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Authors: Christine Fournier-Chambrillon, Ingrun Vogel, Pascal Fournier, Benoît de Thoisy, and Jean-Christophe Vié

Source: Journal of Wildlife Diseases, 36(1) : 131-140

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-36.1.131

Journal of Wildlife Diseases, 36(1), 2000, pp. 131–140

IMMOBILIZATION OF FREE-RANGING NINE-BANDED AND GREAT LONG-NOSED ARMADILLOS WITH THREE ANESTHETIC COMBINATIONS

Christine Fournier-Chambrillon,[1,2,3] Ingrun Vogel,[1] Pascal Fournier,[1] Benoît de Thoisy,[1] and Jean-Christophe Vié[1]

[1] Programme ''Faune Sauvage'', E.D.F./C.N.E.H., Savoie Technolac, 73373 Le Bourget du Lac cedex, France
[2] Present Address: La Peyrère, Route de Préchac, 33730 Villandraut, France
[3] Corresponding author (e-mail: pfournier@wanadoo.fr).

ABSTRACT: Nine-banded (n = 47) and great (n = 31) long-nosed armadillos (*Dasypus novemcinctus* and *Dasypus kappleri*) were immobilized for clinical examination and collection of biological samples as part of a wildlife rescue during the filling of a hydroelectric dam (Petit Saut, French Guiana) from May 1994 to April 1995. Three intramuscular (i.m.) anesthetic combinations were evaluated: (1) tiletamine/zolazepam (T/Z) at a dose of 8.5 mg/kg in 12 nine-banded long-nosed armadillos (NBA) and 10 great long-nosed armadillos (GLA), (2) ketamine at 40 mg/kg combined with xylazine at 1.0 mg/kg (K/X) in 18 NBA and nine GLA, and (3) ketamine at 7.5 mg/kg combined with medetomidine at 75 μg/kg (K/M) in 17 NBA and 12 GLA, antagonized by 375 μg/kg atipamezole. Induction was smooth, ranged from $\bar{x} \pm SD = 2.8 \pm 0.6$ to 4.3 ± 1.8 min, and did not differ significantly between protocols, species, or sex. In NBA, immobilization time ranged from 43.8 ± 27.8 to 66.5 ± 40.0 min and did not differ between protocols or sex. Muscle relaxation was judged to be better with K/X and K/M versus T/Z. In GLA, the response to the anesthetic protocols was more variable and immobilization time ranged from 30.4 ± 6.2 to 98.4 ± 33.7 min. The main difference was observed in GLA females receiving the T/Z combination, in which immobilization time was significantly longer versus males, but also versus GLA K/M group, and versus NBA T/Z group. Effects on body temperature, heart rate and respiratory rate were limited. Thirty six to 50% of the individuals showed hypoxemia ($S_pO_2 < 85\%$) throughout anesthesia and values <80% also were recorded but the hypoxemia was not associated with clinical signs. With T/Z and K/X, recovery was irregular and prolonged up to 2 to 3 hr in some individuals. In K/M groups, first standing was observed 1.0 to 16.4 min after i.m. atipamezole injection without adverse effects. Finally, the three anesthetic combinations used in this study were effective and safe agents for 30 to 40 min immobilizations including minor surgery procedures. The ability to antagonize the medetomidine-induced sedation with atipamezole significantly reduces the recovery time, making the K/M combination preferable, especially in field conditions.

Key words: Atipamezole, *Dasypus kappleri, Dasypus novemcinctus,* great long-nosed armadillo, immobilization, ketamine, medetomidine, nine-banded armadillo, tiletamine-zolazepam, xylazine.

INTRODUCTION

Long-nosed armadillos (*Dasypus* spp.) belong to the order Xenarthra and the family Dasypodidae which is composed of three subgenera and six species (Nowak, 1991). The nine-banded long-nosed armadillo (*Dasypus novemcinctus*), also called the common long-nosed armadillo (Montgomery, 1985), is the more common and widespread armadillo, and is the only xenarthran that occurs as far north as the United States (Nowak, 1991). Its geographic range is North, Central, and South America, whereas the geographic range of the great long-nosed armadillo (*Dasypus kappleri*) is limited to South America (Emmons and Feer, 1990). The two species are morphologically very similar, but can be easily distinguished because the great long-nosed armadillo is the only species with projecting scutes on the hind knees (Emmons and Feer, 1990). Reports on great long-nosed armadillo (GLA) biology, ecology, physiology or medicine are particularly scarce, in contrast to those on the nine-banded long-nosed armadillo (NBA).

Moreover, NBA recently has proved valuable to medical research, especially in leprosy (Nowak, 1991). However, the anesthesia of armadillos is poorly documented. In NBA, Szabuniewicz and McCrady

(1969) used pentobarbital sodium at 25 to 35 mg/kg intraperitoneally, or a combination of droperidol at 4 to 5 mg/kg with fentanyl at 0.08 to 0.1 mg/kg intramuscularly (i.m.). Storrs and Greer (1973) used phencyclidine hydrochloride at 5 mg/kg i.m. for minor surgery, and ketamine hydrochloride at 25 mg/kg i.m. for extensive abdominal examinations and most surgical procedures, with occasional cautious use of ether by cone for complete relaxation of the animal. Herbst (1991) used a combination of 100 mg ketamine hydrochloride with 5 mg xylazine hydrochloride and 0.5 mg acepromazine maleate, then halothane or enflurane to implant telemetry devices in 14 adult female NBA. Other drugs at different dosages are recommended by others for xenartrans (Wallach and Boever, 1983; Divers, 1986; Gillepsie, 1993). However, physiologic and monitoring data for these species are not available.

