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REPEATED CHEMICAL IMMOBILIZATION OF A CAPTIVE GREATER ONE-HORNED RHINOCEROS (*RHINOCEROS UNICORNIS*), USING COMBINATIONS OF ETORPHINE, DETOMIDINE, AND KETAMINE

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Abstract: An adult, 23 yr-old, male greater one-horned rhinoceros (*Rhinoceros unicornis*) was repeatedly immobilized with combinations of etorphine, detomidine, and ketamine to provide medical and surgical care to chronic, bilateral, soft tissue lesions on the hind feet and to collect semen by electroejaculation. The rhinoceros was successfully immobilized on 24 occasions over a 55 mo period at approximately 8–10 wk intervals, 17 times with a combination of etorphine and detomidine (M99–D, i.m.) by projectile dart and seven times with a combination of etorphine, ketamine, and detomidine (M99–K–D, i.m.) by pole syringe. The combination of etorphine, detomidine, and ketamine repeatedly and safely induced prolonged anesthesia, and a suitable drug combination includes 3.5–3.8 mg etorphine, 14 mg detomidine, and 400 mg ketamine (M99-K-D) administered i.m. into the neck.

Key words: Etorphine, detomidine, ketamine, chemical immobilization, greater one-horned rhinoceros, *Rhinoceros unicornis*.

INTRODUCTION

The greater one-horned rhinoceros (*Rhinoceros unicornis*) has been chemically restrained in the field using etorphine and acepromazine,[3] although there are few references to chemical immobilization of this species in captivity, where immobilization may be necessary for physical examination, surgery, reproductive manipulation, or medical treatment.[1,10,11] The need for intervention is evidenced by the large number of medical problems, particularly chronic, nonhealing foot lesions in adult male *R. unicornis* within the zoo population, which may require frequent chemical restraint to facilitate treatment.[20,24,25]

Opioids, such as etorphine, provide excellent restraint and analgesia in many nondomestic species,[5,6,7,17] including the rhinoceros.[3,7,14,15,26] In combination with alpha-2 adrenergic agonists such as detomidine, etorphine provides prolonged and controlled anesthesia with good muscle relaxation. The addition of alpha-2 agonists improves the quality of induction and maintenance of opioid immobilization.[12] Opioids, however, cause respiratory depression and hypoxia in rhinoceroses.[8,13] A chemical immobilization regimen using azaperone–butorphanol combinations has been used successfully in other rhinoceros species.[18]

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Prolonged lateral recumbency places a large rhinoceros at risk of hypoventilation, ventilation–perfusion mismatching, pulmonary shunting, progressive atalectasis, and hypoxemia.[8,22] This necessitates the recognition and careful evaluation of oxygenation trends and the degree of hypoxemia during anesthesia.

Detomidine is a potent alpha-2 adrenoceptor agonist that produces effective and prolonged analgesia in the horse[9] and is a suitable analgesic agent in horses with chronic hoof pain.[16] Ketamine is frequently used as a supplemental agent to opioid–alpha-2 agonist anesthesia in nondomestic perissodactylids. In tapirs, ketamine prolongs the immobilization period, increases the depth of sedation, and maintains a desired plane of anesthesia induced by butorphanol–xylazine.[4,23] Alpha-2 agonists reduce ketamine requirements by their effect on the central nervous system and by increasing ketamine bioavailability.[12]

CASE REPORT

A captive, adult, 23-yr-old, male greater one-horned rhinoceros (*R. unicornis*) was immobilized 24 times using combinations of etorphine (M99-Ten, Wildlife Pharmaceuticals, Fort Collins, Colorado 80524 USA), detomidine (Dormosedan, Pfizer, Exton, Pennsylvania 19380, USA), and ketamine (Ketaset, Fort Dodge Laboratories, Inc., Fort Dodge, Iowa 50501, USA) between June 1996 and January 2001. The primary purpose of the immobilizations was to permit long-term medical and surgical care to chronic, active, bilateral, hind foot soft tissue lesions. On eight of the occasions, semen

collection by electroejaculation was attempted after provision of foot care.

