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IMMOBILIZING WILD MOUNTAIN LIONS (*FELIS CONCOLOR*) WITH KETAMINE HYDROCHLORIDE AND XYLAZINE HYDROCHLORIDE

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ABSTRACT: A mixture of 120 mg ketamine hydrochloride (KHCL)/20 mg xylazine hydrochloride (XHCL)/ml was used to immobilize 37 wild mountain lions (*Felis concolor*) 46 times. Observations were recorded during 37 trials that included kittens, adult females, and adult males. Dosages were based on 11 mg KHCL and 1.8 mg XHCL/kg estimated body weight. Actual doses for 24 lions requiring a single injection for immobilization ranged from 4.7–15.8 mg KHCL/kg and 0.8–2.6 mg XHCL/kg. Induction, duration, and recovery times did not differ ($P > 0.05$) between the sex and age classes. Two kittens were overdosed with the drug combination, but the effects were not life threatening. Eleven other lions, nine of which were initially underdosed, required additional injections of the drug combination for safe handling. Immobilization was characterized initially by semi-consciousness, open eyelids, pupillary dilation, and muscle rigidity. Later, most lions appeared unconscious, muscles relaxed, and breathing slowed considerably. No convulsions or hypersalivation occurred. The KHCL/XHCL mixture given at approximately 11 mg KHCL and 1.8 mg XHCL/kg body weight proved useful for immobilizing wild mountain lions for research purposes. Suggestions for care of immobilized cats are included.

INTRODUCTION

Chemical immobilization of wild mammals is a valuable tool in wildlife research and management (Harthoorn, 1976; Hebert and McFetridge, 1981; Nielsen et al., 1982). Combinations of ketamine hydrochloride (KHCL) and xylazine hydrochloride (XHCL) have been used to immobilize large free-ranging carnivores, including black bears (*Ursus americanus*), polar bears (*U. maritimus*), grizzly bears (*U. arctos*), and feral and stray dogs (Addison and Kolenosky, 1979; Schweinsburg et al., 1981; Lynch et al., 1982; McWade, 1982). Lay and Turnbull (data in Hebert and McFetridge, 1981) tabulated induction time and duration of immobilization in eight mountain lions; and Jessup (1982) noted the use of these drugs for immobilizing "over a dozen" lions in California, but he did not describe the effects. This paper reports the use of a KHCL/XHCL mixture for immobilizing wild mountain lions in cold climatic conditions for research purposes.

MATERIALS AND METHODS

Drug combinations were prepared by lyophilization of KHCL (Vetalar (KHCL 100 mg/ml), Parke-Davis, Division of Warner-Lambert Co., Morris Plains, New Jersey 07950, USA and Ketaset (KHCL 100 mg/ml), Veterinary Products, Bristol Laboratories, Division of Bristol-Meyers Co., Syracuse, New York 13201, USA) and reconstituting it with XHCL (Rompun (XHCL 20 mg/ml), Haver-Lockhart, Bay Vet Division, Cutter Laboratories, Inc., Shawnee, Kansas 66201, USA). Sufficient KHCL was lyophilized that a six part KHCL : one part XHCL ratio with approximately 120 mg KHCL and 20 mg XHCL/ml was achieved. Moderate warming of the mixture with tap water aided in resuspending the KHCL. Aseptic technique was followed in drug mixture preparation, and mixed drugs were stored at room temperature.

Data were gathered during a 2-yr study of the ecology of mountain lions in the Big Horn Mountains, Wyoming (Logan, 1983). We captured lions primarily during winter when snow facilitated searches for tracks. When fresh tracks were found, trained dogs were used to track and tree or bay the cats. Captured lions were immobilized using a dose of 11 mg KHCL and 1.8 mg XHCL/kg estimated body weight. Actual doses received were later calculated after lions were weighed with a spring scale.

