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**A retrospective study on the effects of perioperative surgical
antimicrobial prophylaxis on occurrence of postoperative
complications in elective surgeries in horses**

Diploma Thesis

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Submitted by

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Wien, 01.06.2025

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Zusammenfassung

Elektive chirurgische Eingriffe an Pferden sind geplante Operationen, die trotz aller Vorbereitung Risiken für postoperative Komplikation, wie Wundinfektionen oder andere nosokomiale Infektionen, tragen. Da antimikrobielle Resistenzen zunehmen und gesetzliche Änderungen auf nationaler und internationaler Ebene prophylaktische Antibiotika-Gabe stark einschränken, wird der Einsatz perioperativer Antibiotikaphylaxe bei elektiven Operationen immer stärker hinterfragt. Ziel dieser retrospektiven Studie war es, den Effekt von perioperativer Antibiotikaphylaxe auf die Entstehung von postoperativen Komplikationen zu untersuchen. Es wurde die Hypothese aufgestellt, dass diese keinen signifikanten Einfluss auf das Auftreten von postoperativen Komplikationen hat. Zwischen November 2022 und Juni 2024 wurden 400 Equiden an der Pferdeklinik der Veterinärmedizinischen Universität Wien elektiven Operationen unterzogen. Die Krankenakten dieser Fälle wurden verwendet, um verschiedene prä-, intra- und postoperative Parameter zu erheben. Diese wurden mittels uni- und multivariabler logistischer Regressionsmodelle auf einen Zusammenhang mit dem Auftreten von Komplikationen statistisch analysiert. In 38,75 % der Fälle traten postoperative Komplikationen auf. Eine längere Operationsdauer, eine vorangegangene Behandlung außerhalb der Klinik sowie Folgeoperationen erhöhten das Risiko für postoperative Komplikationen signifikant. Eine orthopädische Diagnose bei der Ankunft senkte hingegen das Risiko signifikant. Die Gabe von Antibiotikaphylaxe hatte keinen signifikanten Einfluss auf deren Auftreten. Da sie im Durchschnitt jedoch zu früh verabreicht wurde, könnte dies die fehlende Wirksamkeit erklären. Zukünftige prospektive Studien sollten den Effekt von Antibiotikaphylaxe unter standardisierten Bedingungen weiter untersuchen, außerdem sollte ein Fokus auf die Therapie, die der Patient vor Klinik-Aufnahme erhalten hat, sowie auf eine möglichst kurze Operationsdauer, gelegt werden.

Abstract

Elective surgeries in equine medicine, although planned, carry risks of postoperative complications, such as surgical site infections or other nosocomial infections. Considering the rise of antimicrobial resistances and recent changes in national and international laws restricting prophylactic antimicrobial use heavily, the use of perioperative surgical antimicrobial prophylaxis in such procedures is under debate. This retrospective study investigates the influence of perioperative surgical antimicrobial prophylaxis, and we hypothesized that it does not affect the development of postoperative complications. Medical records of 400 equids treated at the Equine Clinic of the University of Veterinary Medicine Vienna between November 2022 and June 2024 were reviewed. Several pre-, intra- and postoperative variables were documented and statistically analyzed. Uni- and multivariable logistic regression models were used to determine associations to the development of post-surgical complications. In 38.75 % of cases complications occurred postoperatively. Prolonged surgical duration, treatment prior to admission and the need for follow-up procedures significantly increased the risk of postoperative complications, whereas an orthopedic diagnosis upon admission decreased it. Surgical antimicrobial prophylaxis had no significant influence on the occurrence of postoperative complications. However, it was administered on average too early, which could possibly explain its ineffectiveness. Future prospective studies should further evaluate the effect of surgical antimicrobial prophylaxis under standardized conditions and focus on a detailed documentation of the patient's treatment prior to hospital admission, as well as keeping the duration of surgery as short as possible.

Abbreviations

AM = antimicrobial

AMs = antimicrobials

AMR = antimicrobial resistance

GA = general anesthesia

PSC = postsurgical complication

SAP = surgical antimicrobial prophylaxis

SSI = surgical site infection

WBCC = white blood cell count

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1 Introduction

Procedures not initiated due to emergency admission, but which are planned beforehand are classified as elective. However, they might still be urgently needed, medically necessary or aimed at improving quality of life (1, 2). Even under perfect conditions, these procedures are not free of any risk. Besides the intra- and postanesthetic complications, which come with every equine surgery under general anesthesia (GA), e.g. hypotension, hypercapnia, myopathies or injuries during recovery (3), patients can develop postoperative complications. These include infections caused by bacterial or viral pathogens, like surgical site infections (SSI) or other nosocomial infections (4).

