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**Perioperative anaesthesia-related mortality in rabbits - a
retrospective study
(2014-2024)**

Diplomarbeit

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vorgelegt von

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1. ZUSAMMENFASSUNG

Einleitung

Kaninchen, die am dritthäufigsten anästhesierte Tierart, sind von einer höheren anästhesiebedingten Sterblichkeit betroffen als Hunde oder Katzen, wobei die Sterberate bei Kaninchen zwischen 2,05 % und 4,8 % liegt. Um die Ergebnisse und den Schutz der Patienten zu verbessern, ist die Identifizierung weiterer Risikofaktoren von entscheidender Bedeutung.

Zielsetzung

Analyse der Sterberate und möglicher Risikobewertungen der anästhesiebedingten Sterblichkeit in einer Population von Kaninchen an einem einzigen Zentrum (Lehrkrankenhaus).

Material und Methoden

In dieser retrospektiven Studie wurden die klinischen Aufzeichnungen von Kaninchen untersucht, die im Zeitraum von 2014 bis 2024 an der Veterinärmedizinischen Universität Wien anästhesiert wurden. Patientendaten und Informationen zum Anästhesiemanagement und Verfahren wurden aus der Datenbank der Klinik gesammelt und mit einem allgemeinen linearisierten Modell und Pearson's Chi-Quadrat-Tests ausgewertet.

Ergebnisse

Die Daten von 899 Kaninchen bzw. 1.230 Narkoseereignissen wurden analysiert. Dabei starben 70 Tiere, die eine Sedierung oder Narkose erhielten ($n = 1.116$), was eine Gesamtsterblichkeitsrate von 6,3 % ergab. Die ASA-Klassifizierung war der stärkste Prädiktor für das Überleben ($p < 0,0001$), und auch die Art des Eingriffs beeinflusste das Ergebnis erheblich ($p = 0,003$). Bei ophthalmologischen Eingriffen war die Sterblichkeitsrate am höchsten (20 %). Dies scheint vor allem auf das Auftreten eines okulokardialen Reflexes zurückzuführen zu sein, der bei 9 Patienten vermutet wurde, von denen 5 starben. Andere Risikofaktoren (z. B. Demographie, Atemwegsmanagement, Verwendung von Alpha-2-Agonisten) konnten nicht identifiziert werden.

Schlussfolgerung

Die Studie zeigt, dass die Sterblichkeitsrate während der Anästhesie bei Kaninchen nach wie vor höher ist als bei anderen Kleintieren wie Katzen und Hunden. Die Ergebnisse zeigen eine höhere Sterblichkeitsrate bei kranken Patienten anhand der ASA-Klassifizierung und ein

hohes Risiko bei ophthalmologischen Eingriffen. Dies muss weiter erforscht werden, insbesondere in Bezug auf ophthalmologische Fälle.

2. ABSTRACT

Introduction

Rabbits, the third most anaesthetized species, face higher anaesthesia-related mortality than dogs or cats, with rates ranging from 2.05 % to 4.8 % reported in domestic rabbits. To improve both outcome and patient safety, identifying specific risk factors is crucial.

Objective

To investigate the incidence and possible risk factors of anaesthesia-related mortality in a pet rabbit population at a single center (teaching hospital).

Materials and Methods

This retrospective study investigated the clinical records of pet rabbits anaesthetized at the University of Veterinary Medicine, Vienna over the period 2014 - 2024. Patient data, anaesthetic management and procedure details were collected from the institution's database and analyzed with a general linearized model and Pearson's Chi-square tests.

Results

Data from 899 rabbits and 1,230 anaesthetic events were analyzed, and 70 animals receiving sedation or anaesthesia ($n = 1,116$) died, resulting in an overall peri-anaesthetic mortality rate of 6.3 %. ASA classification was the strongest predictor of survival ($p < 0.0001$), and procedure type also significantly influenced outcomes ($p = 0.003$). Ophthalmologic procedures had the highest mortality rate (20 %). This seems to be due mostly to the occurrence of an oculocardiac reflex. An oculocardiac reflex was suspected based on clinical observation by the anaesthetist in charge in 9 patients out of which 5 died. Other risk factors (e.g. demography, airway management, use of alpha-2-agonists) could not be identified.

Conclusion

The study shows that there is still a higher anaesthetic mortality rate in rabbits than in other small animals like cats and dogs. Findings confirm a higher mortality rate in sick patients as indicated by ASA classification and show a high risk for ophthalmic procedures. There is a need to research further on this, especially on ophthalmologic cases.

3. INTRODUCTION

Rabbits are increasingly popular as companion animals, and their care has received growing attention. As the third most frequently anaesthetized species, rabbits undergo anaesthesia almost as often as dogs or cats [1], nevertheless their risk of anaesthesia related death is much higher. In 2018, Lee et al. presented a mortality rate of 4.8 % within 72 hours after anaesthesia in pet rabbits [2], another recently published study shows an overall perioperative mortality of 2.05 % within 48h of anaesthesia [3], in comparison to 0.17% and 0.24% reported for dogs and cats, respectively [1].

