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REVERSAL BY TOLAZOLINE HYDROCHLORIDE OF XYLAZINE HYDROCHLORIDE–KETAMINE HYDROCHLORIDE IMMOBILIZATIONS IN FREE-RANGING DESERT MULE DEER

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ABSTRACT: We captured 10 free-ranging desert mule deer (*Odocoileus hemionus crooki*) (five males and five females) by net-gun from a helicopter and immobilized them with xylazine hydrochloride (HCl) (100 mg) and ketamine HCl (300 to 400 mg) injected intramuscularly. Arousal and ambulation times were 13.9 ± 4.2 and 14.3 ± 4.2 min in eight deer injected intravenously with tolazoline HCl (3.0 mg/kg). We observed a curvilinear relationship ($R = 0.50$, $P < 0.01$) between rectal temperature and time after induction of anesthesia. Mean peak temperature (41.4 C) occurred at 23.7 ± 3.2 min postinduction and was greater ($P < 0.01$) than the mean temperature measured initially (40.8 C). Heart and respiratory rates (108 beats/min and 75 breaths/min) were elevated prior to immobilization. Mean heart rate increased ($P < 0.05$) from 90 ± 9 beats/min in anesthetized deer to 120 ± 13 beats/min after tolazoline HCl injection. A 20% capture-related mortality rate suggests this combination of physical and chemical capture has serious limitations. Captive deer permitted to recover from xylazine HCl–ketamine HCl immobilization without a reversal agent were able to walk in 290 ± 79 min.

Key words: Chemical immobilization, desert mule deer, ketamine hydrochloride, net-gun, *Odocoileus hemionus crooki*, tolazoline hydrochloride, xylazine hydrochloride.

INTRODUCTION

The effectiveness of xylazine HCl and xylazine HCl–ketamine HCl combinations for immobilizing deer (*Odocoileus* spp.) and reversing these immobilizations with yohimbine HCl (Jessup et al., 1983; Hsu and Shulaw, 1984; Mech et al., 1985) or tolazoline HCl (Kreeger et al., 1986) have been reported. Most of these studies involved captive white-tailed deer (*O. virginianus*) and Rocky Mountain mule deer (*O. hemionus hemionus*). Information on the effectiveness of these drugs in free-ranging deer has been limited (Jessup et al., 1983; Kreeger et al., 1986). Use of xylazine HCl and ketamine HCl to immobilize desert mule deer (*O. hemionus crooki*) and the effectiveness of antagonists to reverse these immobilizations have not been reported.

In rugged desert habitats, Krausman et al. (1985) used a net-gun from a helicopter for capturing free-ranging desert mule deer for radio-collaring. Chemical restraint may offer advantages when handling procedures require more time than collaring and involve physiological data collection, administration of treatments, and morphological measurements (Seal and Bush, 1987). Krausman et al. (1984) immobilized free-ranging desert mule deer by remote injection of etorphine HCl from a helicopter; however a 15% mortality rate of deer was associated with this technique.

We examined the efficacy of xylazine HCl and ketamine HCl for immobilizing free-ranging desert mule deer after net-gun capture and reversing immobilizations with tolazoline HCl. We report rectal temperatures and effects of capture, immobilization, and reversal on heart and respiratory rates.

STUDY AREA

We captured deer in the Rincon Mountain District of Saguaro National Monument (Tucson, Arizona, USA; 32°12′N, 110°41′W). This district is bordered on the north, east, and south sides by Coronado National Forest. The study area was characterized by desert scrub habitat (altitude of <1,000 m) dominated by palo verde

TABLE 1. Capture and chemical immobilization of free-ranging desert mule deer in Saguaro National Monument, Arizona, February 1988.

		Chase time[a] (min)		Weight (kg)		Drug dosage: Xylazine HCl (mg/kg)		Drug dosage: Ketamine HCl (mg/kg)		Induction time (min)	
	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Males	5	8.0	2.1	60.7[b]	4.8	1.69[b]	0.13	5.71[c]	0.1	6.4[b]	0.6
Females	5	4.2	0.7	46.9	2.8	2.16	0.12	6.48	0.4	4.6	0.2

[a] Deer were captured by net-gun shot from a helicopter; chase time began with pursuit and ended when a deer was netted.
[b] Significant ($P < 0.05$) difference between sexes.
[c] Difference ($P = 0.07$) between sexes.

(*Cercidium* spp.) and saguaro (*Carnegiea gigantea*). Mean maximum monthly temperature in February 1988 was 21 C.

