DOI: 10.7589/2017-12-296

Journal of Wildlife Diseases, 54(3), 2018, pp. 617–621

A Mixture of Butorphanol, Azaperone, and Medetomidine for the Immobilization of American Beavers (*Castor canadensis*)

Annette Roug,[1,4] Heather Talley,[2] Troy Davis,[1] Marilei Roueche,[3] and Darren DeBloois[1] [1]Utah Division of Wildlife Resources, 1594 W North Temple, Suite 2110, Salt Lake City, Utah 84116, USA; [2]Utah Division of Wildlife Resources, 1470 N Airport Rd., Cedar City, Utah 84721, USA; [3]933 Roueche Lane, Kayesville, Utah 84037, USA; [4]Corresponding author (email: aroug@utah.gov)

ABSTRACT: A total of 58 American beavers (*Castor canadensis*) was immobilized with butorphanol, azaperone, and medetomidine (BAM) for the purpose of health assessments, sex determination, and placement of very high-frequency tail transmitters in a subset of animals. Isoflurane gas anesthesia was available to aid with induction when needed, and all animals received supplementary oxygen. Thirty-one beavers immobilized with a mean (SD) dose of 0.65 (0.15) mg/kg butorphanol, 0.22 (0.05) mg/kg azaperone, and 0.26 (0.06) mg/kg medetomidine did not require supplemental isoflurane during induction and the mean induction time was 8 min (range: 3–21 min). This dose was equivalent to 0.024 (0.005) mL of BAM per kilogram. A total of 29 beavers that were immobilized with a mean (SD) of 0.51 (0.07) mg/kg butorphanol, 0.17 (0.02) mg/kg azaperone, and 0.2 (0.03) mg/kg medetomidine needed supplementary isoflurane at 5% and 5 L/min for <1 min to induce full anesthesia. In none of the beavers did BAM alone provide sufficient depth of anesthesia to drill a hole in the tail for transmitter placement, and supplementary isoflurane was administered to reach a sufficient level of analgesia for the procedure. The beavers were reversed with 5 mg of atipamezole per milligram of medetomidine and 1 mg of naltrexone per milligram of butorphanol. No adverse effects or mortalities were observed. Butorphanol-azaperone-medetomidine can be considered safe for use in American beavers for minor procedures.

Key words: BAM, beaver, *Castor canadensis*, immobilization, isoflurane.

American beavers (*Castor canadensis*) are large, semi-aquatic rodents that are distributed from Mexico across the US to the arctic tundra and are classified as "least concern" on the International Union for Conservation of Nature Red List (Cassola 2016). Beavers typically inhabit areas near streams and ponds and can significantly modify the environment through dam building (Cassola 2016). They are therefore considered a nuisance animal in some areas but are used for restoration of riverine habitats in others.

Beavers are widely distributed across Utah, and in some parts of the state, nuisance beavers are trapped and translocated to other areas where their activity is desired for habitat restoration (Utah Division of Wildlife Resources 2017). Before release, the beavers are quarantined for 72–120 h and provided access to a pool with clean water that is changed daily to reduce the risk of moving aquatic pests. Immobilization may be necessary to conduct health assessments, determine sex, collect samples, and administer preventive care.

Published immobilization protocols for beavers mostly include combinations containing ketamine or tiletamine-zolazepam (Heard 2014; Yarto-Jaramillo 2014). These drug combinations are considered safe for immobilizing beavers but have the disadvantage of not being immediately reversible. Gas anesthesia alone has also been used to immobilize beavers with success (Breck and Gaynor 2003); however, the manual restraint during induction without any other sedation may be stressful for the animal and can be challenging with a large beaver.

This study was first initiated when the Utah Division of Wildlife Resources needed to relocate more than 30 captive-born beavers located on a private property in northern Utah. The captive-born beavers were housed in family groups or alone in concrete pens with flowing water and a den that was accessible from the water. Release was not considered an option for these animals, and the beavers were therefore placed in zoos and sanctuaries. The beavers needed to be immobilized to conduct health assessments and determine their sex before placement. Be-

cause of the number of animals, a reversible drug combination was desired. The protocol was then applied to wild-caught beavers that were tail-tagged and translocated within southern Utah.

The free-ranging (wild-caught) beavers were trapped using Koro or Hancock traps (Tomahawk Live Trap, Hazelhurst, Wisconsin, USA) in multiple locations of southern Utah. The traps were set and checked every morning. Beavers were transported in the trap to a quarantine facility, where they were held for 72–120 h before release into the new habitat. The wild-caught beavers were immobilized once during the quarantine period.

