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IMMOBILIZATION OF HIMALAYAN TAHR WITH A XYLAZINE–KETAMINE MIXTURE AND REVERSAL WITH ATIPAMEZOLE UNDER FIELD CONDITIONS

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ABSTRACT: Twenty-nine free-ranging Himalayan tahr (*Hemitragus jemlahicus*) were darted in the Sagarmatha National Park (Nepal) using different combinations of xylazine and ketamine. Animals in Group 1 ($n=4$) received a mean xylazine–ketamine dose of 2.77 ± 0.99 mg/kg xylazine plus 3.32 ± 0.19 mg/kg ketamine in males and 2.39 ± 0.10 mg/kg xylazine plus 4.29 ± 0.17 mg/kg ketamine in females. Animals in Group 2 ($n=25$) received a mean xylazine–ketamine dose of 1.70 ± 0.41 mg/kg xylazine plus 3.06 ± 0.74 mg/kg ketamine in males and 1.82 ± 0.29 mg/kg xylazine plus 3.29 ± 0.52 mg/kg ketamine in females. No anesthetic-related mortality was recorded. Anesthesia was reversed by a standard dose of 11 mg/animal of atipamezole administered by intramuscular injection. Although all anesthetic dosages immobilized free-ranging tahr successfully, a quick and smooth recovery was obtained (11.1 ± 5.6 min) only with the dosages of Group 2.

Key words: Anesthesia, atipamezole, *Hemitragus jemlahicus*, Himalayan tahr, ketamine, reversal, xylazine.

INTRODUCTION

The Himalayan tahr (*Hemitragus jemlahicus*; family Bovidae, subfamily Caprinae) is found in Nepal, Sikkim, China (Tibet), and India (Himachal Pradesh, Jammu and Kashmir, and Uttar Pradesh). Himalayan tahr were introduced into New Zealand early in the 20th century and currently number around 30,000. In Nepal, the Himalayan tahr was previously distributed between 1,500 and 5,200 m above sea level (Green, 1978; Green, 1979; International Union for the Conservation of Nature and Natural Resources [IUCN], 1997), but increasing human encroachment, habitat loss, and poaching (IUCN, 1997) has reduced the population to an estimated minimum number of 1,000 animals. Tahr currently are found in the Sagarmatha, Makalu-Barun, and Langtang national parks as well in the Annapurna Conservation Area (Bauer, 1988; Lovari, 1992) and are listed in the 2004 IUCN Red List of Threatened Animals, classified as "vulnerable"; this species is likely to move into the "endangered" category in the near future (IUCN, 2004).

Based on the available literature, Kreeger et al. (2002) recommended the combination of 1.5 mg/kg ketamine plus 0.09 mg/kg medetomidine, antagonized with atipamezole (Jalanka and Roeken, 1990). Alternative drugs include the following: 0.001 mg/kg carfentanil plus 0.01 mg/kg xylazine antagonized with naloxone plus yohimbine; a mixture of 2 mg etorphine plus 8 mg acepromazine and 10 mg xylazine antagonized with diprenorphine; or 2.2 mg/kg tiletamine plus 2.2 mg/kg zolazepam (Gray et al., 1974; Rapley and Mehren, 1975; Wiesner et al., 1982; Wiesner et al., 1984; Göltenboth and Klös, 1987; Jalanka and Roken, 1990; Allen et al., 1991). Wiesner (1977) reports the use of 100 mg xylazine plus 80 mg ketamine to immobilize adult Himalayan tahr in captivity. The chemical capture of Himalayan tahr is poorly documented,

with anesthetic dosages only derived from work with animals in zoological collections.

The present study was carried out within an international framework (Scientific and Technological Research in Himalaya and Karakorum [Ev-K^2-CNR] and the Royal Nepal Academy of Science and Technology [RONAST]) which, beyond its scientific intent, aims to train local professionals in capture and field management operations. The objective of this study was to evaluate the effects of predetermined xylazine and ketamine combinations to be administered irrespective of differences in body weight. Moreover, in order to form a local, fully autonomous research team, it was important to set up an anesthetic protocol suitable for the Nepalese context where obtaining and purchasing drugs for the immobilization of wildlife (especially antagonists) is difficult (director of the zoological garden of Kathmandu, R. K. Shresta, pers. comm.).

