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CONDUCTIVE HEARING LOSS IN BIGHORN SHEEP

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ABSTRACT: In January 1993 we simulated a conductive hearing loss in three Mexican bighorn sheep (*Ovis canadensis mexicana*) by placing bone wax or saline solution in their ear canals. Our objective was to test whether lesions of the external auditory canal caused by psoroptic mites (*Psoroptes ovis*) may lead to conductive hearing loss in bighorn sheep. We assessed the effects of these manipulations using the auditory brainstem response test. Placing saline solution in the external auditory canal, which loads the tympanic membrane, had a more dramatic effect on the auditory brainstem response than did bone wax. We propose that decreased hearing sensitivity or alterations in resonance characteristics of the external auditory canal, due to psoroptic scabies lesions, may make bighorn sheep more susceptible to predation.

Key words: Auditory brainstem response, bighorn sheep, conductive hearing loss, *Ovis canadensis, Psoroptes ovis*.

INTRODUCTION

Scabies caused by the psoroptic mite (*Psoroptes* spp.) is widely distributed in North American wildlife including bighorn sheep (*Ovis canadensis*) (Lange, 1980). The psoroptic mite maintains itself in the ear canal of bighorn sheep as the primary site of habitation (Wright et al., 1981). Kinzer et al. (1983) reported that bighorn sheep with scabies lesions caused by psoroptic mites had ear canals that were completely plugged with hard, packed concentric rings of dry necrotic tissue and mite exuvia. Elenowitz and Humphreys (1989) found that the ear canals of five of nine bighorn sheep killed by mountain lions (*Felis concolor*) were plugged with solid exudate resulting from scabies mite infestation. Clark and Jessup (1992) reported that all nine bighorn sheep that they examined in 1989 had ". . . crusted exudative plugs occluding the ear canals." Eight of nine had purulent otitis externa and six had abnormal tympanic membranes. Clark and Jessup (1992) speculated that plugging of the ear canal predisposed sheep to mountain lion predation because it may have caused moderate to severe auditory impairment.

Blockage of the external auditory canal can affect the transmission of airborne sound into the cochlea. Depending on the extent of blockage the result can be decreased hearing sensitivity (a conductive type of hearing loss) and an alteration of the resonance effects of the ear canal. Our objective was to determine the nature of the changes in the mid- to high-frequency hearing sensitivity in bighorn sheep after altering transmission characteristics of the ear canal.

MATERIALS AND METHODS

We conducted the study in January 1993 following established animal research guidelines (Anonymous, 1986; Curtis, 1988). We restrained three bighorn sheep from the University of Arizona Wildlife Research Area, by injection with 4 cc (400 mg) of ketamine hydrochloride (Fort Dodge Laboratories, Fort Dodge, Iowa, USA), and 1 cc (100 mg) of xylazine hydrochloride (Lloyd Laboratories, Shenandoah, Iowa). Animals then were blindfolded, hobbled, and transported to the Arizona Health Sciences Center, Tucson, Arizona (USA) and anesthetized to a light plane (approximately 2.5%) of anesthesia with halothane (Halocarbon Laboratories, Inc., North Augusta, South Carolina, USA) followed by endotracheal intubation. We recorded auditory brainstem responses using a Nicolet Spirit® Portable EP System (Nicolet Instruments, Inc., Madison, Wisconsin, USA).

Acoustic stimuli were rarefaction clicks of 100 μsec in duration presented monaurally through Nicolet TIP-300 tubal insert phones at the rate of 21.4/sec. The insert earphones introduced a

delay in the responses of 0.9 msec. Clicks were initially presented at 105 decibels peak equivalent sound pressure level (dB pe SPL) and decreased in 10 dB steps until auditory brainstem responses no longer were detected.

