CHEMICAL IMMOBILIZATION IN FREE-RANGING AFRICAN UNGULATES

TITUS MLENGEYA, Serengeti Wildlife Research Institute, P.O Box 661, Arusha, Tanzania and JOACHIM OTTE, Veterinary Epidemiology and Economics Research Unit (VEERU), Department of Agriculture, University of Reading, P.O Box 236, Earley Gate, Reading RG6 2AT, England.

SUMMARY

Chemical immobilization has been a major method of capturing wildlife over the last two decades, but few investigations have attempted to evaluate the efficacy and safety of different drugs in wild animal species in their natural habitat. This study made opportunistic use of observations on chemical restraint of free-ranging wild animals made during the Pan African Rinderpest Campaign (PARC) Project in Tanzania and of data obtained when assisting with ecological studies. African buffalo (Syncerus caffer) were immobilized using a combination of either etorphine HCl (Immobilon®)/xylazine (N=342) or carfentanil/xylazine (N=54) whereas wildebeest (Connochaetes taurinus) were immobilized using a combination of either etorphine /xylazine (N=54) or Immobilon®/azaperone (N = 28). The etorphine/xylazine combination was also used to immobilize 9 topi (Damaliscus korrigum), 3 hartebeest (Alcephalus cokii), 5 waterbuck (Kobus deffasa) and 11 zebra (Equus burchelli). Drugs were administered via Distinject® and Daystate® dart guns. Diprenorphine (Revivon®) was used to antagonize etorphine and cerfentanil, and Rx821002A, a newly developed drug, was used to antagonize xylazine. Carfentanil proved to be superior to etorphine for the immobilization of buffalo and wildebeest. Azaperone provided faster induction (4.7 min) than xylazine (7.9 min) when used in conjunction with etorphine. Hartebeest were the most difficult animals to immobilize. Etorphine caused excitability in in waterbuck. After injection of 2 ml of diprenorphine, etorphine-induced buffalo recovered faster than carfentanil-induced buffalo (2.7 min vs. 3.6 min). Rx821002A proved effective as an antidote for xylazine. It would be advantageous if the drugs were more concentrated to be carried by lighter darts which cause less

trauma. Availability of another antagonist for xylazine would reduce the risk of capture stress and falling prey to predators.

INTRODUCTION

Wildlife are captured for research, translocation, diagnosis and treatment of diseases (Harthoorn 1972, Borner 1988, Caldecott 1988, Nielsen 1988). Over the last two decades, chemical immobilization has been a major method of capturing wildlife (Jessup 1992). Although much research has been carried out on sedation and immobilization in humans and domestic animals, the same cannot be said for wild animals. Nevertheless, the drugs used to tranquillize and immobilize wild animals are similar to those used to anaesthetize humans. These drugs and their combinations act at various sites within the nervous system to produce tranquillization, sedation, analgesic, a trance-like or psychotic effect and/or anaesthesia or paralysis (Clark and Jessup 1991).

Intramuscular injection via darts is the route of remote drug delivery commonly used in free-ranging species. The average distance covered by darts is 30 to 40 m, although projectile guns capable of propelling a dart up to 100 m have been reported (Kock 1987). The effect usually takes longer and requires higher doses compared to intravenous injection. Sites preferred for distant injection are muscle masses of the neck (for larger animals only), shoulder and hind quarters (Nielsen 1988). Problems encountered in remote drug delivery systems include equipment and drugs which are potentially injurious to both man and animals, equipment failure, trauma caused by the impact of the dart, atypical reaction to drugs, insufficient immobilization, mortalities caused by drug actions, over dosing, environmental factors, psycho-physiological factors, post-capture handling and medical complications (Nielsen 1988, Clark and Jessup 1991).

Despite some improvement in capture techniques, the difficulty and risks involved with animal restraint for examination, treatment and/or drug administration

remain the major problem in health management of wild species. Capture and restraint techniques can be detrimental to animal's survival. In early attempts to immobilize species such as hartebeest and wildebeests in Kenya, it was observed that a large proportion of released animals disappeared quickly (Plowright 1988). The premature release of immobilized animals apparently led to their rapid recognition by predators, probably from gait abnormalities, and speedy despatch by ever-present hyenas. Hence a study of wild animal capture is necessary as it is a basic tool for many epidemiological or biological studies in these species.

