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Authors: Haviernick, Martine, Côté, Steeve D., and Festa-Bianchet, Marco

Source: Journal of Wildlife Diseases, 34(2) : 342-347

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-34.2.342

Journal of Wildlife Diseases, 34(2), 1998, pp. 342–347

IMMOBILIZATION OF MOUNTAIN GOATS WITH XYLAZINE AND REVERSAL WITH IDAZOXAN

Martine Haviernick,[1] Steeve D. Côté,[1] and Marco Festa-Bianchet[1,2]

[1] Groupe de recherche en écologie, nutrition et énergétique, Département de biologie, Université de Sherbrooke, Sherbrooke, Québec, Canada, J1K 2R1

[2] e-mail: mbianche@courrier.usherb.ca

ABSTRACT: Mountain goats (*Oreamnos americanus*) were captured in traps and immobilized with xylazine, later reversed with idazoxan. One hundred and forty-one goats were immobilized, 94 with a single injection and 47 with multiple injections. Dosage (mg/kg of body weight) of xylazine received, induction time, and recovery time after handling did not differ among sex-age classes. Increasing the dosage did not shorten induction time. The first injection of xylazine in multiple-injection captures was lower than the dose given in single-injection captures, suggesting that insufficient initial doses of xylazine made multiple injections necessary. Xylazine is an effective drug for immobilization of mountain goats captured in traps, at dosages of about 4.9 mg/kg. The dosage of xylazine required to immobilize mountain goats is higher than that reported for bighorn sheep and white-tailed deer.

Key words: Idazoxan, immobilization, mountain goat, *Oreamnos americanus*, xylazine.

INTRODUCTION

The capture of wild animals is a stressful event, and information on reducing the impacts of capture operations is essential for wildlife research (Dawkins and Gosling, 1992; Côté et al., 1998). In a review of capture methods for bighorn sheep (*Ovis canadensis*), Kock et al. (1987) concluded that chemical immobilization had the highest risk of mortality through respiratory and gastrointestinal problems, bradycardia, and capture myopathy (see also Ballard and Tobey, 1981; Hsu and Shulaw, 1984; Seal et al., 1985). The development of antagonists to reverse the sedative effects of drugs has lowered the risk of accidental death for captured animals by reducing recumbency and handling time (Hsu and Shulaw, 1984; Jessup et al., 1985b; Van Der Eems and Brown, 1986; Kreeger, 1996; Côté et al., 1998).

Researchers have used a wide range of immobilizing drugs to capture wild mammals (Berger et al., 1983; Jacobsen, 1983; Jessup et al., 1985a; Festa-Bianchet and Jorgenson, 1985; Seal et al., 1985). Although xylazine presents some disadvantages, including long recovery times and risks of regurgitation (Jessup et al., 1983, 1985b; Jorgenson et al., 1990; Wallingford et al., 1996), it is more easily available than narcotics, is less expensive, has wide safety margins, and is relatively safe for field staff (Festa-Bianchet and Jorgenson, 1985; Doherty et al., 1987; Doherty and Tweedie, 1989). Although xylazine has been often used in combination with other drugs such as ketamine (Festa-Bianchet and Jorgenson 1985), for bighorn sheep no difference in the effects of xylazine were found when used alone or in combination with ketamine (Jorgenson et al., 1990). Other combinations of drugs such as ketamine-medetomidine and etorphine-xylazine also have been recommended for mountain goats (Kreeger, 1996). As a reversing agent to antagonize xylazine, the potent α-2 antagonist idazoxan has been used successfully on several ungulates (Doherty et al., 1987; Doherty and Tweedie, 1989; Jorgenson et al., 1990). Also, idazoxan can reverse respiratory and cardiovascular depression produced by xylazine and appears more efficient than yohimbine (Doherty et al., 1987; Doherty, 1988).

Our long-term study of mountain goats (*Oreamnos americanus*) required capturing and marking individuals. Goats captured in traps could not be handled without chemical immobilization because of their aggressive nature and dangerous horns. The decision to use xylazine to im-

mobilize goats and idazoxan as a reversal agent was taken largely on the basis of previous experiences with bighorn sheep (Jorgenson et al., 1990).