During the course of a wildlife rescue and research project in French Guiana, we had a unique opportunity to capture and study a large number of species (Vié, 1999), and to document the anesthesia of various wild neotropical mammals (Fournier et al., 1998; Vié et al., 1998), including xenarthrans (Fournier-Chambrillon et al., 1997; Vogel et al., 1998). Three anesthetic combinations were used in armadillos: tiletamine/zolazepam (T/Z), ketamine/xylazine (K/X), and ketamine/medetomidine (K/M). Tiletamine, a powerful dissociative anesthetic combined in a 1:1 ratio with the benzodiazepine zolazepam, a major muscle relaxant and anti-convulsant, has very good anesthetic properties and many advantages such as the small volume required, a wide safety margin, and dose-related effects (Lin et al., 1993). This combination therefore has been used extensively in many exotic and wild species (Gray et al., 1974; Boever et al., 1977; Lin et al., 1993). The dissociative and cataleptic anesthetic ketamine has good sedative and analgesic properties, but induces poor muscle relaxation (Wright, 1982). The alpha$_2$-adrenoceptor agonist xylazine complements the action of the ketamine and may equilibrate its negative effects (Wright, 1982; Waterman, 1983), and this combination has been successfully used in numerous domestic and wild species (Wright, 1982; Greene and Thurmon, 1988). The alpha$_2$-adrenoceptor agonist medetomidine is more potent and selective than xylazine (Virtanen, 1989) and potentiates ketamine to a greater extent than xylazine, reducing the effective dose of ketamine by 30 to 75% (Jalanka, 1989a; Jalanka and Roeken, 1990; Moens and Fargetton, 1990; Verstegen et al., 1991a). In addition, the medetomidine-induced sedation can be reversed using the potent and selective alpha$_2$-adrenoceptor antagonist atipamezole. Thus, the use of ketamine/medetomidine combinations in wild species recently considerably increased (Jalanka, 1989b; Virtanen, 1989; Barnett and Lewis, 1990; Jalanka and Roeken, 1990).

The objectives of this study were to assess the duration and the quality of immobilization of free-ranging nine-banded and great long-nosed armadillos with three anesthetic combinations, and to compare the effects between the combinations and the species.

MATERIALS AND METHODS

Animals

Data were recorded from 47 free-ranging NBA and 31 free-ranging GLA, captured between May 1994 and April 1995, during the flooding of 365 km^2 of primary rainforest (4°45′ to 5°04′N, 52°55′ to 53°15′W) by the Petit Saut hydroelectric dam on the Sinnamary river in French Guiana. Like the other terrestrial mammals, armadillos were captured on the islands that progressively appeared from the hilly environment, while the water was rising. NBA and GLA were captured at their den using net pouches attached at the exits (n = 36 and n = 22, for NBA and GLA, respectively), by den excavation (n = 3 and n = 5, for NBA and GLA, respectively), with live-traps (n = 7 and n = 2, for NBA and GLA, respectively), with vertical net during battues (2 GLA), or while swimming in the reservoir water (1 NBA). Once captured, the animals were individually housed in plastic cages. Two models were used

according to the size of the individual: (1) large cages (650 × 450 × 450 mm) with a grid door and lateral slits for ventilation (Doskocil Manufacturing, Dallas, Texas); and (2) small handmade tubular cages (500 mm long and 250 mm in diameter) bored with 20 holes of 10 mm in diameter for ventilation. The animals were transferred to the veterinary facility after a 1 to 2 hr pirogue trip depending on the capture location on the lake. They were placed in a quiet shady room for a minimum of 1 hr before immobilization for various clinical procedures including a clinical exam, collection of biological samples (blood, ectoparasites, skin biopsy), determination of body dimensions and identification with color-tag and tattoo. A 30 to 40 min long immobilization was necessary.

The animals in this study appeared clinically healthy and body weight averaged $\bar{x} \pm SD$ = 4.9 ± 1.1 kg in NBA and 9.7 ± 1.4 kg in GLA.

Anesthetic drugs

Three intramuscular anesthetic combinations were used in both species. Twelve NBA (3 males and 9 females) and 10 GLA (5 males and 5 females) received 8.5 ± 0.3 mg/kg and 8.5 ± 0.2 mg/kg tiletamine/zolazepam (Zoletil 50®, Reading, Carros, France), respectively. Eighteen NBA (8 males and 10 females) and nine GLA (6 males and 3 females) received 40.1 ± 1.3 mg/kg ketamine hydrochloride (Ketamine 500 UVA®, Laboratoires UVA, Ivry-sur-Seine, France) combined with 1.0 ± 0.1 mg/kg xylazine hydrochloride (Rompun®, Bayer Pharma, Puteaux, France) and 40.5 ± 1.7 mg/kg ketamine hydrochloride combined with 1.0 ± 0.0 mg/kg xylazine hydrochloride, respectively. Seventeen NBA (7 males and 10 females) and 12 GLA (7 males and 5 females) received 7.5 ± 0.3 mg/kg ketamine hydrochloride combined with 75.6 ± 3.1 μg/kg medetomidine hydrochloride (Domitor®, Pfizer Corporation, Orsay, France) and 7.7 ± 0.4 mg/kg ketamine hydrochloride combined with 77.0 ± 3.4 μg/kg medetomidine hydrochloride, respectively. When the procedures were completed, 378.1 ± 15.5 μg/kg and 385.1 ± 16.9 μg/kg atipamezole hydrochloride (Antisedan®, Pfizer Corporation) were used intramuscularly for reversal in NBA and GLA K/M groups, respectively. Four NBA and four GLA did not receive atipamezole in order to observe spontaneous recovery, and four NBA and three GLA showed spontaneous recovery before the injection of atipamezole.