The objectives of this study were to evaluate the efficiency, ease and safety of some chemical immobilization techniques for the restraint of African ungulates and to assess the efficacy of Rx821002A, a newly developed antagonist for xylazine.

MATERIALS & METHODS

All animals except zebras were captured to obtain samples for rinderpest seroloical survey under the European Economic Community (EEC)-Pan African Rinderpest Campaign (PARC) Project. Zebras were immobilized to assist other ecological study projects. A total of 509 observations were compiled from 1987 to 1989 in various game areas of Tanzania namely Serengeti, Lake Manyara, Tarangire, Ruaha, Mikumi, Ngoraongoro Crater and Katavi National Parks, and Loliondo open area. These areas vary greatly in ecological conditions from one another and within themselves. Habitat ranges from open savannah grasslands of central and western Serengeti and Mikumi national parks to thick bush and miombo forests in Lake Manyara, Ruaha, Northern Serengeti National parks and Selous Game Reserve.

Most of the observations were made on buffalo (N=398), which were samples in all the national parks. Two-hundred-and-one buffalo, 3 hartebeest, 9 topi 4 waterbuck, 78 wildebeest and 11 zebra

were immobilized in Serengeti National Park. A waterbuck and 4 wildebeests were immobilized in Tarangire and Ngorongoro respectively.

Buffalo were aged to the nearest quarter of a year according to dentition (Anderson *et al.*, 1990), horn shape and development and body size. The other species were aged to the year on size alone based on the experience of the collaborating scientists.

The following drugs were used in the study: Etorphine HCl/Acepromazine HCl (Immobilon® C-vet., at 2.45:10 mg/ml), Carfentanil HCl (Wildnil® Wildlife Labs Inc., at 3 mg/ml), Xylazine (Rompun® Bayer, at 20 mg/ml) and Azaperone (Stresnil® Janssen, at 40 mg/ml) as immobilizing drugs (Table 1). Immobilizing drugs were dispensed using a charge-powered dart gun (Dist-inject®, Peter Ott Ltd, P.O.Box 16, CH-4007, Basel Switzerland) or a pressurized dart gun (Daystate®, Daystate Ltd, Newcastle Street, Stone, Staffs ST15 8JU, UK). Both guns were used from a stationery car, but when darting was done while chasing the animal, only Dist-inject® was used. Chasing was carried out with a 110 Landrover station wagon. Metallic darts of 2, 3, 4 and 5 ml capacity were employed.

The majority of buffaloes were darted after chasing because they could not be approached by a car. Injections were mostly aimed at the heavy muscles of the hind limbs although occasionally forelimb muscles were targeted. The level of immobilization was assessed initially from the car by approaching the animal, followed by manipulating it cautiously. If the animal was only partially immobilized, an additional dose was administered either by dart dun or by a hand-held syringe. Buffalo were tied securely with rope and blindfolded to minimise excitation. Ruminants were positioned in sternal recumberncy to avoid regurgitation and aspiration of ruminal contents. Zebra were placed in lateral recumbency. The airways were checked to make sure they were clear. Overheated and exhausted animals received steroids (IM), Ringer's lactate and sodium bicarbonate solution (IV or SC) and were soaked with cold water.

After samples had been collected, an antidote was administered intravenously. Diprenorphine (Revivon® C-vet) was used to reverse etorphine and carfentanil whereas Rx821002A (Rx) was used to reverse xylazine. When diprenorphine and Rx were both administered to an animal, Rx was injected first. One mg of Rx was used for antagonising xylazine whereas equal volumes of diprenorphine were used against etorphine (1 ml Revivon® for 1 ml Immobilon®). Twelve mg of diprenorphine were used to antagonize any volume of carfentanil. Thereafter the blindfold was removed and the animal was observed until it joined the main herd to reduce the risk of falling prey to scavengers.

