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A COMPARISON OF TWO FIELD CHEMICAL IMMOBILIZATION TECHNIQUES FOR BOBCATS (*LYNX RUFUS*)

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Abstract: Anesthetic protocols that allow quick induction, short processing time, and rapid reversal are necessary for researchers performing minimally invasive procedures (including morphometric measurements or attachment of radiocollars). The objective of this study was to evaluate the effectiveness of medetomidine and butorphanol as a substitute for xylazine in ketamine-based field immobilization protocols for bobcats (*Lynx rufus*) to reduce recovery and total field times. During 2008 and 2009, 11 bobcats were immobilized with an intramuscular combination of ketamine (10 mg/kg)-xylazine (0.75 mg/kg) (KX) or ketamine (4 mg/kg)-medetomidine (40 mcg/kg)-butorphanol (0.4 mg/kg) (KMB). Time to initial sedation, recumbency, and full anesthesia were recorded postinjection. Time to head up, sternal, standing, full recovery, and total processing times were recorded post-reversal. Throughout anesthesia, heart rate (HR), respiratory rate (RR), rectal temperature (RT), and noninvasive hemoglobin-oxygen saturation (SpO_2) were recorded at 5-min intervals. The KX combination had a median time to full anesthesia of 10 min, a median recovery time of 46 min, and a median total processing time of 83 min. Alternatively, the KMB combination had a median time to full anesthesia of 21 min, a median recovery time of 18 min, and a median total processing time of 64 min. The KX protocol produced a median HR of 129 beats/min, RR of 25 breaths/min, RT of 38.3°C, and SpO_2 of 93%. The KMB protocol produced a median HR of 97 beats/min, RR of 33 breaths/min, RT of 38.4°C, and SpO_2 of 92%. Though both protocols provided safe and reliable sedation, the benefits of using medetomidine and butorphanol to lower ketamine doses and decrease processing time for brief nonsurgical sedation of bobcats in the field are presented.

Key words: Anesthesia, bobcat, induction rate, ketamine, *Lynx rufus*, recovery rate.

INTRODUCTION

The use of chemical restraint has been successfully used for many years in wildlife research and management.[16] Generally, immobilizing drugs are selected to allow wildlife to be handled in a safe, effective, predictable, and minimally stressful manner.[26] Further, anesthetic protocols that allow quick induction, short processing time, and rapid reversal are necessary for researchers performing minimally invasive procedures (e.g., morphometric measurements or attachment of radiocollars). Although bobcats (*Lynx rufus*) have been studied throughout the United States, reports on doses of anesthetic agents, response, and effectiveness are limited. Doses have been reported as 10–22 mg/kg of ketamine[11,12,19] or 8–11 mg/kg of ketamine combined with 0.71–1.7 mg/kg xylazine.[3,25,28,33] The use of a ketamine-medetomidine-butorphanol (KMB) drug combination compared to the ketamine-xylazine (KX) combinations previously used for bobcats was evaluated as part of a study that analyzed microhabitat use, movement, and genetic relatedness of bobcats at Bull Neck Swamp Research Forest, North Carolina (Rockhill, North Carolina State University, unpubl. data).

For carnivores, KX has been widely used and typically results in stable cardiovascular function and good muscle relaxation.[16] Ketamine is a dissociative anesthetic that generates rapid immobilization in carnivores.[10,26] Also, ketamine is nonreversible and the margin of safety is high when used alone.[6,27] Advantages of using ketamine for field sedation of small carnivores include safety, intramuscular administration, rapid effect, availability, affordability, and compatibility with other anesthetic agents.[4,32,38] Side effects of ketamine may include increased heart rate and blood pressure, muscle rigidity, convulsions, and catatonia.[2,4,6,38] Xylazine is often used in combination with ketamine to reduce the amount of ketamine needed for anesthesia and to mitigate the negative effects of both drugs.[4,8,23] Xylazine is an α-2 adrenoreceptor agonist that produces moderate sedation, analgesia, and muscle relaxation and is

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reversible in carnivores with the antagonist yohimbine.[4,8,27,35] In addition, xylazine can decrease heart rate and cardiac output and induce vomiting in felids.[4]

