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IMMOBILIZATION OF NORTH AMERICAN PORCUPINES (*ERETHIZON DORSATUM*) USING KETAMINE AND XYLAZINE

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ABSTRACT: We performed 345 immobilizations on 150 North American porcupines (*Erethizon dorsatum*) using a mixture of ketamine hydrochloride (KH) and xylazine hydrochloride (XH). A subsample of 184 immobilizations performed on 124 individuals from 4 May to 7 November 2000 and from 22 January to 30 April 2001 is thoroughly analyzed. In contrast to published procedures, we found that injecting drugs into tail muscles was more efficient than into longitudinal muscles of the lower back, because tail injections decreased the need of multiple injections by 26%. Using tail injections, we were able to reduce the dose by 50% from other published reports without significantly affecting induction, immobilization, standing, or recovery times. We suggest that injection of 5 mg KH/kg and 2 mg XH/kg in the tail as a standard procedure to immobilize North American porcupines. Body mass significantly affected the induction and standing times for single injections performed in the tail, irrespective of dose or sex. Sex, dose, and mass had no effect on the quality of immobilizations and the respiration rate of individuals during immobilization. We report a 0.87% mortality rate using a mixture of KH and XH and suggest ways to further decrease this rate.

Key words: Dosage, *Erethizon dorsatum*, immobilization, injection site, ketamine, mortality risks, North American porcupine, xylazine.

INTRODUCTION

Capture and immobilization of North American porcupines (*Erethizon dorsatum*) present unique challenges because the species is defended by a dense armor of quills, which makes manipulations potentially dangerous for both porcupines and investigators. In addition, porcupines are often found in dens and trees, which requires special safety measures for immobilized or recovering individuals, as sub-optimal procedures could result in individuals falling from trees or suffering in dens from respiratory obstruction.

Techniques currently used to immobilize porcupines are varied and some confusion is found in the literature as to which technique should be used. Roze (1987) used ketamine hydrochloride (KH) (10 mg/kg). Sweitzer (Sweitzer, 1996; Sweitzer and Berger, 1998) used a mixture of KH (10 mg/kg) and xylazine hydrochloride (XH) (4 mg/kg), but Sweitzer and Berger (1992) incorrectly reported a dose 10 times higher than their used dosage. Hale et al. (1994) used a 1:1 mixture of tiletamine hydrochloride (HCl) and zolazepam HCl (Telazol®, Aveco Co. Inc., Fort Dodge, Iowa, USA) at doses varying from 7 mg/kg to 10 mg/kg. Recovery periods using tiletamine HCl and zolazepam HCl were excessively long, and some porcupines were still stumbling 250 min after injection (Hale et al., 1994). More recently, Zimmerling and Croft (2001) used KH (10 mg/kg) combined with XH (1 mg/kg).

Ketamine HCl has been widely used on many species of carnivores and herbivores (Pond and O'Gara, 1996). Some of its side effects are apnea, excessive salivation, and hypothermia. Administered alone, it can also cause convulsions, muscle rigidity, and violent recoveries. However, KH is often given in combination with other drugs such as XH, in order to reduce its adverse effects (Lumb and Jones, 1984b; Pigozzi, 1987; Pond and O'Gara, 1996; Mudappa and Chellam, 2001). Administered via intramuscular injection, the KH-XY mixture induces rapid non-cumulative anesthesia

while insuring a wide margin of safety (Pigozzi, 1987), an attribute that is critical in fieldwork.

In 2000 we started a long-term study of a porcupine population and wished to individually mark all individuals in our study area and use telemetry routinely. We therefore needed a safe way to repeatedly immobilize individuals. Published reports allowed us to exclude the use of tiletamine HCl and zolazepam HCl, given the excessively long recovery periods (Hale et al., 1994) that were incompatible with our intense capture schedules. We therefore used a KH-XY mixture and, given the diversified procedures reported in the literature, collected data to answer four specific questions: 1) what is the most appropriate site of injection for immobilization of porcupines, 2) what are the effects of dose of KH-XH on different parameters of anesthesia, 3) what is the optimal dose of KH-XH that should be administered given that three common constraints to wildlife immobilization are to minimize induction time, recovery time, and cost of immobilization, and 4) what are the mortality risks when immobilizing North American porcupines with KH-XY.