The time taken by the animal from dart injection to the time when the animal can be safely handled (anaesthesia induction time, IT), the total time spent down (TD) and time taken from injection of the antagonist to the time when the animal is stable and appears to be in control of its physical movements, especially while standing (recovery time, (RT) as well as body temperature, pulse rate and respiration rate were recorded (Table 1).

Variables and their inter-relationships were analyzed using statistix Version 4.0© (19912,Analytical Software). Non-normally distributed variables were logarithmically transformed. Pairs of variables were compared using Student's t-test, the median test, or the X2-test depending on the type of distribution of the two variables. Unweighted multiple least squares linear regression using a forward including approach was used to assess the relationship between three or more variables. Categorical variables were coded as 0 or 1.

In the linear regression analyses, a number of observations were excluded due to incomplete data and/or due to extreme deviations from the other observations. Two buffalo which were given azaperone as a secondary drug were not included in any of the analyses and 2 wildebeest which were immobilized with carfentanil were always treated separately. In the analysis of IT, data from 18

buffalo and 10 wildebeest, which required redarting were excluded from the analysis. Eighteen other wildebeests with incomplete data were excluded. In the analysis of RT, 5 buffalo were eliminated because they had extremely long RT (more than 30 min) (8.4 SDs from the mean). In wildebeest, 1 animal which received a non-standard azaperone dose (>116 mg), 4 cases which received Rx and 21 cases which did not receive the standard diprenorphine dose of 4.5 mg were excluded from the analysis.

RESULTS

The light Dist-inject® capture gun was appropriate for fast moving animals such as buffalo and could easily be handled in a moving vehicle. It was necessary to clean the barrel and cartridge at least after every two dartings because of the accumulation of soot. The cartridge charge prescribed for a darting range of 15 to 25 m caused numerous misfires. Thus, most of the dartings were done using the charge prescribed for ranges of 30 to 50 m even though most darting occurred within 10 to 30 m. The preset sight of the gun could not be changed in accordance with varying distances from the animal and it was sometimes difficult to assess precisely the distances when chasing the animals. The Daystate pressure gun was powerful and accurate when used from a stationery position but was too powerful at short ranges (10-15 m).

The darts of both projectile systems were metallic and sometimes caused traumatic injury at the impact site. The darts were accurate and wind resistant. Smaller darts (eg. 3 ml) appeared to fly faster and to be less traumatic. The primary limitation of the darts was the inconsistency of the charge which sometimes did not detonate on impact, and hence did not administer the drug. The strength of the needles was satisfactory, except at close and angled ranges when the needles would often bend or break.

Side holes in the needles increased drug injection rate. Barbs helped to keep the dart on site and increased the change of drug administration and recovery of the dart. Bright coloured tails and shiny darts were useful to identify darted animals in the group.

Table 1: Drug combinations and doses used for the immobilization of various animal species.

	No	Etorphine (mg)	Carfentanil (mg)	Xylazine (mg)	Azaperone
Buffalo	322	5.0	0	40.0	0
	18	10.02	0	0	0
	8	0	2.1	20.0	0
	20	0	2.4	24.0	0
	15	0	2.7	22.0	0
	11	0	3.0	20.0	0
Wildebeest	5	1.5	0	56.0	0
	15	2.5	0	28.0	0
	11	3.0	0	26.0	0
	41	3.75	0	20.0	100.0
Zebra	9	5.0	0	40.0	0
Antelopes	5	3.75	0	26.0	0

[1]Combinations with less than five animals are not shown on the table, [2]Redarted

Undamaged darts and needles could be reused. Chasing buffalo before darting, noise of the gun and impact of the dart produced excitement in the animal causing it to run for some time. The majority of darted buffalo and antelopes (e.g. topi and Coke's hartebeest) were able to run with the herd for distances ranging from 200 m to 2 km, often disappearing from sight. Immobilization of antelopes posed some difficulties because getting into good range and sight needed much patience and haggle. Their first reaction to the sound of the gun was to dash and run very fast which caused the darts to miss or to hit them at a slanted angle resulting in either bending or breaking of the needles, drug spillage and subcutaneous or sub-optimal injection of the drug. Buffaloes in tourist areas were not agitated as much by the process and 2 to 4 animals could be darted before the herd was disturbed and moved away. Wildebeests and zebras could dash and

later trot for about 20 to 30 m before the drug took effect. In waterbucks, the initial reaction was aimless running for long distances of up to 5 km before collapsing.

