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BUTORPHANOL, AZAPERONE, AND MEDETOMIDINE ANESTHESIA IN FREE-RANGING WHITE-TAILED DEER (*ODOCOILEUS VIRGINIANUS*) USING RADIOTRANSMITTER DARTS

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ABSTRACT: Fourteen free-ranging white-tailed deer (*Odocoileus virginianus*) were successfully anesthetized for a total of 15 anesthetic events using a combination of butorphanol (mean±SD, 0.58±0.1 mg/kg), azaperone (0.37±0.06 mg/kg), and medetomidine (0.19±0.03 mg/kg) (BAM) administered by radiotelemetry darts from hunting blinds between November 2006 and May 2007. Mean time to locate deer (mean±SD, 17. 3±7 min), to recumbency (21.4±5 min), to initiation of data acquisition (27.5±8 min), total down time (37±6 min), and average distance run (161±82 m) were recorded. Physiologic monitoring was done every 5 min for a total of 20 min. Arterial blood gases were collected every 10 min. Mild to moderate hypoxemia and mildly depressed ventilation occurred in some animals. Muscle relaxation and plane of anesthesia were adequate for completion of all procedures; two deer were administered intravenous butorphanol supplementation to achieve light anesthesia (mean±SD, 0.19 mg/kg; 0.12 mg/kg). Recovery following intramuscular administration of naltrexone (1.34±0.42 mg/kg; 2× butorphanol dose) and atipamezole (0.93±0.14 mg/kg; 5× medetomidine dose) was rapid, smooth, and complete. Mean±SD recovery time was 4.5±1.5 min. Overall efficacy of the Pneu-Dart radiotelemetry system was 65%. Negative attributes of this protocol included long induction time and dart failure. No known mortalities occurred as a result of the study. This drug combination provided safe, reliable, short-term anesthesia of free-ranging white-tailed deer. Further evaluation for use in field procedures in other cervids is warranted.

Key words: Anesthesia, azaperone, butorphanol, medetomidine, *Odocoileus virginianus*, radiotelemetry dart, white-tailed deer.

INTRODUCTION

Successful anesthesia of free-ranging cervids involves the use of safe, effective, potent anesthetics that are reversible, have a small injection volume, are rapid in onset of action, produce minimal undesirable side effects, and are affordable. Potent opioid/α_2 agonist, opioid/α_2 agonist/dissociative anesthetic, opioid/α_2 agonist/neuroleptic tranquilizer, α_2 agonist/dissociative anesthetic, and tiletamine/zolazepam combinations have been used to provide rapid onset of anesthesia in both captive and free-ranging cervids (Wilson et al., 1996a, b; Tsuruga et al., 1999; Caulkett et al., 2000; Janovsky et al., 2000; Murray et al., 2000; Moresco 2001; Miller et al., 2003; Wolf et al., 2004; Arnemo et al., 2005; Storms et al., 2005, 2006; Walter et al., 2005; Smith et al., 2006). Reported disadvantages of these combinations include human risks associated with handling potent opioids, unpredictable inductions, apnea/respiratory depression, hyperthermia, lactic acidosis, muscle rigidity, altered arterial blood pressure, excitement, regurgitation, decreased gastrointestinal motility, incomplete reversibility, and prolonged recovery times (Tsuruga et al., 1999; Caulkett et al., 2000; Janovsky et al., 2000; Moresco et al., 2001; Miller et al., 2003, 2004; Wolf et al., 2004; Storms et al., 2005, 2006; Smith et al., 2006).

Most opioid-containing combinations used for anesthesia of white-tailed deer

(*Odocoileus virginianus*; WTD) have involved the use of ultrapotent opioids, such as carfentanil or thiafentanil, with limited information on the use of the less-potent, mixed agonist-antagonist opioid, butorphanol. Specific α_2 agonists commonly included in anesthetic combinations to provide greater muscle relaxation, improved margins of safety, and improved induction and recovery characteristics include xylazine and medetomidine. Finally, few studies report on the efficacy or use of neuroleptic tranquilizers in immobilization combinations in cervids (Mich et al., 2008).

Given the negative side effects reported with previous anesthetic combinations, use of an alternative combination of drugs for WTD anesthesia was investigated. The objective of this study was to develop a protocol with minimal negative side effects for rapid, reliable, reversible, and safe anesthesia of free ranging WTD using a combination of butorphanol, azaperone, and medetomidine (BAM) administered by radiotransmitter dart.

Efficacy of the anesthesia protocol was based on quantified anesthetic and physiologic parameters recorded throughout the anesthetic event, ability of this drug combination to successfully anesthetize and be antagonized in free-ranging deer, and on subjective quality ratings. Evaluation of radiotransmitter darts was based on successful drug delivery and animal tracking following dart administration.

MATERIALS AND METHODS

This study was conducted from November 2006 to May 2007; protocols were approved by the White Oak Conservation Center Animal Research Committee (IACUC No. PR2006-09). Environmental temperature ranged from 11 C to 28 C (mean±SD, 22.2±4.1 C; median, 22.2 C) during the study period. Fourteen free-ranging WTD (seven females, seven males) were opportunistically immobilized at White Oak Conservation Center (White Oak Plantation, Yulee, Florida, USA, 30°45′N, 81°45′W) from hunting blinds stationed at deer-feeding stations maintained on property. Hunting blinds were positioned approximately 7–10 m from the feeding stations. Feeding stations were positioned in small grassy areas and surrounded by natural vegetation: hardwood hammocks, pine forest, tidal wetlands, marshes, dense brush and palms, pastures, and riparian habitat. One animal was anesthetized twice, for a total of 15 anesthetic events. Animals were fed a 50:50 mixture of corn (Triple Cleaned Whole Corn, Central States Enterprises, Lake City, Florida, USA) and pelleted deer feed (Country Acres Deer and Elk 20 Brand, Country Acres Feed Co., Brentwood, Missouri, USA).

