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ANOTHER LOOK AT CHEMICAL IMMOBILIZATION OF RACCOONS (*PROCYON LOTOR*) WITH KETAMINE HYDROCHLORIDE

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ABSTRACT: Forty-one wild raccoons (*Procyon lotor*) were captured in Kentucky (USA) and immobilized with 7 to 16 mg/kg of ketamine hydrochloride, January to May 1987. Eight raccoons had muscle tremors in response to ketamine, but recovered with no other observable adverse effects. Mean (±SD) induction and duration of immobilization times were 3.2 ± 1.8 and 42.3 ± 14.5 minutes, respectively. Based on multiple regression analysis, the interaction of sex (P = 0.0030), body mass (P = 0.0036), dose (P = 0.0159), and the interaction of sex × dose (P = 0.0030) and body mass × dose (P = 0.0021) had a significant effect on the duration of raccoon immobilization.

Key words: Raccoon, *Procyon lotor*, ketamine, chemical immobilization.

INTRODUCTION

Ketamine hydrochloride is a non-barbiturate, phencyclidine derived dissociative agent with a large margin of safety (Beck et al., 1971). Originally developed to be used in humans, ketamine was approved for veterinary use in 1970 (Beck, 1976). The wide margin of safety to overdose and the rapid onset of, and recovery from, anesthesia have made ketamine a common chemical for use in field studies involving wild animals (Ramsden et al., 1976). Ketamine (100 mg/ml) has been recommended for use in raccoons (*Procyon lotor*) at a dose of 8 to 10 mg/kg given intramuscularly (IM) (Bigler and Hoff, 1974).

Optimum dosages of ketamine are highly variable among and within species. Little is known concerning the factors contributing to the high degree of variability observed. Our objectives were to evaluate the response of raccoons anesthetized with ketamine, and to determine factors influencing the duration of effective immobilization.

MATERIALS AND METHODS

Raccoons were live trapped at the Lake Cumberland State Resort Park (85°2'N, 36°55'W), Russell County, Kentucky (USA). Twenty-one baited live traps (Tomahawk Live Trap Co., Tomahawk, Wisconsin, USA) were inspected three times per night on selected weekends between 30 January to 12 April 1987.

Before raccoons were removed from traps, their approximate body mass was estimated as the difference between the weight of both the animal and trap, and the known weight of the trap. Once restrained, raccoons were given an IM injection of ketamine hydrochloride (100 mg/ml; Vetalar, Parke-Davis Co., Detroit, Michigan, USA) in the gluteal muscles of the rear leg. The dosages were intended to vary between 5 to 15 mg/kg.

Anesthetized raccoons were reweighed to determine the exact dose (mg/kg) of ketamine injected. Raccoons were ear-tagged and placed in holding cages for observation. The induction time (elapsed time from injection to lateral recumbency) and duration of immobilization (duration of lateral recumbency) were recorded. Each animal was identified as either a juvenile or adult based on external sexual characteristics (Sanderson and Nalbandov, 1973), and body mass (Johnson, 1970). Also recorded were the behaviors exhibited by each anesthetized raccoon. All animals were provided with canned cat food and water, and later released after fully recovering from anesthesia.

Time to induction and duration of immobilization were tested for correlation with dose using Pearson correlation coefficients (SAS Institute, Inc., 1985a). Plots of body mass and dose versus duration of immobilization were performed to check for nonlinear effects. Body mass was tested for correlation with dose using Pearson correlation coefficients to check for the possibility of multicollinearity. Observer effect was a nuisance variable in the model, and a one-way analysis of variance (SAS Institute, Inc., 1985b) was performed to determine whether

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the average duration of immobilization differed for the three observers. Since this did not appear to be the case, multiple regressions (SAS Institute, Inc., 1985b) were used to test four variables (sex, body mass, age, and dose) for their effect on the duration of immobilization. All possible two-way interactions among these main effects also were added to the regression model. Backward elimination was employed to arrive at a final model. Residual plots were examined and the residuals were tested for normality using the Shapiro-Wilk statistic (SAS Institute, Inc., 1985a) to check the model's validity. Equations derived from this final multiple regression model were used to predict the duration of immobilization of male and female raccoons at different dosages of ketamine for various body masses. Dosages of ketamine and body masses used in the equations were within the range of values used to derive the equations themselves.

RESULTS

Forty-one raccoons were captured (25 females, 14 adults and 11 juveniles; 16 males, 12 adults and 4 juveniles). Actual dosages of ketamine injected ranged from 7 to 16 mg/kg. Onset of anesthesia was indicated in all raccoons by ataxia, nystagmus of the eyes, and loss of aggressiveness.

Mean (±SD) time to induction and duration of immobilization for all raccoons was 3.2 ± 1.8 and 42.3 ± 14.5 min, respectively. Immobilization time had a significant positive correlation ($r = 0.612$, $P = 0.0001$) to increasing dose levels. Induction times slightly decreased with increased dosages, but the relationship was not significant ($r = -0.219$, $P = 0.20$).

To arrive at a model for the prediction of duration of immobilization, some preliminary analysis was needed. Since plots of body mass and dose versus duration of immobilization were linear, there was no need to consider nonlinear terms. Body mass and dose were not correlated ($r = 0.147$, $P = 0.36$) so this eliminated the problem of multicollinearity. The average duration of immobilization did not differ significantly for the three observers ($F = 2.38$, $P = 0.11$) so that observer effect could be eliminated from further consideration in the model.