The challenges of anaesthetizing and sedating rabbits are largely due to their unique anatomical features and their predisposition to certain health conditions. Some specific factors are a narrow range of anaesthetic agents, with alpha-2-agonists possibly being a factor for complications [4], sensitivity to both gastrointestinal and cardiorespiratory stressors associated with anaesthesia, as well as higher tendencies to extreme hypoventilation [5]. Intubation of the trachea is particularly difficult because of their long and narrow pharynx and large tongue, and repeated attempts can lead to complications like laryngospasm [6], edema or hemorrhage of the larynx [7] and even death [8]. An easier, faster and less traumatic way is the use of supraglottic airway devices (SGAD), however, they are displaced more easily and take up more space in the oral cavity [9, 10]. Body temperature is also an important factor, due to their small size and large surface area, rabbits are prone to hypothermia [11]. In 2016 Girolamo et al. showed that a low rectal temperature at admission is associated with a higher perioperative mortality rate, and thus a possible sign of sickness. [12]. As prey animals, rabbits often mask signs of disease [13], so that underlying issues such as respiratory, gastrointestinal, or fluid balance disorders may go unnoticed [14]. Necropsy results of perianaesthetic deaths often show respiratory and other systemic diseases [15].

Given the known difficulties associated with rabbit anaesthesia, this study investigates the mortality rate of rabbits undergoing anaesthesia over a long period of time in a single center, covering a wide range of different diagnostic or interventional procedures such as orthopedic and ophthalmologic surgeries. A further aim was to identify contributing factors, including demographics, American Society of Anaesthesiologists physical status (ASA) classification, airway management, type of procedure, use of alpha-2-agonists and occurrence of an oculocardiac reflex.

4. MATERIALS AND METHODS

In this retrospective study the data of all pet rabbits that underwent anaesthesia or sedation at the University of Veterinary Medicine, Vienna between April 2014 and March 2024 were collected and analyzed. The data was obtained from the medical records and anaesthesia protocols out of the clinic's database through an automated query and then curated manually. Data from between 2014 and 2017 were already present from a previous investigation [16].

The following patient data was collected: gender, body weight, age, breed, ASA classification, anaesthetic protocol, airway management, type of anaesthetic event, type of procedure, suspected occurrence of an oculo-cardiac reflex and peri-anaesthetic mortality. ASA classification was allocated by the anaesthesiologist in charge of the case based on patient history, clinical examination and blood results (if available). Regarding the anaesthetic protocol, the following data was collected: premedication, induction, airway management, maintenance and postoperative analgesia. Airway management was documented as either using a face mask, a supraglottic airway device (SGAD), an endotracheal tube, or no airway support. Patients were categorized as receiving either anxiolysis, sedation or anaesthesia. Anaesthesia was defined according to Brodbelt et al. as a condition that allows endotracheal intubation if intended [1]. Sedation was defined as a condition that does not allow endotracheal intubation but in this state, the patient does not respond to mild or moderate stimuli [1]. Anxiolysis was defined as a calming method where only midazolam and butorphanol were used. Only cases involving anaesthesia or sedation were included in the statistical analysis. Anaesthesia-related death was defined as death occurring within 48h after anaesthesia, if no other plausible cause of death, e.g. due to a life-threatening disease, was suspected [1]. Cases where euthanasia was performed due to poor prognosis were excluded. The remaining cases were classified into three categories based on the timing of death: during introduction (deaths occurring between the start of premedication and start of surgery or intervention), during maintenance (during the procedure itself), and in the postoperative phase (between the end of procedure and discharge from the hospital). These variables served as explanatory variables that potentially influenced the main outcome variable: survival, a zero/one coded qualitative variable. It is noted that qualitative variables contain less information than quantitative ones, requiring relatively high sample sizes for meaningful and reliable inference.

The anaesthetic events were assigned to the following procedure categories: soft tissue surgery (separated in abdominal and non-abdominal surgery), orthopedic surgery, dental procedures, ophthalmologic surgery, diagnostic imaging, oncologic radiation therapy and endoscopy. A rabbit that had several anaesthetic events was treated as a separate case each time with a minimum of two weeks wash-out period in between.