MATERIALS AND METHODS

During February 1988, we captured adult desert mule deer (five males, five females) with a net-gun (Coda Enterprises, Mesa, Arizona 85203, USA) (Krausman et al., 1985) shot from a Bell Jet Ranger helicopter. We measured chase times to the nearest minute beginning with initiation of pursuit of an individual and ending with successful netting. Pursuit was limited to 10 min to minimize capture-related excitement and associated adverse physiological effects (Seal and Bush, 1987); one exception involved a male that required 15 min and a second net to complete capture.

We measured heart and respiratory rates of deer before immobilization while physically restrained in the net by field personnel. Within 2 to 7 min of capture a combination of 100 mg xylazine HCl (Rompun, Haver-Lockhart Laboratories, Shawnee, Kansas 66201, USA) and 300 to 400 mg of ketamine HCl (Ketaset, Bristol Laboratories, Syracuse, New York 13201, USA) was injected intramuscularly (i.m.) by hand-held syringe. Induction time was the interval between injection and the time deer could be handled without physical response. During immobilization, we recorded initial rectal temperature, and heart and respiratory rates at 8 ± 1, 45 ± 8, and 45 ± 9 min postinduction, respectively. We also weighed deer, collected blood and urine samples and fitted each with a radio-collar. We injected deer intravenously (i.v.) with 2.0 or 3.0 mg/kg (20 mg/ml) tolazoline HCl (Sigma Chemical Co., St. Louis, Missouri 63178, USA) at 50.7 ± 7.8 min postinduction of immobilization. Dosage recommendations followed Kreeger et al. (1986). We characterized recovery by arousal (e.g., headup) and walking, and recorded the time to each.

In a separate study, four captive desert mule deer (two juveniles, <1.5-yr-old; two adults, ≥1.5-yr-old) maintained in an outdoor enclosure in Tucson, Arizona, were injected by pole-syringe with 50 to 100 mg xylazine HCl and 200 to 400 mg ketamine HCl during April 1988. These deer were permitted to recover without the use of a reversal agent.

Data were analyzed statistically by one-way analysis of variance and by *t*-tests (Hintze, 1982). Regression analysis of temperature data was conducted according to Weisberg (1982). Data in the text are presented as means and standard error of means.

RESULTS

Induction time was significantly shorter ($P < 0.05$) for females (range = 4 to 5 min) than males (range = 5 to 8 min) (Table 1). Shorter induction times were associated with smaller body weights and greater weight-specific dosages of xylazine HCl ($P < 0.05$) and ketamine HCl ($P = 0.07$) (Table 1). Dosages in females ranged from 1.78 to 2.02 mg/kg xylazine HCl and 5.33 to 7.35 mg/kg ketamine HCl; the ranges were 1.34 to 1.93 mg/kg xylazine HCl and 5.38 to 5.83 mg/kg ketamine HCl in males.

The first wild immobilized deer was reversed with 2.0 mg/kg tolazoline HCl, but required 33 min for recovery. We attempted to reverse a second deer with 2.0 mg/kg tolazoline HCl. Signs of recovery were not noted after 46 min; however, 8 min after a supplemental dose of 1.0 mg/kg tolazoline HCl was administered i.v., this animal could walk unsteadily. Consequently, the remaining eight deer were reversed with 3.0 mg/kg tolazoline HCl. Arousal and walking times in these deer

TABLE 2. Mean body temperatures, heart and respiration rates, and recovery times of free-ranging desert mule deer captured by net-gun, anesthetized with xylazine HCl and ketamine HCl, and reversed with tolazoline HCl (3.0 mg/kg) in Saguaro National Monument, Arizona, Feburary 1988.[a]

	n	$\bar{x}$	SE	Range
Body temperature (C)				
Initial	10	40.8	0.3	39.2–43.0
Highest	10	41.4[b]	0.3	40.2–43.2
Heart rate (beats/min)				
Pre-anesthesia	9	108	11	42–160
Pre-tolazoline HCl	10	90	9	32–124
Posttolazoline HCl	7[c,d]	120[e]	13	68–164
Respirations (breaths/min)				
Pre-anesthesia	10	75	6	44–104
Pre-tolazoline HCl	10	54	9	20–96
Posttolazoline HCl	7[c,d]	51[f]	7	24–76
Recovery time (min)				
Arousal	8[c]	13.9	4.2	1.0–33.0
Walking	8[c]	14.3	4.2	1.0–33.0

[a] Net-gun shot from a Bell Jet Ranger 205 helicopter.
[b] Significant ($P < 0.01$); highest versus initial temperature.
[c] Two deer received initial dosages of 2.0 mg/kg tolazoline HCl.
[d] One deer fled before heart and respiration rates were measured.
[e] Significant ($P < 0.05$); posttolazoline HCl versus pre-tolazoline HCl.
[f] Significant ($P < 0.05$); pre-anesthesia versus posttolazoline HCl.

were 13.9 ± 4.2 and 14.3 ± 4.2 min, respectively (Table 2). Ambulation times for the two free-ranging deer that received 2.0 mg/kg tolazoline HCl initially were beyond a 99% upper confidence limit of corresponding times for deer receiving initial dosages of 3.0 mg/kg. Sex did not appear to influence recovery in the wild deer. Immobilization time for free-ranging deer was 50.7 ± 7.8 min.