Medetomidine, an α-2 adrenoreceptor agonist, has been used in combination with ketamine for Canada lynx (*Lynx canadensis*),[1] tigers (*Panthera tigris*),[7] European wildcats (*Felis silvestris*),[20] cougars (*Puma concolor*),[21] and domestic cats (*Felis catus*)[34] but has not been reported for bobcats. Medetomidine has a much higher α-2:α-1 selectivity ratio than xylazine,[13] resulting in greater potency and more complete reversal with the antagonist atipamezole.[26,29] However, bradycardia has been reported as a side effect of medetomidine-ketamine combinations used in cats.[13,17,34] Butorphanol is a κ-opioid agonist and a μ-opioid antagonist with relatively weak analgesic properties, a wide margin of safety and, when combined with medetomidine, provides additional sedation and improved muscle relaxation.[8,30] Combinations of KMB have been reported for European badgers (*Meles meles*),[22] patas monkeys (*Erythrocebus patas*),[14] ring-tailed lemurs (*Lemur catta*),[37] red wolves (*Canis rufus*),[18,30] and ferrets (*Mustela putorius furo*),[15] but not for free-ranging, wild felids.

The study required a large trapping effort (up to 85 traps/night over 2,400 ha) with the possibility of numerous nontarget species including gray fox (*Urocyon cinereoargenteus*), Virginia opossum (*Didelphis virginiana*), and northern raccoon (*Procyon lotor*). Therefore, the goal was to reduce field time by reducing the overall processing time of anesthetized bobcats, thereby allowing for safe and quick trap release. Specifically, the effectiveness of KMB as a substitute for KX in field procedures with bobcats that required nonsurgical, brief anesthesia was evaluated.

MATERIALS AND METHODS

During 01 March 2008–09 March 2008 and 07 March 2009–22 March 2009, bobcats were captured at Bull Neck Swamp Research Forest, North Carolina using foot hold traps (#1.5 Victor Softcatch, Minnesota Trapline Products, Inc., Pennock, Minnesota 56279, USA) with a 1.81-kg pan tension. Between 37 and 85 traps were set per night in locations with high bobcat activity based on preliminary data from camera and scent station surveys (Rockhill, North Carolina State University, unpubl. data). Once captured, bobcats were randomly assigned to an immobilization protocol of 10 mg/kg ketamine (Ketaset®, Fort Dodge Animal Health, Fort Dodge, Iowa 50505, USA) and 0.75 mg/kg xylazine (Xyla-ject® 20 mg/ml, Phoenix Pharmaceutical Inc., St. Joseph, Missouri 64506, USA) (KX) or 4 mg/kg ketamine, 40 mcg/kg medetomidine (Domitor®, Pfizer Animal Health, Exton, Pennsylvania 19341, USA), and 0.4 mg/kg butorphanol (Torbugesic®, Fort Dodge Animal Health) (KMB). Immobilization doses were developed from similar protocols used on captive Pallas' cats (*Felis manul*) at the North Carolina State University's College of Veterinary Medicine.[24] Doses were calculated based on estimated body weight and the drugs were administered via intramuscular injection. The time to initial sedation, recumbency, and anesthesia were monitored. Time to initial sedation was recorded at first signs of anesthetic effect (e.g., ataxia and disorientation) and time to anesthesia was recorded when animals were no longer responsive to a noxious stimulus (e.g., ear pinch). During anesthesia, heart rate (HR), respiratory rate (RR), rectal temperature (RT), noninvasive hemoglobin-oxygen saturation (SpO_2), and capillary refill time were recorded at 5-min intervals. SpO_2 was measured with a pulse oximeter (V3402 Handheld Pulse Oximeter, Smiths Medical, Dublin, Ohio 43017, USA). Bobcats were weighed, measured, ear-tagged, sexed, aged based on tooth wear and eruption,[5] and fitted with a global positioning system (GPS) very high frequency (VHF) radio collar weighing 250 g (Tellus GPS System, Followit, Lindesberg 711 34, Sweden). Blood samples were collected from the jugular vein for disease surveillance and a tissue sample was collected from an ear punch for genetic analysis. Anesthesia was reversed with 0.2 mg/kg yohimbine (Yobine®, Lloyd Laboratories, Shenandoah, Iowa 51601, USA) or 0.2 mg/kg atipamezole (Antisedan®, Pfizer Animal Health) for KX and KMB, respectively. Bobcats were placed in a 2×1 meter transportable animal cage post-reversal, and we recorded time to initial raising of the head (i.e., head-up), sternal recumbency, standing, and full recovery (i.e., when no signs of sedation were present). Release time was documented and total processing time was calculated as the time from initial injection of the anesthetic agent to time of release. Bobcats were released at the capture site and monitored with GPS-VHF for up to 9 mo post-release.

