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CAPTURE AND MEDETOMIDINE-KETAMINE ANESTHESIA OF FREE-RANGING WOLVERINES (*GULO GULO*)

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ABSTRACT: Capture and anesthesia with medetomidine-ketamine were evaluated in free-ranging wolverines (*Gulo gulo*) immobilized for marking with radiocollars or intraperitoneal radiotransmitters in Norrbotten, Sweden, during early June 2004 and 2005. Twelve juvenile wolverines were captured by hand and injected with 0.14±0.03 mg/kg (mean±SD) medetomidine and 7.5±2.0 mg/kg ketamine. Twelve adult wolverines were darted from a helicopter or the ground, or captured by hand. Adults received 0.37±0.06 mg/kg medetomidine and 9.4±1.4 mg/kg ketamine. Arterial blood samples were collected between 15 min and 30 min and between 45 min and 60 min after drug administration and immediately analyzed for selected hematologic and plasma variables. Hyperthermia was recorded initially in one juvenile wolverine and 11 adults. Rectal temperature, heart rate, and lactate decreased significantly during anesthesia, whereas hemoglobin oxygen saturation, pH, partial pressure of arterial carbon dioxide, and base excess increased. Adult wolverines darted from a helicopter had a significantly higher rectal temperature, higher glucose and hematocrit values, and a lower heart rate than juveniles captured by hand. Impaired arterial oxygenation was evident in all wolverines. This study provides baseline data on physiologic variables in adult and juvenile wolverines captured with different methods and anesthetized with medetomidine-ketamine.

Key words: Acid-base status, anesthesia, arterial blood gases, *Gulo gulo*, immobilization, medetomidine, ketamine, wolverine.

INTRODUCTION

Conservation and management of wildlife populations often involve research that requires immobilization of free-ranging animals. Assessment and improvement of capture and immobilization are important parts of wildlife conservation where veterinary involvement adds strength in a multidisciplinary approach to conservation projects (Karesh and Cook, 1995). In addition, safe handling of wildlife with minimal stress to the animals is imperative ethically and from animal welfare concerns. Few studies describe anesthesia in free-ranging wolverines (*Gulo gulo*), and there is limited information on physiologic variables during anesthesia (Hash and Hornocker, 1980; Ballard et al., 1982; Golden et al., 2002). Ketamine is a dissociative anesthetic that has been used alone for immobilization of wolverines, but its disadvantages include muscle rigidity, excessive salivation, and reaction to painful stimuli (Hash and Hornocker, 1980). In Sweden and Norway, ketamine has been used in combination with medetomidine for anesthesia in free-ranging wolverines since 1998 (Arnemo and Fahlman, 2007). Medetomidine, an α_2-agonist with sedative, muscle-relaxing, and analgesic properties, can counteract some of the side effects of ketamine (Verstegen et al., 1989; Jalanka and Roeken, 1990). Furthermore, the effects of medetomidine can be reversed with the α_2-antagonist atipamezole. Mortality in wolverines anesthetized with medetomidine-ketamine is low; during 210 captures of free-ranging wolverines, no deaths occurred (Arnemo, unpubl. data). However, in addition to low

mortality, safe handling should also ensure stable physiology to minimize the risk of complications.

The capture event and the immobilizing drugs influence the well-being of the animals by altering physiologic variables (Cattet et al., 2003). Physical exertion or resistance during capture can result in elevated body temperature, oxygen depletion, and lactic acid production. Acidosis and hyperthermia can lead to organ failure and death during or after anesthesia (Spraker, 1993). Immobilizing drugs may interfere with the normal respiratory function and lead to respiratory depression and hypoxemia. Arterial blood gases and acid-base status are valuable means for evaluation of the physiologic effects that different capture methods and drugs have on animals (Suzuki et al., 2001). Evaluation should be based on several variables and not on a single value (Kock et al., 1987). Our objective was to evaluate capture and anesthesia with medetomidine-ketamine by assessing physiologic variables in free-ranging wolverines immobilized for marking with radiocollars or intraperitoneal radiotransmitters.