The effect of xylazine varies with the level of excitement: excited animals require higher doses (Jacobsen, 1983). Box traps are dark and captured animals cannot see out, while goats caught in Clover traps (Clover, 1956) can see researchers approaching them. Therefore, it was expected that goats would have longer induction times in Clover traps than in box traps.

This paper reports the effects of different xylazine and idazoxan dosages upon induction and recovery times of mountain goats of different sex-age classes. Recommendations for immobilizing wild mountain goats captured in traps are given.

MATERIALS AND METHODS

Goats were studied from 1988 to 1997 at Caw Ridge (54°03′N, 119°27′W), in the front range of the Rocky Mountains of west-central Alberta (Canada). Goat captures took place between June and October with self-tripping nylon mesh Clover traps (Clover, 1956) and remotely-controlled Stevenson's box traps, baited with salt. Xylazine (Rompun®, 100 mg/ml, Bayvet Division, Etobicoke, Ontario, Canada) was injected intramuscularly with a long-pole syringe. Kids and most yearlings were handled without drugs. Each goat was weighed with a spring scale and the dosage of xylazine used was calculated as mg/kg. In this study, dose of drug is defined as the total amount of xylazine (mg) administered to a goat, and dosage as the amount of xylazine given per unit of body weight (mg/kg). Multiple-injection captures refer to goats that needed more than one injection of xylazine. After injection (in the rump 98% of the time), researchers moved out of sight of the goat until a few minutes after it was recumbent. Induction time was calculated from injection to when the goat was recumbent. Immobilized goats were blindfolded and hobbled. Samples of dry idazoxan (RX 811059, Reckitt & Colman, Kingston-upon-Hull, England) were prepared in advance, and 1 cc of distilled water was added about 30 min before injection. Adult goats received 1 to 1.2 mg, and 1- to 2-yr-olds were given 0.7 to 1 mg. Idazoxan was injected intramuscularly after all processing of the animal was completed. Recovery was the time between the injection of idazoxan and when the goat could stand on its feet and walk. Handling time was between the injection of xylazine and that of idazoxan.

Yearling and 2-yr-old goats of each sex were combined because small sample sizes precluded separate analyses. Adults were ≥3-yr-old. Because not all data were normally distributed according to Shapiro-Wilk tests (Sokal and Rohlf, 1981), the Kruskal-Wallis ANOVA was used to compare dosages, induction time, and recovery time among sex-age classes of goats immobilized with a single injection. Mann-Whitney *U* tests were used to determine whether the type of trap influenced induction times and to compare dosage of xylazine and idazoxan and recovery time between single- and multiple-injection captures (pooling all sex-age classes because of small sample size). Although idazoxan was administered to all goats drugged, the dose injected was not systematically noted in 1988–94, explaining the smaller sample size for idazoxan dosages compared to xylazine dosages. A *G*-test was used to compare the frequency of single- and multiple-injection captures between Clover and box traps, and Kendall's rank correlation coefficient to assess the effect of xylazine dosage on induction time and the effect of idazoxan dosage (all sex-age classes pooled) on recovery time. All analyses involving induction time were limited to single-injection captures, because induction time in multiple-injection captures could not be determined precisely (Sillero-Zubiri, 1996). The parameter z_t stands for the z-transformation of the statistical parameter of each test (Sokal and Rohlf, 1981). Statistical procedures followed Sokal and Rohlf (1981), and probability values were two-tailed, with significance level set at $\alpha = 0.05$. Averages are reported with one standard deviation.

RESULTS

Of 141 immobilizations of mountain goats, 94 involved a single injection of xylazine and 47 required multiple injections. A few minutes after the injection, goats gradually dropped their heads, had difficulty standing, and finally lied down. When those reactions were not observed 15 to 20 min after injection, a smaller second dose was injected. Goats immobilized with a single injection received dosages ranging from 2.4 to 7.5 mg/kg, while goats that required multiple injections received from 2.6 to 14.0 mg/kg.

For single-injection captures, goats were

TABLE 1. Immobilization and handling of mountain goats after a single injection of xylazine in Alberta, 1988 to 1997.