MATERIALS AND METHODS

Study area

Porcupines were captured and immobilized in Parc National du Bic (68°46′W, 48°21′N), Québec, Canada. One hundred and fifty individuals were captured 735 times and immobilized 345 times. Detailed data were recorded for a subsample of 184 immobilizations (124 individuals: 60 females, 64 males), which form the basis for the current analysis. Immobilizations were carried out from 4 May to 7 November 2000 and from 22 January to 30 April 2001. All immobilizations were necessary to ear-tag, measure, or radio-collar the animals.

Immobilizations

Immobilizations ($n=146$) for which we gathered detailed data were performed during night capture sessions, after individuals that were feeding or traveling on the ground were captured using a modified dip net (3.5 cm mesh-size). Thirty-eight immobilizations were performed after porcupines were captured using one of the following methods: dip net while porcupine was in a tree, gloved hands (PVC coated gloves with leather work gloves underneath), noose pole, vertical trap (three or four live traps [Tomahawk Live Trap Co, Tomahawk, Wisconsin, USA] strapped against tree trunk), or guiding porcupine down trees using long aluminum or fiberglass tent poles. Once captured, animals were weighed in a net to adjust the dose to their body mass.

Injections were administered intramuscularly in one of two sites: 1) longitudinal muscles (Longissimus dorsi) that run along the vertebral column in the lower back (called "back" hereafter) or 2) muscles at the base of the tail halfway between the spinal column and the edge of the tail ("tail"). Injections were performed using a hand-held syringe while porcupines were restrained in the net (back) or grabbed by the tail with one gloved hand (tail).

Porcupines were administered a mixture of 100 mg/ml KH (Vetalar® [100 mg/ml] Vetrepharm Canada Inc., London, Ontario, Canada) and 20 mg/ml XH (Anased® [20 mg/ml] Novopharm Limited, Toronto, Ontario) at a 1:2 ratio. Following the procedures used by previous authors, we initially injected doses of 10 mg KH/kg and 4 mg XH/kg. This dose will be referred to as "full dose" hereafter. During our study, we lowered the doses in order to determine the lowest dose compatible with safe manipulations (tagging or radio-collaring). We always used the 1:2 KH-XH ratio. A second dose was administered after 15 min if there was no sign of drug effect or if the plane of immobilization was not sufficient to safely manipulate the individual. If necessary, a third dose was administered 15 min after the second dose.

Measured parameters

In the following, *induction time* is defined as the time lapse between injection of the drug and immobilization induction, when the animal could be handled safely, which usually corresponded to the animal rolling down to its side. This state is also referred to as loss of righting reflex (Pond and O'Gara, 1996) or recumbancy (Belant, 1991). *Immobilization time* is the time elapsed between induction and the time when the porcupine first lifted its head. *Standing time* is the amount of time elapsed from the end of immobilization to recovery of righting reflex, that is when the porcupine first stood on its four legs. *Recovery time* is the amount of time elapsed between the time when the porcupine first stood on its four legs and the time when all signs of intoxication disappeared.

During immobilization procedures, we collected data on induction time, respiration rate,

TABLE 1. Initial doses of ketamine hydrochloride and xylazine hydrochloride administered to porcupines at two injection sites and consequences on total number of injections required to safely immobilize the animal. Results based on 184 immobilizations performed in Parc National du Bic, Québec, Canada, from 1 May 2000 to 30 April 2001.

Site of injection	n	Ketamine HCl (mg/kg)		Xylazine HCl (mg/kg)		Number of injections needed
		Mean ± SD	Range	Mean ± SD	Range	
Back	77	9.7 ± 1.4	4.5–11.4	3.9 ± 0.6	1.8–4.6	1
	23	8.7 ± 1.8	5.4–10.6	3.6 ± 0.7	2.2–4.2	2
	4	9.5 ± 1.5	7.4–10.7	3.8 ± 0.6	3.0–4.3	3
Tail	75	6.6 ± 2.0	2.9–10.9	2.6 ± 0.8	1.2–4.3	1
	5	4.8 ± 0.4	4.3–5.3	1.9 ± 0.1	1.7–2.1	2
	0	—	—	—	—	3

immobilization quality, immobilization time, standing time, and recovery time. Immobilization quality was classified as deep (animal perfectly still during manipulations), intermediate (slight movements or muscle tremors and/or vocalizations), and shallow (movements in response to stimuli, animal difficult to manipulate because state of immobilization never fully reached). During our first field season (May to November 2000), animals were attended until completely recovered. After we gained confidence in our immobilization techniques (January to April 2001), porcupines were left to fully recover by themselves once they were able to defend themselves against potential predators by erecting their quills and striking their tail.