As the drug took effect, locomotion changes were observed. The drugs induced a high stepping gait in ruminants; there was uncoordinated trotting in zebras. Wildebeests showed muzzle movements or nibbling and some could be bled in standing position. These initial signs were followed by progressive ataxia, standing still, swaying, trembling, and ultimately, collapse. Pedal and palpebral reflexes were often maintained. Regurgitation of ruminal contents was common in ruminants. Waterbuck showed a high degree of sweating, dilation of the nostrils and muscular rigidity. Excessive salivation occurred in all species.

In etorphine-induced immobilization, IT was measured for 257 buffalo; 85 buffalo were lost from sight after injection. Most of these animals were traced and sampled. Induction time after etorphine injection ranged from 2 to 40 min with a mean of 6.58 min (SD 4.94) and a mode between 4 and 6 min. The distribution was skewed to the right and 65.4% (168/257) of the buffalo which did not escape from sight had ITs above 6 min, which was about as long as the team was able to follow a buffalo, only 49.1% (168/342) collapsed within 6 minutes. Induction time was influenced by sex and age. Induction of males took 20% ($p = 0.006$) longer than of females. Induction time was related to loge of age in form of a 40% ($p < 0.001$) increase per unit increase of log age. There was no interaction between age and sex.

Among the 56 buffalo immobilized with carfentanil, only 2 escaped from sight (3.6%). Carfentanil-induced immobilization of buffalo had ITs between 2 and 20 min and 70.4% (38/54) went down within 6 min. The mean IT was 5.9 min; modal IT was 4 - 6 min. As in the etorphine group, IT was found to influenced by sex and loge of age. In addition, the dose of the complementary sedative drug, xylazine, had an effect on IT. Males took 20% ($p = 0.076$) longer than females to be immobilized and for every

unit increase in log of age, there was an increase of IT by 40% (p=0.22). Combination with xylazine reduced IT by 20% (p=0.025) per ml of xylazine added. No significant effect (p>0.10) of the dose of carfentanil nor any interaction was detected between the above variables.

In Serengeti, where both etorphine and carfentanil were used, all (46) carfentanil-immobilized buffaloes went down in sight while only 96 out of 154 (62.3%) of the etorphine group dropped down in sight (Odds Ratio> 25.31, X^2=24.40, df=1, p< 0.001). Most of the animals which dropped out of sight could be traced and sampled as usual. However, 13 buffaloes immobilized with etorphine in Serengeti could not be found or were found dead, which constitutes a rate of loss of nearly 10%. The deaths were diagnosed to be due to asphyxiation, aspiration of ruminal contents, hyperthermia and by falling prey to carnivores.

Induction time for 62 wildebeest immobilized using etorphine and xylazine or azaperone were 0.1 to 80 min (mean of 7.5 min; SD 10.08, N = 62). Out of 62 animals, 34 (54.8%) were immobilized within 6 min. Five wildebeests dropped immediately after injection of the drug. The distribution of ITs was similar to that of etorphine-induced buffalo. Induction time was influenced by loge of age and the complementary sedative drug. Induction time increased by 50% (p=0.001) per unit increase in $\log_e$ age. When azaperone was used, the IT was 40% (p=0.048) shorter than in xylazine combinations (average 4.7 min vs 7.9 min). No statistically significant relationship between IT and sex nor doses of etorphine or any of the complementary drugs were observed. In 2 wildebeests immobilized by carfentanil, IT were 4 and 6 min. Immobilization took average of 5.6 min for zebra (N=8), and 8.2 min for topi (N=5), 99.3 min for hartebeest (N=3), and 57.8 min for waterbuck (N=5) with etorphine xylazine combination. In the case of waterbuck, this average is highly inflated by 2 animals with too long IT. One waterbuck took 4 h to immobilize, 2 hartebeest took more than 1h to immobilize and one took 3 h to immobilize with 3 sub-optimal injections, and 2 darts missing.