All of the wild-caught beavers were moved into a metal wire cage (63.5×46.4×49.2 cm or 78.7×50.8×21.5 cm; ConTour, MidWest Homes for Pets, Muncie, Indiana, USA) before immobilization. The captive-born beavers were immobilized either in their den or by moving them into a cage. The weight of each beaver was estimated, and a mixture of butorphanol (27.3 mg/mL), azaperone (9.1 mg/mL), and medetomidine (10.0 mg/mL) was injected intramuscularly (BAM, Wildlife Pharmaceuticals, Windsor, Colorado, USA). A dose of 0.51 mg/kg butorphanol, 0.17 mg/kg azaperone, and 0.21 mg/kg medetomidine was chosen as the initial dose on the basis of an estimated weight, and then adjusted with the goal of identifying the minimum dose necessary without needing supplementary isoflurane for induction. All beaver cages were placed in a quiet and shady location, partially covered with towels, and the beaver observed from a distance. When beavers were recumbent, the cage was carried to a processing table and the beaver removed from the cage. If considered safe for the animal, a blood sample was drawn before administration of supplemental oxygen. If the level of sedation upon removal from the cage did not allow for easy manual handling, the animal was restrained in a hessian sack and induced further by administering 5% isoflurane at 5 L/min for 0.5–1 min delivered from a portable gas anesthesia unit (Veterinary Anesthesia Systems, Phoenix, Arizona, USA) with a face mask. As soon as the beaver was anesthetized, it was maintained on oxygen alone at 1.5–2 L/min.

Heart rate and respiratory rate were monitored every 2–5 min. We initially attempted to measure temperature with a general rectal thermometer; however, the readings were not considered accurate and therefore were not reported, as they were consistently extremely low because of the low temperature in the cloaca. We proceeded to use a digital thermometer with a flexible probe (Cooper-Atkins TM99A, Tech Instrumentation, Elizabeth, Colorado, USA).

The sex of the beaver was determined by examining the color and viscosity of the anal gland secretion (Schulte et al. 1995). Up to 3 mL of blood was collected from ventral bypass vein or the segmental arteries and veins in the tail (Cutright amd McKean 1979) and placed in sodium heparin vials. An attempt was made to classify the blood as either venous or arterial on the basis of the color of the blood and pressure with which it was filling the syringe. If the blood was drawn before the application of supplemental oxygen, the blood was analyzed with a CG4+ cartridge (Abaxis, Union City, California, USA) on a handheld analyzer (Vet-Scan i-STAT, Abaxis) within 1–3 min of the blood draw. The oxygen saturation was monitored with a pulse oximeter (Nelcor, Medtronics, Minneapolis, Minnesota, USA) attached to the foot web for the duration of the procedure.

All adult free-ranging beavers were equipped with a very high-frequency tail transmitter (M3500, Advanced Telemetry System, Isanti, Minnesota, USA) by drilling a hole in the tail and securing the transmitter with washers and a screw. All beavers were provided supplementary isoflurane at 3–5% for a few minutes before and during the drilling in the tail to ensure sufficient analgesia. All tail-tagged animals received ketoprofen at a dose of 0.45 mg/kg intramuscularly. Beavers were weighed and reversed with intramuscular atipamezole at a dose of approximately 5 mg of atipamezole per milligram of medetomidine, and naltrexone at a dose of approximately 1 mg of naltrexone per milligram of butorphanol.

A total of 35 captive-born (three juvenile and 11 adult females, two juvenile and 19 adult males) and 25 wild-caught beavers (three juvenile and nine adult females, four juvenile and nine adult males) were included in the study. Supplementary isoflurane had to be used to induce full anesthesia in 29 beavers (four juvenile and 11 adult females, two juveniles and 12 adult males), whereas 31 beavers (two juvenile and nine adult females, four juveniles and 16 adult males) could be handled and bled without supplementary isoflurane. There was no significant difference between the mL/kg of BAM between different ages and sexes within the captive-born (age: χ^2 [1]=0.036, P=0.850; sex: χ^2 [1]=3.185, P=0.0743) and wild-caught (age: χ^2 [1]=0.179, P=0.672; sex: χ^2 [1]=0.145, P=0.703) beavers, or between ages and sexes within the groups that received supplementary isoflurane (age: χ^2 [1]=0.104, P=0.747; sex: χ^2 [1]=1.493, P=0.222) or no supplementary isoflurane (age: χ^2 [1]=0.640, P=0.424; sex: χ^2 [1]=0.206, P=0.649) for induction as determined using the Kruskal-Wallis test, and the data from the age classes and sexes are therefore presented together.

For beavers that did not require supplementary isoflurane during induction, the mean (SD) dose based on the actual weight of the animals was 0.65 (0.15) mg/kg butorphanol, 0.22 (0.05) mg/kg azaperone, and 0.26 (0.06) mg/kg medetomidine, which translated to 0.024 (0.005) mL of BAM (Wildlife Pharmaceuticals) per kilogram of beaver. The mean induction time was 8 min (range: 3–21 min).

