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IMMOBILIZATION OF GRIZZLY BEARS (*URSUS ARCTOS*) WITH DEXMEDETOMIDINE, TILETAMINE, AND ZOLAZEPAM

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ABSTRACT: Safe and effective immobilization of grizzly bears (*Ursus arctos*) is essential for research and management. Fast induction of anesthesia, maintenance of healthy vital rates, and predictable recoveries are priorities. From September 2010 to May 2012, we investigated these attributes in captive and wild grizzly bears anesthetized with a combination of a reversible α_2 agonist (dexmedetomidine [dexM], the dextrorotatory enantiomer of medetomidine) and a nonreversible *N*-methyl-D-aspartate (NMDA) agonist and tranquilizer (tiletamine and zolazepam [TZ], respectively). A smaller-than-expected dose of the combination (1.23 mg tiletamine, 1.23 mg zolazepam, and 6.04 μg dexmedetomidine per kg bear) produced reliable, fast ataxia (3.7±0.5 min, $\bar{x}\pm$SE) and workable anesthesia (8.1±0.6 min) in captive adult grizzly bears. For wild bears darted from a helicopter, a dose of 2.06 mg tiletamine, 2.06 mg zolazepam, and 10.1 μg dexmedetomidine/kg produced ataxia in 2.5±0.3 min and anesthesia in 5.5±1.0 min. Contrary to published accounts of bear anesthesia with medetomidine, tiletamine, and zolazepam, this combination did not cause hypoxemia or hypoventilation, although mild bradycardia (<50 beats per min) occurred in most bears during the active season. With captive bears, effective dose rates during hibernation were approximately half those during the active season. The time to first signs of recovery after the initial injection of dexMTZ was influenced by heart rate ($P<0.001$) and drug dose ($P<0.001$). Intravenous (IV) injection of the reversal agent, atipamezole, significantly decreased recovery time (i.e., standing on all four feet and reacting to the surrounding environment) relative to intramuscular injection. Recovery times (25±8 min) following IV injections of the recommended dose of atipamezole (10 μg/μg of dexmedetomidine) and half that dose (5 μg/μg) did not differ. However, we recommend use of the full dose based on the appearance of a more complete recovery. Field trials confirmed that the dexMTZ + atipamezole protocol is safe, reliable, and predictable when administered to wild grizzly bears, especially during helicopter capture operations.

Key words: α_2 agonist, anesthesia, dexmedetomidine, grizzly bear, immobilization, tiletamine, *Ursus arctos*, zolazepam.

INTRODUCTION

Safe and effective immobilization of grizzly bears (*Ursus arctos*) is essential for research and management (e.g., Riley et al. 1994; Hilderbrand et al. 1999). The anesthetic combination of a NMDA receptor agonist (tiletamine) and a tranquilizer (zolazepam) in a 1:1 ratio (Telazol® [TZ]) provides temporary (i.e., approximately 45 min to 2 hr) anesthesia in bears and is commonly used (e.g., Taylor et al. 1989; Cattet et al. 2003b). However, immobilization with only TZ can produce a protracted recovery period, especially if additional doses are administered (Cattet et al. 1999). Rapid induction in grizzly bears can be achieved at doses of 7–9 mg TZ/kg. However, because no reversal agent exists for TZ, recovery depends on the dose and rate of metabolism of that dose.

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Delivering multiple anesthetic agents within the initial injection can produce faster induction when an additional suite of central nervous system receptors is targeted. That, in turn, decreases dose and volume of drug required for anesthesia. Smaller drug volumes and dart sizes are more suitable for remote drug delivery and less likely to cause injury (Jessup 2001; Cattet et al. 2006). The addition of an α_2-adrenergic agonist to a drug cocktail can inhibit release of noradrenaline and improve analgesia (Langer 1980). Medetomidine, a third generation α_2 agonist, has been used in combination with TZ to provide reversible immobilization of bears (Arnemo et al. 2001; Fahlman et al. 2011). Medetomidine is a 1:1 racemic mixture of the dextrorotary and levorotatory enantiomers (Domitor®; Orion Corporation, Espoo, Finland). Although dexmedetomidine (dexM) is the compound with more desired effects, levomedetomidine can produce unwanted side-effects, including depressed cardiorespiratory rates (Jansson et al. 1998; Kuusela 2004). As an α_2 agonist, the effects of both enantiomers of medetomidine can be reversed with an antagonist, such as atipamezole. The combination of dexmedetomidine and TZ (dexMTZ) has the potential to be an effective, safe, and reversible anesthetic for bears.