4.1. Statistical analysis

Data was collected and curated in Microsoft Excel Version 2408, which was also used for descriptive statistics (e.g., tables and graphics). A generalized linear model (GLM) with a binomial logit link function was employed to estimate the association between predictor variables and the probability of survival, using the statistical software 'R' [17]. A GLM of the binomial family is appropriate given the binary outcome and thus the non-normal distribution of the outcome variable. Predictor variables included gender, age, body weight, ASA classification and type of procedure. For pairwise tests, a sample size of at least 15 per group is recommended for qualitative variables in controlled experimental settings. As in the present study many uncontrolled explanatory variables influence the outcome, this number was increased to at least 20 for reliable inference. Diagnostic imaging (computed tomography only) was used as the reference group in statistical analysis, as it is noninvasive and therefore expected to have the lowest mortality rate. All other procedures were compared to it. For the graphic representation of results, the inferred means plus/minus standard errors were transformed back from the underlying logit scale (between minus and plus infinity) to the risk scale (between zero and one) using the inverse of the logit function.

Additional analyses, including Pearson's Chi-square tests, were conducted to assess associations between categorical variables such as ASA classification, type of procedure, and the suspected presence of an oculocardiac reflex. Statistical significance was set at $p < 0.05$.

5. RESULTS

5.1. Study population

Search results identified 899 rabbits that underwent sedation or anaesthesia and data for a total of 1,230 anaesthetic events were recorded. In total, 54.9 % (19.3 % intact, 34.9 % castrated) of the events involved male rabbits and 45.3 % female (32.4 % intact, 12.9 % castrated). In a small number of rabbits (0.6 %) gender was not recorded. Most represented were dwarf breeds (table 1), with a median body weight for all breeds of 1.8 kg (interquartile ranges 1-2.6 kg). Age ranged from one months to 13 years with a median of 3 years (interquartile ranges 1-5 years).

Table 1: Distribution of breeds in rabbits in a total of 1,230 anaesthetic events at a single center (teaching hospital).

Breed		n =	Percentage	Breed		n =	Percentage
Dwarf	Dwarf	420	31.1%	Others	Angora	11	0.9%
	Dwarf lop	125	10.2%		Belgian hare	4	0.3%
	Dwarf lionhead	4	0.3%		English Spot	4	0.3%
	Dwarf rex	2	0.2%		Tan Rabbit	4	0.3%
	Netherland dwarf	2	0.2%		Vienna blue	4	0.3%
Giant	Giant checkered	2	0.2%	Dutch	3	0.2%	
	Flemish giant	1	0.1%	Teddy	3	0.2%	
	German giant	1	0.1%	Argenté	2	0.2%	
Lionhead		20	1.6%	NHD	2	0.2%	
Lop	Lop	2	0.2%	Rhineland	2	0.2%	
	English Lop	1	0.1%	Teddy mix	2	0.2%	
	Lop mix	1	0.1%	Albino	1	0.1%	
Rex	Dalmatian rex	2	0.2%	Californian	1	0.1%	
	Grey rex	2	0.2%	Half angora	1	0.1%	
	Rex	1	0.1%	NHD lop	1	0.1%	
Unknown breeds		595	48.4%	Russian	1	0.1%	
				Thuringian	1	0.1%	
				Tan	1	0.1%	
				Thuringian	1	0.1%	

5.2. ASA Classification

In 12.7 % (n = 156) cases, an ASA classification grade 1 was assigned, 46.3 % (n = 570) of cases were classified as grade 2, 35.2 % (n = 433) as ASA grade 3, 5.4 % (n = 67) cases as ASA grade 4 and in 4 cases the patient was considered as ASA grade 5.

5.3. Anaesthetic management

A variety of different anaesthesia protocols were administered (figure 1), based on the choice of the clinician in charge of anaesthesia. For premedication the following drugs were used in several different combinations: midazolam (Dormicum®, Cheplapharm GmbH, Germany), medetomidine (Narco Start®, Richterpharma AG, Austria), dexmedetomidine (Dexdomitor®, Orion Pharma, Finland), buprenorphine (Buprenovet®, Bayer Health Care, Austria), alfaxalone (Alfaxan®, Jurox Pty Ltd, Australia), ketamine (Ketamidor®, Richterpharma AG, Austria), methadone (Methadon Streuli®, Streuli Pharma AG, Switzerland), butorphanol (Alvegesic®, Alvetra u. Werfft GmbH, Austria), fentanyl (Fentanyl Hameln®, Hameln Pharma GmbH, Germany) morphine (Vendal®, G.L. Pharma, Austria). Most commonly used was midazolam, it was included in 802 protocols (of 1,230), followed by alpha-2-agonists in 731 cases (medetomidine n = 600, dexmedetomidine n = 131).