General procedures

The armadillos were given an intramuscular injection of the anesthetic combination, in the thigh, with doses based on estimated body weights by weighing each animal with its individual cage. Exact weights were determined during anesthesia and actual dosages calculated. Injection was made in a large wire cage (3.0 × 1.5 × 2.0 m), holding the tail of the animal by hand. After complete injection, it was released into the wire cage to monitor the effects of the drugs. After completion of the procedures, the animal was placed back into its cage where the recovery process was monitored. The animal was released the next day in a 150 km^2 protected forest area contiguous to the flooded area.

The following times from anesthetic injection were monitored: (1) initial effects to first appearance of ataxia; (2) first recumbency; (3) induction time when there was no response to external stimuli (auditory and tactile); (4) first signs of recovery with head-up and limbs movements and response to external stimuli; and (5) time to first standing. Immobilization time was defined as the time between induction and first signs of recovery, and recovery time as the time between first signs of recovery and first standing. It was not possible to evaluate the time to first standing in all animals, and impossible to reliably assess the return to normal locomotion (i.e., complete recovery) because the animals often remained placid and motionless in their cage even after complete recovery.

Throughout immobilization, the degree of anesthesia was graded as no effect, insufficient sedation, good sedation, light anesthesia, complete anesthesia, deep anesthesia and death due to drug overdose. The degree of muscle relaxation was graded as poor, moderate, good, or excellent. Rectal temperature (C), heart rate (beats/min), respiratory rate (breaths/min), and relative oxyhemoglobin saturation (% S_pO_2) were recorded at 5, 15 and 30 min post-injection, respectively. Heart rate was measured by cardiac auscultation, respiratory rate by direct observation and body temperature by rectal digital thermometer (Artsana, Casnat-Bernate, Como, Italy). Oxyhemoglobin saturation was monitored using a portable pulse oximeter (model N20/N620P, Nellcor Inc., Hayward, California, USA), with the probe placed on the tongue or for the males, on the penis, but, due to technical problems, it could not always be measured.

Data analysis

Quantitative data are given as mean ± standard deviation (SD). For each protocol, anesthetic intervals and physiological data at 5, 15 and 30 min post-injection were compared between the two species, and for each species between sexes, using a Mann-Whitney *U*-test (So-

kal and Rohlf, 1981; Scherrer, 1984). Mean values of males and females were presented separately only when significant differences were observed. For each protocol and each species, serial recording of physiological data were compared using the Friedman's method for randomized blocks (Sokal and Rohlf, 1981). For each species, anesthetic intervals and physiological data at 5, 15 and 30 min post-injection were compared between the three protocols using a Kruskal-Wallis test, followed by a nonparametric multiple comparison test to discriminate variables which differed (Scherrer, 1984). The qualitative parameters were compared between species or protocols using the Fisher's exact test after pooling the data in two classes (≤light and ≥complete anesthesia, and ≤moderate and ≥good muscle relaxation, respectively), because the samples were too small to be performed with Chi-square tests. Statistical-analyses were performed with STATISTICA (StatSoft, Inc., Tulsa, Oklahoma, USA). Calculated P values ≤0.05 were considered as statistically significant.

RESULTS

Anesthesia intervals

Though some significant differences were observed in first recumbency between groups, species, or sexes (Table 1), induction time did not differ between protocols, species or sexes, and ranged from 2.8 ± 0.6 to 4.3 ± 1.8 min. Induction was smooth and uneventful, except for one NBA with T/Z which showed an excitatory phase. Supplemental doses were needed to achieve induction in one NBA with T/Z and one GLA with K/X. These animals were excluded from the statistical analysis, except the qualitative parameters.

In all groups, but the GLA K/M group, the anesthetic effects were highly variable between individuals. In NBA, recovery values did not differ between protocols or sexes and immobilization time ranged from 43.8 ± 27.8 to 66.5 ± 40.0 min (Table 1). In GLA, immobilization time was more variable and ranged from 30.4 ± 6.2 to 98.4 ± 33.7 min. With T/Z, immobilization time was significantly longer in females than in males. Ketamine/medetomidine induced a shorter immobilization time than K/X and than T/Z in females, respectively. First standing appeared significantly later with K/X versus K/M (Table 1). Tiletamine/zolazepam induced a longer immobilization time in GLA females versus NBA. Ketamine/xylazine induced longer recovery time to standing in GLA versus NBA (Table 1).