Our objectives were to 1) determine induction success and times for various doses of dexMTZ in captive and wild bears; 2) understand the interaction between the dexMTZ dose, physiological parameters, and duration of anesthesia; 3) measure the rate and completeness of recovery as affected by dose and route of administration of the dexM reversal (atipamezole); and 4) make recommendations on the use of the drug combination for a variety of applications while maximizing safety for bears and biologists.

MATERIALS AND METHODS

We immobilized 10 captive grizzly bears (three adult males, three adult or subadult females, and four male cubs of the year) at the Washington State University Bear Center during the months that comprise the bears' active season (May–September) and denning season (November–March). Immobilizations during April and October required doses intermediate between active and denning seasons and were administered at the discretion of Bear Center personnel. The dexMTZ mixture was mixed by adding 2.8 mL of dexmedetomidine (0.5 mg/mL; DexDomitor®, Orion Corporation, Espoo, Finland) to 1 vial of TZ (Telazol, 572 mg/vial, Fort Dodge Animal Health, Fort Dodge, Iowa, USA) to yield 3.5 mL containing 0.40 mg dexmedetomidine/mL and 163.4 mg TZ/mL. Anesthetics were delivered intramuscularly via blow-dart (Telinject™ darts, Telinject USA Inc., Agua Dulce, California, USA; 3.8-cm needle) or jabstick (18 gauge, 3.8-cm needle). Because darting or injecting distances were small (1–3 m), we generally targeted muscles of the front leg (i.e., triceps/biceps, lower deltoid) or rear leg (i.e., vastus, gluteus) to ensure rapid drug absorption. We also field-tested the anesthetic combination with grizzly bears (18 adult females, three subadult males) on the Kenai Peninsula, Alaska, US; the Rocky Mountain Front, Montana, US; and Denali National Park, Alaska, US. We delivered drugs with Pneu-dart™ (Pneu-dart Inc., Williamsport, Pennsylvania, USA), Palmer Cap-Chur™ (Palmer Cap-Chur Inc., Powder River, Georgia, USA), and Dan-inject™ (Dan-Inject ApS, DK-7080 Børkop, Denmark) systems; 20 of 21 free-ranging bears were immobilized from a helicopter. Because of the distance of darting and required velocity of the projected dart, we were unable to repeat delivery methods used with the captive bears in field settings. We rated dart placement as poor, fair, or good, depending on the proximity to large muscle groups. The darted bears were closely monitored, either on foot at a safe distance or by fixed-wing aircraft and helicopter. Once a bear was anesthetized, we immediately began physiologic monitoring of the animal and constantly assessed the depth of anesthesia and overall vital signs. We weighed all bears while immobilized to accurately determine drug doses. All drug doses are reported in either milligrams (TZ) or micrograms (dexM) per kilogram of bear. We timed stages of induction (i.e., from darting to first ataxia and from darting to lying immobile with head down), workable anesthesia (i.e., from beginning of immobility with head down to eventual head movement after anesthesia), and recovery (i.e., from injection of the reversal agent to up on four legs). At the point of standing on four feet, bears were still

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slightly ataxic but could readily recognize and react to humans or other bears. Wild bears often left the capture site as soon as standing. All available precautions were taken to ensure the safety of bears and personnel, as outlined in Institutional Animal Care and Use Committee (IACUC) protocols (ASAF 3054 and 4037). We immobilized both captive and wild bears between September 2010 and May 2012.

