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Immobilization of Raccoons (*Procyon lotor*) with Nalbuphine, Medetomidine, and Azaperone

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ABSTRACT: Chemical immobilization is widely used by wildlife and veterinary professionals for the safe handling of animals. A combination of nalbuphine (40 mg/mL), azaperone (10 mg/mL), and medetomidine (10 mg/mL), known as NAM, is a low-volume combination with field immobilization practicality and fewer regulations restricting its use in the US than some other drug combinations. We evaluated the safety and effectiveness of NAM as an immobilizing agent for raccoons (*Procyon lotor*). From May 2021 to February 2022, 16 adult raccoons were captured in cage traps and immobilized with 0.3 mL NAM intramuscularly (12 mg nalbuphine, 3 mg medetomidine, and 3 mg azaperone, regardless of body weight). After administration, time to sedation was measured; body temperature, heart rate, respiratory rate, and oxygen saturation were monitored and recorded every 5 min for 20 min. Each raccoon was weighed; the dose administered was calculated (range 2.2–4.1 mg/kg, mean 3 mg/kg). Mean induction time was 6 min (4–17 min); time to recovery following administration of 15 mg atipamezole, 7.5 mg naltrexone for reversal, was 10 min (6–18 min). Heart rate, oxygen saturation, and respiration rate remained steady during immobilization. Rectal temperature steadily declined. Overall, NAM appeared to be a practical option for raccoon immobilization, providing rapid induction and reversal as well as adequate sedation for short-term handling and minimally invasive sampling.

Key words: chemical immobilization, induction time, NalMed-A, NAM, raccoons, reversal time.

Chemical immobilization is an essential tool used by wildlife professionals and veterinary personnel for the safe handling of animals during research, disease surveillance, and management activities (Chinnadurai et al. 2016). Specific protocols vary extensively depending on factors such as wildlife species, degree of immobilization needed, and drug delivery options. Commonly used immobilization agents and agent combinations for wildlife include butorphanol-azaperone-medetomidine, ketamine, ketamine-xylazine, tiletamine, tiletamine-zolazepam, and tiletamine-zolazepam-xylazine, among others (Bigler and Hoff 1974; Deresienski and Rupprecht 1989; Belant 2004; Pitt et al. 2006; Miller et al. 2009). These drugs typically have short induction times; however, they may have an extended reversal period, which presents challenges such as time-sensitive research, high animal numbers, and wildlife release logistics (Miller et al. 2009). In addition, many immobilization agents are regulated by the US Drug Enforcement Administration (DEA), making US interstate transport and use by nonveterinary wildlife professionals during field activities challenging (Wolfe et al. 2014a).

A combination of nalbuphine, azaperone, and medetomidine, NAM (NalMed-A, ZooPharm, Laramie, Wyoming, USA), contains 40 mg/mL nalbuphine HCl, 10 mg/mL medetomidine HCl, and 10 mg/mL azaperone tartrate. It is an effective, low-volume unscheduled drug combination with field immobilization practicality for many species including Rocky Mountain elk (*Cervus elaphus nelsoni*), American black bear (*Ursus americanus*), American bison (*Bison bison*), bighorn sheep (*Ovis canadensis*), and aoudad (*Ammotragus lervia*) (Wolfe et al. 2014b, 2016, 2017; Thomas et al. 2022). However, NAM did not induce desirable levels of immobilization, or there was extreme variation in levels of sedation, in American beaver (*Castor canadensis*) and feral pigs (*Sus scrofa*; Ellis et al. 2019; Roug et al. 2019). Thus, additional studies on diverse wildlife species

are needed to further explore the utility and efficacy of NAM.

We evaluated the use of NAM to immobilize raccoons (*Procyon lotor*). Raccoons use a variety of landscapes and are highly adaptable to anthropogenic change, sometimes resulting in nuisance-related issues (Prange et al. 2003). Raccoons are also rabies vectors and may transmit additional zoonotic pathogens, highlighting the importance of immobilization drugs that allow for safe handling by wildlife professionals (Robert et al. 2012).

From May 2021 to February 2022, 16 raccoons (12 males and four females) were captured at field sites in Clarke County, Georgia, US, and Claiborne County, Tennessee, US, as part of ongoing tick surveillance studies. Raccoons were captured using cage traps (Havahart Products, Littiz, Pennsylvania, USA) baited with canned sardines. During each trapping session, 20–40 traps were set and checked daily before 10:00 am. Raccoons were processed immediately at the field site or transported to a nearby location for processing.

All raccoons were given 0.3 mL of NAM (i.e., 12 mg nalbuphine HCl, 3 mg medetomidine HCl, and 3 mg azaperone tartrate) intramuscularly in the hind limb by hand injection using a 3 mL syringe with a 22-gauge, 2.5 cm needle. The manufacturers suggested this dosage as a starting point to determine a standard dose for field use when animal weight is not available. After administration, the cage was partially covered to reduce stress while still enabling monitoring of behavior and induction time. After sedation was achieved, body temperature, heart and respiratory rate, and oxygen saturation were monitored and recorded every 5 min for up to 20 min. Some data points were not recorded due to equipment failure. Percent oxygen saturation and heart rate were monitored using a pediatric pulse oximeter (Nellcor, Covidien, Boulder, Colorado, USA) attached using a lingual tip on the paw pad. Body temperature was monitored by rectal thermometer. Supplemental heat and oxygen were not provided to assess drug effects during immobilization.