Recovery time in etorphine-immobilized buffalo ranged from 0.3 to 55 min (mean of 2.69 min; SD 5.97, N = 317). One animal stood up only 0.3 min after receiving the antidote whereas 5 animals only got up after more than 30 min. Most (93.1%) stood within 3 minutes.

Out of 303 (58%) buffalo, 176 were considered had good anaesthesia and these animals received only the normal diprenorphine dose (6 mg). The mean RT of these animals was 2.45 min. Recovery time was inversely proportional to log of pulse rate and body temperature. There was no statistically significant relation between RT and IT, TD, sex, loge of age and respiration.

The remaining 127 (42%) buffalo were considered to be in poor anaesthetic condition. Seventy-five of these animals received 12 mg of diprenorphine whereas 52 received 12 mg diprenorphine and 1 mg Rx. The mean RT of this sub-group was 1.57 min. Recovery time was influenced by the application of Rx and sex. Rx reduced RT by 23% ($p < 0.001$). The animals looked brighter and steadier and often were able to raise their head before being given diprenorphine. Males were found to have a prolonged RT by 10% ($p = 0.044$).

Mean RT in the carfentanil-immobilized buffalo was 3.6 min (N = 51). Only 7 (14%) animals immobilized with this drug were considered to be in poor anaesthetic condition. RT was influenced by loge of age, sex, and body temperature. Recovery time increased with age, whereas animals with high body temperatures (>39.5oC) made faster recoveries. Males 23% shorter RT ($p = 0.011$). No statistically significant effect was observed with IT, TD, diprenorphine dose, pulse, respiration or temperature.

Recovery time was 1.5 min longer in carfentanil than in etorphine-immobilized buffaloes when 6 mg diprenorphine were used for revival (Median test, $x2 = 64.15$, $df = 1$, $p < 0.001$). However, in the etorphine group, there was a significantly higher proportion of animals considered to be in poor anaesthetic condition (Odds Ratio = 4.84, $x2 = 16.38$, $p < 0.001$) thus receiving a higher dose of diprenorphine

and Rx. These animals had higher body temperatures ($t = 6.59$, $df = 208.2$, $p < 0.001$), higher pulse rates ($t=5.32$, $df = 208.8$, $p < 0.001$) and higher respiration rates ($t = 2.68$, $df = 227.8$, $p = 0.008$) compared to those considered in good anaesthetic condition.

The mean RT in etorphine-immobilized wildebeests was 2.1 min (N=69). Most of the animals (90%) had recovered within 3 min, and most of them (72.5%) were in good anaesthestic condition. Recovery time was found to be influenced by loge of IT, pulse, and by sex. While the RT was positively correlated to IT, it was negatively correlated to pulse. Male animals had 40% ($p = 0.010$) longer RTs than females. No statistical difference in RT was observed between animals immobilized with azaperone or xylazine as supplementary immobilizing drug ($p = 0.857$). There was no statistically significant relation between RT and TD, age or dose of diprenorphine.

Recovery time in two carfentanil-immobilized wildebeests were 3.75 and 5.0 min (mean 4.4 min). This was twice as long as RT in etorphine. Mean RT was 6.8 min for zebra (N=9), 2.3 min for topi (N=6), 3 min for hartebeest (N=2), and 2.1 min for waterbuck (N=4) reversed with diprenorphine.

DISCUSSION

The highly excitable nature of antelopes makes these animals unsuitable for chemical immobilization. Aimless running occurring in waterbuck after etorphine injection was thought to be due to the effect of the drug rather than normal animal behaviour (Booth and McDonald 1982). It could not be explained why some wildebeest stood while anaesthetized. Other behavioral alterations such as locomotory changes following anaesthetic injection have been described (Booth and McDonald 1982).

Mean ITs of 6.6 and 5.9 min for etorphine and carfentanil, respectively, at doses of 5 mg etorphine and 2.7 mg carfentanil observed in buffalo were within the 2 to 10 min range reported elsewhere (Clark and Jessup 1991). Buffaloes darted with etorphine could run for long distances and often dropped

out of sight. Such animals were at a higher risk of death due to asphyxiation, aspiration of ruminal contents, hyperthermia, capture stress and falling prey to carnivores. Similar observations have been made elsewhere and are thought to be augmented by the drug's inhibition of respiratory and thermoregulatory centres (Booth and McDonald 1982; Clark and Jessup 1991).

