Current practice for the chemical immobilisation of non-domestic feline species: An online survey study

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Abstract

Background: Safe chemical immobilisation of wild felids is essential for both conservational management and clinical purposes. However, little is known about drug protocols and current practice.

Methods: This study was designed as an online survey based on a questionnaire. Descriptive/correlation statistics and analysis of proportions were used for data analysis.

Results: The preferred immobilisation technique was the use of darts (37% of the respondents), while the most popular drug combination was a mixture of benzodiazepines, alpha-2 adrenoreceptor agonists and dissociative anaesthetics (27%). The inclusion of ketamine in the drug mixture was associated with a quicker anaesthetic onset, as estimated by the participants (p < 0.001). Common complications were prolonged recovery (46%), bradycardia (35%), hypoventilation (32%), hypothermia (26%) and arousal (26%). Commonly encountered problems were inappropriate equipment (39%), lack of suitable drugs (27%) and inadequate knowledge of species-specific pharmacology (29%) and physiology (24%).

Limitations: Incomplete adherence to the Checklist for Reporting Results of Internet E-Surveys is acknowledged.

Conclusions: Drug protocols including both alpha-2 adrenoreceptor agonists and dissociative anaesthetics are preferred in wild felids, and the inclusion of ketamine may be useful to achieve a quick onset. Equipment/drug availability and species-specific knowledge are potential areas of improvement to improve wild felid anaesthesia.

KEYWORDS

cheetahs, free-ranging wild cats, lions, tigers, wildlife anaesthesia and sedation, zoo/captive felids

INTRODUCTION

Chemical immobilisation is used in wild feline species for various purposes. In captive animals, anaesthesia may be required to allow physical examination, collection of biological samples for diagnostic/research purposes and clinical treatment of injured individuals.1 In free-ranging felids, conservation management of ecosystems is a more common reason, and chemical immobilisation is essential for operations such as moving individual subjects between populations to maintain genetic diversity and attaching radiotracking devices for research purposes.2

It is essential to perform immobilisation of potentially dangerous animals, both efficiently and safely, to decrease the risk of peri-anaesthetic complications and the stress of the animals while minimising the professional risk for the personnel involved. However, there is a paucity of literature with respect to safe anaesthesia management in non-domestic feline species, with a very few reports focused on a limited number of species, including lions, tigers, serval cats and cheetahs.3–11 Species-specific drug protocols are often reported in veterinary textbooks for practitioners, either based on the authors’ clinical experience and anecdotal reports or extrapolated from studies.
conducted in other animal species.\textsuperscript{12,13} Traditionally, combinations of alpha-2 adrenoreceptor agonists and dissociative anaesthetics have been used and reported to be successful in several species of exotic carnivores, including felids; however, data concerning pharmacokinetics and pharmacodynamics are generally lacking with, at present, only one research work published in tigers and leopards.\textsuperscript{8}

The aim of this study was to gain a greater understanding of current practice for the immobilisation of non-domestic wild cats by gathering information, from colleagues who routinely deal with these animal species, on the preferred and most effective drug protocols and their effects, as well as on the most frequently encountered complications.

**MATERIALS AND METHODS**

**Study design**

This observational study was designed as an online survey based upon a questionnaire developed by the authors with dedicated software (Qualtrics XM, 2019) and accessed online via a hyperlink. The questionnaire was designed in adherence with the Checklist for Reporting Results of Internet E-Surveys (CHERRIES guidelines).\textsuperscript{14}

The internet protocol (IP) addresses of the participants’ computers and cookies were used to identify potential duplicate entries from the same user and to assign a unique user identifier to each email address. Email addresses were requested for registration but not disclosed in the data file generated by the software to ensure anonymity. The respondents were able to review and change their answers through a ‘Back’ button anytime until submission.

**Recruitment of participants**

The target population was represented by professionals routinely dealing with non-domestic feline species and included not only veterinarians but also veterinary nurses and zookeepers involved in the care of the animals. Any potential participants eligible to complete the survey and whose contact details were known by the authors were contacted directly via a personalised email invitation with the link to complete the survey. Upon request of the authors, the British Veterinary Zoological Society, American Association of Zoo Veterinarians, European Association of Zoo and Wildlife Veterinarians and Wildlife Vets International (WVI) shared the link with their own members through their mailing lists. Additionally, WVI posted the survey on their Facebook page.

