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SURGICAL IMPLANTATION OF RADIO TRANSMITTERS IN ARCTIC FOXES (*ALOPEX LAGOPUS*) ON SVALBARD, NORWAY

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Abstract: Twelve captive wild-caught adult arctic foxes (*Alopex lagopus*) were anesthetized a total of 24 times for an equal number of surgical procedures involving implantation of heart rate (HR) and core body temperature transmitters (T_b) between October 1995 and April 1997. Xylazine–ketamine and medetomidine–ketamine anesthesia was used, resulting in an unacceptably high death rate. One out of four foxes anesthetized with xylazine–ketamine died, whereas two of nine foxes anesthetized with medetomidine–ketamine died out of a total of 20 surgical procedures. Durations of the surgeries for implantation of T_b transmitters and HR transmitters were 73 ± 7 min and 95 ± 13 min, respectively.

Key words: *Alopex lagopus*, arctic fox, ketamine, medetomidine, xylazine, radio transmitter.

INTRODUCTION

The arctic fox (*Alopex lagopus*) has a circumpolar distribution. It lives above the tree line in alpine areas in Fennoscandia, on the tundra mainland of arctic Eurasia and North America, and on islands in the Arctic, North Atlantic, and North Pacific oceans and ranges widely over the pack ice. On the Svalbard archipelago, Norway, these foxes experience extreme contrasts in light and temperature, and periodic limitations of food availability. The sun remains above the horizon from mid April to late August, resulting in 24 hr of daylight. In contrast, the sun is below the horizon from late October to mid February, which results in 24 hr darkness from mid November to the end of January.[8] Food is abundant during the summer (May–July) and sparse during winter (November–March). The arctic fox, in spite of its small body size, manages to overcome the extreme variations in its environment and survive year-round in the high Arctic—a remarkable feat.

Little information has been published on the physiologic adaptations of the arctic fox to these conditions. Before studying physiologic adaptations in free-ranging animals, basic standardized examinations should be carried out in the laboratory. Two important physiologic parameters, heart rate (HR) and core body temperature (T_b), can be monitored in the species using radiotelemetry, although the small transmitters have short transmission ranges and brief battery life. Effective surgical protocols and techniques for the implantation of these transmitters in arctic foxes are needed.

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Xylazine has been the most commonly used α_2-adrenoceptor agonist for sedation and immobilization of animals.[13] The newer α_2-adrenoceptor agonist, medetomidine, which is more selective and potent than xylazine, has dose-dependent sedative, analgesic, and muscle-relaxing properties in canids.[13,16] However, a complete and reliable immobilization requires the addition of a potent anesthetic agent such as ketamine.[12,16] Medetomidine–ketamine combinations have been used successfully in a wide range of domestic and nondomestic mammals[12,15] including such canids such as the gray wolf (*Canis lupus*),[9,16] red wolf (*Canis rufus*),[23] and farmed blue fox (*Alopex lagopus*).[11] Only one study has used medetomidine and ketamine in free-ranging arctic foxes.[1]

Our study evaluated anesthesia induced by xylazine–ketamine and medetomidine–ketamine in arctic foxes and sought to develop a reliable technique for the surgical implantation and replacement of HR and T_b transmitters. The animals implanted with the transmitters were later used in studies to investigate the physiologic adaptation of the animals to high arctic conditions.[3–6]

MATERIALS AND METHODS

Animals

Twelve 2.8–5.2 kg adult arctic foxes, including 1 female and 11 males, were captured between 1993 and 1996 in baited live traps near Ny-Ålesund (78°55′N, 11°56′E), Svalbard, Norway. Two of the foxes (all males) were captured in 1993, six in 1994 (five males, one female), two in 1995 (all males), and two in 1996 (all males). The foxes were held individually throughout the year in outdoor adjacent wooden-framed cages (2.5-m long × 2-m wide × 2-m high) at the Field Research Station of the Norwegian Polar Institute in Ny-Ålesund, Svalbard, Norway. Foxes were held in captivity for 28 ± 14 mo (range: 4–51). The cage walls, floor, and roof

Table 1. Ambient temperature (T_a) of the outdoor cages, body weight (BW), number of heart rate (HR) and core body temperature (T_b) transmitters implanted, and number of surgeries carried out in 12 arctic foxes on Svalbard in 1995, 1996, and 1997.

