 9.6 y (s = 5.1) and 3.8 y (s = 3.6), respectively. The llamas were significantly older than the alpacas ($P < 0.001$). A variety of coat and iris color combinations were recorded (Table 1).

Positive hearing ability was determined by identifying peaks I and V on the BAER recording. The electrodiagnostic recording device was found to be useful for determining hearing status. The electrodiagnostic device was not calibrated to provide amplitude values (μV), and because of the presence of large amounts of sebum in the ear canals of some of the animals, latencies could not be reliably determined for peaks II to IV. In general, the presence of sebum within the ear canals resulted in lower amplitude tracings. Peaks II to IV (peak IV observed in only 1 llama) were not readily discernable in one or both ears of 7 llamas and 15 alpacas. Our finding of an absent peak IV in the BAER tracing is consistent with that found in adult Holstein cows (3). It has been proposed that peak IV is fused with peak V due to the simultaneous occurrence of peaks IV and V because of conduction-time similarities or because of the orientation of brain structures to the recording electrodes (3). Regardless, the latencies for peaks I and V were discernable in all animals. Mean latencies for peaks I and V for llamas were 1.8, s = 0.2 ms and 4.9, s = 0.3 ms, respectively. Mean latencies for peaks I and V for alpacas were 1.9, s = 0.2 ms and 4.9, s = 0.2 ms, respectively. Regardless of the coat or iris color, all animals examined by BAER testing (15/17 llamas; 20/23 alpacas) were found to be hearing bilaterally (Figure 1). Of the llamas not examined by BAER testing, 1 was black with a white face, 1 was white with brown patches, and both had heterochromic irides. Of the 3 alpacas not examined by BAER testing, 1 was brown with a white face with brown irides, 1 was grey with a white face with heterochromic irides, and 1 was blue roan with a white face with heterochromic irides.

Ophthalmic examination revealed mean IOPs to be 15, s = 4 mmHg for the right eye (OD) and 17, s = 5 mmHg for the left eye (OS) for llamas, and 20, s = 4 mmHg OD and 19, s = 5 mmHg OS for alpacas. There were no differences between IOPs for different genders of alpacas ($P > 0.05$), nor were there differences in IOP measurements between eyes within each species ($P > 0.05$). The overall mean IOPs for llamas (33 eyes) and alpacas (46 eyes) was 16, s = 5 mmHg and 19, s = 4 mmHg, respectively. Llamas had significantly lower mean IOP compared with alpacas ($P < 0.001$). Ocular findings included iris-to-iris persistent pupillary membranes (PPMs) (14/17 llamas; 5/23 alpacas); PPM pigment spots (anterior lens capsule) (1/17 llamas; 1/23 alpacas); incipient anterior cortical cataracts (2/17 llamas; 3/23 alpacas); incipient posterior capsular cataracts (5/17 llamas; 1/23 alpacas); immature posterior capsular and cortical cataracts (3/17 llamas; 0/23 alpacas);

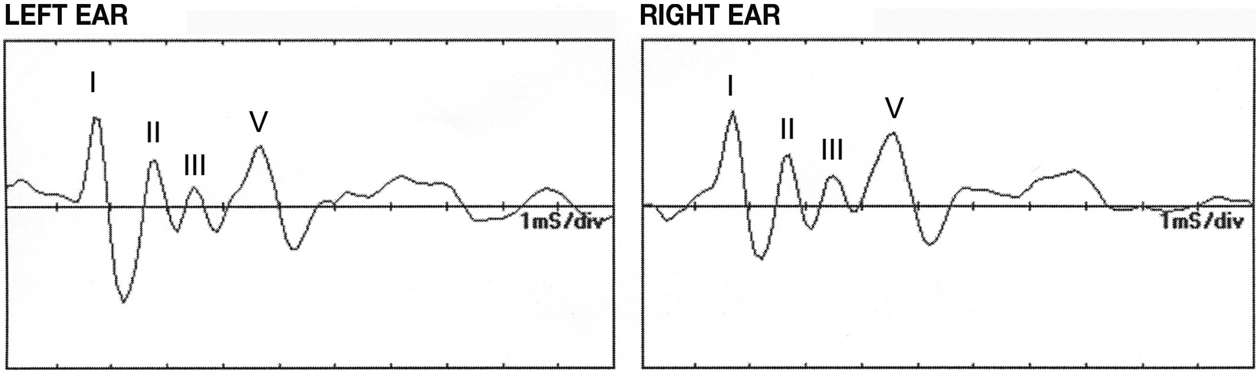

Figure 1. Brainstem auditory evoked responses (BAER) from the left and right ears of an adult alpaca. The peaks represent activation of different parts of the hearing pathway (peak IV not discernable in the present tracing). Peak I is generated by the inner ear and the cochlear nerve, peaks II to V are generated by central auditory pathways. Brainstem auditory evoked responses of animals with inherited sensorineural deafness appear as flat lines (no waveform).

superficial corneal scarring (1/17 llamas; 1/23 alpacas); anterior stromal corneal dystrophy (0/17 llamas; 2/23 alpacas); conjunctival or palpebral masses (0/17 llamas; 2/23 alpacas); unilateral enucleation (1/17 llamas; 0/23 alpacas); and no abnormal ocular findings (1/17 llamas; 10/23 alpacas).

