Anaesthesia of
Wild Carnivores and Primates

Physiological Effects and Reversibility of
Medetomidine and Dissociative Anaesthetics

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The man of the forest
the queen of the jungle
and the glutton

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Abstract

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Anaesthesia of wild animals is often carried out under difficult conditions. Rapid induction and recovery can minimise stress and the risk of injury to the animals. Assessment and improvement of anaesthesia are important parts of wildlife conservation and animal welfare since physiological disturbances influence the well-being of the animals.

The aim of this thesis was to develop and evaluate reversible anaesthetic protocols for wild carnivores and primates. The physiological effects of medetomidine-zolazepam-tiletamine, and reversal with atipamezole, were evaluated in free-ranging lions (*Panthera leo*) and in four species of South-East Asian primates: Bornean orangutan (*Pongo pygmaeus pygmaeus*), Bornean gibbon (*Hylobates muelleri*), long-tailed macaque (*Macaca fascicularis*) and pig-tailed macaque (*Macaca nemestrina*). The physiological effects of capture and medetomidine-ketamine anaesthesia were evaluated in free-ranging wolverines (*Gulo gulo*).

Cardiorespiratory parameters and body temperature were monitored in all animals. Arterial blood samples were analysed for blood gases, acid-base status and selected haematological and plasma parameters in lions and wolverines.

For primates and lions the developed anaesthetic protocols, including low doses of medetomidine and zolazepam-tiletamine, were effective for anaesthesia with a rapid and smooth induction. During anaesthesia, respiratory and heart rates were stable whereas rectal temperature decreased in primates and increased in lions. Analysis of arterial blood samples from lions revealed no obvious alterations. Reversal of the effects of medetomidine with atipamezole resulted in a smooth and calm recovery.

In wolverines, capture and medetomidine-ketamine anaesthesia affected several physiological, haematological and plasma parameters. Hyperthermia, metabolic acidosis and impaired arterial oxygenation were evident. Significant differences in several parameters were found between adult and juveniles, which could be due to capture method, drug dose and age.

The alterations in rectal temperature measured in all species emphasize the importance of physiological monitoring throughout anaesthesia to be able to detect, prevent or treat disturbances. In addition, the possibility of analysing arterial blood samples during field studies provides detailed data needed to ensure stable physiology and refine anaesthesia.

In conclusion, this thesis contributes new knowledge to the field of wildlife anaesthesia by the development of new anaesthetic protocols for use in four species of primates and in lions. Further, it is the first study to provide detailed physiological data in anaesthetised wolverines.

Key words: anaesthesia, immobilisation, physiology, arterial blood gases, acid-base status, medetomidine, ketamine, tiletamine, zolazepam, atipamezole

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Imagination is more important than knowledge.

Knowledge is limited.
Imagination encircles the world.

Albert Einstein (1879-1955)

Contents

Appendix

This thesis is based on the following papers, which are referred to in the text by their Roman numerals:

I.   Fahlman, Å., Bosi, E.J. and Nyman, G. 2005. Reversible anaesthesia of South-East Asian primates with medetomidine, zolazepam, and tiletamine. (*Submitted for publication*)

II.   Fahlman, Å., Loweridge, A., Wenham, C., Foggin, C., Arnemo, J.M. and Nyman, G. 2005. Reversible anaesthesia of free-ranging lions (*Panthera leo*) in Zimbabwe. (*Submitted for publication*)

III.   Fahlman, Å., Arnemo, J.M., Persson, J., Segerström, P. and Nyman, G. 2005. Physiological effects of capture and medetomidine-ketamine anaesthesia in free-ranging wolverines *Gulo gulo.* (*Manuscript*)

Licentiate degree at the Swedish University of Agricultural Sciences
- information for international colleagues and friends

A licentiate degree requires two years of postgraduate research studies and includes course work, presentation of research results at conferences and the completion of a thesis. The recipient has demonstrated ability to investigate and to solve problems scientifically, has planned and executed research, is knowledgeable within his or her area of expertise and has contributed to the development of this area through his or her own research. The licentiate thesis is presented before a board of examiners at a public seminar.

Abbreviations

BE	base excess (actual)
HCO_3	bicarbonate (actual)
HR	heart rate
i.m.	intramuscular
IUCN	the International Union for the Conservation of Nature and Natural Resources
$[P(A\text{-}a)O_2]$	alveolar-arterial oxygen tension difference
PAO_2	partial pressure of alveolar oxygen
PaO_2	partial pressure of arterial oxygen
P_IO_2	partial pressure of inspired oxygen
R	respiratory exchange ratio
RR	respiratory rate
SaO_2	haemoglobin oxygen saturation in arterial blood calculated by i-STAT®1
s.c.	subcutaneous
SpO2	haemoglobin oxygen saturation in arterial blood measured by pulse oximetry

Introduction

Wild animals have always been captured by man. Early hunters used physical restraint, but for several thousand years chemical restraint was practiced for hunting by the use of blowpipe darts or arrows prepared with poison. Live capture of wild animals by chemical immobilisation was introduced in the 1950's (Rausch & Ritcey, 1961; Bush, 1992; Swan, 1993). When the construction of the Kariba Dam across the Zambezi River in Southern Rhodesia (now Zimbabwe) was completed, many wild animals were trapped on shrinking islands. Although mortality rates were high during "Operation Noah", large numbers of stranded animals were captured and rescued using novel drugs and darting techniques (Nielsen, 1999). Since these early stages, the development of numerous new drugs and darting equipment has improved chemical capture of wild animals.

Immobilisation of wild animals is often conducted under difficult circumstances. Assessment and improvement of capture and immobilisation are important parts of conservation and management of wildlife where veterinary involvement adds strength in a multidisciplinary approach to wildlife conservation projects (Karesh & Cook, 1995). In addition, safe handling of wildlife with minimal stress to the animals is imperative ethically and from animal welfare concerns. There are numerous species of wildlife and many are threatened with extinction. Wildlife species react in different ways to capture and to the various drugs used for immobilisation. Veterinary anaesthesia has developed rapidly in the last decade and this thesis contributes new knowledge to the field of wildlife anaesthesia.

Wildlife chemical immobilisation and anaesthesia

Handling of wild animals often requires physical or chemical restraint. Chemical restraint includes immobilisation and anaesthesia. An immobilised animal is incapable of moving. Chemical immobilisation can vary from light sedation to unconsciousness depending on the method, drugs and doses used. Therefore, to prevent reaction to external stimuli it can be important to use earplugs and blindfold on the immobilised animal. General anaesthesia includes reversible loss of sensation and loss of consciousness, as opposed to local anaesthesia which only causes reversible loss of sensation in a certain area (Thurmon *et al.*, 1996). An anaesthetised animal is always immobilised, whereas an immobilised animal may or may not be anaesthetised. For example, an animal immobilised with opioids such as etorphine (Immobilon® or M99®) is not anaesthetised. The effect of dissociative anaesthetics is dose-dependent, varying from sedation to anaesthesia.

