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Partially Reversible Immobilization of Free-Ranging Huemul Deer (*Hippocamelus bisulcus*) with Medetomidine-Ketamine and Atipamezole

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ABSTRACT: A combination of intramuscular medetomidine and ketamine was used to immobilize 46 free-ranging huemul deer (*Hippocamelus bisulcus*) with a remote drug delivery system in Chilean Patagonia for tagging and biological sampling. Captures occurred in May–October of 2005–09 between fall and early spring in the southern hemisphere. An initial dose of 6.6 mg medetomidine and 185 mg ketamine was adjusted after 17 captures to 3 mg and 200 mg, respectively, in the 29 remaining deer. Mean±SD adjusted dose was 0.042±0.012 mg/kg of medetomidine and 2.929±0.427 mg/kg of ketamine. Inductions were calm and the mean±SD time to sternal recumbency was 10.3±10.1 min. Palpebral reflex and jaw tone were present during immobilization. Atipamezole at 5 mg/mg of medetomidine was administered intramuscularly for reversal after 55.3±18.8 min procedure time. Recoveries were smooth and mean±SD time to standing was 10.2±3.3. All immobilized animals were hypoxemic by pulse oximetry (blood oxygen saturation approximately 81%). Three animals that developed apnea were resuscitated through chest compression and atipamezole administration, another regurgitated during capture, and all developed tachypnea. The combination of medetomidine-ketamine and atipamezole can be used for partially reversible immobilization of huemul, but supplemental oxygen should be administered, blood oxygenation should be monitored, and equipment for intubation and manual ventilation should be available.

Key words: Anesthesia, atipamezole, *Hippocamelus bisulcus*, huemul deer, ketamine, medetomidine.

Chemical capture is often required for management or research purposes in wildlife. For endangered species, the safety of individual animals is critical, and selected protocols should be selected to minimize the anesthetic risk (Chinnadurai et al. 2016). The combination of medetomidine with ketamine has been widely used for immobilization of free-ranging ungulates and is the recommended anesthetic combination in several deer species (Kreeger and Arnemo 2018; Lian et al. 2019). Ketamine has no known antagonist and immobilization typically lasts from 45 min to 2 h (Caulkett and Arnemo 2015). The effects of medetomidine can be reversed by administration of atipamezole and recoveries of immobilized animals can thus be shortened in order to restore normal physiologic functions.

The huemul deer (*Hippocamelus bisulcus*), endemic to southern Chile and Argentina, is the most endangered Neotropical deer species (IUCN 2020). Huemul populations are highly fragmented, and the total number of animals is estimated to be <1,500 (IUCN 2020). Here, we report a retrospective and opportunistic evaluation of the use of medetomidine (Zalopine, 10 mg/mL, Orion Pharma Animal Health, Turku, Finland), ketamine (Imalgéne 1000, 100 mg/mL, Boehringer Ingelheim Animal Health, Lyon, France), and atipamezole (Antisedan, 5 mg/mL, Orion Pharma Animal Health) for partially reversible immobilization of free-ranging huemul deer. Deer were immobilized during assessment of huemul population dynamics (Corti et al. 2010). Although medetomidine-ketamine has been used in huemul deer, clinical and physiologic assessment of this combination has not been reported in free-ranging Neotropical deer. Our goals were to determine an effective regime for handling during the planned procedures without any spontaneous recovery, assess physiologic drug effects, and evaluate postcapture long-term outcome.

