Reversal of arterial oxygen desaturation with the use of an oxygen concentrator during injectable anaesthesia in feral cats positioned in the Trendelenburg, dorsal or lateral surgical position

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Optimierung der arteriellen Sauerstoffkonzentration durch den Einsatz eines Sauerstoffkonzentrators während der Injektionsanästhesie bei verwilderten Hauskatzen in der Trendelenburg-, dorsalen oder lateralen Operationsposition

In dieser Studie wurden die Auswirkungen einer Sauerstoffergänzung mittels Sauerstoffkonzentrator auf die Sauerstoffsättigung des peripheren arteriellen Blutes (SpO2) bei anästhesierten Katzen in drei unterschiedlichen Operationspositionen zur Ovarioektomie gemessen. Insgesamt wurden die Daten von 192 weiblichen verwilderten Hauskatzen im Rahmen eines Kastrationsprogrammes analysiert. Die Katzen wurden mit einer intramuskulären Kombination aus Butorphanol (0,4 mg/kg), Ketamin (7–10 mg/kg) und Medetomidin (0,03–0,05 mg/kg) anästhesiert. Die Katzen wurden nach dem Zufallsprinzip einer Kastration entweder in Trendelenburg- (TR) (Kopfneigung um 70° nach unten), lateraler (LR) oder dorsaler Lage (DR) unterzogen. Die Katzen atmeten spontan entweder Raumluft oder über eine eng anliegende Gesichtsmaske 2 l/Minute Sauerstoff. Die Pulsfrequenz (in Schlägen pro Minute), Atemfrequenz (in Atemzügen pro Minute) und SpO2 (in Prozent) wurden zu Beginn in der linken Seitenlage und danach kontinuierlich nach Positionierung in der zugewiesenen Operationsposition gemessen. Am Ende der Operation wurden die Katzen wieder in die linke Seitenlage gebracht und alle Parameter wurden nach fünf Minuten erneut bewertet. Insgesamt zeigten 33 % der Katzen zu Studienbeginn beim Einatmen von Raumluft eine ungenügende arterielle Sauerstoffsättigung (SpO2 < 90 %). Eine Sauerstoffzufuhr während der Operation führte zu einer optimalen SpO2 bei allen Katzen. Bei

Abstract

This study observed the effects of oxygen supplementation, via an oxygen concentrator, on peripheral arterial blood oxygenation (SpO2) measured by pulse oximetry in anaesthetised cats undergoing spay in three different surgical positions. A total of 192 female feral cats were investigated for a large-scale trap-neuter-release program. Cats were anaesthetised with an intramuscular combination of butorphanol (0,4 mg / kg), ketamine (7–10 mg / kg) and medetomidine (0,03–0,05 mg / kg). Cats were randomly allocated to undergo spay in either Trendelenburg (TR) (70° downward head tilt), lateral (LR) or dorsal (DR) recumbency. Cats were breathing spontaneously either room air or 2 L/minute oxygen via a tight-fitting face mask. Pulse rate (in beats per minute), respiratory rate (in breaths per minute) and SpO2 (in percentage) were measured at baseline in left lateral recumbency and afterwards continuously after being positioned in allocated surgical position. At the end of surgery, cats were placed again in left recumbency, and all parameters were re-evaluated after five minutes. Overall, 33 % of cats showed severe arterial oxygen desaturation (SpO2 < 90 %) at baseline when breathing room air. When oxygen was supplemented during the procedure, arterial oxygen desaturation resolved in all cats. At the end of the procedure, 29 % of cats were hypoxaemic when oxygen was not supplemented, with an overall higher percentage of hypoxaemic cats in TR as compared to DR and LR recumbencies. All cats recovered well from surgery and were released within 24 hours post-anaesthesia. Arterial oxygen desaturation is frequent in cats anaesthetised with injectable anaesthesia for spay under field conditions. Oxygen supplementation administered via a tight-fitting mask resolved arterial oxygen desaturation in this feral cat population regardless of the surgical position and therefore

29% der Katzen ohne zusätzliche Sauerstoffzufuhr trat eine Hypoxie auf, wobei der Prozentsatz hypoxämischer Katzen in TR im Vergleich zu DR und LR insgesamt höher war. Alle Katzen erholten sich gut von der Operation und wurden innerhalb von 24 Stunden nach der Narkose entlassen. Während einer Injektionsanästhesie unter Feldbedingungen kommt es häufig zu einer ungenügender SpO2 bei Katzen. Mittels der zusätzlichen Sauerstoffzufuhr über eine enganliegende Maske konnte in der vorliegenden Studie bei verwilderten Hauskatzen, unabhängig von der Operationsposition, eine optimale SpO2 erreicht werden, weshalb eine Sauerstoffergänzung in jedem Fall empfohlen wird.

Schlüsselwörter: Katze, Hypoxämie, Kastration, Sedierung, Sauerstoffergänzung, Kastration

oxygen supplementation is recommended in any case.

