Note

Application of Oxygen During Medetomidine and Ketamine Immobilization of Wolverines (*Gulo gulo*)

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Chemical immobilization involves risks for study animals. Research indicates that anesthetized Wolverines (*Gulo gulo*) can develop hypoxemia due to drug-induced physiological changes and altitude. We administered supplemental oxygen intranasally at flow rates between 0.5 and 1.5 L/min to Wolverines immobilized by medetomidine and ketamine between ~2110–2880 m in the Rocky Mountains. Following capture in log box traps, we measured hemoglobin oxygen saturation (SpO_2) and rectal temperature before and after application of oxygen using a pulse oximeter and digital thermometer. We determined oxygen flow rates based on the volume required to reach a SpO_2 reading over 90%. We observed initial hemoglobin oxygen saturation below 75%, indicating hypoxemia, for all Wolverines handled. Supplemental oxygen reversed the hypoxemia, increasing hemoglobin oxygen saturation to over 90% within 13 min in all cases. We recommend that supplemental oxygen be provided to immobilized Wolverines anesthetized using medetomidine and ketamine to guard against hypoxemia.

Key Words: Altitude; anesthesia; chemical immobilization; elevation; *Gulo gulo*; ketamine; medetomidine; oxygen; Wolverine

Introduction

Chemical immobilization is critical to many wildlife studies to restrain animals for procedures such as radio-marking or biological sampling. Physiological changes caused by chemical immobilization drugs can carry risks for animals under anesthesia. Wolverines, *Gulo gulo* (Linnaeus, 1758) have been immobilized using several drug combinations including telazol (Golden *et al.* 2002), ketamine and xylazine (Copeland 1996), and medetomidine and ketamine (Quigley 2000; Fahlman *et al*. 2008). Of these, medetomidine is a potent alpha-2 sedative that can cause bradycardia (Virtanen 1989) and decreased partial pressure of arterial oxygen (Caulkett *et al.* 1999). Arterial oxygen saturation (SpO_2) during immobilization of free-ranging Wolverines can decrease due to drug-related physiological changes or due to high altitude. Fahlman *et al.* (2008) presented data indicating that reduced oxygen saturation in Wolverines immobilized using medetomidine and ketamine at their study site in Scandinavia at altitudes of 500–1300 m was partially attributable to drug-induced intrapulmonary changes (70%), and partially due to altitude (30%). Decreased air pressure at higher altitudes can result in decreased oxygen concentration in the lungs leading to lower oxygen saturation in the blood. Generally, arterial hemoglobin oxygen saturation under 90% is considered unfavourable, is indicative of impaired cardiopulmonary performance (McDonnell and Kerr 2007), and can lead to impaired brain function. Researchers and wildlife professionals immobilizing wildlife should also be mindful of the possibility that pulse oximetry may overestimate SpO_2 and miss cases of hypoxemia (Fahlman *et al.* 2010). Administering oxygen to chemically immobilized wildlife will increase oxygen saturation in uncompromised animals and treat or prevent hypoxemia (Fahlman 2014).

The altitude at our study site (2400–3100 m) is significantly higher than the highest immobilization sites in Scandinavia. Thus, in addition to the data presented by Fahlman *et al*. (2008), we hypothesized that Wolverines immobilized with medetomidine and ketamine at our study site would have reduced oxygen saturation and that oxygen saturation could be improved with oxygen from a portable oxygen cylinder. We tested this hypothesis by using a pulse oximeter to record an estimate of SpO_2 of Wolverines immobilized with medetomidine and ketamine before and after intranasal oxygen supplementation.

Methods

As part of a larger study of Wolverine ecology (Inman *et al.* 2012), we captured and anesthetized Wolverines during the spring of 2008 and winter of 2008–2009. Our study area included the Rocky Mountains of Idaho, Montana, and Wyoming (45°N, 111°W). Temperatures during winter captures generally ranged between -20°C and 0°C. During spring, capture temperatures could reach 15°C. Capture altitudes ranged from ~2110–2880 m. We captured adult and subadult Wolverines using log box traps (Copeland *et al.* 1995; Lofroth *et al.* 2008) equipped with trap-transmitters (Telonics, TBT-500, Mesa, Arizona, USA). We also captured juvenile

Wolverines by hand at den or rendezvous sites (Persson *et al.* 2006). We used a variable-powered CO_2 pistol (CO_2 PI, Dan-Inject, Knoxville, Tennessee, USA) or a hand syringe to deliver a dose of ketamine and medetomidine. We injected adult and subadult Wolverines in variable locations (usually in a large mass of muscles towards the rear of the animal) with ~0.34 mg/kg medetomidine + 10.1 mg/kg ketamine (3 mg medetomidine + 100 mg ketamine total dose per animal) and juveniles with ~0.11 mg/kg medetomidine + 3.3 mg/kg ketamine (0.3 mg medetomidine + 10 mg ketamine total dose per animal). When it was safe to handle the Wolverines we examined them, applying eye lubricant and a blindfold fashioned from a section of sock, before recording body temperature, pulse, and respiration rate. We placed Wolverines in synthetic sleeping bags modified to fit a Wolverine with a 1.9 L rubber latex water bottle filled with hot water to retain body heat. We surgically implanted all Wolverines with an intra-peritoneal VHF radio-transmitter (Advanced Telemetry Systems M1255B, M1250B, M1245B, Isanti, Minnesota, USA). We followed handling procedures approved by the Institutional Animal Care and Use Committee, Montana Department of Fish, Wildlife and Parks (IACUC 1-2006, FWP2-2010) as permitted by US Department of Agriculture, Animal and Plant Health Inspection Service (Permits 81-R-0015 and 81-R-0018). Based on age at reproductive maturity for female Wolverines (Persson *et al*. 2006) and the age through which dispersal movements occur, we classified Wolverines of three years or older as adults, Wolverines between one and three years of age as subadults, and Wolverines in their first year of life as juveniles. We estimated adult and subadult Wolverine age by assessing tooth wear and eruption. Juveniles were identified by their body size and presence at den or rendezvous sites.

