Journal of Zoo and Wildlife Medicine 49(4): 1041–1046, 2018

Brief Communication:

REPEATED ANESTHESIA IN A BLACK RHINOCEROS (*DICEROS BICORNIS*) TO MANAGE UPPER RESPIRATORY OBSTRUCTION

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Abstract: This report describes weekly repeated anesthesia in a 7-yr-old, 1,030 kg, female Eastern black rhinoceros (*Diceros bicornis michaeli*), that was immobilized six times using a combination of 2 mg etorphine (0.002 mg/kg), 5 mg medetomidine (0.005 mg/kg), 25 mg midazolam (0.024 mg/kg), and 300 mg ketamine (0.29 mg/kg) delivered intramuscularly (IM) via remote dart to facilitate long-term medical care of a bilateral, obstructive *Actinomyces* sp. rhinitis. The drug combination described in this study resulted in reliable, rapid recumbency of the animal within 2–8 min after initial administration via dart and produced deep anesthesia for 34–78 min without supplemental anesthetic administration. Antagonist drugs (100 mg naltrexone [0.1 mg/kg] and 25 mg atipamezole [0.024 mg/kg] IM) produced reliable and uneventful recoveries in all the procedures. During each anesthetic procedure, the animal was intubated and provided intermittent positive pressure ventilation with a megavertebrate demand ventilator. Tachycardia and hypoxia noted after induction resolved after positive pressure ventilation with oxygen. This report provides useful information on a novel anesthetic protocol used repeatedly for intensive medical management in a black rhinoceros.

Key words: Chemical restraint, *Diceros bicornis*, etorphine, ketamine, medetomidine, midazolam, rhinoceros.

BRIEF COMMUNICATION

Zoologic institutions have played an important role in black rhinoceros (*Diceros bicornis michaeli*) conservation, supporting an estimated global breeding population of 186 individuals in 2014, with 200 eastern black rhinoceros calves reported in the North American Regional Studbooks.[4] The health and well-being of free-ranging black rhinoceros has been greatly advanced through the knowledge gained from caring for rhinoceroses in zoos.[5,7,11] While research related to anesthesia in managed and wild populations has contributed significantly to the care of this species, there is a paucity of literature describing repeated, safe anesthetic protocols in black rhinoceros.

Existing literature describes mostly single anesthetic events in the different rhinoceros species, with only one previous report describing multiple anesthetic events in the same animal, a captive greater one-horned rhinoceros (*Rhinoceros unicornis*) anesthetized over a 55-mo period at approximately 8–10-wk intervals.[1] In this report, the physiologic parameters associated with anesthetic induction, maintenance, and recovery are reported for a 7-yr-old, 1,030 kg, female eastern black rhinoceros. The rhinoceros was anesthetized weekly for a 6-wk duration to facilitate treatment of an obstructive *Actinomyces* sp. rhinitis and postoperative surgical care of a related bilateral dorsal sinusotomy.

A combination of 2 mg etorphine HCl (Wildlife Pharmaceuticals Inc., Windsor, CO 80550, USA; 10 mg/ml, 0.002 mg/kg), 5 mg medetomidine HCl (Wildlife Pharmaceuticals Inc.; 20 mg/ml, 0.005 mg/kg), 25 mg midazolam (Wildlife Pharmaceuticals Inc.; 50 mg/ml, 0.024 mg/kg), and 300 mg ketamine (Wildlife Pharmaceuticals Inc.; 200 mg/ml, 0.29 mg/kg) were delivered via remote injection with a 3.0-ml plastic dart (DanInject LLC, Austin, TX 78753, USA) and a 60-mm needle (DanInject LLC) using a compressed carbon dioxide-powered pistol (DanInject LLC) as the induction protocol (Table 1). The only variation was a one-time administration of 3 mg of medetomidine instead of 5 mg (Table 1).