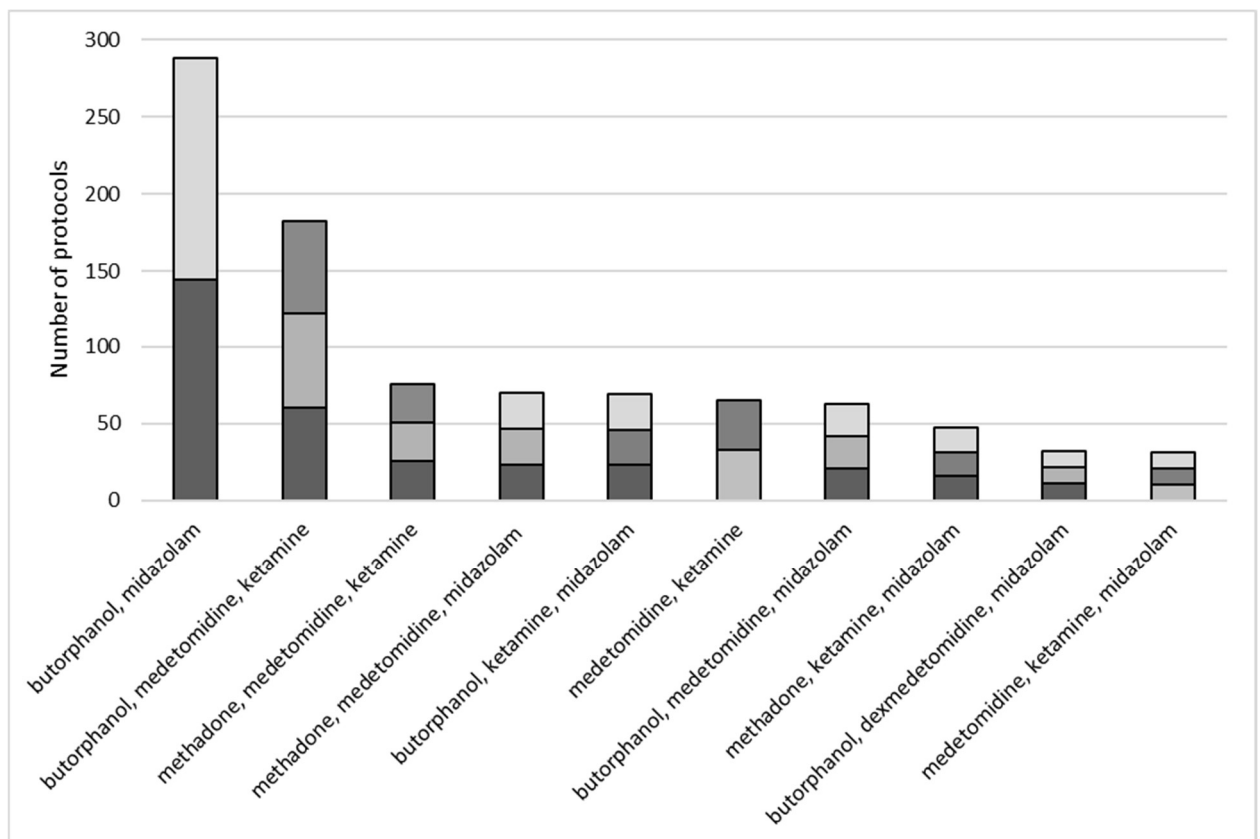


Figure 1: Different combinations of drugs used for premedication in rabbits in a total of 1,230 anaesthetic events at a single center (teaching hospital). Only combinations used in more than 30 anaesthetic events are represented.

Of the 600 procedures where an induction agent was administered, the most frequently used was alfaxalone (Table 2), others included propofol (Propofol “Fresenius” 1% MCT®, Fresenius Kabi, Germany), isoflurane (Vetflurane®, Virbac S.A. Carros, France), sevoflurane (Sevorane® AbbVie GmbH, Austria) and ketamine.

Table 1: Different drugs used for induction in rabbits in a total of 1,230 anaesthetic events at a single center (teaching hospital). Only the drugs or combinations that were used in more than 30 cases are represented.

Drug	Number of anaesthetic events
Alfaxalone	392
Propofol	70
Ketamine	42
Ketamine, Midazolam	34

Regarding airway management, rabbits received oxygen with or without inhalation with either a face mask (36.7 %), endotracheal tube (35.4 %), or supraglottic airway device (16.8 %). The rest had no airway support (11.0 %), these were cases for computed tomography placed in a VetMouseTrap (Universal Medical Systems Inc., Solon, USA) device receiving oxygen.

For maintenance, inhalational anaesthesia with isoflurane (n = 317) or sevoflurane (n = 184) in oxygen alone was used in most cases, followed by alfaxalone (n = 52). Other drugs used included medetomidine, dexmedetomidine, alfaxalone, propofol, ketamine, midazolam and opioids.

Table 2: Different medications used for maintenance of anaesthesia in rabbits in a total of 1,230 anaesthetic events at a single center (teaching hospital). Only the combinations that were used in more than 30 cases are represented.