Deer were anesthetized with a combination of butorphanol at 24–40 mg/dart (30 or 50 mg/ml; Wildlife Pharmaceuticals Inc., Fort Collins, Colorado, USA), azaperone at 15–20 mg/dart (50 mg/ml; ZooPharm, Laramie, Wyoming, USA), and medetomidine at 8–10 mg/dart (20 or 40 mg/ml; Wildlife Pharmaceuticals Inc., Fort Collins, Colorado, USA), based on visually estimated weights of 45.5 kg for an adult doe and 55 kg for an adult buck. All drugs were administered simultaneously via a single dart injection.

Dart administration time, time to locate animal (time until animal was found minus time when animal was darted), time to recumbency (time until animal was recumbent minus time when animal was darted), time to data collection (time of initiation of data collection minus time when animal was darted), lag time (time of initiation of data collection minus time until to recumbency), and estimated distance run (m) were recorded. Once located, the animal's level of anesthesia was assessed, and supplemental anesthetics administered if indicated. Once a plane of heavy sedation to light anesthesia was achieved, the time was noted as Time 0, and data collection was initiated.

Upon securing the animal, the eyes were blindfolded with a towel, and the deer was maintained in sternal or lateral recumbency with the head elevated above the level of the rumen, with the nose oriented downward throughout the procedure. Physiologic monitoring was started once the animal was secured (Time 0), and continued at 5-min intervals for a 20-min period. Physiologic data collected included heart rate (HR), respiration rate (RR), rectal temperature (T), oxyhemoglobin saturation (SpO_2), end tidal carbon dioxide ($ETCO_2$), and indirect arterial blood pressure (systolic arterial pressure [SAP]; diastolic arterial pressure [DAP]; and mean arterial pressure [MAP]). Heart rate was determined by auscultation of the heart, respiration rate by counting chest excursions, and SpO_2 was

measured using a portable pulse oximeter (Nellcor N-200, Nellcor, Inc., Pleasanton, California, USA; $n=10$) or the multiparameter monitor (Cardell Veterinary Monitor 9405, Sharn Veterinary Inc., Tampa, Florida, USA; $n=5$) with the sensor placed on the tongue, inguinal region, vulva, or a shaved portion of the ear. Indirect arterial blood pressure (BP) was measured in 12 anesthetic events using a blood pressure monitor (Reli On, Mabis Healthcare, Inc., Waukegan, Illinois, USA, $n=3$) or the Cardell monitor ($n=9$), with the cuff placed at the proximal aspect of the antebrachium of the foreleg. Rectal temperature was determined using a digital thermometer (GLA M700 digital thermometer, GLA Agricultural Electronics, San Luis Obispo, California, USA). End tidal CO_2 was determined in 11 anesthetic events using a portable capnograph (Nellcor NPB-75, Nellcor, Inc., Pleasanton, California, USA; $n=7$) or the Cardell monitor ($n=4$), with the gas-sampling port positioned at one nostril. Arterial blood samples were collected from the auricular artery into heparinized syringes at Time 0, Time 10 min, and Time 20 min (three samples/animal). Blood gas samples were maintained on crushed ice and analyzed within 20–40 min of collection on an Osmetech Opti Critical Care blood gas analyzer (AVL Scientific Corporation, Roswell, Georgia, USA) for measurement of blood pH, arterial partial pressure of oxygen (P_aO_2), and arterial partial pressure of CO_2 (P_aCO_2), corrected to the measured body temperature at each time point, and arterial oxygen saturation (S_aO_2), as measured by the analyzer. Blood was collected from the jugular vein and placed into ethylenediaminetetraacetic acid (EDTA) and serum collection tubes for hematology and serum banking.

Physical and dental examinations and standard morphometrics were done during the monitoring period. Opportunistic fecal samples were collected manually from the rectum; fecal floatations were performed within 40 min of collection or were stored refrigerated and analyzed within 24 hr of collection. Deer were categorized as adults, subadults, or juveniles based on body size, dental wear, presence and size of antlers, and pregnancy status. Anesthetized WTD were identified by shaving areas of fur on the shoulders or hips bilaterally, and/or placement of an ear tag. Deer (14/15; 93%) were weighed before recovery, and actual drug dosages (mg/kg) were calculated later. Weight was not obtained for one animal but was estimated based on body size, and weights recorded for the other study deer.

Quality of induction, maintenance of anesthetic plane, muscle relaxation, anesthetic recovery, and overall anesthetic procedure were subjectively evaluated by the authors (J.S.W. and S.B.C.) on a scale of 1 to 5 (1=excellent, 2=good, 3=fair, 4=poor, 5=unacceptable). Quality ratings were based on time to induction or recovery after drug administration, need for supplemental drug administration, degree of muscle relaxation (relaxed, intermittent rigidity or fasciculations, extreme rigidity or fasciculations, or responsiveness to stimuli), and induction/recovery characteristics (smooth, rough, rapid/lengthy, dangerous, complete/incomplete). After the 20-min monitoring period, anesthetic induction drugs were reversed with individual intramuscular (IM) administrations of naltrexone (50 mg/ml; ZooPharm) at two times the butorphanol dose (60–100 mg/animal) and atipamezole (5 mg/ml; Antisedan, Pfizer Animal Health, Exton, Pennsylvania, USA) at five times the medetomidine dose (40–50 mg/animal). Recovery time (time to standing minus time of reversal agent administration) and total down time (time to standing minus time at recumbency) were recorded. Deer were immediately released to the wild following successful recovery.