MATERIALS AND METHODS

Study area and animals

The study was conducted in and around the Sarek National Park, Norrbotten, Sweden (Kvikkjokk: 67°00′N, 17°40′E) during early June 2004 and 2005. Twenty-five anesthetic events of 24 free-ranging wolverines were studied. Twelve wolverines were adults (two males, 10 females) and 12 were juveniles (six males, six females) approximately 3 mo old. Body mass ranged from 8.6 kg to 15.2 kg in adults and from 3.4 kg to 7.3 kg in juveniles. Wolverines were anesthetized for radiomarking as part of an ongoing study on wolverine ecology. Eight adult wolverines received intraperitoneal radiotransmitters and global postioning system (GPS) radiocollars, whereas five adults received only GPS radiocollars. All juvenile wolverines received intraperitoneal radiotransmitters. For access to the peritoneal cavity, a ventral midline incision was made using standard surgical procedures (Arnemo and Fahlman, 2007). Approval was given by the Ethical Committee on Animal Experiments in Umeå, Sweden. Anesthesia was carried out at altitudes from 500 m to 1,300 m above sea level; ambient temperature ranged from −5 C to 25 C.

Capture methods, drugs, and darting equipment

We located previously radiomarked adult wolverines and their juveniles by radio tracking or by tracking spoor in the snow from a helicopter. On eight occasions adult wolverines were darted from a helicopter and on three occasions from the ground at or near a rendezvous site (a site where juveniles are left while the female forage). One adult female was anesthetized twice; once each from a helicopter and the ground. For remote injection, 1.5-ml dart syringes with 1.5×25-mm barbed needles were fired from a CO_2-powered rifle (Dan-Inject, Børkop, Denmark) at distances of 1–6 m. Two adult wolverines were dug out of rendezvous sites and captured by hand with a snare pole, and the drugs were hand-injected intramuscularly. For anesthesia, medetomidine hydrochloride (Zalopine®, 10 mg/ml, or Domitor® vet., 1 mg/ml, Orion Pharma Animal Health, Turku, Finland) was used in combination with ketamine hydrochloride (Narketan® 10, 100 mg/ml, Chassot, Dublin, Ireland). Adult wolverines were anesthetized with 4 mg of medetomidine and 100 mg of ketamine (total dose per animal). Juvenile wolverines were dug out of rendezvous sites and captured with a snare pole. After estimation of body mass or being weighed in a canvas bag, juveniles were hand-injected intramuscularly with 0.1 mg/kg medetomidine and 5–10 mg/kg ketamine. Up to four wolverines were captured on the same occasion, and juveniles were kept separately in canvas bags until the drugs were administered and the animals were anesthetized.

When darting adult wolverines from a helicopter, the distance the wolverine moved after it was sighted from the helicopter until it was darted, and the distance it moved from darting until recumbency, was subjectively estimated by the field technician and the pilot. The time from darting until recumbency (induction time) was only recorded in adults, because juveniles were kept in a canvas bag after drug injection. During anesthesia, an eye gel (Viscotears®, CIBA Vision AG, Hetlingen, Switzerland) was applied to the cornea to prevent desiccation, and the animals were positioned in lateral recumbency, but for surgery ($n=20$) they were moved into dorsal recumbency. For analgesia, 4 mg/kg carprofen (Rimadyl® vet. 50 mg/ml, Orion Pharma Animal Health) was administered subcutane-

TABLE 1. Doses in milligrams per kilogram of medetomidine-ketamine (initial doses) and atipamezole used for reversible anesthesia of free-ranging wolverines in Norrbotten, Sweden.

Age and capture method (n)	Medetomidine	Ketamine	Atipamezole
	Mean±SD (Range)[a]	Mean±SD (Range)[a]	Mean±SD (Range)
Adults darted from a helicopter (n=8)	0.37±0.06 (0.26–0.44)	9.4±1.4 (6.6–11.0)	2.05±0.31 (1.67–2.75)
Juveniles captured by hand[b] (n=12)	0.14±0.03 (0.10–0.21)	7.5±2.0 (5.2–11.0)	0.84±0.27 (0.52–1.47)

[a] Two adult wolverines received supplemental drugs leading to a total dose of 0.46–0.55 mg/kg medetomidine and 13.2–16.5 mg/kg ketamine. Five juvenile wolverines received supplemental drugs leading to a total dose of 0.16–0.20 mg/kg medetomidine and 9.8–12.5 mg/kg ketamine.

[b] Captured by hand with a snare pole and hand-injected.

ously preoperatively. To minimize the risk of wound infection, procaine benzylpenicillin and benzathine benzylpenicillin were injected intramuscularly at 100,000 IU/kg (PENI-kél L.A. 15+15, Kela Laboratoria NV, Hoogstraten, Belgium).