To lower the risk of bacterial postoperative complications in elective and emergency procedures alike, surgical antimicrobial prophylaxis (SAP) has been suggested as early as the 1960s and has been a part of modern medicine ever since (5, 4). There are different types of antibiotic prophylaxis, with SAP being a primary perioperative prophylaxis, meaning that the goal of administration is to prevent an initial infection. Other forms of prophylaxis are the secondary type, which is used to prevent the reemergence of preexisting diseases, and eradication prophylaxis, which aims at the complete disappearance of a present pathogen to prevent infection (6). The latter types of prophylaxis will not be discussed further in the following study.

Since Alexander Fleming's discovery of penicillin in 1928 (7), antimicrobials (AMs) have become essential for treating bacterial infections in both human and veterinary medicine (8). However, their imprudent and excessive use has led to the rise of antimicrobial resistance (AMR) which is considered to be one of the biggest threats to modern medical care (9). In 2016, it was estimated that approximately 700,000 people die annually due to resistant pathogens. Experts believe that in 2050, the lives of 10 million people and an economic value of roughly 100 trillion USD will be in jeopardy because of AMR. This can be prevented if actions are taken to slow down the current development (10). AMR is also on the rise in the field of equine medicine. Since veterinarians cannot expect that there will be new antimicrobial drugs for equine treatment, they need to be more aware of correct antimicrobial stewardship, in order to avoid antibiotic resistant infections becoming a daily concern. Additionally, equids hold a unique position globally due to their various points of interaction with the human population, for instance direct contact as companion animals or indirect, as their manure can be used as fertilizer. Thus, a continued rise of AMR in the species can have severe consequences for the public health as well (11). Examples for those consequences are higher chances of dying due to infections, longer hospitalization of patients and, as a result, also higher financial costs for patients or the patient's owner (12, 10).

To counteract this development, AMs should only be applied when necessary and improper use must be avoided (13). In response to these concerns and to slow down the development of AMR, the European Union introduced Regulation 2019/6, which came into effect on January 28, 2022. This resulted in the implementation of a new Veterinary Medicinal Products Act (Tierarzneimittelgesetz) in Austria, which became operative on January 1, 2024, making this topic as relevant as ever (14, 15). One aspect of this new legislation covers antimicrobial prophylaxis, which results in prophylactic application being heavily restricted. The European legal text states in article 107 §3 “Antimicrobial medicinal products shall not be used for prophylaxis other than in exceptional cases, for the administration to an individual animal or a restricted number of animals when the risk of an infection or of an infectious disease is very high and the consequences are likely to be severe” (16). Due to this legislation, the necessity and use of SAP in clean and elective surgeries is currently discussed more than ever (17).

These changes in legislation result in modifications of SAP protocols at the Equine Clinic of the University of Veterinary Medicine Vienna. As those alterations are being implemented, the question is raised, if there might be a negative impact and increased risk for patients undergoing elective surgery without the use of perioperative AMs. Concerns are, for example, whether this results in these patients experiencing more postoperative complications, such as pyrexia, pneumonia or SSI, compared to equids that receive antimicrobials. Another aim of the present study is to investigate additional parameters which may influence the development of such complications.

Recent scientific literature suggests that SAP in clean and elective surgical procedures such as castrations or arthroscopies cannot minimize the risk of postsurgical complications (PSC). Therefore, SAP is deemed an unnecessary use of AMs in these cases and should be avoided, as it may enhance the development of AMR (18, 8, 17). The study by Borg et al., which focused on elective arthroscopy, also found that the risk of developing a septic joint postsurgery without preoperative SAP was considerably lower than the risk of antimicrobial (AM) associated diarrhea (17). Furthermore, studies were able to determine other factors which significantly influence PSC. Prolonged time spent under GA, as well as longer surgical time itself, are significantly associated with an increased occurrence of PSC (19, 20). Looking at the duration of surgery specifically, Cheng et al. showed that the chance for PSC development increases by 5 % every 10 minutes of surgery, but 37 % every 60 minutes, however, no linear trend could be observed (19). The type of procedure which was performed is another influential parameter for the development of PSC (20). Equids undergoing elective arthroscopy were found to have a lower risk of PSC compared to other procedures (21). Hardefeldt et al. proposes that extended or inappropriate AM therapy can have a negative impact on the patient's convalescence as well. On one hand, inappropriate AM treatment can enhance the development of AMR and result in more severe PSC. On the other hand, the duration of AM

therapy, which is needed to resolve a bacterial infection, is probably shorter than what is commonly applied, as recent studies in human and veterinary medicine show. Using AMs for a shorter period results in a lower risk of AM side effects, decreases selection for resistant bacterial strands and is likely to increase owner compliance (9).