Darts used included metal, 1- or 2-ml radiotransmitter, double-barbed Pneu-Darts (Pneu-Dart, Inc., Williamsport, Pennsylvania, USA) or plastic, 3-ml radiotransmitter, single-barbed Dan-Inject darts (Dan-Inject, Fort Collins, Colorado, USA) for drug administration and animal tracking. Dart efficacy was assessed based on ballistic reliability, success of drug administration (partial or complete), IM maintenance during animal tracking, and tracking success. Darting was achieved using a Pneu-Dart rifle, Model 193 (Pneu-Dart) or Simmons M3 rifle (Zoolu Arms of Omaha, Omaha, Nebraska, USA) for Pneu-Dart administration, or the Dan-Inject JM Special rifle (Dan-Inject, Ft. Collins, Colorado, USA) for Dan-Inject dart administration.

Tracking was initiated after awarding a short time (approximately 5–10 min) to allow drugs to reach full effect. Animal tracking was done using a Telonics (Telonics, Inc., Mesa, Arizona, USA) TR-2 very high frequency (VHF) receiver (frequency range, 150–152 MHz) and RA-2AK H-type VHF antenna (frequency range, 150–154 MHz).

Descriptive statistics are reported in tabular or graphic format for the anesthetic and physiologic parameters monitored. General linear models (GLM) were developed for each of the following variables: HR, RR, and T. Blood pressure models were fit separately to

TABLE 1. Anesthetic induction and recovery times and estimated distance run recorded for free-ranging white-tailed deer (*Odocoileus virginianus*) anesthetized with butorphanol, azaperone, and medetomidine from November 2006 to May 2007.[a]

Variables	Time to locate (min)	Time to recumbency (min)	Time to data collection (min)	Lag time (min)	Time to recovery (min)	Total down time (min)	Distance run (m)
Mean	17.3	21.4	27.5	6.1	4.5	37	161
Range	3–30	13–35	16–40	0–17	2–8	29–47	46–320
SD	7	5	8	5	1.5	6	82.5

[a] Time to locate = time deer was found minus time when darted; time to recumbency = time animal was recumbent minus time when darted; time to data collection = time of initiation of data collection minus time when darted; lag time = time of initiation of data collection minus time to recumbency; time to recovery = time until standing minus time of reversal agent administration; total down time = time at recovery minus time of recumbency.

SAP, DAP, and MAP. Each blood gas variable was evaluated by GLM; variables included pH, P_aCO_2, P_aO_2, and S_aO_2. In each of the above modeling efforts, the design used was a single repeated-measure factor over time for duration of the study. Assumptions of variance homogeneity and sphericity were tested by Levene's test and Mauchly's test, respectively. In addition to the univariate model, a between-groups factor of sex (male versus female) was evaluated for this model. For each of these models, a covariate of animal weight was introduced and evaluated for model fit, variance reduction, and effect size. Significance of tests of hypotheses were determined using the $P<0.05$ test level.

RESULTS

Twenty-three darting attempts were made, and 15 (65%) were successful. For 13 of 15 (87%) anesthetic events, deer were heavily sedated (1/13; 8%) to lightly anesthetized (12/13; 92%) using butorphanol (mean±SD, 0.58±0.1 mg/kg), azaperone (0.37±0.06 mg/kg), and medetomidine (0.19±0.03 mg/kg). Two deer were administered intravenous butorphanol supplementation to achieve light anesthesia (0.19 mg/kg; 0.12 mg/kg). Complete recovery was achieved using naltrexone (1.34±0.42 mg/kg) and atipamezole (0.93±0.14 mg/kg). Dart administration time, average time to locate animal, to recumbency, to initiation of data collection, lag time, estimated distance run, time to recovery, and total down time are shown (Table 1). One deer was estimated to have traveled ~1,609 m; this animal was considered an outlier and was not included in the descriptive statistics.

Average heart rate (range, 59–66 bpm; mean±SD, 61±2.8 bpm) and respiration rate (range, 24–29 bpm; mean±SD, 26±1.9 bpm) remained within physiologic limits throughout the anesthetic procedures, with the exception of one animal exhibiting persistent tachypnea (Fig. 1). Average systolic, diastolic, and mean arterial blood pressures ranged from 122 to 128 mmHg (mean±SD, 124±2.3 mmHg), 66–79 mmHg (70±5.3 mmHg), and 93–110 mmHg (100±7.4 mmHg), respectively, and were relatively stable throughout the anesthetic event (Fig. 2). Average rectal temperatures were elevated (range, 39.3–39.5 C; mean±SD, 39.4±0.08 C) but not consistent with persistent hyperthermia (T>103 F; T>39.4 C). Bradycardia (HR<60 bpm) or tachycardia (HR>150 bpm) were not observed, and the average mean arterial blood pressure (MAP) remained greater than 90 mmHg and less than 110 mmHg. Arterial blood gas, SpO_2, and $ETCO_2$ values revealed mild to moderate hypoxemia and/or mildly depressed ventilation ($SpO_2<90\%$), without hypercapnea (P_aCO_2 and/or $ETCO_2>60$ mmHg) or acidosis (pH<7.3) (Figs. 3 and 4). There were no significant differences in HR, RR, T, SAP, DAP, MAP, SpO_2, $ETCO_2$, or blood gas values over time when evaluated