Attempts to determine deafness by observing the behavior of an animal are unreliable when applied to a herd animal and are ineffective for diagnosing unilateral deafness in any species. The BAER test can definitively determine whether or not deafness exists, unilaterally or bilaterally. Testing by BAER has been used extensively to diagnose inherited, sensorineural deafness in dogs and cats (2). A BAER is produced by applying an auditory stimulus via an earphone to the ear being tested (2). The BAER is recorded by measuring the neuroelectrical activity arising from the auditory pathways in the inner ear and the brain by using subdermal scalp electrodes (2). Little BAER testing has been done in ruminants (3). Nevertheless, the latencies of peaks I and V of the BAER in our llamas and alpacas are equivalent to those evaluated in adult Holstein cattle (3). Given that we were interested in determining whether animals were able to hear, the BAERCOM was a useful portable device. Detailed analysis of the BAER in llamas and alpacas, however, should be evaluated with more sophisticated equipment to enable testing with increasing degrees of loudness (increasing decibels), by using bone-conducted stimulation in animals that have exuberant sebum in their external ear canal, or both.

Inherited deafness has been reported in cats and numerous breeds of dogs. Deafness results from deficits in either the conducting structures within the ear or the sensorineural structures in the inner ear and brain. The most common form of sensorineural deafness in cats and dogs results from the degeneration of inner ear structures and neurons within the spiral ganglion (2). This cochleosaccular type degeneration occurs after birth and is thought to arise because of failure of migration of neural crest cells to the inner ear during development (2). In dogs, 2 pigmentation genes, the merle and the piebald, are associated with congenital deafness (2). Dalmatians are a classic breed of dog with deafness being associated with piebald genetics. In cats, there is a white pigment gene that is autosomal dominant (2). Homozygous white cats are prone to developing blue irides and deafness (2). An association is seen between coat color and pigmentation of irides and fundi in alpacas (the lighter the coat color the less pigmented the iris and fundus) (4). Recently, researchers have presented preliminary results of inherited congenital deafness in llamas and alpacas in the United States (5). The results of these preliminary studies indicate that 90% of llamas and alpacas with solid white hair coats and sky-blue to white irides are deaf. The total number of animals examined, however, was not reported. Our failure to identify any deaf animals in this small sample of llamas and alpacas likely reflects the fact that there was only 1 white alpaca with combined dark and light blue irides (Table 1).

Although deafness is one of the traits that is recognized by the Canadian Llama and Alpaca Association as being a disqualifier for registration of an animal, few owners of these species routinely conduct BAER testing. Our results indicate that future studies should evaluate the prevalence of deafness in a large population of llamas and alpacas, ensuring that many white animals with pale blue or white irides are included. Future studies may indicate the need to routinely test the BAER on llama and alpaca breeding stock, as is done in many breeds of dogs susceptible to inherited congenital sensorineural deafness.

The IOPs in our sample population of llamas and alpacas were similar to those reported for llamas and alpacas in the United States (6,7). The IOPs in the present study were significantly lower for llamas than for alpacas, however. This difference is likely because the llamas were significantly older than the alpacas; IOP decreases with advancing age for both llamas and alpacas (7). Importantly, the IOP is similar between age-matched llamas and alpacas (7).

In our study, the most common iris abnormality in both species was iris-to-iris PPMs, which have not previously been reported as a common occurrence in these camelids (4,8). Persistent pupillary membranes are reported to be the most common form of anterior segment dysgenesis in domesticated animals (9). Persistent pupillary membranes appear as strands of pigmented tissue attaching from one part of the iris to another (may affect the pupil), from the iris to the corneal endothelium, or from the iris to the lens. Oftentimes, PPMs are incidental findings and cause no vision impairment or other ocular problems. Sometimes, however, PPMs may impair vision directly, or cause opacification of the cornea and lens. Inherited forms of PPMs causing significant vision impairment are reported for many breeds of dogs (10). The most common lenticular abnormality we noted was cataract, consistent with previous reports of lenticular abnormalities in llamas and alpacas (4,8). None of the cataracts were found to be vision threatening, nor were they associated with underlying or previous ocular disease. Considering the frequency of occurrence of PPMs and cataracts in our llamas and alpacas, and the potential for these ocular abnormalities to cause vision impairment, llamas and alpacas should be screened prior to breeding for potentially inherited ocular conditions, as is done for dogs and horses (10). Preferably, a complete ophthalmic examination should be performed on llamas and alpacas as part of a routine prepurchase examination.

Addendum

During the publication process of this manuscript, the results of BAER testing on 25 llamas and 38 alpacas were reported (11). Of these animals, 7 of 10 pure white-coated, blue-eyed animals were bilaterally deaf and 1 was unilaterally deaf. As suspected, congenital sensorineural deafness is associated with pure white-coats and blue irides in llamas and alpacas. CVJ

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