Protocol	Number of anaesthetic events
Isoflurane	317
Sevoflurane	184
Alfaxalone	52
Isoflurane in oxygen, fentanyl	43

Postoperatively, rabbits received the following drugs as needed: antagonists: flumazenil (Flumazenil Kabi, Fresenius Kabi Austria GmbH, Austria), naloxone (Naloxon Amomed, Amomed Pharma GmbH, Austria) or atipamezole (Antisedan®, Orion Pharma/Richter Pharma AG, Austria), gastro-intestinal support: metoclopramide (Metmotyl, VetViva Richter GmbH, Austria) and analgesia with meloxicam (Metacam®, Boehringer Ingelheim Vetmedica GmbH,

Germany), metamizole (Novasul®, Richterpharma AG, Austria), or opioids (buprenorphine, butorphanol, methadone, morphine).

Table 3: Different medications used for postoperative care in rabbits in a total of 1,230 anaesthetic events at a single center (teaching hospital). Only the combinations that were used in more than 30 cases are shown.

Antagonists	Number of anaesthetic events
Flumazenil	346
Atipamezole	337
Atipamezole, Flumazenil	158
Atipamezole, Naloxone	83
Postoperative analgesia	Number of anaesthetic events
Meloxicam	395
Meloxicam, Buprenorphine	155

5.4. Type of anaesthetic event

Of the 1,230 cases a total of 114 (9.3 %) rabbits received anxiolysis, 188 (15.3 %) sedation and 928 (75.3 %) anaesthesia. Mortality rates were calculated from the total of animals receiving either sedation or anaesthesia (n = 1,116).

5.5. Procedure categories

Soft tissue surgery was the most frequently performed procedure, involving 385 rabbits. An overview of cases and mortality is shown in table 5. Endoscopy included four cases of rhinoscopy and one tracheoscopy. A total of 37 rabbits underwent radiation therapy for treatment of thymoma, with no deaths reported. As radiation therapy requires repeated daily anaesthesia sessions, these cases were excluded due to statistical dependence. For pairwise tests, all procedure categories with 20 or fewer cases were removed, so that five procedure categories remained in the data set: diagnostic imaging, dentistry, ophthalmologic, orthopedic, and soft tissue surgery.

Table 5: List of all procedures in rabbits in a total of 1,230 anaesthetic events at a single center (teaching hospital).

Procedure type	n=	Procedure type	n=
Soft Tissue (pathological)		Ophthalmology	
Ovariohysterectomy, pathological	63	Enucleation	33
Abscess/wound treatment	46	Lid correction	15
Gastro-intestinal	41	Dacryocystotomy	2
Genitourinary system	21	Phacoemulsification	2
Others	12	Abscess	1
Neoplasia	10	Vitreocentesis	1
Castration male, pathological	7	Keratectomy	1
Hernia	5	Diagnostic imaging	
Soft tissue (non pathological)		Computed Tomography	298
Castration male	123	Cone-Beam CT Head	17
Ovariohysterectomy	57	Fine needle aspiration biopsy	13
Orthopedic		Thoracocentesis	2
Fracture repair	56	Xrax (leg)	1
Amputation	10	Radiation therapy	37
Others (Hipluxation, corrective osteotomy)	2	Endoscopy	5
Dental		Szintigraphy	1
Dental correction	218		
Teeth extraction	67		
Abscess	56		
Endoscopy	5		
Others (Removal of cerclage, ablation and right ventral bulla osteotomy)	2		

In total, 173 rabbits underwent several anaesthetic events (excluding anxiolysis), with one individual undergoing anaesthesia 13 times.

Table 6: Number of anaesthetic events per patient in rabbits in total of 1,230 anaesthetic events at a single center (teaching hospital).

Number of anaesthetic events	Number of patients
1	726
2	111
3	32
4	8
5	7
6	5
7	3
8	3
9	1
10	1
12	1
13	1

A suspected oculocardiac reflex, as reported by the clinician in charge of the case, occurred in nine cases, all associated with ophthalmologic procedures. Of these, five patients died. Six out of the nine rabbits had received an alpha-2-agonist as part of the anaesthetic protocol (three of those that died).

5.6. Peri-anaesthetic mortality risk

A total of 70 rabbits receiving sedation or anaesthesia ($n = 1,116$) died during the procedure or in the postoperative period, resulting in an overall mortality rate of 6.3 %, excluding cases of euthanasia ($n = 43$) due to poor prognosis. One case was excluded because of lack of information. Neither gender, body weight nor breed were found to influence mortality, as expected. Age also did not significantly influence mortality.

A model only including ASA status as predictor shows a highly significant influence of ASA status (included as a fixed effect or factor) on survival ($p < 0.0001$). We report deviances as a measure of the model fit: the null deviance is 466.3 and the deviance 53.0 on four degrees of freedom. The Akaike information criterion for this model is: $AIC = 423.27$. Including the procedure, the deviance increases to 69.0 on eight degrees of freedom, a considerable increase compared to the model with only ASA status, with both factors significant (ASA: $p < 0.0001$; procedure: $p = 0.003$). The Akaike information criterion for this model is: $AIC = 415.32$. As $\Delta AIC > 4$, this can be considered a strong difference between the two models. Administration of an alpha-2 agonist did not have a significant influence on mortality; neither did the type of device used for airway management.