Immobilisation of wild animals can be necessary for a number of reasons. In captivity, immobilisation is often required for physical examination as well as for diagnosis and treatment of disease. Free-ranging wildlife might be immobilised for translocation, snare removal, disease surveillance or for fitting of radio-collars for research studies. The methods used for immobilisation of wildlife should minimise stress and the risk of injuries to the animals. For remote dart injection, it is an advantage to use concentrated potent drugs which require less volume for an

effective dose. The use of small lightweight darts reduces the risk of dart impact injuries and improves accuracy at longer distances. The drugs should preferably have a wide safety margin since it is not possible to do a physical examination of wild animals before drug administration and because the exact body weight is unknown. Further, the drugs should preferably be safe for people to handle. During free-ranging conditions, rapid induction is critical to avoid losing sight of the animal in dense bush or in darkness and to enable early physiological monitoring. The use of reversible drugs is an advantage in case of an emergency, such as respiratory depression. Also, administration of an antagonist at the end of the immobilisation enables a quick recovery, which is important for the animal to regain mobility and ability to defend itself. If the recovery is prolonged it increases the risk of the animal getting killed by predators or hurting itself while still under drug influence (Kreeger *et al.*, 2002).

Safe handling of wildlife should not only warrant low mortality but also low morbidity and ensure stable physiology. When immobilising free-ranging wildlife, the capture event as well as the immobilising drugs influence the well-being of the animals by altering physiological parameters (Cattet *et al.*, 2003b). Detailed knowledge on adverse physiological effects is needed to be able to minimise and to treat complications. Muscular exertion during helicopter pursuit and resistance to handling during manual restraint result in increased stress, including elevated body temperature, oxygen-depletion and lactic acid production. Increased lactic acid levels lead to a drop in pH and development of lactic acidosis, which can predispose the animal to muscle fatigue, cardiac arrhythmias, cellular death and organ failure (Spraker, 1993). Acidosis and hyperthermia can lead to death during or after anaesthesia. Immobilising drugs may interfere with the normal respiratory function, leading to respiratory depression, acidosis and hypoxemia. Arterial blood gases and pH are used to assess the efficacy of breathing, tissue oxygenation and acid base balance (DiBartola, 2000). Further, blood gases and acid-base status are valuable means for evaluation of the physiological effects that different capture methods and drugs have on animals (Suzuki *et al.*, 2001).

Primates and carnivores

World wide primate and carnivore species are threatened with extinction. The order Primates is a large and diversified group consisting of 233 species, ranging from 120-g pygmy marmosets (*Cebuella pygmaea*) to 180-kg gorillas (*Gorilla gorilla*). Most primates are arboreal and live in tropical forests. The primary threat to free-ranging primates is widespread habitat destruction. Primate populations are also declining due to the illegal animal trade, the poaching of animals for food and their persecution as agricultural pests (Davies, 1986).

Four species of South-East Asian primates are included in this thesis: Bornean orangutan (*Pongo pygmaeus pygmaeus*), Bornean gibbon (*Hylobates muelleri*), long-tailed macaque (*Macaca fascicularis*) and pig-tailed macaque (*Macaca nemestrina*). Orangutans are classified as endangered on the Red List of threatened species by the International Union for the Conservation of Nature and Natural Resources (IUCN Red List) and are facing a very high risk of extinction in

the wild in the near future (IUCN, 2004). Free-ranging orangutans currently exist only in a few areas of tropical rain forest on the islands of Borneo and Sumatra in Malaysia and Indonesia (Fig. 1). Within the state of Sabah in Malaysia, orangutans that are stranded in forest fragments are captured for translocation to protected habitat (Andau *et al.*, 1994; Kilbourn *et al.*, 1997). At Sepilok Orangutan Rehabilitation Centre in Sabah, orphaned and injured orangutans, as well as other primates, are raised and treated before release into the wild. Anaesthesia is often required for health examination and treatment of captive-held primates and for translocation of free-ranging orangutans.

Figure 1. The location of Sepilok Orangutan Rehabilitation Centre in the state of Sabah, Malaysia (white on the map). Free-ranging orangutans currently exist only on the islands of Borneo and Sumatra in Malaysia and Indonesia.

The order Carnivora includes 233 species, ranging in size from the 30-g least weasel (*Mustela nivalis*) to the 600-kg polar bear (*Ursus maritimus*) (Macdonald, 2001). Wild carnivores are able to adapt to all major types of habitats and occur naturally on every continent except Antarctica and Australia. Carnivores live primarily by hunting and are excellent runners. Some are good long-distance runners, but most are rapid sprinters that stalk the prey and capture it after a brief burst of speed. This thesis includes two species of carnivores: wolverines (*Gulo gulo*) and lions (*Panthera leo*).

The wolverine is a member of the family Mustelidae family which also includes badgers, otters and weasels. Wolverines have a circumpolar distribution and inhabit forest and arctic tundra of the northern hemisphere (Pasitschniak-Arts & Lariviere, 1995). The wolverine is classified as vulnerable by IUCN (IUCN, 2004) and endangered on the national red list in Sweden (Swedish Species Information Centre, 2005) where it has been a protected species since 1969. The main prey for wolverines in Sweden is semi-domesticated reindeer (*Rangifer tarandus*), which puts the wolverine in conflict with the interests of the reindeer herding Sámi people (Persson, 2003). This conflict continually leads to illegal harvest of wolverines and demands for increased hunting quotas. Ongoing research projects

studying the ecology of wolverines in Scandinavia involve anaesthesia of animals for radio-marking.

The African lion is classified as vulnerable on the IUCN Red List and its future is uncertain (IUCN, 2004). Major threats to the African lion are loss of habitat and prey base and persecution (Cardillo *et al.*, 2004). Today, most free-ranging lions live in isolated protected populations with increased risk of inbreeding (Bauer & Van Der Merwe, 2004). Field anaesthesia of lions is necessary for various reasons, e.g. fitting of radio-collars for research studies, disease surveillance and control of problem animals (Fig. 2).

Fig. 2. Lion anaesthetised after dark for radio-collaring for the Hwange Lion Research Project in Zimbabwe. The heart is auscultated and a blood sample is collected from a vein on the hind leg. The rest of the pride is out there in the dark.