Keywords: feline, hypoxaemia, neutering, sedation, oxygen supplementation, spay

Introduction

Hypoxaemia commonly develops during injectable anaesthesia in cats administered ketamine and medetomidine-opioid combinations, especially when oxygen supplementation is unavailable.[5,11,15,10] It is well known that hypoxaemia contributes to anaesthesia-related morbidity and mortality. In human medicine, the use of pulse oximetry monitoring to measure percentage of peripheral haemoglobin saturation with oxygen (SpO_2) under general anaesthesia has contributed to a reduction of hypoxia-related deaths.[34,32,7] Additionally, it also leads to improvement of overall patient outcomes when appropriate treatment can be provided when needed.[3] Although blood gas analysis is the gold standard for measuring arterial oxygenation, this method is not readily available during most field conditions. Alternatively, a pulse oximeter is a simple and inexpensive device that estimates arterial oxygenation. In cats, the measurement of SpO_2 via pulse oximetry has proven to be a simple and reliable method to estimate arterial oxygenation during anaesthesia.[17,3,21] Like in humans, the introduction of SpO_2 monitoring under general anaesthesia has aided the early detection of arterial oxygen desaturation and likely reduced the odds of overall anaesthetic-related deaths.[3,25] The principle behind pulse oximetry is based on photoplethysmography by which SpO_2 values can be easily obtained and are reliable under most conditions.[21] However, older SpO_2 analysers may be prone to artefacts from motion or ambient light and are not always accurate, especially in small cats or when perfusion is not optimal.[18] Newer methods, such as pulse co-oximetry (e.g. rainbow technology from Masimo), are very precise in humans, dogs and horses even during difficult measuring conditions.[30,36,27]

The most effective means of preventing hypoxaemia in the perioperative period is by providing additional oxygen (O_2), either via an endotracheal tube or via a tight-fitting face mask.[22] While oxygen supplementation is a standard practice during surgical procedures in modern veterinary practices, it is often unavailable during large-scale trap-neuter-release (TNR) programs. Recently, oxygen concentrators have become more readily available in both human and veterinary medicine providing an oxygen source even at remote locations.[24,9]

Although oxygen supplementation may effectively prevent hypoxaemia, it remains unknown whether this method also prevents hypoxaemia in cats operated in the Trendelenburg position, in which the body is positioned with the head downwards. This position is preferred by some operators for spay in cats given that both ovaries are easily exposed without excessive organ manipulation.[14,1] Therefore, the goal of the present study was to evaluate the effectiveness and feasibility of oxygen supplementation obtained from an oxygen concentrator, administered via a tight-fitting face mask on the haemoglobin saturation in cats undergoing spay in either Trendelenburg, dorsal or lateral surgical position.

Material and Methods

Study design

This prospective study was a follow-up project performed during a trap-neuter-release (TNR) programme in feral cats in Romania financed by Network for Animal Protection (NetAP) Switzerland. All observations concerning the study were non-invasive and performed in the anaesthetised cats only. Animals were captured and handled with care according to the standards of the Center of Hope Veterinary Hospital Pitesca, Ilfov, Romania. All procedures were performed by experienced professionals according to the standards of NetAP Switzerland.

Animals

In total, 288 cats were admitted to a large-scale TNR program in Romania as part of the NetAP-Switzerland and Romania Animal Rescue (RAR) neutering programs. All cats were captured from local colonies using commercially available cages or traps and were referred to a local veterinary hospital the evening before surgery. Cats were carefully observed in their cages for general pathologies or health concerns at the veterinary facility. Then, cats were offered a commercial food diet and weighed.

After an acclimatisation period of two hours, cats were re-assessed regarding their neurologic and interactive behaviour inside the cage. Pupillary reflexes, level of consciousness, and eating behaviour were evaluated. Any signs of abnormal neurologic function were noted. Food but not water was withheld for 10 - 16 hours prior to general anaesthesia. Although a routine physical examination prior to anaesthesia was not always possible due to the uncooperative character of cats, only evidently healthy female cats were included in the study after the first examination phase.

Surgical procedure and anaesthesia

A total of 204 female cats of unknown age were included in the study. Female cats underwent ovariectomy in parallel by three experienced surgeons depending on their preference and familiarity with the surgical position. Cats were randomly spayed in three positions: Trendelenburg 70° downward tilt (TR group, cat spayed hanging head down) (Figure 1), dorsal group (cat spayed in dorsal recumbency (DR)) and lateral group (cat spayed in right lateral recumbency (LR)).

Anaesthesia was induced with a standard TNR protocol (https://www.netap.ch/de/) consisting of an intramuscular (IM) injection of medetomidine (0,03 – 0,05 mg / kg) [Medetor 1 mg / ml ad us. vet.; D-Burgdorf-Virbac AG, Europastrasse 15, 8152 Opfikon, Switzerland], ket- amine (7 - 10 mg / kg) [Narkamon 100 mg / ml; Bioveta a.s, Komenského 212/12, 683 23 Ivanovice na Hané, Czech Republic] and butorphanol (0,4 mg / kg) [Butomidor 10 mg / ml; Richter Pharma AG, A4600 Wels, Austria], depending on the bodyweight of the cats. The medetomidine-ketamine-butorphanol (MKB) mixture was consistently injected into the supraspinatus muscle. If the first injection of MKB did not cause recumbency or reliable anaesthesia (withdrawal reaction to touch, vocalisation) within 10 minutes, an additional dose of ketamine (5 mg / kg) was injected IM. Once the cats were in lateral recumbency and unresponsive to touch nor vocalising, the bladder was emptied manually and tolfedine (4 mg / kg) [Tolfedine; Vetoquinol AG Freiburgstrasse 255, 3018 Bern, Switzerland] and amoxicillin (15 mg / kg) [Amoxycen 200 Long Acting 200 mg / ml; SC Biotur Exim SRL, soseana Turum Magurele km 5 Judetul Teleorman, Alexandria 140003, Romania] were administered subcutaneously (SC). Eyes were protected with vitamin A eye ointment [Vitamin A Bausch & Lomb Swiss AG, Industriestrasse 15A, 6301 Zug, Switzerland]. The surgical area was clipped (either abdomen or flank) and the cats were moved to the surgery room where they were placed in lateral recumbency. During surgery, if cats were showing signs to surgical stimulation (moving, vocalising, increase in respiratory or heart rate), ketamine (0,1 ml = 10 mg) was administered IM and anaesthetic depth re-assessed closely every minute. Surgical time was defined as time from the first surgical cut to the end of the surgical procedure.