Data were not normally distributed and sample sizes were low; therefore, medians were used for analysis.[31,32] Differences were compared for anesthesia time (sedation, recumbency, and complete anesthesia), HR, RR, RT, SpO_2, recovery times (head up, sternal, standing, full recovery), and total processing times between KX and KMB

Table 1. Median, range, and comparison of monitored parameters for ketamine-xylazine (KX) and ketamine-medetomidine-butorphanol (KMB) in immobilized bobcats captured at Bull Neck, North Carolina 2008–2009.

Parameter	KX ($n = 5$)		KMB ($n = 6$)		Mann-Whitney *U*-test
	Median	Range	Median	Range	
Sedation time[a,b]	3.0	2.0–7.0	6.5	1.0–13.0	7.5
Recumbency time[a,b]	8.0	3.0–10.0	14.0	9.0–28.0	3.0[d]
Anesthesia time[a,b]	10.0	3.0–21.0	20.5	13.0–38.0	3.0[d]
Heart rate	128.6	112.0–186.7	97.0	82.8–120.0	28.0[d]
Respiratory rate	24.6	16.0–38.0	33.2	15.0–41.3	11.0
Rectal temperature (°C)	38.3	37.6–38.8	38.4	36.5–39.2	10.0
Oxygen saturation	93.0	90.0–95.0	92.3	82.0–94.1	8.0
Head-up time[a,c]	5.0	3.0–14.0	1.5	−5.0–6.0	24.0
Sternal time[a,c]	8.0	7.0–23.0	5.0	0.0–10.0	24.0
Standing time[a,c]	29.0	11.0–103.0	9.5	5.0–15.0	28.0[d]
Full recovery time[a,c]	46.0	33.0–103.0	17.5	9.0–37.0	29.0[d]
Total process time[a,b]	83.0	74.0–140.0	64.0	49.0–77.0	28.0[d]

[a] Time in minutes.
[b] Time calculated from immobilization injection.
[c] Time calculated from reversal injection.
[d] Indicates that the drug combinations (i.e., KX and KMB) differed; alpha was set at $P = 0.05$.

with a Mann-Whitney *U*-test;[36] alpha was set at $P < 0.05$.

All procedures were approved by the Institutional Animal Care and Use Committee at North Carolina State University (Protocol # 08-012 O) and the North Carolina Wildlife Resources Commission (Statues GS113-261 & GS113-272.4, Rules NCAC 10B.0119) and followed guidelines provided by the American Society of Mammalogists.[9]

RESULTS

A total of 11 captures (8 females, 3 males; at time of capture 5 adults, 6 juveniles) were recorded. Two juvenile female bobcats captured in 2008 were recaptured in 2009 as adults, resulting in 11 anesthetizations of 9 bobcats. Median weights of bobcats were similar for individuals treated with KX (7.1 kg) compared to KMB (6.9 kg; $P = 0.855$). Bobcats anesthetized under KX received 9.61–13.89 mg/kg ketamine (median = 13.46) and 0.71–1.05 mg/kg xylazine (median = 0.89). Bobcats anesthetized under KMB received 3.29–9.91 mg/kg ketamine (median = 4.80), 0.03–0.05 mg/kg medetomidine (median = 0.05), and 0.33–0.52 mg/kg butorphanol (median = 0.45). The median time to initial sedation was similar between protocols ($P = 0.169$; Table 1). However, time to recumbency and anesthesia for bobcats anesthetized with KX were 6 and 11 min faster, respectively, than bobcats anesthetized under KMB (recumbency: $P = 0.027$; anesthesia: $P = 0.028$; Table 1). The median heart rate differed between protocols ($P = 0.018$); heart rates for bobcats receiving KMB (median = 97.0 beats/min) were lower for the first 20 min of anesthesia than heart rates for bobcats receiving KX (median = 129 beats/min) (Fig. 1a). Differences in heart rates were statistically significant to the 0.05 level at 5 ($P = 0.033$), 10 ($P = 0.025$), 15 ($P = 0.036$), and 20-min ($P = 0.046$) intervals (Fig. 1a). Median respiratory rates were similar between KX (25 breaths/min) and KMB (33 breaths/min; $P = 0.645$; Fig. 1b). Rectal temperatures were within the accepted range throughout anesthesia and similar between protocols ($P = 0.670$; Fig. 1c). Oxygen saturation was similar between protocols ($P = 0.480$; Fig. 1d).