Immobilization should permit handling of the animals for fitting of radiocollars and surgery for placement of intraperitoneal radiotransmitters. In case of an inadequate plane of anesthesia or spontaneous recovery, supplemental doses of medetomidine, medetomidine-ketamine, or ketamine were given intramuscularly at 25–100% of the initial dose, depending on the depth and prolongation of anesthesia needed. All wolverines were weighed during anesthesia, and the actual drug doses were calculated in milligrams per kilogram (Table 1).

For reversal of the effects of medetomidine, atipamezole hydrochloride (Antisedan® vet., 5 mg/ml, Orion Pharma Animal Health) was administered intramuscularly at 5 times the dose of medetomidine. The time from darting until injection of atipamezole was recorded. After injection of atipamezole, the animals were left undisturbed to recover in lateral recumbency at the rendezvous site. Postanesthetic survival was followed up by radiotracking.

Monitoring

Respiratory rate was monitored by observation of chest movements. Rectal temperature was monitored with a digital thermometer with continuous reading and a measurement range from 28.9 C to 42.2 C (Welch Allyn Diatek 600, Welch Allyn, Inc., Skaneateles Falls, New York, USA). Animals were placed on an insulated blanket (Fjellduken®, Jerven AS, Odda, Norway) to avoid cooling, unless their rectal temperature was elevated. Hyperthermic animals (rectal temperature ≥40.0 C) were kept directly on the ground and cooled by applying snow to the tongue, axilla, groin and footpads. Heart rate and relative hemoglobin oxygen saturation (SpO_2) were monitored continuously by pulse oximetry, with the pulse oximeter probe attached to the tongue (Nellcor NPB-40 Handheld Pulse Oximeter, Nellcor Inc., Pleasanton, California, USA, or Tuffsat® Pulse Oximeter, Datex-Ohmeda Inc., Madison, Wisconsin, USA). The presence of the toe pinch reflex was monitored.

Arterial blood samples were collected anaerobically for analysis of blood gases, acid-base status, and selected hematologic and plasma variables. One to two samples were collected from each animal between 15 min and 30 min and between 45 min and 60 min after drug administration. In animals undergoing surgery, the first sample was collected before the incision was made, and the second sample was collected approximately 5 min after the incision was closed with sutures. The samples were collected anaerobically from the femoral artery using 0.8×40-mm needles and self-filling arterial syringes with heparin (PICO™ 70, Radiometer Copenhagen, Brønshøj, Denmark). The femoral pulse was palpated in the groin, and the needle was inserted percutaneously into the artery, confirmed by pulsating blood. Firm pressure was applied to the sample site for 5 min postsampling to avoid bleeding. Samples were processed immediately in the field using a portable analyzer and cartridges (i-STAT®1 Portable Clinical Analyzer and i-STAT® cartridges CG4+ and 6+, Abbott Laboratories, Abbott Park, Illinois, USA). Because the i-STAT® analyzer only operates in +16 C to 30 C, it was kept on a warm water bottle in a polystyrene foam box in an insulated cooler bag. The analysis included measured values for pH, partial pressure of arterial carbon dioxide ($PaCO_2$), partial pressure of arterial oxygen (PaO_2), lactate, hematocrit,

sodium (Na), potassium (K), chloride (Cl), urea, and glucose. Blood gas values and pH were corrected to the rectal temperature. Calculated values were provided for actual base excess (BE), actual bicarbonate (HCO_3), arterial hemoglobin oxygen saturation (SaO_2), and hemoglobin. The strong ion difference (SID) was calculated as (Na+K)−(Cl+lactate). The alveolar-arterial oxygen tension difference [$P(A\text{-}a)O_2$] at standard temperature (37 C) was estimated in all wolverines by calculation according to the equation: $PAO_2 = F_IO_2(PB - PH_2O) - (PaCO_2/RQ)$, where PAO_2=partial pressure of alveolar oxygen, F_IO_2=fraction of inspired oxygen (0.21), PB=barometric pressure, PH_2O=saturated vapor pressure for water at 37 C (47 mmHg), and RQ=respiratory quotient (assumed to be 0.8, primarily protein metabolism) (Sjaastad et al., 2003).

