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FIELD IMMOBILIZATION OF FERAL 'JUDAS' DONKEYS (*EQUUS ASINUS*) BY REMOTE INJECTION OF MEDETOMIDINE AND KETAMINE AND ANTAGONISM WITH ATIPAMEZOLE

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ABSTRACT: The Judas technique is a method used for landscape control of feral donkeys (*Equus asinus*) in northern Australia. Central to the success of any Judas program is the safe, efficient, and humane attachment of the telemetry device. For feral donkeys, this involves the use of field immobilization. We examine the replacement of the current chemical capture agent, succinylcholine, with contemporary immobilization agents to achieve positive animal welfare outcomes. A combination of medetomidine and ketamine delivered by remote injection from a helicopter was used to capture 14 free-ranging feral donkeys for the fitting of telemetry collars in Western Australia in November 2010. Dose rates of 0.14 mg/kg medetomidine and 4.1 mg/kg ketamine were appropriate to immobilize animals in 9 min (±SD=3). Mean recovery time (total time in recumbency) was 21 min (±14). All animals recovered uneventfully after being administered atipamezole, a specific antagonist of medetomidine, intramuscularly at 0.35 mg/kg. Physiologic parameters were recorded during recumbency, with environment-related hyperthermia being the only abnormality recognized. No significant complications were encountered, and this drug combination represents an efficient approach to capturing wild donkeys. This new method allows a rapid, safe, cost-effective approach to the immobilization of feral donkeys for use as Judas animals. This drug combination will replace the relatively inhumane succinylcholine for the field immobilization of feral donkeys.

Key words: Atipamezole, donkey, feral, immobilization, invasive, ketamine, medetomidine, welfare.

INTRODUCTION

Invasive herbivores impact environmental, economic and cultural values in Australia (Bradshaw et al., 2007). Management of these impacts has traditionally focused on population reduction. The most efficient methods to reduce abundance for these species include aerial shooting at high population densities and use of the "Judas" animal technique at low densities (Campbell et al., 2005). The Judas techique assists in the location of gregarious pest species via the tracking of a telemetry-collared Judas individual to lead an aerial shooting team to a larger group of animals. The collared individual is left alive to locate another group of animals (Taylor and Katahira, 1988; Campbell et al., 2005; Woolnough et al., 2006). Capture of gregarious individuals is required to allow the fitting of telemetry collars. The standard technique used for large species in inaccessible environments involves chemical immobilization via remote injection from a helicopter. In Australia, field immobilization in operational control programs is routinely conducted by nonveterinarians (Walters, 2007). We describe a safe and humane chemical immobilization system for the capture of Judas feral donkeys (*Equus asinus*) that could be adopted by nonveterinary field operators.

Donkeys were introduced into Australia as haulage animals in the late 1800s. With the advent of motorized transport in the early 20th century, many donkeys were liberated and have established significant feral populations (Bough, 2006). In northern and western Australia, large feral donkey populations now impact conservation and agriculture and pose a threat as potential exotic disease hosts (Bradshaw et al., 2007). Overgrazing by donkeys results in direct competition with domestic stock and exacerbates land degradation and habitat destruction (Choquenot, 1990; Carrion et al., 2007). As an integral part of feral donkey control programs, the Judas technique has been used to aid aerial culling since 1994. Management programs across northern Australia require large numbers of donkeys to be captured each year, with succinylcholine, a neuromuscular blocker, employed as the sole chemical agent for immobilization (Walters, 2007). Neuromuscular blockers have been widely abandoned in wildlife immobilization for decades because of animal welfare and safety concerns (Kreeger et al., 2002; Arnemo et al., 2003; Miller et al., 2009). Since feral donkey Judas programs began, advances in wildlife anesthesia have allowed safer, more rapid, and more humane capture protocols to be developed. However, many of these advances, despite their widespread adoption for use with endangered species, are not used in pest animal management, where animal welfare standards have tended to lag (Littin and Mellor, 2005).