**Questionnaire**

The questionnaire was divided into nine separate sections with a total of 60 questions, comprising both open-answer (32%, 19/60) and multiple-choice questions (68%, 41/60); the latter were designed as either one single best answer (49%, 20/41) or multiple possible answer questions (51%, 21/41). The sections included demographics (13%, 8/60 questions), animal population (17%, 10/60 questions), drug protocols (18%, 11/60 questions), induction of general anaesthesia (22%, 13/60 questions), monitoring during anaesthesia (8%, 5/60 questions), intra-anaesthetic complications (8%, 5/60 questions), postanaesthetic period (8%, 5/60 questions), limitations and areas of improvement (3%, 2/60 questions) and open comments (2%, 1/60 question).

Regarding ‘animal population’, the respondents were asked which species they worked with between lions, tigers, leopards, jaguars, cheetahs, caracals and ‘others’ (the latter to be typed as free text by the participants).

For variables such as onset (defined as the minutes elapsed from injection to achieving immobility and unresponsiveness of the animal when approached) and duration of the anaesthetic effects (minutes elapsed from onset of anaesthesia to arousal), the participants were asked to provide an estimation based on their observation/experience.

Response templates for numerical variables were both entry of free text (a number) and single best answer between multiple choices (with incremental ranges as possible answers, e.g., 0–5, 6–10 minutes).

**Data protection**

Consent for the use of data for publication was requested from each participant prior to accessing the online survey and represented the prerequisite for the actual questionnaire to be delivered.

The responses were anonymised, and the personal details of the participants were not recorded. The IP addresses of the respondents, recorded by the system to prevent duplication, were not displayed.

The results were stored both on Qualtrics and in a cloud-based storage system (Google Drive); access to the study data was password protected, with the password known only by the primary investigator (R.W.).

**Data analysis and statistical methods**

All data generated by the software from the submitted questionnaires were analysed, including those from incomplete entries.

The completion rate was calculated. Descriptive statistics, correlation statistics and analysis of proportions were used. The Kolmogorov–Smirnov and Shapiro–Wilk tests were used to assess data distribution. The Pearson correlation coefficient was used to detect associations between ordinal continuous variables, while the chi-square test was used in the analysis of contingency tables to determine if there were associations between categorical variables and binary-dependent variables. Commercially available statistical software was used (SigmaStat 3.5 and
**RESULTS**

A total of 144 individuals responded to the survey and submitted their questionnaire; the overall completion rate was 65%. Data are represented as proportions and as either medians and interquartile ranges (25%–75%) or means and SD, depending on data distribution. When numbers are reported in brackets before the proportions, the denominator represents the number of participants who answered that specific question.

**Demographics**

Most participants were from the USA (35%, 50/144), followed by the UK (31%, 44/144). Ten percent (15/144) were from Europe and 9% (13/144) were from Oceania, while Africa (6%, 9/144), Asia (5%, 7/144) and South America (4%, 6/144) were the least represented.

The majority of the participants had qualified as veterinary surgeons (63%, 71/112). Only 22% (25/112) were board-certified specialists, while 14% (16/112) were classified as advanced practitioners. Seventy-three percent of the participants (88/120) worked in a zoological park, 21% (25/120) worked in private practice and the remaining 6% (7/120) worked in academia. The respondents had been qualified for 12 (6–24) years and reportedly performed 5 (5–5) anaesthetic procedures per month.

**Animal population**

The most represented species were tigers (70%, 101/144) and lions (62%, 90/144), followed by servals (42%, 60/144), leopards (39%, 56/144), cheetahs and jaguars (both 37%, 54/144) and caracals (31%, 45/144). Other species reportedly anaesthetised were Eurasian lynx (24%, 34/144), bobcats and pumas (both 17%, 24/144), Canadian lynx and snow leopards (both 12%, 18/144), cougars (10%, 15/144) and ocelots and black-footed cats (both 8%, 12/144). The least represented were Scottish wild cats, sand cats and marble cats (all <1%, 1/144).