The study was carried out in the Aysén District, Chilean Patagonia, at Lago Cochrane National Reserve (currently the Patagonia National Park) in May–October 2005–09, mostly after rut during fall, winter, and early spring in the southern hemisphere. Captures were authorized by the Chilean Agriculture and Livestock Service (permit nos. 1434/2005, 5420/2005, 9/2006, 22/2007, 7376/2009), Santiago, and approved by the Animal Care Committee, Université de Sherbrooke, Sherbrooke, Québec, Canada. All procedures were performed and supervised by a veterinarian (P.C.). We captured a total of 46 huemul: 38 adults >3 yr (22 females, 16 males) and eight juveniles 1–3 yr (three females, five males; Corti et al. 2010). We approached the animals on foot to within 15 m and administered an intramuscular combination of medetomidine-ketamine with a CO_2-powered dart projector and 3-mL darts fitted with a 1.5-×25-mm barbed needle with side ports (Dan-Inject, Børkop, Denmark), aiming for the hindquarter muscle groups. The time from dart injection to first effect (e.g., ataxia) and recumbency were recorded. To establish an initial dose of drug combination, we used information reported in the literature for other deer of similar size (e.g., white-tailed deer, *Odocoileus virginianus*, Millspaugh et al. 2004; Svalbard reindeer, *Rangifer tarandus platyrhynchus*, Arnemo and Aanes 2009) and previous captures from Chile's Forest Service. Initially, 6.6 mg of medetomidine and 185 mg of ketamine per animal were administered to 17 individuals (eight females, nine males). After three individuals developed apnea during anesthesia, doses were changed, reducing the medetomidine dose to 3 mg and increasing the ketamine to 200 mg per animal to compensate for the lower medetomidine dose; this dose was used on 29 individuals. Immobilized animals were blindfolded, kept in sternal recumbency on an insulated blanket, and physically examined. The palpebral reflex and jaw tone were used to assess depth of anesthesia (Kreeger and Arnemo 2018). Rectal temperature was measured with a digital thermometer, and the respiratory rate was recorded by counting chest movements. In animals immobilized with the initial dose, the heart rate was recorded with a stethoscope. In animals immobilized with the adjusted dose, the pulse rate and relative arterial oxygen saturation were monitored with a pulse oximeter, with the sensor applied to the tongue (Nellcor 20P, Nellcor Inc., Pleasanton, California, USA). Physiologic parameters were checked after recumbency in the middle of the immobilization period (20–30 min) and before reversal injection. All animals were weighed and ear-tagged, and 27 individuals (five males, 22 females), seven from the initial dose and 20 from the adjusted dose group, were fitted with a VHF radio-collars with mortality sensors (model V5C 176A, Sirtrack Ltd., Havelock North, New Zealand; Corti et al. 2010). After processing was complete, atipamezole was administered intramuscularly at 5 mg/mg of medetomidine for reversal (33 mg for the initial dose, 15 mg for the adjusted dose). Animals were observed during recovery, and the time from administration of atipamezole to lifting of the head and standing were recorded. Postcapture survival and reproduction of 22 females were assessed by radio telemetry or visual observations (Corti et al. 2010). All data were analyzed by R software (R Core Development Team 2020). The Mann-Whitney *U*-test was used to compare female and male median body mass, with $P \leq 0.05$ considered significant.

All 46 animals became immobilized after one dart injection, and no injuries or mortalities occurred during the capture events. Because no significant differences between female (mean±SD=69.1±6.4 kg, median=68 kg) and male (70.9±8.8 kg, 70.9 kg) body mass were detected ($n_{\text{females}}=25$, $n_{\text{males}}=21$, $U=232.5$, $P=0.515$), all data were pooled. The summary statistics for the initial and adjusted doses are given in Table 1. Inductions were smooth, muscle relaxation was good, and there was no reaction to handling or minor painful stimuli (e.g., ear tagging). The palpebral reflex and jaw tone were present during immobilization. Two females and one male in the initial dose group developed apnea, but they were resuscitated by chest compression and admin-

TABLE 1. Summary statistics for 46 anesthesia events of huemul deer (*Hippocamelus bisulcus*) with medetomidine-ketamine combination and reversal with atipamezole. Animals were darted during southern hemisphere fall, winter, and spring (April–November) between 2005 and 2009 in Lago Cochrane National Reserve, Aysén District, Chilean Patagonia. Because no significant differences were observed between female and male body mass, data from all animals were grouped and analyzed together.

	Respiratory rate (breaths/min)			Heart or pulse rate[b] (beats/min)			SpO2 (%)[c]			Rectal temperature (C)			Capture time (min)[d]				
Parameter[a]	Start	Middle	End	Start	Middle	End	Start	Middle	End	Start	Middle	End	Recumbent	Head-down	Antagonist	Head-up	Standing
Initial dose[e]																	
n	14	7	13	16	9	16	—	—	—	15	7	15	17	17	17	17	17
Mean (SD)	81 (14)	87 (19)	83 (15)	87 (26)	85 (29)	89 (24)	—	—	—	37.9 (1.0)	38.0 (1.2)	38.1 (1.0)	8.0 (5.3)	14.2 (9.8)	51.5 (9.4)	6.6 (2.4)	10.9 (4.4)
Median	78	80	80	88	88	93	—	—	—	38	37.8	38.1	6	10	51.5	6	10
Adjusted dose[f]																	
n	24	22	18	27	23	22	23	17	21	27	25	22	29	27	29	27	24
Mean (SD)	88 (20)	83 (12)	79 (15)	56 (12)	60 (18)	53 (14)	82 (10)	80 (9)	81 (12)	38.1 (0.9)	38.2 (0.7)	38.1 (0.5)	10.3 (10.1)	19.9 (14.9)	57.6 (22.4)	6.7 (1.4)	10.2 (3.3)
Median	80	80	80	56	56	51	83	77	81	38.3	38.4	38.1	7.3	14	48	7	9.8
U	202	68.5	112.5	—	—	—	—	—	—	263	101.5	231	285	313	248.5	275	203.5
P value	0.308	0.681	0.872	—	—	—	—	—	—	0.114	0.537	0.042	0.386	0.05	0.973	0.272	0.100

[a] Median was used in the Mann-Whitney *U*-test results of dose group comparisons.