In K/M groups, the time of atipamezole injection of 39.3 ± 10.3 min and 48.5 ± 11.9 min for nine NBA and five GLA, respectively, did not differ from the time of first signs of spontaneous recovery. First signs of recovery were observed 3.2 ± 1.8 min and 6.0 ± 4.2 min after atipamezole injection and first standing was observed 4.8 ± 2.6 min and 9.0 ± 5.5 min after atipamezole injection in NBA and GLA, respectively. Reversal characteristics did not differ between the species. When the two species were combined, the mean recovery time to standing of 2.1 ± 1.4 min recorded in individuals which received atipamezole was significantly shorter than the 13.8 ± 8.5 min observed in individuals which did not receive atipamezole. Recovery time to standing was also significantly shorter in individuals which received atipamezole versus individuals anesthetized with K/X for both species, and with T/Z in GLA, respectively. Two NBA of K/M group, one receiving atipamezole before and the other after the first signs of spontaneous recovery, and two NBA of K/X group were restless during recovery. No other abnormal behavior was observed during the recovery period.

Clinical data

Anesthesia was obtained in around 90% of the animals in all groups. No significant differences were observed in anesthetic levels between NBA groups: complete to deep anesthesia was observed in 75%, 61%, and 82% of the individuals with T/Z, K/X, and K/M respectively. In GLA, complete to deep anesthesia was more often reached with T/Z (100%) versus K/M (42%). With K/X it was observed in 67% of the animals. Nine-banded armadillos more often reached complete to deep anesthesia than GLA with K/M. Degree of

TABLE 1. Mean ± SD (range) values of immobilization characteristics of nine-banded and great long-nosed armadillos with three anesthetic combinations (T/Z: tiletamine/zolazepam, K/X: ketamine/xylazine, K/M: ketamine/medetomidine). Values of males and females are presented separately only when the differences were significant.

Anesthesia times (min)	Nine-banded long-nosed armadillos (NBA)			Great long-nosed armadillos (GLA)			
				Group T/Z			
	Group T/Z	Group K/X	Group K/M	Males	Females	Group K/X	Group K/M
Induction							
Initial effects	1.0 ± 0.4 (0.7–1.9)	0.8 ± 0.3 (0.2–1.3)	1.0 ± 0.4 (0.5–2.1)	1.2 ± 0.5 (0.7–2.3)		0.8 ± 0.4 (0.3–1.4)	1.3 ± 0.5 (0.7–2.2)
First recumbency	1.5 ± 0.4[1a] (1.0–2.3)	1.3 ± 0.5 (0.4–2.3)	1.9 ± 0.8 (1.0–3.2)	3.0 ± 0.9[1,6] (2.3–4.6)	2.0 ± 0.5[1] (1.3–2.5)	1.4 ± 0.6[6,7] (0.5–2.5)	2.7 ± 1.1[7] (0.8–4.2)
Induction time	3.0 ± 0.5 (2.3–3.8)	3.7 ± 2.2 (1.2–10.0)	3.5 ± 1.7 (1.3–8.0)	4.0 ± 1.5 (2.8–7.1)		2.8 ± 0.6 (1.9–3.5)	4.3 ± 1.8 (1.2–7.0)
Spontaneous recovery							
First signs	56.2 ± 38.7[2] (14.0–122.0)	70.2 ± 38.7 (13.1–160.0)	47.5 ± 26.3[c] (25.0–105.0)	56.8 ± 24.9 (38.0–100.0)	102.0 ± 33.3[2,8] (70.0–150.0)	73.9 ± 34.8[9] (36.0–133.0)	35.0 ± 4.9[d,8,9] (30.0–42.0)
First standing	113.6 ± 94.3 (24.6–310.0)	95.8 ± 46.1[b,4] (28.0–225.0)	65.0	111.1 ± 39.9 (55.0–166.0)		150.4 ± 62.6[d,4,10] (68.0–240.0)	48.3 ± 5.8[e,10] (45.0–55.0)
Immobilization time	53.1 ± 38.7[3] (11.3–119.2)	66.5 ± 40.0 (9.8–157.3)	43.8 ± 27.8[c] (20.8–105.0)	52.3 ± 24.3 (31.0–93.5)	98.4 ± 33.7[3,11] (66.1–147.2)	71.1 ± 34.7[12] (34.0–130.0)	30.4 ± 6.2[d,11,12] (23.0–40.0)
Recovery time to standing	57.5 ± 67.1 (5.0–188.0)	23.3 ± 26.3[b,5] (0.0–109.0)	10.0	31.7 ± 26.7[f] (0.0–68.0)		82.3 ± 50.2[d,f,5] (10.0–154.0)	15.0 ± 10.0[e,f] (5.0–25.0)

[a] Mean values with same superscript numbers are significantly different ($P \leq 0.05$).
[b] $n = 17$.
[c] $n = 8$.
[d] $n = 7$.
[e] $n = 3$.
[f] Kruskal-Wallis test significant, but no discrimination of the variables with the multiple comparison test ($P \leq 0.05$).

muscle relaxation in GLA was satisfactory in all groups (70%, 78%, and 83% of good to excellent muscle relaxation with T/Z, K/X and K/M, respectively) and did not differ between anesthetic combinations. In NBA, muscle relaxation was not satisfactory in 50% of the individuals anesthetized with T/Z, and was significantly better with K/X (89%) or K/M (88%). Indeed, these individuals essentially maintained their jaws tonicity throughout anesthesia.