Longer induction times in males than in female buffaloes observed with both drugs was probably due to larger body sizes and weights of males than females at the same age. Since the dart was filled with the drug before identifying the specific animal to be darted, males received lower doses per kg body weight than females. It is unlikely that the observed difference was due to a sex-related response to the drugs. Older animals had longer IT than younger animals and this too was probably attributable to larger body sizes of older individuals. Larger adipose tissue reserves in adults absorbing a greater amount of injected drugs may also be a factor (Booth and McDonald 1982).

The absence of a direct effect of the dose of carfentanil on IT despite its use over a wider dose range (1.5 to 3.0 mg) suggests that after a threshold level to induce anaesthesia has been reached, the receptors might be occupied and any additional drug in the body does not change IT. Knowledge of the minimum level of carfentanil required could avoid the unnecessary use of larger dosages which will consequently require larger dosages of antagonist and at the same time increase the risk of the drug recycling in the animal. The speed of induction, was however, influenced by the dose of xylazine, the secondary sedative drug. This observation differs to Franzmann *et al.* (1984) who reported no noticeable benefit using xylazine as an adjunct to carfentanil in moose for field immobilization in cold weather.

Renarcotization with etorphine and carfentanil which is the major setback of these drugs (Haigh 1982, de Vos 1987, Franzmann and Lance 1988;) was not observed, possibly because the animals were only

observed until they had joined the herd. Renarcotization occurring 48 hrs after immobilization has been reported in moose and polar bear using carfentanil at a dosage of 1 mg/100 kg (Franzmann and Lance 1988). However, higher dosages (2.0 to 5.0 mg/100 kg) have been used in mule deer, bighorn sheep, tule elk and wild horse achieving consistently reversible immobilization (Jessup *et al.*, 1984; Jessup *et al.*, 1985)

Etorphine-induced immobilizations were characterized by excitation. It might be more appropriate to combine etorphine with higher doses of xylazine or other sedatives to counteract excitation. The effect of xylazine in aroused animals has been reported to persist for as long as 6 hours is not reversed (Clark and Jessup 1991, Diehl 1988). Apart from other xylazine side effects, the sleep-like state can expose the animals to predators.

Induction time in wildebeest immobilized by etorphine/xylazine was the same as in buffalo under the same drugs. In wildebeest azaperone appeared to have a more pronounced synergistic effect with etorphine than xylazine. Azaperone, which has been extensively used on bighorn sheep and red deer is though to posses anti-serotonin properties, which may reduce the risk of capture myopathy (Clark and Jessup 1991). Considering such side effects as bloat, emesis, regurgitation and aspiration of ruminal contents, bradycardia, hyperglycaemia, uterine contraction and premature delivery associated with xylazine (Booth and McDonald 1982, Lees and Meredith 1983, Clark and Jessup 1991, Jalanka 1991), the advantages of azaperone appear to supersede those of xylazine in ungulates, although azaperone has been reported to lower blood pressure to 70% to 84% (Clarke 1969). The dose of 3.7 mg etorphine to 100 mg azaperone was appropriate. However, that dose required a 4-ml dart, which is heavy and hence traumatic. A more concentrated solution of azaperone would be advantageous.

There were no serious side effects observed during immobilization of zebra and wildebeests. Their habitat of

open plains facilitates immobilization without the risk of losing them in sight. The excitation effect of etorphine in these animals was not pronounced. Immobilization of adult zebra can be accomplished with 5 mg etorphine and 40 mg xylazine.

The long IT in waterbuck appeared to be related to the effect of the drug. Similar excitation in waterbuck after etorphine injection has been reported elsewhere (Booth and McDonald, 1982). It is assumed to be a result of the acepromazine present in etorphine. Hartebeest were the most difficult species to immobilize mainly because it was difficult to get into good darting range and their fast dashing response to any unusual sound. This resulted in many darts missing the target, subcutaneous injection and sub-optimal doses.

