PROBLEMS ASSOCIATED WITH HEART RATE TELEMETRY IMPLANTS

MARK C. WALLACE, PAUL R. KRAUSMAN, DONALD W. DEYOUNG, AND MARA E. WEISENBERGER

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Mark C. Wallace
School of Renewable Natural Resources
University of Arizona
Tucson, AZ 85721

Paul R. Krausman
School of Renewable Natural Resources
University of Arizona
Tucson, AZ 85721

Donald W. DeYoung
University Animal Care
University of Arizona
Arizona Health Sciences Center
Tucson, AZ 85724

Mara E. Weisenberger
School of Renewable Natural Resources
University of Arizona
Tucson, AZ 85721

Recent concerns about environmental noise and its effects on wildlife have prompted activity in 2 different spheres of research: the intentional influences on pest species (Bomford and O'Brien 1990) and the possible effects of physiological or psychological stress to species inadvertently caused by human activities (Fletcher and Busnel 1978, Borg 1981, Fletcher 1988). Noise is effective as a short term deterrent to pest species but is most effective when it resembles natural alarm calls made by the species (Bomford and O'Brien 1990). Stress is considered a body's non-specific response to an insult, such as noise (Sapolsky 1990). Difficulties measuring stress in wild populations led researchers to remote sensing techniques that reduce the animals response to the observers themselves.

Heart rate is a descriptive measure of animals response to disturbances (Ward and Cupal 1979, MacArthur et al. 1982). MacArthur et al. (1979) found telemetered heart rates of mountain sheep were related to activity and the degree of transient stimuli animals experienced. Harlow et al. (1987) documented a linear relationship between heart rate and blood cortisol levels in domestic sheep and suggested that remote monitoring of cardiac frequency was a potential gauge of an animal's physiological condition under stress.

Our objectives were to document the distance that signals from RT and T transmitters could be received, the causes of transmitter failures, and to describe the modifications we made to protocols used to implant heart rate and temperature transmitters into mountain sheep and desert mule deer (Bunch et al. 1989).

We acknowledge the support and assistance provided by the Nevada Department of Wildlife, the U.S. Fish and Wildlife Service, and the Experimental Surgery and Clinical Services Section of the University of Arizona's University Animal Care. We thank S. Cameron, and V. Patula who assisted with surgery and care of captive animals and C. Hayes for observations of wild mountain sheep. Dr. O. E. Maughan was instrumental in project administration. This study was supported by the U.S. Air Force, Noise and Sonic Boom Technology Program, and the University of Arizona.

METHODS

We used captive and semi-free ranging animals in this study. Captive mountain sheep (n = 5) and desert mule deer (n = 6) were held at the University of Arizona Wildlife Research Center, Tucson. All animal care and treatment followed guidelines established by the American Society of Mammalogists (1987). Captive animals were not tame. Their intractability necessitated immobilization for capture or treatment and often limited prophylactic treatments. We used free ranging mountain sheep captured in 1990 (n = 3) and 1991 (n = 5) from the Sheep Range, Nevada and released them into a 3.2 km² enclosure in the Desert National Wildlife Refuge, Nevada. These animals were not recaptured.

Heart rate (model ECG-2) and temperature transmitters (model TTE-100) were calibrated and checked before use (Jacobsen and Stuart 1978, Jacobsen et al. 1981). Transmitters were sewn into a nylon mesh fabric and sterilized with ethylene-oxide and placed in an aerator ≥12 hours prior to surgery.

We immobilized captive animals between March 1990 and February 1991 with ketamine hydrochloride (HCL) and xylazine HCL (DelGiudice et al. 1989). We monitored respiration and general condition of immobilized animals was monitored during transport to the University of Arizona Animal Care surgical lab where anesthesia was induced or deepened with halothane by face mask induction. Mean time from restraint to halothane induction under veterinary care was 22 ± 8 minutes. While the animal was under anesthesia we used an electrocardiogram to continuously monitor heart rates for arrhythmia and to check HR accuracy. Animals were endotracheally intubated and the hair from the ventral abdomen and right thorax was clipped. The exposed areas were scrubbed with alcohol and povidine-iodine antiseptic.

We modified surgical procedures from those previously described (Jacobsen et al. 1981, Bunch et al. 1989). A 9-cm ventral midline incision was made through the skin and body wall. Transmitters that were surrounded by fabric were sutured immediately caudal to the sternum to the ventro-lateral body wall with 0 polypropylene. Teflon coated-stainless steel leads from HR transmitters exited the body cavity through a separate stab incision through the skin adjacent to the initial mid-line incision. Stab incisions were made at the mid-point of the sternum and two-thirds of the dorsal distance along the tenth or eleventh right rib (Cassirer et al. 1988, Bunch et al. 1989). Subcutaneous dissections were made from the stab incisions to the mid-line incision with a 7.11-cm trocar. Transmitter leads were passed through the trocar to the sternum (reference lead) and right lateral thorax (measurement lead) and were attached with 0 polypropylene sutures. Initially, we sutured the leads but found that sutured leads contributed to lead failure. Upon discovery we looped stainless steel suture in, out, and around the end of the lead. Incisions in the body wall were closed with 0 polyglactin absorbable sutures and skin incisions were closed with 0 polypropylene or nylon sutures. All animals were intramuscularly (IM) provided a long-acting penicillin. Halothane anesthesia was terminated and animals were transported back to study pens where yohimbine HCL was administered intravenously (IV) to reverse the effects of the xylazine immobilization (Mech et al. 1985).