Measure	Oct 1995 (n = 9)	Apr 1996 (n = 8)	Apr 1997 (n = 7)
T_a (°C)	−6 to −13	−9 to −13	−3 to −11
BW (kg)	4.0 ± 0.7	4.0 ± 0.7	4.0 ± 0.8
(Range)	(3.1–5.2)	(3.1–5.2)	(2.8–5.0)
No. of HR transmitter implanted	4	3	5
No. of T_b transmitter implanted	4	3	0
No. of transmitters removed[a]	—	—	2
No. animals having first procedure	9 initial implantations (1 died)	2 initial implantations	1 initial implantation
No. of animals having second procedure	—	6 replacements (2 died)	2 replacements
No. of animals having third procedure	—	—	4 (two replacements, two removals)

[a] Transmitters removed = removal only of previously implanted transmitter.

were covered with a plastic-coated wire mesh netting, and inside each cage was a wooden kennel (0.5-m long × 0.5-m wide × 1-m high). Dry food (FK-Revepellets, Felleskjøpet, Norway) softened in water, and water were provided ad lib. Freezing of food and water was prevented during the winter by use of thermostatically controlled heating elements in the foodbox. Ambient temperatures in the outdoor cages at the time of the year during which the surgical procedures were carried out are shown in Table 1.

Surgical implantation

All surgical procedures were performed at the field research station in Ny-Ålesund, Svalbard, Norway. A room adjacent to the outdoor holding facility was used as a field operating theater. Temperature in the surgical suite was maintained at 20–25°C. A total of 24 anesthesia–surgical procedures was performed from 1995 through 1997, including transmitter implantations, transmitter replacements, and transmitter removals (Table 1). Anesthesia and surgical implantation of transmitters were carried out in nine foxes in October 1995 (in 1 female that died under anesthesia and in 8 of the 11 males). In April 1996, eight male foxes had surgical procedures performed (six of these males had their first surgical implantations in 1995, and these six male foxes had their transmitters replaced, whereas the remaining two had new transmitters implanted). In April 1997, seven male foxes had surgical procedures performed (five had implantations, and two had transmitters removed but not replaced). Four of these males had transmitters initially implanted in 1995, replaced once before in 1996. Of these four, two had the transmitter replaced a third time, and two had a transmitter removed but not replaced in 1997. Two of the seven males had transmitters initially implanted in 1996; both the males had the transmitter replaced in 1997. One of these seven males had a HR transmitter implanted for the first time. All surgery involving the implantation of HR and T_b radio transmitters was performed under aseptic conditions and under general anesthesia. The foxes were fasted overnight with free access to drinking water before each anesthesia and surgery. The animals were weighed approximately 24 hr before surgery.

In 1995, four of the nine surgeries (involving one female and three males) were performed with an anesthetic mixture of xylazine (Rompun® 20 mg/ml, Bayer AG, Leverkusen, Germany; 1.2 mg/kg, i.m.) and ketamine (Ketalar® 50 mg/ml, Parke-Davis, S. A. Barcelona, Spain; 25 mg/kg, i.m.)[10] by hand injection while the animals were under manual restraint in their cages. The remaining five surgeries performed in 1995, and all those performed in 1996 (n = 8) and 1997 (n = 7), used an anesthetic mixture of medetomidine (Domitor® 1 mg/ml, Orion Corporation Animal Health, Turku, Fin-

land; 0.05 mg/kg, i.m.) and ketamine (Ketalar® 50 mg/ml, Parke-Davis; 3 mg/ml, i.m.)[11] injected together into the thigh while the animals were in their outdoor holding cages. The immediate preanesthetic condition and the time from injection to first sign of sedation (FSS), lateral recumbency (LR), and complete immobilization (CI) were recorded in foxes anesthetized with medetomidine–ketamine only. The first signs of sedation involved lowering of the head, reduced alertness, and slight swaying while standing, whereas LR was characterized as permanent lateral recumbency and CI as no reaction to handling. The foxes were brought indoors to the operating theatre after CI was reached outside, and a catheter (0.8/25 mm, BOC Ohmeda AB, Helsingborg, Sweden) was inserted in the cephalic vein to facilitate administration of supplemental anesthetics as required. This i.v. line was kept open with a continuous slow infusion (2–3 ml/min) of physiologic saline. Immediately after the induction of anesthesia, the animals were given a prophylactic injection of procaine penicillin and dihydrostreptomycine (3 ml of Proca-Mycin vet., 200 mg procaine penicillin + 250 mg dihydrostreptomycin/ml; Alpharma, Oslo, Norway, i.m.).