In order to investigate whether this also applies to the clinical setting at the Equine Clinic of the University of Veterinary Medicine Vienna and to determine if there might be additional factors which contribute to the development of PSC, this retrospective study was conducted. Horses and other equine species which underwent elective surgery between November 2022 and June 2024 were assessed and several pre-, intra- and postoperative parameters were documented.

We hypothesized that perioperative SAP does not affect the development of postoperative complications.

2 Material and Methods

Between November 2022 and June 2024, 400 horses and other equine species underwent elective surgery at the Equine Clinic of the University of Veterinary Medicine Vienna. Their medical records were reviewed in retrospect and evaluated for this study using the hospital's computer program for medical records, "Tierspitalinformationssystem". The information was documented using Microsoft Excel for Microsoft 365 MSO Version 2408 (Microsoft Corporation, Redmond, USA). Elective surgery was defined as a non-emergency, medically necessary or life-improving, planned procedure, with varying degrees of urgency (1, 2). Any pathology which developed after a surgical procedure, standing or under GA, was noted as a PSC. The classification of PSC will be described in the following paragraphs.

Readmission due to the development of PSC after discharge was treated as one case. If the patient was readmitted due to other reasons and unrelated to the previous visit, it was treated as a separate case. For this study, several pre-, intra- and postoperative parameters were obtained as stated below.

Documented parameters concerning the patient's signalment were age (years), sex (mare/jenny, stallion/jack, gelding), breed and weight (kilogram). Breeds were categorized into Warmblood, Draft Horse, Thoroughbred-type (Thoroughbred, Arabian and Part-Bred), pony (any breed with a standard wither height under 1.48 meters), Icelandic Horse and donkey (including hybrids). Recorded medical history data included treatment prior to hospital admission, classified into AM, pain medication, a combination of both or corticosteroids. Treatment given at the clinic before the first procedure (AM, pain medication or both) was also documented and if there was an episode of fever ($>38.5\text{ }^{\circ}\text{C}$) prior to surgery. Regarding the equid's laboratory parameters, the white blood cell count (WBCC) and neutrophils count (cells/ μl) pre- and post-surgery were included.

Furthermore, the diagnosis (soft tissue pathology, orthopedic issue, ophthalmological issue, pathologies of the oral cavity, respiratory tract or middle ear) was recorded, along with the type of procedure performed and whether it was done under GA. The procedure type was categorized into mass removal, surgery on structures of the respiratory tract or middle ear, tooth extraction or procedure of the sinus system, orthopedic surgery, castration and laparotomy/laparoscopy, including procedures on the penis and excision of septic funiculitis, and ophthalmological procedures. If a patient had a second surgery, it was documented in the category "Procedure 2", using the same subcategories as described for the first procedure categories. The patient's ASA status, use of SAP and the specific regimen thereof (benzylpenicillin, benzylpenicillin and gentamicin, trimethoprim-sulfonamide) were documented. Additionally, the time between SAP administration and the start of surgery (hours) was noted. The use of intraoperative AMs (amikacin, bacitracin/neomycin, benzylpenicillin and

gentamicin, benzylpenicillin, gentamicin) was also recorded. The duration of GA and surgery (hours) were included, as well as the occurrence of intraoperative complications.

The postsurgical data was categorized based on the occurrence of complications and the following treatment approach. PSC categories included abnormal rectal temperature, wound associated complications, pathology of the respiratory tract, cardio-vascular pathology and pathology of the gastro-intestinal tract. The category of abnormal rectal temperature included hypothermia ($<36.8^{\circ}\text{C}$ in more than two consecutive measurements) and fever ($>38.5^{\circ}\text{C}$). In each case, it was documented whether it was left untreated, treated with antibiotics or without. Additionally, it was recorded whether the patient had an episode of fever ($>38.5^{\circ}\text{C}$) post-surgery, as well as the peak temperature of that episode. Furthermore, the postoperative medication was documented, subcategorized into systemic and local AMs and non-antibiotic treatment. Recorded systemic AMs included doxycycline, trimethoprim-sulfonamide, benzylpenicillin, gentamicin and a combination of benzylpenicillin and gentamicin. Regarding local AMs, the subcategories consisted of amikacin, chlortetracycline hydrochlorid, bacitracin/neomycin, ofloxacin, moxifloxacin, benzylpenicillin, oxytetracycline and azithromycin. Included non-antibiotic drugs for treatment post-surgery were flunixin, phenylbutazone, methadone, firocoxib, metamizole, a combination of methadone, lidocaine and ketamine as a constant rate infusion, meloxicam and lidocaine. The duration of each treatment was recorded in days.