Studying the model with ASA status and procedure in more detail, we find that mortality risk increases with ASA status as expected; the mortality risk was lowest in diagnostic imaging and highest in ophthalmologic procedures. This seems to be related to the occurrence of an oculocardiac reflex. Indeed, a chi-squared test showed a significant association of mortality and a suspected oculocardiac reflex within ophthalmologic procedures ($p = 0.01$).

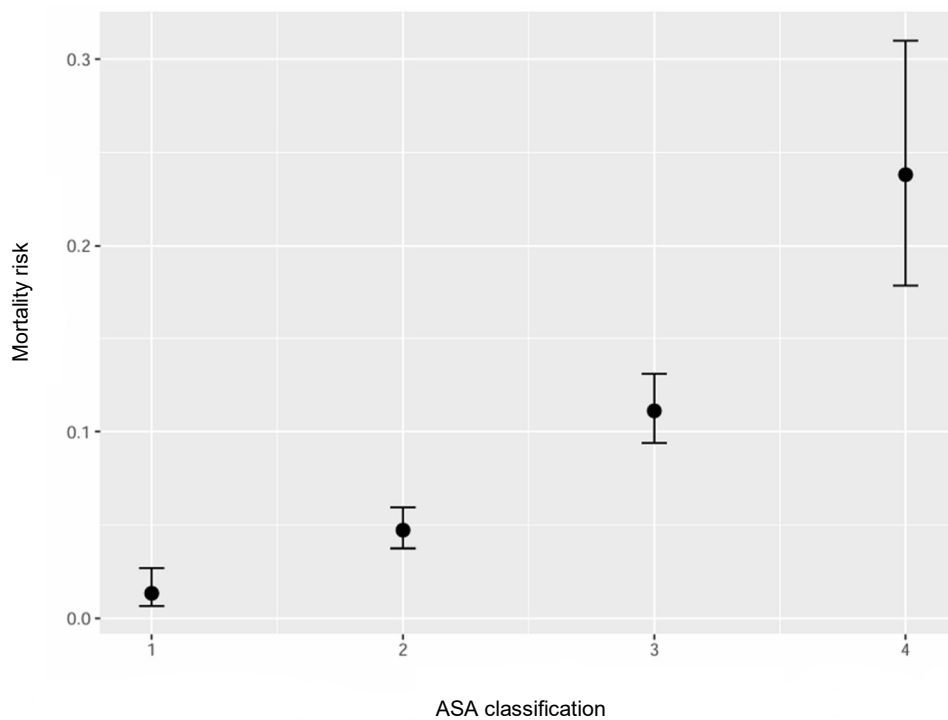


Figure 2: Mortality risk depending on the ASA classification in rabbits in a total of 1,230 anaesthetic events at a single center (teaching hospital). Dots indicate the average mortality risk, whiskers the upper and lower standard errors, both after back-transformation to the risk scale.

Soft tissue surgery was the most frequently performed procedure ($n = 385$), with 28 deaths occurring (7.2 %). Orthopedic procedures were performed on 68 rabbits, with 7 deaths reported (10.3 %). Dental procedures were carried out 348 times, in which 19 rabbits died (5.5 %). A total of 55 rabbits had an ophthalmologic procedure, of which 11 died (20.0 %). Four rabbits died in association with diagnostic imaging (1.2 %), one during x-ray for a planned fracture repair and three in the post-operative period after computed tomography. One death occurred during endoscopic examination of the trachea in a patient with dyspnea.

5.7. Time of death

Neither time of death and age nor time of death and ASA status showed a significant association.