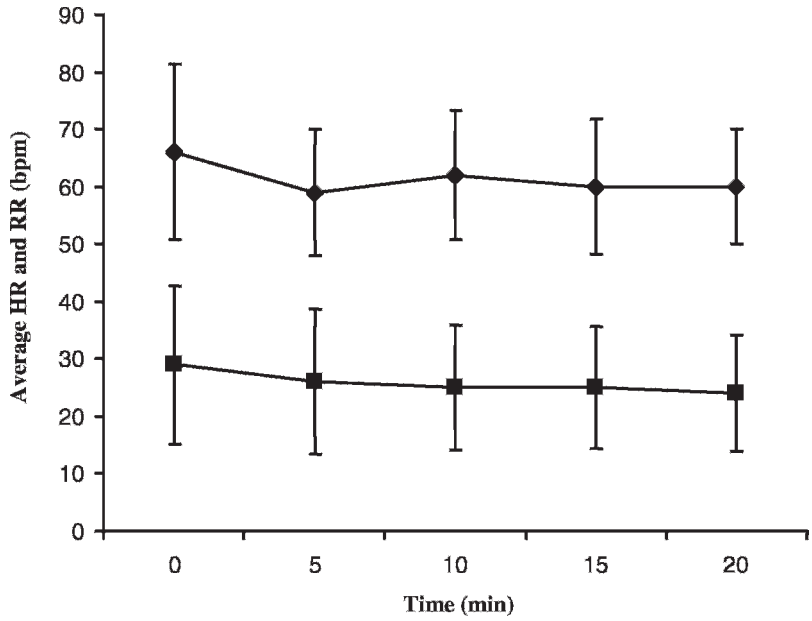

FIGURE 1. Mean±SD heart rate (HR; diamonds) and respiratory rate (RR; squares) of adult white-tailed deer (*Odocoileus virginianus*) anesthetized with butorphanol, azaperone, and medetomidine from November 2006 to May 2007.

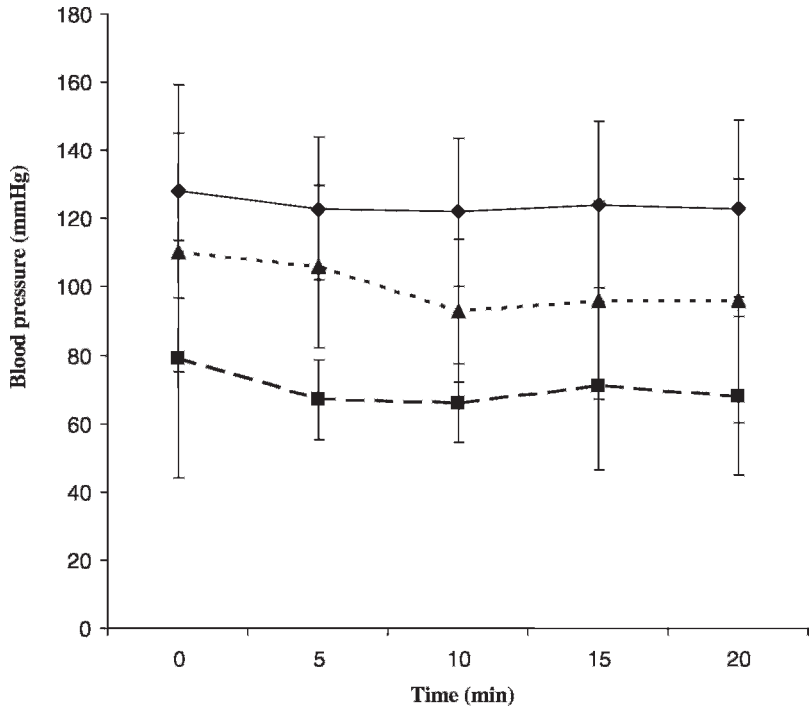

FIGURE 2. Mean±SD indirect systolic (diamonds) and diastolic (squares) and mean (triangles) arterial blood pressure of adult white-tailed deer (*Odocoileus virginianus*) anesthetized with butorphanol, azaperone, and medetomidine from November 2006 to May 2007.