Diprenorphine proved to be a more effective antagonist for etorphine than for carfentanil. Despite using twice the dose used to antagonise etorphine, RT for carfentanil induced animals were longer than for etorphine immobilizations. This may be because the potency of etorphine is lower, and it is more easily displaced from its receptor sites in the brain by diprenorphine. Carfentanil is more concentrated and may require a higher dosage of diprenorphine than the one used of 8 mg. Diprenorphine dose was not varied according to changing carfentanil doses. The recommended dose ratio for diprenorphine antagonism a carfentanil is 7:1 (Clark and Jessup 1991). Franzmann and Lance (1988) observed incomplete denarcotization even after using a 10:1 ratio of the drugs. Carfentanil is long-acting narcotic agent (Clark and Jessup 1991) and hence requires a long acting antagonist to overcome the delayed arousal and recycling in the animal. Naloxone (Narcan®), a specific antagonist for carfentanil, has not solved the post-immobilization mortalities occurring due to renarcotization (Franzmann et al. 1984, Franzmann and Lance 1988) because of its short half-life. Thus, it is outlasted by the carfentanil in the animal (de Vos 1978, haigh 1982). The newly discovered purely narcotic antagonists, naltrexone and nalmaphin, which have longer

half-lives (Clark and Jessup 1991), might provide a solution to the recycling problem of the long lasting narcotics, e.g. carfentanil. Diprenorphine is a specific antidote to etorphine with a similar half-life and a recommended ratio of 2:1 (Booth and McDonald 1982; Clark and Jessup 1991); however, it worked well at the 1:1 ratio. Since RT was not affected by age, diprenorphine dose apparently had no significant effect on the RT in etorphine-induced animals. This is possibly due to the displacement phenomenon, such that after the receptor sites which were formerly occupied by the narcotic had been replaced by diprenorphine, the additional antidote did not change the RT.

Rx821002A, which was used as a trial xylazine antagonist, appeared to effectively reduce the recovery time by half despite the initial bias of its use in animals with poor anaesthetic condition. Xylazine is known to produce a long sleep-like state in the animals lasting up to 6 hours if not antagonised.

In buffalo with good anaesthetic condition, animals with higher pulse rate and body temperatures appeared to be aroused faster than those with low pulse rate and low temperatures. This could be due to higher metabolic rate and faster transportation of the antagonist to the receptor sites in the brain and clearance in the liver (Booth and McDonald 1982). In anaesthetically poor animals, males appeared to recover more slowly than females. Most of the males had relatively longer IT and hence had more exercise which was expected to have stimulated metabolic rate and blood circulation and consequently resulted in faster narcotic breakdown and antagonist spread and hence faster recovery. However, this was not the case. Excited animals respond poorly to anaesthesia (Booth and McDonald 1982).

In wildebeest, faster arousal was a function of loge of IT, pulse, and sex. Unexpectedly, pulse was negatively correlated to RT. It is possible for the IT effect to be noticeable in this group of animals because they were not initially excited and did not run long distances.

Recovery time in two carfentanil immobilized wildbeest was twice as long than after the use of etorphine. This seems to be consistent to what was seen in buffalo and hence substantiates the better antagonistic properties of diprenorphine for etorphine than for carfentanil.

All the antelopes seemed to respond well to diprenorphine antagonism. In any situation, however, where immobilising drug is used, the lack of its specific antagonist could severely limit situations in which it could be of choice. Therefore, the effectiviness of alpha2-adrenergic antagonist, Rx821002A, is a promising discovery towards a wider use of xylazine in the immobilization of wildlife.

ACKNOWLEDGEMENTS

This study was sponsored by the European Economic Community through the Pan African Rinderpest Campaign. We would like to extend our gratitudes to the Project Leader Dr. Euan Anderson for his rich experience, knowledge and cooperation during this work. We are also thankful to Tanzania Wildlife Corporation (TAWICO) and the Tanzania National Parks (TANAPA) staff. We thank D. Babu and H. Ndolanga for allowing us use of their facilities.

REFERENCES

Anderson, E. C., Jago, M., Mlengeya, T., Timms, C., Payne, A. and Hirji, K. (1990). A serological survey of rinderpest antibody in wildlife and sheep and goats in Northern Tanzania. J. Epid. and Infect. 105, 203-214.