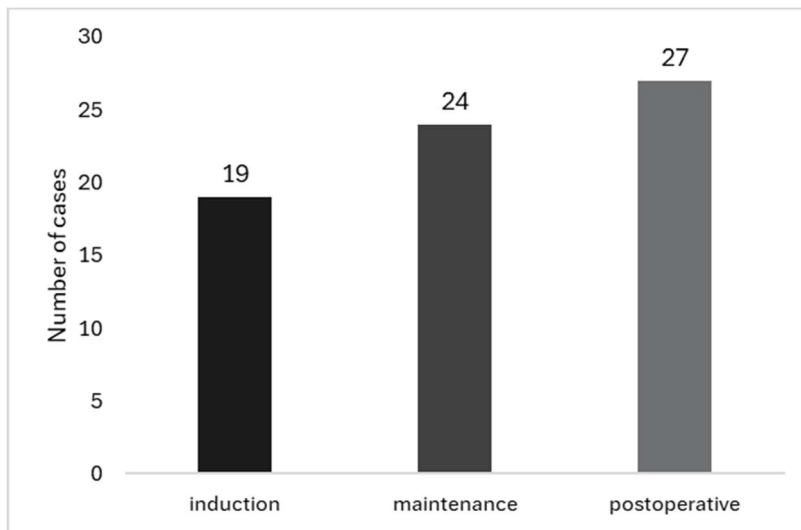


Figure 3: Distribution of deaths in rabbits in a total of 1,230 anaesthetic events at a single center (teaching hospital). The time periods are defined as during introduction (between the start of premedication and start of surgery or intervention), during maintenance (during the procedure itself), and in the postoperative phase (between the end of procedure and until discharge from the hospital). No statistical difference could be detected regarding time of death.

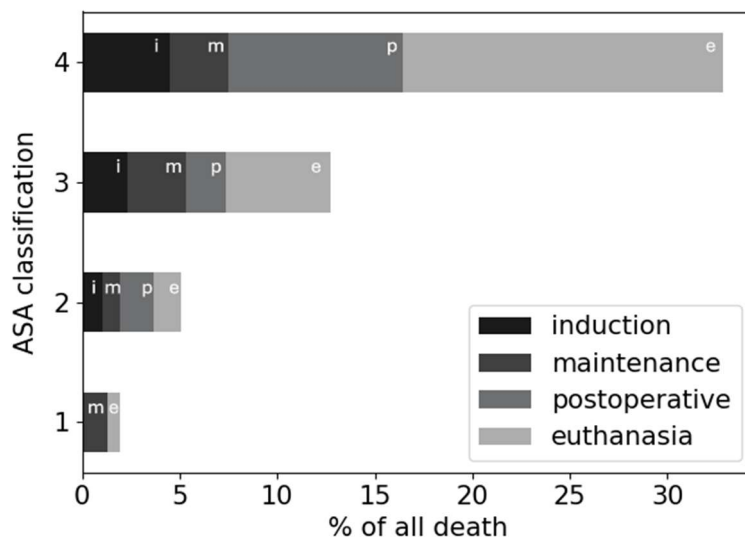


Figure 4: ASA classification and time of death deaths in rabbits during a total of 1,230 anaesthetic events at a single center (teaching hospital). No statistical difference could be detected regarding ASA classification and time of death.

6. DISCUSSION

As pet owners increasingly prioritize the health and well-being of their animals, diagnostic or therapeutic interventions are becoming more frequent and complex. This trend is reflected in the broad scope of procedures analyzed in the present study, encompassing areas such as ophthalmology and oncology. The inclusion of a wide range of disciplines offers a comprehensive perspective that has maybe not been present in prior research.

In this retrospective analysis spanning ten years, the overall perioperative mortality rate was 6.27 % (70/1,116). This is notably higher than the 1.39 % overall mortality reported in a prospective UK study from 2008 [2], but aligns more closely with their findings for sick rabbits (7.37%) and the results of Lee et al. of 4.8 % [10]. A more recent retrospective study reported a lower rate of 2.05 % [1]. One plausible explanation for the elevated mortality in our study may lie in the cases included. The University of Veterinary Medicine, Vienna is both a first opinion and a referral center. Unlike studies focused primarily on routine interventions in healthy animals, the present data encompass both elective surgeries (e.g., neutering) and emergency procedures in critically ill patients (e.g., pyometra). Corresponding to the slightly higher mortality rate (6.3 % vs. 4.8 %), the present study has higher percentages of patients with ASA grade 3 and 4 than that of Lee et al., with grade 3 in 1.4% and grade 4 in 0.95% of cases vs. 35.2 % and 5% respectively in the present study [2]. While it is difficult to compare ASA grades to Pieper et al., because their study grouped animals in ASA grades 1 to 2 and 3 to 4, with mortality rates of 2.05 % and 5.69 %, respectively, 1474 out of their 1757 cases (83.9 %) were routine desexing procedures, compared to 180 out of 1230 (14.6 %) in the present study. The higher mortality rate in the group of sick patients (5.69% in ASA grade 3 to 4) matches the present results and underlines our findings of ASA classification as a significant risk factor.

Regarding statistical analysis, it is noted that among the many potentially influential predictor variables recorded, only some are likely to make a difference. In addition to statistical considerations for model selection, emphasis was also placed on interpretability.

When analyzing demographic data such as gender, body weight, age and breed, no significant correlation with perioperative mortality was found. However, body weight may be an insufficient criterion, particularly in assessing obesity. Recent studies in dogs have demonstrated that obesity can significantly impact perioperative outcomes [18]. Incorporating the Body Condition Score (BCS) in future studies may therefore enhance risk stratification and provide a more

accurate assessment of surgical risk. Age could pose a potential factor; while young animals often undergo routine procedures like spaying, older animals may face more complex or emergent surgeries, potentially influencing outcomes. Counterintuitively, age-related risks could not be detected in the present study. This could be due to the retrospective nature of the data, the age was stated by the owners and might not always be correct or sometimes unknown when adult animals are taken in from a shelter, or it might be due to the heterogeneity of cases, which might have veiled specific risk factors.