The anesthetic drugs are referred to by alphanumeric designation, with etorphine = M99, detomidine = D, and ketamine = K.[21] Immobilizing doses of M99–D (n = 17) were administered i.m. by projectile dart (PneuDart, Inc., Williamsport, Pennsylvania 17703, USA). Combinations of M99–K–D (n = 7) were administered i.m. with a spring-loaded pole syringe (DanInject, Wildlife Pharmaceuticals). Each restraint episode was performed within a 36-m^2 concrete stall with sliding doors, steel pipe fence, and gates. The floor of the stall was thickly bedded with hardwood mulch. The animal's estimated weight was 2,500 kg.

For procedures using M99–D the mean immobilizing dosages were 3.36 ± 0.2 mg i.m. and 12.65 ± 1.54 mg i.m., respectively. For M99–K–D the mean immobilizing dosages were 3.71 ± 0.15 mg i.m., 400 mg i.m., and 14 mg i.m., respectively (Table 1). To achieve consistent immobilization results, the M99–D dosage was gradually increased, from 3 mg in June 1996 to 3.5 mg in June 2000 for M99–D and from 3.5 mg in November 1999 to 3.8 mg in January 2001 for M99–K–D. For both combinations, ketamine (100–250 mg i.v. by hand syringe into an auricular vein) was administered at 20- to 30-min intervals (or as required) to lengthen the immobilization period and increase the depth of sedation. Total dose of supplemental ketamine was 100–2,250 mg per restraint episode, depending on the depth and duration of anesthesia required. At the termination of each procedure, the effects of etorphine were antagonized by administration of naltrexone (150–300 mg, half i.v. and half i.m.). No reversal agent was administered to antagonize the effects of detomidine.

Time from injection to recumbency, total immobilization time, and time to standing after reversal were recorded. Patient monitoring included cardio-pulmonary auscultation, measurement of rectal body temperature (°C), and pulse oximetry (pneuPAC, Bedfordshire, U.K.) with the probe placed over a lingual artery, dependant ear, or peripheral skin fold. Arterial blood oxygenation trends (S_aO_2) were continuously recorded during all immobilizations. In 15 out of 24 immobilization episodes, 100% oxygen was administered through a nasal cannula by a demand valve resuscitator (LSP1, Allied Health Care Products, St. Louis, Missouri 63110, USA) capable of flow rates up to 160 L/min. Oxygen was administered on the basis of S_aO_2 trends (decreasing trends of S_aO_2 below 80%). Mean ± SD times to recumbency were 16.6 ± 8.9 min and 7.6 ± 2.4 min after M99–D and M99–K–D administrations, respectively. Mean ± SD times of immobilization were 65.8 ± 22.2 min and 76.6 ± 25.5 min for M99–D and M99–K–D procedures, respectively. To achieve consistent immobilization results, the etorphine dosage was gradually increased, from 3 mg in June 1996 to 3.8 mg in June 2000. To maintain an adequate plane of anesthesia during procedures, the mean total amounts of supplementary ketamine administered were 767.7 ± 537.9 mg for M99–D and 428.6 ± 215.8 mg for M99–K–D.

Heart rates were 45–75 (x = 60 ± 11.11) beats/min and 46–69 (x = 56 ± 8.07) beats/min for M99–D and M99–K–D immobilizations, respectively. Respiratory rates were 8–19 (x = 11 ± 2.62) breaths/min and 8–14 (x = 9 ± 3.43) breaths/min for M99–D and M99–K–D immobilizations, respectively. Rectal body temperatures were 36–38.4°C (x = 36.9 ± 1.03) and 37.1–38.4°C (x = 37.8 ± 0.59) for M99–D and M99–K–D immobilizations, respectively. Pulse oximetry readings were 70–98% (x = 87% ± 5.15) and 80–95% (x = 87% ± 4.26) for M99–D and M99–K–D immobilizations, respectively. After administration of naltrexone, mean times to standing were 3.5 ± 1.7 min and 2.5 ± 0.6 min for M99–D and M99–K–D procedures, respectively. Reversal was considered smooth and controlled for all procedures but was always accompanied by transient, mild to moderate facial pruritis.

DISCUSSION

Both drug combinations proved effective for repeated immobilization of one adult *R. unicornis*. Despite adequate immobilization after drug administration by darting, difficulties were encountered. Although the massive musculature and relatively thin skin make the neck a suitable dart site for adult rhinoceroses, such peculiar anatomical features as the large skin folds of the neck significantly reduce the target area in *R. unicornis*.