We performed otoscopic examinations on all animals to rule out impacted cerumen or debris lying in the ear canal. We conducted the examinations with a hand held halogen otoscope (Welch-Allyn, Inc., Skan Falls, New York, USA) with an appropriate diameter and length speculum, inserted into each ear. We examined the ear canal and tympanic membrane for debris and defects. If debris was found we thoroughly cleaned and dried the ear canal before proceeding. We altered the transmission characteristics of the ear canal by placing approximately 2 cc total volume of bone wax (Ethicon Inc., Somerville, New Jersey, USA) in the canal or filling it with approximately 3.5 cc of 0.9% saline solution (Boster Healthcare Corp., Deerfield, Illinois, USA). We assessed the mid- to high-frequency hearing sensitivity by recording click evoked auditory brainstem responses from each sheep before and after the ear canal manipulation. We recorded auditory brainstem responses using platinum subdermal electrodes (Grass Instrument Co., Quincy, Massachusetts, USA). A non-inverting electrode was placed rostral to the braincase and an inverting electrode was placed at the mastoid of the test ear. Both of these electrodes were referenced to an electrode placed at the mastoid of the non-test ear. Electrophysiological signals were amplified and filtered (150 to 3,000 Hz) before being averaged. The sampling epoch was 10 msec post-stimulus onset and the sampling rate was 25,000 Hz resulting in a dwell time of 40 μ sec. The responses to a minimum of 500 stimulus presentations were averaged and near threshold the measurements were repeated. The two indices used to assess hearing sensitivity were threshold of the response and wave IV-V latency-intensity functions; these were the fourth and fifth positive peaks of the auditory brainstem response, respectively. Threshold was defined as the lowest SPL at which wave IV-V of the auditory brainstem response was reliably observed. The slopes of the latency-intensity functions were calculated using the linear model $Y = m\chi + B$, where Y is the y value, m is the slope, χ is the x value, and B is the y intercept. Latencies among the various conditions were analyzed with paired t-tests (Shavelson, 1988).

RESULTS

The addition of saline solution to the external auditory canal (Fig. 1c) resulted in more dramatic auditory brainstem response changes than did bone wax (Fig. 1b) when compared to an unaltered external auditory canal (Fig. 1a). Adding bone wax to the ear canal of sheep number 5 neither changed the threshold of the response (55 dB pe SPL) nor did it significantly change the observed wave IV-V latencies, t (5 df) = -1.1, $P = 0.31$ (Fig. 2). For sheep number 3, the threshold of the auditory brainstem response was 45 dB pe SPL under both conditions (Fig. 2). The addition of bone wax to the ear canal resulted in significantly ($P = 0.01$) increased latencies; however, the slopes of the latency-intensity functions were similar: 24 μsec/dB in the unaltered ear canal condition and 19 μsec/dB in the bone wax condition.

The addition of saline solution to the ear canal to sheep number 5 resulted in a 30 dB poorer wave IV-V threshold (Fig. 3). Wave IV-V latencies, for intensity levels of 85, 95, and 105 dB pe SPL, were significantly ($P = 0.025$) longer in the saline condition than in the unaltered ear canal condition. For lower intensity levels, wave IV-V in the saline condition was no longer observed. The slope of the latency-intensity function was 22 μsec/dB in the unaltered ear canal condition and 40 μsec/dB in the saline condition. Placing saline solution into the ear canal of sheep number 4 resulted in a 50 dB poorer wave IV-V threshold. Because only one data point was available for sheep number 4, the t-value and the slope of the latency-intensity function could not be calculated.

DISCUSSION

The auditory brainstem response threshold and latency-intensity function are indices used to estimate hearing sensitivity in humans. For example, abnormal wave IV-V thresholds or steeper latency-intensity functions are associated with hearing loss (Glattke, 1983). The threshold for the click-evoked auditory brainstem response roughly corresponds with mid- to high-frequency hearing sensitivity in humans (Glattke, 1983). DeYoung et al. (1993) re-