To assess the physiologic response of bears to anesthesia with dexMTZ, we monitored heart rate (beats per minute), percentage of hemoglobin O_2 saturation via pulse-oximetry (SpO_2, N-20PA Handheld Pulse Oximeter, Nellcorr Puritan Bennett LLC, now Covidien, Mansfield, Massachusetts, USA), respiration rate (breaths per minute), and rectal temperature (403001 digital thermometer, Becton Dickinson, Franklin Lakes, New Jersey, USA). For each bear, we attempted to collect one arterial blood sample from the femoral artery with heparinized syringes. We either submitted samples to the Washington State University (WSU) Clinical Pathology Laboratory or used an i-STAT® (Abaxis, Union City, California, USA) to obtain blood chemistry data representative of anesthesia. The i-STAT CG4+ cartridges provided hemoglobin O_2 saturation (SaO_2), partial pressures of arterial oxygen (PaO_2), partial pressure of arterial carbon dioxide ($PaCO_2$), pH, HCO_3 concentration, and lactate concentration. Blood gas and pH values were corrected to rectal temperature of the bear at the time of blood draw. The WSU Clinical Pathology Laboratory also measured serum creatinine kinase. We kept the i-STAT analyzer within operable temperature range when working at cold temperatures by storing the analyzer in an insulated box containing a hot water bottle (Fahlman et al. 2011). We measured blood pressure of anesthetized bears by placing a cuff around the bear's forearm or rear leg proximal to the heel. We tested the accuracy of that method by comparing instantaneous measurements of blood pressure from the cuff technique and from a transducer placed within the femoral artery of captive bears ($n=5$). Paired systolic and diastolic values were never more than 8 mmHg apart.

We tested the efficacy of intramuscular (IM) and intravenous (IV) injections of the atipamezole reversal using paired immobilizations of four captive, adult bears. To ensure that metabolic state varied negligibly, paired within-individual immobilizations were less than 1 mo apart during the summer months of July and August. Paired immobilizations involved injecting each bear with a dexMTZ dose (per kilogram) and reversing with an atipamezole dose (per kilogram) identical to its previous immobilization. Reversals were performed at the same time postinjection. Captive bears were weighed weekly and thus were accurately dosed. We also tested recovery time with full (10 μg/μg of dexM) and half (5 μg/μg) doses of atipamezole with paired immobilizations. As with tests of IM and IV reversals, individual bears were dosed at the same rate, immobilized in the same month, and reversed at the same time postinjection during repeated immobilizations.

Relationships between dexMTZ dose, heart rate, induction time, and total time of workable anesthesia were modeled with linear least-squares regression analysis. All single-dart immobilizations, regardless of rating of injection placement and route and dose of reversal, were pooled for the regression analyses. Heart rate was used as an index of overall metabolic activity and, therefore, the rate at which drugs might be absorbed and metabolized. We used *t*-tests to test for differences in physiologic parameters between captive and wild bears. We used analysis of variance (ANOVA), blocking for variation among bears, to compare differences in recovery times between IM versus IV and between half versus full dose reversals. Recovery times were evaluated based on minutes elapsed between injection of the reversal and 1) head movement, and 2) up on all 4 feet, and between head movement and up on all four feet. All analyses were run within program R (R Development Core Team 2010). All assumptions of ANOVA were met, and significance was assessed at $\alpha=0.05$. Means are reported ±SE.

RESULTS

No additional anesthetic beyond the initial injection was required for complete anesthesia in 82% (80 of 98) of the immobilizations of captive bears. Immobilizations that required additional drug for induction also had dart placement rated as poor or fair in 15 of 18 attempts. Captive, active-season, adult bears received an average dose of 2.46±0.07 mg TZ/kg and 6.04±0.19 μg dexM/kg. The average time to first signs of ataxia was 3.7±0.5 min. Workable anesthesia was reached after 8.1±0.6 min ($n=45$). During hibernation, the average drug dose for adults was 1.40±0.11 mg TZ/kg and

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3.62±0.25 μg dexM/kg. Induction time to first signs of ataxia averaged 9.1±1.4 min, with workable anesthesia reached in 15.5±1.7 min (n=15). Effective drug doses, defined as a dose that initiated anesthesia in <10 min, ranged from 1 mg TZ and 2.45 μg DexM/kg in winter to 2.81 mg TZ and 6.87 μg dexM/kg in summer. Summer volumes of drug in initial darts ranged from 0.2 (cubs-of-the-year) to 5.0 mL for bears ranging in mass from 17–301 kg. Larger drug doses significantly shortened induction times in both summer and winter ($F_{1,41}$=5.82, P=0.02).