In the recovery area animals received praziquantel (5,7 mg / kg) [Prazicest 56,8 mg / ml; FarmaVet S.C. Pasteur Filiala Filipesti S.R.L. Str. Principala nr 944, Filipestii de Padura, Jud. Prahova, Romania] and ivermectin (1 mg / kg) [Biomec 10 mg / ml; Bioveta a.s.,Komenského 212/12, 683 23 Ivanovice na Hané, Czech Republic] SC and were closely monitored until body temperature had normalized and the cats were alert and able to walk.

Eight, 12 and 24 hours after the end of anaesthesia all cats were observed for abnormal neurological behaviour or delayed pupillary reflexes. When no abnormalities were observed and cats were fully awake, the cats were returned to their original geographic location.

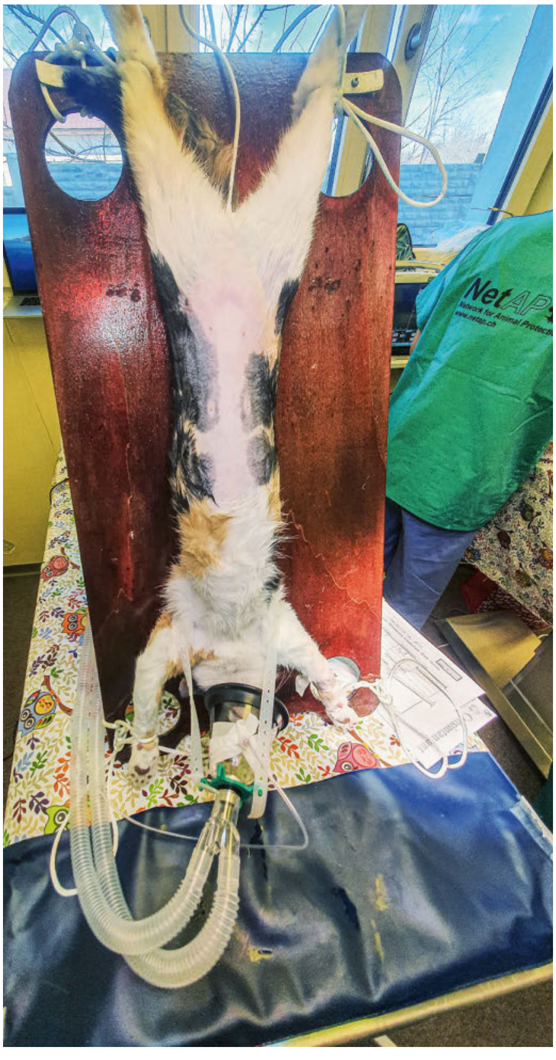

Figure 1: A feral cat spayed in the Trendelenburg surgical position.

Oxygen concentrator, oxygen delivery and SpO2 measurements

Oxygen supplementation was administered through a continuous flow from an electrically powered oxygen concentrator previously installed at the veterinary facility (Oxygen Concentrator Oxy-Gen; Burtons Veterinary, Guardian Industrial Estate, Marden, Kent TN129QD, UK).

The end-tidal carbon dioxide (ETCO_2), the rebreathing of carbon dioxide (FICO_2) and the inspired fraction of oxygen (FIO_2) were measured with a previously calibrated multiparametric monitor (GE Datex-Ohmeda Cardiocap/5; GE Healthcare, Technologies Datex-Ohmeda Inc., WI, USA). For this purpose, a capnography line was connected to a catheter that was then inserted into the face mask and positioned in front of the nose of the patient (Figure 2). Monitoring of the inspiratory and expiratory fractions of CO_2 ensured no rebreathing of CO_2 as depicted in the capnography waveforms displayed by the multiparametric monitor.

The calibration was performed against a standard, known mixture of gases according to the manufacturer. Each cat received a flow rate of 2 L/minutes. At this flow rate, there was no rebreathing of carbon dioxide (FICO_2< 0,05). The oxygen flow was delivered through a breathing circuit using a commercial, clear, plastic, tight-fitting face mask (Figure 2). The size was chosen based on proper fitting and sealing, which was aided by a rubber band and a black rubber diaphragm. This arrangement ensured the mask enveloped the patient's mouth and nose securely.

Figure 2: Tight-fitting face mask applied on a feral cat during spay for oxygen supplementation and measurement of inspired and expired carbon dioxide and oxygen concentrations via a capnography line attached to a catheter sensor that was then inserted into the face mask.

