Reversible anaesthesia of free-ranging lions (*Panthera leo*) in Zimbabwe

Å Fahlman[a*], A Loveridge[b], C Wenham[c], C Foggin[d], J M Arnemo[e,f] and G Nyman[a]

ABSTRACT

The combination of medetomidine-zolazepam-tiletamine with subsequent antagonism by atipamezole was evaluated for reversible anaesthesia of free-ranging lions (*Panthera leo*). Twenty-one anaesthetic events of 17 free-ranging lions (5 males and 12 females, body weight 105–211 kg) were studied in Zimbabwe. Medetomidine at 0.027–0.055 mg/kg (total dose 4–11 mg) and zolazepam-tiletamine at 0.38–1.32 mg/kg (total dose 50–275 mg) were administered i.m. by dart injection. The doses were gradually decreased to improve recovery. Respiratory and heart rates, rectal temperature and relative haemoglobin oxygen saturation (SpO_2) were recorded every 15 min. Arterial blood samples were collected from 5 lions for analysis of blood gases and acid–base status. For anaesthetic reversal, atipamezole was administered i.m. at 2.5 or 5 times the medetomidine dose. Induction was smooth and all lions were anaesthetised with good muscle relaxation within 3.4–9.5 min after darting. The predictable working time was a minimum of 1 h and no additional drug doses were needed. Respiratory and heart rates and SpO_2 were stable throughout anaesthesia, whereas rectal temperature changed significantly over time. Atipamezole at 2.5 times the medetomidine dose was sufficient for reversal and recoveries were smooth and calm in all lions independent of the atipamezole dose. First sign of recovery was observed 3–27 min after reversal. The animals were up walking 8–26 min after reversal when zolazepam-tiletamine doses <1 mg/kg were used. In practice, a total dose of 6 mg medetomidine and 80 mg zolazepam-tiletamine and reversal with 15 mg atipamezole can be used for either sex of an adult or subadult lion. The drugs and doses used in this study provided a reliable, safe and reversible anaesthesia protocol for free-ranging lions.

Key words: anaesthesia, atipamezole, immobilisation, lion, medetomidine, *Panthera leo,* reversible, tiletamine, zolazepam.

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INTRODUCTION

The African lion (*Panthera leo*) is classified as vulnerable on the IUCN Red List and the future of the species is uncertain. Africa's free-ranging lion population may have halved in the last 20 years and today there are less than 30 000 individuals left in the wild[1,14]. The geographical range of free-ranging lions has declined due to loss of habitat and prey base and because of persecution. Today, most lions live in isolated protected populations with increased risk of inbreeding. The current status of lions as vulnerable and conservation-dependent could change to endangered by 2030 if pre-emptive measures are not taken to halt declines[4].

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. When anaesthetising free-ranging lions it is important to use reliable methods that expose the animals to minimal stress. Rapid induction is critical to avoid losing sight of the animal in dense bush or in darkness and to enable early physiological monitoring. A quick recovery is important for the animal to regain mobility and ability to defend itself.

Free-ranging lions are commonly anaesthetised with a dissociative anaesthetic such as ketamine or tiletamine in combination with a sedative, a tranquilliser, or both. Frequently used sedatives are the alpha-2-adrenoceptor agonists, *e.g.* medetomidine and xylazine. Ketamine combined with xylazine has the disadvantage that a large volume of ketamine is required for an effective dose, which can necessitate repeated drug administration[8,23]. Further, induction times over 10 min have been reported[8,20]. The ketamine dose can be reduced markedly if ketamine is combined with medetomidine, which is a potent and highly specific alpha-2-adrenoceptor agonist. Induction is rapid, muscle relaxation is good and anaesthesia can be reversed with the alpha-2-adrenoceptor antagonist atipamezole[15]. Possible side-effects include bradycardia, changes in blood pressure and vomiting. Only subtle signs precede recovery from medetomidine-ketamine anaesthesia and close monitoring towards the end of anaesthesia is necessary to prevent sudden, unexpected awakening[2,15]. Tiletamine is only available in combination with the benzodiazepine tranquilliser zolazepam, which improves muscle relaxation and prevents convulsions, and is sold under the trade names Zoletil®, Tilest® and Telazol® as dry substance. This drug combination can be made up to highly concentrated solutions and hence the delivery volume is low and small darts can be used. The induction is rapid and zolazepam-tiletamine has a wide safety margin, but major disadvantages are prolonged recoveries and lack of a reversal agent for tiletamine. The use of medetomidine in combination with zolazepam-tiletamine (from here on referred to as MZT) in free-ranging lions has only been briefly described[2,7]. Our intent in using the MZT combination was to decrease the zolazepam-tiletamine dose and, when reversing the effects of medetomidine with atipamezole, avoid prolonged recovery induced by zolazepam-tiletamine. The aim of this study was to evaluate the anaesthetic and cardiorespiratory effects of the combination of MZT and atipamezole for reversible anaesthesia of free-ranging lions.