Immobilization of wild equids is notoriously difficult (Matthews et al., 1995; Linklater et al., 1998). When helicopter darting in remote areas is also required, the nature of the immobilizing drug regime is important. An ideal drug combination for such work must be highly concentrated such that an effective dose does not exceed the quantity that can be carried in a 6-ml dart; be nonirritant and hence suitable for intramuscular injection; provide rapid and smooth onset of induction; be reversible; provide wide safety margins; have minimal risks from self-injection for operators; and allow usage by nonveterinary field staff. The opiate etorphine is the preferred chemical agent for capture of wild equids (Plotka et al., 1987; Linklater et al., 1998), and many other large-mammal species (Portas et al., 2003; McMahon and Bradshaw, 2008). However, restrictions on its use in Australia, in combination with occupational hazards for operators, make its use by nonveterinarians unfeasible.

A combination of medetomidine and ketamine has become one of the most widely used drug regimes for immobilizing a wide range of nondomestic species, including ungulates (Jalanka and Roeken, 1990; Tsurunga et al., 1999; Kreeger et al., 2002; Portas et al., 2003). Medetomidine is an injectable, highly specific alpha-2 adrenergic receptor agonist with sedative and analgesic properties. Clinical effects include bradycardia, respiratory depression, hypotension, disruption of thermoregulation, and muscle relaxation. Ketamine is an injectable short-acting cyclohexamine dissociative anesthetic that produces only mild cardiorespiratory depression. As a combination, medetomidine and ketamine act synergistically, with lower required doses of both and wide safety margins. Atipamezole is a specific antagonist, or reversal agent, for medetomidine and can be used at two to five times the dose of medetomidine (Jalanka and Roeken, 1990). There are no effective antagonists to ketamine available.

We describe the trial of a combination of medetomidine with ketamine for the immobilization of feral donkeys. Medetomidine was chosen for its potency as a sedative and muscle relaxant, its highly concentrated nature, and its ability to be reversed using a specific antagonist, atipamezole. Ketamine was chosen for its excellent complementary effects with medetomidine, wide safety margins, highly concentrated nature, and short duration of action. The combination of these two

drugs has proven highly successful for immobilization of a wide range of wild animal species including equids (Jalanka and Roeken, 1990).

MATERIALS AND METHODS

All immobilizations were performed on pastoral stations in the Pilbara region of Western Australia (21°38′S, 120°45′E) in November 2010. Maximum air temperatures in the shade were extremely high at the field site on all days of the study (44.9±0.6 C; Australian Government, Bureau of Meteorology, 2010). Animals to be captured were chosen on the basis of suitability as Judas individuals. Mature, nonpregnant females, without young at foot are considered the most gregarious class of donkeys and were preferred. Animals with an estimated body weight of close to 200 kg were preferred to minimize the dart size required.

Fourteen feral donkeys were captured using a combination of medetomidine (Kyron Laboratories, Johannesburg, South Africa) at a concentration of 20 mg/ml and ketamine (Mavlab, Queensland, Australia) at a concentration of 200 mg/ml. Initial dosages for donkeys were extrapolated from the related Przewalski's horse (*Equus przewalskii przewalskii*; Matthews et al., 1995) and other ungulate species (Jalanka and Roeken, 1990; Tyler et al., 1990). Initial dosages were then raised to allow for the completely wild, free-ranging nature of the donkeys (Matthews et al., 1997) and the agitation that accompanies helicopter pursuit.

The drug combination was delivered by remote injection in C-type 6-ml darts, fitted with 3.8-cm wire barbed needles (Pneu-Dart, Williamsport, Pennsylvania, USA). They were fired from a .22 caliber cartridge fired Pneu-Dart 193 dart projector (Pneu-Dart), from a Robinson 44 helicopter (Robinson Helicopter, Torrance, California, USA). All animals were darted at a distance of 5–15 m. Body weights of animals were estimated from visual examination.