Adult lions and large kittens (>15 kg) were injected remotely using 3 to 5 ml capacity alu-

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TABLE 1. Dosages and timed observations for mountain lions immobilized with intramuscular injections of a ketamine hydrochloride[a] and xylazine hydrochloride[b] mixture.[c]

Lion class	Weight range (kg)[d]	Age range[e]	Actual doses (mg/kg) KHCL	Actual doses (mg/kg) XHCL	Induction time range (min)	Duration time range (min)	Recovery time range (min)
Kittens[f] (n = 9)	11.3–34.0	3–11 mo	4.7–15.2 $\bar{x}$ = 10.4 SD = 3.9	0.8–2.5 $\bar{x}$ = 1.7 SD = 0.6	4–23 $\bar{x}$ = 7.4 SD = 5.9 n = 9	36–82 $\bar{x}$ = 51 SD = 16.7 n = 6	57–63 n = 2
Adult females (n = 9)	30.4–45.4	15–24 mo to 5–6 yr	9.9–15.8 $\bar{x}$ = 11.7 SD = 1.7	1.7–2.6 $\bar{x}$ = 2.0 SD = 0.3	4–10 $\bar{x}$ = 6.0 SD = 1.9 n = 9	46–101 $\bar{x}$ = 69.9 SD = 23.1 n = 7	51–118 $\bar{x}$ = 77.3 SD = 29.2 n = 4
Adult males (n = 6)	40.8–74.8	15–24 mo to 5–6 yr	8.8–11.8 $\bar{x}$ = 10.5 SD = 1	1.5–2.2 $\bar{x}$ = 1.9 SD = 0.2	3–8 $\bar{x}$ = 5.0 SD = 1.9 n = 5	12–103 $\bar{x}$ = 71.5 SD = 41.1 n = 4	21–118 $\bar{x}$ = 81.7 SD = 52.9 n = 3

[a] Ketamine hydrochloride = KHCL.
[b] Xylazine hydrochloride = XHCL.
[c] Desired doses were 11 mg KHCL/kg and 1.8 mg XHCL/kg from a mixture of 120 mg KHCL/20 mg XHCL/ml.
[d] Lions were weighed using a spring scale.
[e] Lions were aged using the technique described in Ashman et al. (1983).
[f] Two kittens in poor physical condition that were overdosed were omitted from this table.

minum projectile syringes with 20 to 25 mm barbed needles fired from a CO_2-powered pistol (Palmer Chemical and Equip. Co., Douglasville, Georgia 30134, USA). Most darts injected the drug into the caudal thigh. Smaller kittens (10–15 kg) were restrained with a catchpole device, and the drug combination was injected intramuscularly (i.m.) using a hand syringe. Kittens weighing less than 10 kg were not drugged.

Darted lions that remained in the trees after induction were quickly lowered to the ground using a long nylon cord tied to one of the cats' legs. Occasionally lions jumped from trees after being darted, but were easily approached on the ground after the drug took effect.

Immobilized cats were usually placed on a thermal blanket or a bed of conifer boughs to help retain body heat on cold days. Ointment (Forte Topicale, Upjohn Co., Kalamazoo, Michigan 49001, USA) was placed in each eye to prevent desiccation of the cornea and conjunctiva. In bright light, the eyes were covered. Hypostasis in the downside lung was prevented by turning the lion over on its opposite side every 15–20 min, or by maintaining sternal recumbency. Many lions were also administered a prophylactic dose of antibiotic i.m. (Combi Pen (penicillin G benzathine and penicillin G procaine, 4,500 units each/kg) Veticare, John D. Copanos, Inc., Baltimore, Maryland 21225, USA) to prevent possible infection caused by using unsterilized dart needles.

While lions were under the influence of the drugs, both ears were tattooed with an identifying number; most were also ear-tagged. Adults were fitted with a radio-collar or a nylon neckband bearing a numbered pendant. In addition, sex and weight were determined, and several body measurements were taken. The lions were aged by tooth replacement, wear, and coloration characteristics (Ashman et al., 1983).

Clinical signs and timing of effects of the KHCL/XHCL combination were recorded whenever possible. In this paper, induction pertains to the period between injection and when lions could be handled safely. Duration of immobilization is the period of recumbency during which cats were tractable. Recovery refers to the period from induction until lions were apparently aware of their surroundings and able to walk about under control. A Student's t-test ($P < 0.05$) was used for all comparisons (Zar, 1974).