Limitations of dart size also precluded the addition of other agents to the immobilizing dose. A pole syringe allows rapid administration of a relatively large volume, but success is limited by how closely the operator can approach the animal. In the present case, suitable facilities, skilled animal management staff, and a relatively tractable patient allowed successful drug administration.

Multiple confounding variables make the relative advantages and disadvantages of each drug combination difficult to ascertain. Subjectively, the anesthetic events improved when the etorphine dosage was increased, ketamine was administered with the immobilizing combination, and the drugs were

Table 1. Drug dosages and anesthetic parameters of an adult, male greater one-horned rhinoceros (*Rhinoceros unicornis*) repeatedly immobilized with etorphine (M99), detomidine (D), and ketamine (K) combinations.

	Date of event	M99 (mg)	D (mg)	K (mg)	Induction time (min)	K suppl. (mg)	Immobilization time (min)	Naltrexone (mg)	Reversal time (min)	Respiratory rate (breaths/ min)	S_aO_2 (%)
M99-D	Jun 1996	3	10	0	8	600	64	300	2	8	93
	Aug 1996	3	10	0	5	100	47	200	5	8	88
	Sep 1996	3	10	0	18	250	56	150	8	11	76
	Dec 1996	3.3	12	0	15	600	97	175	2	19	86
	Jan 1997	3.5	14	0	19	600	56	175	4	13	85
	Feb 1997	3.6	13	0	15	600	44	200	4	8	90
	Apr 1997	3.5	14	0	21	1,400	67	250	2.5	12	89
	Nov 1997	3.2	12	0	12	350	48	200	2	11	86
	Jan 1998	3.5	12	0	15	600	59	300	2	12	97
	Mar 1998	3.5	12	0	27	400	61	300	4	12	87
	Nov 1998	3.2	12	0	12	900	40	200	2.5	12	85
	Dec 1998	3.4	14	0	20	1,200	96	250	3	11	92
	Feb 1999	3.4	14	0	33	600	74	250	2	12	92
	Mar 1999	3.5	14	0	36	2,250	122	200	3	11	87
	Jun 1999	3.5	14	0	5	1,500	83	250	6	11	84
	Aug 1999	3.5	14	0	10	600	55	250	3	8	85
	Apr 2000	3.5	14	0	11	500	49	250	4	10	78
Mean		3.36	12.65	0.00	16.59	767.65	65.76	229.41	3.47	11.12	87.06
SD		0.20	1.54	0.00	8.87	537.92	22.20	46.13	1.65	2.62	5.15
M99-K-D	Nov 1999	3.5	14	400	8	400	111	250	3	7	87
	Feb 2000	3.5	14	400	6	500	52	200	2	8	93
	Jun 2000	3.8	14	400	4	300	44	250	3	7	88
	Aug 2000	3.8	14	400	10	750	95	250	3	13	86
	Oct 2000	3.8	14	400	6	200	82	250	2	14	89
	Dec 2000	3.8	14	400	11	650	90	250	2	6	80
	Jan 2001	3.8	14	400	8	200	62	250	2	13	89
Mean		3.71	14.00	400.00	7.57	428.57	76.57	242.86	2.43	9.71	87.43
SD		0.15	0.00	0.00	2.44	215.75	24.53	18.90	0.53	3.45	3.95

Table 2. Selected anesthetic parameters of an adult, male greater one-horned rhinoceros (*Rhinoceros unicornis*) repeatedly induced with 3.5 mg etorphine (M99) and 14 mg detomidine (D), and with the same dosages of M99-D and 400 mg ketamine (K).

	Date of event	Induction time (min)	K suppl. (mg)	Immobilization time (min)	Naltrexone (mg)	Reversal time (min)	Respiratory rate (breaths/min)	S_aO_2 (%)
Induced with M99-D	Jan 1997	19	600	56	175	4	13	85
	Apr 1997	21	1,400	67	250	2.5	12	89
	Mar 1999	36	2,250	122	200	3	11	87
	Jun 1999	5	1,500	83	250	6	11	84
	Aug 1999	10	600	55	250	3	8	85
	Apr 2000	11	500	49	250	4	10	78
Mean		17.00	1,141.67	72.00	229.17	3.75	10.83	84.67
SD		11.05	696.00	27.28	33.23	1.25	1.72	3.72
Induced with M99-D and 400 mg K	Nov 1999	8	400	111	250	3	7	87
	Feb 2000	6	500	52	200	2	8	93
Mean		7.00	450.00	81.50	225.00	2.50	7.50	90.00
SD		1.41	70.71	41.72	35.36	0.71	0.71	4.24

