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EFFECTS OF INTRAPERITONEAL TRANSMITTER IMPLANTS ON YELLOW-BELLIED MARMOTS

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Abstract: I implanted radio transmitters in 183 yellow-bellied marmots (*Marmota flaviventris*); transmitters were replaced ≤6 times in 73 animals, for 300 surgeries. Surgical procedures were simple, effective, and largely trouble-free. Survival 30 days later was ≥98%, and growth rates (21 g/day) were the same for animals with or without implants. Pregnancy rate (0.52 litters/yr) and mean litter size (4.3) of implanted females were similar to pregnancy rate (0.48) and litter size (4.2) of females without implants. Intraperitoneal implants offer an alternative to radio collars for yellow-bellied marmots.

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Radio telemetry is an important tool in studies of free-roaming mammals. Transmitters typically are attached to animals by external collars; radio collars, however, are impractical for some species because of life-style or body shape (Smith and Whitney 1977). Hence, surgical implantation of sealed, physiologically inert transmitters into the peritoneal cavity has been explored as an alternative. Early attempts in the 1960's produced equivocal results (Shirer and Downhower 1968), but with improved procedures and equipment, the approach has been applied successfully to several species of mammals (Smith and Whitney 1977, Melquist and Hornocker 1979, Garshelis and Siniff 1983, Davis et al. 1984, Eagle et al. 1984, Green et al. 1985, Madison et al. 1985, Koehler et al. 1987).

Intraperitoneal surgery, however, involves a number of risks, including the stress of anesthesia and surgery (Smith and Whitney 1977, Smith 1980), postoperative infection (Eagle et al. 1984, Green et al. 1985), incision dehiscence (Melquist and Hornocker 1979, Smith 1980, Eagle et al. 1984, Koehler et al. 1987), and physical blockage of internal organs by the transmitter (Guynn et al. 1987, Koehler et al. 1987). Moreover, effects of implanted transmitters on survival, growth, and reproduction have been suspected, although these suspicions appear unfounded for some species (Smith and Whitney 1977, Smith 1980, Eagle et al. 1984, Madison et al. 1985, Reid et al. 1986, Guynn et al. 1987, Koehler et al. 1987).

Since 1983 I have used intraperitoneally implanted radio transmitters to study dispersal in the yellow-bellied marmot. Previous attempts to attach transmitters to marmots, by collars, harnesses, or subcutaneous implants, were problematic (Downhower 1968, Thompson 1979). I describe a successful surgical procedure and assess the effects of implants on survival, growth, and reproduction of marmots.

G. L. Florant showed me the surgical technique, and K. B. Armitage generously provided unpublished data and helped in many ways. M. P. Bray trapped animals and assisted with surgery. K. B. Armitage, G. L. Florant, R. S. Hoffmann, and N. A. Slade kindly reviewed the manuscript. Financial support was provided by grants from Sigma Xi, the Theodore Roosevelt Memorial Fund of the American Museum of Natural History, the American Society of Mammalogists, the Rocky Mountain Biological Laboratory, the Lee R. G. Snyder Memorial Fund, and the University of Kansas; by a Graduate Honors Fellowship and a Graduate Summer Fellowship from the University of Kansas; and by a University of Kansas General Research Grant and National Science Foundation grants DEB81-21231 and BSR86-14690 to K. B. Armitage.

METHODS

I implanted transmitters in marmots living in the upper East River Valley near Rocky Mountain Biological Laboratory (2,900 m elevation), Gunnison County, Colorado. Marmots in this area have been the subject of a long-term study (Armitage 1986) each summer since 1962 were live-trapped, weighed, dye-marked for individual recognition, and released. Young of the year were trapped soon after emergence from their natal burrow and identified permanently with numbered ear tags. Most animals were retrapped and reweighed periodically through the summer.

In my study, marmots were trapped and taken to a nearby laboratory maintained at 16–18 C, then weighed, given an intramuscular injec-

tion of antibiotic, and anesthetized with an intramuscular injection of ketamine hydrochloride (dosage = 100 mg/kg). After immobilization, animals were secured in a dorsal recumbent position, all hair was shaved from the area around the site of the incision, and the skin was cleaned thoroughly with povidone-iodine scrubs. Tools and transmitter were soaked in povidone-iodine solution for 12 hours before surgery, and sterile gloves were worn.