Bobcats anesthetized under KX received 0.18–0.28 mg/kg yohimbine (median = 0.24) and bobcats anesthetized under KMB received 0.20–0.26 mg/kg atipamezole (median = 0.25) for reversal. Time to head up and time to sternal were similar between protocols (head up: $P = 0.099$; sternal: $P = 0.098$). Standing time, full recovery time, and total processing time, however, differed between protocols (standing: $P = 0.017$; full: $P = 0.011$; total: $P = 0.018$). Bobcats anesthetized with KX had longer times to standing, full recovery, and total processing time compared to the KMB protocol times to standing, full recovery, and total processing time (Table 1). No signs of paddling, vomiting, or convulsions were observed with either drug combination during anesthesia, although a pregnant bobcat had convulsions approximately 29 min after the reversal for KMB was administered.

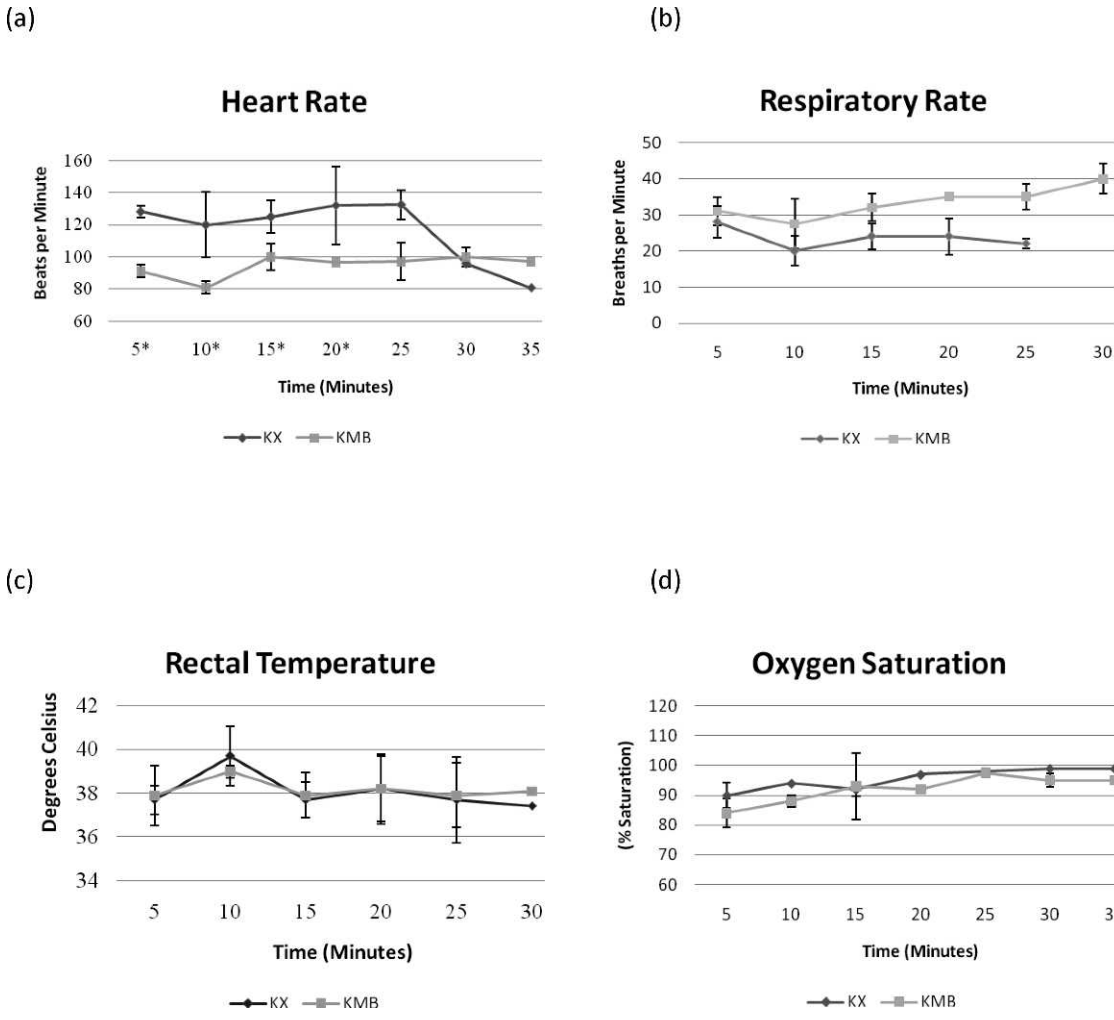

Figure 1. Median values and standard deviations for ketamine-xylazine (KX) vs. ketamine-medetomidine-butorphanol (KMB) at 5-min intervals for (**a**) heart rate, (**b**) respiratory rate, (**c**) rectal temperature, and (**d**) oxygen saturation. An * indicates a statistically significant difference ($P < 0.05$).

DISCUSSION

The results indicate that KMB is a safe and suitable drug combination for brief, nonsurgical field sedation of bobcats. In general, bobcats anesthetized under KMB exhibited smooth sedation and immobilization along with quicker recovery than under KX (Table 1). Although induction times of KMB were, on average, 11 min longer than KX, the total processing times of KMB were, on average, 19 min shorter than with KX. Lower doses of ketamine have been reported to result in longer induction times and quicker recovery times.[27] The addition of medetomidine and butorphanol allowed for lower ketamine doses and, overall, significantly shorter processing times. Bobcats anesthetized under KMB appeared to be more responsive to surrounding noises or motions, and induction time could be reduced by minimizing disturbance at the field site (e.g., reduce noise and visibility). Importantly, trapped bobcats should be approached with caution and can inflict severe injury if not properly immobilized.[26] Although KX provided rapid induction along with acceptable heart rates, respiratory rates, rectal temperature, and oxygen saturation, recovery was long and variable (33–103 min). During this study, bobcats under KX took, on average, 28 min longer to recover fully and exhibited signs of swaying or trembling at some point during recovery. Only one bobcat