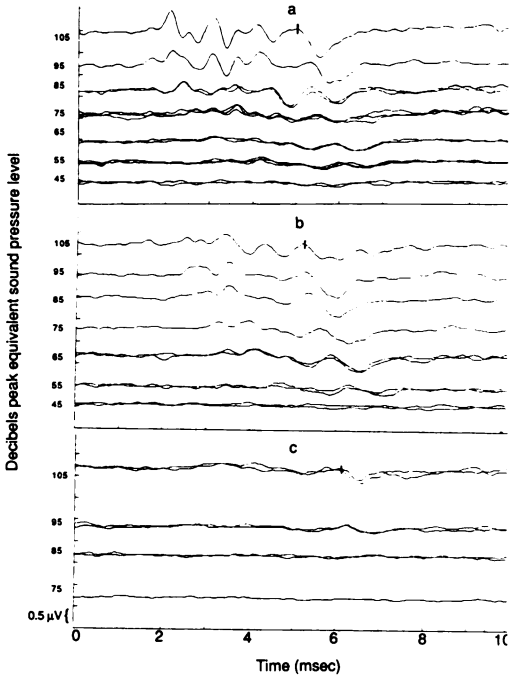

FIGURE 1. Auditory brainstem responses as recorded by IV-V waves (vertical mark) from bighorn sheep number 5 under three conditions: a) no alteration of the external auditory canal; b) bone wax placed in the external auditory canal; c) saline solution placed in the external auditory canal. Wave IV-V thresholds of the auditory brainstem responses were higher and latencies were significantly longer in the saline condition than in the unaltered condition (P = 0.024) and the bone wax condition (P = 0.029).

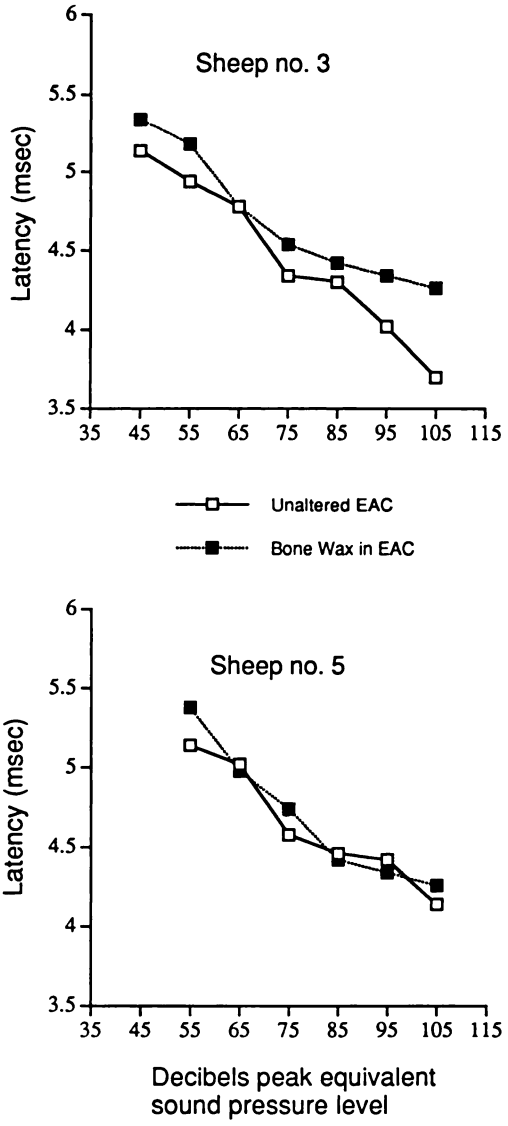

FIGURE 2. Latency-intensity functions for wave IV-V of the auditory brainstem response for sheep number 3, and 5. Adding bone wax to the external auditory canal (EAC) did not change the threshold of the responses (45 and 55 decibels peak equivalent sound pressure level for sheep 3 and 5, respectively). Adding bone wax did not significantly alter the latency of wave IV-V for sheep number 5 (P > 0.05); however, latencies were significantly delayed for sheep number 3 (P = 0.01).

ported the click auditory brainstem response threshold to be very similar to the 4,000 Hz toneburst-evoked brainstem response threshold. Based on our results, hearing for bighorn sheep in this frequency region can be compromised when transmission properties of the ear canal are altered. Filling the ear canal with saline solution dramatically increased the auditory brainstem response wave IV-V threshold latencies. We believe that these changes in the brainstem response are associated with a reduced stimulus level reaching the cochlea. The intensity level of the stimulus was reduced by increasing the effective mass of the tympanic membrane by loading it with saline solution. Mass loading impedes high frequencies more than it does low frequencies (Gulick et al., 1989). The click-evoked auditory brainstem response, being sensitive to the mid- to high-frequency regions of the cochlea, therefore, reflects the effects of this mass loading of