In 57% (12 of 21) of immobilizations of wild bears, ataxia was observed in 2.5±0.3 min and workable anesthesia in 5.5±1.0 min of initial injection with only one injection (mean dose rate of 4.12±0.44 mg TZ/kg and 10.11±1.04 μg dexM/kg). The remaining nine immobilizations required additional drug to achieve anesthesia; however, in each case, the placement of the initial dart was rated as either poor (n=8) or fair (n=1). The volume of drug in initial darts ranged from 1.8–4.0 mL for bears ranging in mass from 85–171 kg.

Anesthesia times and physiologic parameters

Workable anesthesia lasted for 86±3 min in captive, active-season bears; 60±4 min in captive, hibernating bears; and 88±10 min in wild bears darted from a helicopter. Total time down during anesthesia was negatively associated with heart rate of the bear (t=−3.77, P<0.001) and was positively associated with drug dose (t=7.60, P<0.001; adjusted R^2=0.40, $F_{2,86}$=29.89, P<0.001). Rectal temperatures of captive, active-season bears averaged 36.9±0.1 C, and none required active measures to reduce body temperature (Fig. 1). Initial rectal temperatures of wild bears averaged 39.1±0.4 C, and snow or water was used to reduce the body temperature in four bears. Temperatures of all wild bears throughout the anesthesia averaged 39.4±0.3 C (Fig. 1). Mean heart rates of captive, active-season and wild, adult bears were 47±2 and 66±7 beats/min, respectively. Heart rates of captive hibernating adult bears averaged 34±4 beats/min (Fig. 2). Average respiration rates of captive and wild bears were 11±1 and 28±7 breaths/min, respectively (Fig. 1). Mean systolic/diastolic blood pressures (mmHg) for captive and wild bears were 223±13/140±8 (n=19) and 217±12/127±8 (n=13), respectively.

Percentage of hemoglobin saturated with oxygen (SaO_2) measured from arterial blood averaged 91±1% (n=24, range=84–96%) in captive bears and 95±1% (n=10, range=90–99%) in wild bears (Table 1). Twenty-eight of 34 observations were above 90%, and no wild bears experienced oxygen saturations below that benchmark. Arterial samples were taken between 28 and 77 min after initial injection. We found no association between oxygen saturation and sampling time ($F_{1,26}$=0.031, P=0.862). Blood pH did not differ between captive and wild bears ($t_{1,32}$=−1.050, P=0.302), and we observed no instances of marked acidemia requiring treatment (pH<7.20) (Table 1). We observed significant differences in partial pressures of both oxygen (PaO_2) and carbon dioxide ($PaCO_2$) between wild and captive bears (Table 1; $t_{1,32}$=−3.574, P=0.001 and $t_{1,32}$=5.297, P<0.001, respectively). Wild bears were hypocapnic ($PaCO_2$<35 mmHg) during immobilization, likely from maximum ventilation and metabolic acidosis resulting from the chase phase of darting, whereas captive bears were mildly hypercapnic ($PaCO_2$=45–60 mmHg) (Table 1). We observed no instances of hypoxemia (PaO_2<60 mmHg) during captive or field immobilizations (Table 1). Supplemental oxygen was given to only one bear during immobilization. Lactate and creatinine kinase concentrations were as much as seven times higher and HCO_3 was 34% lower in wild than in captive bears (P<0.001; Table 1).