Rectal temperature (T_r; Fluke 2176A, multi-point digital thermometer, Fluke Norge AS, Postboks 6054 Etterstad 0601, Oslo, Norway) and HR (ECG, diascope DS 521, S&W Medico Teknik A/S, Albertslund, Denmark) were monitored continually during surgery. Respiratory rate (RR) was determined sporadically by counting thoracic excursions. Assessment of anesthetic depth was based on loss of palpebral reflexes and on response to pinching of the skin between the toes. Peripheral circulatory status was assessed by subjective monitoring of mucus membrane color. Equipment for intubation and pulmonary ventilation was available in case of an emergency. Time of occurrence of each event was recorded after the initial dose of the anesthetic—for FSS, LR, CI, total time under anesthesia, and for changes in anesthetic depth—and when supplemental dose of anesthesia was administered. In addition, the times of occurrence of miscellaneous events such as vomiting or tonic convulsions were also recorded. Supplemental doses of the same anesthetic combination that was given initially to a particular animal were administered when that animal reacted to tactile stimuli (presence of palpebral or interdigital reflex [or both]). Each supplemental dose was equivalent to 20% of the initial anesthetic dose.

Radio transmitters

The 6.3-cm-long × 2.3-cm-wide, 44 g radio transmitters (DataCol 5.0, Mini Mitter, Oregon 97707, USA) constituted approximately 1% of a fox's body weight. The temperature transmitter, model VHF-T-1, and HR transmitter, model VHF-C-1, were equipped with lithium batteries (2,000 and 1,600 mAh) that could last for up to 5 mo and had signal ranges of at least 100 m. A T-shaped dipole antenna (ANT-1; Mini Mitter, Oregon 97707, USA) and a telemetry receiver (TR-2; Telonics, Arizona 85204-6699, USA) received the transmitter signals. A cable supplied with the receiver transmitted the signals to a computer equipped with DataCol 5.0 hardware and software; the latter was used for collection, storage, and display of data. Table 1 gives an overview of the transmitters implanted in 1995, 1996, and 1997. The HR transmitters came equipped with two silicone-coated electrodes. The electrodes were cut to a predetermined length (9 and 6 cm or a length that gave a total separation of the electrode tips of approximately 12–15 cm). Approximately 2 cm of the silicone insulation was removed from the distal (free) end of each electrode. The exposed electrode wire was then bent back on itself to form a small noose-shaped loop. To prevent the loop from opening, a small piece of silicone tubing was placed on top of the bare wire, about 1 cm behind the loop (Fig. 1a). Before implantation, the thin piece of silicone tubing was expanded by soaking it for a few minutes in xylene. When the xylene evaporated, the silicone tubing shrunk back to its original size. The mersilene-enclosed transmitter (see below) was then disinfected by placement in 70% alcohol for 2 hr before surgery.

All the eight transmitters implanted in 1995 and five implanted in 1996 were placed in bags of mersilene-net (Ethicon GmbH & Co. KG, Norderstedt, Germany) to ensure firm adhesion to the abdominal wall through ingrowth of connective tissue. However, because it was necessary to replace the old transmitters with new ones, this turned out to be impractical. The extensive ingrowth of connective tissue on the mersilene-netting, which, in some cases extended to other organs such as the liver, spleen, and stomach, caused excessively vascularized tissue to grow around the transmitter and thus caused excessive hemorrhage. Therefore, radio transmitters were implanted without the mersilene net in the last fox in 1996 and in five animals in 1997. Instead, a thick multifilament, nonabsorbable suture (Mersilence® Ethicon 1 UPS) that was formed into three parallel belts around each transmitter was used. Each belt had two small loops on opposite sides of the transmitter to facilitate attachment to the abdominal wall (Fig. 1c).

Surgery

The animal was placed in dorsal recumbency, and the legs were secured to the table. An area measuring 10 cm × 5 cm caudal to the umbilicus was prepared for surgery. The fur was clipped, and the exposed skin was shaved and disinfected with chlorhexidine–ethanol (Klorhexidin 5 mg/ml, Nycomed Pharma AS, Oslo, Norway). The animal was then covered with a sterile surgical drape. Each animal received only one type of transmitter at a time. No animal ever had both types of transmitters implanted simultaneously.