Drugs used in primates and carnivores

The most widely used immobilising drugs in wild carnivores and primates are the dissociative anaesthetics phencyclidine, tiletamine and ketamine. Phencyclidine is long-acting and the most potent of the three drugs, whereas ketamine is weaker and short-acting and tiletamine is intermediate in potency and duration of action (Bree, 1972).

Phencyclidine was used during early lion immobilisations even though it had many disadvantages. In lions darted with phencyclidine, the induction period could be up to 30 minutes and muscle spasms and convulsions commonly occurred (Campbell & Harthoorn, 1963; Bush *et al.*, 1978). The recovery period was so prolonged that lions immobilised in the wild must often be guarded for many hours (Campbell & Harthoorn, 1963; Holmes & Ngethe, 1973).

With ketamine the recovery period is shorter than with phencyclidine (Smuts *et al.*, 1973). However, disadvantages of anaesthesia with ketamine or tiletamine alone include poor muscle relaxation, convulsions, excessive salivation and there is no specific antagonist (Kreeger *et al.*, 2002). Today, tiletamine is only available in combination with the benzodiazepine tranquiliser zolazepam and is sold under

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the trade names Zoletil[®], Telazol[®] and Tilest[®]. The combination of zolazepam-tiletamine has been used for immobilisation or anaesthesia in many species of wild carnivores and primates (Eads, 1976; King *et al.*, 1977; Schobert, 1987; Stander & Morkel, 1991; Andau *et al.*, 1994; Golden *et al.*, 2002; Fowler & Miller, 2003). Induction is rapid but recovery is usually prolonged.

When combining a dissociative anaesthetic with a sedative, a tranquilliser or both, muscle relaxation is improved and the dose of the dissociative anaesthetic can be reduced (Hayama *et al.*, 1989; Jalanka & Roeken, 1990; Lewis, 1993; Röken, 1997). Frequently used sedatives are alpha$_2$-agonists, e.g. xylazine and medetomidine. Free-ranging orangutans can be immobilised with xylazine and ketamine but the induction time is longer and the drug volume larger than when zolazepam-tiletamine is used (Andau *et al.*, 1994; Kilbourn *et al.*, 1997). In lions, the combination of xylazine and ketamine has been used but a large volume of ketamine is required for an effective dose, which can necessitate repeated drug administration (Herbst *et al.*, 1985; Van Wyk & Berry, 1986). The ketamine dose can be reduced markedly when ketamine is combined with medetomidine, which is a more potent and specific alpha$_2$-agonist than xylazine. When medetomidine is combined with zolazepam-tiletamine, the dose of zolazepam-tiletamine can be reduced by at least 50% in many species (Röken, 1997; Cattet *et al.*, 1999; Kreeger *et al.*, 2002). The effects of medetomidine can be reversed with the alpha$_2$-agontagonist atipamezole, which shortens recovery from anaesthesia.

Few studies describe immobilisation of wolverines (Hash & Hornocker, 1980; Ballard *et al.*, 1982; Golden *et al.*, 2002). Etorphine is a highly potent opioid that has been used in wolverines in combination with xylazine (Ballard *et al.*, 1982). Although opioids commonly cause respiratory depression (Haigh, 1990), no physiological parameters are reported in the wolverine (Ballard *et al.*, 1982). Free-ranging wolverines have also been immobilised with ketamine alone or with zolazepam-tiletamine (Hash & Hornocker, 1980; Golden *et al.*, 2002). In Scandinavia, medetomidine has been used in combination with ketamine for anaesthesia in free-ranging wolverines since 1998. Although mortality is low (Arnemo *et al.*, Accepted 2005), there is a lack of detailed knowledge of the adverse physiological effects of capture and anaesthesia in the species.

Aims

The general aim was to develop and evaluate reversible anaesthetic protocols for selected species of wild carnivores and primates.

The specific aims of Study I and II, including four species of South-East Asian primates and free-ranging lions, were to:

- develop anaesthetic protocols including the alpha$_2$-agonist medetomidine and zolazepam-tiletamine

- evaluate physiological effects during anaesthesia

- evaluate anaesthetic reversal with the alpha$_2$-antagonist atipamezole.

The specific aim of Study III, including free-ranging wolverines, was to:

- evaluate physiological effects of capture and medetomidine-ketamine anaesthesia.

Materials and Methods

Animals and study areas

Four species of primates and two species of carnivores were included in the studies (Table 1). The animals were anaesthetised as part of routine work (Study I) or on-going research projects (Study II and III). A variety of procedures were performed such as physical examination, intradermal tuberculin testing, translocation, fitting of radio-collars and surgery for intraperitoneal radio-transmitters (wolverines only). The field work for this thesis was carried out in three countries on three different continents: Malaysia in South-East Asia, Zimbabwe in Southern Africa and Sweden in Northern Europe.

Table 1. Species, number of individuals and procedures, sex and body weight of the animals included in the different studies in this thesis.

Study and species	Number of individuals	Sex M /F[a]	Number of procedures		Body weight (kg)
I. Bornean orangutan	12	4 / 8	Captivity	13	3.9 - 45.5
(*Pongo pygmaeus pygmaeus*)			Free-ranging	3	20.0 - 26.0
I. Bornean gibbon (*Hylobates muelleri*)	2	- / 2	Captivity	2	2.9 - 3.0
I. Long-tailed macaque (*Macaca fascicularis*)	2	2 / -	Captivity	3	2.6 - 3.4
I. Pig-tailed macaque (*Macaca nemestrina*)	2	2 / -	Captivity	2	2.2 - 3.7
II. African lion (*Panthera leo*)	17	5 /12	Free-ranging	21	105.0-211.0
III. Wolverine (*Gulo gulo*)	24	8 /16	Free-ranging	25	3.4 - 15.2

[a] M / F = male / female.

I. Primates

The primate study was performed within the state of Sabah in Malaysia, on the island of Borneo (Fig. 1). A total of 23 anaesthetic procedures involving 18 individual primates were evaluated. Twenty procedures involved temporarily captive-held primates at Sepilok Orangutan Rehabilitation Centre and three procedures were translocation of free-ranging orangutans within the state of Sabah. The age of the animals varied from infants to adults. Ambient temperature ranged from 30-33 °C during the procedures.

II. Lions

Twenty-one anaesthetic events of 17 free-ranging adult and subadult lions were evaluated in Hwange National Park and Malilangwe Trust in Zimbabwe. Ambient temperature ranged from 15-34 °C.