Statistical analysis

A G-test (Fowler et al., 1998) was used to test whether the number of injections required to immobilize the animals differed between the two sites of injection. Analysis of covariance (ANCOVA) was used to test for the effects of mass, dose, and sex on the different times (induction, immobilization, standing, and recovery) characterizing immobilization. When needed, data were log-transformed prior to the ANCOVA to respect the assumption of normality. All differences in means between two groups were tested with Mann-Whitney U tests because the normality assumption was always violated (Fowler et al., 1998). A G-test adjusted with Williams' correction factor (Fowler et al., 1998) was used to test if dose had an impact on the need for multiple injections. Tests were performed using SYSTAT version 9 (SPSS Inc. 1998). Significance level was set at 0.05.

RESULTS

Site of injection

A single injection was sufficient to safely immobilize porcupines in 98% of cases when drugs were injected in the tail (n=80, Table 1). In contrast, a single injection was sufficient to safely immobilize porcupines in only 72% of cases when drugs were administered in the back (n=104, Table 1). These two proportions are significantly different ($G=14.97$, $P<0.01$, df=2). A third injection was never required when injecting drugs in the tail, but a third injection was necessary in 3.9% of cases when drugs were injected in back. To understand the origin of the difference in efficiency of drugs between the two injection sites, we compared the initial KH dose (XH always given in constant proportion to KH) that was given in each case. Mean initial dose of KH was significantly lower for tail than for back injections (Tail: n=80, mean=6.52±1.95 mg KH/kg; Back: n=104, mean=9.46±1.57 mg KH/kg; Mann-Whitney, U=7,158.00, $P<0.001$, Table 1), indicating that the higher efficiency of tail injection was obtained despite a lower average dose. Initial KH dose was significantly lower for immobilizations that required multiple (two or three) injections than for immobilizations reached after a single injection (Tail: single 6.64±1.95 mg/kg, multiple 4.75±0.37 mg/kg, Mann-Whitney U=317.5, P=0.01; Back: single 9.67±1.44 mg/kg, multiple 8.84±1.77, Mann-Whitney U=1,375.5, P=0.013).

Reaching a safe plane of immobilization after a single injection was our priority. A preliminary analysis of results suggested that tail injections were the most efficient.

We therefore focused our efforts on tail injections from 13 July to 7 November 2000 and from 22 January to 1 April 2001. The following results deal only with immobilizations that required a single injection and were performed in the tail.

Effect of dose on measured parameters

Immobilizations that required a single injection and were performed in the tail (n=75) were done on 28 females and 47 males, with average body masses of 7.05±1.76 kg (range=3.50–10.55) and 7.98±1.74 kg (range=4.30–10.60) for females and males, respectively. Mean induction time was 5.2±2.8 min (range: 0.5–14.8, n=71), mean immobilization time was 31.6±13.1 min (range: 8.5–77.0, n=49), mean standing time was 9.4±7.5 min (range: 0–29, n=46), and mean recovery time was 29.5±16.8 min (range: 11.8–98.3, n=27). The 0 values obtained for standing time correspond to cases (n=2) when individuals woke up suddenly and stood up right at the end of the immobilization period. Mean respiration rate during the immobilization period was 48.3±20.9 inspirations per minute (range=18–120, n=67). A series of ANCOVAs with induction, immobilization, standing, or recovery times as dependent variables and body mass, sex, and dose as independent variables showed that a higher body mass (m) resulted in a longer induction (i) (F=16.27, P<0.001) and standing (s) (F=6.478, P=0.015) times. Mass had no effect on immobilization and recovery times, while sex and dose had no effect on induction, immobilization, stand, and recovery times. The relations between mass and induction and standing times can be described by $\log(i)=0.067m+0.136$ and $\log(s)=0.170m+0.70$. There was no effect of sex, dose, or mass on the quality of immobilization or the respiration rate of individuals during immobilization.

Optimal dose

Our initial results indicated injection in the tail was more appropriate than injection in the back, and there was no effect of dose on the standard descriptive measures of immobilization. Accordingly, we focused subsequent investigation on injections performed in the tail and we tested a wide range of doses (29–114% of full dose) to decide on a critical minimum dose. Here we compare immobilizations performed with 29–49% of the full dose to those performed with 50–114% of the full dose. Multiple injections occurred more often at doses less than half of full dose. Injections less than 50% of full dose (n=20) were mostly done in the tail (n=18) and were therefore not as constantly efficient as doses greater or equal to 50% of full dose (G_{ajd}=6.99, P<0.01, df=1). A second dose was necessary in 22.2% of cases when the initial dose was inferior to 50% of full dose, as opposed to 1.61% when a dose greater or equal to 50% of full dose was administered in the tail.