A ventral midline incision was made to approach the abdominal cavity. On both sides of the midline incision, the skin was dissected from the s.c. tissue laterally for a distance of about 2 cm. Before the operation, four absorbable sutures strands (0.48 mm, Ethicon Chrom Catgut) were attached to the four corners of the mersiline-netting surrounding the transmitter. Atraumatic needles were attached to the free end of each of the four suture strands. These suture strands were used to anchor the transmitter in a stable position abutting the inside wall of the abdominal cavity. The orientation of the transmitter inside the abdominal cavity was such that two of the free suture strands lay toward the right side and two toward the left side of the animal. With the aid of the atraumatic needles the suture strands were passed completely through the abdominal wall from the inside to the outside. The exit sites were located at a distance of about 1.5 cm lateral to the midline, i.e., the sutures did not pass through the skin. The midline incision in the abdominal cavity was closed as a single layer with simple interrupted absorbable sutures (0.48 mm, Ethicon Chrom Catgut). After the closure of the abdominal cavity, the transmitter was lifted into its final position abutting the inside wall of the ventral abdominal cavity by gently pulling the free ends of the four anchoring sutures that had been previously passed through the abdominal wall. The transmitter was then held in place by keeping the strands taut and then tying together the two respective right- and left-hand suture pairs. Care was taken that the suture knots lay to the side of the midline incision.

The HR transmitters with their two silicone-covered electrodes were implanted into the abdominal cavity in a similar fashion. The two HR electrodes exited the abdominal cavity through the abdominal incision. These two electrodes were then guided through s.c. tunnels to their final position. Two electrode placements under the skin were used (Fig. 1b). In one animal, the first electrode was placed under the skin above the sternum, whereas the second was positioned on the inside of the left axilla. In the 11 other surgical procedures both electrodes were fixed in a midline position, one in an anterior position and the other in a posterior position, 1 cm off midline, with approximately 15 cm electrode separation.

In 3 of the 12 HR transmitter implantations, the tips of the electrodes were located by palpation of the skin. The skin overlying the electrode was shaved, and a small skin incision was made. The exposed electrode tip was sutured to the underlying tissue with an absorbable suture. In four of the HR implantations, the electrodes were not anchored, and in five implantations the leads were sutured with three stitches to the underlying tissue with a nonabsorbable suture. External registration of HR using surface needle electrodes was used to control the placement of the implanted electrodes to ensure that the HR transmitters were functioning correctly.

After final placement of each transmitter, the skin incision was closed by an interrupted horizontal mattress pattern with nonabsorbable, multifilament sutures (Mersilence® 2-0 USP, Ethicon). No postoperative analgesics were administered. The foxes were kept indoors in small cages for 1–2 days for recovery, with regular observations before being returned to their outdoor holding cages.

RESULTS

One fox, a female, anesthetized with xylazine–ketamine died 80 min after the beginning of the first surgery in 1995, whereas two male foxes anesthetized with medetomidine–ketamine died 30–35 min after the beginning of surgery in 1996 (during the second procedure performed on each of these individuals). Necropsies were not performed.

After administration of medetomidine–ketamine, FSS occurred within 1.5 ± 0.4 min, LR after 2.6 ± 0.7 min, and CI after 6.8 ± 1.3 min. These parameters were not recorded in animals anesthetized with xylazine–ketamine. In one medetomidine–ketamine immobilization, the initial dose was not sufficient to induce anesthesia nor were six supplemental doses of medetomidine–ketamine given over the next 1.5 hr. The total supplemental dose given to this fox was 0.06 mg/kg medetomidine and 3.6 mg/kg ketamine, or 1.2 times the initial dose. Further procedures were not performed, and the animal was released into its outdoor holding cage. Another animal became restless after the initial dose, running and jumping intensively in its cage, but reached CI first after 18 min. It was given a supplemental dose of the anesthetic 3 min after reaching CI. Two of the four foxes that were given xylazine–ketamine vomited shortly after drug ad-