MATERIALS AND METHODS

We conducted our study in the Upper Khumbu Valley of the Sagarmatha National Park, Nepal (27°20′N, 86°45′E). The study area included two slopes with southeast and southwest aspects; the slopes were separated by a watershed and the village of Namche. Elevations ranged from 2,950 m, along the Dudh Kosi (west) and Bhote Kosi (east) rivers, to 3,950 m on the Khumjung plateau. The local climate is temperate, with snowfall mostly occurring in January and February. The driest months are from March to May and from October to December, and the warmest and wettest periods occur from June to the end of September (the monsoon period). The vegetation of this area includes blue pine (*Pinus wallichiana*) forests, with some whitebeam (*Sorbus cuspidate*) and willow (*Salix sikkimensis*) up to 3,400–3,600 m. Above the tree line, high cliff ledges, small isolated stands of blue pine, Himalayan grassland and shrubs (*Juniperus recurva, Rododendrum arborea*) are found (Buffa et al., 1998). Our study was conducted during two capture sessions, in November 2004 and November 2005, with ambient temperatures ranging from −7 to 17 C. Six fulltime workers (work time, 108 hr) participated in the capture. Free-ranging tahr (at approximately 4,000 m above sea level) were approached on foot to within 10–20 m for darting. This was possible because animals are accustomed to human presence and are not hunted in the Sagarmatha National Park.

Combinations of ketamine and xylazine were used in this study. Xylazine is an alpha-2-adrenergic agonist acting as a nonnarcotic sedative analgesic, and ketamine is a dissociative anesthetic. The combination of the two drugs enables their dosages to be reduced, enhances muscle relaxation and duration of effect, and has been associated with faster and smoother induction (Lin, 1996). Furthermore, this combination has been reported as effective for several wild species of Bovidae (Festa-Bianchet and Jorgenson, 1985; Wiesner and von Hegel, 1985; Fico, 1988; Gauthier, 1993; Peracino and Bassano, 1993). The effects of alpha-2-adrenergic agonists were reversed using a specific alpha-2-adrenergic antagonist; currently there are no effective antagonists for ketamine (Kreeger et al., 2002).

Drugs were injected with a 3-ml-capacity projectile syringe and 1.5 × 30–mm plain needles fired from a Dan-inject® Air-pressure pistol 15 (barrel diameter=11 mm; Sturzelbronn, France). Initially (Group 1), two males were immobilized with a standard dose of 250 mg xylazine plus 300 mg ketamine, prepared by dissolving 500 mg xylazine (Rompun® dry substance, Bayer, Leverkusen, Germany) in 6 ml ketamine (100 mg/ml; Ketavet® 100, Parke-Davis GmbH, Berlin, Germany), and two females were immobilized with a standard dose of 167 mg xylazine plus 300 mg ketamine, prepared by dissolving 500 mg xylazine in 9 ml ketamine. Subsequently (Group 2), 18 males were immobilized with a standard dose of 167 mg xylazine plus 300 mg ketamine and seven females with a standard dose of 111 mg xylazine plus 200 mg ketamine, prepared by dissolving 500 mg xylazine in 9 ml ketamine. The females received a lower dose per animal compared to the males because of their lower estimated body weight.

Anesthesia was reversed using a standard dose of 11 mg atipamezole (5 mg/ml; Antisedan®, Orion Corporation Farmos, Turku, Finland), administered by intramuscular injection. During immobilization, the following data were recorded: the time interval from anesthetic injection to complete immobilization with head down (induction time); the time from the antagonist administration until the animal was standing (recovery time); the interval between induction time and the injection of atipamezole (handling time).

During handling time, the animals were

hobbled, blindfolded, placed in right lateral recumbency, weighted with a spring scale and ear-tagged; metric measures were taken and the age was estimated by horn notches and tooth eruption and wear. Anesthesia was monitored to assess signs of stress related to capture. Heart rate (HR), respiratory rate (RR), and rectal temperature (RT) were recorded at two moments (designated 1 and 2 for HR, RR, and RT): immediately after the animals were placed in right lateral recumbency and immediately before antagonist administration, regardless of handling time.

Blood samples were collected from the jugular vein. During the same day, these were centrifuged and the serum was stored at −20 C for further analysis.

All tahr were individually identified by marked plastic ear tags. Each animal was monitored until it left the capture site and, thereafter, monitored from a minimum of 5 to a maximum of 14 days postcapture. In addition, the survival estimate for each individual, based on mark-resight techniques (Cormack, 1964), was assessed 1 yr later (in 2005).

Because data were not normally distributed according to the Shapiro–Wilk W test (Altman, 1991), the Spearman rank correlation coefficient was used to assess the association between the following: 1) anesthetic dosage and induction time; 2) HR/RR and anesthetic dosage; and 3) HR/RR and induction time. The paired sample Wilcoxon test was performed to compare HR and RR. The R 1.8.0 statistic program was used for all statistical tests (Ihaka and Gentleman, 1996). Statistical significance was determined at $P<0.05$. Means have been reported with standard deviation.