After the animal had been darted, the helicopter would leave the immediate vicinity of the animal in an attempt to decrease excitation during induction. Visual contact with the animal was maintained at all times. The helicopter would then return and land near the animal immediately after recumbency. Recumbent animals were approached on foot, moved into lateral recumbency and blindfolded to reduce visual stress and stimulation. Physical restraint consisted of light pressure on the lateral neck. Anesthetic monitoring consisted of recording heart rate, respiratory rate, rectal body temperature, pulse strength, mucous membrane color, corneal reflex strength, and muscle tone. Heart rates were measured by auscultation, and body temperatures were measured using a digital rectal thermometer. Degree of anesthesia was categorized as light, moderate, deep, or very deep based on the strength of corneal reflexes, degree of muscle tone, and pulse strength (Matthews et al., 1997). Measuring tissue oxygenation was attempted using a Trusat pulse oximeter (Datex Ohmeda, Louisville, Kentucky, USA) but proved unreliable due to battery life constraints.

After required data had been recorded, atipamezole (Antisedan, Novartis, Sydney, New South Wales, Australia), a specific antagonist to medetomidine, was administered intramuscularly into the lateral neck, at a dose of 5 mg/ml. Atipamezole was administered a minimum of 15 min after darting to minimize any residual ketamine effect. Atipamezole dose rates were extrapolated from recommended dose rates for equids and other related species (Jalanka and Roeken, 1990; Matthews et al., 1995). Blindfolds were removed and animals released from physical restraint after reflexes became strong and consistent and full muscle tone returned. The animals were observed until they stood and regained coordinated locomotion. They were then circled from a distance with the helicopter in a "fly-over" procedure 5 min after standing to ensure recovery was complete and uneventful. Captured animals were then located using radiotelemetry 24–48 hr after capture for visual examination. Because of logistic and economic restraints, a customary 14-day postcapture observation could not be performed. Results are presented as mean ±SD, unless otherwise stated.

RESULTS

Estimated drug dose rates, time to recumbency and recovery, and physiologic variables recorded during recumbency are presented in Table 1. Two animals (12 and 14; Table 1) did not become recumbent after a single dart and required a second dart. These two animals had the highest body weights in the study, both estimated at 300 kg. All other animals became recumbent soon after a single dart was successfully administered. Inductions,

TABLE 1. Summary of immobilization procedures performed on 14 feral donkeys (*Equus asinus*), November 2010, Pilbara region, Western Australia, Australia.[a]

ID	Sex	Estimated weight (kg)	Medetomidine (mg/kg)	Ketamine (mg/kg)	Atipamezole (mg/kg)	Time 1 (min)	Time 2 (min)	Depth	HR	RR	T (°C)
1	F	180	0.22	5.55	0.55	6	27	Deep	56	34	39.5
2	M	250	0.12	3.20	0.30	12	10	Light	45	51	39.6
3	F	230	0.13	3.48	0.33	9	12	Light	60	54	38.4
4	F	220	0.14	3.64	0.34	10	15	Moderate	48	60	39.8
5	F	250	0.12	3.20	0.30	14	8	Light	54	57	39.1
6	F	210	0.14	4.76	0.36	9	54	Very deep	60	36	39.6
7	M	200	0.15	5.00	0.37	12	17	Moderate	72	36	40.0
8	F	180	0.13	5.55	0.42	6	47	Deep	75	38	39.3
9	F	240	0.15	3.33	0.31	12	10	Light	51	45	39.5
10	M	200	0.14	4.00	0.37	10	21	Moderate	60	39	39.5
11	F	220	0.13	3.64	0.34	8	23	Moderate	54	39	38.7
12	F	300	0.13	3.67	0.33	10	17	Light	48	66	41.3
13	F	230	0.13	3.48	0.33	5	19	Light	56	52	39.3
14	M	300	0.13	4.67	0.25	8	10	Light	60	30	41.6
$\bar{x}$±SD		229±37	0.14±0.03	4.1±0.9	0.35±0.07	9±3	21±14		57±8	45±11	39.7±0.9

[a] ID = individual animal identification; Time 1 = time from dating to recumbency; Time 2 = total recumbency time; Depth = depth of sedation; HR = heart rate; RR = respiratory rate; T = rectal body temperature.

from darting to recumbency, progressed calmly in all cases, with no evidence of distress, agitation, or injuries sustained. Induction time was consistently short (9±3 min).