To optimise SpO_2 measurements, a reflectance probe was placed on the previously clipped tail, ventrally at the level of the coccygeal artery.[14] The probe was fixed with a non-tight external wrapping and a good pulse signal was observed on the plethysmography waveform prior the recording of a value.

Monitoring

After one minute in lateral position (T=0), the first baseline measurements (SpO_2, pulse rate (PR) and respiratory rate (RR)) were taken using a Rad-67 Pulse Co-Oximeter (Masimo International Sarl, Puits Godet 10, 2000 Neuchâtel, Switzerland) and temperature with a rectal thermometer. Following baseline measurements, the spontaneously breathing cats either received room air (no face mask placed) or 2 L/min oxygen (FIO_2 0,5–0,7; no rebreathing of CO_2 detected) via a tight-fitting face mask and then were aseptically prepared and positioned for surgery. After one minute in surgical position, SpO_2, PR, and RR were measured and then surgery was initiated. Surgeries were performed by surgeons experienced with the given surgical method. During surgery, SpO_2, PR and RR were recorded every minute. Before moving the cats from the surgery position to lateral recumbency at the end of the surgery, all parameters were measured again (SpO_2, PR, RR and temperature). After that, cats were placed in lateral recumbency for recovery from anaesthesia and SpO_2, RR and PR were re-evaluated after 5 minutes in lateral recumbency.

Duration from the first IM injection to the start of surgery was recorded. Duration of surgery was defined as time between the first surgical cut until the end of the surgical procedure. Three anaesthetists (ER, LN, PH) recorded all data during surgery, each rotating daily to record data from a different group.

Statistical analysis

All data were analysed in R.[31] Data were analysed by a generalised additive mixed model (GAMM) using the Beta 1 inflated model.[26] Thus, any variation in SpO_2 and PR between the different positions and possible linear and non-linear variation over time were analysed whilst controlling for repeated measures within each cat. Various models were compared and the model that gave the lowest Akaike information criterion (AIC) was chosen. Residuals were checked using a Quantile – Quantile plot (Q-Q plot). The level of significance was set at $p < 0,05$ for all analyses. One way ANOVA corrected for repeated measures was used to analyse surgery time.

Results

Animals

Out of 288 male and female cats, a total of 204 female feral cats were anaesthetised with MKB and were randomly allocated into three groups, with 58 cats in the TR (of which

29 received oxygen supplementation), 59 cats in the DR (of which 28 cats received oxygen supplementation) and 87 cats in the LR (of which 38 cats received oxygen supplementation). Of the initially included cats, twelve were excluded during surgery (3 from TR, 1 from DR and 8 from LR) due to intraoperative complications (bleeding, diaphragmatic hernia, advanced gestation). This resulted in 192 female cats being included in the data analysis (55 cats in TR, 58 cats in DR and 79 cats in LR). The distribution among groups was even, with 95 cats receiving oxygen supplementation and 97 cats breathing room air. While one cat required endotracheal intubation due to temporary apnoea following intramuscular ketamine, spontaneous ventilation resumed after some manual breaths were provided. All cats survived the procedure to discharge, recovered well from anaesthesia and no post-operative complications were evident.

Body weights of the cats enrolled in the study ranged from 1,1 to 4,4 kg (2,5 ± 0,54 kg; mean ± standard deviation). There was no significant difference between the groups regarding body weight. No signs of gastric content coming out of the mouth or nostrils were evident during and at the end of surgery in any cat.

The times after first MKB injection to start of surgery were not significantly different between the groups, 14,6 ± 6,5 minutes in TR, 13,7 ± 6,1 minutes in LR and 13,6 ± 5,3 minutes in DR. Significant difference was found for the surgery times (8,6 ± 2,2 minutes in TR, 7,3 ± 2,8 minutes in LR and 9,0 ± 4,2 minutes in DR) ($p<0,008$).

Monitored parameters during anaesthesia

Overall, the PR ranged between 62 - 215 beats/minute (73 - 208 beats/minute in TR, 71 - 215 beats/minute in LR and 62 - 212 beats/minute in DR). Pulse rate did not vary significantly with time but there was a tendency of decreased PR over time when oxygen was given (Figure 3). However, position LR had a higher pulse rate compared to position DR and TR when oxygen was supplemented ($p<0,004$). The respiratory rate did not vary significantly between groups at any time point. At baseline, when breathing room air the RR ranged between 4 – 60 breaths/minute (8 – 60 breaths/minute in TR, 4 – 52 breaths/minute in LR, 8 – 60 breaths/minute in DR). At the end of the procedure when supplemented with oxygen, the RR ranged between 4 – 68 breaths/minute (12 – 48 breaths/minute in TR, 4 – 60 breaths/minute in LR, 8 – 68 breaths/minute in DR). At the end of the procedure, when breathing room air the RR ranged between 4 – 72 breaths/minute (8 – 60 breaths/minute in TR, 4 – 54 breaths/minute in LR, 12 – 72 breaths/minute in DR).

SpO_2 in cats receiving room air and effect of surgical position

At baseline (breathing room air), 33 % of cats were hypoxaemic (SpO_2 < 90 %). Overall, 50 % of cats had SpO_2 < 92 % at baseline measurements.