The vast majority of the participants reportedly anaesthetised captive animals (97%, 140/144), while 12% (17/144) anaesthetised both captive and free-ranging animals and 4% (6/144) anaesthetised only free-ranging animals.

**Perianaesthetic procedures and anaesthetic protocols**

Common indications for anaesthesia were routine clinical examination, vaccination, transportation, diagnostic procedures and minor surgeries (wound management and male castration).

Most of the participants (75%; 69/92) reported that they did not perform routine preprocedural blood tests on blood sampled from the animal under anaesthesia prior to commencing other clinical procedures (e.g., surgery). However, the proportion of veterinarians performing preprocedural blood tests on a routine basis was higher for those dealing with captive animals (22%; 23/85) than for those dealing with free-ranging animals (0%; 0/7) \( (p < 0.001) \). Reportedly, fasting and water withholding times applied only to captive animals and not to free-ranging ones, and were 12 (12–24) hours and 2 (2–6) hours, respectively.

The preferred technique for chemical immobilisation was the use of darts (37%, 36/97), followed by the crush cage (7%, 7/97). However, 56% (54/97) of the participants reportedly used both techniques depending on the size of the animal and on the circumstances.

The most popular anaesthetic protocol was a mixture of a benzodiazepine, an alpha-2 adrenoreceptor agonist and a dissociative anaesthetic (27%, 25/92). The least popular were alfaxalone-based protocols (2%, 2/92), reportedly used by respondents who routinely anaesthetised Scottish wild cats and sand cats, and combinations of benzodiazepine and dissociative anaesthetics (2%, 2/92), used by respondents who routinely anaesthetised servals, Scottish wild cats, sand cats, marble cats and black-footed cats. For those who used alpha-2 adrenoreceptor agonists, medetomidine and dexmedetomidine were the most popular choices, while butorphanol was the preferred opioid agent. There was a preference for ketamine over tiletamine (93%, 25/27 vs. 7%, 2/27) and for midazolam over zolazepam (74%, 20/27 vs. 26%, 7/27). There was a significant association between proportions with respect to the use of drug combinations that included both a dissociative anaesthetic and an alpha-2 adrenoreceptor agonist (\( \chi^2 \) test, \( p < 0.001 \)). The reported duration of the anaesthetic effects was 45 ± 20 minutes.

Most participants reported the routine establishment of an intravenous (IV) access after intramuscular injection of sedatives/anaesthetic agents (77%, 50/65), as well as routine endotracheal intubation followed by the administration of an inhalational agent and oxygen for maintenance of anaesthesia (71%, 47/66). For the respondents who reported the routine use of inhalational anaesthesia, isoflurane was the most popular choice (96%, 45/47).

There was no significant difference in the proportions of veterinarians establishing an IV access between the categories of professionals (specialist, advanced practitioners and doctors of veterinary medicine; \( p = 0.29 \)). Similarly, there was no difference in the proportion of participants reportedly performing endotracheal intubation (\( p = 0.085 \)) or using inhalational anaesthesia for maintenance (\( p = 0.53 \)).
between universities, zoological parks and private practices. Perioperative fluids were administered by 77% (48/63) of the participants, 25% (12/48) of whom preferred the subcutaneous route and 75% (36/48) of whom preferred the IV route.

Reversal agents/antagonists with either atipamezole, naltrexone or both (depending on the anaesthetic protocol) were reportedly used by 88% of the respondents (57/65).

At the end of the procedure, 81% (53/65) of participants extubated the trachea when swallowing was observed, although the remaining 19% (12/65) reported doing this earlier, at the first appearance of the palpebral reflex.

**Perianaesthetic monitoring**

Forty-eight percent (30/63) of participants reportedly used complete instrumental monitoring, inclusive of capnography, pulse oximetry, ECG and arterial blood pressure measurement, while 41% (26/63) used a combination of up to three instrumental devices and the remaining 11% (7/63) relied on clinical monitoring only (pulse palpation, visual assessment of breathing, palpebral reflexes, jaw tone and mucous membrane colour and capillary refill time).