Rectal temperature recorded at 5 min varied from 32.4 to 37.7 C in NBA and from 33.2 to 38.6 C in GLA, and mean values did not differ between groups or species. However, one NBA of each anesthetic group showed a temperature <32 C at 5 min and throughout anesthesia. Mean rectal temperature recorded with T/Z and K/X in NBA significantly decreased (<1 C) throughout anesthesia, but remained stable in all other groups.

Heart rates at 5 min varied from 52.0 to 162.0 beats/min in NBA and from 68.0 to 168.0 beats/min in GLA, and serial mean values did not differ between species or between groups in NBA. In GLA, mean heart rate was significantly higher with T/Z (130.6 ± 22.6 beats/min at 5 min) versus K/M (100.3 ± 25.7 beats/min at 5 min). Mean heart rate significantly decreased (from 10.9 to 18.5 beats/min) in all groups throughout anesthesia, except in the NBA T/Z group, in which it remained stable.

Respiratory rates were highly variable between individuals of a same group, and in all groups, mean values 5 min post-injection (28.6 ± 14.7, 51.4 ± 21.7 and 48.4 ± 17.6 breaths/min in NBA with T/Z, K/X and K/M, respectively, and 32.0 ± 15.8, 55.0 ± 20.6 and 62.7 ± 17.5 breaths/min in GLA with T/Z, K/X and K/M, respectively) remained stable throughout anesthesia. T/Z induced significantly lower mean respiratory rate than did K/X and K/M at 5 min in NBA, and than did K/M at 5 and 30 min in GLA. Mean respiratory rate recorded with K/M was significantly lower in NBA versus GLA, 5 and 15 min post-injection, respectively.

Relative oxyhemoglobin saturation could not be recorded in GLA T/Z group and only in two individuals in NBA T/Z group, in which it was >90% throughout anesthesia. In the other groups, mean values did not vary between groups or species, and were stable (around 90%) throughout anesthesia. Fifty to 64% of the individuals never showed hypoxemia (<85%) throughout anesthesia. In the others, values <85% were recorded at 5, 15 or 30 min post-injection. Values <80% were recorded at least at one of the serial records in four NBA and one GLA with K/M, and in two NBA and one GLA with K/X. In all these cases, this was not associated with clinical signs such as tachycardia, cyanosis or any other complication. On the other hand, one NBA showed cyanosis during anesthesia with K/M, but its relative oxyhemoglobin saturation could not be recorded. Its heart and respiratory rates were normal.

One GLA anesthetized with K/X and one NBA anesthetized with T/Z showed excessive salivation during anesthesia. No other side effects such as regurgitation or bloating were observed in our study.

DISCUSSION

General

The three anesthetic combinations were effective for immobilizing nine-banded and great long-nosed armadillos with short and smooth inductions. Nevertheless, a 30 min immobilization time was not obtained in all individuals, except in GLA with T/Z. Immobilization times as short as 10 min were observed in NBA with T/Z and K/X. Indeed, the individual response to anesthetics was highly variable within a group. Physical condition due to the deterioration of the environment and stress are two major factors that could influence the anesthetic effects and increase individual variations, but stress was difficult to assess, as armadillos generally exhibit a calm behavior in captivity. We did not observe such a variability in individual response to anesthetics in other xenartrans or mammal spe-

cies anesthetized in the same context (Fournier-Chambrillon et al., 1997; Fournier et al., 1998; Vié et al., 1998; Vogel et al., 1998), and this may be a peculiarity in armadillos.

Dosages

The T/Z dosage we used was higher than the doses of 1.9 to 6.0 mg/kg recommended by Wallach and Boever (1983) in xenarthrans for immobilization and surgical procedures. With a 8.5 mg/kg T/Z dose, one NBA was not completely immobilized and in four other individuals, immobilization time was <30 min. Lower dosages would not have been sufficient for our procedures. In the same way, mean immobilization time recorded in two-toed sloths *Choloepus didactylus* (Vogel et al., 1998) with a 10 mg/kg T/Z dose, was similar to those obtained in this study. Different response to T/Z anesthesia between sexes have been previously reported in lions (*Panthera leo*) and leopards (*Panthera pardus*) by King et al. (1977) and in laboratory rats (*Rattus* sp.) by Silverman et al. (1983). As in Silverman et al. (1983), but in opposition to King et al. (1977), we observed a longer duration of anesthesia in GLA females, but the recovery time to standing was not increased. We certainly could have significantly decreased the T/Z dosage in GLA females, for a 30 to 40 min immobilization.

The ketamine dose used in combination with xylazine was also higher than the doses of 10 to 25 mg/kg usually recommended in xenartrans (Wallach and Boever, 1983; Divers, 1986; Gillepsie, 1993), and actually effective in two-toed sloths (Vogel et al., 1998), and collared anteaters *Tamandua tetradactyla* (Fournier-Chambrillon et al., 1997). Initial trials with a lower ketamine : xylazine ratio (30:1 versus 40:1) showed that this lower dosage was often not sufficient to achieve induction, particularly in GLA.