Wild mountain sheep were captured in 1990 (n = 14, 3 of which were selected for surgical implants) and 1991 (n = 5) with helicopter and net gun from the Sheep Range, Nevada. In 1990, sheep were immobilized as above after helicopter net-capture and transported 258 km to the veterinary clinical facility at Nellis Air Force Base, Las Vegas, for transmitter implantation and then returned to the release site. In 1991, sheep were not immobilized, but were transported via helicopter to a field surgical station 14.5 km from the release site. Anesthesia was administered and surgery done in the field surgery station established in 1991. After transmitter implantation mountain sheep were released into a 3.2 km² enclosure in the Desert National Wildlife Refuge, Nevada.

Surgical facilities at the University of Arizona Health Sciences Animal Care Center included a pre-surgery preparation room and sterile operating theater. Surgery in 1990 for animals captured in Nevada was performed at the Nellis Air Force Base Veterinary clinical facility. In 1991, field surgery was conducted near the release site in the refuge office area and garage workshop. The office was used as the surgeons

1 Present address: Department of Natural Resources Sciences, University of Rhode Island, Kingston, RI 02881.
2 Present address: San Andreas National Wildlife Refuge, Las Cruces, NM 88004.
Phase I

3.2 km² enclosure, Desert National Wildlife Refuge, Nevada, between May 1990 and May 1992. Desert mule deer, 1990-91. Phase I animals were semi-tame mountain sheep and desert mule deer held at the University of Arizona Wildlife Research Center. Tucson, between Jan 1990 and Dec 1991. Phase II animals were wild mountain sheep captured from The Sheep Range, Nevada, and held in a 3.2 km² enclosure, Desert National Wildlife Refuge, Nevada, between May 1990 and May 1992.

### Table 1. Animal mortalities associated with a study involving surgical implantation of heart rate and temperature transmitters in mountain sheep and desert mule deer, 1990-91

<table>
<thead>
<tr>
<th>Species</th>
<th>Sex</th>
<th>Mortality date</th>
<th>No. days in study</th>
<th>Probable cause of mortality*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase I</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mountain sheep</td>
<td>M</td>
<td>14 Aug 1990</td>
<td>118</td>
<td>Died after accidentally breaking leg in fence in Tucson</td>
</tr>
<tr>
<td>Mountain sheep</td>
<td>F</td>
<td>29 Mar 1991</td>
<td>354</td>
<td>Died from peritonitis, from prolonged exposure of open incision</td>
</tr>
<tr>
<td>Mountain sheep</td>
<td>M</td>
<td>6 Sep 1991</td>
<td><img src="https://via.placeholder.com/15" alt="" /></td>
<td>Found moribund after termination of study, Died because of long-term kidney failure</td>
</tr>
<tr>
<td>Mule deer</td>
<td>M</td>
<td>28 May 1991</td>
<td>153</td>
<td>Asphyxiated on rumen contents during transport after immobilization</td>
</tr>
<tr>
<td><strong>Phase II</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mountain sheep</td>
<td>F</td>
<td>1 May 1990</td>
<td>0</td>
<td>Died during transport to Nellis Air Force Base (NAFB) veterinary lab</td>
</tr>
<tr>
<td>Mountain sheep</td>
<td>M</td>
<td>1 May 1990</td>
<td>0</td>
<td>Died after surgery and transport to and from NAFB veterinary lab</td>
</tr>
<tr>
<td>Mountain sheep</td>
<td>F</td>
<td>7 Jun 1991</td>
<td>&lt;67</td>
<td>Found dead in field enclosure. Transmitters still working</td>
</tr>
</tbody>
</table>

*Cause as determined from necropsy of animals or from examination of remains found at field mortality site.

**RESULTS**

Captive mountain sheep (n = 5) were immobilized 13 times with ketamine HCL (x = 6.0 ± 1.4) and xylazine HCL (x = 4.3 ± 0.8 mg/kg). Captive mule deer (n = 6) were immobilized 16 times with ketamine HCL (x = 4.5 ± 1.7) and xylazine HCL (x = 3.0 ± 1.0 mg/kg). The drug dosages we used were based upon our previous experience (DelGiudice et al. 1989) immobilizing desert mule deer and mountain sheep. Each individual captive animal could experience several surgeries (x = 2, range = 1–6) to replace failed transmitters or determine causes of transmitter failures.

Initial trials on the flat areas surrounding the Tucson study site suggested that reliable HR and temperature signals could be detected for ±0.5 km. In the steep terrain that is characteristic of mountain sheep habitat in Nevada, signals were reliably detected ±1.3 km. However, it was essential that a direct line-of-site between transmitter and receiver be maintained. Any solid obstacle severely reduced reception.