To conclude, the time from admission to the first surgery (days) and from admission to discharge (days) was documented. It was also noted if the patient was readmitted or if the admission resulted in the patient's euthanasia. Additionally, the need for a follow-up procedure was recorded, excluding cases where a staged procedure was planned in advance. This includes for example the complete incisors extraction due to equine odontoclastic tooth resorption and hypercementosis.

Statistical analysis was performed using Stata IC 15.1 (StataCorp LLC, College Station, Texas, USA). Overall, 400 horses and other equids were included in the statistical analysis. Descriptive statistics were performed on all recorded parameters. Concerning categorical data, the absolute and relative (%) frequency was determined. As for the continuous data, the mean, median and standard deviation/interquartile range were calculated. A chi-squared-test was performed to compare the different groups of categorical data. To investigate the potential univariable association between all independent variables and the dichotomous outcome "developed PSC" vs. "did not develop PSC", simple logistic regression models were applied. Predictive variables with a univariable p-value of <0.25 , which also had a sufficient number of data points and were deemed of clinical relevance, were used in a multivariable logistic regression model, with the occurrence of post-surgery complications as the dichotomous

dependent variable. Backwards elimination procedures were applied until the final model included only significant ($p < 0.05$) associations with the dependent variable. Presence of interaction between independent variables were assessed and model assumptions checked.

3 Results

During the study period of 19 months, 400 horses and other equine species underwent elective surgeries.

3.1 Signalment and preoperative parameters

The results of signalment and preoperative parameters are displayed in Table 1. 33 % (132/400) of equids were mares/jennies, 25.75 % (103/400) were stallions/jacks and 41.25 % (165/400) were geldings. Geldings showed a significantly higher risk for complications than mares ($p=0.038$). The distribution of breeds was 65.75 % (263/400) Warmbloods, 7.25 % (29/400) Draft Horses, 4 % (16/400) horses of Thoroughbred-type, 16.25 % (65/400) Ponies, 5.25 % (21/400) Icelandic Horses and 1,5 % (6/400) Donkeys. Horses of Thoroughbred-type were three times more likely to exhibit complications than Warmbloods ($p=0.039$). 62.5 % of the documented patients belonging to this breed-group showed some type of PSC compared to 37.5 % with no complications post-surgery. The average age and weight were 10.8 ± 7.5 years and 495.6 ± 130.1 kg, respectively. There was no association between the development of PSC and the equid's age or ($p=0.632$) weight and ($p=0.122$).

As for preoperative parameters, 26 patients were treated in the field prior to hospital admission. A third each (9; 34.62 %) received only AM therapy or sole treatment with pain medication, 26.92 % (7/26) received AMs and pain medication and one horse (3.85 %) received corticosteroids. A history of previous treatment outside of the Equine Clinic of the University of Veterinary Medicine Vienna led to a 1.44-times increased risk of getting PSC ($p=0.027$). Concerning treatment at the clinic prior to surgery, 11.25 % (45/400) received pain medication, AMs or both. The preoperative treatment at the clinic itself showed no significant association with PSC ($p=0.249$). Preoperative fever was observed in 4.5 % (18/400) of the cases. There was no significant association to PSC ($p=0.141$). The most common main diagnosis, which led to the admission of the patient, was soft tissue related with 39 % (156/400), followed by 32.75 % (131/400) patients with orthopedic issues. The remaining patients showed ophthalmological pathologies (4 %; 16/400) and pathologies concerning the oral cavity, respiratory tract or the middle ear (24.25 %; 97/400). The parameter of diagnosis was significantly connected to the development of PSC. Out of all subcategories, orthopedic diagnoses showed a statistically significant association with the development of PSC, as patients were 43 % less likely to develop them compared to patients with a soft tissue pathology ($p=0.022$). A detailed display of diagnosis and the occurrence of PSC can be found in Figure 1. Leukopenia prior to surgery occurred in 2.94 % (6/204), leukocytosis in 12.75 % (26/204). Neutropenia was noted in 5.88 % (12/204) of cases, neutrophilia in 13.73 % (28/204). The association of leukopenia pre-surgery and PSC was approaching significance ($p=0.054$).