When controlled for (nonlinear) effects of time and oxygen supplementation, with cat as a random intercepts (repeat measure in each cat) and time as a random slope (repeat measures over time), there was an effect of position. Average SpO_2 for each group was 91 % ± (90,4–91,7 %) in TR, 91 % ± (90,1–91,3 %) in DR, 89 % ± (88,6–90,3 %) in LR when oxygen was not supplemented during surgery (Figure 4). The incidence of hypoxaemic cats within each group was significantly higher (negative parameter. -0,111, $p < 1e\text{-}04$) in cats operated in the TR group when compared to LR and DR groups (Table 1).

At the end of the procedure, SpO_2 values had improved over time ($p<2e\text{-}16$) but only minimally when compared to cats receiving oxygen supplementation. Nevertheless, 29 % of included cats showed severe arterial oxygen desaturation (SpO_2 < 90 %) when surgery finished compared to 0 % when oxygen was supplemented.

SpO_2 in cats supplemented with oxygen

Within one minute of oxygen administration via a tight-fitting face mask, SpO_2 values improved significantly in all cats (Figure 4.). As such, arterial oxygen desaturation resolved in all cats when oxygen was supplemented. At the end of surgery, severe arterial oxygen desaturation (SpO_2<90 %) was not present in any cat.

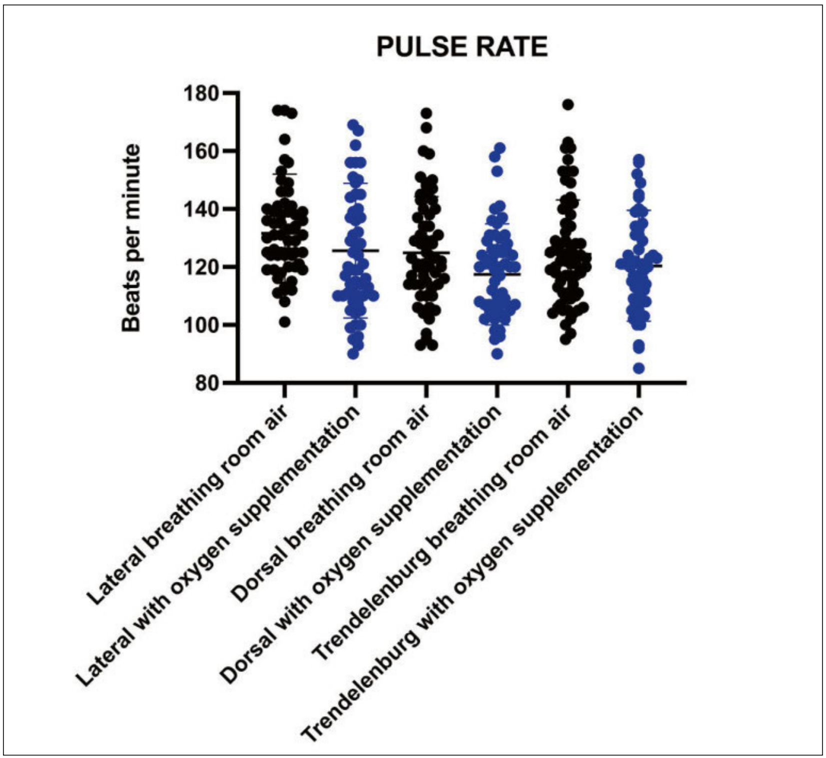

Figure 3: Pulse rates (mean ± SD) from 192 cats undergoing neutering in different body positions [TR (Head down/Trendelenburg recumbency), LR (Lateral recumbency), DR (Dorsal recumbency)].

Need for additional anaesthesia

Twentynine cats required a second IM injection of ketamine after the first injection of MKB, which included 17 cats in the LR, 5 in the TR and 7 in the DR. Median additional ketamine dose range was 5,5 ± 1,3 mg/kg in the LR (room air) group and 6,7 ± 2,9 mg/kg in the LR (oxygen supplementation) group; 6 ± 5,3 mg/kg in the TR (room air) group and 4 mg/kg in the TR (oxygen supplementation) group; 6,9 ± 4,3 mg/kg in the LR (room air) group and 3,8 ± 1,4 mg/kg in the LR (oxygen supplementation) group. In total, 15 % of all enrolled female cats (29/192) needed supplemental ketamine. In some of the cats, incomplete intramuscular injection of the first dose was suspected.

Discussion

The results of this study show the importance of oxygen supplementation in feral cats undergoing ovariectomy during injectional anaesthesia. Interestingly, normoxaemia (based on SpO_2 monitoring) returned in all included cats when oxygen was supplemented, regardless of the recumbency during surgery. This highlights the need and the effectiveness of oxygen supplementation via a tight-fitting face mask.

The causes of hypoxaemia during anaesthesia are multifactorial. They include hypoventilation, a low inspired fraction of oxygen (FIO_2), ventilation-perfusion mismatch, pulmonary shunting and diffusion impairment.[28] Most commonly, hypoventilation occurs under anaesthesia secondary to a blunted response rate of the respiratory centres in the brainstem. Arterial oxygen desaturation at baseline in our cat population most likely occurred during the plasmatic peak effect of the intramuscularly administered anaesthesia drugs. This is supported by our results, as SpO_2 values increased over time corresponding with the drugs' metabolic process. This suggests that the improvement in SpO_2 could indeed be attributed, at least in part, to the waning effects of medetomidine. In trap-neuter-release programs, pre-established, standard doses of medetomidine, ketamine and an opioid are typically administered intramuscularly to cats.[33,35] Therefore, it is likely that the anaesthetic depth might vary between animals in order to achieve a stable anaesthetic plane. As seen in our study, almost 30 % of cats required an additional anaesthesia, which might have subsequently deepened the anaesthesia possibly causing more hypoventilation and hypoxaemia.