III. Wolverines

Twenty-five anaesthetic events of 24 free-ranging wolverines (12 adults, 12 juveniles) were studied in and around the Sarek National Park, north of the Arctic Circle in Sweden. Anaesthesia was carried out at altitudes of 500-1300 m above sea level with an ambient temperature of -5 to +25 °C. The wolverines were anaesthetised as part of the Swedish Wolverine project with ethical approval from the Ethical Committee on Animal Experiments in Umeå, Sweden.

Drugs and drug delivery methods

For anaesthesia, medetomidine was used in combination with zolazepam-tiletamine in primates and lions and in combination with ketamine in wolverines. Medetomidine hydrochloride was used either at a concentration of 1 mg/ml (Domitor®, Orion Pharma Animal Health, Turku, Finland) or at a concentration of 10 mg/ml (Zalopine®, Orion Pharma Animal Health), depending on dose and drug delivery method. Zolazepam hydrochloride and tiletamine hydrochloride (Zoletil®100, Virbac S.A., Carros, France and Virbac RSA (Pty) Ltd, Halfway House, South Africa) were prepared by dissolving the powder in sterile water to a total drug concentration of 100 or 200 mg/ml, depending on species (Fig. 3). Ketamine hydrochloride was used at a concentration of 100 mg/ml (Narketan®10, Chassot, Dublin, Ireland). All animals were weighed during anaesthesia and the actual drug doses were calculated in mg/kg (Table 2, page 21).

  For reversal of the effects of medetomidine, atipamezole hydrochloride was used at a concentration of 5 mg/ml (Antisedan®, Orion Pharma Animal Health). The time for reversal was determined during each anaesthetic event, depending on the procedure being performed. Post-anaesthetic survival was followed up in free-ranging lions and wolverines by radio-tracking, whereas primates in captivity were inspected daily.

Figure 3. Medetomidine (Zalopine® 10 mg/ml), zolazepam-tiletamine (Zoletil®100) and atipamezole (Antisedan® 5 mg/ml), the drug protocol used in lions. Zoletil® was prepared to a concentration of 200 mg/ml for lions.

  Delivery of anaesthetic drugs by dart syringes fired from a rifle was only used in free-ranging animals. In Malaysia, a Telinject Vario 4V Rifle (Telinject USA Inc., Saugus, California, USA) was used for darting of free-ranging orangutans. In Zimbabwe and Sweden, a CO_2 powered Dan-Inject rifle (Dan-Inject SA, Skukuza, South Africa and Dan-Inject, Børkop, Denmark) was used for darting of lions and adult wolverines.

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I. Primates

In primates, medetomidine was used at a concentration of 1 mg/ml (Domitor®) and zolazepam-tiletamine was prepared to a total drug concentration of 100 mg/ml. For captive primates at Sepilok Orangutan Rehabilitation Centre, the drugs were administered i.m. by hand syringe while physically restraining the animals. Free-ranging orangutans in trees were darted from the ground at a distance of 8-15 m. Drug doses used in the different primate species are presented in Table 2.

For anaesthetic reversal, atipamezole was injected i.m. at 5 times the medetomidine dose.

II. Lions

In lions, medetomidine was used at a concentration of 10 mg/ml (Zalopine®) and zolazepam-tiletamine was prepared to a total drug concentration of 200 mg/ml (Fig. 3). All lions were darted from a vehicle at distances of 10-33 m. Up to three lions were darted and kept under anaesthesia on the same occasion. The initial aim was to administer 0.06 mg/kg medetomidine and 1.45 mg/kg zolazepam-tiletamine, based on estimated body weight. For the first six lions, drug doses were prepared after estimation of the body weight once the lions were sighted. Thereafter, lions were given drug doses according to sex: males received 6-8 mg medetomidine and 80-100 mg zolazepam-tiletamine whereas females received 4-6 mg medetomidine and 50-80 mg zolazepam-tiletamine. The drug doses were gradually decreased according to observed reactions. Actual doses in mg/kg are presented in Table 2 (page 21).

For reversal, atipamezole was administered i.m. at 5 times the dose of medetomidine during the first eight anaesthetic events, and thereafter at 2.5 times the medetomidine dose.

III. Wolverines

The concentration of medetomidine used in adult wolverines was 10 mg/ml (Zalopine®) and in juveniles 1 mg/ml (Domitor®). Ketamine was used at a 100 mg/ml concentration. On eight occasions adult wolverines were darted from a helicopter and on three occasions from the ground. The darting distance was 1-6 m. Two adult wolverines were dug out of rendezvous sites (a site where juveniles are left while the female forage), captured by hand with a snare on a pole and hand-injected i.m. with the drugs. A standard dose of 4 mg medetomidine and 100 mg ketamine was used in adult wolverines. Juvenile wolverines were dug out of rendezvous sites and captured with a snare on a pole. After estimation of body weight or being weighed in a canvas bag, juveniles were hand-injected i.m. with 0.1 mg/kg medetomidine and 5-10 mg/kg ketamine. Drug doses given according to actual body weight are shown in Table 2 (page 21). Surgery for implantation or replacement of intraperitoneal radiotransmitters was performed in 8 adult and 12 juvenile wolverines. For analgesia, 4 mg/kg carprofen (Rimadyl®, Orion Pharma Animal Health) was administered s.c. pre-operatively. To minimise the risk of wound infection, procaine benzylpenicillin and benzathine benzylpenicillin were injected intramuscularly at 100 000 IU/kg (PENI-kél L.A. 15+15, Kela Laboratoria NV, Hoogstraten, Belgium).

For anaesthetic reversal, atipamezole was administered i.m. at 5 times the dose of medetomidine.

Anaesthesia

Induction

Times from drug injection or darting to first sign of sedation and to recumbency (induction time) were recorded.

Physiological parameters

In all species, respiratory rate, body temperature, heart rate and haemoglobin oxygen saturation were monitored throughout anaesthesia and recorded every 5-15 min. Respiratory rate was monitored by observation of chest movements. Rectal temperature was monitored with a digital thermometer with continuous reading and a measurement range of 28.9-42.2 °C (Welch Allyn Diatec 600, Welch Allyn, Inc., Skaneateles Falls, New York, USA) (Fig. 4). In primates, tympanic temperature was measured using a tympanic thermometer for the ear (Braun ThermoScan Instant Thermometer IRT 1020, Thermoscan Inc., San Diego, California, USA). To avoid development of hypothermia, wolverines were placed on an insulated blanket (Fjellduken®, Jerven AS, Odda, Norway), unless their rectal temperature was elevated. Hyperthermic animals (rectal temperature over 40 °C) were cooled with water or snow and fanned.