Drug administration via dart was recorded as time zero, and mean (±SD) time to recumbency was 4.8 min (±2.11). During each procedure, the

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Table 1. Anesthetic drug combinations and induction, supplementation, and recovery times in six procedures performed weekly in a black rhinoceros (*Diceros bicornis*).[^]

		Induction drugs administered												Antagonist drugs				
		Ketamine		Medetomidine		Midazolam		Etorphine						Naltrexone		Atipamezole		
Date	Weight, kg	mg/kg	Total mg	mg/kg	Total mg	mg/kg	Total mg	mg/kg	Total mg	Induction time, min	Supplemental drugs, mg	Time of supplement, min from start of procedure	Total anesthesia time, min	mg/kg	total mg	mg/kg	total mg	Recovery duration, min
6 Feb 2018	1,057	0.28	300	0.005	5	0.024	25	0.002	2	2	P (100)	41	140	0.09	100	0.024	25	4
											K (300)	44						
14 Feb 2018	1,039	0.29	300	0.003	3	0.024	25	0.002	2	8	P (60)	34	94	0.1	100	0.024	25	4
											A (12.5)	40						
											P (60)	47						
											P (100)	48						
											P (60)	48						
											D (10)	51						
22 Feb 2018	1,019	0.29	300	0.005	5	0.025	25	0.002	2	3	None		61	0.1	100	0.024	25	6
1 Mar 2018	1,026	0.29	300	0.005	5	0.024	25	0.002	2	5	None		75	0.1	100	0.024	25	7
8 Mar 2018	1,023	0.29	300	0.005	5	0.024	25	0.002	2	7	None		58	0.1	100	0.024	25	7
15 Mar 2018	1,030	0.29	300	0.005	5	0.024	25	0.002	2	4	K (300)	78	162	0.1	100	0.024	25	7
											P (100)	110						
											P (100)	129						
											K (300)	145						
											D (10)	148						

[^] K = ketamine (MWI Animal Health, Boise, ID 83705, USA; 100mg/ml); P = propofol (Propoflo 28™, Abbott Laboratories; 10 mg/ml); A = azaperone (Wildlife Pharmaceuticals Inc.; 50 mg/ml); D = detomidine (Detomidine HCl, Zoetis Inc.; 10 mg/ml).

animal was positioned in either sternal or lateral recumbency depending on the need for a different position for treatment or diagnostic imaging. A blindfold and ear plugs were used to reduce sensory stimulation. When the animal was in sternal recumbency for more than 1 hr, its position was changed to lateral recumbency to allow for improved circulation to the limbs.

Following recumbency, a hydraulic wedge jack (Strongway 4 TON Hydraulic Ram Pump, Northern Tool + Equipment, Burnsville, MN 55306, USA) was positioned between the maxillary and mandibular dental arcades and spread apart to facilitate access to the oropharynx to allow intubation with a 26- or 28-mm endotracheal tube (Smiths Medical North America, Inc., Norwell, MA 02061, USA). A standard equine gastric tube was placed by direct palpation into the trachea and used as a guide stylet for the endotracheal tube. Mechanical ventilation was performed immediately after intubation using a megavertebrate demand ventilator (In Case of Anesthesia, La Jolla, CA 92037, USA). A compressed oxygen tank powered the ventilator with drive gas pressure of 70 PSI to generate an expected fraction of inspired oxygen (FiO_2) of 40% for all anesthetic events. Inspiratory pressure and respiratory rate ranged from 25 to 35 cm H_2O and from 2 to 12 breaths/min, respectively.

Oxygen saturation (SpO_2) was recorded using a pulse oximeter and reflectance probe (Masimo-SET Rainbow, Masimo Corporation, Irvine, CA 92618, USA) placed against the nictitating membrane in the medial canthus of the eye. The probe was secured by taping the eyelids closed. Prior to intubation and ventilation, SpO_2 ranged from 55–76% but subsequently improved to 88–100%. Cardiopulmonary auscultation and a multiparameter monitor (Datascope Passport 2, Datascope Corp., Mahwah, NJ 07430, USA) with electrocardiogram (ECG) leads positioned in a base-apex configuration using 18-ga, 1.5-inch intradermal needles were used to monitor heart rate (HR). HR prior to intubation and ventilation was 124 ± 11 beats/min (mean ± SD) but changed to 60 ± 9 beats/min (mean ± SD) after ventilation. Once intubated, the animal was provided 6 (±3) breaths/min by positive pressure ventilation at a target peak inspiratory pressure of 30 cmH_2O. Indirect blood pressure (systolic 184 ± 39 mmHg, diastolic 128 ± 32 mmHg, mean ± SD), end tidal CO_2 (49 ± 8 mmHg, mean ± SD), and body temperature (96.8 ± 2.8 °F, mean SD) were also measured throughout the procedure. Data are summarized in Table 2.