However, there was no significant influence between the neutrophil count pre-surgery and PSC.

Table 1, univariable association between signalment and preoperative variables and the occurrence of postoperative complications in 400 equids undergoing elective surgery at the Equine Clinic of the University of Veterinary Medicine Vienna, November 2022 – June 2024, based on simple logistic regression models.

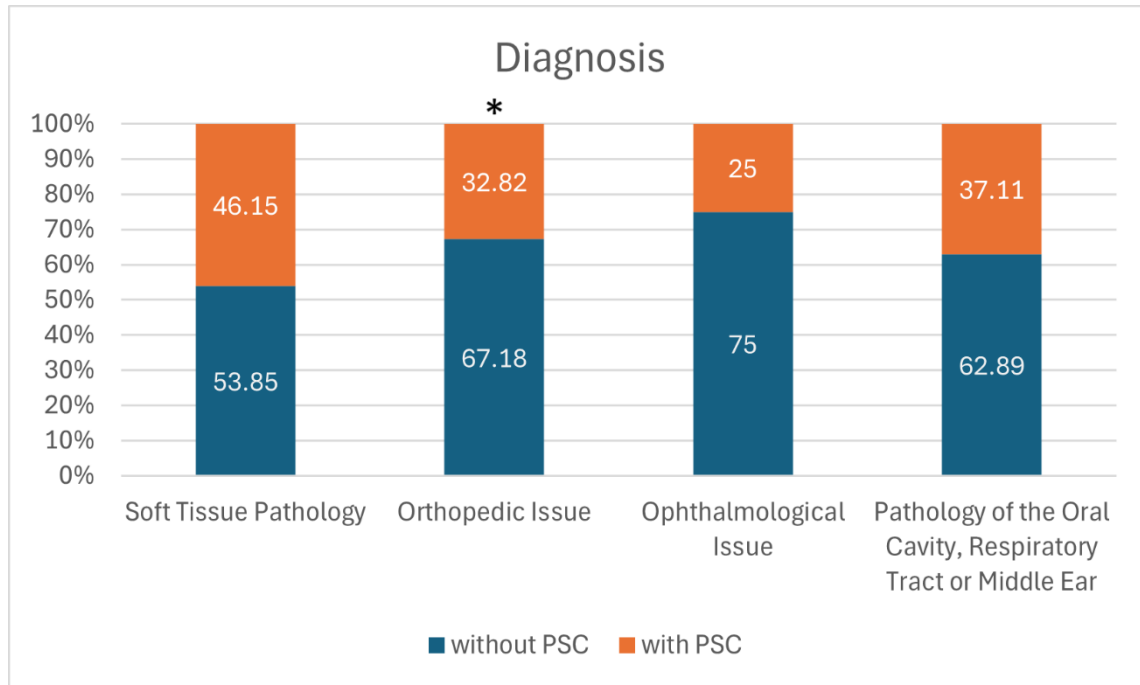
Variable (unit) (n)	Category	post-surgical complication		OR	95 % CI	p-value
		no	yes			
Age (years) (400)		10.96 ± 7.53	10.59 ± 7.51	0.99	0.97 - 1.02	0.632
Sex (400)	Mare/Jenny	68.18 % (90)	31.82 % (42)	referent		0.109 ^a
	Stallion/Jack	60.19 % (62)	39.81 % (41)	1.42	0.83 - 2.43	0.204
	Gelding	56.36 % (93)	43.64 % (72)	1.66	1.03 - 2.68	0.038
Breed (400)	Warmblood	64.26 % (169)	35.74 % (94)	referent		0.251 ^a
	Draft Horse	65.52 % (19)	34.48 % (10)	0.95	0.42 - 2.12	0.893
	Thoroughbred	37.5 % (6)	62.5 % (10)	3.00	1.06 - 8.5	0.039
	Pony	53.85 % (35)	46.15 % (30)	1.54	0.89 - 2.67	0.123
	Icelandic	57.14 % (12)	42.86 % (9)	1.35	0.55 - 3.32	0.515
	Donkey	66.67 % (4)	33.33 % (2)	0.90	0.16 - 5.00	0.903
Weight (kg) (397)		503.73 ± 125.75	482.94 ± 136.15	0.999	0.997 - 1.000	0.122
Diagnosis (400)	soft tissue	53.85 % (84)	46.15 % (72)	referent		0.073 ^a
	orthopedic	67.18 % (88)	32.82 % (43)	0.57	0.35 - 0.92	0.022
	ophthalmological	75 % (12)	25 % (4)	0.39	0.12 - 1.26	0.115
	oral cavity/respiratory tract/middle ear	62.89 % (61)	37.11 % (36)	0.69	0.41 - 1.16	0.158
Fever pre-surgery (400)	no	62.04 % (237)	37.96 % (145)	referent		
	yes	44.44 % (8)	55.56 % (10)	2.04	0.79 - 5.30	0.141
Previous Treatment (400)	no	62.73 % (234)	37.27 % (139)	referent		
	yes	40.74 % (11)	59.26 % (16)	2.45	1.10 - 5.43	0.027
Medication pre-surgery at clinic (400)	no	62.25 % (221)	37.75 % (134)	referent		
	yes	53.33 % (24)	46.67 % (21)	1.44	0.77 - 2.69	0.249
WBCC pre-surgery (204)	normal	62.79 % (108)	37.21 % (64)	referent		0.041 ^a
	low	16.67 % (1)	83.33 % (5)	8.44	0.96 - 73.84	0.054
	high	50.00 % (13)	50.00 % (13)	1.69	0.74 - 3.86	0.216
Neutrophil count pre-surgery (204)	normal	59.76 % (98)	40.24 % (66)	referent		0.851 ^a
	low	66.67 % (8)	33.33 % (4)	0.71	0.21 - 2.57	0.638
	high	57.14 % (16)	42.86 % (12)	1.11	0.49 - 2.51	0.795