We delivered compressed, medical grade oxygen using an M6 aluminum oxygen cylinder tank, a CGA 870 0–8 L/min oxygen regulator, and a human neonate size nasal cannulae. We inserted the double cannula fully (~1 cm) into both nostrils of the Wolverines. The cannula was held in place by the blindfold. We administered oxygen intranasally at flow rates between 0.5 and 1.5 L/min. We modified flow rates based on the SpO_2 readings while Wolverines were under anesthesia until SpO_2 readings were greater than 90%. We used an N-20 PA pulse oximeter (Nellcor, Boulder, Colorado, USA) with the probe clipped to the tongue to measure SpO_2. We recorded initial SpO_2 of anesthetized Wolverines as soon as they were safe to handle. We then began oxygen administration and continued recording SpO_2 throughout handling. After initiating oxygen administration, we recorded the time elapsed before reaching a SpO_2 reading over 90%. We continued administering oxygen at flow rates between 0.5 and 1.5 L/min for the duration of handling. We used a continuous read DataTherm II (Geratherm Medical AG, Geschwenda, Germany) digital thermometer to measure rectal temperature and record temperatures at 1 min intervals. Combined, the oxygen cylinder, regulator, hoses, cannula, pulse oximeter, and thermometer weighed 3.2 kg. At such low weights, including these items in capture kits did not impair travel to remote, backcountry capture sites.

Results

We recorded SpO_2 and rectal temperatures during anesthesia using ketamine and medetomidine for two juvenile, two subadult, and one adult Wolverine (Table 1). The initial SpO_2 readings, taken as soon as possible upon handling for all five Wolverines ranged from 49% –74% (mean = 64%). SpO_2 readings rose to over 90% within 2–13 min (mean = 7 min) after administration of intranasal oxygen. After reaching an SpO_2 reading over 90%, readings generally stabilized between 93% and 97%. All rectal temperatures were considered normal, ranging from 36.5–39.2 °C.

Discussion

Wildlife professionals using chemical immobilization have a responsibility to minimize the adverse effects that the capture methods and immobilizing

TABLE 1. Arterial oxygen saturation (SpO_2) and rectal temperatures of Wolverines (*Gulo gulo*) during anesthesia by ketamine and medetomidine.

Sex	Age*	Dosage (mg/kg) Med.†	Dosage (mg/kg) Ket.‡	Air (°C)	SpO_2 (%)§ Initial	SpO_2 (%)§ First >90%	Min.to SpO_2 >90%‖	Rectal Temp. (°C)
F	JV	0.11	3.2	13	74	91	<13	37.4–38.3
M	JV	0.11	3.4	13	61	95	<2	37.9–39.2
M	SA	0.28	8.3	-12	67	93	<5	36.5–37.5
M	SA	0.34	10.2	-9	68	–	<9	38.0–38.3
F	AD	0.39	11.7	-9	49	96	<4	37.7–37.9

* Age classes JV (juvenile), SA (subadult), and AD (adult).
† Medetomidine.
‡ Ketamine.
§ SpO_2: measure of hemoglobin oxygen saturation in the blood by pulse oximetry.
‖ Minutes between first administering oxygen and SpO_2 exceeding 90%.

drugs may have on study animals. Our results suggest that oxygen supplementation for Wolverines immobilized with ketamine and medetomidine at high altitudes can reverse hypoxemia. Each of the five Wolverines we immobilized had initial SpO_2 readings much lower than 90%, indicating severe hypoxemia. All Wolverines in our study had SpO_2 readings equal to or lower than Wolverines at lower altitudes in Scandinavia (Fahlman *et al.* 2008).

The SpO_2 increased after we applied supplemental oxygen to above 90% within 13 min for all Wolverines immobilized. However, we anticipate SpO_2 levels will exceed 90% more quickly when supplemental oxygen flow rates are optimized. The Wolverine that took just under 13 min to reach an SpO_2 reading of 90% (12 min 20 s) was the first to be given supplemental oxygen during our study before we had experimented with different flow rates. Originally, we were concerned that application of compressed oxygen could be problematic at cool temperatures during captures. This is because compressed air cools as it expands, potentially putting Wolverines at risk of low body temperatures. Captures during our study occurred mostly during winter in log box traps where temperatures were frequently below freezing. Given the small body size of Wolverines, we were concerned with the possibility of hypothermia (Fahlman *et al.* 2008). However, after taking steps to retain body heat during immobilization with sleeping bags and hot water bottles, we observed normal rectal temperatures for all five Wolverines treated.

From our experience, we strongly recommend that researchers and wildlife professionals immobilizing Wolverines with medetomidine and ketamine administer oxygen throughout handling. Supplemental oxygen is used to treat or prevent hypoxemia for many wildlife species under anesthesia (Fahlman 2014). If logistics and flight restrictions limit the use of oxygen cylinders in the field, a portable battery-driven oxygen concentrator is another useful source for oxygen that can be used for wildlife immobilization (Fahlman *et al.* 2012). More research is advisable to verify the findings of our study by blood gas analysis, using other drug combinations, and to evaluate minimum effective oxygen flow rates that can maintain SpO2 above 90% consistently. However, our results suggest that Wolverines immobilized at higher altitudes are at risk of hypoxemia. Because medetomidine and ketamine can lead to hypoxemia at any altitude, we recommend intranasal oxygen supplementation for all Wolverines immobilized using these drugs.

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