under KMB exhibited negative signs during recovery; the female bobcat that had a seizure 29 min after the reversal, atipamezole, was administered. This bobcat received 4 mg/kg more ketamine than necessary and had an abnormally long recovery time (37 min). She was monitored for 8 mo following initial capture and movement activities were consistent with activities of other bobcats in the study.

Decreases in heart rate with KMB were consistent with previous reports.[14,22,30] Bradycardia was likely a reflex due to peripheral vasoconstriction associated with medetomidine administration.[17] Field conditions precluded reliable blood pressure measurement and hypertension could not be confirmed. Some bobcats exhibited less than optimal oxygen saturation, and we recommend providing supplemental oxygen when possible.

Most bobcat studies that require the collection of blood, standard measurements, and application of a radiocollar and ear tags can be performed in 20–30 min. The effective dose of ketamine begins to wear off in this period.[16] Although no surgical procedures were performed for this project, ear tags were inserted that required taking a 1-mm punch biopsy of cartilage from the ears. The biopsy punch was performed last and, typically, resulted in partial arousal in bobcats sedated with KMB. Reducing the ketamine dose by adding medetomidine and butorphanol may result in partial arousal in bobcats; therefore, appropriate safety precautions should be taken when using KMB. Although a speedy arousal is desirable when a quick return to normal function is important, for processing times that extend beyond 30 min, the KX combination may be necessary.

CONCLUSIONS

Although ketamine or ketamine-xylazine combinations are widely accepted in the literature as appropriate immobilizing protocols for bobcats, field anesthesia of bobcats with a combination of KMB followed by atipamezole for reversal is recommended as an alternative for brief, nonsurgical field sedation. Though both protocols provide safe and reliable sedation, the benefits of using KMB for faster recovery and decreased processing time are presented. This protocol is appropriate for nonsurgical, brief procedures and we recommend that researchers minimize disturbance by reducing field crew and noise, especially during initial sedation. To the knowledge of the authors, there are no other studies on chemical immobilization of bobcats, and further research is needed to analyze the possible effects of age, sex, ambient temperature, and disturbance when anesthetizing bobcats.

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