The ASA classification was, as expected, a significant factor, which shows the importance of clinical and if possible, further diagnostic assessment of rabbits before anaesthesia. The health condition has a strong influence on the outcome of the procedure, since the reported mortality has a wide range from 0.826 % in healthy to 7.14 % in sick rabbits, in moribund rabbits it is even 29.5 % [3]. In the previous study of Pieper et al. the poor health status was also the strongest indicator leading to death [2]. This information is also important to discuss with owners before procedures and can potentially influence decisions on how to proceed with a case.

An accurate assessment of an animal's health status is also essential for the anaesthetist to select an appropriate drug protocol tailored to the individual case. Based on this evaluation, for example medetomidine is typically used as premedication in healthy or mildly ill rabbits, whereas midazolam is preferred for patients with systemic illnesses [19]. Regarding anaesthetic management, the present study encompassed a variety of protocols with different drug combinations. While this diversity reflects personalized care, it poses challenges for direct comparison and might have veiled other risk factors. In contrast to previous studies, the present data did not confirm either alpha-2 agonists [4], or the use of endotracheal tubes vs. SGADs as risk factors [3]. Standardizing some aspects of anaesthetic and perioperative protocols in future studies could enhance comparability while preserving clinical relevance.

The different types of procedures had a significant influence on the outcome, with ophthalmologic procedures more likely to result in death. A possible reason for this new finding may be the occurrence of an oculocardiac reflex. The oculocardiac reflex is a response of the cardiovascular system to pressure on the eye or the ocular adnexa. It leads to arrhythmia, possibly resulting in cardiac arrest [20]. As it is a potentially lethal complication during ophthalmic surgery, it should be taken into account when planning perioperative management. It is advisable to prepare anticholinergic agents in advance to allow immediate intervention if needed. Studies in dogs have shown that retrobulbar nerve blocks can significantly reduce the

incidence of oculocardiac reflex during enucleation [21]. However, equivalent data for rabbits are currently unavailable. Future prospective research should focus on evaluating the effect of retrobulbar anaesthesia and the role of alpha-2 agonists in oculocardiac reflex in this species. Another reason why these interventions carry a higher mortality rate would be bleeding due to a large vascular sinus or plexus within the orbit of rabbits [22]. Indeed, in 3 of the cases, hemorrhage was suspected as complication.

In earlier research, the timing of mortality has offered further insight with studies reporting that more than half of the patients died in the post-anaesthetic phase (48 h) [1]. Rabbits in poor health were more likely to die postoperatively, whereas in healthier individuals the mortality was higher intraoperatively [1]. This could not be shown in the present study. After invasive procedures, rabbits often show gastrointestinal stasis as a sign of postsurgical pain [23]. Gastrointestinal complications have been observed in up to 38% of rabbits within 72 hours after an anaesthetic event [2]. This will lead to post-anaesthetic morbidity and mortality (lethargy and swelling of the surgical wounds as postoperative complications) [3]; therefore gastro-intestinal support should be a priority in recovery. Assisted feeding post-surgical could potentially prevent gut stasis [24].

6.1. Limitations

As in all retrospective studies, the non-uniformity of data poses a challenge. This was most apparent in the diversity of anaesthesia protocols, with many different drugs and combinations making robust statistical conclusions difficult. This may be the reason why the present study did not confirm previous findings of alpha-2-agonist based drug combinations as a risk factor, among others, for complications and possibly death [4]. In future research, it would be valuable to also consider the route of administration of drugs (e.g., intramuscular, intravenous, intranasal, or oral). Unfortunately, this was not possible in the current study due to insufficient data. Previous studies have indicated that intramuscular injections may cause complications in rabbits. [25]. Prospective studies with standardized protocols for this aim would be worthwhile to gain further knowledge and improve patient safety. Furthermore, evaluation of an animal's health status and grading of ASA classification should ideally be carried out by a single observer, as different individuals might introduce subjectivity which could in turn influence the results [26].

Regarding the occurrence of post-anaesthetic death, some data might have been lost due to an unstandardized monitored and documented follow-up period. Patients were discharged depending on the procedure and physical status, which could be the same day (e.g. elective castration) or several days after the intervention, leading to loss of additional cases of mortality.

7. CONCLUSIONS

Overall, peri-anaesthetic mortality was significantly associated with ASA status and procedure type, but not with demographic data, use of alpha-2-agonists or type of airway management device. The highest mortality occurred in ophthalmologic procedures, likely due to the oculocardiac reflex. Further prospective research is warranted to possibly identify additional risk factors.

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