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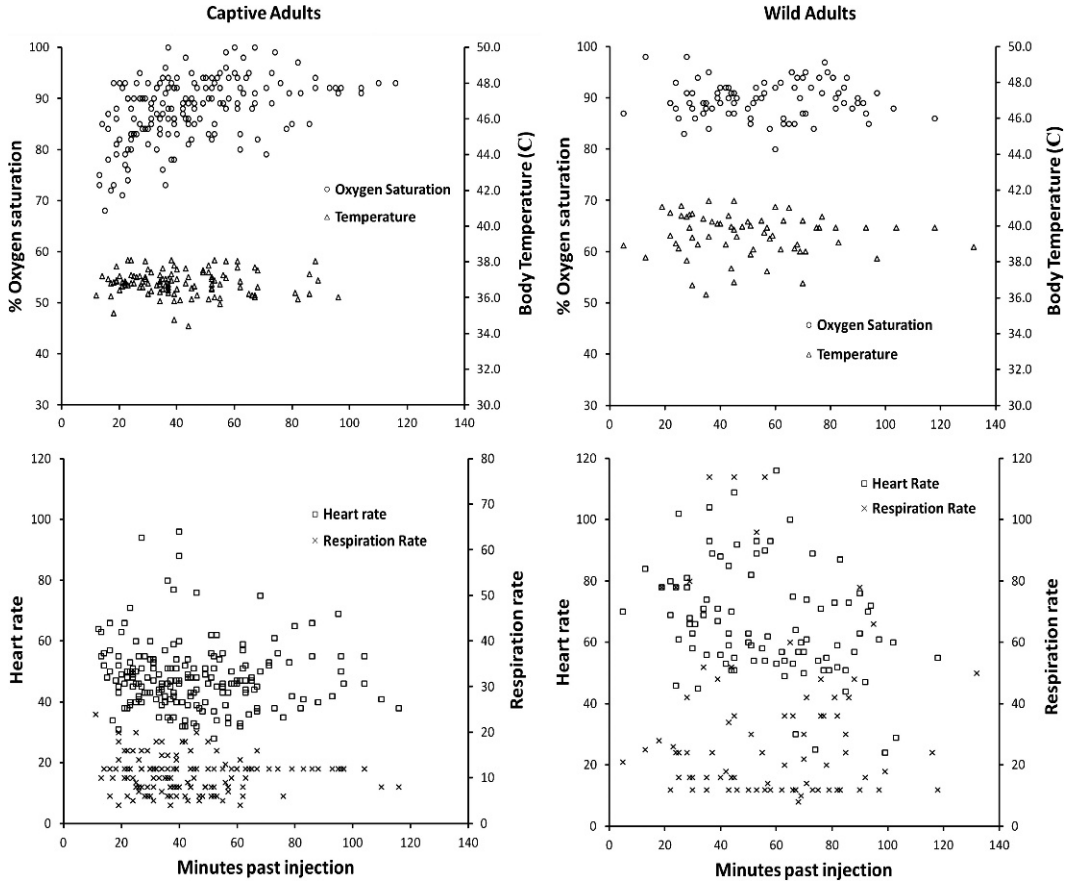

FIGURE 1. Vital rates during the active season (% oxygen saturation measured with pulse oximetry [SpO_2], rectal temperature [C], heart rate [beats/min], and respiration rate [breaths/min]) for captive (71 immobilizations of 10 individuals) and wild-captured adults (21 individuals, each immobilized once) while under dexmedetomidine-tiletamine-zolazepam (dexMTZ) anesthesia. Measurements were taken every 5–15 min after induction.

Recovery

Recovery (i.e., animal up on all four feet) following IV injection of atipamezole occurred in 28.4±3.4 min (n=20) in captive bears and 39.4±13.6 min (n=9) in wild bears. In paired trials with captive bears, recovery time following IV injection of atipamezole (25±8 min) was less than when the reversal was injected IM (52±11 min, n=10) ($F_{1,11}$=7.902, P=0.017), with most of the effect seen as a decreased interval between reversal injection and first head movement ($F_{1,11}$=5.455, P=0.0395). The IV injection of atipamezole relative to IM injection did not significantly decrease time spent between head movement and up on four feet ($F_{1,11}$=2.902, P=0.117). Overall recovery times did not differ when bears were given either full or half doses of atipamezole ($F_{1,11}$=0.510, P=0.490), although bears given the full dose appeared, subjectively, to become conscious faster. We observed no sudden recoveries or mortalities from anesthesia with the combination.

DISCUSSION

Telazol and dexmedetomidine act synergistically when given together as an anesthetic, which is similar to other

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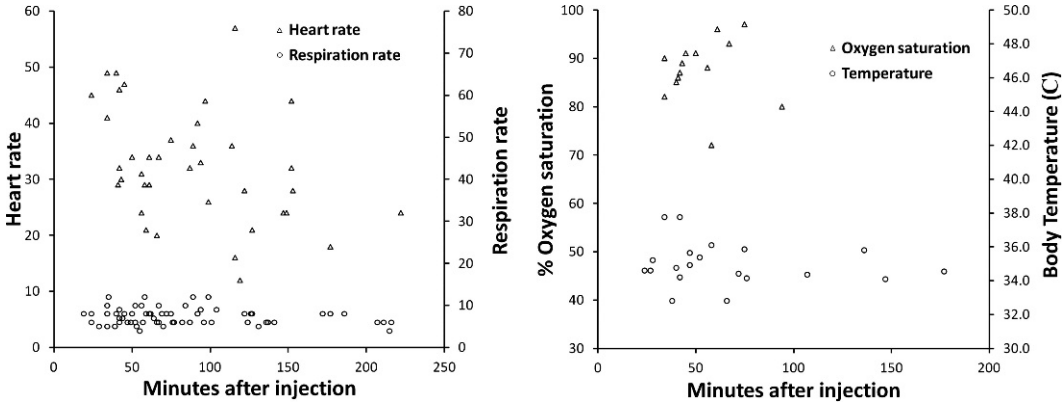