Figure 4. Anaesthesia in an adult female wolverine monitored with pulse oximetry (Tuffsat®) and continuous measurement of rectal temperature (Welch Allyn Diatec 600) (left). A blood sample is collected with a self-filling arterial syringe (PICO^{TM}70) from the femoral artery of a wolverine for analysis of blood gases and acid-base status (right).

Haemoglobin oxygen saturation (SpO$_2$) was monitored continuously by pulse oximetry with the pulse oximeter probe attached to the tongue in lions and wolverines (Nellcor NPB-40 Handheld Pulse Oximeter, Nellcor Inc., Pleasanton, California, USA and Tuffsat® Pulse Oximeter, Datex-Ohmeda Inc., Madison, Wisconsin, USA) (Fig. 4). In primates, the pulse oximeter probe was attached to the tongue, a finger or a toe and a pulse oximeter that required electricity was used (Engström Eos Pulse Oximeter, Gambro Engström AB, Bromma, Sweden) (Fig. 5).

Heart rate was monitored by pulse oximetry, by palpation of peripheral pulse or by auscultation of the heart.

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Systolic arterial blood pressure was measured oscillometrically in only adult orangutans (Fig. 5). A non-invasive device with a cuff width of 140 mm was used (Omron Digital Blood Pressure Monitor Model HEM-400 C, Omron Corporation, Tokyo, Japan). The cuff was placed over the left brachial artery; the cuff width was approximately half the circumference of the limb.

Figure 5. Anaesthesia in an adult male orangutan monitored with pulse oximetry (Engström Eos Pulse Oximeter) and measurement of blood pressure (Omron Digital Blood Pressure Monitor Model HEM-400 C). Blood smears are prepared and an individual number is tattooed in the groin.

Arterial blood samples were collected from five lions and all wolverines for analysis of blood gases, acid-base status and selected haematological and plasma parameters. One to three samples were collected per animal between 15-60 min after drug administration. The samples were collected anaerobically from the femoral artery using self-filling arterial syringes with heparin (PICO^{TM}70, Radiometer Copenhagen, Brønshøj, Denmark) (Fig. 4). The femoral pulse was palpated in the groin and the needle was introduced percutaneously into the artery, confirmed by pulsating blood. Firm pressure was applied to the sample site for 5 min post-sampling to avoid bleeding.

Figure 6. The i-STAT®1 analyser used for field analysis of arterial blood samples (left). Storage of the i-STAT®1 during field work to ensure optimal temperature conditions (right).

Arterial blood samples were processed immediately in the field using a portable analyser and cartridges (i-STAT®1 Portable Clinical Analyser and i-STAT® cartridges CG4+, 6+, CG8+, Abbott Laboratories, Abbott Park, Illinois, USA)

(Fig. 6). Since the i-STAT[®]1 analyser only operates in +16 to +30 °C, it was kept with freeze blocks in a polystyrene foam box in an insulated cooler bag during hot days in Zimbabwe. In Sweden, a warm water bottle in the polystyrene foam box prevented the analyser becoming too cold (Fig. 6). The analysis included measured values for pH, partial pressure of arterial carbon dioxide ($PaCO_2$), partial pressure of arterial oxygen (PaO_2), lactate, haematocrit, sodium, potassium, chloride, urea, ionised calcium and glucose. Blood gas values and pH were corrected to the current rectal temperature. Calculated values were provided for actual base excess (BE), actual bicarbonate (HCO_3), arterial haemoglobin oxygen saturation (SaO_2) and haemoglobin. In wolverines, the alveolar-arterial oxygen tension difference $[P(A-a)O_2]$ was calculated. Partial pressure of alveolar oxygen (PAO_2) was calculated as $PAO_2 = P_IO_2 - (PaCO_2/R)$. P_IO_2 = partial pressure of inspired oxygen. Respiratory exchange ratio (R) = 0.8.

Recovery

Time from drug injection or darting until injection of atipamezole (reversal) was recorded in all animals. In primates, times from reversal until first signs of recovery and, if obvious, to full recovery, were recorded. In lions, time from reversal until first sign of recovery, head up, sternal, standing and walking were recorded. In wolverines, time from reversal until initial sign of recovery was recorded. After reversal, wolverines were left undisturbed to recover in lateral recumbency at the rendezvous site.

Statistical analysis

Physiological parameters were analysed by repeated measures analysis of variance (Procedure Mixed, SAS[®] System 9.1, SAS Institute Inc., Cary, North Carolina, USA). Significant difference was considered when $p < 0.05$. For animals anaesthetised twice, only the first anaesthetic event was included in the analyses. Data from adult wolverines darted from a helicopter were compared to juveniles captured by hand. Paired measurements of rectal and tympanic temperature in eight orangutans were compared using the intra-class correlation coefficient model 2 [ICC (2)].

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Results and Discussion

Induction of anaesthesia and drug doses

Medetomidine in combination with zolazepam-tiletamine rapidly induced anaesthesia in all four species of primates and in all free-ranging lions. A rapid induction was also seen in wolverines, which were anaesthetised with medetomidine in combination with ketamine. Drug doses used in the different species are presented in Table 2.

Table 2. Drugs and actual mean doses (range[a]) in mg/kg used in four species of South-East Asian primates, in African lions and in wolverines.

Study and species	Number of procedures		Medetomidine	Zolazepam-tiletamine	Ketamine
I. Bornean orangutan	Captivity	13	0.02	1.1 (0.9-1.3)	-
	Free-ranging	3	0.02	1.3 (1.2-1.3)	-
I. Bornean gibbon	Captivity	2	0.02	0.9 (0.8-0.9)	-
I. Long-tailed macaque	Captivity	3	0.04 (0.02-0.05)	1.5 (0.9-1.9)	-
I. Pig-tailed macaque	Captivity	2	0.06 (0.05-0.06)	2.0 (1.7-2.3)	-
II. African lion	Free-ranging	21	0.04 (0.03-0.06)	0.7 (0.4-1.3)	-
III. Wolverine	Free-ranging	25	Adults 0.37 (0.26-0.44)	-	9.4 (6.6-11.0)
			Juveniles 0.14 (0.10-0.21)	-	7.5 (5.2-11.0)

[a] If no range is presented, all animals received the same dose.

I. Primates

Captive-held primates

First sign of sedation was seen in 1-3 min and recumbency occurred within 1-7 min of injection. Signs of spontaneous recovery before reversal were observed in four orangutans and one gibbon between 19 and 40 min after the initial drug injection. In order to complete the procedures, three of these orangutans required supplemental drug injection.

Free-ranging orangutans

Recumbency occurred within 4 min of darting in two out of three free-ranging orangutans. The induction was smooth because the orangutans were able to grip and hold on to branches as they gradually descended to the ground. In contrast, orangutans darted with zolazepam-tiletamine alone (3 mg/kg) fall unconscious from the tree, which can be hazardous for the animal (E.J. Bosi and E. Tambing, personal communication).