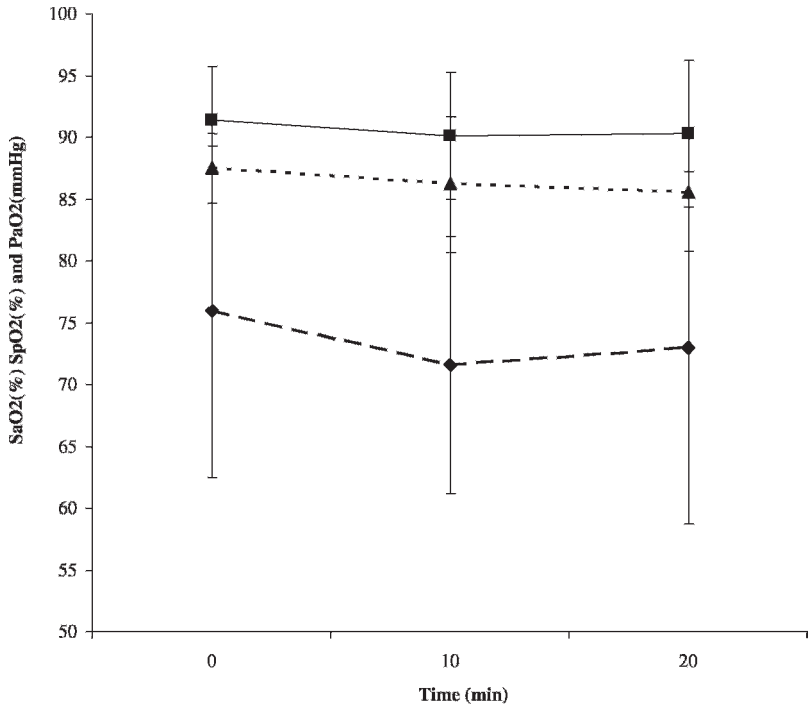

FIGURE 3. Oxygenation status of adult white-tailed deer (*Odocoileus virginianus*) anesthetized with butorphanol, azaperone, and medetomidine from November 2006 to May 2007. Mean±SD oxyhemoglobin saturation (SpO_2; triangles), arterial oxygen saturation (S_aO_2; squares), and arterial partial pressure of oxygen (P_aO_2; diamonds) are depicted.

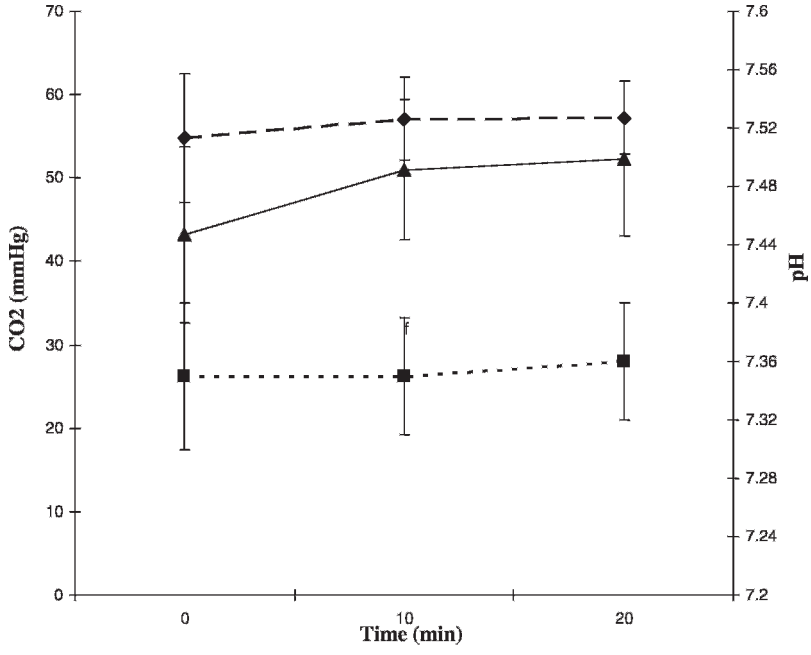

FIGURE 4. Mean±SD pH (squares), end tidal carbon dioxide (CO_2; triangles), and arterial partial pressure of CO_2 (diamonds) in adult white-tailed deer (*Odocoileus virginianus*) anesthetized with butorphanol, azaperone, and medetomidine from November 2006 to May 2007.

TABLE 2. Morphometric measurements (mean± SD) from free-ranging adult male and female white-tailed deer (*Odocoileus virginianus*) anesthetized with butorphanol, azaperone, and medetomidine from November 2006 to May 2007.

Measurement	Male	Female
Weight (kg)	59.3±8.4	46.2±3.6
Shoulder height (cm)	88.4±6.1	83.2±4.7
Half girth (cm)	45.5±5.7	40.5±4.2
Skull to tail base (cm)	109.6±7.4	103.5±5.4

using GLMs. In addition, no significant differences existed for the above parameters based on gender or weight.

Physical examination findings included right mandibular fracture ($n=1$), purulent vaginal and mammary gland discharge ($n=1$), subcutaneous abscess or abscesses ($n=2$), early pregnancy based on abdominal palpation ($n=1$), mild to moderate bloating ($n=3$), and poor body condition ($n=2$). Ectoparasites (deer keds and ticks; species not identified) were noted on nine (64%) of 14 deer, and endoparasites (strongyles) were detected in four (40%) of 10 fecal floatation examinations. With the exception of one buck with a heavy ectoparasite load and one doe with purulent vaginal discharge, all deer appeared to be in good body condition. Antibiotics (300,000 IU/ml; penicillin G benzathine and penicillin G procaine; G. C. Hanford Manufacturing Co., Syracuse, New York, USA; or 200 mg/ml; ceftiofur [Excede], Pfizer) and/or antiparasitics (10 mg/ml; ivermectin [Ivomec], Merial Limited, Duluth, Georgia, USA; or 10 mg/ml; doramectin [Dectomax], Pfizer) were administered as indicated based on overall condition and physical examination findings. All deer were subjectively categorized as adults, and standard morphometrics (height at shoulder, half-girth, skull to tail base length, and weight) were recorded (Table 2).

Subjective quality ratings for anesthetic induction, maintenance, muscle relaxation, recovery, and overall anesthetic event were good to excellent (Table 3).