FIGURE 2. Vital rates during hibernation (% oxygen saturation measured with pulse oximetry [SpO_2], rectal temperature [C], heart rate [beats/min], and respiration rate [breaths/min]) for captive adults (17 immobilizations of six individuals) while under dexmedetomidine-tiletamine-zolazepam (dexMTZ) anesthesia. Measurements were taken every 5–15 min after induction.

combinations of dissociative drugs and benzodiazepines or α_2 agonists (Ben-Shlomo et al. 1990; Hendrickx et al. 2008). Interactions between the three drugs in dexMTZ reduced the dose of TZ required by at least 50%, considerably shortening the time a bear may spend recovering from anesthesia (Taylor et al. 1989; Table 2). Induction times for wild bears anesthetized with dexMTZ were comparable with other drug combinations currently used (Table 2). Some wild-caught bears required second injections for induction; in each case dart placement was rated as poor ($n=8$) or fair ($n=1$). Hence, improper dart placement (i.e., not in a large muscle mass) could explain the need for additional anesthetic and does not necessarily indicate inadequate dose or drug failure. Additionally, study personnel estimated 30–50% of fired darts failed to inject drug (Carnahan, Alaska Department of Fish and Game, unpubl. data). Such failures may have led to 1) the need to fire a second dart, and 2) artificially increased induction times. We did not test the efficacy of yohimbine as a reversal agent, but its lesser affinity for α_2 receptors, compared with atipamezole, might result in incomplete or less-predictable reversals of dexM (Klein and Klide 1989; Jalanka and Roeken 1990).

As with the immobilization of other animals and bears with medetomidine, we observed mild bradycardia and a reduced respiration rate (Vainio and Palmu 1989;

TABLE 1. Mean (SE) for the percentage of arterial O_2 saturation (SaO_2), pH, partial pressure of arterial carbon dioxide ($PaCO_2$), partial pressure of arterial oxygen (PaO_2), HCO_3 concentration (mmol/L), lactate concentration (mmol/L), and creatinine kinase (U/L) for grizzly bears (*Ursus arctos*) immobilized with dexmedetomidine-tiletamine-zolazepam (dexMTZ) in captive and field settings. Sample sizes reflect the number of immobilizations sampled.

	No.	SaO_2	pH	$PaCO_2$	PaO_2	HCO_3	Lactate	Creatinine kinase
Captive	24[a]	91.2 (0.7)	7.349 (0.006)	42.87 (0.96)	66.55 (1.53)	23.50 (0.35)	0.67 (0.07)	57.4 (25.0)
Wild	10[b]	94.7 (0.9)	7.369 (0.026)	29.64 (2.05)	81.69 (5.55)	17.94 (1.45)	5.86 (1.24)	203.1 (25.7)
All	34	92.2 (0.6)	7.354 (0.009)	38.98 (1.37)	71.00 (2.25)	21.87 (0.65)	2.46 (0.58)	147.1 (27.1)

[a] Ten captive bears were sampled during multiple immobilization events. Sample size represents the number of immobilizations.

[b] Ten wild bears were sampled during immobilization. None were sampled multiple times.

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TABLE 2. Comparison of drug combinations commonly used to immobilize wild (free-ranging) grizzly bears (*Ursus arctos*).