Statistical analysis

Physiologic data from adult wolverines darted from a helicopter ($n=8$) and juveniles ($n=12$) were analyzed with a two-way analysis of variance with repeated measures on one factor (Procedure Mixed, SAS® System 9.1, SAS Institute Inc., Cary, North Carolina, USA). Data are presented as mean±SD (range). Differences were considered significant when $P<0.05$. Spearman rank order correlation was used to investigate the correlation between the lactate concentration and the total distance that adult wolverines moved before and after darting.

RESULTS

Recumbency occurred within 5±3 (3–12) min in adult wolverines darted from a helicopter; six were recumbent within 4 min. The distance moved by adult wolverines after they were sighted from the helicopter until darting was 1.5±1.1 km, followed by 0.2±0.2 km after darting. There was no correlation between the distance moved and the lactate concentration ($r_S=-0.02$, $P=0.97$). The initial medetomidine-ketamine dose (Table 1) induced anesthesia in all wolverines except one adult female, which was darted from the ground and required a second drug dose to become recumbent. During anesthesia, two adult and five juvenile wolverines required supplemental drug doses 29±11 (10–41) min after the initial drug administration. Six of these wolverines were undergoing surgery. The five juveniles that required supplemental drugs initially received 0.12±0.03 (0.10–0.16) mg/kg medetomidine and 6.1±1.3 (5.2–8.0) mg/kg ketamine. The seven juvenile wolverines that did not need supplemental drugs received 0.15±0.03 (0.12–0.21) mg/kg medetomidine and 8.4±2.0 (5.8–11.0) mg/kg ketamine, and atipamezole was injected 71±19 (51–93) min after the initial drug administration.

A significant decrease in heart rate and rectal temperature occurred during anesthesia (Table 2). Juvenile wolverines captured by hand had significantly higher heart rate, lower rectal temperature, and lower PaO_2 (temperature-corrected values) than adults darted from a helicopter. The PAO_2 and $P(A\text{-}a)O_2$ (standard temperature) did not differ between adults and juveniles. The PAO_2 was 89±5 mmHg between 15 min and 30 min (Fig. 1) and 82±7 mmHg between 45 min and 60 min after drug injection. The $P(A\text{-}a)O_2$ was 27±8 mmHg between 15 min and 30 min and 11±15 mmHg between 45 min and 60 min after drug injection. Hyperthermia was recorded initially in one juvenile and 11 adults. In six of these adults, temperatures ≥41.0 C were recorded. Of the 11 adults with initial hyperthermia, seven were darted from a helicopter, two were darted from the ground, and two were captured by hand. Hypothermia was recorded approximately 1 hr after initial drug injection in one adult wolverine (rectal temperature 35.0 C) and two juveniles (rectal temperatures 34.4 C).

A significant increase in SaO_2, $PaCO_2$, pH, base excess, and HCO_3 occurred during anesthesia, whereas lactate decreased (Table 2). The pH was significantly lower in adult wolverines than in juveniles. Initially, pH<7.35 was recorded in all wolverines except one juvenile, and pH<7.2 was recorded in five adult wolverines. Three of these adults were darted from a helicopter, one was darted from the ground, and one was captured by hand.

TABLE 2. Physiologic variables, arterial blood gases, and acid-base status during medetomidine-ketamine anesthesia in adult wolverines darted from a helicopter ($n=8$) and juvenile wolverines captured by hand[a] ($n=12$) in Norrbotten, Sweden. Mean±SD (range) is presented.