[b] No statistical comparisons were carried out between heart rate recorded with a stethoscope in the initial dose animals and pulse rate recorded by pulse oximetry in the adjusted dose animals. — = not applicable.

[c] Oxygen saturation is only for adjusted capturing dose. — = no data.

[d] Capture time is from darting to recumbency, head-down, and antagonist injection, then time from antagonist application to animal head-up and standing.

[e] The first 17 captures were carried out with an initial dose of 6.6 mg of medetomidine and 185 mg of ketamine. Atipamezole dose was 5 mg/mg of medetomidine.

[f] The adjusted dose was 3.0 mg of medetomidine and 200 mg of ketamine. Atipamezole dose was 5 mg/mg of medetomidine.

istration of atipamezole. One immobilized female regurgitated and was positioned with the head and nose lower than the chest to avoid aspiration of rumen contents. This individual survived at least 3 yr postcapture. Mean recovery time was about 10 min after atipamezole was injected.

The adjusted dose of medetomidine was 0.042±0.012 mg/kg, whereas the adjusted dose for ketamine was 2.929±0.427 mg/kg. The atipamezole dose was 0.211±0.060 mg/kg. Assessment of postcapture reproduction in 22 adult females showed that 11 gave birth the same year and three gave birth the following year (Corti et al. 2010).

Huemul deer are calm and lack the shyness to people usually seen in most other wild deer. Thus, individuals of this species can be approached and darted from 10–15 m without eliciting any obvious flight response. A rapid onset of drug effects is therefore not as important as in other wildlife capture situations, and the prolonged inductions found in huemul deer, including a slight difference between initial and adjusted dose head-down time, were considered clinically acceptable. In a study on Svalbard reindeer (a species with a similar behavior and body mass), the same drug combination and capture method has been used (Arnemo and Aanes 2009). Those authors compared two different dose ratios for medetomidine:ketamine—1:5 and 1:20, respectively—and recommended the 1:20 dose ratio. On the basis of the initial drug responses in the present study, we adjusted the dose ratio from 1:28 to 1:67 to achieved fewer side effects.

Although medetomidine-ketamine effectively induced immobilization in the huemul deer, pulse oximetry showed that most animals were hypoxemic (blood oxygen saturation approximately 81%, hypoxemia defined as $SpO_2<85\%$; Caulkett and Arnemo 2015), so supplemental oxygen should be included in the anesthetic protocol of future studies on this species. We are not aware of any published reference ranges for vital signs in huemul deer. We assume that the body temperature in huemul is 38–39 C, similar to other mammalian species of comparable body size (e.g., reindeer, *Rangifer tarandus*; Lian et al. 2019), and mean rectal temperatures were within this normal range. Although rectal temperatures at the end of the procedure were statistically different between initial and adjusted doses, the difference is not clinically significant. The heart rate in animals immobilized with the initial dose was much higher than the pulse rate in animals immobilized with the adjusted dose. This result was unexpected because medetomidine is known to cause a dose-dependent bradycardia in domestic animals. Unfortunately, we did not record variables collected through stethoscope and pulse oximeter in parallel for comparison in any of the animals. The mean pulse rates in huemul deer were 50–65 beats/min, which is higher than the reference range of 35–45 beats/min for resting *R. tarandus* in winter (Lian et al. 2019) and twice as high as the mean values of 31–32 beats/min reported in Svalbard reindeer immobilized with medetomidine-ketamine in winter (Arnemo and Aanes 2009). Even though the huemul deer showed no other signs of stress or excitement, tachypnea was a prominent response in most animals, possibly contributing to hypoxemia. The mean respiratory rates were in the range of 80–95 breaths/min, which is six to seven times higher than in the study on Svalbard reindeer. The resting respiratory rate in *R. tarandus* is 23–36 breaths/min (Lian et al. 2019). Anesthetic drugs tend to depress respiratory function, with signs of hypoventilation recognized by a lowered respiratory frequency and shallow breathing (Bouts et al. 2011). Mental stress, however, may increase the respiratory frequency, and under experimental conditions, rates >250 breaths/min have been recorded (Lian et al. 2019). All recoveries were uneventful, and the mean times from administration of the antagonist to standing of 10 min are comparable to reversal times in the Svalbard reindeer study (10–13 min; Arnemo and Aanes 2009).

We conclude that the adjusted doses used in the present study effectively immobilized free-ranging huemul deer. Because of pronounced respiratory depression observed in the initial captures and hypoxemia and tachypnea in all captures, supplemental oxygen should be administered, blood oxygenation should be closely monitored, and equipment for intubation and manual ventilation should be available.

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