The original multiple regression model which consisted of four independent variables (sex, body mass, age, and dose) as well as the six two-way interactions between these variables, explained 59% ($R^2 = 0.594$) of the total variability of the duration of immobilization. After backward elimination, three variables and two interactions among these variables had significant effects on the duration of immobilization of raccoons (sex $F = 10.20$, $P = 0.0030$; body mass $F = 9.74$, $P = 0.0036$; dose $F = 6.43$, $P = 0.0159$; sex × dose $F = 10.20$, $P = 0.0030$; body mass × dose $F = 11.04$, $P = 0.0021$). This regression model explained 58% ($R^2 = 0.587$) of the total variance in the duration of immobilization.

The final model produced the following prediction equations: $\hat{y} = 103.9800 - 26.8860$ (mass) $- 6.5446$ (dose) $+ 2.6695$ [(mass)(dose)] for female raccoons, and $\hat{y} = 166.2888 - 26.8860$ (mass) $- 11.9335$ (dose) $+ 2.6695$ [(mass)(dose)] for male raccoons; where $\hat{y}$ is the predicted immobilization times (min), mass is the body mass (kg), and dose is the amount of ketamine injected (mg/kg).

DISCUSSION

Raccoons were handled without incident before becoming recumbent. Ketamine can reduce aggressive behavior at dosages below optimum (Hime, 1974). Ketamine is a dissociative agent that causes sensory isolation in the brain (Collins, 1975), while reflex activities are maintained (Beck et al., 1971). While anesthetized, all raccoons exhibited increased licking activity. Licking behavior was probably in response to excess salivation, a common characteristic of ketamine anesthesia (Beck et al., 1971).

The cataleptoid nature of ketamine (Beck et al., 1971) was evident in all raccoons anesthetized. Individuals maintained varying degrees of muscle rigidity which was characterized by extension of the forelimbs and tremors. Tremors appeared to be more pronounced in hyper-

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excitable individuals. Overstimulated animals are more prone to have muscle spasms when sedated (Commons, 1970). Mild clonic-tonic convulsions were exhibited by six raccoons in our study and some individuals in Bigler and Hoff's (1974) study. In our study, the occasional convulsions increased in frequency when anesthesia began to wane. We concur with Commons (1970) that animals anesthetized with ketamine should be placed in a darkened room away from external stimuli during recovery to reduce the likelihood of convulsions.

Eight of the raccoons exhibited a negative response to ketamine. Characteristic symptoms were a tucked body position, extended extremities, extreme muscle rigidity, and lips drawn away from clinched teeth. Raccoons exhibiting such behavior recovered with no observable adverse effects. Normally, severe reactions to ketamine occur at high dosages (Ramsden et al., 1976), but were exhibited in this study at dosages varying between 8 to 14 mg/kg (Bigler and Hoff, 1974). Such sensitivity of raccoons to ketamine anesthesia has not been reported previously.

Sedatives such as diazepam or acetylpromazine used in combination with ketamine have been recommended to prevent convulsions (Fowler, 1978). Bigler and Hoff (1974) used acetylpromazine as a sedative for raccoons prior to injections of ketamine. The waiting period required before administration of ketamine was believed to reduce the value of acetylpromazine as a field technique (Bigler and Hoff, 1974). Xylazine and ketamine have been injected together to anesthetize raccoons and were successful in eliminating muscle spasms, but recovery times were prolonged (Roloff, 1990).

Average time to induction and duration of immobilization for all raccoons in this study corresponded closely to times reported previously for raccoons given similar dosages of ketamine (Bigler and Hoff, 1974).

For the final model, plots of predicted duration of immobilization, dose, and body mass versus the residuals had no apparent patterns. There was some indication that the residuals violated the normality assumption (Shapiro-Wilk's $W = 0.939$, $P = 0.04$). This violation of normality occurred for all models considered in the backward elimination process. However, since all terms eliminated from the model had P-values >0.55, and all terms left in the model had P-values <0.02, and since the model was being used primarily for estimation purposes, this did not appear to be a significant problem.

There are no known reports on the differential response to ketamine by male and female raccoons. Based on our results, we propose that male and female raccoons differ in their ability to metabolize ketamine. Beck et al. (1971) proposed that ketamine crossing the placenta is rapidly metabolized by neonates, and young domestic cats require higher doses than older cats. If a similar relationship pertains to raccoons, the predictions associated with dosages of 12 and 15 mg/kg could be closer to the real-life situation than are those of the 9 mg/kg condition.

Predicted duration of ketamine-induced immobilization times in this study generally increased with increasing dosages within raccoon weight classes. However for males having a body mass less than 4.47 kg and for females having a body mass less than 2.45 kg, the predicted duration of immobilization times decreased with increasing dosages. Within each sex, raccoons of similar mass probably have similar metabolic efficiencies, therefore an increase in dose would prolong anesthesia.

For female and male raccoons having the same body mass, the predicted duration of immobilization times were less for female than for male raccoons when the dose was <11.56 mg/kg. For doses >11.56 mg/kg, male raccoons had a larger predicted duration of immobilization time.

The prediction model reported in this study should only be used for doses between 7 and 16 mg/kg, for females whose mass are between 2.4 and 5.5 kg, and for

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males whose mass are between 3.1 and 7.3 kg, as these were the ranges used in the study.

Based on our results, we propose that there are several factors in addition to dose affecting the response of raccoons to ketamine. Paramount in wildlife field research involving the chemical restraint of animals is the need for the sedative to be as safe and as humane as possible. To achieve these goals and to more effectively use ketamine in raccoon research, we believe more laboratory-oriented experiments are needed to investigate the complex processes suggested by this study.

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