The proportion of participants performing complete instrumental monitoring was significantly higher among veterinarians employed by universities (60%, 3/5) and zoological parks (69%, 25/36) than among those working in private practice (15%, 2/13) ($p = 0.015$). The reported incidence of perianaesthetic complications was 10%.

Postoperatively, the animals were monitored closely for 2 (2–8) hours and isolated from other animals for 8 (4–24) hours.

**Complications and limitations**

Commonly reported perianaesthetic complications (including both the intra-anaesthetic and early postanaesthetic periods) were prolonged recovery (46%, 31/68), bradycardia (35%, 24/68), hypotension (32%, 22/68), hypothermia (26%, 18/68) and arousal (26%, 18/68), while nociception (18%, 12/68), tachycardia (12%, 8/68), vomiting/aspiration (10%, 7/68) and hyperthermia (4%, 3/68) were less commonly experienced by the participants.

For captive animals, for which monitoring could be extended to 72 hours after the anaesthetic, the most frequently observed medium-term complications were vomiting (42%, 22/52) and decreased appetite (38%, 20/52). Other reported postanaesthetic complications were pain (11%, 6/52) and polyuria/polydipsia (8%, 4/52).

Tigers were perceived as the species more prone to develop perianaesthetic complications (83%, 15/18), followed by lions (11%, 2/18) and cheetahs (5%, 1/18).

In the participants’ opinion, commonly encountered problems that could contribute to the development of complications were inappropriate equipment (39%, 26/66), lack of suitable drugs (27%, 18/66) and inadequate knowledge of species-specific pharmacology (including both pharmacodynamics and pharmacokinetics; 29%, 19/66) and physiology (24%, 16/66).

The most perceived limitation during wild felid anaesthesia was drug availability (39%, 17/43). Other reported limitations were a lack of experienced personnel (5%, 2/43), climate (2%, 1/43) and poor facilities (2%, 1/43).

**DISCUSSION**

The main finding of this study is that practitioners who are routinely involved in wild felid immobilisation generally prefer drug combinations based on both alpha-2 adrenoreceptor agonists and dissociative anaesthetics, which seem to be associated with both quicker onset, especially when ketamine is added to the mixture, and longer duration of the anaesthetic effects.

Quick onset of action is particularly desirable in free-ranging animals, as progressive sedation with partially preserved ability to move may expose the injected subjects to risks such as drowning in ponds or falling victim to other predators present in the area. Reliable and predictable immobilisation is a particularly desirable feature when procedures involve larger and potentially more dangerous wild cats that may pose a risk to the life of personnel. On the other hand, a longer than needed duration of the anaesthetic effects would most likely increase the risk for prolonged recovery, possibly contributing to increased morbidity and mortality.

Although a thorough investigation of morbidity and mortality was beyond the scope of this work, some anaesthesia-related complications, namely, hypothermia, hypoventilation, bradycardia and vomiting, were frequently reported by the respondents. This finding was not unexpected, as these complications are regarded as relatively common during the capture of free-ranging animals. On the contrary, capture-related complications such as hyperthermia and hypertension, which have been reported in cheetahs, were perceived as relatively uncommon by the respondents. Among the causes of complications, inappropriate equipment was reportedly perceived by the majority of the respondents. Field anaesthesia poses the challenge of performing adequate monitoring of physiological parameters with simple and lightweight equipment; moreover, most equipment devices are validated for use in either humans or domestic animal species, but their reliability in wild felids is unknown.

As is expected for feral and potentially dangerous animals, preprocedural blood tests were not common practice. It is speculated that, although in some...
cases blood sampling may have been one of the indications for anaesthesia, blood tests did not classify as 'preprocedural' for the respondents because the remaining clinical procedures were completed regardless of the blood results. Nevertheless, the design of this specific question may not have allowed proper differentiation, creating the potential for misunderstanding.

The tendency to supplement oxygen and establish a patent IV access after immobilisation, as well as to administer IV fluids during anaesthesia, reflects an attempt to adhere to good clinical practice principles despite the challenges encountered. This attitude was unaffected by the type of employment, with respondents from the universities, zoological parks and private practices producing similar responses. On the contrary, the type of employment did affect monitoring during anaesthesia, with respondents from universities and zoological parks reportedly using complete monitoring more than private practitioners. A possible interpretation of this finding may be the potential differences in equipment availability, although this was not specifically asked.