RESULTS

Thirty-seven wild mountain lions were immobilized 46 times with the KHCL/XHCL mixture. Observations were recorded during 37 trials involving kittens, adult females, and adult males. Recap-

tures and radio-relocations of lions subsequent to immobilization verified there were no mortalities related to the drug combination or our capture techniques. However, two serious injuries occurred; once when a dart needle embedded in the femur of a lion, and once when a small kitten was mauled by the dogs.

Darts of 3, 4 and 5 ml capacity were adequate to immobilize lions of all sizes long enough to lower them to the ground. Once on the ground, underdosed cats, particularly large males, could be hand-injected i.m. with additional drug.

Twenty-four lions each required a single remote injection (Table 1). Nine kittens received 4.7–15.2 mg KHCL/kg ($\bar{x}$ = 10.4) and 0.8–2.5 mg XHCL/kg ($\bar{x}$ = 1.7). Induction time ranged from 4–23 min ($\bar{x}$ = 7.4, n = 9). Duration of immobilization was 36–82 min ($\bar{x}$ = 51, n = 6), and recovery occurred in 57–63 min (n = 2). Two 18.1 kg kittens in poor physical condition were inadvertently overdosed, each receiving 19.9 mg KHCL/kg and 3.3 mg XHCL/kg; hence, they had short induction times (1, 3 min), long duration (135, 141 min), and long recovery (271, 199 min) periods. But drug effects were not life-threatening in either case.

Nine adult females were injected with 9.9–15.8 mg KHCL/kg ($\bar{x}$ = 11.7) and 1.7–2.6 mg XHCL/kg ($\bar{x}$ = 2.0). Induction time ranged from 4–10 min ($\bar{x}$ = 6.0, n = 9). Duration lasted 46–101 min ($\bar{x}$ = 69.9, n = 7), and they recovered in 51–118 min ($\bar{x}$ = 77.3, n = 4). Six adult males were injected with 8.8–11.8 mg KHCL/kg ($\bar{x}$ = 10.5) and 1.5–2.2 mg XHCL/kg ($\bar{x}$ = 1.9). Induction occurred in 3–8 min ($\bar{x}$ = 5.0, n = 5), and duration lasted 12–103 min ($\bar{x}$ = 71.5, n = 4). They recovered in 21–118 min ($\bar{x}$ = 81.7, n = 3). Induction, duration, and recovery times did not differ significantly ($P > 0.05$) between kittens and adults or between adult females and adult males.

Eleven other lions required additional doses of the drug mixture for safe handling (Table 2). Three kittens were apparently underdosed with 3.8–8.4 mg KHCL/kg ($\bar{x}$ = 6.6) and 0.6–1.4 mg XHCL/kg ($\bar{x}$ = 1.1). Immobilization was achieved after each received an additional dose of 2.8–3.8 mg KHCL/kg ($\bar{x}$ = 3.5) and 0.5–0.6 mg XHCL/kg ($\bar{x}$ = 0.56). Two adult females initially injected with 11.2 and 10.6 mg KHCL/kg and 1.9 and 1.8 mg XHCL/kg required additional doses of 2.8 and 5.3 mg KHCL/kg and 0.5 and 0.9 mg XHCL/kg for safe handling. Six adult males were underdosed with 7.1–8.5 mg KHCL/kg ($\bar{x}$ = 7.9) and 1.2–1.4 mg XHCL/kg ($\bar{x}$ = 1.3). They were tractable after each received an additional dose of 1.6–7.1 mg KHCL/kg ($\bar{x}$ = 3.0) and 0.3–1.2 mg XHCL/kg ($\bar{x}$ = 0.5).

Although the induction, duration, and recovery periods varied between individuals, progression of each of the stages could be predicted. Induction was characterized by a trance-like, semi-conscious state, with open eyelids, and pupillary dilation. Lions' heads bobbed slowly. Muscles were rigid, but enough control was retained to allow cats to remain in the trees. Even as they were lowered to the ground, some would grasp branches or the trunk of the tree. Hypersalivation was not observed.