Based on complete drug administration, IM maintenance of the dart, ability to track the deer, and successful immobilization of WTD, overall dart efficacy was 65%. Dart failures occurred as follows: inadequate drug dosage ($n=2$), incomplete drug delivery ($n=2$), failure of the dart to remain intramuscularly (loss of needle barbs within the animal, use of single-barbed needle, or suspected contact with bone upon impact; $n=3$), poor ballistics ($n=1$), and/or human error ($n=1$). Specifically, use of plastic Dan-Inject darts failed because of excessive dart tail weight resulting in poor ballistics, poor radio signal for successful tracking, and failure of the single-barbed needles to maintain the dart intramuscularly. In one case, the dart contacted the deer but was not maintained, and the animal could not be tracked; in a separate case the dart failed to make contact because of the excessive tail weight, and the drugs were wasted. Pneu-Darts were used for all remaining darting attempts. Pneu-Dart failures were attributed to incomplete/no drug delivery ($n=2$), inadequate IM dart

TABLE 3. Quality ratings[a] for anesthetic induction, maintenance, muscle relaxation, recovery, and overall anesthetic event for free-ranging white-tailed deer (*Odocoileus virginianus*) anesthetized with butorphanol, azaperone, and medetomidine and reversed with naltrexone and atipamezole during November 2006 to May 2007.

Variables	Induction	Maintenance	Relaxation	Recovery	Overall
Mean	1.7	1.5	1.4	1.1	1.3
Range	1–2	1–2	1–2	1–2	1–2
SD	0.5	0.5	0.5	0.4	0.5

[a] Quality ratings were based on subjective scoring, with 1=excellent, 2=good, 3=fair, 4=poor, and 5=unacceptable.

maintenance ($n=2$), and/or human error. Animals in which darts were not maintained intramuscularly were not recovered, despite extensive searching.

DISCUSSION

Free-ranging WTD were successfully anesthetized using an average combination of butorphanol (mean±SD) 0.58±0.1 mg/kg, azaperone 0.37±0.06 mg/kg, and medetomidine 0.19±0.03 mg/kg. For most deer (11/15; 73%), anesthesia was achieved using a combination of 30 mg butorphanol, 20 mg azaperone, and 10 mg medetomidine per dart, despite a wide range in weights. The wide weight range and various physiologic states of deer successfully anesthetized without negative consequence implies a wide margin of safety for this anesthetic combination. This is ideal for field anesthesia, where animal weights are visually estimated before darting, and animals are immediately returned to the wild upon recovery. A relatively long induction delay was required before manipulation of the deer was possible; however, deer recovered within approximately 4 min of reversal administration (Table 1).

Regular monitoring of HR, RR, T, and BP at 5-min intervals revealed stable parameters that remained within physiologic limits throughout the anesthetic event, with repeated measures models showing no significant changes over time (Figs. 1 and 2; Caulkett et al., 2000; Miller et al., 2003; Caulkett and Haigh 2007). Persistent development of bradycardia (HR<60 bpm) or tachycardia (HR>150 bpm) noted in other cervid anesthesias did not occur in this study (Caulkett et al., 2000; Arnemo et al., 2005; Storms et al., 2005; Smith 2006; Caulkett and Haigh 2007; Mich et al., 2008). Although electrocardiograms were not performed, pathologic arrhythmias were not detected during cardiac auscultation, and HRs were comparable to those reported for other cervid anesthesias (Tsuruga et al., 1999; Janovsky 2000; Miller et al., 2003; Wolf et al., 2004; Walter et al., 2005; Storms et al., 2006). Only one animal exhibited persistent tachypnea (RR>50 bpm). The increased respiratory rate in this individual was attributed to poor ventilation, evidenced by the decreased SpO_2 and S_aO_2 readings. The poor ventilation was attributed to large body size (73.4 kg), poor patient positioning (slightly lateral recumbency), and mild-moderate bloating resulting in pressure on the diaphragm. Respiratory rate and severity of bloating decreased when the animal was repositioned into sternal recumbency. Despite the high-normal average rectal temperatures (mean±SD, 39.4±0.08 C), persistent hyperthermia (T>103 F; T>39.4 C) was not encountered (Caulkett and Haigh 2007). This is in contrast to other cervid anesthetic combinations, in which hyperthermia, poor muscle relaxation, and/or abnormal respirations (apnea, bradypnea, tachypnea) were documented, despite relatively short induction times, minimal to no distance traveled, and the use of potent anesthetic combinations (Caulkett et al., 2000; Janovsky et al., 2000; Moresco et al., 2001; Miller et al., 2003; Arnemo et al., 2005; Storms et al., 2005, 2006; Smith, et al., 2006). Average systolic, diastolic, and mean arterial blood pressures were comparable to values recorded in other cervid anesthesias (Caulkett et al., 2000; Posner et al., 2005; Smith et al 2006).

Mean arterial blood gas values of BAM-anesthetized deer revealed mild hypoxemia and depressed ventilation (SpO_2< 90%) but adequate oxygenation (P_aO_2> 60 mmHg, S_aO_2>90%), without hypercapnea or acidemia, and without significant change over time (Figs. 3 and 4). Average SpO_2 did not fall below 85 mmHg for any deer during the 20-min anesthetic event. Because P_aO_2 and S_aO_2 values were measured directly, and not calculated based on human oxygen-hemoglobin dissociation curves, they represent more accurate indicators of oxygenation status than SpO_2. Based on P_aO_2 and S_aO_2

values, all deer in this study were adequately oxygenated. In contrast, poor oxygenation of captive WTD anesthetized with BAM was likely due to larger deer body size, lateral recumbency, anesthetic drugs used, and study site altitude (Mich et al., 2008). Average P_aCO_2 readings remained less than 60 mmHg but were mildly elevated. In some cases, repositioning of the animal into sternal recumbency from a more lateral position improved pulse oximetry and capnograph readings. Supplemental oxygen administration or intubation was not necessary or used in any deer in this study. In contrast, cervids anesthetized with tiletamine/zolazepam or potent opioid combinations have experienced apnea or alterations in RR, with some requiring intubation (Janovsky et al., 2000; Smith et al., 2006). Other opioid-containing combinations have resulted in marked hypoxemia and hypercapnea (Caulkett et al., 2000; Moresco et al., 2001; Arnemo et al., 2005; Storms et al., 2005, 2006; Mich et al., 2008). Acidemia ($pH<7.3$) of respiratory and/or metabolic origin has been noted in cervids using other anesthetic combinations but was not evident in this study (Storms et al., 2005, 2006; Smith et al., 2006).