RESULTS

Thirty-six free-ranging Himalayan tahr (26 males, 10 females) were chemically immobilized. A minimum of one and a maximum of five subjects were successfully darted each day, at a rate of 3 hr per animal during the total field session. Ages ranged from 3 to 14 yr (8.2±2.7) in males and from 2 to 11 yrs (8±3) in females; body mass ranged from 56 to 124 kg (105±17.2) in males and from 48 to 72 kg (62±9.6) in females.

Most darts were fired into the rump, hip, or thigh. On seven occasions (six males, one female), darts bounced off immediately on hitting, causing incomplete drug injection; these animals were excluded from analysis leaving data from 20 males and 9 females. No clinical anesthetic-related problems were encountered. All dosages resulted in rapid sedation after a single dose. Induction was calm and the animals became sedated without apparent clinical stress. For Group 1, the two male and two female tahr were immobilized with an initial mean dose of 2.77±0.99 mg/kg xylazine plus 3.32±0.19 mg/kg ketamine, and 2.39±0.10 mg/kg xylazine plus 4.29±0.17 mg/kg ketamine, respectively. Mean induction time was 3.6±0.07 min in males and 5.8±1.8 min in females; mean recovery time was 18.8±2.3 min in males and 11.2±2.2 min in females. There was no significant correlation between drug dosage and induction time ($r_s=0.3$, $P>0.05$).

The twenty-five tahr in Group 2 were immobilized with a lower dosage; 18 males received a mean dose of 1.7±0.41 mg/kg xylazine plus 3.06±0.74 mg/kg ketamine, and the seven females received a mean dose of 1.82±0.29 mg/kg xylazine plus 3.29±0.52 mg/kg ketamine. Mean induction time was 6.3±3 min in males and 9.3±6.8 min in females. A significant very low correlation was assessed between drug dosage and induction time ($r_s=0.15$, $P<0.001$). Handling time in all combinations was 29.6±11.4 min.

No excessive hypo- or hyperthermia was detected. Mean RT1 was 38.8±0.6 C (range 38–40 C) whereas RT2 was 39±0.5 C (range 38.2–40 C). Respiratory rate increased slightly during immobilization (RR1 mean=60±17 breaths/min, range=30–90 breaths/min; RR2 mean=60±15 breaths/min, range=30–78 breaths/min), but the difference was not significant ($V_{RR}=128.5$, $P>0.05$). Heart rate during immobilization showed a similar pattern (HR1 mean=83±20 beats/min, range=55–125 beats/min; HR2 mean=89±22 beats/min, range=50–132), with no significant difference ($V_{HR}=83.5$, $P>0.05$). No significant correlation was

found between HR/RR and drug dosages, whereas a significant correlation was obtained between HR1 and induction time (r_s=0.4, P<0.001).

Abundant salivation was observed immediately prior to immobilization and continued until after initial recovery, but tahr retained pharyngeal and laryngeal reflexes.

One animal died during immobilization after falling asleep with its mouth and nose in a puddle of water, out of sight of the operators. Although necropsy was not possible, signs of drowning such as abundant water in the airway were evident. All tahr were monitored after each capture session and additional mortality was not observed. Sixteen out of 20 tahr, eartagged during the first capture session (November 2004), were observed the following year (November 2005), leading to a minimum survival rate of 0.8.

The males of Group 1 that received an atipamezole:xylazine dose ratio of 1:23 (0.12±0.04 mg/kg atipamezole) had a mean recovery time of 18.8±2.3 min, whereas the males of Group 2 receiving a dose ratio of 1:15 (0.11±0.03 mg/kg atipamezole) had a mean recovery time of 12.7±5.7 min. The females of Group 1 receiving an atipamezole:xylazine dose ratio of 1:15 (0.16 ± 0.01 mg/kg atipamezole) had a mean recovery time of 11.2±2.2 min, whereas the females of Group 2 that received a dose ratio of 1:10 (0.18±0.03 mg/kg atipamezole) had a mean recovery time of 7.1±2.5 min.