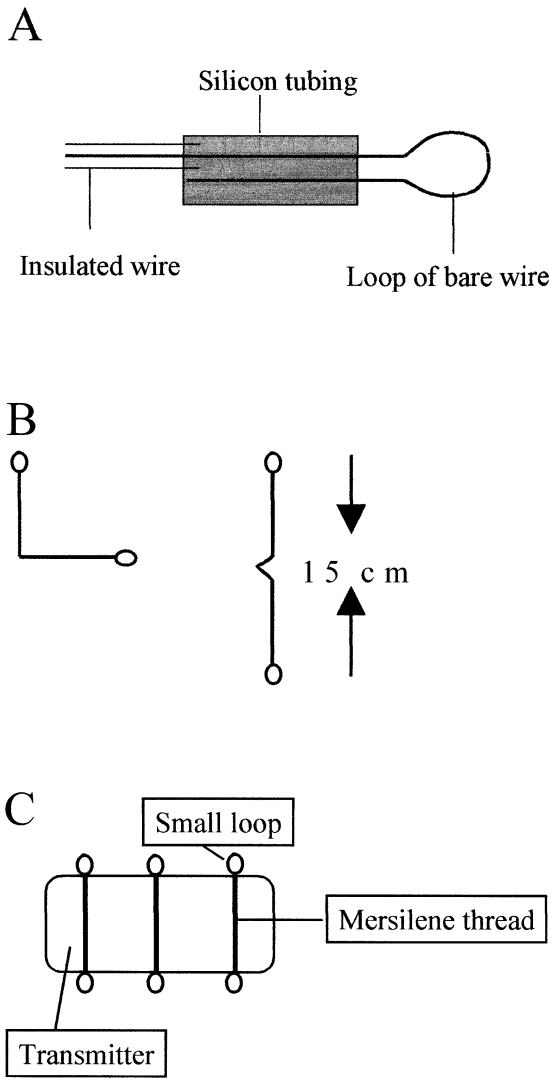

Figure 1. Illustration of how the electrode wire's distal end was prepared to form a nonopening loop before implantation **A.** Illustration of the two different electrode placements under the skin. **B.** Illustration of how the three parallel mersilene thread belts were formed around each transmitter, showing the position of the small mersilene loops on opposite sides of the transmitter, which were used as anchoring points to facilitate attachment to the abdominal wall **C**.

ministration. One of these also had tonic convulsions during the surgery. One of the four animals that was given xylazine–ketamine spontaneously recovered during surgery, but supplemental anesthetic quickly reversed this situation. In foxes anesthetized with medetomidine–ketamine, vomiting occurred in 13 of 20 cases (65%) shortly after drug administration. No tonic convulsions or spontaneous recoveries were observed in any of these animals.

Table 2. Ranges and means ± SD for respiratory rate (RR; respirations per minute [rpm]), heart rate (HR; beats per minute [bpm]), HR within 5 min after supplemental doses of anesthesia were administered (HR supl), and rectal temperature (T_r) in °C of arctic foxes during anesthesia and surgery, but before the first incision was made.

	Number of animals	Number of recordings	Range	Mean ± SD
RR (rpm)[a]	4	4	30–36	33 ± 3
HR (bpm)[a]	4	4	105–127	120 ± 10
HR supl (bpm)[a]	3	3	117–130	123 ± 7
T_r (°C)[a]	4	4	37.5–39.5	38.7 ± 1.0
RR (rpm)[b]	8	17	24–45	32 ± 6
HR (bpm)[b]	8	18	93–147	119 ± 17
HR supl (bpm)[b]	8	18	97–149	121 ± 16
T_r (°C)[b]	8	18	37.7–40.6	39.0 ± 0.9

[a] Xylazine plus ketamine: 1.2 plus 25 mg/kg, respectively.
[b] Medetomidine plus ketamine: 0.05 plus 3 mg/kg, respectively.

Mean values of RR, HR, HR within 5 min after supplemental anesthesia, and T_r before the first skin incision in foxes anesthetized with xylazine–ketamine and medetomidine–ketamine are given in Table 2. With both xylazine–ketamine and medetomidine–ketamine, HR normally increased briefly within the first 5 min after each supplemental dose of anesthesia (Table 2), being more evident in some foxes compared with others. The mean time from initial administration of the anesthetic combinations to incision of the skin was 38 ± 7 min (range 25–52). From the first incision until the skin was sutured, T_r dropped by 1.1 ± 0.0°C in foxes anesthetized with xylazine–ketamine and by 1.2 ± 0.7°C in foxes anesthetized with medetomidine–ketamine. The time taken from closure of the peritoneum until skin closure was, on average, about 29 min. During the interval between closure of the peritoneum and completion of skin closure (29 ± 15 min), T_r increased by 0.2 ± 0.3°C and 0.7 ± 0.6°C in foxes anesthetized with xylazine–ketamine and medetomidine–ketamine, respectively.