Sex-age class	Xylazine dosage (mg/kg)	n[a]	Induction (min)	Idazoxan dosage (mg/kg)	n[a]	Recovery (min)	Handling time (min)
Juvenile males	4.9 ± 1.3[b]	19	6.0 ± 2.1	0.021 ± 0.003	10	5.4 ± 4.3	44.1 ± 16.7
	(2.4–6.5)		(2.6–10.0)	(0.017–0.027)		(0–14.1)	(23.5–80.7)
Adult males	4.9 ± 0.8	12	6.2 ± 2.5	0.013 ± 0.004	6	6.3 ± 7.7	43.7 ± 11.9
	(3.4–6.3)		(3.1–11.4)	(0.008–0.019)		(0–20.6)	(26.7–60.5)
Juvenile females	5.2 ± 1.0	23	6.7 ± 3.6	0.030 ± 0.014	10	4.9 ± 4.9	34.6 ± 11.0
	(3.3–6.9)		(2.9–18.0)	(0.018–0.060)		(0–16.0)	(17.0–68.0)
Adult females	4.7 ± 0.8	40	7.6 ± 4.4	0.020 ± 0.005	11	6.0 ± 5.5	43.0 ± 11.1
	(3.4–7.5)		(1.3–21.8)	(0.013–0.031)		(0–18.0)	(22.2–69.2)

[a] Note that sample sizes for xylazine and idazoxan dosages differed.
[b] Mean ± SD with ranges in parentheses.

recumbent within 14 min of injection, except for three goats that were recumbent after 18 to 21.8 min. All sex-age classes received comparable dosages (Table 1) ($H = 5.98$, $df = 3$, $P = 0.11$). Induction times did not vary among sex-age classes (Table 1) ($H = 1.75$, $df = 3$, $P = 0.6$). Goats received an average of 0.022 ± 0.010 mg/kg of idazoxan, and recovery time of immobilized animals varied from <5 sec from when the needle was withdrawn to 20.6 min ($\bar{x} = 5.7$ min; Table 1). Recovery started with movements of the legs and attempts to stand. Once the goat was able to stand, it could usually run within a few seconds.

Increasing dosages of xylazine did not reduce induction time in any sex-age class (juvenile males: $z_t = -0.28$, $P = 0.8$; adult males: $z_t = -0.62$, $P = 0.5$; juvenile females: $z_t = -0.16$, $P = 0.9$; adult females: $z_t = 0.29$, $P = 0.8$). Similarly, dosage of idazoxan did not affect recovery time (all sex-age classes combined, $z_t = 0.03$, $P = 1.0$).

Prior to the injection of xylazine, goats in box traps appeared more calm than goats caught in Clover traps. When approached, goats in box traps typically just looked at the small door through which the pole syringe was inserted, while those in Clover traps usually jumped and tried to escape, repeatedly hitting the nylon netting. Type of trap, however, did not affect induction time (all sex-age classes combined, $z_t = -1.03$, $P = 0.3$). Mean handling time for all sex-age classes was 41 ± 13 min.

The first dose of xylazine in multiple-injection captures was lower than that administered in single-injection captures for juvenile males ($z_t = -2.80$, $P = 0.01$), juvenile females ($z_t = -2.67$, $P = 0.01$) and adult females ($z_t = -2.39$, $P = 0.02$), but not for adult males ($z_t = -0.33$, $P = 0.7$) (Table 2). The total dosage injected in multiple-injection captures was higher than the dosage given in single-injection captures for adults (females: $z_t = -5.62$, $P = 0.001$; males: $z_t = -2.45$, $P = 0.01$) but the difference was not significant in juveniles (females: $z_t = -0.45$, $P = 0.7$; males: $z_t = 0$, $P = 1.0$) (Tables 1, 2). The frequency of single- and multiple-injection captures was similar in both type of traps ($G = 0.70$, $P = 0.4$, $N = 139$).

Goats immobilized with more than one injection of xylazine received a similar amount of idazoxan ($\bar{x} = 0.017$ mg/kg) as those immobilized with a single injection ($\bar{x} = 0.022$ mg/kg) ($z_t = -1.57$, $P = 0.12$). Dosage of idazoxan did not affect recovery time of goats immobilized with multiple injections of xylazine (all sex-age classes combined, $z_t = -0.56$, $P = 0.6$). Recovery time did not vary between goats immobilized with a single injection and those that required multiple injections ($z_t = -1.23$, $P = 0.22$).