During the rescue project, ketamine-medetomidine has been successfully used on various Guianan species, including two-toed sloths (Vogel et al., 1998), three-toed sloths *Bradypus tridactylus* (P. Chabaud, unpubl. data), kinkajous *Potos flavus* (Fournier et al., 1998), red howler monkeys *Alouatta seniculus* (Vié et al., 1998), golden-handed tamarins *Saguinus midas* (I. Vogel et al., unpubl. data) and white-faced sakis *Pithecia pithecia* (J-C. Vié et al., unpubl. data). Both ketamine and medetomidine doses used in this study were twice higher than the doses required in two-toed sloths for similar immobilization times (Vogel et al., 1998). In GLA, K/M induced a shorter immobilization time than K/X, but it remained in the 30 to 40 min range initially expected. Anesthesia level also was globally lower, but remained compatible with our procedures. In opposition to the results obtained in carnivores (Jalanka, 1989a; Moens and Fargetton, 1990; Spelman et al., 1994) and two-toed sloths (Vogel et al., 1998), K/M did not induce a better muscle relaxation than K/X in armadillos at the dose we used. Generally speaking our results showed that long-nosed armadillos were less sensitive to ketamine and required a higher dosage than other xenarthrans.

Physiological effects

All xenarthrans are incomplete homeotherm animals and body temperature fluctuates depending on environment, air temperature, and activity (Johansen, 1961; Divers, 1986; Gillepsie, 1993). In our study, at an ambient temperature around 30 C, significant decrease in body temperature were only recorded with T/Z and K/X in NBA, and the mean values at 30 min remained in the range of 30 to 36 C cited for armadillos (Johansen, 1961; Burns and Waldrip, 1971; Wallach and Boever, 1983; Divers, 1986). Alpha$_2$-agonists are known to induce a loss of thermoregulation (Ponder and Clark, 1980; Livingston et al., 1984; McDonald et al., 1989; Virtanen, 1989), as well as T/Z (King et al., 1977), but these effects were insignificant in our study.

In opposition to Burns and Waldrip

(1971), we did not observe differences in rectal temperatures and heart rates between sexes. Effects of T/Z on the cardiovascular system appear to be greatly variable according to studies and species (Lin et al., 1993) and in our study there was no effect in NBA. In GLA, mean heart rate was relatively high at 5 and 30 min with the T/Z combination, but without references on heart rate ranges in this species, it was difficult to conclude to a tachycardic effect at 5 min or a bradycardic effect at 15 min. Although the centrally stimulating effects of ketamine upon the cardiovascular system may compensate the depressive effects of alpha$_2$-agonistic compounds (Moens and Fargetton, 1990; Verstegen et al., 1991a), in both NBA and GLA, heart rate significantly decreased during immobilization with the K/X and K/M combinations, as previously reported in other xenarthrans (Fournier-Chambrillon et al., 1997; Vogel et al., 1998) and several other species (Jalanka and Roeken, 1990; Arnemo et al., 1994; Spelman et al., 1994; Fournier et al., 1998; Vié et al., 1998).

As in some other Guianan species (Fournier-Chambrillon et al., 1997; Fournier et al., 1998; Vogel et al., 1998) mean respiratory rate remained stable throughout anesthesia with all anesthetic combinations, but in opposition to two-toed sloths (Vogel et al., 1998), the lowest rates were recorded with T/Z. Indeed, values recorded with T/Z were in the ranges of 18 to 24 and 32 ± 9 breaths/min cited in NBA by Szabuniewicz and McCrady (1969) and Burns and Waldrip (1971), respectively, and values recorded with K/M and K/X were slightly higher. Nevertheless, low S_pO_2 values (<85%) were recorded in both species with K/M and K/X in 36 to 50% of individuals, at least at one of the serial records, and values <80% were also recorded, reflecting a respiratory depression. However, hypoxemia was generally not related to clinical signs, as previously reported in two-toed sloths (Vogel et al., 1998). Only one NBA had evidence of cyanosis. Hypoxemia generally resolved with time in several species anesthetized with K/M combinations (Spelman et al., 1994; Fournier et al., 1998; Vié et al., 1998; Vogel et al., 1998), as well as in two-toed sloths anesthetized with K/X. In armadillos mean values remained around 90% throughout the whole anesthesia.

Recovery

Long recovery periods as observed with T/Z and K/X are undesirable. With these anesthetic combinations, first standing occurred after more than 1.8 hr in four individuals and after around 3 hr in four others. In K/M groups, atipamezole given i.m. at a dose of 5 times the medetomidine dose rapidly reversed the medetomidine-induced component of anesthesia. No serious adverse effects were observed: only two NBA were restless but not overexcited. A lower dose ratio of atipamezole : medetomidine (2-3:1) is sometimes recommended in nondomestic carnivores to avoid overexcitation (Jalanka and Roeken, 1990; Lewis, 1991), but this dose ratio of 5:1 has been used successfully in large felids and bears (Barnett and Lewis, 1990), mustelids (Arnemo and Søli, 1992; Arnemo et al., 1994), kinkajous (Fournier et al., 1998), red howler monkeys (Vié et al., 1998) and two-toed sloths (Vogel et al., 1998) and seems appropriate in armadillos.