MATERIALS AND METHODS

Animals, drugs, and darting equipment

Twenty-one anaesthetic events of 17 free-ranging lions (5 males and 12 females) were studied in Hwange National

[a]Section of Anaesthesiology and Emergency and Critical Care, Department of Clinical Sciences, Faculty of Veterinary Medicine and Animal Science, Swedish University of Agricultural Sciences, PO Box 7018, SE-750 07 Uppsala, Sweden.

[b]Wildlife Conservation Research Unit, Oxford University, Tubney House, Abingdon Rd, Abingdon OX13 5QL, UK.

[c]Malilangwe Trust, Private Bag 7085, Chiredzi, Zimbabwe.

[d]Wildlife Veterinary Unit, Division of Livestock and Veterinary Services, BW 6238 Borrowdale, Harare, Zimbabwe.

[e]Section of Arctic Veterinary Medicine, Department of Food Safety and Infection Biology, Norwegian School of Veterinary Science, PO Box 6204, NO-9292, Tromsø, Norway and [f]Faculty of Forestry and Wildlife Management, Evenstad, NO-2480 Koppang, Norway.

*Author for correspondence.
E-mail: asa_fahlman@hotmail.com

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Park and Malilangwe Trust in Zimbabwe between 2001 and 2005. The lions were adults (>4 yr) or subadults (2–4 yr) and body weight ranged between 169 and 211 kg in males and 105 and 165 kg in females. Anaesthesia was conducted for fitting of radio-collars or ear tags, or for testing for bovine tuberculosis (*Mycobacterium bovis*). Testing for tuberculosis necessitated anaesthesia on 2 separate occasions approximately 72 h apart. All individuals were healthy, based on physical examination during anaesthesia. During each anaesthetic event, blood samples were taken for storage of serum.

For anaesthesia, medetomidine hydrochloride (Zalopine® 10 mg/mℓ, Orion Pharma Animal Health, Espoo, Finland) was used in combination with zolazepam and tiletamine (Zoletil® 100, Virbac RSA , Midrand, South Africa). Zoletil powder was mixed with sterile water to a drug concentration of 200 mg/mℓ (100 mg/mℓ zolazepam hydrochloride and 100 mg/mℓ tiletamine hydrochloride). The drug doses were gradually decreased according to observed reactions. The initial intent was to administer 0.06 mg/kg medetomidine in combination with 1.45 mg/kg zolazepam-tiletamine, based on estimated body weight. These doses were determined by extrapolating published doses of MZT in captive lions and zolazepam-tiletamine in wild lions[17,20], combined with the authors' experiences of using MZT in other species. For the 1st 6 lions, drug doses were prepared after estimation of the body weight once the lions were sighted. Thereafter, lions were given standard 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. All lions were weighed during anaesthesia and the actual drug doses were calculated in mg/kg.

Five darting procedures were carried out in the midday and 16 in the evening. Ambient temperature ranged from 15.0–33.5 °C. Baits chained to a tree were used for 15 darting procedures and twice the lions were darted on their own kill. On 4 occasions previously collared individuals were located by radio-tracking and attracted to the darting vehicle by playing a tape-recording of a squealing pig. Most lions were calm and either lying down or eating when darted, though 5 were more alert or wary, standing or walking. Up to 3 lions were darted and kept under anaesthesia on the same occasion. The drugs were delivered in 1.5 or 3.0 mℓ dart syringes with 1.5 × 25 mm or 2.0 × 40 mm collared needles (Dan-Inject SA, Skukuza, South Africa). The darts were fired from a dart rifle (Dan-Inject CO_2 Injection Rifle Model JM Special, Dan-Inject SA) from a vehicle at distances of 10–33 m. The distance was measured with a range finder. Dart impact site was rated as poor (s.c., near bone, or in small muscle group), good (i.m.) or excellent (deep i.m. in large muscle group).