p^a – overall p-value for categorical data, based on logistic regression analysis

OR – odds ratio, CI – confidence interval, WBCC – white blood cell count

Figure 1, proportion of equids with and without PSC in relation to their diagnosis.

* Equids with orthopedic issues were significantly less likely to develop PSC ($p=0.022$).



3.2 Intraoperative parameters

The results of all intraoperative parameters are displayed in Table 2. The most common type of first procedure was orthopedic surgeries (27.75 %; 111/400). 16.75 % (67/400) of patients underwent a second procedure. The most common procedure was tooth extraction or surgery on the sinus system (67.16 %; 45/67). A detailed description of the distribution of procedure types for the first procedure can be found in Figure 2, the percentages for the second procedures can be found in Figure 3. Neither the type of first procedure nor the type of second procedure had a significant influence on the development of PSC.

Out of all 400 patients, 48.75 % (195/400) received SAP prior to their first procedure. The most common SAP regimen was a combination of benzylpenicillin (20.000 – 30.000 IE/kg every 6 hours intravenously) and gentamicin (6.6 mg/kg once daily intravenously) with 63.59 % (124/195) of patients receiving this regimen. A sole benzylpenicillin regimen (20.000 – 30.000 IE/kg every 6 hours intravenously) was used in 33.33 % (65/195) of cases, and the remaining 3.08 % (6/195) were given trimethoprim-sulfonamide (5 mg/kg + 25 mg/kg bidaily orally) as SAP pre-surgery. The administration of SAP preoperatively did not change the odds that complication occurred ($p=0.127$). A detailed display of the proportion of patients concerning the development of PSC and whether they received SAP can be found in Figure 4. The mean

time between the administration of preoperative SAP and the start of surgery was 1.68 ± 0.68 hours. For patients with PSC this result was at 1.59 ± 0.63 hours and 1.75 ± 0.71 hours for those without. This parameter was not significantly associated with the occurrence of PSC ($p=0.127$). 46 patients (11.50 %) received AMs during surgery as well, but there was no significant link between the intraoperative application of AMs and the development of PSC ($p=0.706$) either. Complications during surgery occurred in 30.25 % of patients (121/400), with 45.45 % of them (55/121) developing complications post-surgery subsequently. However, this variable had no significant influence on the development of PSC ($p=0.071$).