During three of the six anesthetic events, the animal was supplemented with varying combinations of intravenous doses of 60–100 mg propofol (Propoflo 28™, Abbott Laboratories, North Chicago, IL 60064, USA; 10 mg/ml, 0.06–0.1 mg/kg), 300 mg ketamine (0.28–0.29 mg/kg), and 10 mg detomidine (Detomidine HCl, Zoetis Inc., Kalamazoo, MI 49007, USA; 10 mg/ml, 0.01 mg/kg) to maintain an adequate depth of anesthesia for the needed surgical treatments or to treat hypertension (12.5 mg azaperone [Wildlife Pharmaceuticals Inc.]; 50 mg/ml, 0.01 mg/kg)). The times at which a supplement was needed from the start of the procedure (initial darting) ranged from 34–148 min and were well tolerated in all cases.

Anesthetic reversal was accomplished with 100 mg Naltrexone HCl (Wildlife Pharmaceuticals Inc.; 50 mg/ml, 0.1 mg/kg) and 25 mg atipamezole (Wildlife Pharmaceuticals Inc.; 25 mg/ml, 0.024 mg/kg) administered in the dorsolateral cervical musculature. Total immobilization time from darting to reversal drugs and time from reversal to standing were recorded (Table 1) with a mean ± SD of 98.3 ± 43.3 min and 5.6 ± 1.5 min, respectively.

Etorphine, a potent opioid, is the most-frequently used agent for anesthesia in black rhinoceros[12] and was used in all procedures in this report. Etorphine is typically used in combination with one or multiple other agents including α-2 agonists, butyrophenones, benzodiazepines, and N-Methyl-D-aspartate receptor (NMDAR) antagonists-dissociative anesthetic agents.[1,16,17] Rhinoceros are reportedly particularly sensitive to the effects of etorphine, which has resulted in a number of reported complications including hypertension, tachycardia, acidemia, and respiratory depression with hypoxemia and hypercapnia,[3,9,10,11] all of which were seen intermittently during the procedures described in this report.

The α-2 agonists, such as detomidine and medetomidine, enhance sedation and analgesia, providing improved muscle relaxation,[5] but can exacerbate respiratory depression and alter thermoregulatory mechanisms.[14] In the reported rhinoceros, adequate sedation and analgesia were obtained, respiratory depression was present, and body temperature remained within normal range. The butyrophenone, azaperone, can enhance tranquilization in rhinoceroses, shorten induction, cause peripheral vasodilation, and reduce hypertension induced by opioids.[12] Azaperone was used once during the longest anesthetic event (Table 1) to address

Table 2. Summary of the physiologic parameters obtained in an anesthetized black rhinoceros (*Diceros bicornis*) before and during positive pressure ventilation with oxygen supplementation. Values are pooled from six separate procedures and presented as mean ± SD.^

	Preventilation			During ventilation						
	RR (rpm)	HR (bpm)	SpO_2 (%)	RR (rpm)	HR (bpm)	ET CO_2 (mmHg)	SpO_2 (%)	SAP (mmHg)	DAP (mmHg)	Temp (°F)
Mean ± SD	3 ± 1.7	124 ± 9.6	64 ± 8.7	6 ± 2.6	60 ± 9.5	49 ± 8.3	94 ± 4.6	185 ± 39.6	128 ± 32.2	96.84 ± 2.84