I made a 4-cm diagonal incision in the skin low on the left side of the abdomen, over the juncture between the rectus abdominis and external oblique muscles. A 3-cm incision was then made between these 2 muscles and into the peritoneal cavity. This site offered several advantages, including little or no bleeding, protection from contact with the substrate during healing, and an alternate entry site on the right side of the abdomen that facilitated subsequent surgery to replace transmitters. The transmitter was inserted and floated freely in the peritoneal cavity. Each incision was closed with a simple interrupted pattern of 3-0 synthetic, absorbable sutures spaced 4 mm apart, then irrigated liberally with povidone-iodine solution. Additionally, the skin closure was coated with an antibiotic ointment. Animals were held overnight, then examined for loose sutures and signs of infection, given another injection of antibiotic, and released.

Two transmitter designs were used, both of them constructed as sealed cylinders with internal antennas. Transmitters implanted in 1983 and 1984 (Wyo. Biotelemetry Inc., Longmont, Colo.) measured 16 × 88 mm, weighed 31 g, and were sealed in clear epoxy; all these transmitters failed shortly after implantation. Transmitters implanted thereafter (Custom Telemetry and Consulting Inc., Athens, Ga.) measured 21 × 90 mm, weighed 35 g, and were coated with surgical-grade beeswax. Transmitter weight never exceeded 4% of animal weight. After 1984 transmitters had an expected life of 30 months (pulse rate = 30/min) and a range, under excellent conditions, of 2–5 km using a hand-held 4-element Yagi antenna.

I located marmots almost daily following release. Survival was calculated on the basis of number of animals alive 30 days after implantation, allowing ample time for complete recovery from surgery. Most implanted animals were yearlings, and calculations of growth rates were restricted to animals of this age class that were recaptured ≥20 days after surgery but before onset of hibernation. The difference between weights at recapture and at surgery, less transmitter weight, was divided by the number of days elapsed to determine mean daily weight gain. Almost all yearlings captured from 1983 to 1988 were implanted, so for a control group I used yearlings captured in the study area from 1979 to 1982 for which ≥2 weights were recorded ≥20 days apart (K. B. Armitage, Univ. Kansas, unpubl. data). Reproduction of mature (≥2 yr old) females that carried transmitters during pregnancy was indicated by emergence of a weaned litter at the female's burrow.

RESULTS

I implanted transmitters in 183 marmots; 146 were yearlings that weighed a mean of 1.3 kg (range = 0.8–2.2 kg) when implanted. The remainder were adults weighing ≤4.3 kg. Replacement of failed or expired transmitters required ≥1 additional surgery for 73 animals; 24 animals underwent ≥3 surgeries, and 1 animal was operated on 7 times during 4 summers. I performed 300 surgeries.

The time required for surgery, from injection of ketamine hydrochloride until the animal was returned to its cage, averaged 28 minutes (range = 16–64 min). Most surgeries, particularly those on animals receiving transmitters for the first time, required 20–25 minutes.

Marmots usually became fully immobilized 2–3 minutes after injection and remained so for 30–45 minutes. Some animals, notably those implanted with transmitters after midsummer, required ≥1 additional injection of ketamine hydrochloride (≤210 mg/kg aggregate dosage) to effect complete immobilization. Addition of an equal volume of sterile physiological saline to the injection of ketamine hydrochloride (G. L. Florant, Swarthmore Coll., pers. commun.) improved late-summer effectiveness.

Besides the increased dosage requirements for some animals, problems associated with the use of ketamine hydrochloride were limited to induction of torpor in 1 animal that underwent 2 surgeries on consecutive days. The day after the second surgery, the animal was discovered in torpor (body temp = 18.5 C; heart rate = 36 beats/min, 8 respirations/min). The animal recovered after being placed in an environmental chamber set hourly at 2 C above body temperature, underwent 2 more surgeries within the

next 2 months, then was killed by a predator 1 year later.

Marmots appeared fully recovered from anesthesia by about 1 hour after surgery, and subsequent recaptures indicated healing was completed in about 1 week. Marmots never chewed or scratched sutures; indeed, marmots in the lab and in the field seemed oblivious to the incision.

Surgery to replace transmitters often revealed a thick, fibrous, sometimes highly vascularized membrane encasing the transmitter. Such transmitters were successfully recovered by making a scalpel incision in the membrane at 1 end of the transmitter.