Doses calculated are presented as estimates, given the inherent lack of precision involved in estimating animals' body weight by eye. Estimated doses rates were medetomidine 0.14±0.03 mg/kg, ketamine 4.1±0.9 mg/kg, and atipamezole 0.35±0.07 mg/kg. Three animals entered deep or very deep anesthesia after darting, displaying weak palpebral responses and muscle tone. Estimated dose rates received by these animals ranged from 0.13 mg/kg to 0.22 mg/kg for medetomidine and from 4.8 mg/kg to 5.5 mg/kg for ketamine. These animals had longer recumbency times and were more ataxic upon standing. Total recumbency times were variable but generally short (21±14 min). The majority of animals (n=11) attained a light-moderate plane of anesthesia appropriate to the fitting of telemetry collars. In all cases, collar fitting took <2 min.

All physiologic parameters were measured immediately after recumbency and then at 5-min intervals. Heart rates ranged between 40/min and 75/min (mean = 57±9). Respiratory rates were 30–57 min (45±12 min). No animals displayed apnea, cardiac arrhythmia, or abnormal mucous membrane color. Pulse strength was weak to moderate with capillary refill times 0–1 sec in all animals during recumbency. Body temperatures were uniformly high and ranged from 38.4 C to 41.6 C (39.7±0.9 C). Two individuals (animals 12 and 14; Table 1) had body temperatures above the generally recognized critical limit of 41 C (Sedgwick, 1979; Miller et al., 2009), and required medical attention to improve evaporative cooling. Cooling was facilitated by pouring water over the head and axillary and inguinal regions of hyperthermic animals. Both animals responded rapidly to treatment and exhibited reduced body temperatures, uneventful recoveries, and normal appearance on postrecovery observation.

Recovery after administration of atipamezole was generally rapid but variable (21±14 min). In all cases, recoveries were smooth and uneventful. The typical recovery sequence consisted of peripheral pulse strength increasing, then palpebral reflexes strengthening, and then muscle tone increasing. Animals were then observed to lift their heads, sit up in a sternal position, and attempt to stand. At this point animals were released from physical restraint. In almost all cases, this sequence was completed in a few minutes. All animals displayed some ataxia, moved slowly, and appeared disoriented at their first efforts to stand upright. Within 5 min of standing, all animals assumed a normal gait and achieved coordinated locomotion. When fly-overs were performed 5 min postrecovery, all animals were rapidly returning to normal behavior. Restraints on project timing restricted visual examinations, 24–48 hr after capture, to 10 of the 14 animals. All animals observed showed no signs of disability. No animals suffered any injury as a result of these procedures.

DISCUSSION

Remote injection of wild donkeys with dose rates on the order of 0.14 mg/kg medetomidine and 4.1 mg/kg ketamine proved a reliable method for immobilization. A single 6-ml dart was sufficient to produce immobilization in the majority of animals. All 14 animals darted were immobilized without injury, with consistently short times to recumbency. Depth of anesthesia was moderately variable as were recovery times, though donkeys are known to exhibit relatively long anesthetic recovery times (Matthews et al., 1997). The initial doses administered to animal 1 were unintentionally high because difficulties in estimating body weight, and may not have been appropriate as a first test of medetomidine/ketamine in feral donkeys.

The degree of variability in response to drug dose rates was thought to be due to a lack of accuracy in body weight estimation and the inherent variability of remote darting systems in delivering a known quantity of drug. Long (3.8-cm) needles were chosen to maximize the probability of injection into optimal deep muscle sites. However, darting fast-moving mobile animals from a helicopter entails a high degree of variability in administration sites. In all cases, drug leakage from darts, and absorption from darts that bounce off the animal or dislodge is unknown and was assumed to be zero when calculating dose rates.