TABLE 2. Immobilization and handling of mountain goats after multiple injections of xylazine in Alberta, 1988 to 1997.

Sex-age class	First xylazine dosage (mg/kg)	Total xylazine dosage (mg/kg)	n[a]	Idazoxan dosage (mg/kg)	n[a]	Recovery (min)
Juvenile males	2.7 ± 1.1[b]	4.9 ± 1.9	6	0.020 ± 0.002	2	8.8 ± 3.7
	(1.3–4.0)	(2.6–7.6)		(0.019–0.022)		(5.3–14.0)
Adult males	4.6 ± 1.4	6.7 ± 1.8	13	0.015 ± 0.004	7	9.1 ± 12.9
	(1.8–6.7)	(4.3–9.5)		(0.009–0.021)		(0–43.0)
Juvenile females	3.3 ± 1.3	4.8 ± 1.4	5	0.019	1	3.0 ± 4.4
	(1.3–4.8)	(2.6–6.4)		(0.019)		(0–8.0)
Adult females	3.9 ± 1.2	7.3 ± 2.3	23	0.021 ± 0.001	2	7.9 ± 7.6
	(1.2–6.3)	(4.7–14.0)		(0.020–0.022)		(1.0–26.5)

[a] Note that sample sizes for xylazine and idazoxan dosages differed.
[b] Mean ± SD with ranges in parentheses.

DISCUSSION

The results of this study confirm the efficacy of xylazine for ungulates (Jacobsen, 1983; Doherty et al., 1987; Doherty and Tweedie, 1989; Jorgenson et al., 1990). Xylazine has no long-lasting side effects or effects on long-term survival (Festa-Bianchet and Jorgenson, 1985; Berger and Kock, 1988; Côté et al., 1998). Dosages needed to induce immobilization in goats (4.7–5.2 mg/kg) were higher than those required for white-tailed deer (*Odocoileus virginianus*), 2.8–3.7 mg/kg (Hsu and Shulaw, 1984), and bighorn sheep, 3.5–3.8 mg/kg (Jorgenson et al., 1990). Side effects of xylazine include bradycardia, increased risk of bloat and regurgitation, respiratory depression and decreased blood pressure, but α-2 adrenoceptor antagonists like idazoxan appear to reduce the risk of mortality and permit a rapid recovery (Hsu and Shulaw, 1984; Jessup et al., 1985b; Doherty, 1988; Jorgenson et al., 1990). No cases of regurgitation during immobilization were observed during this study. However, Côté et al. (1998) reported that drugging goats with xylazine may decrease kid production by young females and increase the risk of kid abandonment. Therefore, females aged 2 to 4 yr and lactating females should not be drugged.

Jacobsen (1983) reported that increasing xylazine dosage for trapped black-tailed deer (*Odocoileus hemionus columbianus*) reduced induction time. The lack of a relationship between dosage and induction time suggests that increasing dosage will not improve the effectiveness of xylazine. Therefore, dosage should be kept to the minimum level required for immobilization, to reduce the risks of complications.

Of the 141 mountain goats immobilized in this study, 47 (33%) required multiple injections. Mechanical problems with the syringe, bleed-back of drugs, insufficient dose or injection in avascular tissues can lead to incomplete or ineffective injections. Also, individual variability in response to drugs may cause unsuccessful immobilizations and increase variance in recovery times after injection of an antagonist (Ballard and Tobey, 1981; Renecker and Olsen, 1985).