Table 1: Incidence of arterial oxygen desaturation at the end of the procedure represented as percentage ± 95 % confidence interval. [TR (Head down/Trendelenburg recumbency), LR (Lateral recumbency), DR (Dorsal recumbency)

	TR	LR	DR
Hypoxaemic cats within each group	38,5 % (10 out of 26 cats)	27,5 % (11 out of 40 cats)	23,3 % (7 out of 30 cats)
95 % CI	20,2 %-59,4 %	14,6 %-43,9 %	9,9 %-42,3 %

In addition to hypoventilation, positioning during surgery might affect ventilation and oxygenation.[6] In our study, a higher incidence of arterial oxygen desaturation was found at the end of the procedure when cats were operated in the Trendelenburg position whilst breathing room air. In contrast, in a previous similar study during a large-scale trap-neuter-release program, SpO_2 values did not differ in cats operated in the Trendelenburg position.[5] Differences in SpO_2 measurements (reflectance probe instead of clip transmittance probe) might account for the higher arterial oxygen desaturation detected in our study in the Trendelenburg group. The transmittance probe could exert additional pressure on vessels already constricted by medetomidine. In contrast, the reflectance probe on the tail does not cause pressure and is not affected by the tight oxygen mask.

In dogs and cats, the Trendelenburg position during spontaneous ventilation has been shown to impair ventilation by increasing atelectasis, the work of breathing and decreasing pulmonary compliance as abdominal organs push on the diaphragm.[19] Given that oxygen supplementation resolved arterial oxygen desaturation quickly in this study, oxygen supplementation should be recommended in anaesthetised cats independently of the surgical position. Also to consider is, that surgical positioning might favour the risk for regurgitation of gastric contents, as the viscera push on the gastric wall but no visible signs of regurgitation were evident in this large scale study.[8] In animals in which there is a high risk for regurgitation, endotracheal intubation is warranted. Also, the use of a tight-fitting face mask might increase the risk of severe aspiration when endotracheal intubation is not performed given that fluid contents will accumulate within the mask.

Given the study's field conditions, the measurement of arterial oxygenation was limited in our cats to an indirect method, such as SpO_2. Pulse oximetry values < 90 % were considered indicative of clinically significant arterial oxygen desaturation.[10,28] Multiple factors can influence and falsify SpO_2 readings. Especially in cats, pulse oximetry may not be entirely accurate given their small size and lack of species-specific instrumentation.[21] To optimise SpO_2 readings in this study, a reflectance probe was placed on the previously ventrally clipped tail at the level of the coccygeal artery.[18] In this way, low or faulty SpO_2 readings due to excessive clip pressure that may occur with conventional transmittance probes were avoided. Nevertheless, the accuracy of pulse oximetry can be affected by some factors which could not be controlled, such as tissue heterogeneity, total blood volume, venous pulsations or optical shunting.[20,29] The SET® technology used in the pulse oximetry in this study offers reliable readings even during states of low perfusion or patient motion due to a novel pulse signal extraction technology and may therefore provide an advantage also in small cats. While arterial blood gas analysis would have been ideal, it was unavailable and not clinically appli-

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cable in daily practice.[12] In our study, given the optimisation of SpO_2 readings and the large number of studied animals in which readings were similar and obtained with a good pulse signal, SpO_2 readings were considered accurate.

On the other hand, the efficacy of oxygen supplementation might be limited during intrapulmonary shunting, which is observed in some species that receive alpha two adrenergic agonists as part of the anaesthetic protocol.[2,13] Also, intrapulmonary shunting results in increased venous admixture, which might be worsened with positioning.[4,23] In our animals, oxygen supplementation quickly corrected arterial oxygen desaturation, with most animals responding within one minute of supplementation making a large shunt unlikely.

The major limitation of the present study is that arterial oxygenation was only measured indirectly with pulse oximeters that were calibrated for humans and not for cats. Moreover, vasoconstriction and resulting bradycardia, could have reduced the accuracy of SpO_2 values due to decreased pulsation.[16] The inspiratory fraction of oxygen could also have varied between measurements. Lastly, not all included cats had prior physical examination nor preoperative testing performed given the feral nature of the cats. Underlying disease rather than surgical positioning could have been the cause for low SpO_2 values in some cats.

Finally, while hypoxaemia was defined as SpO_2 <90 % in this study, the sigmoid curve of the oxygen-haemoglobin dissociation curve implies that small decrements in SpO_2 below the 90 % cut-off can rapidly progress to severe hypoxaemia. Therefore, even moderate hypoxaemia warrants prompt clinical attention to avoid the development of severe hypoxaemia.

Conclusions

Arterial oxygen desaturation in this feral cat population was quickly reversed when oxygen at 2 L/min was supplemented via a tight-fitting face mask in all three surgical positions: Trendelenburg, lateral and dorsal. This study's findings highlight the need for oxygen supplementation during injectional anaesthesia with medetomidine, ketamine and butorphanol in cats undergoing ovariectomy given the high incidence of arterial oxygen desaturation.