For reversal of the effects of medetomidine, atipamezole hydrochloride (Antisedan® 5 mg/mℓ, Orion Pharma Animal Health, Espoo, Finland) was administered at 5 times the dose of medetomidine during the 1st 8 anaesthetic events, and thereafter at 2.5 times the medetomidine dose. Atipamezole was injected by hand in the shoulder muscle and if the drug volume exceeded 5 mℓ it was divided into 2 different injection sites. The time for reversal was determined during each anaesthetic event, depending on the procedure being performed and the number of lions anaesthetised at the same time. In 2 lions anaesthetised with the lower MZT dose, atipamezole was not administered until 2 h and 45 min after darting in order to determine whether spontaneous recovery would occur. Long-term survival was followed-up post-anaesthesia by radio-tracking.

Monitoring

Times from darting to 1st sign of drug effect and to recumbency (induction time) were recorded. The distance the lion moved from darting until recumbency was estimated. On approach, lions were blindfolded and positioned in lateral recumbency in the shade. Physiologic parameters were recorded every 5–15 min and data were averaged into 15-min intervals. Respiratory rate was monitored by observation of chest movements and rectal temperature was monitored with a digital thermometer with continuous reading (Welch Allyn Diatec 600, Welch Allyn, Skaneateles Falls, New York, USA). If the rectal temperature reached 39 °C, the animal was cooled with water and fanned. Relative haemoglobin oxygen saturation (SpO_2) was monitored continuously by pulse oximetry with the pulse oximeter probe attached to the tongue (Nellcor NPB-40 Handheld Pulse Oximeter, Nellcor Inc., Pleasanton, California, USA, or Tuffsat® Pulse Oximeter, Datex-Ohmeda Inc., Madison, Wisconsin, USA). Heart rate was monitored by pulse oximetry, by palpation of peripheral pulse or by auscultation of the heart. Muscle relaxation was assessed subjectively by control of muscular tone in an extremity and the jaw. Capillary refill time was measured and presence or absence of the palpebral reflex was assessed. Time from darting until injection of atipamezole was recorded. Times from injection of atipamezole until 1st sign of recovery, head up, sternal, standing and walking were also recorded.

Arterial blood samples were obtained from 5 lions for analysis of blood gases, acid-base status and selected haematological and plasma parameters. One to 3 samples were collected from each lion between 13 and 65 min after darting. The samples were collected anaerobically from the femoral artery using 21-gauge needles and self-filling arterial syringes with heparin (PICO™70, Radiometer Copenhagen, Denmark). The femoral pulse was palpated and the needle was inserted percutaneously into the artery, confirmed by pulsating blood. Firm pressure was applied to the sample site for 5 min post-sampling to avoid bleeding. The samples were processed immediately in the field using a portable analyser and cartridges (i-STAT®1 Portable Clinical Analyzer, and i-STAT® cartridges CG4+, 6+, CG8+, Abbott Laboratories, Abbott Park, Illinois, USA). The analyser provided measured values for pH, partial pressure of carbon dioxide ($PaCO_2$), partial pressure of oxygen (PaO_2), lactate, haematocrit, sodium, potassium, chloride, urea, ionised calcium and glucose. Blood gas values and pH were corrected to the rectal temperature. Calculated values were provided for actual base excess (BE), actual bicarbonate (HCO_3), arterial haemoglobin oxygen saturation (SaO_2) and haemoglobin.

Statistical analysis

Respiratory and heart rates, rectal temperature and SpO_2 were analysed by repeated measures analysis of variance (Procedure Mixed, SAS® System 9.1, SAS Institute, Cary, North Carolina, USA) and the *P*-value was adjusted using a Bonferroni correction. For lions anaesthetised twice, only the 1st anaesthetic event was included in the analyses. *P*-values <0.05 were considered significant.