All WTD were categorized as adults in good body condition, with most having mild to moderate ectoparasite infestations. Physical exam abnormalities were detected in five individuals and were treated as indicated, and standard morphometrics are reported (Table 2).

The overall quality of BAM anesthesia in free-ranging WTD was good to excellent (Table 3) and was characterized by satisfactory induction time, induction to heavy sedation to light anesthesia, maintenance of adequate anesthetic plane and muscle relaxation for completion of all data collection and physical examination, and rapid, smooth recovery following administration of reversal agents. Despite a relatively long induction time compared with some combinations and the inability to monitor the entire induction period, the overall induction period was deemed satisfactory based on the absence of negative or life-threatening consequences, such as injuries, tachycardia, bradypnea/tachypnea, hypoxemia, hyperthermia, lactic acidosis, or acute capture myopathy, associated with the capture/anesthetic event (Tsuruga et al., 1999; Janovsky et al., 2000; Moresco et al., 2001; Arnemo et al., 2005; Storms et al., 2005; Smith et al., 2006; Caulkett and Haigh 2007). Comparable induction times were recorded in free-ranging and captive cervids anesthetized with other anesthetic combinations (Wilson et al., 1996b; Tsuruga et al., 1999; Walter et al., 2005; Mich et al., 2008). Shorter induction times reported using BAM in captive WTD may be attributed to the acclimated state of captive versus free-ranging deer (Mich et al., 2008).

Initiating tracking and locating the animal before full anesthetic effect ($n=3$) led to stimulation and movement of the animal (recumbent to standing, standing to ataxic walking). In two cases, animals were approached, a blindfold placed, manual restraint applied, and supplemental butorphanol (0.19 mg/kg; 0.12 mg/kg) administered intravenously to induce a light plane of anesthesia. In the authors' opinion, a longer time delay between dart administration and manipulation of these two animals likely would have resulted in full drug effect, negating the need for supplemental anesthetics. In other anesthesias successfully performed during the study, blindfolding sedated deer or simply allowing for additional time to pass without animal manipulation resulted in successful immobilization to a plane of light anesthesia. Although successful in the present study, this drug combination and relatively long induction period may not be ideal in other free-ranging situations where other environmental risks are present (predators, cliffs, large bodies of water, other natural barriers) or where animals are in a more excited state before darting.

In the remaining 13 cases, once the

animal was secured and a blindfold placed, supplemental drugs were not required, and muscle relaxation and anesthetic planes remained stable. Intramuscular administration of the reversal agents resulted in consistently smooth, rapid, uneventful recoveries, with little variation in recovery times. First signs of recovery (ear twitch, head movement, standing) occurred within an average of 3.2 min of drug administration, and WTD were fully ambulatory and alert within an average of (mean±SD) 4.5±1.5 min. This is comparable or superior to recovery times reported for opioid/α_2 agonist, α_2 agonist/ketamine, opioid/α_2 agonist/neuroleptic tranquilizer, or tiletamine/zolazepam combinations (Wilson et al., 1996b; Tsuruga et al., 1999; Caulkett et al., 2000; Murray et al., 2000; Miller et al., 2004; Arnemo et al., 2005; Storms et al., 2005; Walter et al., 2005; Mich et al., 2008). In the majority of cases, WTD not only stood within this time period but also were alert with a steady, rapid gait. This allowed for a rapid return to the deer's natural environment, with minimal risk of postanesthetic predation or capture myopathy.

Long-term monitoring of WTD following anesthetic recovery was not done, and potential negative consequences may have gone undetected. However the risk of such consequences is considered less likely using the reversible BAM protocol than in cervids anesthetized with tiletamine/zolazepam combinations, where recovery from anesthesia is often prolonged or rough (Miller et al., 2003) and is supported by use of BAM in captive WTD (Mich et al., 2008).

Use of radiotelemetry Pneu-Darts allowed for successful drug administration and tracking in 65% of the darting attempts, which is comparable to darting success rates reported in other studies (Wolf et al., 2004; Walter et al., 2005). Radiotelemetry Pneu-Darts were successfully tracked in riparian, swampy, and forested areas, often in dense plant growth and brush, and for long distances. Double-barbed needles were maintained in the IM dart sites in the majority of anesthetized WTD. Use of highly concentrated anesthetic agents allowed for small drug volumes and smaller, single-dart requirements. Based on our findings, radiotransmitter-equipped Pneu-Darts were more successful and reliable than Dan-Inject darts and are recommended for delivery of anesthetic agents and animal tracking.

Relative to carfentanil or thiafentanil combinations, the BAM anesthesia protocol was comparatively safer, with fewer opioid-related side effects recorded. Disadvantages associated with the use of potent opioids, including poor induction quality, decreased respirations, moderate to severe hypoxemia, hypercapnea, hyperthermia, excitement before induction, regurgitation/vomition, and renarcotization, were not observed in this study (Caulkett et al., 2000; Moresco et al., 2001; Miller et al., 2003; Wolf et al., 2004; Storms et al., 2005).