The first surgical implantation, defined as time from initial dose of anesthesia to placement of the last suture, lasted for 73 ± 7 min (n = 6) for T_b transmitters and for 95 ± 13 min (n = 5) for HR transmitters. Implantation of transmitters the second time involved removal of old transmitters for battery change and implantation of new ones and lasted for 92 min for one T_b transmitter and 110 ± 10 min (n = 5) for HR transmitters. The third sur-

gical intervention involved the same procedure as the second and lasted for 112 ± 19 min (n = 4) for HR transmitters, which were the only new transmitters implanted. We experienced no problems with the retraction of the HR electrodes, anchored or not, and the HR signals seemed not to be affected by the location of the electrodes or type of anchoring used.

Apart from the three deaths, all recoveries were uneventful. All foxes were carefully observed for several days after surgery, and daily food intake was recorded. Their activity levels and behaviors were normal. Eight foxes started to eat within 24 hr of surgery and three foxes within 48 hr. All foxes were eating a normal amount of food within 3.3 ± 1.7 days (n = 11) after surgery. Wound sites were not inspected on a daily basis to avoid disturbing the implanted equipment before it was well anchored, and the wounds were healed. At least 6 wk elapsed after surgery before the foxes participated in physiologic experiments for energetic studies.[3–6]

DISCUSSION

Xylazine–ketamine anesthesia caused tonic convulsions, vomiting, and spontaneous recovery. Although there was no published data available in 1996–1997 concerning the use of medetomidine in wild arctic foxes, medetomidine is a good alternative to xylazine in carnivore anestheisa,[12,13,16] and it has been used successfully in farmed blue foxes. We modified the protocols and used published blue fox medetomidine dosages.[11]

Medetomidine potentiates the anesthetic effect of ketamine to a greater extent than does xylazine, reducing the effective ketamine dose by as much as 75%.[13] Mortality has not been reported in previous studies involving medetomidine–ketamine in arctic foxes and farmed blue foxes.[1,11] Necropsies might have helped determine the cause or causes of our three fox deaths.

Medetomidine–ketamine induced effective and reliable anesthesia in the rest of the arctic foxes, except on one occasion when one fox did not achieve a surgical plane of anesthesia even after several supplemental doses. This may have been due to increased handling time of the fox before the drugs were administered. Animals should be kept calm after injection with medetomidine.[14] Redosing, as described in this fox, is not recommended.

One fox with a longer CI time under medetomidine–ketamine anesthesia may have received an s.c. injection of the agents. The dosages of medetomidine (0.05 mg/kg) and ketamine (3.0 mg/kg) used in the present study are comparable with those used successfully in farmed blue foxes[11] and free-living wild arctic fox cubs.[1] Vomiting during medetomidine–ketamine induction has not been reported in farmed blue fox or in arctic fox cubs,[1,11] although it has been seen during recovery in 56% of gray wolves immobilized with the same anesthetic combination.[9]

Mean time to CI after immobilization with medetomidine–ketamine was 6.8 min. This is long when compared with the mean time to CI of farmed blue fox, which was within 2.5 min[11] and of arctic fox cubs, which was within 58–150 sec.[1] However, in approximately 90% of carnivores, the mean time to CI was within 10 min after darting or hand injections with medetomidine–ketamine combinations.[9,13,23]

Potential side effects of medetomidine include bradycardia, decreased cardiac output, hypotension, emesis, hypersalivation, loss of thermoregulatory ability, and decreased respiration rate.[2,15,22] When medetomidine is combined with the dissociative anesthetic ketamine, immobilization is more complete, and the potential for side effects is reduced.[13,19] The RR of adult conscious arctic foxes is about 12 rpm.[3] Our mean RR values of 33 and 32 rpm during immobilization with xylazine–ketamine and medetomidine–ketamine, respectively, agree with values reported under similar anesthetic conditions in red wolves (23–28 rpm and 20–27 rpm, respectively),[23] in farmed blue fox (25–35 rpm), in and arctic fox cubs (55 rpm).[1,11] Similar RR increases have been reported in dogs and river otters.[21,24]