Reasons for transmitter failures or complications related to implants are reported only for captive animals because we did not recapture animals in Nevada. Early failures (≤38 days) of HR (n = 7) were due to leads breaking or disconnecting from transmitters (x = 8.3, range = 2–38). Seven transmitters short-circuited (x = 26.1 for 60.14 [SE] days, range = 126–509 days) because body fluids leaked into them along HR leads. Nine transmitters were still functioning when they were removed, 5 (x = 129.60 ± 41.87 days, range = 90–153) from animals that died and 4 (x = 131.50 ± 16.19 days) from healthy animals that were removed from the study for other uses. Transmitters were still functioning in 1 captive mountain sheep (456 days) and 1 wild sheep (328 days) at the end of this study.

Heart rate and T transmitters that were implanted too near the midline were engulfed by the weight of the rumen. The HR leads for a mountain sheep found in the abomasum were digested and failed after 145 days, while those of a mule deer found in the rumen were still functioning after 195 days. Temperature transmitters in both animals were still functioning properly, though the paraffin-elvax coatings were partially digested. Herniation or extrusion of transmitters through the ventral body wall also occurred when placement of transmitters was too near the mid-line where the weight of the rumen may have pushed them through the body wall. One transmitter still worked though it was pushed through a herniation of the peritoneum and another worked while hanging on the leads entirely outside the integument.

Seven animals died during the study (Table 1); 3 captive mountain sheep, 1 captive mule deer, and 3 wild mountain sheep. However, only 1 death was attributable to complications related to implants. An infection in a captive mountain sheep resulted from the exposure of a wound caused by the extrusion of a HR transmitter through the body wall. The transmitter was still functioning so the wound was irrigated with saline, disinfected with povidone-iodine solution, the transmitter replaced, and the wound sutured closed on-site. Because the animal would not permit handling without restraint we administered a 1-time injection of antibiotics, 1 gm chloramphenicol and 8 cc benzathine penicillin, and gave trimethoprim and sulfadiazine orally with her food. Despite treatments the ewe died 25 days later of peritonitis. One wild mountain sheep died while unattended during transport to surgery in 1990. A second was alive after surgery and release at enclosure site but exhibited opisthotonus, rear limb weakness, and inability to stand. This animal died before further assistance could be rendered. The carcass of a third wild mountain sheep was found 29 days after surgery and release but cause of mortality could not be determined. The captive mule deer asphyxiated on his rumen contents during transport to surgery after immobilization and could not be revived. One captive mountain sheep died after accidentally breaking an open incision in a fence and the other was found moribund 4 months after the conclusion of the study. Necropsy determined his death was due to long-term kidney failure.

**DISCUSSION**

This is 1 of the largest known samples of surgically implanted biotelemetry transmitters into wild ruminants. Effective ranges of transmitters were adequate for our studies of animal heart rates, temperatures, and behaviors in large enclosures.

Complications encountered during implant surgeries included profound bradycardia, including 1 mule deer that had to be completely resuscitated, and slow recovery from immobilization. Bradycardia occurred only while animals were deeply under halothane anesthesia. To counteract this problem yohimbine (x = 0.23 mg/kg) was administered immediately after halothane induction and atropine was administered...
after xylazine reversal if needed to speed up heart rate (Booth and McDonald 1988).

Modifications were made in handling protocols that were effective in speeding recovery from immobilization and anesthesia. The most effective combination we found was IV administration of yohimbine HCL ($x = 0.23$ mg/kg) immediately after induction by halothane to counteract the xylazine. We administered doxapram HCL ($x = 2.42$ mg/kg) (IV) as a respiratory stimulant to help eliminate halothane (McGuirk et al. 1990) and naloxone HCL ($x = 0.44$ mg/kg) as a narcotic reversal agent (Booth and McDonald 1988) upon release. Naloxone was given even though no narcotics were used because evidence suggests that ketamine HCL may act on the same opiate receptor sites (Booth and McDonald 1988).

Early failures of HR transmitters due to lead breakage were corrected by modifying the surgical technique after Bunch et al. (1989). Reference and measurement leads were not sutured in place but, were wrapped with additional stainless steel suture and left unfastened in situ before suturing the incision. Failures due to fluids seeping through the parafilm-elvax encapsulant were not remedied during this study. Promising new transmitter encapsulants, that should solve this problem, are currently being tested (Telonics Inc. Mesa, Ariz.). Maximum battery life for the transmitters used in this study is not yet known. However, 2 HR transmitters are still working after 328 and 456 days, respectively. Signals from the temperature transmitter still implanted became too intermittent for accurate use after 310 days. We do not know why this transmitter failed because this semi-free mountain sheep has not been recaptured.

Sterile surgical procedures are essential to successful use of this new technology. Our modified surgical protocols worked well. Heart rate data can be collected under field conditions. However, transmitters still failed because of encapsulant leakage.

LITERATURE CITED