	Drug combination[a]			
	DexMTZ[b]	MTZ[c]	XTZ[d]	TZ[e]
Recommended dose(s) (mg/kg)	3.0–3.5	2.7–4.2	6.7–7.0[f]	7.0–9.0
Cost (US$/kg)[g]	0.56–0.64	1.23–1.93	0.56–0.58	0.63–1.00
Drug volume (mL)[h]	2.8–3.2	1.5–2.3[i]	4.5–4.7[j]	5.0–6.4
Induction (min; mean [SE])	5.5 (1.0)	5.3 (0.3)[k]	6.2 (0.1)	4.3 (0.2)
Heart rate (beats/min; mean [SE])	66 (7)	63 (3)	68 (2)	98–100 (2–3)
Respiration rate (breaths/min; mean [SE])	28 (7)	16 (4)	16 (6)	17–30 (1–2)
Oxygen saturation (%; mean [SE])	95 (1)	89 (1)	91	NM
Analgesic properties?	Yes	Yes	Yes	No
Reversible?	Yes	Yes	Yes	No

[a] Abbreviations: DexMTZ = dexmedetomidine-tiletamine-zolazepam; MTZ = medetomidine-tiletamine-zolazepam; XTZ = xylazine-tiletamine-zolazepam; TZ = tiletamine-zolazepam; NM = not measured.

[b] Data from this study.

[c] Data from Fahlmann et al. (2011).

[d] Data from Cattet et al. (2003b).

[e] Data from Taylor et al. (1989).

[f] Includes recommended doses from Radandt (2009) and Cattet et al. (2003).

[g] Includes cost of the appropriate dose of reversal (atipamezole, 20 mg/mL solution).

[h] Calculated for a 150-kg bear.

[i] Mixed with 10 mg/mL medetomidine solution.

[j] Mixed with 100 mg/mL xylazine solution.

[k] Adult females only; from Arnemo et al. (2001).

Vainio et al. 1992; Caulkett et al. 1996a, b; Fahlman et al. 2011). However, the observed heart and respiration rates during dexMTZ immobilization were similar or higher than those of sleeping captive grizzly bears (O.L.N. unpubl. data). Oxygen saturations were consistently higher in bears anesthetized with dexMTZ than they were with medetomidine-tiletamine-zolazepam (MTZ) which may reduce the need for supplemental oxygen (Table 2; Fahlman et al. 2011). These differences were presumably due to the much greater respiratory rate of captive, active season and wild, bears anesthetized with dexMTZ (32±7 breaths per min) than with MTZ (15±4; Fahlman et al. 2011; current study).

Although dexM is a potent agonist of α_2-adrenergic receptors in certain parts of the brain, peripheral α_2 receptors are also stimulated. Similar to medetomidine, dexM administration can result in systemic hypertension and secondary bradycardia. These effects are most prominent in the early phases after initial injection and wane with time as the drug is metabolized (Caulkett and Cattet 1997). The hypertensive effect with this drug class has also been noted in other large carnivores (Curro et al. 2004). However, we do not feel that these blood pressures were dangerously elevated given that the systolic blood pressures obtained from active, unanesthetized, captive grizzly bears generally range between 208–225 mmHg in the active period and 175–185 mmHg during hibernation (January). These values were obtained by the same indirect method as used in this study (Nelson pers. comm., unpubl. data).

Deep analgesia is often required for field procedures (e.g., when extracting teeth or tending to injuries). We have performed a range of medical procedures with captive bears given dexMTZ, including fat and liver biopsies and spinal taps. We observed no changes in heart rate

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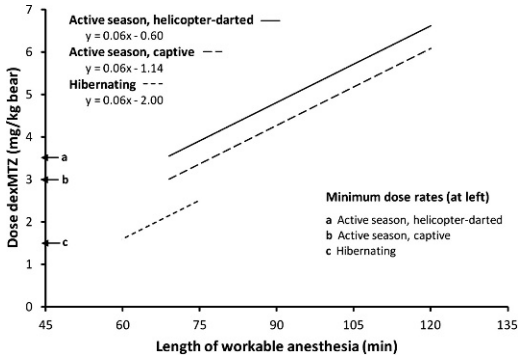

FIGURE 3. Predicted relationships between doses of dexmedetomidine-tiletamine-zolazepam (dexMTZ) in the ratio of 2.45 μg dexM per mg TZ/kg bear and the length of workable anesthesia for bears of differing metabolic states. Metabolic states were categorized as hibernating, captive (sedentary), and helicopter-darted. Minimum recommended dose rates are indicated for (a) active season, helicopter-darted bears, whose metabolic state is elevated from exertion, 3.5 mg TZ and 8.59 μg dexM/kg; (b) active season, captive bears, 3.0 mg TZ and 7.36 μg dexM/kg; and (c) hibernating, captive bears, 1.5 mg TZ and 3.68 μg dexM/kg bear.