For beavers that needed supplementary isoflurane for induction, the mean (SD) dose was 0.51 (0.07) mg/kg butorphanol, 0.17 (0.02) mg/kg azaperone, and 0.2 (0.03) mg/kg medetomidine. The supplementary isoflurane was administered for <1 min for these beavers, after which they were maintained on oxygen at 1.5–2 L/min.

The mean time from administering the reversal drugs to the beaver being ambulatory was 9 min in beavers that did not require supplementary isoflurane, and 6 min in beavers that did receive supplementary isoflurane during induction. The mean heart rate was not significantly different in beavers that received and did not receive supplementary isoflurane (Kruskal-Wallis test, χ^2 [1]=0.855, P=0.355), whereas the mean respiratory rate was significantly lower (Kruskal-Wallis test, χ^2 [1]=6.139, P=0.013) in beavers that did need supplementary isoflurane during induction (Table 1).

The cloacal temperatures were low and likely did not reflect the true body temperatures of the animals. Blood from 17 of the beavers that did not require supplementary isoflurane during induction was analyzed with the i-STAT CG4+ cartridge. Two blood samples could be classified as arterial blood with confidence, and both animals had a partial pressure of oxygen (pO_2) of 81 mmHg (Table 2). The remaining pO_2 values were below or equal to 65 mmHg.

We successfully used BAM to immobilize 58 beavers and no adverse effects or mortalities were observed. Butorphanol-azaperone-medetomidine has been used in other species including white-tailed deer (*Odocoileus virginianus*), black bears (*Ursus americanus*), elk (*Cervus elaphus nelsoni*), and bighorn sheep (*Ovis canadensis*) with success (Mich et al. 2008; Wolfe et al. 2008; Smith et al. 2014; Wolfe et al. 2014). None of the beavers required constant administration of isoflurane for processing and BAM provided sufficient analgesia for minor procedures such as blood draw and expression of the anal glands for sex determination. Analgesia was not sufficient to allow for drilling a hole in the tail for transmitter placement, and BAM may therefore not be the first choice for more invasive procedures unless supplementary gas anesthesia is available.

The ventral bypass vein or the segmental arteries and veins, part of a countercurrent arrangement of arteries and veins (Cutright 1979) in a beaver tail, cannot be visualized for a blood draw, and with the exception of two samples, it was difficult to classify the blood as either arterial or venous. In other species, immobilization with BAM causes significant hypoxemia (Mich et al. 2008; Wolfe et al. 2014). For example, white-tailed deer immobilized with BAM that did not receive

TABLE 1. Dose of butorphanol-azaperone-medetomidine (BAM, Wildlife Pharmaceuticals, Windsor, Colorado, USA), induction and reversal times, mean heart rate, respiratory rate, cloacal temperature, and oxygen saturation in captive-born and wild-caught American beavers (*Castor canadensis*) from Utah, USA. Supplementary oxygen was provided to all animals.

Drug or parameter (unit)	No supplementary isoflurane needed for induction					Supplementary isoflurane needed for induction[a]				
	n	Median	Mean	SD	Range	*n*	Median	Mean	SD	Range
Butorphanol (mg/kg)	31	0.65	0.65	0.15	0.38–1.11	29	0.49	0.51	0.07	0.37–0.64
Azaperone (mg/kg)	31	0.22	0.22	0.05	0.13–0.37	29	0.16	0.17	0.02	0.12–0.21
Medetomidine (mg/kg)	31	0.26	0.26	0.058	0.15–0.44	29	0.20	0.20	0.03	0.15–0.26
BAM/kg (mL)	31	0.024	0.024	0.005	0.014–0.041	29	0.018	0.019	0.002	0.014–0.023
Atipamezole (mg/kg)	31	1.20	1.22	0.28	0.69–2.03	29	0.95	0.99	0.15	0.71–1.31
Naltrexone (mg/kg)	31	0.62	0.65	0.18	0.33–1.17	29	0.48	0.52	0.14	0.38–1.12
Injection—full effect (min)	31	7	8.09	3.8	3–21	—	—	—	—	—
Reversal to first recovery (min)	31	6	7.26	5.35	2–27	25	5	4.68	2.87	0–13
Reversal to ambulatory (min)	31	8	8.90	5.64	2–27	26	6	5.81	2.94	1–13
Mean heart rate (beats/min)	31	51	49	8	30–62	29	52	52	7	37–67
Mean respiratory rate (breaths/min)	31	40	41	10	24–66	29	36	35	8	21–60
Mean cloacal temperature (C)	14	31.94	31.87	2.08	27.44–34.56	7	31.94	31.56	3.70	26.67–35.28
Oxygen saturation (%)[b]	23	99	98	5	79–100	27	99	98	2	91–100

[a] — = not recorded as isoflurane was administered during induction.

[b] Measured with a pulse-oximeter.