Fates of all but 11 animals were known 30 days after surgery: 4 were killed by predators, 5 died of accidents unrelated to surgery, 3 died of uncertain causes that may have been surgery-related, and the remainder were alive and behaving normally. Among the 3 animals that died of uncertain causes, 1 weakened soon after surgery and died in the laboratory 3 days later after failing to respond to antibiotics. A necropsy found no sign of infection or of physical obstruction by the transmitter, but did reveal an infestation of ectoparasites. The animal probably was somewhat debilitated before implantation, and the added stress of surgery may have led to contraction of pneumonia. The other 2 animals died of unknown causes in their burrows 1–3 weeks following surgery. Excluding animals whose fates were unknown or who died of known causes unrelated to surgery, survival rates were 99% on the basis of number of surgeries (n = 280), 98% on the basis of number of animals (n = 163), and 100% for animals implanted >1 time (n = 64).

Growth rates of 73 implanted yearlings averaged 21 g/day, identical to the mean growth rate of 54 yearlings without implants. Thirty adult females carried transmitters 1–4 years each, for a total of 56 possible pregnancies. Twenty-nine litters emerged aboveground; the pregnancy rate of implanted females (0.52) was similar to the 22-year mean (0.48) for nonimplanted females in the study area (Armitage 1986). Litters produced by implanted females averaged 4.3 young, very close to the 22-year mean of 4.2 young for nonimplanted females in the study area (Armitage 1986).

DISCUSSION

Surgical procedures used in this study were simple, effective, and trouble-free. Although achieving full immobilization occasionally was a problem and torpor was induced once, ketamine hydrochloride proved to be a safe and effective anesthetic, despite dosages much greater than those typical for other mammals (Wright 1983). Infection was never a problem; the few mild inflammations that appeared around the incision were treated successfully by holding the animals an extra day and administering additional antibiotic by injection and by topical ointment. Individual sutures occasionally failed shortly after surgery, but the use of a simple interrupted pattern maintained closure until failed sutures were discovered and replaced the following day. Marmots never disturbed sutures, a response consistent with some species (Koehler et al. 1987) but not others (Smith 1980, Eagle et al. 1984, Koehler et al. 1987).

Encapsulation of transmitters in tissue occurred in marmots and in other species (Eagle et al. 1984, Green et al. 1985, Guynn et al. 1987), but posed no discernable difficulties to the marmot or during transmitter removal. Transmitter adhesion to internal organs, which probably caused the death of an implanted beaver (*Castor canadensis*) (Guynn et al. 1987) and prevented transmitter recovery in an implanted Franklin's ground squirrel (*Spermophilus franklinii*) (Eagle et al. 1984), was never observed in marmots.

High survival of implanted marmots is consistent with results from other mammals; a few animals may be lost initially (Eagle et al. 1984, Koehler et al. 1987), but once procedures are refined, survival of implanted animals is very high (Koehler et al. 1987) or indistinguishable from that of nonimplanted animals (Smith and Whitney 1977, Smith 1980, Eagle et al. 1984). Replacement or recovery of transmitters has been attempted in several species (Eagle et al. 1984, Green et al. 1985, Koehler et al. 1987). Serial implants may not be suitable for some species (Green et al. 1985), but results for yellow-bellied marmots and for 3 other mammals (Koehler et al. 1987) indicate there is no effect on survival. Green et al. (1985) found that the necessity of cutting through scar tissue impeded surgery only slightly in serial implants; similarly, among 24 yellow-bellied marmots implanted ≥3 times, cutting through scar tissue increased surgery duration somewhat and reduced minor bleeding, but posed no serious difficulties.

Previous reports have shown that reproduction can occur in implanted females, but quantitative evaluation of implant effects was lacking

in most cases (Garshelis and Siniff 1983, Eagle et al. 1984, Green et al. 1985, Reid et al. 1986, Guynn et al. 1987). Two studies, however, which did determine effects on pregnancy rate and litter size (Smith 1980, Madison et al. 1985) reported findings that agree with my results; implants did not affect pregnancy rate or litter size. Similarly, the absence of any effect of implants on subsequent growth rates of marmots is in agreement with all other studies that have compared growth rates of implanted and nonimplanted animals (Smith 1980, Eagle et al. 1984, Madison et al. 1985).

Intraperitoneal implantation of transmitters was first introduced as a possible alternative for those species in which radio collars were infeasible. Early reports of efficacy were largely qualitative and established that implanted animals did survive surgery and that some of them subsequently bore young. My results and those of other recent studies establish quantitatively that intraperitoneal implants do not discernably affect survival, growth, or reproduction. Thus, intraperitoneal implants are an alternative to radio collars for marmots.

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