Mortality

Over a total of 345 immobilizations, three porcupine deaths (0.87%) were likely attributable to immobilization. Here we describe the context of each death in order to help future investigators further refine our procedures. The first porcupine received, on 7 March 2001, a dose of 7.0 mg KH/kg+2.8 mg XH/kg (body mass=5.7 kg) in the tail. After being radio collared, it was left partially recovered under the low branches of a conifer tree. The next day the porcupine was found dead, head first in one of our snowshoe tracks, 5 m from where it was left recovering. The temperature during immobilization was −8 C and reached −13 C during the following night. This porcupine had previously been immobilized twice (25 May 2000 with 10.7 mg KH/kg+4.3 mg XH/kg [body mass=7.5 kg]; 28 June 2000 with 3.7 mg KH/kg+1.5 mg XH/kg [body mass=8.1 kg]) and had shown a normal response to drugs.

The second porcupine to die received, on 11 May 2001, a dose between 10 mg KH/kg+4 mg XH/kg and 5 mg KH/kg+2

mg XH/kg (body mass=5.9 kg; exact dose not recorded) in the tail. The porcupine stood up before the end of the tagging procedures. After being tagged, but before having fully recovered from the immobilization, it was placed in a rock cavity, with its back and tail facing out. The porcupine was found in the same position 1 wk later. The physical condition of this animal was very poor, as shown by inspection of bone marrow of one femur that contained virtually no fat. This porcupine was immobilized for the first time.

The third porcupine died during the induction phase. It received a dose of 6.3 mg KH/k+2.5 mg XH/kg (body mass=9.45 kg) on 16 June 2001 in the tail. Field workers reported that the animal seemed stressed before injection. This porcupine had previously been immobilized twice (3 May 2000, 10.3 mg KH/kg+4.1 mg XH/kg [body mass=7.8 kg]; and 05 June 2000, 10.1 mg KH/kg+4.0 mg XH/kg [body mass=8.9 kg]), and had responded to drugs with unusually short induction times of 0.5 and 2 min.

DISCUSSION

Our results show that in North American porcupines, administration of KH/XH in the tail is less prone to necessitate multiple injections and requires a lower dose than drug injection in the back. We discuss below the mechanics of drug injection in North American porcupines and how it explains our results, the implications of our results regarding the optimal dose that should be used for safe immobilization in this species, and the possible causes for mortalities observed in our study.

Mechanics of injection

When the KH-XH mixture was administered in the back, a significantly higher dose was required to safely immobilize the animal than when injection was performed in the tail. For both sites of injection, however, the initial dose was significantly higher for single than for multiple injections.

We do not know why back injections resulted in a higher need for multiple injections. We note, however, that they have a higher probability of missing muscles because back muscles can be very thin, especially in late winter and spring when porcupines have exhausted most of their fat and protein reserves. Autopsies of road-killed animals at this time period and throughout our field season clearly revealed how easily a needle can go straight through back muscles and result in an intraperitoneal injection. It remains to be understood why intraperitoneal injections might be less efficient than intramuscular injections. An additional reason to favor tail injections resides in risks of peritonitis associated with back injections.

On the other hand, the tail of porcupines is highly muscularized, since it is used as a prop when porcupines climb trees and as a defense weapon against predators. Tail muscles can hardly be missed during tail injections, as long as care is taken to avoid the tailbones. Inserting the needle at a 45° angle from the vertical while holding the tail from under is a safe way to perform intramuscular injections in the tail. Tail muscles of porcupines do not atrophy as much as back muscles in late winter, which is another advantage of tail injections.

Drugs can also be administered in thigh muscles to immobilize porcupines (Hale et al., 1994). We did not include this injection site in our methods, as we find that the tail is a safer injection site for two reasons: 1) the hind leg is more complex anatomically with major blood vessels, tendons, and nerves that can potentially be damaged by a needle, especially if the animal is attempting to escape, 2) injecting in the tail requires the investigator to hold the tail, hence decreasing the risks of porcupine attack.

Optimal dose

Porcupines with a greater body mass took longer to reach a safe plane of immobilization and to stand on their four legs after immobilization. Because there

was no significant effect of dose on induction time, there is no reliable means of overcoming this potential difficulty. Although induction is slower in larger animals, they will stay immobilized for the same period and fully recover within the same time bounds.