RESULTS

In all the lions, MZT rapidly induced anaesthesia and no additional doses were needed. Medetomidine was given at 0.027–0.055 mg/kg (total dose 4–11 mg, mean dose 0.043 mg/kg) and zolazepam-tiletamine at 0.38–1.32 mg/kg (total dose 50–275 mg, mean dose 0.69 mg/kg). Only 3 lions received zolazepam-tiletamine doses >1 mg/kg. First sign of drug effect was observed within 1.8–7.7 min (mean 3.4 min) and recumbency within 3.4–9.5 min (mean 5.9 min) after darting. The induction period was smooth and the most common sign of drug effect for lions standing or walking

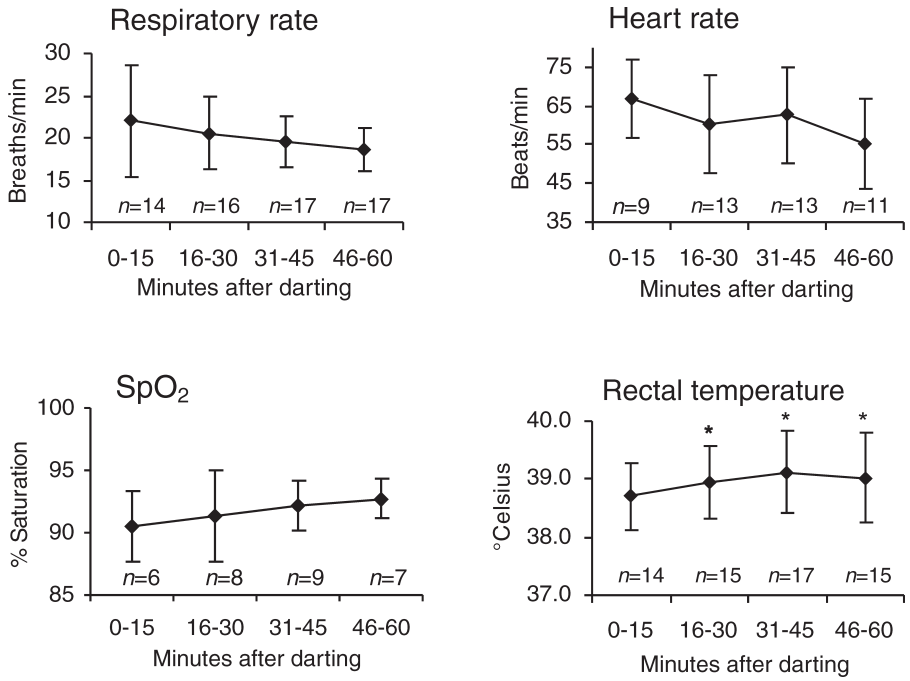

Fig. 1: **Respiratory and heart rates, relative haemoglobin oxygen saturation** (SpO_2) **and rectal temperature in free-ranging lions anaesthetised with medetomidine-zolazepam-tiletamine. Values expressed as mean ± SD. * Indicates a significant difference from the 1st time period** (0–15 min)**.**

Table 1: **Haematological and plasma parameters (range) in five free-ranging lions immobilised with medetomidine-zolazepam-tiletamine.**

Parameter	*n*	Range
Haematocrit (%)	5	34–41
Haemoglobin (g/dℓ)	5	12–14
Sodium (mmol/ℓ)	5	146–153
Potassium (mmol/ℓ)	5	3.3– 3.8
Ionised calcium (mmol/ℓ)	3	1.23–1.34
Chloride (mmol/ℓ)	3	117–128
Urea (mmol/ℓ)	3	17.2–19.5
Glucose (mmol/ℓ)	5	3.6–14.9

was that they started to sway. Baited lions stopped eating and had a glassy stare or lowered their heads. All lions became recumbent within sight of the darting vehicle, except 1 wary lioness which ran out of sight and was tracked and found recumbent 150 m away within 6 min after darting. Most lions that were darted while eating, or while being near a bait or a kill, stayed on the spot or moved less than 70 m. Five lions ran a short distance after darting and then walked away 150–300 m. Dart impact sites were the muscles of the neck or shoulder on 15 occasions, the front leg once, and the hindquarter 5 times. All dart impact sites were rated as good or excellent, except for the one in the muscle of the front leg which was poor, but the induction time was similar with all ratings. No dart failures were experienced.