The mean HR values in arctic foxes anesthetized with both xylazine–ketamine and medetomidine–ketamine, 120 bpm and 119 bpm, respectively, are higher than the mean value of 82 bpm measured in conscious arctic foxes.[3] Heart rates were 156–225 bpm in arctic fox cubs anesthetized with medetomidine–ketamine,[1] 60–120 bpm in farmed blue fox,[11] 81–104 bpm in red wolves immobilized with xylazine–ketamine, and 82–99 bpm in red wolves immobilized with medetomidine–ketamine.[23] A small transient increase in HR was also recorded in our animals immediately after the supplemental injection of medetomidine–ketamine. This is not in agreement with previous data in dogs and farmed blue fox, where HR decreased after administration of the same dosages.[11,14] Xylazine–ketamine is also known to cause cardiovascular depression in the arctic fox.[18] However, HR can increase in dogs, red wolfs, and arctic fox cubs receiving α_2-adrenoceptor agonists.[1,22,23,25] Because ketamine has cardiostimulatory properties, the increase in HR might be

due to ketamine's stimulation of the sympathetic nervous system.[20]

Mean T_b in adult conscious arctic foxes is 38.5°C during winter and 38.9°C in summer.[3] The relatively high T_r recorded in some of our immobilized foxes before surgery (38.7 and 39.0°C; Table 2) may be due to excitement associated with manual restraint before injection. In these winter-adapted arctic foxes (i.e., those with winter fur), T_r decreased during xylazine-ketamine– and medetomidine-ketamine–induced immobilization. Similarly, T_b decreased in red wolf immobilized with xylazine–ketamine and medetomidine–ketamine (from 39.9 to 38.8°C and from 39.7 to 38.7°C in 50 min, respectively), farmed blue fox immobilized with medetomidine–ketamine (from 39.5 to 38.5°C in 60 min), and arctic fox cubs immobilized with medetomidine–ketamine (from 39.8 to 39.2°C in 18 min).[1,11,23] Such a decrease is considered as a characteristic effect of the anesthetic used.[15]

Postoperative analgesics, although not administered in this study, should be considered following any similar future surgical procedures.

Transmitter implantation in mersilene-netting should be avoided in relatively small animals where transmitters need to be removed for battery changes because complications may result from extensive ingrowth and vascularization of connective tissue within the netting. This tissue ingrowth was originally intended to take over from the anchoring sutures and permanently bind the transmitter to the inside wall of the abdominal cavity. However, in some foxes, excessive ingrowth extended to the liver, spleen, and stomach. Although the effect of this was unclear, all the animals showed normal behavior in the weeks and months after the surgical procedures, participated in further studies,[3–6] and survived for at least 2 yr after the conclusion of the studies. Connective tissue was much reduced in the foxes implanted without mersilene-netting. Adhesions can cause problems after implantation without mersilene-netting, however. Adhesions were seen in 3 of 10 beavers (*Castor canadensis*) with intraperitoneal transmitters, and one of these died due to intestinal obstruction.[7] Retraction of the HR transmitter leads occurred in silver foxes when the leads were not anchored.[17] However, we experienced no problems with the HR signals or with retraction of the leads. Electrode placement was not affected by handling.[4]

The DataCol 5.0 system has the ability to record T_b and HR over long distances (at least 100 m). Test animals can be placed in large enclosures where they are under less stress. The system gives reliable physiologic data from captive animals. The limited duration of battery life is a problem, however. Studies of annual variation in physiologic parameters may require that transmitters need to be reimplanted in small animals, however. Additionally, T_b and HR data must be recorded by separate transmitters, so two transmitters must be implanted to simultaneously record both parameters. This was prohibited by the size of the arctic fox.

In conclusion, we have demonstrated a method for implanting radio transmitters into the abdominal cavity of arctic foxes for extended periods of time. Although mersilene-netting provided good transmitter anchorage, this material caused excessive amounts of ingrowth of connective tissue, and its use should be avoided. A simpler and shorter attachment procedure is described to overcome this problem. The number of deaths (1 of 4 animals anesthetized with xylazine–ketamine and 2 of 20 surgical procedures with medetomidine–ketamine) cannot be regarded as acceptable. Although it is uncertain as to whether or not these were related to the anesthesia or the surgical procedures (or to both), it is, nevertheless, recommended that alternative anesthetic protocols should be considered for prolonged surgical procedures in this species.

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