^ RR = respiratory rate; rpm = respirations per minute; HR = heart rate; bpm = beats/min; $ETCO_2$ = end tidal carbon dioxide; mmHg = millimeters of mercury; SpO_2 = oxygen saturation; SAP = systolic arterial pressure; DAP = diastolic arterial pressure; Temp = body temperature; °F = Fahrenheit.

concerns related to hypertension effectively. When used in combination with etorphine, hypercapnia, hypoxemia, and acidemia have been reported.[12,13,15]

Ketamine has been used in rhinoceros anesthesia protocols as a supplemental agent and as a coinduction drug in combination with etorphine and medetomidine.[2] Ketamine can favorably reduce induction duration and decrease necessary supplemental drugs when used as an induction drug.[1,12] For these reasons, ketamine was used as part of this animal's anesthetic induction protocol and as a supplemental anesthetic. This report provides useful information on a novel anesthetic protocol used repeatedly in a black rhinoceros for intensive medical management for upper respiratory obstruction. This information will further expand the options for anesthetic management of black rhinoceroses, particularly those requiring recurrent anesthesia.

The reported drug combination and dosages produced reliable and safe anesthesia with a smooth, rapid induction. The anesthetic protocol maintained a deep anesthetic plane for a period of 34–78 min without supplemental drug requirements. The potential long-term consequences of repeated immobilization on the cardiovascular system are unknown. This protocol, in combination with manual positive pressure ventilation (PPV), allowed anesthetists to overcome complications reported in literature for this species and expanded anesthetic options for rhinoceros.

Recumbency and positioning of the animal varied during every procedure. Sternal recumbency may allow better ventilation[7,8,11] and was ideal for treatment purposes. Lateral recumbency allows for improved peripheral limb circulation based on lower lactate values and reduces the risk of myositis that has been described with large animals in prolonged recumbency.[11] Limbs were flexed and extended at 30–60-min intervals to promote muscle perfusion during anesthetic episodes in this case.[14] Additionally, multiple thick, large animal surgery pads were placed under the animal while it was in sternal and lateral recumbency in an effort to prevent pressure-induced nerve damage.

When a lower total dosage of medetomidine was given, time to recumbency was longer and supplemental drugs were required earlier compared with the other procedures, suggesting that the use of a relatively higher dose of medetomidine may improve induction time and allow the

effects of the initial anesthetic agents to last longer.

Negative effects such as renarcotization, head-pressing, or pacing were not observed in any of the procedures. There was no observed opioid drug tolerance, as described in another report of repeated anesthetic procedures in a rhinoceros;[1] thus, the total etorphine dosage remained the same through all the events.

Compared with normal reported physiologic parameters in standing unrestrained white rhinoceros (*Ceratotherium simum*), HR, end tidal CO_2 measurements, and indirect blood pressure values were higher.[6] This disparity is most-likely attributable to the anesthetic drugs used, but species variations or illness may have been contributing factors. Tachycardia and low oxygen saturation were noted before positive pressure ventilation was initiated. A normalization of HR was observed after intubation when supplemental oxygen was provided via positive pressure ventilation (average HR preintubation 123 beats/min vs. postintubation 60 beats/min). While monitoring trends using pulse oximetry were useful in this case, it is important to note that blood gas analysis is more reliable to detect hypoxemia, as SpO_2 has been shown to overestimate hemoglobin oxygen saturation in rhinoceros.[7]

The drug combination described in this report was effective for weekly repeated anesthesia in a black rhinoceros, producing a smooth and rapid induction with a reliable deep anesthetic plane. Recovery from anesthesia was consistently smooth and uneventful in all the procedures, with a short recovery time from antagonist administration to the animal standing with no evidence of renarcotization.

Acknowledgments: The authors thank the dedicated animal care and veterinary staff of the Chicago Zoological Society for their significant contributions and assistance with this case. The authors further thank Dr. Mathew Gerard, Dr. Anthony Blikslager, and John Ladner from North Carolina State University, and Dr. Jeffery Zuba and Dr. Christopher Downs for sharing their experience and assisting with this case.

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Accepted for publication 23 August 2018