The third free-ranging orangutan, an adult female carrying an infant, showed first sign of sedation 9 min after darting. After falling from the tree, the orangutan was harassed by dogs from the plantation and therefore further stressed. An additional drug dose (zolazepam-tiletamine 1.2 mg/kg) was required to induce anaesthesia, but the orangutan developed hyperthermia (40.0 °C) followed by apnea. After resuscitative treatment, the orangutan recovered without further problems. The apnea was probably a result of capture stress and hyperthermia, drug related or both.

In this study similar drug doses were used in captive and in free-ranging orangutans. In two out of three free-ranging orangutans these doses were sufficient for capture of the animals. However, the duration of anaesthesia was short and supplemental drug doses were required between 9-29 min after darting. Further studies are needed to determine suitable doses of medetomidine-zolazepam-tiletamine for anaesthesia with a longer duration in free-ranging orangutans.

II. Lions

Medetomidine in combination with zolazepam-tiletamine was safe and efficient for anaesthesia of free-ranging lions. Advantages of this combination included a small drug volume for darting, rapid and smooth induction (Table 3), predictable duration of anaesthesia and ability to reverse the anaesthesia.

Table 3. Induction times (in minutes after darting) in free-ranging lions darted with medetomidine-zolazepam-tiletamine.

Induction	Mean	Range
1st sign of sedation	3 min	2-8 min
Recumbency	6 min	3-10 min

Interestingly, very low doses of medetomidine and zolazepam-tiletamine were sufficient to anaesthetise free-ranging lions (Table 2). The lowest doses we used were 0.027 mg/kg medetomidine and 0.38 mg/kg zolazepam-tiletamine. In contrast, medetomidine doses over 0.160 mg/kg have been used with ketamine in free-ranging lions (Quandt, 1992). Further, zolazepam-tiletamine alone at 0.6-8.3 mg/kg has successfully been used, which indicates a wide safety margin for these drugs (Stander & Morkel, 1991). In our study, even though the drug doses are very low, no lions required additional drug doses. However, spontaneous movements before reversal were observed in one lion 1 hr after darting when it was lifted in a sling to be weighed. The lion was left undisturbed for 10 min, after that it was possible to resume the procedure without additional drug dosing.

The predictable working time was a minimum of 1 hr and in four lions anaesthesia lasted over 2 hr. The predictable duration of anaesthesia is a major advantage for personnel safety, especially if anaesthetising several lions on the same occasion. However, handling that includes changing position of the animal, such as weighing or turning it over, should preferably take place early during

anaesthesia since moving the animal during the later part of anaesthesia could stimulate recovery.

After completion of the study, the developed drug protocol including medetomidine and a low dose of zolazepam-tiletamine is being used for anaesthesia of lions in Zimbabwe. Five free-ranging lions have successfully been anaesthetised with 4 mg medetomidine and 50 mg zolazepam-tiletamine. After administration of atipamezole, the lions were walking within 15 min. In addition, a whole pride of 10 lions have been anaesthetised at one occasion for translocation between game reserves (C. Wenham, personal communication). Four adult females were darted with a total dose of 6 mg medetomidine and 100 mg zolazepam-tiletamine whereas six cubs received 1 or 2 mg medetomidine and 30 or 50 mg zolazepam-tiletamine, depending on size. Time from darting until reversal with atipamezole was 6 hr. During this period, only one adult female required an additional drug dose due to signs of spontaneous recovery. At the final destination, atipamezole at 2.5 times the medetomidine dose was administered and the lions were walking within 15 min.

Anaesthesia and reversal with the drugs used in our study was excellent for free-ranging lions. Based on body weight, medetomidine at 0.030 mg/kg and zolazepam-tiletamine at 0.40 mg/kg can be recommended for 1-2 hour anaesthesia of an adult or subadult male or female lion. At low doses of zolazepam-tiletamine in combination with medetomidine, atipamezole can be administered already after 45 min of anaesthesia resulting in a rapid recovery.

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Practical advice

It is possible to use a dose of

- 4-6 mg medetomidine
- 50-80 mg zolazepam-tiletamine

for anaesthesia of an adult or subadult male or female free-ranging lion.

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III. Wolverines

Medetomidine in combination with ketamine rapidly induced anaesthesia in wolverines. Recumbency occurred within 5 ± 3 min (range 3-12 min) of darting in adult wolverines. One adult female wolverine required a second drug dose to become recumbent, probably because the initial dart injection was incomplete or subcutaneous.

Due to the potentiating effect of medetomidine, the dose of ketamine could be significantly reduced (35-80 %) compared to the ketamine doses reported by Hash & Hornocker (1980). However, the medetomidine doses used in adult wolverines in this study are high compared to doses used in most other wildlife species (Jalanka & Roeken, 1990).

During anaesthesia, two adult and five juvenile wolverines required supplemental drug doses due to signs of spontaneous recovery 10-41 min after drug administration. These juveniles received 5-8 mg/kg ketamine, whereas juveniles receiving 9-11 mg/kg ketamine needed no supplemental drug doses.

Physiological effects during anaesthesia

Elevated rectal temperatures were recorded in lions and wolverines. High rectal temperature was also measured in three long-tailed macaques but not in the other primate species. High ambient temperature, physical exertion during the darting procedure and manual restraint of an animal for drug administration can all lead to an elevated body temperature. Since body temperatures above 41°C can cause organ failure and be life-threatening (Thurmon *et al.*, 1996), it is important to monitor and stabilise the animal's temperature early during anaesthesia.

I. Primates

Respiratory and heart rates were stable throughout anaesthesia and were regarded as within the acceptable physiological range although individual variation occurred.

Body temperature decreased significantly over time and in three orangutans rectal temperature below 36 °C was recorded.

Temperature measurements with rectal and tympanic thermometers were in good agreement [ICC(2) = 0.88]. The tympanic thermometer was fast and simple to operate in adolescent and adult orangutans, but in younger orangutans and the smaller primate species the ear canal was too narrow. For accurate measurement it is important that the thermometer is in close contact with the tympanic membrane and, therefore, the conformation of the ear canal limits the use in different animals (Hammond & Walters, 1999).

Systolic arterial blood pressure decreased significantly in adult orangutans, which is in agreement with medetomidine use in other primate species (Capuano III *et al.*, 1999; Horne, 2001). Values below 80 mmHg were recorded in four orangutans. To prevent hypotension in orangutans anaesthetised with medetomidine-zolazepam-tiletamine it is advisable to administer i.v. fluid, especially during long procedures.