Signs of cardiopulmonary depression were minimal. Heart rates and respiratory rates were all moderately higher than normal levels (heart rate range 36–68, mean 44; respiratory rate range 12–44, mean 20; French and Patrick, 1995), despite high doses of medetomidine. Alpha-2 adrenergic receptor agonists commonly cause some degree of bradycardia, but the animals in this study had exerted themselves running from the helicopter immediately prior to darting. This exertion, combined with very high environmental temperatures, very likely contributed to the relatively high heart and respiratory rates observed. Although high doses of medetomidine were employed and two animals entered a state of deep anesthesia, cardiopulmonary performance was uniformly stable. This is consistent with the relatively unreactive nature of the donkey cardiopulmonary system to anesthesia (Matthews et al., 1997). All animals in the study were considered to be at minimum risk of anesthetic complication or injury.

All animals had body temperatures far above the reported normal resting range of domestic donkeys of 36.2–37.8 C, mean 37.1 C (French and Patrick, 1995). The body temperatures above the 41 C critical limit for animals 12 and 14 can be explained by the extremely high air temperatures during the study and the exertion experienced by the animals immediately before and after darting from helicopter pursuit. Many comparable studies report similar degrees of hyperthermia in free-ranging ungulates (e.g., Delvaux et al., 1999; Arnemo et al., 2005). Due to timing and logistic constraints, some animals were regrettably pursued and captured throughout the hottest parts of the day. Centrally mediated disruption of thermoregulatory mechanisms by medetomidine, an alpha-2 adrenergic receptor agonist (Jalanka and Roeken, 1990), may have also contributed to hyperthermia. Immobilized animals with rectal temperatures above 40 C are generally considered to be at high risk of injury, while temperatures exceeding 41 C require immediate medical treatment to cool the animal (Miller et al., 2009). Rapid reversal of immobilization reduced these risks. Hence, atipamezole should be administered as a reversal agent as soon as possible when the risk of hyperthermia is high. We would recommend that in future operations, when maximum air temperatures exceed 35 C, animal capture should be restricted to early morning and late afternoon to minimize hyperthermia risks. Capture operations should also be planned to avoid the months of most extreme heat (November–February in northern Australia) where possible.

We used very high medetomidine levels. The vast majority of researchers employing the medetomidine–ketamine combination for wildlife capture in a variety of species have employed medetomidine dose rates in the range of 0.06–0.10 mg/kg (Jalanka and Roeken, 1990). Medetomidine has, however, repeatedly been shown to be safe at much higher dose rates than those commonly employed (e.g., Tyler et al., 1990; Haulena et al., 2000; Fournier-Chambrillon et al., 2003). High doses of medetomidine were needed in this study for three main reasons. Firstly, the temperament of the free-ranging wild animals made them refractory to capture chemicals. Many comparable

studies report dose rates from captive (e.g., Portas et al., 2003), semidomesticated (e.g., Matthews et al., 1995), or habituated animals (e.g., Linklater et al., 1998). Secondly, all animals experienced exertion and agitation prior to darting from the stress of helicopter pursuit. Thirdly, fast recovery times were a priority. The use of high medetomidine doses allows concurrent ketamine doses to be lowered, and thus higher dose of atipamezole to be administered sooner after induction, reducing recumbency times.

Although medetomidine is readily reversible with the antagonist atipamezole, the irreversible nature of ketamine prolongs recovery times. By administering relatively high doses (0.25–0.55 mg/kg) of atipamezole relatively soon after ketamine administration (15 min), recovery time was reduced to a minimum, but some residual ketamine effect was encountered. This effect concerns the situation where a drug that has been used in combination with ketamine is antagonized, leaving ketamine as the sole active drug in the animals' system. This can produce unsteady recoveries, particularly in flighty species such as equids (Jalanka and Roeken, 1990). Timing of antagonist administration is important to ensure that the effect of medetomidine is neutralized only as ketamine plasma levels are dropping due to endogenous metabolism. For this reason, intravenous administration of atipamezole was not utilized in this study. We strongly recommend against administering atipamezole to donkeys sooner than 15 min after darting. If time constraints are not restrictive, atipamezole should ideally be administered 30–40 min after induction to further reduce risks of residual ketamine effect in recovering animals.