Acknowledgements

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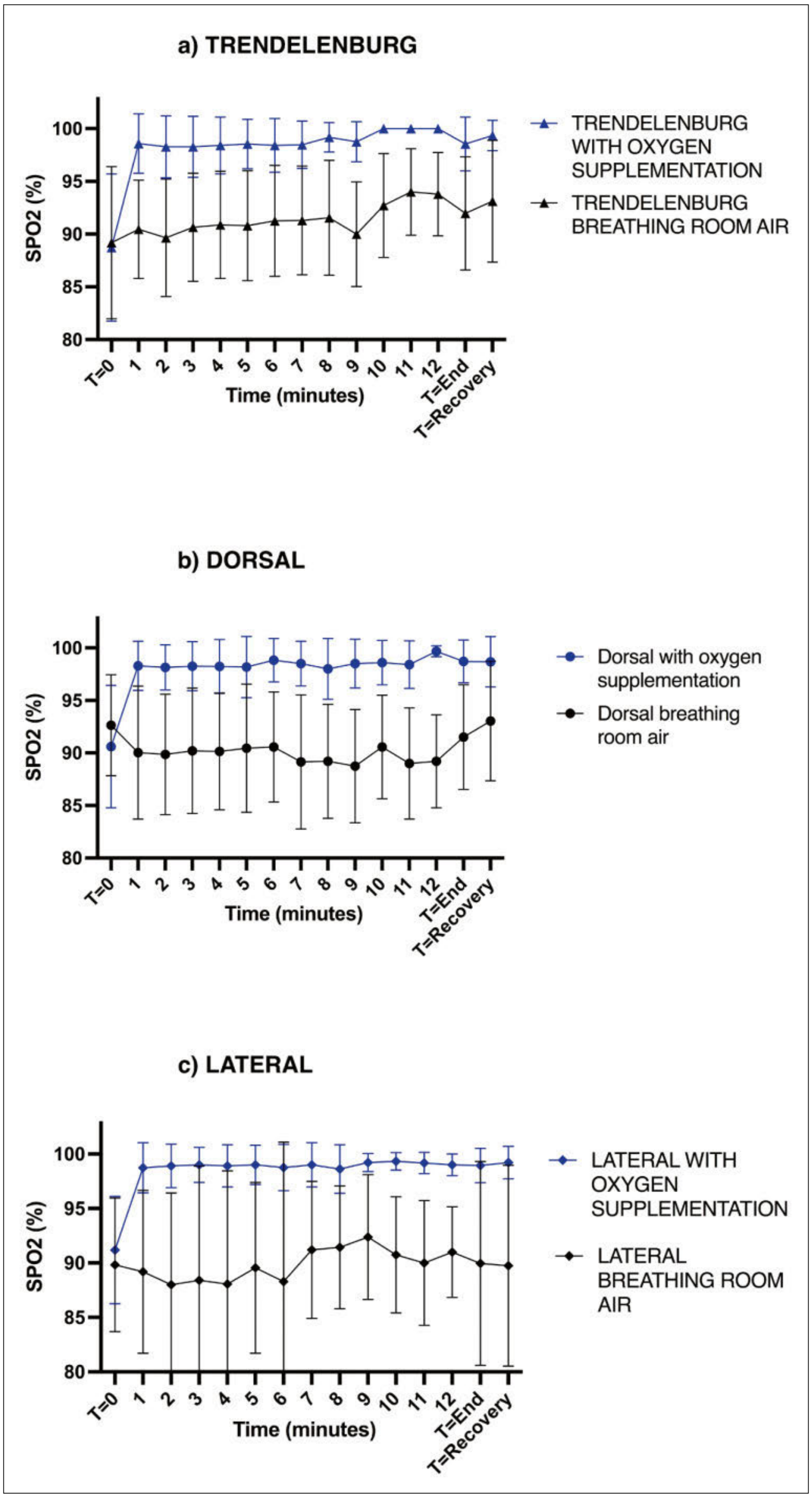

Figure 4: Mean pulse oximetry (SpO_2) from 192 cats undergoing neutering in different body positions [a) TRENDELENBURG: 55 cats in TR (head down/Trendelenburg recumbency); b) DORSAL: 58 cats in DR (dorsal recumbency); c) LATERAL: 79 cats in LR (lateral recumbency)]. All baseline measurements (T=0) were obtained after sedation without oxygen supplementation. When oxygen was supplemented, cats received oxygen directly after the first baseline measurements (prior to T1).

T0 = Baseline prior supplementation of oxygen; 1–12 = 12 minutes during surgery; T-End = End of surgery; T+5 = 5 minutes in lateral recumbency after end of the surgical procedure.

Reversal of arterial oxygen desaturation with the use of an oxygen concentrator during injectable anaesthesia in feral cats positioned in the Trendelenburg, dorsal or lateral surgical position

Elisabeth Ranninger et al.