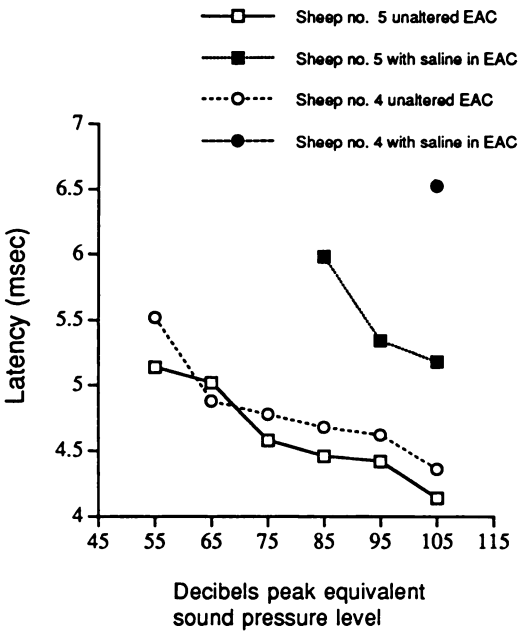

FIGURE 3. Latency-intensity functions for wave IV-V of the auditory brainstem response for sheep numbers 4 and 5. Filling the external auditory canal (EAC) with saline dramatically increased the thresholds of the responses and significantly increased the latencies of wave IV-V ($P = 0.024$ for sheep number 5; insufficient data to perform t-test for sheep number 4).

the tympanic membrane by exhibiting increased wave IV-V thresholds and delayed wave IV-V latencies. Placing bone wax in the ear canal had no impact on wave IV-V thresholds but did have a significant impact on the latency of the auditory brainstem response for one sheep. We believe the bone wax, in these instances, was not impeding the movement of the tympanic membrane but rather was acting as an incomplete blocking substance within the ear canal. The significant delays in wave IV-V latency for sheep number 3 probably resulted from changes in ear canal resonance and reflect an apical shift in the population of hair cells and neurons contributing to the auditory brainstem response. These resonance changes, which result in a selective reduction in high frequency hearing, alter the normal spectral patterns of sounds reaching the ears. Spectral patterns are important to sound localization (Brown et al., 1980) and source identification (Fay, 1992). Bighorn sheep with psoroptic scabies may become susceptible to mountain lions and other predators due to decreased hearing sensitivity or changes in spectral patterns of environmental sounds. Based on our findings, we believe that if ear mites and their debris totally occlude the ear canal or lie proximal to the tympanic membrane and thus load the tympanic membrane and impede its normal movement, decreased hearing sensitivity can be suspected. A total occlusion is likely to result in a flat conductive hearing loss (van Dishoeck and DeWit, 1944), while loading of the tympanic membrane is likely to interfere with high frequency hearing sensitivity (Gulick et al., 1989). The amount of conductive hearing loss incurred will depend on the amount of occlusion, and the extent of the increased mass of the outer ear and tympanic membrane system. Debris that is sitting in the distal part of the ear canal but not totally occluding the ear canal likely will alter the resonance effects of the ear canal. Decreased hearing sensitivity and altered ear canal resonances caused by psoroptic scabies could make awareness, identification, and localization of predators a difficult task for desert bighorn sheep.

Currently there is no universally accepted protocol for effective treatment of scabies in bighorn sheep in the wild. Boyce et al. (1991a, 1992) demonstrated that psoroptic scabies can be treated in free-ranging bighorn sheep. However, wide-spread treatment has not been attempted because of the expense. Answers to treatment questions will depend partly on factors related to the population of sheep affected such as threat of extinction and characteristics of the surrounding habitat. Continuing research efforts to develop effective treatment protocols for psoroptic scabies affecting various populations of bighorn sheep (Boyce et al., 1991a, b, 1992; Clark et al., 1993) is highly encouraged.

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