Muscle relaxation was good based on the lack of muscle tone in the extremities and the ease of opening the jaw. In some lions, the jaw tone slightly increased after 1 h of anaesthesia. Capillary refill times were <2 sec. Palpebral reflex was initially sluggish or absent in most lions and towards the end of anaesthesia more prominent. However, in 3 lions the palpebral reflex was present throughout anaesthesia.

Serial recordings of respiratory and heart rates, SpO_2 and rectal temperature are presented as mean ± SD values in Fig. 1. Before darting, respiratory rates between 60 and 100 breaths/min were observed in 2 lions resting near a buffalo kill. During anaesthesia, respiratory rate ranged between 14 and 34 breaths/min and was stable in most lions although it decreased over time in 5 lions. Heart rate was stable throughout anaesthesia in all lions although individual variations occurred (range 39–84 beats/min). Rectal temperature changed significantly over time. It generally increased during the 1st 30 min of anaesthesia and thereafter declined slightly, although never below 37.6 °C. In 11 lions the rectal temperature increased over 39.0 °C and in 4 of those it reached 40.0 °C or higher despite cooling. During 10 of 21 anaesthetic events, SpO_2 was recorded. The SpO_2 was stable throughout anaesthesia and ranged between 85 and 96 %, although values below 90 % were recorded only in 2 lions. Individual arterial blood gases and acid-base status in 5 lions are presented in Fig. 2. Selected haematological and plasma parameters are presented in Table 1.

Spontaneous movement before reversal was observed in only 1 lion. The lion was weighed 1 h after darting and moved its head slightly while in the weighing sling. When the lion was taken out of the sling it got up, moved 3 m and lay down again. It was left undisturbed for 10 min when it was possible to resume TB testing and blood sampling without additional drug dosing. No lion reacted to minor painful stimuli such as blood sampling. No lion vomited but 1 male retched during recovery from its 1st anaesthetic event and also during induction the 2nd time it was anaesthetised.

Recoveries were smooth and calm without excitement in all lions. Atipamezole administered at 2.5 times the medetomidine dose was sufficient for reversal. When the time for reversal depended on the performed procedure, atipamezole was administered 46–140 min (mean 86 min) after darting. For 2 lions, the administration of atipamezole was delayed until 2 h and 45 min after darting. These lions did not show any signs of spontaneous recovery before reversal. In all lions, the 1st signs of recovery were blinking or head movements, which were observed within 5–30 min (mean 13.6 min) after injection of atipamezole. The animals subsequently lifted their heads and turned onto sternal recumbency within 5–47 min (mean 20 min) after reversal. The lions stayed sternal until they were able to get up at the 1st attempt and thereafter walk in a directed manner, although some showed mild hind-leg ataxia for a few minutes. Time to standing and walking ranged between 8 and 109 min (mean 33 min) and 8 and 166 min (mean 39 min), respectively, after reversal. The 3 lions anaesthetised with zolazepam-tiletamine doses of >1 mg/kg had smooth but prolonged recoveries and did not walk until 50–166 min after reversal. With zolazepam-tiletamine doses of <1 mg/kg, 9 lions were up walking within 8–26 min after reversal. Time to walking was not observed during midday anaesthesia of 2 lions because after becoming conscious they stayed in the shade where they had been reversed.

No anaesthesia-related mortalities occurred. All study animals were alive 1 year post-anaesthesia, apart from 4 male lions that were shot by the safari hunting industry in the Hwange area within 3–5 months of being anaesthetised.