Degree of sedation was scored on a 1–5 scale where 1=animal could not be handled, 2=sedated but moved away when stimulated (woke up, but remained sedate, attempted to crawl away, required supplemental dose), 3=sedated but responded to stimulus without moving away (e.g., react significantly with large head or feet movements when manipulated), 4=slight response to stimulus (e.g., ear twitches, small transient limb movements or slight muscle rigidity), and 5=no response to handling or stimulus (desired level of sedation). Reversal agents, 15 mg of atipamezole (atipamezole, ZooPharm, Laramie, Wyoming, USA) and 7.5 mg of naltrexone (naltrexone, ZooPharm), were administered intramuscularly in the opposite hind limb by hand injection using a 1 mL syringe with a 25-gauge, 1.6 cm needle after 20 min of sedation. Time points were recorded for induction time (time from administration of drug to complete sedation) and reversal time (time from antagonist administration to no immobilization effect).

While sedated, animals were checked for ectoparasites, ear tagged, and a blood sample was taken from the cephalic vein using a 3 mL syringe with a 22-gauge 2.5 cm needle. Raccoons were released at the site of capture after no visual immobilization effects were observed. All trapping, handling, and immobilization methods were approved by the University of Georgia's Institutional Animal Care and Use Committee (A2018-06-027 and A2021-08-007).

Overall, NAM provided safe and effective chemical immobilization for raccoons in this study. All raccoons received a dose ranging from 2.2 to 4.1 mg/kg with a mean of 3 mg/kg. All raccoons used in this study were apparently healthy adults. Fifteen of 16 raccoons were sedated with no or only a slight response to stimulus (sedation score 4 or 5) after the single dose. The mean sedation score was 4.6. The quality of sedation was satisfactory for raccoons based on ease of handling and ability to remove ectoparasites and collect blood. Only one animal did not receive a sedation score of 4 or 5. This raccoon, a large male (8.2 kg compared to a mean of 6 kg), received the

lowest dose per kg body weight (2.2 mg/kg) and had the longest induction time (17 min). The raccoon briefly became aroused during handling but reached sedation approximately 5 min after arousal and did not require a second dose. The arousal of the largest individual may suggest that 2.2 mg/kg is on the lower end of the effective dose range for NAM in raccoons. Therefore, we suggest that 3 mg/kg be used in raccoons as a starter dose.

The mean induction time was 6±0.2 min (mean±standard deviation; range 4–17 min). The mean reversal time was 10±0.2 min (range 6–18 min). Animals were considered ready for release if they were standing, alert, and responsive to stimuli. Previous studies with tiletamine-zolazepam-medetomidine and ketamine-xylazine sedation combinations in raccoons have reported longer times to reversal following injection of reversal agents than in our raccoons with NAM, but differences in reporting parameters make comparisons complicated (Deresienski and Rupprecht 1989; Brown and Jamieson 2022). For ketamine-medetomidine immobilization, similar reversal times to ours have been reported, but their indicator of full recovery was heads up while our study required standing, alertness, and responsiveness (Robert et al. 2012). One important difference between NAM and other commonly used immobilization drugs mentioned is the lack of a required waiting period for administration of reversal, which is needed after administration of ketamine or tiletamine, because these agents are not reversed. Therefore, NAM may be a more practical sedation alternative than some other commonly used drug combinations for time-critical field studies due to its immediate reversibility.

Body temperature slowly dropped over the 20-min immobilization period. We recommend supplying supplemental heat or insulation to counteract this (Baldwin et al. 2008). Heart rate remained steady with means ranging between 64 and 72 bpm for all time periods from 5 to 20 min. Respiratory rates were stable at 13 breaths/minute. Respiration followed a cyclical pattern of three or four deep breaths followed by approximately 10 s of apnea. Mean oxygen saturation remained nonhypoxic (86.2–88.8%; Table 1). Supplemental oxygen has been used in previous studies and may also be considered for raccoons during longer periods of immobilization with NAM (Wolfe et al. 2017). However, due to short sedation periods and nonhypoxic levels of oxygen saturation, supplemental oxygen was not necessary in this study.

Overall, we found that NAM provided appropriate sedation of raccoons for short-term handling and procedures. This, combined with the lack of DEA scheduling, makes NAM a practical choice for field use in the US. The relatively short induction and reversal times make NAM an ideal option for time-

TABLE 1. Vital rates, induction, reversal, and handling times for 16 adult raccoons (*Procyon lotor*) immobilized in a field setting using 0.3 mL of NAM (40 mg/mL nalbuphine HCl, 10 mg/mL medetomidine HCl, and 10 mg/mL azaperone tartrate; NalMed-A, ZooPharm, Laramie, Wyoming, USA).

Parameter	Time (min)	*n*	Mean ±SD[a]	Range
Induction time (min)		16	6±0.2	4–17
Body temperature (C)	Induction	16	39.1±0.7	37.8–40.4
	5	16	38.9±0.9	37.3–40.9
	10	15	38.7±0.8	37–40.2
	15	14	38.6±0.8	36.9–39.7
	20	13	38.3±0.6	37.4–39.7
Heart rate (beats/min)	Induction	14	74±26	46–142
	5	13	67±22	51–137
	10	15	70±24	52–132
	15	14	63±20	40–124
	20	12	62±19	44–113
Respiration rate (breaths/min)	Induction	16	18±2	8–32
	5	16	14±1	8–28
	10	15	13±1	8–24
	15	14	13±1	8–20
	20	13	14±2	4–28
Oxygen saturation (%)	Induction	15	86.8±9.7	65–99
	5	13	87.2±8.7	60–93
	10	15	86.2±9.2	58–96
	15	14	87.8±4.1	76–91
	20	13	88.8±4.5	77–96
Reversal time (min)		15	10±0.2	6–18
Total handling time (min)		15	47±0.5	36–62

[a]SD = standard deviation.

sensitive research applications with high numbers of raccoons where prolonged recovery times may be problematic. Further studies will be needed to assess the effectiveness of NAM on other wildlife species.

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