The dose of KH-XH did not affect immobilization parameters within the dose range tested, indicating that a dose lower than the published full dose of 10 mg KH/kg+4 mg XH/kg (Sweitzer, 1996; Sweitzer and Berger, 1998) can be used without affecting immobilization quality. Focusing on data regarding injections in the tail, we were able to establish that doses inferior to 5 mg KH/kg+2 mg XH/kg have a greater chance of requiring a second dose. Therefore we suggest that doses half those reported in the literature are just as efficient, while they increase safety and decrease costs of immobilization. Our results contrast with Plumb (1999) who indicated that an increase in KH dose should increase the duration of immobilization (but not the intensity). The KH-XH mixture might behave differently than KH alone, or porcupines might handle the drug differently than animals treated in veterinary practice and referred to by Plumb (1999).

The fact that doses lower than 50% of full dose were less efficient than doses 50–100% of the full dose and that we detected virtually no effect of dose in the parameters of immobilization led us to use 5 mg KH/kg and 2 mg XH/kg (50% of the full dose) as a standard for North American porcupine immobilization.

Mortality

We were not able to determine the cause of mortality for three individuals that died during or following our immobilizations, but hypothermia or drug hypersensitivity (Lumb and Jones, 1984a) may be involved for the first individual that died; respiratory obstruction due to an unfavorable positioning or drug hypersensitivity may be involved in the second death, and drug hypersensitivity was likely the cause of the third death. All three individuals received their injection in the tail. The second porcupine to die was in poor physical condition, which probably made this individual more susceptible to immobilization complications, although we have immobilized many other individuals in similar condition. The third individual exhibited a high degree of sensitivity to KH-XH on two occasions before the fatal dose, as shown by the short induction times leading to previous immobilizations. These were perhaps warning signals of predisposition to complications, and we suggest researchers should be vigilant about these cues. Plumb (1999) reported cardiac arrest and respiratory depression as adverse effects for ketamine and reduced respiratory rate and bradycardia for xylazine. Although these effects were observed in domestic animals such as dogs, cats, and horses, they could also exist in porcupines.

The 0.87% mortality rate we observed in this study is not particularly surprising. Mortality has been observed in other studies using KH-XH: 12% on crested porcupines (*Hystrix cristata*) $n=17$, Pigozzi (1987); 1% on domestic dogs, $n=200$, Lumb and Jones (1984b), and using tiletamine HCl and zolazepam HCl: 1.5% on North American porcupines, $n=66$, Hale et al. (1994), or XH: 2.1% on mountain goats (*Oreamnos americanus*), $n=141$, Haviernick et al. (1998). Some studies have experienced no mortalities using KH-XH: on fishers (*Martes pennanti*) $n=6$, Belant (1991); on coypus (*Myocastor coypus*), $n=8$, Bó et al. (1994); on common genets (*Genetta genetta*), $n=15$, Palomares (1993) and using medetomidine and KH: on California sea lions (*Zalophus californianus*), $n=51$, Haulena et al. (2000). Although this literature review is representative rather than comprehensive, it does show mortality rate we describe is within the lower range of observed mortality rates.

Our procedures might be improved in two ways that could be tested in future studies. First, XH could be injected alone

followed 10 min later with KH, as mentioned by Lumb and Jones (1984b) and tested by Pigozzi (1987). Second, a specific antagonist, yohimbine, would reverse partially the effects of a KH-XH anesthesia, as it is fully efficient against XH but not totally against KH (Plumb, 1999). This latter option was suggested by Belant (1991), and could help to shorten recovery time and perhaps prevent mortality when complications arise.

Mortalities are always possible during anesthesia even when all precautions are taken. Consequently, reducing the dose should always be a goal for field biologists. As an example, the dose used to immobilize crested porcupines was progressively reduced from 27 mg KH/kg (Alkon, 1984) to 11 mg KH/kg (Pigozzi, 1987) to 10 mg KH/kg (Sonnino, 1998).

CONCLUSION

We propose a new injection site for immobilization of North American porcupines. Injection of drugs in the tail dramatically reduces the need for multiple injections compared to injection in the back. In addition, this procedure requires the investigator to hold the porcupine's tail (its best weapon), making manipulations safer. We also show that KH doses can be reduced to 50% of the doses previously reported in the literature (Sweitzer and Berger, 1998) without significantly changing induction, immobilization, standing, and recovery times. This reduction in dose has management implications due to the enhanced safety for animals and field workers and the reduced monetary cost of immobilization. We hope attempts will be made to validate similar safety enhancements to other wildlife species.

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