DISCUSSION

The MZT combination was safe, effective and reliable for anaesthesia of free-ranging lions. The mean induction time with MZT was similar or quicker

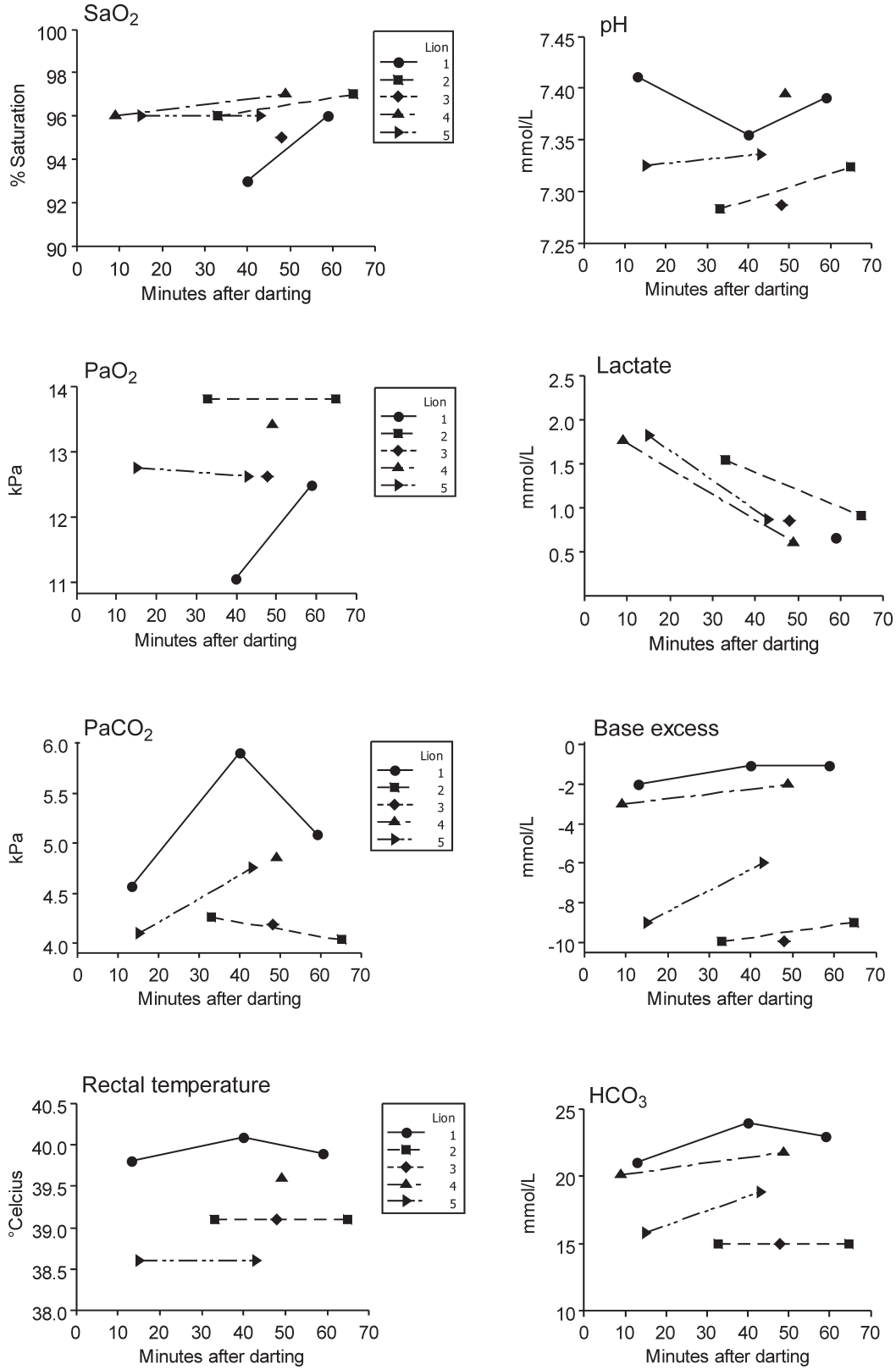

Fig. 2: **Arterial blood gases and acid-base status in 5 free-ranging lions anaesthetised with medetomidine-zolazepam-tiletamine. Blood gas values and pH are corrected to the rectal temperature. SaO_2 = arterial oxygen haemoglobin saturation, PaO_2 = partial pressure of oxygen, $PaCO_2$ = partial pressure of carbon dioxide, HCO_3 = bicarbonate.**

than observed in free-ranging lions immobilised with higher doses of zolazepam-tiletamine alone[10,15,20], with medetomidine-ketamine[15]or with xylazine-ketamine[8,20,23]. If multiple darts are needed for drug delivery of xylazine-ketamine, the induction time reported elsewhere is longer than with MZT[8].