TABLE 2. Blood gases (partial pressure of carbon dioxide [pCO_2], partial pressure of oxygen [pO_2], total carbon dioxide [tCO_2], and oxygen saturation [sO_2]), pH, bicarbonate (HCO_3^-), base excess (BE), and lactate values from 14 wild-caught and three captive-born American beavers (*Castor canadensis*) immobilized with butorphanol-azaperone-medetomidine before administration of supplementary oxygen in Utah, USA. The blood was collected from the ventral bypass vein or segmental arteries of the tail. Values therefore likely reflect a mixture of venous and arterial blood samples.

Parameter (unit)	*n*	Median	Mean	SD	Range
pH	17	7.4	7.4	0.09	7.27–7.62
pCO_2 (mmHg)	17	46.0	43.5	10.74	28.30–65.50
pO_2 (mmHg)	17	46.0	49.1	16.40	23.00–81.00
BE (mmol/L)	17	5.0	4.4	4.72	−3.00–13.00
HCO_3^- (mmol/L)	17	29.1	28.5	4.10	22.10–36.50
tCO_2 (mmol/L)	17	30.0	29.9	4.28	23.00–38.00
sO_2 (%)	17	84.0	78.7	17.17	32.00–98.00
Lactate (mmol/L)	17	3.3	3.5	1.49	1.53–5.77

supplementary oxygen had arterial oxygen saturations of 41.9 (8.9) and 42.2 (7.8) mmHg at 0 and 15 min after immobilization respectively (Mich et al. 2008). Even though the two arterial blood samples showed pO_2 values of 81 mmHg, it cannot be ruled out that other samples with lower pO_2 also stemmed from arterial blood. Given that BAM causes significant hypoxemia in other species, supplementary oxygen is recommended in beavers immobilized with BAM.

In conclusion, BAM can safely be used in American beavers for minor procedures such as sex determination and blood draw, with the advantage of being immediately reversible, which allows the animal to return to water sooner. If more invasive procedures need to be performed, other drug combinations may be preferable if gas anesthesia is not available, and the use of supplementary oxygen is generally recommended when using BAM to reduce possible hypoxemia.

This study was funded by the Utah Division of Wildlife Resources (UDWR). We thank the many UDWR staff and volunteers who helped with beaver processing.

LITERATURE CITED

Breck SW, Gaynor JS. 2003. Comparison of isoflurane and sevoflurane for anesthesia in beaver. *J Wildl Dis* 39: 387–392.

Cassola F. 2016. *Castor canadensis*. In: *The International Union for Conservation of Nature red list of threatened species: e.T4003A22187946*. http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T4003A22187946.en. Accessed November 2017.

Cutright WJ, McKean T. 1979. Countercurrent blood vessel arrangement in beaver (*Castor canadensis*). *J Morphol* 161:169–176.

Heard D. 2014. Rodents. In: *Zoo animals and wildlife immobilization and anesthesia*, West G, Heard D, Caulkett N, editors. Blackwell Publishing, Ames, Iowa, pp. 893–903.

Mich PM, Wolfe LL, Sirochman TM, Sirochman MA, Davis TR, Lance WR, Miller MW. 2008. Evaluation of intramuscular butorphanol, azaperone, and medetomidine and nasal oxygen insufflation for the chemical immobilization of white-tailed deer, *Odocoileus virginianus*. *J Zoo Wildl Med* 39:480–487.

Schulte BA, Müller-Schwarze D, Sun L. 1995. Using anal gland secretion to determine sex in beaver. *J Wildl Manag* 59:614–618.

Smith JB, Jenks JA, Grovenburg TW, Klaver RW. 2014. Disease and predation: Sorting out causes of a bighorn sheep (*Ovis canadensis*) decline. *PLoS One* 9:e88271.

Utah Division of Wildlife Resources. 2017. *Utah beaver management plan. DWR publication 17–20*. Utah Division of Wildlife Resources, Salt Lake City, Utah. https://wildlife.utah.gov/furbearer/pdf/beaver_plan_2010-2020.pdf. Accessed February 2018.

Wolfe LL, Fisher MC, Davis TR, Miller MW. 2014. Efficacy of a low-dosage combination of butorphanol, azaperone, and medetomidine (BAM) to immobilize Rocky Mountain elk. *J Wildl Dis* 50:676–680.

Wolfe LL, Goshorn CT, Baruch-Mordo S. 2008. Immobilization of black bears (*Ursus americanus*) with a combination of butorphanol, azaperone, and medetomidine. *J Wildl Dis* 44:748–752.

Yarto-Jaramillo E. 2014. Rodentia. 42. In: *Fowler's zoo and wild animal medicine*, Miller RE, Fowler ME, editors. Elsevier Health Sciences, St. Louis, Missouri, pp. 384–421.

Submitted for publication 6 December 2017.
Accepted 21 January 2018.