Variable[b]		Adult wolverines		Juvenile wolverines	
		15–30 min[c]	45–60 min	15–30 min	45–60 min
Respiratory rate	(breaths/min)	37±11 (24–56)	30±8 (20–44)	29±14 (8–52)	35±11 (16–52)
Heart rate[de]	(beats/min)	125±13 (102–137)	102±18 (75–131)	168±22 (114–200)	142±24 (91–167)
Rectal temperature[de]	(C)	40.1±0.8 (38.8–41.0)	37.3±1.1 (35.0–38.5)	38.6±0.8 (37.5–40.5)	36.3±1.1 (34.4–37.8)
SpO_2[e]	(%)	85±3 (80–89)	90±3 (86–93)	82±5 (74–89)	90±3 (86–95)
SaO_2[e]	(%)	89±1 (88–91)	92±2 (89–96)	87±5 (76–92)	93±2 (90–95)
PaO_2[d]	(mmHg)	81±6 (69–88)	75±13 (62–100)	66±9 (51–79)	69±4 (63–73)
	(kPa)	10.8±0.8 (9.2–11.7)	10.0±1.7 (8.3–13.3)	8.8±1.2 (6.8–10.5)	9.2±0.5 (8.4–9.7)
$PaCO_2$[e]	(mmHg)	38±4 (32–47)	41±4 (34–47)	41±2 (38–45)	43±3 (39–48)
	(kPa)	5.1±0.5 (4.3–6.3)	5.5±0.5 (4.5–6.3)	5.5±0.3 (5.1–6.0)	5.7±0.4 (5.2–6.4)
pH[de]		7.22±0.06 (7.12–7.29)	7.27±0.06 (7.18–7.36)	7.30±0.02 (7.25–7.35)	7.36±0.03 (7.31–7.39)
Lactate[e]	(mmol/l)	3.4±1.8 (1.1–6.8)	1.3±0.6 (0.4–2.0)	2.1±1.2 (1.0–4.2)	0.7±0.4 (0.3–1.7)
Base excess[de]	(mmol/l)	−11±3 (−15 to −6)	−8±4 (13–0)	−6±2 (−9 to −1)	−1±2 (−4 to +2)
HCO_3[de]	(mmol/l)	15±3 (13–21)	19±4 (14–26)	20±2 (17–24)	24±2 (22–27)
SID[e]	(mEq/l)	27±3 (22–32)	31±4 (25–36)	28±3 (22–33)	31±2 (29–35)

[a] Captured by hand with a snare pole and hand-injected with the anesthetic drugs.

[b] SpO_2 = hemoglobin oxygen saturation measured by pulse oximetry; SaO_2 = arterial oxygen saturation calculated by i-STAT®; PaO_2 = partial pressure of arterial oxygen; $PaCO_2$ = partial pressure of arterial carbon dioxide; HCO_3 = bicarbonate; SID = strong ion difference. Blood gas values and pH were corrected to the rectal temperature.

[c] Time period after drug administration.

[d] Significant difference between groups.

[e] Significant difference over time.

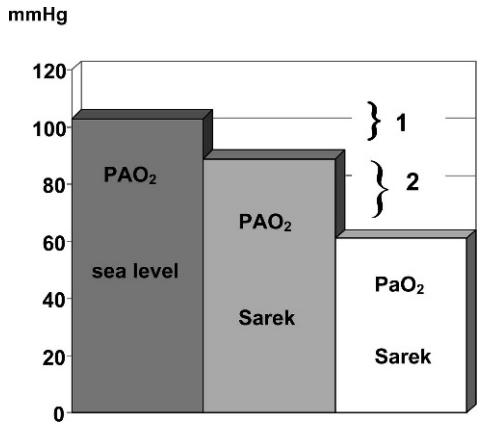

FIGURE 1. The mean alveolar-arterial oxygen tension difference at standard temperature in adult and juvenile wolverines [P(A-a)O_2] 15–30 min after injection of medetomidine-ketamine. Anesthesia was carried out from 500 m to 1,300 m above sea level in Sarek National Park, Norrbotten, Sweden. 1 = altitude influence; 2 = intrapulmonary influence on PaO_2. PAO_2 = partial pressure of alveolar oxygen; PaO_2 = partial pressure of arterial oxygen.

The two adult wolverines that were dug out of rendezvous sites and captured by hand vigorously fought the snare, and their initial lactate concentrations were 2.79 and 5.23 mmol/l, respectively.

In adult wolverines darted from a helicopter, significantly higher values of glucose and hematocrit were recorded compared with juveniles captured by hand (Table 3). In adults darted from the ground, glucose and hematocrit ranged between 13.1 mmol/l and 19.8 mmol/l and between 36% and 56%, respectively, and the range was 12.1–18.2 mmol/l and 48–60% in adults captured by hand.

Atipamezole was injected 76±8 (63–86) min after darting in adults and 68±17 (49–93) min after initial hand-injection in juveniles. First sign of recovery was recorded within 15 min after reversal in 15 wolverines. No mortalities occurred during or within 10 wk after anesthesia.