Jorgenson et al. (1990) reported that bighorn sheep caught in box traps could be immobilized with lower dosages than needed for free-ranging sheep. Darkness in box traps and the absence of external stimulation may have increased drug efficacy for bighorn sheep. However, in our study the use of box traps did not reduce dosages required for immobilization of goats compared to Clover traps. We suspect that individual stress level probably had a great influence on drug efficacy for goats. In their study on white-tailed deer, Hsu and Shulaw (1984) reported that a

second injection of xylazine had little additional sedative effect, but in our study a second injection of xylazine increased the level of sedation of goats (see also Renecker and Olsen, 1985). In the case of multiple-injection captures, the lower dosage of the first injection compared to single-injection captures was apparently insufficient, and made multiple injections necessary. The dosage of xylazine given in the first injection was probably insufficient to inhibit the release of norepinephrine acting on α2-adrenergic receptors, and the goat could still use some of its locomotor functions (Kreeger, 1996). The need for additional injections may then be reduced by an adequate initial dosage. We recommend the following doses of xylazine for mountain goats captured in traps during summer: 140 mg for yearlings, 240 mg for 2-yr-old females, 270 mg for 2-yr-old males, 290 mg for 3-yr-old females, 400 mg for 3-yr-old males, 310 mg for female ≥4 yrs and 430 mg for males ≥4 yrs.

Three goats died within 15 min of drugging (1.6% of drugged goats). All three goats received a single dose of xylazine (4.5, 5.2 mg/kg, and unknown dose). High excitement levels may contribute to the risk of chemical immobilization because agitated animals usually require higher dosages (Jacobsen, 1983; Renecker and Olsen, 1985; Kreeger, 1996). However, overdose appeared unlikely in our study because Roughton (1975) reported dosages of xylazine of up to 8 mg/kg body weight in white-tailed deer, without any mortality. As suggested by Jorgenson et al. (1990), greater individual stress before immobilization, leading to cardiopulmonary problems, was a more probable explanation of these deaths. Therefore, an antagonist such as idazoxan should always be administered to counter the effects of xylazine because of its capacity to reversed respiratory and cardiovascular depression (Doherty et al., 1987).

Xylazine is an effective drug for immobilizing mountain goats captured in traps. The dosage of xylazine required to immobilize mountain goats is higher than that reported for bighorn sheep and white-tailed deer, but the low mortality rate recorded in this study suggests that it is safe. Dosages used in this study (mean of 4.9 mg/kg) resulted in 98% of captured goats successfully immobilized and released alive. Kock et al. (1987) reported an average of 8% mortality in free-ranging bighorn sheep immobilized via a chemical method. Xylazine has proven to be an effective immobilizing agent in confined situations, especially with the use of an antagonist such as idazoxan (Hsu and Shulaw, 1984; Jorgenson et al., 1991). However, since all goats immobilized were trapped, we do not know the dosages necessary to immobilize free-ranging goats. The variability of individual responses to xylazine (Renecker and Olsen, 1985), the high sensitivity of mountain goats to helicopters (Côté, 1996), and the higher doses of xylazine often required to immobilize free-ranging animals (Doherty and Tweedie, 1989; Jorgenson et al. 1990) warrant great caution before dart guns are used to immobilize mountain goats with xylazine, particularly if helicopters were necessary to approach the goats (Côté, 1996).

ACKNOWLEDGMENTS

We are grateful to C. Beaudoin, F. Boulanger, D. Dubé, F. Fournier, D. Hildebrand, P. Jones, S. Lovari, A. Peracino, G. Romeo, G. Simard, L. Vallières, and S. Wendenbaum for help with captures. A special thank to M. Urquhart for his committment to field work. This study was financed by Alberta Natural Resources Service; Alberta Sports, Recreation, Parks and Wildlife Foundation; Natural Sciences and Engineering Research Council of Canada (operating grant to M.F.-B. and postgraduate Scholarships to S.D.C. and M.H.); Fonds pour la Formation des chercheurs et Aide à la Recherche (Québec, grant to M.F.-B.); Alberta Wildlife Enhancement Fund, and the Rocky Mountain Goat Foundation (grants to S.D.C. and M.F.-B.). We thank the Alberta Lands and Forest Service staff in Grande Cache, the Alberta Natural Resources Service staff in Edson and Grande Cache, the Grande Cache Correctional Center, Renewable Resources Consultants and Smoky River Coal Ltd. for logistic support. K. G. Smith constructively

reviewed an earlier draft of this paper. This is contribution No. 118 of the Groupe de recherche en écologie, nutrition et énergétique, Université de Sherbrooke.

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Received for publication 25 February 1997.