Out of all 400 procedures, 55.75 % (223/400) were done under GA. The mean duration was 2.07 ± 0.99 hours. Equids which developed complications after surgery had a mean duration under GA of 2.3 ± 1.8 hours compared to 1.9 ± 0.8 hours in cases which left the clinic without further problems during convalescence. While undergoing GA was not linked to a higher chance of developing complications after surgery ($p=0.249$), a longer duration of GA increased the chances of PSC ($p=0.006$). The majority of patients (55.56 %; 125/225) were classified as ASA-2, followed by 40.89 % (92/225) of equids being ASA-1 and only 3.56 % (8/225) being ASA-3 patients and the patient's ASA status did not influence the development of PSC. Concerning the duration of surgery itself, the mean overall duration was 1.12 ± 0.83 hours. The mean length of surgery for patients with PSC was found to be 1.37 ± 1.02 hours, but only 0.95 ± 0.59 hours for those without (see Figure 5). This parameter was strongly associated with the occurrence of PSC ($p<0.001$). One additional hour of GA and surgery led to an increased chance of PSC occurrence of 51 % and 95 %, respectively.

Figure 2, distribution of procedure types in the category of 1st procedure.

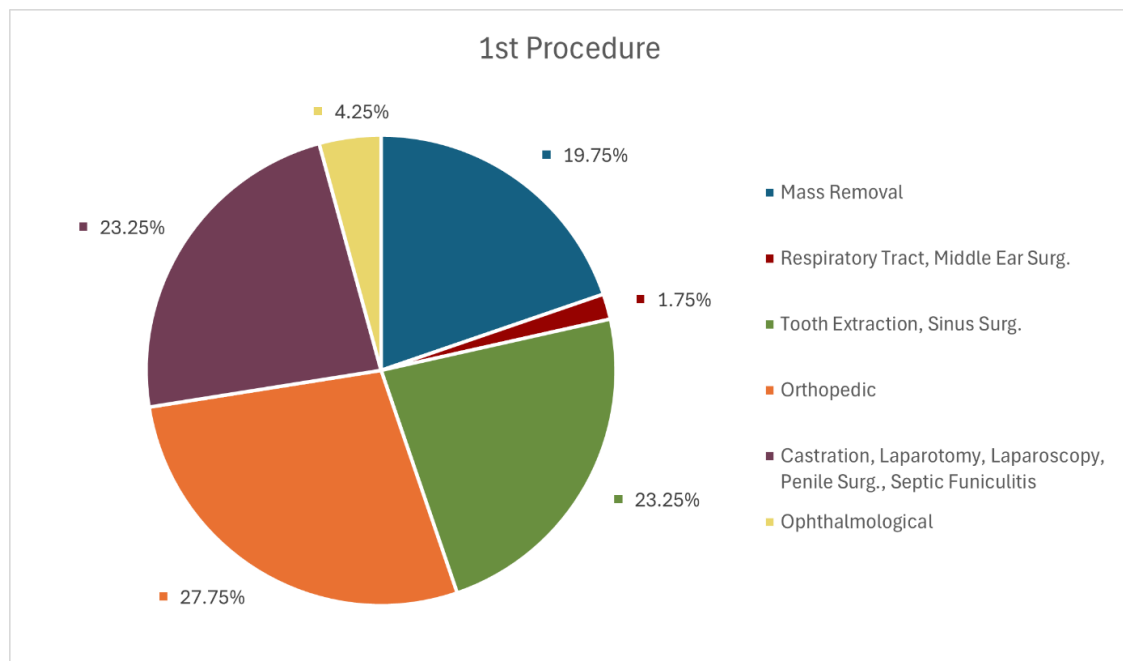


Figure 3, distribution of procedure types in the category of 2nd procedure.