Interestingly, very low doses of MZT were sufficient to anaesthetise free-ranging lions. This is due to the synergistic effect between medetomidine and zolazepam-tiletamine[11]. The lowest doses we used were 0.027 mg/kg medetomidine and 0.38 mg/kg zolazepam-tiletamine. Medetomidine doses over 0.160 mg/kg have been used with ketamine in free-ranging lions[15]. Zolazepam-tiletamine alone at 0.6–8.3 mg/kg has successfully been used, which indicates a wide safety margin. It is reported that the lower

zolazepam-tiletamine dose of 0.6 mg/kg does not induce anaesthesia but will make a lion immobile enough to enable administration of a 2nd drug dose by hand[20]. As shown in this study, even lower doses of zolazepam-tiletamine and medetomidine can be used in combination for field anaesthesia of lions. It is possible to load up a dart with a total dose of 6 mg medetomidine and 80 mg zolazepam-tiletamine and use it for either sex of an adult or subadult lion. If a female needs to be darted, a total dose as low as 4 mg medetomidine and 50 mg zolazepam-tiletamine can be used. Based on body weight, we recommend a dose of 0.030 mg/kg medetomidine and 0.40 mg/kg zolazepam-tiletamine for anaesthesia of an adult or subadult male or female lion.

Few studies report physiological parameters in detail during anaesthesia in free-ranging lions. 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[15,20]. Resting heart rate was estimated by allometric scaling for the actual body weights of the lions[18]. Bradycardia, if defined as a 20 % reduction below the resting heart rate[18], was recorded in 7 lions and is a common cardiovascular side-effect of medetomidine[9,19]. Medetomidine-induced bradycardia can be offset by the sympathomimetic properties of tiletamine[12,19], which probably was the case in the lions that did not develop bradycardia. Since rectal temperature initially increased in all lions, it is important to monitor body temperature throughout anaesthesia to detect changes and prevent hyperthermia. In hot climates lions pant to cool themselves, but this response is depressed during anaesthesia which increases the risk of hyperthermia[23]. Respiratory rate with MZT was similar to that in lions immobilised with zolazepam-tiletamine alone[20]. Haemoglobin oxygen saturation was not recorded during 11 anaesthetic events due to logistics or failure of the pulse oximeters to obtain a reading. Poor performance of pulse oximeters may be due to reduced peripheral blood flow because of vasoconstriction, hypotension, hypovolaemia or hypothermia[16]. Medetomidine-induced vasoconstriction might be a reason why measurement of SpO_2 failed in some lions in this study. Accuracy of pulse oximeters and failure to produce a reading can vary widely between different models of pulse oximeters as well as between different species[13]. Arterial blood values for PaO_2, SaO_2, pH and lactate remained within the reference ranges reported for domestic cats for samples analysed on the i-STAT®1 analyser (G Hallgren, Abbott Scandinavia AB, pers. comm., 2005). The 3 lions with the lowest pH values had decreased BE and HCO_3, indicating a metabolic acidosis, and slightly decreased $PaCO_2$, which probably indicates some respiratory compensation of the acidosis. Since lactate levels and anion gap, calculated as $([Na^+]+[K^+]) - ([Cl^-]+[HCO_3^-])$, were within normal limits for domestic cats, these parameters did not contribute to the metabolic acidosis. Similar acid-base status has been documented in captive Siberian tigers (*Panthera tigris altaica*) anaesthetised with medetomidine or xylazine in combination with midazolam and ketamine, but no explanation for the change was identified[6]. Lions immobilised with zolazepam-tiletamine also experienced metabolic acidosis with some respiratory compensation[3,15]. Lions immobilised with medetomidine-ketamine experienced a mixed metabolic and respiratory acidosis, resulting in pH levels down to 7.16[15]. In domestic cats, catabolism of dietary proteins produces acids, primarily from metabolism of sulphur-containing amino-acids, which contribute to metabolic acidosis[5]. Domestic cats as well as wild felids are strictly carnivorous. It is possible that metabolic acidosis in wild felids is a normal occurrence that is correlated to food intake.