during these procedures, unlike increases in heart rates of polar bears exposed to painful stimuli while under TZ anesthesia (Cattet et al. 2003a). All indications of anaerobic respiration and muscle damage (lower HCO_3 concentrations, lactate acidemia, and higher creatinine kinase levels) in field-immobilized animals were likely due to the exertion and stress of capture (Cattet et al. 2008; Fahlman et al. 2011). Onuma (2003) reported a high prevalence of vomiting in sun bears (*Helarctos malayanus*) immobilized with MTZ. Some captive grizzly bears vomited during darting or induction with dexMTZ in the current study, but such vomiting occurred with those particular bears irrespective of the drug used. No wild animals vomited during induction.

We used coefficients from the significant relationships between drug dose, heart rate, and length of workable anesthesia to develop predictions between drug dose and predicted time of workable anesthesia for captive and wild bears (Fig. 3). However, these predictions do not remove the need to actively monitor the plane of anesthesia for each animal. Variation around predicted values should be expected. For example, 2.3% of immobilizations in this study resulted in head movement more than 15 min before the predicted time. As such, these relationships are intended to identify conservatively high-dose rates to achieve handling objectives. Moreover, there is a degree of safety in exceeding recommended doses of dexMTZ because of its wide safety margin. Higher doses result in longer time down (i.e., approximately 17 min/additional mg dexMTZ/kg; Fig. 3), not deeper anesthesia (Cattet et al. 2003b; Kuusela 2004).

During the height of the active season (i.e., June–August in most North American ecosystems), we suggest using minimum recommended doses of 3.0 and 3.5 mg dexMTZ/kg body mass for captive and helicopter-darted bears, respectively (Fig. 3). Beyond our reported significant relationship between dose and induction time, this range of doses yields subjectively smoother and more reliable induction. During the active season, time from injection to workable anesthesia with a single dart ranged 3–12 min, with first effects (i.e., ataxia) seen within 6 min for both captive and wild bears. Hence, if ataxia is not seen within 6 min, we recommend administering a second dose at 50–100% of the original dose, with dose dependent on placement of initial injection, predicted accessibility of the bear if darted from a helicopter, and required handling time. If additional time is required near the end of anesthesia, another IM dose can be given at 25–75% of initial dose, depending on the additional time required.

Reversal of dexM anesthesia should be administered at or slightly before the time of predicted head movement, unless the safety of the animal is jeopardized. Upon complete induction of reversal, the animal will display an anesthetic plane reflecting the amount of TZ remaining in its system. Consequently, injection of atipamezole

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after the time of predicted head movement will result in quicker apparent recovery (i.e., time from reversal to recovering motor and sensory function) because more TZ has been metabolized. Thus, application of dexMTZ requires careful assessment of the plane of anesthesia when used. Although the subject will not evince spontaneous recovery, nevertheless, the time between first head movement and regaining motor function can be significantly shorter with dexMTZ than it is when using only TZ for immobilization. Earliest signs of recovery from dexMTZ include increased palpebral response, migration of the eyes to a forward stare, and tongue contractility. Because the half-life of dexM ranges from 0.66–0.78 hr (Kuusela et al. 2000), it was not necessary to reverse the full amount of dexM administered from multiple doses. Instead, it was adequate to reverse only the last dose of dexM at the full dose rate of atipamezole.

Injection volumes of dexMTZ ranged from 44% to 71% of volumes reported for xylazine-tiletamine-zolazepam and TZ (Table 2; Taylor et al. 1989; Radandt 2009). The cost of immobilizing a wild bear with the reported doses of dexMTZ and reversing with atipamezole were comparable to using other common combinations (Table 2; prices from MWI Veterinary Supply, Meridian, Idaho, USA, and Zoopharm, Inc., Fort Collins, Colorado, USA). With dexMTZ, we have created a workable, efficient, and flexible immobilization system for use in captive and field settings. Further, we have shown that the combination provides biologists with a reduced and reliable induction time, the ability to reverse anesthesia, and a modestly predictable length of anesthesia, based on known parameters during anesthesia.

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