Body temperatures of immobilized free-ranging deer increased ($P < 0.01$) after induction (Table 2). Highest temperatures were recorded at 23.7 ± 3.2 min postinduction. We observed a significant ($P < 0.01$) curvilinear relationship ($Y = 40.094 + 0.0657x - 8.375e - 4x^2$, $R = 0.50$) between rectal temperature and time (postinduction) of temperature measurement (Fig. 1).

Heart rate of immobilized free-ranging deer increased ($P < 0.05$) following injection of 3.0 mg/kg tolazoline HCl (Table 2). There was no difference ($P > 0.05$) between heart rates of physically restrained wild deer before anesthetization and rates after chemical immobilization or reversal (Table 2). However, respiratory rates in physically restrained deer were greater ($P < 0.05$) immediately after capture compared to rates after tolazoline HCl was administered (Table 2).

Two of 10 animals died as a result of capture and handling. One male found convulsing 5 days after capture was euthanized by a park ranger. Chase time required to capture this animal was only 3 min and peak temperature was 41 C. After induction, heart and respiratory rates both increased to the highest rates documented (124 beats and breaths/min). In contrast to the prevailing observation, tolazoline HCl decreased this animal's heart rate (48 beats/min). Of deer receiving 3.0 mg/kg tolazoline HCl, time to walking was greatest (33 min) in this deer. A second male died about 2 wk after capture. This animal was chased 15 min before capture and exhibited the highest peak temperature (43.2 C). Respiratory rate in this deer was high

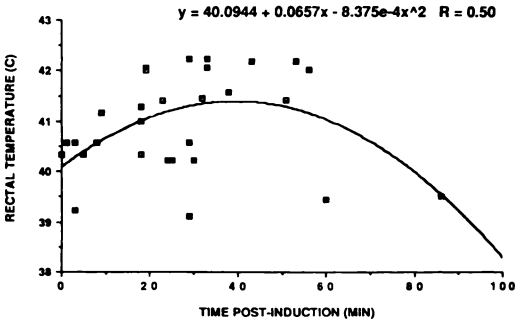

FIGURE 1. Relationship ($P < 0.01$) between rectal temperatures of free-ranging desert mule deer and time after xylazine HCl and ketamine HCl induction, Saguaro National Monument, Arizona, February 1988. (Deer were captured by net-gun shot from a helicopter following a pursuit of ≤10 min.)

during immobilization (96 breaths/min) and after tolazoline HCl injection (120 breaths/min). Immobilization times for these deer were 49 and 36 min.

Although captive deer received lower dosages of xylazine HCl (1.47 ± 0.10 mg/kg) and ketamine HCl (5.45 ± 0.11 mg/kg) than free-ranging male deer, mean induction time (5.3 ± 0.5 min) was between that observed for free-ranging females and males (Table 1). Arousal and walking occurred at 198 ± 94 (range = 51 to 473 min) and 290 ± 79 min (range = 125 to 496 min) in unreversed captive deer. Peak temperature of these deer (38.6 ± 0.1 C) was less ($P < 0.05$) than that in free-ranging deer (41.4 ± 0.3 C). Time of peak measurement was 18.0 ± 3.0 min postinduction. Heart rate was 47 ± 5 beats/min at 9.3 ± 2.3 min postinduction, and respiratory rate was 55 ± 3 breaths/min.

DISCUSSION

Although several factors may affect the induction time of xylazine HCl–ketamine HCl combinations in deer, the difference in induction times between free-ranging males and females in this study was primarily attributed to the difference in weight-specific dosages of xylazine HCl and ketamine HCl administered (Table 1). We observed relatively short induction times using xylazine HCl and ketamine HCl in deer, as compared to previous reports. Kreeger et al. (1986) reported longer induction times (12.1 min) with smaller dosages of xylazine HCl (1.58 mg/kg) and ketamine HCl (4.75 mg/kg) in captive white-tailed deer. Drugs in that study were delivered by pole-syringe, and deer experienced far less physical excitement prior to injection than the desert mule deer we captured. Jessup et al. (1983) reported a longer mean induction time (9.5 min) for captive and free-ranging Rocky Mountain mule deer compared to desert mule deer when less xylazine HCl (0.73 mg/kg) and more ketamine HCl (9.20 mg/kg) were used in that study. In our study, inhibitory effects of excitement on induction (Smeller et al., 1976; Seal and Bush, 1987; Seal and Kreeger, 1988) were apparently overcome by greater weight-specific dosages of xylazine HCl and ketamine HCl administered to free-ranging females (Table 1) compared to males.