Booth, N. H. and McDonald, L. E. (1982). Veterinary Pharmacology and Therapeutics. Fifth ed. Iowa State University Press.

Borner, M. (1988). Translocation of 7 mammal species to Rubondo Island National Park in Tanzania. Pages 117-120 in L. Nielsen and Brown, R.D., eds. Translocation of wild animals. Wisconsin Hum. Soc. and Caeser Kleberge Wildl. Res. Inst., Milwaukee.

Caldecott, J.O. 1988. Strategic guidelines for non-human primate translocation. Pages 64-75 in L. Nielsen

and Brown, R.D. eds. Translocation of wild animals. Wisconsin Hum. Soc. and Caeser Klerberge Wildl. Res. Inst., Milwaukee.

Clark, R. K. and Jessup, D.A. Eds. (1991). Wildlife Restraint Series. Int. Wildl. Vet. Sev., Inc., Fort Collins, Colorado.

Clarke, W. (1969). Effect of azaperone on the blood pressure and pulmonary ventilation in pigs. Vet. Rec. 85, 649.

de Vos, V. (1978). Immobilization of free-ranging wild animals using a new drug. Vet. Rec. 103, 64-68.

de Vos, V. (1987). Remote chemical immobilization of African buffalo (*Syncerus caffer*) J. S. Afr. Vet. Assoc. 58,157.

Diehl, S.R. (1988). The translocation of urban white-tailed deer. Pages 239-249 in L. Nielsen and Brown, R.D. eds. Translocation of wild animals. Wisconsin Hum. Soc. and Caeser Kleberge Wildl. Res. Inst., Milwaukee.

Franzmann, A.W., Schwartz, C. C., Johnson, D. C., Fargo, J.B. and Ballard, W.B. (1984). Immobilization of moose with carfentanil. Alces 20:259-281.

Franzmann, A. W. and Lance, W. R. (1988). Chemical immobilization of wildlife: recent advances. Pages 99-109 in L. Nielsen and Brown, R.D. eds. Translocation of wild animals. Wisconsin Hum. Soc. and Caeser Klerberge Wild. Res. Inst., Milwaukee.

Haigh, J.C. (1982). Mammalian immobilizing drugs: their pharmacology and effects pp 46-62 in L. Nielsen, Haigh, J. C. and Fowler, M.E. eds. Chemical Immobilization of North American Wildlife. Wisconsin Hum. Soc., Inc., Milwaukee.

Harthoorn, A.M. (1972). Restraint and neuroleptanalgesia in ungulates. Vet. Rec. 84, 151.

Jalanka, H.H. (1991). Medetomidine, Medetomidine - ketamine combinations and atipamizole in nondomestic mammals: A clinical, physiological and comparative study. Academic dissertation. Coll. Vet. Med., Helsinki, Finland.

Jessup, D. A., Clark, W.E. and Jones, K. R. (1984). Immobilization of captive mule deer with carfentanil. J. Am. Vet. Med. Assoc. 15, 8-10.

Jessup, D. A., (1992). Veterinary contributions toward improving capture, medical management and anaesthesia of free-ranging wildlife. J. Am. Vet. Med. Assoc. 200, 653-658.

Kock, R.A. (1987). Remote injection systems: science and art. Vet. Rec. 121:76-80.

Lees, P. and Meredith, M. J. 1983. Chemical restraint of large animals. Pages 452-494 in J. A. Bogan, Lees, P., and Yoxall, A.T. eds. Pharmacological Basis of Large Animal Medicine. Blackwell Sci. Publ., Oxford.

Nielsen, L. 1988. Definitions, considerations and guidelines for translocation of wild animals. Pages 12-49 in L. Nielsen and Brown, R.D. eds. Translocation of wild animals. Wisconsin Hum. Soc. and Caeser Kleberge Wildl. Res. Inst., Milwaukee.

Plowright, W. (1988). Research on wildlife disease: is a reappraisal necessary? Rev. Sci. et Tech. Off. Int. des Epiz. 7, 783-795.