Shortly after lions were tractable, most progressed into a state of apparent unconsciousness. Muscle rigidity faded. Respiration slowed, later becoming shallow, irregular, and very slow. But respiratory depression did not appear life-threatening. There were no reactions to pain when tattoo pins were pressed through the ears, during insertion of ear tags, or when antibiotics were injected. No convulsions occurred. Emesis was observed in one large male lion that had consumed an entire mule deer fawn (*Odocoileus hemionus*) the previous night. This was not a problem, however, because normal swallowing and coughing reflexes were maintained. In some lions with short duration of immobilization, loss of consciousness and motor control were incomplete, but the

TABLE 2. Mountain lions requiring additional doses of a ketamine hydrochloride[a] and xylazine hydrochloride[b] mixture[c] for safe handling.

Lion class	Weight range (kg)[d]	Age range[e]	Actual doses (mg/kg) KHCL Initial	KHCL Added[f]	XHCL Initial	XHCL Added[f]	Induction time range (min)	Duration time range (min)	Recovery time range (min)
Kittens (n = 3)	15.8–43.0	3–11 mo	3.8–8.4 $\bar{x}$ = 6.6 SD = 2.5	2.8–3.8 $\bar{x}$ = 3.5 SD = 0.6	0.6–1.4 $\bar{x}$ = 1.1 SD = 0.4	0.5–0.6 $\bar{x}$ = 0.56 SD = 0.06	8–11 $\bar{x}$ = 9.7 SD = 1.5 n = 3	51 n = 1	—
Adult females (n = 2)	43, 45.4	3–4 yr, 7 yr	11.2, 10.6	2.8, 5.3	1.9, 1.8	0.5, 0.9	6, 8	16, 72	90
Adult males (n = 6)	56.7–74.8	2 yr to 5–6 yr	7.1–8.5 $\bar{x}$ = 7.9 SD = 0.5	1.6–7.1 $\bar{x}$ = 3.0 SD = 2.1	1.2–1.4 $\bar{x}$ = 1.3 SD = 0.1	0.3–1.2 $\bar{x}$ = 0.5 SD = 0.4	4–10 $\bar{x}$ = 7.2 SD = 2.6 n = 6	19–107 $\bar{x}$ = 60.4 SD = 31.6 n = 5	34–119 $\bar{x}$ = 79.3 SD = 42.8 n = 3

[a] Ketamine hydrochloride = KHCL.
[b] Xylazine hydrochloride = XHCL.
[c] Desired doses were 11 mg KHCL/kg and 1.8 mg XHCL/kg from a mixture of 120 mg KHCL/20 mg XHCL/ml.
[d] Lions were weighed using a spring scale.
[e] Lions were aged using the technique described in Ashman et al. (1983).
[f] Additional doses were given i.m. with a hand syringe.

cats seemed indifferent and were tractable.

Early stages of recovery were marked by ear-twitching and eyelid blinking. Respiration increased and became regular. Control of the head, although weak, returned first, followed by the hind legs. Control of the forelegs returned last. The lions' initial efforts to stand were weak and uncoordinated. They reacted to rapid movements, tactile stimuli, and loud noises by jerking away; but they were not aggressive. Cats could also be coaxed to move in a different direction if they started toward a ledge or creek. Usually lions moved off only a short distance, then lay down, presumably to rest.

The shelf life of the KHCL/XHCL mixture used is unknown, but it remained effective after 1 yr. Even in extremely cold weather (−28 C), the drug solution rarely crystallized as long as the vial was carried in a pocket next to the body. On the occasions when crystallization occurred, the drugs could be resuspended by gently shaking the vial in cupped hands.

DISCUSSION

Ketamine hydrochloride alone produces a variety of effects. Unconsciousness is due to depression of cortical activity, so sensory isolation occurs in the brain. Visual impulses and sensory impulses from peripheral areas travel unimpaired to the cortex (Collins, 1976, cited in Wright, 1983). Other effects include loss of palpebral reflex, enhanced muscle tone (Ramsden et al., 1976), decline in body temperature (Beck et al., 1971), increased salivation, convulsions (Beck et al., 1971; Hime, 1974), decreased respiration, and cardiac stimulation (Beck et al., 1971; Kolata and Rawlings, 1982). But when used in combination with XHCL, another central nervous system (CNS) depressant that produces analgesia with sedation and muscle relaxation (Hebert and McFetridge, 1981), there is reduction in salivation, muscle rigidity, emesis, and convulsions (McWade, 1982). Synergism of KHCL with XHCL probably produced the signs we observed in immobilized mountain lions.