It is worth noting that demographics may have affected the findings of this study. There were very few respondents from Africa and Asia, possibly as a result of reduced internet availability in developing countries, which seems to reflect the low proportion of participants dealing with free-ranging wild cats, while captive animals located in zoological parks were considerably more represented. With respect to demographics, the fact that limited drug availability was perceived as a limitation was an unexpected finding, considering that most participants were from the USA and the UK, where there is a choice of potent anaesthetic/sedative agents suitable for use in animals.

Regarding preanaesthetic preparation of the animals, the fasting time reportedly ranged from 12 to 24 hours. While 12-hour fasting is commonly reported in domestic cats, 24 hours may be regarded as a relatively long time. However, this may be necessary to allow gastric emptying in large feline species after a large meal; moreover, one study conducted on domestic cats showed that total gastrointestinal transit time may be even longer than 46 hours in senior cats, although younger cats tended to show quicker emptying times.

LIMITATIONS

Although the CHERRIES checklist was consulted and taken into consideration during the phases of study design, adherence to it was partially incomplete. Ideally, this study should have been designed as a closed survey, with a predetermined number of invited participants to allow precise calculation of the participation rate. However, such a design could only have been possible if the target was an entirely known closed population, which could not be the case as we aimed at collecting responses worldwide. Also, invitations could not have been limited to a group of board-certified specialists in zoological medicine as this would have excluded a considerable number of potential participants, considering that, in many cases, anaesthetic procedures on captive or free-ranging animals are carried out by personnel who do not necessarily hold a specialty degree/diploma. Another limitation of the study design was the lack of randomisation of the order of both the questions and the response items within each question, a feature that is regarded as desirable to reduce the risk for response biases. This was reflected in the distribution of the responses, which was skewed towards the first sections of the questionnaire, suggesting that many participants answered the first part of the survey enthusiastically and then lost motivation to complete it. Alternatively, they may have found the questions of the first part of the survey easier to answer; however, whether this really was the case could only have been determined if the order of questions was not the same for every participant.

Regarding the questionnaire’s design, differentiating between species would have allowed the obtaining of more specific and detailed information. This would have been potentially useful to practitioners because, while there seemed to be some consistency in the choice of classes of drugs and drug mixtures, specific agents and dosages are more likely to be species specific. Similarly, the incidence and type of peri-anaesthetic complications may differ among animal species, with some species potentially being more prone to develop certain complications than others. This consideration was made during the phase of study design; however, it was concluded that such differentiation would have considerably increased the number of questions, which could have affected the completion rate. Alternatively, the study could have focused on a few species only; however, this would have potentially decreased the number of suitable participants by excluding veterinarians dealing with other wild cats.

CONCLUSIONS

This work shows that, although not without challenges, practitioners dealing with wild feline species are attentive towards peri-anaesthetic care and anticipation of complications. Drug mixtures including both an alpha-2 adrenoreceptor agonist and a dissociative anaesthetic are usually preferred for these species, and the inclusion of ketamine may be recommended when a quick onset of anaesthesia is particularly desirable. Limited equipment and drug availability is perceived as a factor contributing to the development of complications. Additionally, further advances in species-specific knowledge of both physiology and pharmacology are required to improve current practice and to help veterinarians make informed clinical decisions.
AUTHOR CONTRIBUTIONS
All authors contributed to the conceptualisation of the study. Ryan Walker developed the questionnaire and drafted the original manuscript in collaboration with Chiara Adami. Chiara Adami analysed the data and corrected and edited the manuscript. Iain Cope contributed to the distribution of the questionnaire through both social media and the organisations involved. Iain Cope and Dario d’Ovidio contributed substantially to the final revision of the manuscript. All the authors have read and approved the final manuscript.

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CONFLICT OF INTEREST STATEMENT
The authors declare they have no conflicts of interest.

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DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT
The methods outlined in this study received ethical approval from the Ethics and Welfare Committee of the Department of Veterinary Medicine of the University of Cambridge (license number: CR609 2022). Approval was granted on 28 June 2022, prior to commencing data collection.

REFERENCES

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