Alpha$_2$ agonists used with dissociative anesthetics (i.e., tiletamine-zolazepam mixtures, ketamine) have been associated with rapid onset of action but variable anesthetic quality; respiratory, cardiovascular, and/or gastrointestinal side effects; and incomplete reversibility (Caulkett et al., 2000; Murray, et al., 2000; Storms et al., 2005, 2006). The use of medetomidine, a potent, highly selective α_2 agonist, and the selective antagonist, atipamezole, likely contributed to fewer negative side effects noted with other α_2 combinations. Regurgitation was not detected in any of the anesthetized deer, despite immobilization of deer at feeding stations, although rumination was noted during the anesthetic period. Mild to moderate bloating was noted (3/15; 20%) and improved with animal repositioning. Cardiac arrhythmias were not detected during auscultation, and blood pressures remained within acceptable limits with no significant changes during the anesthetic period. The mild hypoxemia in immobilized WTD was likely due to perfusion mis-

match resulting from poor body positioning (lateral recumbency), bloat, and drug effects because P_aO_2 and S_aO_2 values indicated adequate oxygenation, average respiratory rates remained within normal limits, only mild elevations in P_aCO_2 were present, and pulse oximetry values subjectively improved with animal repositioning (Moresco et al., 2001; Read 2003; Caulkett and Haigh 2007; Mich et al., 2008). Hypoxemia of healthy, nonsedate animals reportedly occurs at P_aO_2 values <80 mmHg, whereas values <60 mmHg in anesthetized individuals warrants correction (Read 2003). In this study, average P_aO_2 values of anesthetized WTD remained above 70 mmHg despite relatively low SpO_2 values (Fig. 3). Increased respiratory rates, marked hypercapnea, and respiratory acidosis (often seen with hypoventilation due to recumbency) were not evident, suggesting other processes, such as peripheral vasoconstriction, induced by the α_2 agonist were occurring (Tsuruga et al., 1999; Janovsky et al., 2000; Read 2003). Ventilation-perfusion mismatch because of rumen bloating or pulmonary hypertension may have contributed to mild hypoxemia detected (Moresco et al., 2001; Read 2003). More severe or prolonged hypoxemia/hypoxia can predispose animals to capture myopathy and other metabolic disorders; a source of supplemental oxygen is recommended during anesthesia of cervids (Moresco et al., 2001; Read 2003; Mich et al., 2008). Based on our findings, SpO_2 values can be used to monitor trends during anesthesia of WTD but may not accurately represent true oxygenation status.

Azaperone is a short-acting butyrophenone tranquilizer that has been used in the translocation of cervids, and in anesthetic combinations (Wilson et al., 1996a, b; Ebedes and Raath 1999; Read and McCorkell 2002; Caulkett and Haigh 2007). Use of azaperone in this study likely contributed to decreased butorphanol and medetomidine doses required, as well as decreased stress, excitement, and injuries in both the induction and recovery stages of anesthesia, where factors such as human presence and release into a new environment (versus the location where darted) were present (Wilson et al., 1996a). Tranquilization and stress reduction are important in species susceptible to capture myopathy, such as WTD, and in free-ranging animals where long-term monitoring following anesthetic recovery is not possible. Potential extrapyramidal side effects of azaperone could not be evaluated based on the current study design but were not detected in captive WTD anesthetized with BAM (Mich et al., 2008). Postanesthetic monitoring of an axis deer (*Cervus axis*) anesthetized with BAM, however, revealed mild head tremors following reversal of medetomidine and butorphanol, which lasted ~10 min, and regurgitation, which spontaneously resolved without negative consequence (Siegal-Willott, pers. obs.). Potential extrapyramidal effects of azaperone may be species or dose-dependent; few reports describe the use of azaperone in cervids, and further investigations are warranted (Wilson et al., 1996a, b; Ebedes and Raath 1999; Read and McCorkell 2002; Mich et al., 2008).

Administration of naltrexone and atipamezole allowed for reversal of butorphanol and medetomidine, respectively. Although highly selective and preferred for antagonism of medetomidine, atipamezole is relatively expensive and may not be feasible for all free-ranging wildlife anesthetic procedures. Alternative α_2 antagonists, such as yohimbine or tolazoline, either alone or in combination with atipamezole, may produce adequate reversal of medetomidine at a reduced cost, although recovery times may be prolonged (Mich et al., 2008). Investigations on use of inexpensive alternative antagonists for reversal of BAM anesthesia are warranted.

In conclusion, the BAM protocol provided safe, reliable, reversible anesthesia of free-ranging WTD and eliminated the

need for potentially hazardous, potent opioids. Despite a relatively long induction period, a stable plane of anesthesia and physiologic parameters were maintained, and undesirable side effects were minimal to nonexistent. Recommended guidelines for successful anesthesia include using 0.6 mg/kg butorphanol, 0.4 mg/kg azaperone, and 0.2 mg/kg medetomidine for induction; allowing an adequate time delay (15–25 min) between dart administration and subsequent tracking and manipulation of the animal; supplemental oxygen availability for cases of severe hypoxemia; positioning animal in sternal recumbency; and using 1.2 mg/kg naltrexone and 1 mg/kg atipamezole for reversal of anesthesia. Evaluation of BAM anesthesia for use in other free-ranging and captive cervids is warranted.

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