Limited data for SpO_2 were collected because the only available pulse oximeter at the time and place for the study required electricity, which was not always available. SpO_2 was measured in four orangutans (range 88-94%), in two long-tailed macaques (range 94-99%) and in two pig-tailed macaques (range 88-99%). Values below 90%, which could indicate hypoxaemia, were recorded in two orangutans and in one short-tailed macaque. Low SpO_2 values may be an artefact due to alpha$_2$-agonist induced peripheral vasoconstriction or it may indicate true hypoxemia due to impaired pulmonary gas exchange. Since hypoxemia might occur in primates anaesthetised with medetomidine and zolazepam-tiletamine, oxygen supplementation could be valuable.

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II. Lions

Respiratory and heart rates, SpO$_2$ and rectal temperature are presented in Figure 7. Heart rates recorded in the present study were similar to those in lions immobilised with higher doses of medetomidine (0.100 mg/kg) and ketamine (3-4 mg/kg) and lower than during immobilisation with zolazepam-tiletamine alone (Stander & Morkel, 1991; Quandt, 1992). Rectal temperatures over 40°C were recorded in four lions. Respiratory rate was similar to that in lions immobilised with zolazepam-tiletamine alone (Stander & Morkel, 1991). SpO$_2$ was recorded in 10 lions and ranged between 85-96%; values below 90% were recorded in two lions.

Arterial blood values for PaO$_2$, SaO$_2$, pH and lactate in lions remained within the reference ranges reported for domestic cats for samples analysed on the i-STAT$^®$ analyser (G. Hallgren, Abbott Scandinavia AB, pers. comm., 2005). In three lions pH values below 7.35 were recorded. These lions had decreased BE and HCO$_3$, indicating a metabolic acidosis, and a slightly decreased PaCO$_2$, which probably indicates some respiratory compensation for the acidosis. The highest lactate concentration measured was 1.83 mmol/L. In contrast, lactate measured 3.44 mmol/L in an adult female lion immobilised with 600 mg zolazepam-tiletamine alone and the quality of anaesthesia was poor with muscle rigidity and athetoid movements (slow involuntary movements) of the legs (Fahlman, unpublished data).
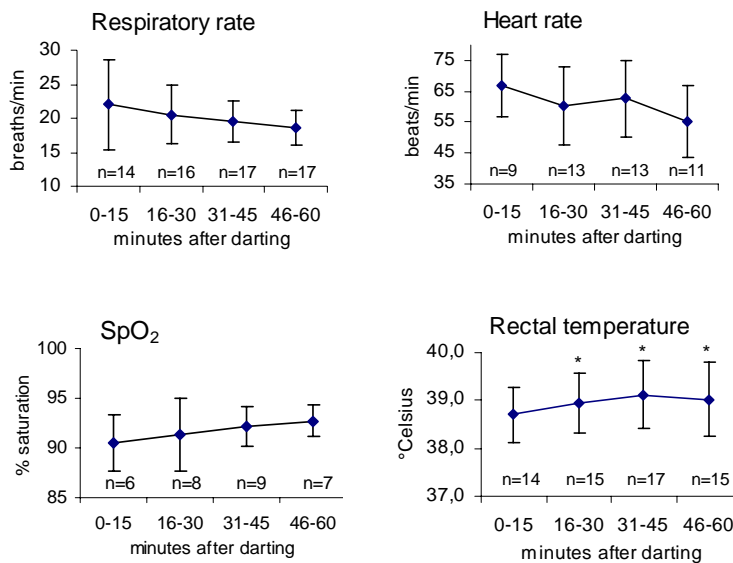

Fig. 7. Respiratory and heart rates, haemoglobin oxygen saturation (SpO$_2$) and rectal temperature in free-ranging lions anaesthetised with medetomidine-zolazepam-tiletamine. Values expressed as mean ± SD. * indicates a significant difference from the first time period (0-15 min).

III. Wolverines

This study is the first to report detailed baseline data on physiological, haematological and plasma parameters in free-ranging wolverines. Several parameters differed significantly between adult and juvenile wolverines, which could be due to capture method, anaesthetic drugs and age. Initially, marked hyperthermia and lactic acidosis developed mainly in adult wolverines. The highest rectal temperature (41.0 °C) and lactate concentration (6.8 mmol/L) and the lowest pH (7.12) were measured in adult wolverines.

Although PaO_2 (temperature corrected values) was higher in adults than in juveniles, this result was related to the higher body temperature measured in adults since blood gases measured by the i-STAT® analyser at 37°C did not differ. Between 15-30 min after drug injection, the PAO_2 was 93 ± 20 mmHg and $P(A-a)O_2$ was 36 ± 9 mmHg, respectively, which indicates an impaired pulmonary gas exchange in both adult and juvenile wolverines. The $PaCO_2$ values suggest that ventilation was adequate during anaesthesia and that hypoventilation is an unlikely cause of the decrease in PaO_2. Altitude was responsible for approximately 20% of the decrease in arterial oxygenation whereas the major contribution is suggested to be intrapulmonary causes, such as ventilation-perfusion mismatch, shunt or diffusion limitation of oxygen. Decreased arterial oxygenation has been observed simultaneously with an increase in pulmonary vascular pressure in horses sedated with alpha$_2$-agonists (Marntell *et al.*, 2005). The increase in pulmonary arterial blood pressure is suggested to disturb the matching of the pulmonary ventilation and perfusion resulting in a decreased PaO_2 (Benumof & Wahrenbrock, 1975). Therefore, if similar changes occur in wolverines anaesthetised with medetomidine-ketamine, it would be interesting to evaluate if a lower medetomidine dose could improve arterial oxygenation. Supplemental oxygen might be beneficial if ventilation perfusion mismatch exists.

Glucose concentrations and the haematocrit were significantly higher in adults (range 7.1-19.7 mmol/L and 26-49%) than in juveniles (range 4.4-12.6 mmol/L and 27-33%), which may be drug-related or a result of capture stress or both.

During anaesthesia, rectal temperature, heart rate and lactate decreased significantly, whereas haemoglobin oxygen saturation, pH, partial pressure of arterial carbon dioxide and base excess increased. The acid-base status improved over time and was not further impaired by anaesthesia. No mortalities occurred during or within ten weeks after anaesthesia.