DISCUSSION

Our study is the first to describe detailed physiologic, hematologic, and plasma variables in anesthetized wolverines. Physiologic differences were identified between adults and juveniles, and over time. Medetomidine-ketamine at the doses used in this study was sufficient for capture and induction of anesthesia in all wolverines but one. However, six of 20 wolverines undergoing surgery for intraperitoneal radiotransmitters required supplemental drug doses during anesthesia. The rapid induction time in adult wolverines in our study was similar to induction reported previously in wolverines immobilized with different drugs (Hash and Hornocker, 1980; Ballard et al., 1982; Golden et al., 2002). We did not observe side effects such as muscle rigidity or salivation, which is common in wolverines immobilized with ketamine alone at 17–26 mg/kg (Hash and Hornocker, 1980). To avoid reaction to painful stimuli, Hash and Hornocker (1980) recommended doses of ketamine >26 mg/kg when used alone for surgery in wolverines. Due to the potentiating effect of medetomidine, the dose of ketamine in our study could be significantly reduced (35–80%) compared with previously used doses (Hash and Hornocker, 1980). Analgesia was provided to wolverines undergoing surgery by the combination of carprofen with medetomidine-ketamine, but the duration of anesthesia was too short in some individuals given our lower doses of ketamine, because signs of spontaneous recovery occurred. Ketamine is short-acting, and the duration of anesthesia is dose dependent (Thurmon et al., 1996). If surgical anesthesia or handling of the wolverine is needed for more than 30 min, we recommend initial use of our higher ketamine doses (up to 11 mg/kg), to avoid the need for supplemental drug doses. The medetomidine doses we used for adult wolverines were high compared with doses used in most other wildlife species (Jalanka and Roeken, 1990). The doses of medetomidine-ketamine used in juvenile wolverines were similar to doses used for surgery in free-ranging European mink (*Mustela lutreola*) and polecats (*Mustela putorius*)

TABLE 3. Hematologic and plasma variables in arterial blood during medetomidine-ketamine anesthesia in adult wolverines darted from a helicopter (n=8) and juvenile wolverines captured by hand[a] (n=12) in Norrbotten, Sweden. Mean±SD (range) is presented.

Variable		Adult wolverines		Juvenile wolverines	
		15–30 min[b]	45–60 min	15–30 min	45–60 min
Sodium[c]	(mmol/l)	143±3 (139–147)	144±3 (140–149)	140±2 (138–144)	140±2 (138–144)
Potassium	(mmol/l)	4.0±0.3 (3.5–4.5)	4.5±0.8 (3.3–5.4)	3.9±0.4 (3.4–5.0)	4.1±0.6 (3.6–5.5)
Chloride[cd]	(mmol/l)	116±3 (111–122)	116±4 (111–123)	114±2 (112–119)	113±2 (112–117)
Urea[e]	(mmol/l)	18.8±6.9 (6.6–29.0)	19.1±7.0 (6.9–29.9)	18.9±5.8 (9.9–26.6)	18.4±4.8 (12.0–24.9)
Glucose[c]	(mmol/l)	13.0±4.3 (7.1–19.7)	11.5±4.0 (6.6–18.2)	8.7±2.0 (4.4–12.6)	8.3±3.1 (3.4–13.0)
Hematocrit[c]	(%PCV)[f]	39±7 (26–49)	40±8 (28–49)	30±2 (27–33)	31±3 (27–35)
Hemoglobin[cd]	(mmol/l)	13±3 (9–17)	14±3 (10–17)	10±1 (9–11)	11±1 (9–12)

[a] Captured by hand with a snare pole and hand-injected with the anesthetic drugs.

[b] Time period after drug administration.

[c] Significant difference between groups.

[d] Significant interaction (group × time).

[e] Significant difference over time.

[f] PCV = packed cell volume.

(Fournier-Chambrillon et al., 2003). Even lower doses of medetomidine in combination with ketamine have been used for immobilization of other mustelids (Arnemo and Soli, 1992; Fernandez-Moran et al., 2001; Thornton et al., 2005).

Hyperthermia, as recorded in 92% of the adult wolverines captured using all methods, was likely a result of physical exertion during the darting procedure or to handling stress when captured by hand. It is important to stabilize the body temperature early during anesthesia because cellular damage in the brain, liver, and kidneys can occur at temperatures above 41 C (Thurmon et al., 1996). Body temperature should be monitored throughout the immobilization period because hypothermia, as recorded in three wolverines, commonly develops in small animals, and if α_2-agonists are used (Arnemo and Soli, 1992; Thurmon et al., 1996).