DISCUSSION

This is the first report on the use of xylazine–ketamine combination in free-ranging Himalayan tahr. All combinations of xylazine–ketamine administered to male and female Himalayan tahr led to effective and rapid immobilization. It has been suggested that xylazine and ketamine have wide safety margins (Golightly and Hofstra, 1989; Garner and Addison, 1994; Kilpatrick and Spohr, 1999), which is substantiated by our data. In fact, the animals were immobilized effectively with a wide range of xylazine–ketamine dosages (respectively, 1.39–3.68 mg/kg and 2.48–5.36 mg/kg), with no apparent clinical side effects. A wide safety margin is very important in field conditions when body mass has to be estimated at a distance.

Festa-Bianchet and Jorgenson (1985) reported that in bighorn sheep (*Ovis Canadensis*) complete immobilization with an intramuscular injection of xylazine–ketamine combination can occur within 2–51 min, Foster (1999) obtained immobilization in gazelles (*Gazella subgutturosa, Gazella gazella*) within 5.1–7.2 min. Jalanka and Roeken (1990) reported an induction time ranging from 1.8 to 15.7 min in Himalayan tahr immobilized with a combination of medetomidine plus ketamine. Similarly, we recorded a fairly short induction time (6.8± 4.2 min); the animals laid down near the injection site, decreasing the risk of their falling from cliff ledges or becoming impossible to locate in the dense forest below. The lack of a relationship between the dosage and induction time suggests that increasing the dosage will not improve the effectiveness of immobilization (Haviernick et al., 1998). The xylazine–ketamine dosage suggested by Wiesner (1977) to immobilize adult Himalayan tahr in captivity is lower than the one we used in the wild. In fact, anesthetic dosages valid for captive individuals are usually lower than those required for free-ranging animals (Bauditz, 1972; Von Rockenschaub, 1982; Fico, 1988).

Xylazine-ketamine immobilization was not associated with serious changes in physiologic parameters in the Himalayan tahr compared to the potential bradycardic and respiratory depressant effects of xylazine in ruminants (Hall and Clarke, 1991). The physiologic parameters monitored during immobilization did not differ significantly between the two values measured, suggesting

a deep sedation without clinical signs of stress. Heart rate 1 was positively correlated to the increase in induction time; this may be because of the excitement level of the animals requiring a longer latency to full sedation. These values should be compared to those of tahr in a rest condition, but these data are not available in literature.

A standard dose of 11 mg/animal atipamezole was administered to reverse immobilization. The dose ratio initially used in Group 1 was of 1:23 in males and 1:15 in females. The animals showed a prolonged recovery time together with rough recovery and resedation in three out of four cases. As reported above (Introduction), a greater dose ratio, without increasing atipamezole, is needed to set up an anesthetic protocol suitable for the Nepalese context, using the lowest effective dose of antagonists. It was decided to reduce xylazine dosage (in Group 2) from 250 to 167 mg/animal (males) and from 167 to 111 mg/animals (females), thereby obtaining an atipamezole:xylazine dose ratio of 1:15 and 1:10, respectively. Recovery was calm and smooth and the animals appeared alert and coordinated within minutes of antagonist administration. The dose ratio in males, even if greater than the optimal one of 1:10 reported by Jalanka and Roeken (1990) and by Arnemo et al. (1993), was satisfactory for a quick return to awareness.

When using partial antagonists, care must be taken to avoid adverse excitatory effects from other components, such as ketamine, in the anesthetic combination. Ketamine shows an elimination half-life of about 60 min in cattle and other domestic species, but the duration of anesthesia, depending on central nervous system concentration, is significantly lower, avoiding excitatory behavior after antagonism of xylazine (Adams, 2001). In fact, an atipamezole injection took place approximately 40 min after anesthetic administration and the recovery of the animals was rapid and complete in Group 2. The xylazine and ketamine combination also presents less risk to field staff. Neither xylazine (Carruthers et al., 1979) nor ketamine (Kreeger et al., 2002) is lethal to humans in small dosages.

No further comparison between the xylazine–ketamine combination used in this study and different drug combinations used in previous studies was possible. Most of these papers report drug dosages only as part of a list referring to anesthesia for zoo animals without evaluating the physiologic responses to treatments (Wiesner, 1977; Wiesner et al., 1982; Shobert, 1987). Male tahr survival rate 1 yr after first capture was similar to that (0.86) reported in an ecological study on Alpine ibex (Dematteis, 2005).

The combination of xylazine and ketamine is useful for the immobilization of free-ranging Himalayan tahr. In a context where immobilizing drugs are difficult to get, such as Nepal, a dose of 167 mg/animal xylazine combined with 300 mg/animal ketamine to immobilize males and one of 111 mg/animal xylazine plus 200 mg/animal ketamine for females, reversed by a standard dose of 11 mg/animal atipamezole, can be used effectively.

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