Cost effectiveness is a critical factor in wildlife management, especially in the case of pest animal species. As such, any capture protocol must be shown to be cost effective for wide-scale uptake. The cost of the drugs used for a 229-kg animal is A$4 (Australian dollars) for medetomidine, A$7 for ketamine, and A$143 for atipamezole (total = A$154). By far the highest cost associated with this regime is the atipamezole at over 10 times the cost per animal of the next highest component. Without the use of atipamezole, the cost of drugs per average Judas animal would be only approximately A$11. For comparison, the cost of succinylcholine at the currently used dose rate of around 1.0 mg/kg (Walters, 2007) would be approximately A$6 per average Judas animal. The scheduling of the potent opiate etorphine as a Prohibited Substance (Australian Government, Department of Health and Aging, 2011) in Australia precludes its legal use for operational immobilization programs. Less potent opiates such as butorphanol are often added to the medetomidine–ketamine combination (e.g., Miller et al., 2009). However, butorphanol and its antagonist, naltrexone, are relatively expensive and add considerably to the cost of reversal when compared with immobilizing drug combinations not including an opiate. For this reason, and restrictions preventing nonveterinarians from handling opiates, we did not include an opiate in our immobilization regime.

Use of antagonists is not a necessity in all animal capture situations but is often desirable. Reversal agents allow more rapid recoveries, lower anesthetic risks, and in this case, lower helicopter running costs. The use of atipamezole as a reversal agent may not be recommended in all situations for donkey capture. In most situations, the use of atipamezole as an antagonist will improve animal welfare but reduce cost effectiveness. We recommend reversing donkeys when environmental temperatures are high (>35 C), when depth of anesthesia is excessive and results in significant cardiopulmonary depression, and when time constraints necessitate fast recoveries. In all other situations, it may be acceptable not to reverse, provided recovering animals are closely observed

and donkeys are only captured when air temperatures are not high.

Judas donkey control programs in Australia utilize the neuromuscular blocker succinylcholine as the sole chemical agent for capture (Walters, 2007). Despite their widespread use in the past, neuromuscular blockers have been rarely employed over the past two decades. Because of their extremely low safety margins, high mortality rates, inconsistent effectiveness, and lack of sedative or analgesic properties, neuromuscular blockers are now widely considered to be inhumane and unsafe for this purpose (Delvaux et al., 1999; Kreeger et al., 2002; Arnemo et al., 2003). For donkeys, succinylcholine has the advantages of a relatively broad therapeutic dose range in equids (Fowler, 2008), rapid inductions and recoveries, and being extremely inexpensive. However, drug costs comprise the minority of total costs associated with helicopter capture programs, with the most expensive component being helicopter flight time (Delvaux et al., 1999). Owing to the higher failure rates of immobilization attempts and higher mortality rates when using succinylcholine, the total cost of using succinylcholine is often higher than for more reliable drug regimes in helicopter capture programs (Delvaux et al., 1999).

Despite disadvantages of the medetomidine–ketamine combination including higher drug costs and some prolonged recoveries, this combination resulted in reliable, reversible, humane immobilization. The use of sedative drugs with analgesic properties represents a considerable improvement in animal welfare over the previous use of neuromuscular blockers as the sole capture drug. We recommend that succinylcholine be replaced in feral donkey capture programs by the more humane, reliable, and safe drug combination trialed in our study. There is considerable evidence to suggest that animal welfare standards for unwanted or unvalued species such as the feral donkey are falling behind advances in valued species (Littin and Mellor, 2005). We encourage the integration of modern, humane approaches pioneered in the field of endangered species management into more pest animal management practices.

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