administered by pole syringe. With time, there was a need to gradually increase the dosage of etorphine to achieve consistently adequate immobilization during the 55 mo of this study. Although the increased dosages of etorphine that were used as the study progressed elevated the risk of hypoxemia and respiratory depression, the quality of anesthesia remained good throughout the study period, and no negative effects were noted. Opioid drug tolerance may explain the need for a gradually increasing etorphine dosage. Anesthetic reversal was consistently smooth, controlled, and rapid. Because of the controlled conditions, postanesthetic monitoring, and desire for prolonged analgesia after surgery, the effects of detomidine were not antagonized. The facial pruritis may have been mediated by the exogenous opioid, although this is uncertain and remains under investigation.

The mean induction time, amount of ketamine supplementation required to maintain anesthesia, duration of immobilization, and reversal time differed according to anesthetic protocol (Table 1). Ketamine supplementation after induction was necessary to maintain or deepen the plane of anesthesia, improve muscle relaxation, and permit surgical procedures to be performed without premature arousal of the animal. Despite the variation in drug dosages, subjective assessment of the data suggests that, when compared with M99–D, M99–K–D produces more rapid induction and is characterized by a reduced requirement for ketamine supplementation and a shorter reversal time after antagonism with naltrexone.

Eight procedures used identical doses of etorphine (3.5 mg) and detomidine (14 mg). Six did not use ketamine during induction, whereas two did (Table 2). Although this data subset is limited, it may be useful in evaluating the potential improvements offered by the addition of ketamine to the immobilizing dose. They suggest three likely advantages of M99–K–D over M99–D: induction time is reduced, total amount of ketamine required to maintain adequate anesthesia is decreased, and reversal time after antagonism is shorter. In terms of the mean amount of ketamine (in mg) required per minute of mean immobilization time (time from injection of immobilizing drugs to complete antagonism), 15.9 mg ketamine/min was required during M99–D procedures, whereas 10.4 mg ketamine/min was required during M99–K–D procedures. Regardless of anesthetic regimen, arterial oxygen saturation values monitored by pulse oximetry were similar between groups, with a mean S_aO_2 value of 87 ± 5.2% for M99–D procedures versus 87 ± 3.9% for M99–K–D procedures.

Pulse oximetry is a useful adjunct to anesthetic monitoring in wildlife species[2], and it should always be used during rhinoceros immobilizations. Decreased S_aO_2 values may be a result of the combined respiratory depressant effects of etorphine and detomidine as well as the effects of lateral recumbency that likely exacerbate ventilation–perfusion mismatch. Based on the normal oxygen–hemoglobin dissociation curve, where oxygen saturation below 90% reflects an arterial pressure of oxygen of 60 mm Hg or below, pulse oximetry

readings below 90% may indicate a hypoxemic state in an immobilized patient.[4] In the present study, in 11 out of 17 (65%) immobilizations using M99–D and six out of seven (86%) using M99–K–D, mean S_aO_2 values were below 90%. Values of S_aO_2 during etorphine anesthesia in white rhinoceros are commonly 80–85% and may fall below 50% in some cases.[15,17,19] Because of the potential inaccuracies of peripheral pulse oximetry monitoring and our lack of knowledge of *R. unicornis* oxygen–hemoglobin dissociation curves, however, the interpretive worth of the mean values is questionable. Trends in S_aO_2 during anesthesia are probably of greater value than individual readings are. A low-percentage reading is not of major concern provided other physiologic parameters are within normal limits. Additional study is needed, however, to assess the value of this noninvasive monitoring technique in the rhinoceros.

CONCLUSIONS

The combination of etorphine, detomidine, and ketamine repeatedly and safely induced prolonged anesthesia in *R. unicornis* under controlled conditions. A suitable drug combination includes 3.5–3.8 mg etorphine, 14 mg detomidine, and 400 mg ketamine (M99–K–D) administered i.m. into the neck. This combination, in conjunction with supplemental i.v. ketamine, provides adequate and prolonged muscle relaxation and sufficient analgesia to perform painful procedures without premature arousal. Initial immobilizing combinations of M99–D without ketamine produced longer induction times, larger amount of ketamine required for supplementation, and longer reversal time after etorphine antagonism with naltrexone.

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