In this study, no life-threatening anaesthetic side-effects occurred in any animals. On the contrary, side-effects such as apnea and vomiting have been reported in free-ranging lions anaesthetised with medetomidine-ketamine or xylazine-ketamine[8,15]. Although lions in this study were monitored by radio-tracking after recovery, it was not possible to record any side-effects after the lions had recovered and left the capture area. The combination of MZT was safely used for repeated anaesthesia 3 days apart.

With our MZT doses, the predictable working time was a minimum of 1 h and in 4 lions anaesthesia lasted over 2 h. The predictable duration of anaesthesia without need for additional doses is a major advantage for personnel safety, especially when 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 on during anaesthesia. Moving the animal during the later part of anaesthesia could stimulate recovery, as experienced in 1 lion in this study. In comparison, the mean duration of immobilisation with medetomidine-ketamine in free-ranging lions is 1.3 h and spontaneous recovery can occur preceded only by unclear signs, such as deeper respiration and increased jaw tension[15]. Immobilisation of lions with zolazepam-tiletamine alone can last over 4 h, depending on the dose. Recoveries are often prolonged and can be rough since the lions often repeatedly try to get up before their sense of balance is restored[10,20]. Therefore, MZT and subsequent administration of atipamezole were shown to be a better alternative. We gradually decreased the zolazepam-tiletamine dose used in combination with medetomidine according to observed reactions during recovery. Most lions that received the lower MZT doses were up walking within 8–30 min of atipamezole injection. Atipamezole effectively shortened recovery from MZT anaesthesia but the rate of recovery, irrespective of atipamezole dose, varied between individuals. This individual variation is in agreement with spontaneous recovery from zolazepam-tiletamine anaesthesia, which depends on age, health status and other factors[12]. The earliest atipamezole was administered in this study was 46 min after darting, resulting in the lion walking steadily within 20 min, whereas later administration resulted in either quicker or slower recoveries. 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[15]. In free-ranging lions immobilised with xylazine-ketamine, recovery was shortened after administration of tolazoline (a combined alpha-1 and alpha-2-adrenoceptor antagonist), although when tolazoline was given i.v. some lions were recovering as it was injected[23]. Even though recovery is rapid when antagonists are given i.v., abrupt changes in cardiovascular function can occur and some animals become excited or over-alert[9,19]. Therefore, i.m. administration is recommended to allow for gradual awakening and to minimise the changes in blood pressure, heart rate and cardiac output.

The recommended atipamezole dose is 5 times the medetomidine dose when given to domestic dogs and a number of wildlife species[9,11,19]. 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[2,7,9,11,21,24]. In this study, we changed the atipamezole dose from 5 times the medetomidine dose to 2.5 times since it should reduce the risk of tachycardia and was adequate for reversal. Also, a lower atipamezole dose reduces cost,

which can be an important consideration for immobilisations undertaken in developing countries, where most free-ranging lions occur.

Since atipamezole only reverses the effects of medetomidine in the MZT combination, the hind-leg ataxia that was observed in a few lions may have been due to residual zolazepam. Zolazepam has a long duration of action and in domestic cats the plasma half-life is 4.5 h, which is longer than for tiletamine[12]. It has been shown in free-ranging lions and captive cheetahs that recovery from zolazepam-tiletamine anaesthesia is calmer and shortened if a benzodiazepine antagonist such as flumazenil or sarmazenil is used[20,22]. In lions anaesthetised with MZT, the addition of a benzodiazepine antagonist to the reversal protocol would probably minimise ataxia during recovery by reversing the effects of zolazepam. However, ataxia was uncommon in our study animals and another reversal agent would add on extra cost.

In conclusion, MZT at the doses used in this study is a reliable and safe anaesthesia protocol for free-ranging lions. Advantages of MZT include a small drug volume for darting, rapid and smooth induction, predictable duration of anaesthesia and ability to reverse the anaesthesia. Based on body weight, medetomidine at 0.030 mg/kg and zolazepam-tiletamine at 0.40 mg/kg are recommended for anaesthesia of an adult or subadult male or female lion. Atipamezole at 2.5 times the medetomidine dose is sufficient for reversal. Physiological parameters should be monitored throughout anaesthesia to be able to detect changes and prevent abnormalities such as hyperthermia.

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