CONCLUSIONS

Tiletamine/zolazepam at 8.5 mg/kg, ketamine at 40 mg/kg combined with xylazine at 1 mg/kg, and ketamine at 7.5 mg/kg combined with medetomidine at 75 μg/kg were found effective and safe agents for 30 to 40 min immobilizations of long-nosed armadillos, including minor surgery procedures. At these doses, quality and duration of anesthesia were globally similar with all combinations and few side effects were observed. The main difference was observed in female great long-nosed armadillos receiving the T/Z combination, in which immobilization time was significantly longer. The K/M combination al-

lowed us to reduce by 80% the effective dose of ketamine combined with xylazine. Moreover, the possibility to antagonize the medetomidine-induced sedation with atipamezole, therefore to significantly reduce the recovery process, gives the K/M combination a strong advantage, especially in field conditions where long recovery periods are undesirable. Moreover, the physiologic changes induced by medetomidine can, at least in part, be reversed by atipamezole (McDonald et al., 1989; Salova, 1989; Vainio, 1990; Verstegen et al., 1991b; Arnemo and Søli, 1992).

ACKNOWLEDGMENTS

The rescue was funded by Electricité de France/Centre National d'Equipement Hydraulique (E.D.F/C.N.E.H.). We thank the staff of the "Faune Sauvage" program for assistance during the captures and manipulations, especially C. Genty, J. Kéravec, C. Richard-Hansen and N. Vidal. We also thank J.-M. Angibault from I.N.R.A./I.R.G.M. for his advice and assistance to capture armadillos with net pouches. We thank the Société d'Etude pour l'Aménagement et la Protection de la Nature en Guyane (SEPANGUY) for its support. Bayer Pharma kindly provided Rompun®. Part of Domitor® and Antisedan® was provided by E. Matthieu from Pfizer Corp.

LITERATURE CITED

ARNEMO, J. M., AND N. E. SØLI. 1992. Immobilization of mink (*Mustela vison*) with medetomidine-ketamine and remobilization with atipamezole. Veterinary Research Communications 16: 281–292.

———, R. MOE, AND N. E. SØLI. 1994. Immobilization of captive pine martens (*Martes martes*) with medetomidine-ketamine and reversal with atipamezole. Journal of Zoo and Wildlife Medicine 25: 548–554.

BARNETT, J. E. F., AND J. C. M. LEWIS. 1990. Medetomidine and ketamine anaesthesia in zoo animals and its reversal with atipamezole: a review and update with specific reference to work in British zoos. Proceedings of the American Association of Zoo Veterinarians: 1990 207–214.

BOEVER, W. J., J. HOLDEN, AND K. K. KANE. 1977. Use of Telazol® (CI-744) for chemical restraint and anesthesia in wild and exotic carnivores. Veterinary Medicine/Small Animal Clinician 72: 1722–1725.

BURNS T. A., AND E. B. WALDRIP. 1971. Body temperature and electrocardiographic data for the nine-banded armadillo (*Dasypus novemcinctus*). Journal of Mammalogy 52: 472–473.

DIVERS, B. J. 1986. Edentata. *In* Zoo and wild animal medicine, 2nd Edition, M. E. Fowler (ed.). W. B. Saunders Company, Philadelphia, Pennsylvania, pp. 622–630.

EMMONS, L. H., AND F. FEER. 1990. Neotropical rainforest mammals. A field guide. The University of Chicago Press, Chicago, Illinois, 281 pp.

FOURNIER, P., C. FOURNIER-CHAMBRILLON, AND J.-C. VIÉ. 1998. Immobilization of wild kinkajous (*Potos flavus*) with medetomidine-ketamine and reversal by atipamezole. Journal of Zoo and Wildlife Medicine 29: 190–194.

FOURNIER-CHAMBRILLON, C., P. FOURNIER, AND J.-C. VIÉ. 1997. Immobilization of wild collared anteaters with ketamine- and xylazine-hydrochloride. Journal of Wildlife Diseases 33: 795–800.

GILLEPSIE, D. S. 1993. Edentata: Diseases. *In* Zoo and wild animal medicine, current therapy 3, M. E. Fowler (ed.). W. B. Saunders Company, Philadelphia, Pennsylvania, pp. 304–309.

GRAY, C. W., M. BUSH, AND C. C. BECK. 1974. Clinical experience using CI-744 in chemical restraint and anesthesia of exotic specimens. Journal of Zoo Animal Medicine 5: 12–21.

GREENE, S. A., AND J. C. THURMON. 1988. Xylazine—A review of its pharmacology and use in veterinary medicine. Journal of Veterinary Pharmacology and Therapeutics 11: 295–313.

HERBST, L. 1991. Pathological and reproductive effects of intraperitoneal telemetry devices on female armadillos. The Journal of Wildlife Management 55: 628–631.

JALANKA, H. H. 1989a. Evaluation and comparison of two ketamine-based immobilization techniques in snow leopards (*Panthera uncia*). Journal of Zoo and Wildlife Medicine 20: 163–169.

———. 1989b. The use of medetomidine, medetomidine-ketamine combinations and atipamezole at Helsinki Zoo—A review of 240 cases. Acta Veterinaria Scandinavia 85: 193–197.

———, AND B. O. ROEKEN. 1990. The use of medetomidine, medetomidine-ketamine combinations, and atipamezole in nondomestic mammals: A review. Journal of Zoo and Wildlife Medicine 21: 259–282.

JOHANSEN, K. 1961. Temperature regulation in the nine-banded armadillo (*Dasypus novemcinctus mexicanus*). Physiological Zoology 34: 126–144.

KING, J. M., B. C. R. BERTRAM, AND P. H. HAMILTON. 1977. Tiletamine and zolazepam for immobilization of wild lions and leopards. Journal of the American Veterinary Medical Association 171: 894–898.