Recovery

I. Primates

Atipamezole was administered 23-54 min after initial drug injection or the last supplemental drug dose. First signs of recovery were observed within 3-27 min after reversal and recovery were smooth and calm in orangutans, gibbons and long-tailed macaques. The two gibbons were fully recovered 11 and 20 min after

reversal, respectively. Time to full recovery could not always be determined in orangutans because after regaining consciousness they often sat still in the cage and were calm and inactive. However, on four occasions the orangutans were fully recovered and active within 12-42 min after reversal and on nine occasions the orangutans were still slightly sedated 8-38 min after reversal. In the pig-tailed macaques, muscle tremor and excitement were observed after reversal, which could be due to a tiletamine residual effect or a too high dose ratio of atipamezole relative to medetomidine or both.

II. Lions

The earliest atipamezole was administered was 46 min after darting, resulting in the lion walking steadily within 20 min. For two lions, we delayed administration of atipamezole until 2 hr and 45 min after darting to determine whether spontaneous recovery would occur before reversal, but the lions remained anaesthetised until reversal.

Recovery was smooth and calm without excitement in all lions. The first signs of recovery were blinking or head movements, followed by the lions lifting their heads and turning onto sternal recumbency (Table 4). The lions stayed sternal until they were able to get up at the first attempt and thereafter walk in a directed manner although some showed mild hind-leg ataxia for a couple of minutes.

Table 4. Recovery times[a] in free-ranging lions after medetomidine-zolazepam-tiletamine anaesthesia and reversal with atipamezole.

Recovery	Mean	Range
1st sign of recovery	14 min	5-30 min
Head up and sternal	20 min	5-47 min
Standing	33 min	8-109 min
Walking [b]	39 min	8-166 min

[a] Time after i.m. administration of atipamezole.
[b] Lions anaesthetised with zolazepam-tiletamine doses >1 mg/kg (*n*=3) had prolonged recoveries and did not walk until 50-166 min after reversal.

We gradually decreased the zolazepam-tiletamine dose used in combination with medetomidine according to observed reactions during recovery. Three lions were anaesthetised with zolazepam-tiletamine doses of >1 mg/kg and they had smooth but prolonged recoveries and did not walk until 50-166 min after reversal. With zolazepam-tiletamine doses of <1 mg/kg, nine lions were up walking within 8-26 min after reversal. In contrast, recovery in lions immobilised with zolazepam-tiletamine alone is often prolonged and can be rough since it is common that the lions repeatedly try to get up before their sense of balance is restored (King *et al.*, 1977; Stander & Morkel, 1991). Free-ranging lions anaesthetised with medetomidine-ketamine are reported to walk in a controlled manner within 10 min of i.v. administration of either atipamezole or yohimbine (Quandt, 1992). Even though recovery is rapid when antagonists are given i.v., abrupt changes in cardiovascular function can occur and some animals become excited or overalert

(Jalanka & Roeken, 1990; Sinclair, 2003). Therefore, i.m. administration is recommended to allow for gradual awakening and to minimise changes in blood pressure, heart rate and cardiac output.

In domestic cats and wild felids, atipamezole doses from 2.5 to 5 times the medetomidine dose have been used but the higher doses can cause severe tachycardia in domestic cats and captive lions (Jalanka & Roeken, 1990a; Verstegen *et al.*, 1991; Grobler, 1997; Tomizawa *et al.*, 1997; Bengis & Keet, 2000; Kreeger *et al.*, 2002). In this study, we decreased the atipamezole dose from 5 times the medetomidine dose to 2.5 times since it should reduce the risk of tachycardia and it proved to be adequate for reversal. Furthermore, a lower atipamezole dose reduces cost, which can be an important consideration for immobilisations undertaken in developing countries, where most free-ranging lions occur.

All lions anaesthetised in this study were alive one year post-anaesthesia, except four male lions that were shot by the safari hunting industry.

III. Wolverines

Atipamezole was injected 76 ± 8 min after darting with medetomidine-ketamine in adults and 68 ± 17 min after hand-injection of the initial drugs in juveniles. First sign of recovery was recorded within 15 min after reversal in 15 wolverines. No mortalities occurred during or within 10 weeks after anaesthesia.

Methodological considerations

The i-STAT® analyser that was used for measurement of arterial blood parameters has been validated with good accuracy and precision for dogs and horses and for humans – even in space! (Smith *et al.*, 1997; Sediame *et al.*, 1999; Silverman & Birks, 2002; Verwaerde *et al.*, 2002). Although it has not been validated in lions or wolverines, the development of the i-STAT® analyser has enabled these studies and similar studies in other species of free-ranging wildlife in remote areas (Horne *et al.*, 2001; Cattet *et al.*, 2003a). The advantages of the i-STAT® are that it is battery driven, it weighs less than 0.5 kg and it only requires a very small amount of blood (60 μl), which it can analyse in less than 2 min. A disadvantage of the i-STAT® is that it is highly sensitive to ambient temperature and weather conditions. Its optimum operating temperature range (+16 to +30 °C) is far from optimal when working with free-ranging wildlife in their natural environment. It was cumbersome to store the i-STAT® within the correct temperature range in Zimbabwe, where ambient temperature reached +34 °C, and in Sweden, where the lowest temperature was -5 °C during the study period. When the i-STAT® was operated after a rain shower in Zimbabwe, it failed to work due to high humidity in the air. Another difficulty during field work is that the i-STAT® cartridges shall be stored refrigerated, or else they must be used within two weeks. However, with the i-STAT® immediate analysis of blood parameters, including blood gases which are sensitive to storage, can be carried out in the field. This enables research studies that are valuable for evaluation of capture and anaesthesia in free-ranging wildlife.

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Conclusions

Anaesthetic methods were developed and evaluated for selected species of wild carnivores and primates. By combining medetomidine with a dissociative anaesthetic, low drug doses could be used. Modern portable equipment enabled analysis of arterial blood samples during extreme field conditions.

Study I and II:

- Effective anaesthetic protocols were developed by combining medetomidine and zolazepam-tiletamine for use in four species of primates and for lions. Advantages include a small drug volume suitable for darting and a rapid and smooth induction. The duration of anaesthesia was predictable in lions but varied in some primates.

- Respiratory and heart rates were stable throughout anaesthesia. Rectal temperature decreased in primates and increased in lions during anaesthesia. No severe disturbances in blood gases or acid-base balance were measured in arterial blood samples collected from five lions.

- The potentiating effect of medetomidine made it possible to use low doses of the dissociative anaesthetic. Thus, anaesthetic reversal with atipamezole resulted in a smooth and calm recovery.

Study III:

- Capture and medetomidine-ketamine anaesthesia affected physiological, haematological and plasma parameters in wolverines. Hyperthermia, metabolic acidosis and impaired arterial oxygenation were evident. Differences in several parameters were observed between adult and juvenile wolverines, which could be due to capture method, drug doses and age.

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