Heart rate decreased significantly over time in all wolverines. Initial heart rates during anesthesia were similar to resting heart rate, calculated by allometric scaling for the actual body mass of the wolverines (Sedgwick and Martin, 1994). Bradycardia, defined as a 20% reduction below the resting heart rate (Sedgwick and Martin, 1994), was observed in one juvenile and six adult wolverines 45–60 min after initial drug administration. The higher medetomidine doses used in adults might explain the bradycardia, a common cardiovascular side effect of medetomidine (Jalanka and Roeken, 1990).

Hypoxemia can be defined as PaO_2 below 80 mmHg at sea level (Thurmon et al., 1996). In wolverines, PaO_2 was decreased, whereas $PaCO_2$ was in a range that is normal for most species (Thurmon et al., 1996). Because blood gases measured by the i-STAT analyzer at 37 C did not differ between adults and juveniles, the presented difference in PaO_2 (temperature-corrected values) is related to the higher body temperature measured in adults. The alveolar-arterial oxygen tension difference calculated in the present study indicates an impaired pulmonary gas exchange in adults and juveniles. The wolverines were anesthetized at altitudes of 500–1,300 m above sea level, which resulted in a PAO_2 of 89 ± 5 mmHg, compared with approximately 103 mmHg at sea level (Fig. 1). Calculated on mean values, altitude was responsible for approximately 30% of the reduction in PaO_2. The $PaCO_2$ values indicate that ventilation was adequate during anesthesia and that hypoventilation is an unlikely cause of the decrease in PaO_2. Thus, we suggest that the major contribution (ca. 70%) to the decrease in PaO_2 is ventilation-perfusion mismatch, shunt, or diffusion limitation of oxygen. Sedation with α_2-agonists in horses results in decreased arterial oxygenation simultaneously with an increased pulmonary vascular pressure (Marntell et al., 2005). Increased pulmonary arterial blood pressure is suggested to disturb the matching of the pulmonary ventilation and perfusion, resulting in decreased PaO_2 (Marntell et al., 2005). Therefore, if similar changes occur in wolverines anesthetized with medetomidine-ketamine, it would be interesting to evaluate whether a lower medetomidine dose would improve arterial oxygenation. Supplemental oxygen might be beneficial if ventilation perfusion mismatch exists.

Initial decreases in pH, HCO_3, base excess, and SID indicate a metabolic acidemia in adult wolverines. At a $pH<7.2$, the contractility of the heart is decreased, and the susceptibility to ventricular arrhythmias is increased (DiBartola, 2006). Arterial pH between 7.12 and 7.19 were recorded in five adult wolverines captured using all methods. The pH increased over time in all animals, and it was not further impaired by medetomidine-ketamine anesthesia. Although lactate concentration did not differ significantly between adults darted from a helicopter and juveniles captured by hand, the highest lactate concentrations were measured in helicopter darted adults and in the two adults that were captured by hand. Interestingly, the muscular

activity related to struggling when captured by hand seemed to give a similar anaerobic response to the physical exertion related to helicopter darting, because increased lactate concentrations were recorded in wolverines captured with either method.

The significantly higher glucose and hematocrit values measured in adult wolverines compared with juveniles may be drug dose related or a result of capture stress. In animals anesthetized with medetomidine-ketamine, increased blood glucose is frequently recorded, which is probably an effect of α_2-mediated inhibition of insulin release from pancreas (Jalanka and Roeken, 1990). Glucose concentrations and the hematocrit can increase due to stress because adrenaline increases the glucose output from the liver and contracts the spleen, which releases erythrocytes into the circulation. It is possible that the stress level was higher in adults than in juveniles because all adults had been captured at least once before, whereas all juveniles were naïve to capture. An age-related difference in glucose cannot be excluded because young animals can have low glycogen and protein stores and inadequate levels of liver enzymes for gluconeogenesis (Lassen, 2004). Furthermore, a lower hematocrit is common in young animals; in cats, the hematocrit does not reach adult levels until the age of 4 mo, and in dogs at the age of 6–12 mo (Weiser, 1995). The highest glucose value (19.8 mmol/l) was recorded in an adult wolverine that was darted from the ground. The highest hematocrit value (60%) was recorded in another adult wolverine, which was captured by hand. Further study is needed to compare physiologic variables from wolverines captured with different methods and to improve arterial oxygenation during medetomidine-ketamine anesthesia.

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