LEWIS, J. C. M. 1991. Reversible immobilisation of Asian small-clawed otters with medetomidine and ketamine. Veterinary Record 128: 86–87.

LIN, H. C., J. C. THURMON, G. J. BENSON, AND W. J. TRANQUILLI. 1993. Telazol—A review of its

pharmacology and use in veterinary medicine. Journal of Veterinary Pharmacology and Therapeutics 16: 383–418.

LIVINGSTON, A., J. LOW, AND B. MORRIS. 1984. Effects of clonidine and xylazine on body temperature in the rat. Journal of Pharmacology 81: 189–193.

MCDONALD, E., A. HAAPALINNA, R. VIRTANEN, AND R. LAMMINTAUSTA. 1989. Effects of acute administration of medetomidine on the behaviour, temperature and turnover rates of brain biogenic amines in rodents and reversal of these effects by atipamezole. Acta Veterinaria Scandinavia 85: 77–81.

MOENS, Y., AND X. FARGETTON. 1990. A comparative study of medetomidine/ketamine and xylazine/ketamine anaesthesia in dogs. The Veterinary Record 127: 567–571.

MONTGOMERY, G. G. 1985. The evolution and ecology of Armadillos, Sloths, and Vermilinguas. Smithsonian Institution Press, Washington D.C., 451 pp.

NOWAK, R. M. 1991. Walker's mammals of the World, 5th Edition. The Johns Hopkins University Press. Baltimore, Maryland, 1615 pp.

PONDER, S. W., AND W. G. CLARK. 1980. Prolonged depression of themoregulation after xylazine administration to cats. Journal of Veterinary Pharmacology and Therapeutics 3: 203–207.

SALOVA, J-M. 1989. Cardiovascular actions of medetomidine and their reversal by atipamezole. Acta Veterinaria Scandinavia 85: 39–47.

SCHERRER, B. 1984. Biostatistique. Editions Gaëtan Morin. Montréal, Québec, Canada, 850 pp.

SILVERMAN, J., M. HUHNDORF, M. BALK, AND G. SLATER. 1983. Evaluation of a combination of tiletamine and zolazepam as an anesthetic for laboratory rodents. Laboratory Animal Science 33: 457–460.

SOKAL, R. R., AND F. J. ROHLF. 1981. Biometry, 2nd Edition. Freeman and Co., New York, New York, 887 pp.

SPELMAN, L. H., P. W. SUMNER, J. F. LEVINE, AND M. K. STOSKOPF. 1994. Anesthesia of North American river otters (*Lutra canadensis*) with medetomidine-ketamine and reversal by atipamezole. Journal of Zoo and Wildlife Medicine 25: 214–223.

STORRS, E. E., AND W. E. GREER. 1973. Maintenance and husbandry of armadillo colonies. Laboratory Animal Science 23: 823–829.

SZABUNIEWICZ, M., AND J. D. MCCRADY. 1969. Some aspects of the anatomy and physiology of the armadillo. Laboratory Animal Care 19: 843–848.

VAINIO, O. 1990. Reversal of medetomidine-induced cardiovascular and respiratory changes with atipamezole in dogs. The Veterinary Record 127: 447–450.

VERSTEGEN, J., X. FARGETTON, I. DONNAY, AND F. ECTORS. 1991a. An evaluation of medetomidine/ketamine and other drugs combinations for anaesthesia in cats. The Veterinary Record 128: 32–35.

———, ———, S. ZANKER, I. DONNAY, AND F. ECTORS. 1991b. Antagonistic activities of atipamezole, 4-aminopyridine and yohimbine against medetomidine/ketamine-induced anaesthesia in cats. The Veterinary Record 128: 57–60.

VIÉ, J.-C. 1999. Wildlife rescues—The case of the Petit Saut Hydroelectric dam. Oryx 33: 115–126.

———, B. DE THOISY, P. FOURNIER, C. FOURNIER-CHAMBRILLON, C. GENTY, AND J. KÉRAVEC. 1998. Anesthesia of wild red howler monkeys (*Alouatta seniculus*) with medetomidine-ketamine and reversal by atipamezole. American Journal of Primatology 45: 399–410.

VIRTANEN, R. 1989. Pharmacological profiles of medetomidine and its antagonist, atipamezole. Acta Veterinaria Scandinavia 85: 29–37.

VOGEL, I., B. DE THOISY, AND J.-C. VIÉ. 1998. A comparison of injectable anesthetic combinations in free-ranging two-toed sloths (*Choloepus didactylus*) in French Guiana. Journal of Wildlife Diseases 34: 555–566.

WALLACH, J. R., AND W. J. BOEVER. 1983. Edentates. *In:* Diseases of exotic animals. Medical and surgical management, J. R. Wallach and W. J. Boever (eds.). W. B. Saunders Co., Philadelphia, Pennsylvania, pp. 613–629.

WATERMAN, A. E. 1983. Influence of premedication with xylazine on the distribution and metabolism of intramuscularly administered ketamine in cats. Research in Veterinary Science 35: 285–290.

WRIGHT, M. 1982. Pharmacologic effects of ketamine and its use in veterinary medicine. Journal of the American Veterinary Medicine Association 180: 1462–1471.

Received for publication 13 January 1999.