Optimisation de la concentration artérielle en oxygène par l'utilisation d'un concentrateur d'oxygène pendant l'anesthésie injectable chez les chats sauvages placés en position chirurgicale de Trendelenburg, dorsale ou latérale

Cette étude a observé les effets d'une supplémentation en oxygène, via un concentrateur d'oxygène, sur l'oxygénation du sang artériel périphérique (SpO2) mesurée par oxymétrie de pouls chez des chats anesthésiés subissant une stérilisation dans trois positions chirurgicales différentes. Au total, 192 chats sauvages femelles ont été examinés dans le cadre d'un programme de piégeage, de stérilisation et de remise en liberté à grande échelle. Les chats ont été anesthésiés avec une combinaison de butorphanol (0,4 mg / kg), de kétamine (7–10 mg / kg) et de médétomidine (0,03–0,05 mg / kg) appliquée par voie intramusculaire. Les chats ont été répartis au hasard pour subir une stérilisation en position de Trendelenburg (TR) (inclinaison de la tête de 70° vers le bas), en décubitus latéral (LR) ou en décubitus dorsal (DR). Les chats respiraient spontanément soit de l'air ambiant, soit de l'oxygène à raison de 2 L/minute par l'intermédiaire d'un masque facial bien ajusté. Le pouls (en battements par minute), la fréquence respiratoire (en respirations par minute) et la SpO2 (en pourcentage) ont été mesurés au départ en décubitus latéral gauche, puis en continu après avoir été placés dans la position chirurgicale attribuée. À la fin de l'opération, les chats ont été replacés en décubitus latéral gauche et tous les paramètres ont été réévalués au bout de cinq minutes. Dans l'ensemble, 33 % des chats présentaient une désaturation sévère en oxygène artériel (SpO2 < 90 %) au départ lorsqu'ils respiraient de l'air ambiant. Lorsque de l'oxygène a été ajouté pendant la procédure, la désaturation en oxygène artériel s'est résorbée chez tous les chats. À la fin de l'intervention, 29 % des chats étaient hypoxémiques lorsque l'oxygène n'était pas administré, avec un pourcentage global plus élevé de chats hypoxémiques en décubitus dorsal qu'en décubitus latéral. Tous les chats se sont bien remis de l'opération et ont été libérés dans les 24 heures suivant l'anesthésie. La désaturation en oxygène artériel est fréquente chez les chats anesthésiés par injection pour la stérilisation dans des conditions de terrain. La supplémentation en oxygène administrée via un masque étanche a résolu la désaturation en oxygène artériel dans cette population de chats sauvages, quelle que soit la position chirurgicale et la supplémentation en oxygène est donc recommandée dans tous les cas.

Mots clés: félin, hypoxémie, stérilisation, sédation, supplément d›oxygène

Inversione della desaturazione dell'ossigeno arterioso con l'uso di un concentratore di ossigeno durante l'anestesia iniettabile in gatti selvatici posizionati in posizione chirurgica Trendelenburg, dorsale o laterale

Questo studio ha osservato gli effetti della supplementazione di ossigeno, tramite un concentratore di ossigeno, sull'ossigenazione periferica del sangue arterioso (SpO2) misurata mediante pulsossimetria in gatti anestetizzati sottoposti a sterilizzazione in tre diverse posizioni chirurgiche. Un totale di 192 femmine di gatto selvatico sono state indagate per un programma su larga scala di trappola-sterilizzazione-rilascio. Le gatte sono state anestetizzate con una combinazione intramuscolare di butorfanolo (0,4 mg / kg), ketamina (7–10 mg/kg) e medetomidina (0,03–0,05 mg/kg). Le gatte sono state assegnate casualmente per essere sottoposte a sterilizzazione in posizione Trendelenburg (TR) (inclinazione della testa verso il basso di 70°), laterale (LR) o dorsale (DR). Le gatte respiravano spontaneamente aria ambiente oppure 2 L/minuto di ossigeno attraverso una maschera facciale aderente. La frequenza del polso (in battiti al minuto), la frequenza respiratoria (in respiri al minuto) e la SpO2 (in percentuale) sono state misurate alla base in posizione laterale sinistra e successivamente in modo continuo dopo essere stati posizionati nella posizione chirurgica assegnata. Al termine dell'intervento, le gatte sono state poste nuovamente in posizione supina sinistra e tutti i parametri sono stati rivalutati dopo cinque minuti. Complessivamente, il 33 % delle gatte presentava una grave desaturazione dell'ossigeno arterioso (SpO2 < 90 %) al basale quando respirava aria ambiente. Quando l'ossigeno è stato integrato durante la procedura, la desaturazione dell'ossigeno arterioso si è risolta in tutte le gatte. Al termine della procedura, il 29 % delle gatte era ipossiemica quando l'ossigeno non era stato integrato, con una percentuale complessiva più alta di gatte ipossiemiche in TR rispetto alle posizioni DR e LR. Tutte le gatte si sono riprese bene dall'intervento e sono state dimesse entro 24 ore dall'anestesia. La desaturazione dell'ossigeno arterioso è frequente nei gatti anestetizzati con anestesia iniettabile durante la loro sterilizzazione. L'integrazione di ossigeno somministrato tramite una maschera aderente ha risolto la desaturazione arteriosa di ossigeno in questa popolazione di gatti selvatici, indipendentemente dalla posizione chirurgica, e quindi l'integrazione di ossigeno è raccomandata in ogni caso.

Parole chiave: felino, ipossiemia, castrazione, sedazione, integrazione di ossigeno, sterilizzazione

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