Similar effects have been observed in other large carnivores immobilized with KHCL/XHCL mixtures. In black bears and polar bears there was loss of palpebral reflexes and respiratory depression (Addison and Kolenosky, 1979; Schweinsburg et al., 1981). Vomition was observed in some black bears that had fed within 4 hr of drug administration, but not when food was withheld for at least 12 hr. In 355 trials with black bears only one death occurred, involving a denning female in poor physical condition; six exhibited muscle rigidity or convulsions (Addison and Kolenosky, 1979). Schweinsburg et al. (1981) reported no deaths, tetany, or convulsions in 45 trials with polar bears. In stray dogs, salivation, vomition, and convulsions were minimal; but catalepsy and depressed heart rate were consistent. Transient cessation of breathing was also evident (McWade, 1982).

In the mountain lions which we immobilized there were no apparent differences in the effects of the KHCL/XHCL mixture in kittens, adult females, or adult males. The approximate dose of 11 mg KHCL and 1.8 mg XHCL/kg body weight produced adequate immobilization for our research purposes.

Workers intending to use the KHCL/XHCL mixture on mountain lions should consider other practical consequences of the drugs. Because of individual variation in induction, duration, and recovery, the handling of lions (approach, hands-on manipulation, administration of additional drugs) should be determined by the qualitative progression of signs rather than time. The wide safety margin of KHCL and XHCL permits additional injections of drug whenever necessary. Due to possible decreases in body temperature (Beck et al., 1971), lions should be guarded from excess cold to prevent hypothermia (e.g.,

cover them with a thermal blanket). Because the palpebral reflex is temporarily lost, the cats' eyes should be protected with an ophthalmic ointment, and covered. As lions recover, workers should prevent them from moving toward physical hazards, such as cliffs or creeks. Although we observed no injuries to lions we lowered from trees, dislocation of limb joints or ligamentous and muscular injuries are possible. Therefore, we recommend that workers handling lions in the future consider using a harness specifically designed for lowering these cats from elevated places.

Other drugs have been used to immobilize mountain lions. Succinylcholine chloride is a rapid-acting paralysant which does not produce sensory loss or anesthesia (Hebert and McFetridge, 1981), therefore affected animals are paralyzed, but conscious. Moreover, it has a narrow safety margin. Use of this drug on treed lions is hazardous because the paralyzing effect may cause cats to fall from trees, resulting in serious injuries or deaths (Hornocker et al., 1965). Phencyclidine hydrochloride is a CNS depressant that has been used to safely immobilize treed lions (Hornocker and Wiles, 1972), but it is no longer readily available for use in North America (Hebert and McFetridge, 1981; Lynch et al., 1982). Because of the availability of KHCL and XHCL and their desirable effects when used in combination, these drugs are appropriate immobilizing agents for mountain lions.

Unique characteristics of the mountain lion, its habitat, and capture methods are important considerations in choosing an appropriate immobilizing agent. Lions are large, cryptic carnivores that usually inhabit remote, rugged country. Capturing them involves long hikes (up to 16 km or more) in difficult terrain. When pursued by dogs, lions usually attempt to escape by climbing trees, but sometimes they are bayed on canyon ledges, or in shallow caves. Because they climb trees, it is desirable that the immobilizing agent allow the cats to retain enough muscular control to remain in trees after induction, but still permit researchers to lower them safely to the ground. In addition, an agent with a wide safety margin is needed because weights of lions and drug dosages are estimated and because accidents involving workers are possible. The KHCL/XHCL mixture and dose (11 mg KHCL and 1.8 mg XHCL/kg) we used produced adequate immobilization in wild mountain lions to permit safe handling for necessary marking and data collection procedures.

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