Kreeger et al. (1986) reported that 2.0 and 4.0 mg/kg tolazoline HCl were equally effective for reversing immobilizations of captive and free-ranging white-tailed deer captured in clover traps. Walking times for those dosages were 10.5 and 9.2 min. Prolonged recoveries in our first two deer, elevated body temperatures, the expense associated with helicopter use, and associated logistical considerations prompted us to increase the tolazoline HCl dose to 3.0 mg/kg. Time to walking decreased with the higher dosage but was comparable to that documented in captive northern white-tailed deer (13.5 min) given 1.0 mg/kg tolazoline HCl (Kreeger et al., 1986). Desert mule deer initially appeared unsteady and often fell during their first attempts to stand. Deer usually walked 10 to 50 m, then would lay sternally and alert in a shaded area, capable of a rapid escape when prompted.

Physical exertion during the capture process and the xylazine HCl–ketamine HCl combination administered to free-ranging mule deer appeared to increase body temperature (Table 2). Xylazine HCl

interferes with normal thermoregulation (Young, 1979; Seal and Bush, 1987). Acute excitement prior to immobilization also elevated temperatures of Pere David's deer (*Elaphus dazidianus*) (Smeller et al., 1976) and moose (*Alces alces*) (Franzmann et al., 1975).

Deer receiving 3.0 mg/kg tolazoline HCl exhibited a tachycardia (Table 2), an effect also observed in white-tailed deer (Kreeger et al., 1986). Heart rates before and after tolazoline HCl administration in our deer were notably higher than in captive white-tailed deer reversed with tolazoline HCl (Kreeger et al., 1986). This difference was probably attributable to the acute excitement during the capture process. This effect was further indicated by greater heart rates and peak body temperatures in the anesthetized wild desert mule deer compared to the captive deer in our study. Smeller et al. (1976) reported a similar heart rate (92 beats/min) for Pere David's deer that were excited before chemical immobilization. Elevated heart rates in physically restrained desert mule deer before chemical immobilization were comparable to those after injection of tolazoline HCl (Table 2).

The absence of a difference in respiratory rates during immobilization and after tolazoline HCl injection in desert mule deer was similar to findings for captive white-tailed deer (Kreeger et al., 1986). Higher rates immediately following capture compared to after injecting tolazoline HCl again reflected the physical excitement associated with the capture process and were comparable to excited Pere David's deer (Smeller et al., 1976). Circumstances did not permit necropsies to determine cause of death for the two male deer. However, strenuous pursuit during capture operations, chemical immobilization, prolonged downtimes, hyperthermia, and high heart and respiratory rates may have collectively predisposed these animals to fatal capture myopathy (Chalmers and Barrett, 1977; Pertz and Sundberg, 1978; Seal et al., 1978; Seal and Bush, 1987). Krausman et al. (1985) captured 34 desert mule deer by net-gun and experienced no mortality. Mean chase time ($\bar{x}$ = 7.6 min) was similar in that study, but deer were not chemically immobilized and handling time ($\bar{x}$ = 4.1 min) was notably shorter than in our study.

CONCLUSIONS

The use of xylazine HCl (100 mg) and ketamine HCl (300 to 400 mg) is an effective combination for immobilizing free-ranging desert mule deer after capture, and 3.0 mg/kg tolazoline HCl facilitates a rapid reversal of this immobilization. However, a 20% capture-related mortality rate (2 of 10 deer) during our study suggests this combination of physical and chemical capture has serious limitations. Pursuit by helicopter and capture by net-gun may cause strenuous overexertion in deer; this results in hyperthermia, tachycardia and tachypnea, and should be limited to <10 min. Disruption of thermoregulation by xylazine HCl and ketamine HCl may exacerbate effects of capture on body temperature. Rectal temperatures measured frequently provide a means of monitoring the animal's response to capture; single measurements may be misleading. Anesthetized animals should be cooled with water; however, rapidly increasing rectal temperatures also dictate reversing the deer as soon as possible. Tolazoline HCl dosages >3.0 mg/kg may provide a more rapid and smoother recovery and should be tested.

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