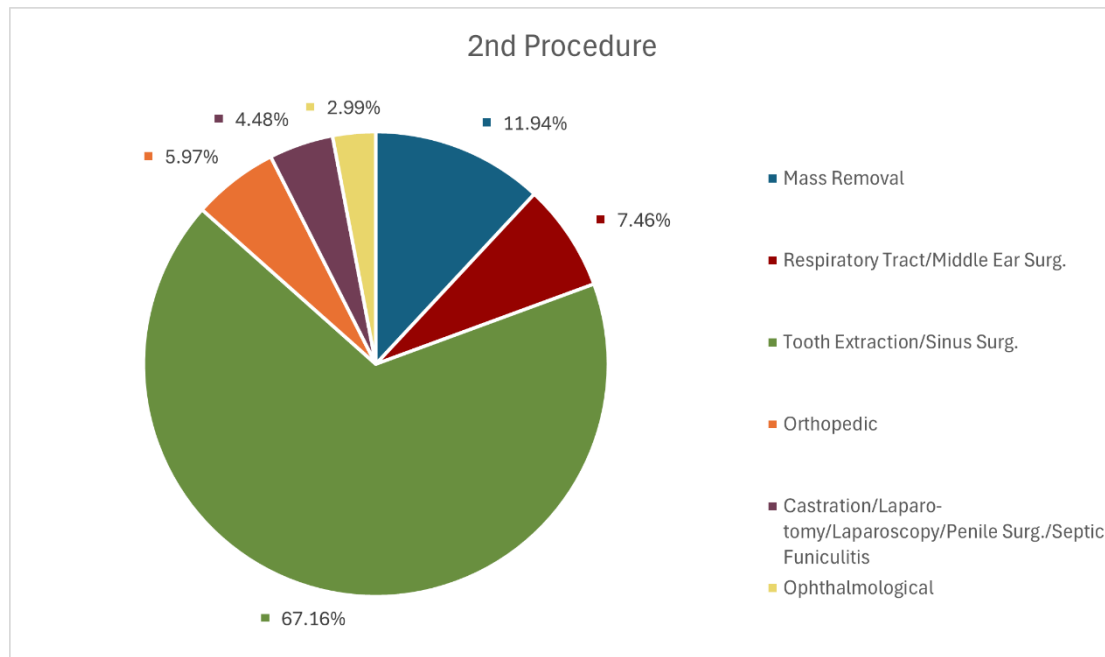


Figure 4, proportion of equids with and without PSC in relation to whether they receive SAP pre-surgery or not.

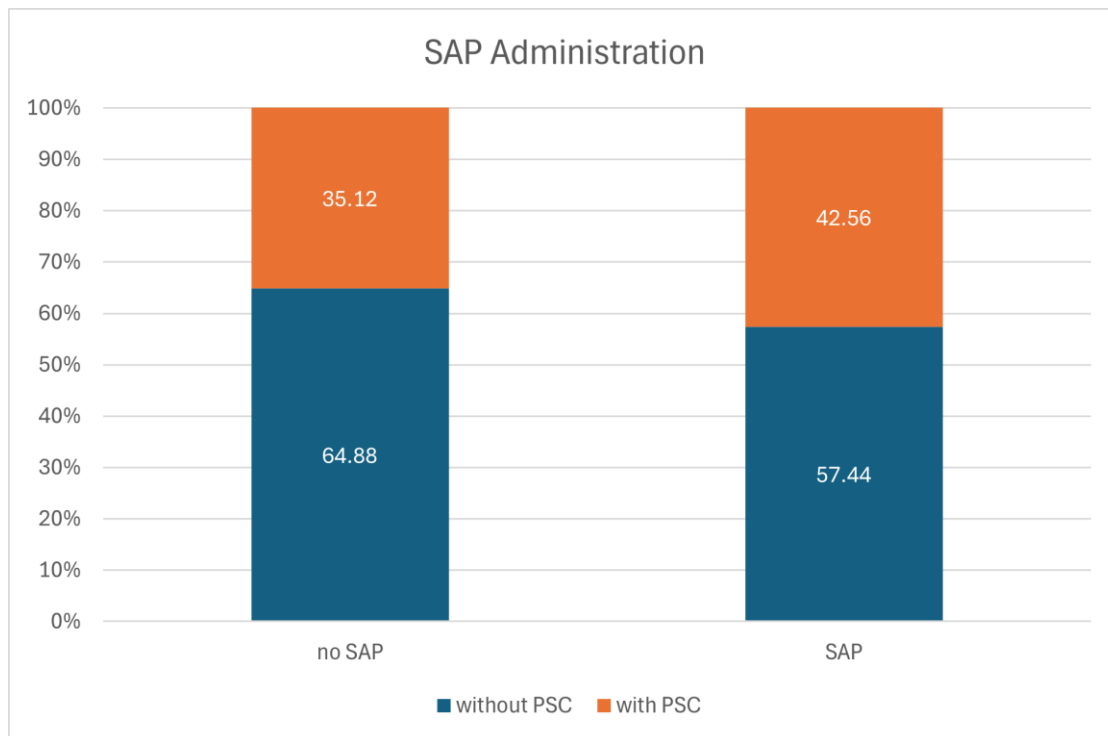


Table 2, univariable association between intraoperative variables and the occurrence of postoperative complications in 400 equids undergoing elective surgery at the Equine Clinic of the University of Veterinary Medicine Vienna, November 2022 – June 2024, based on simple logistic regression models.

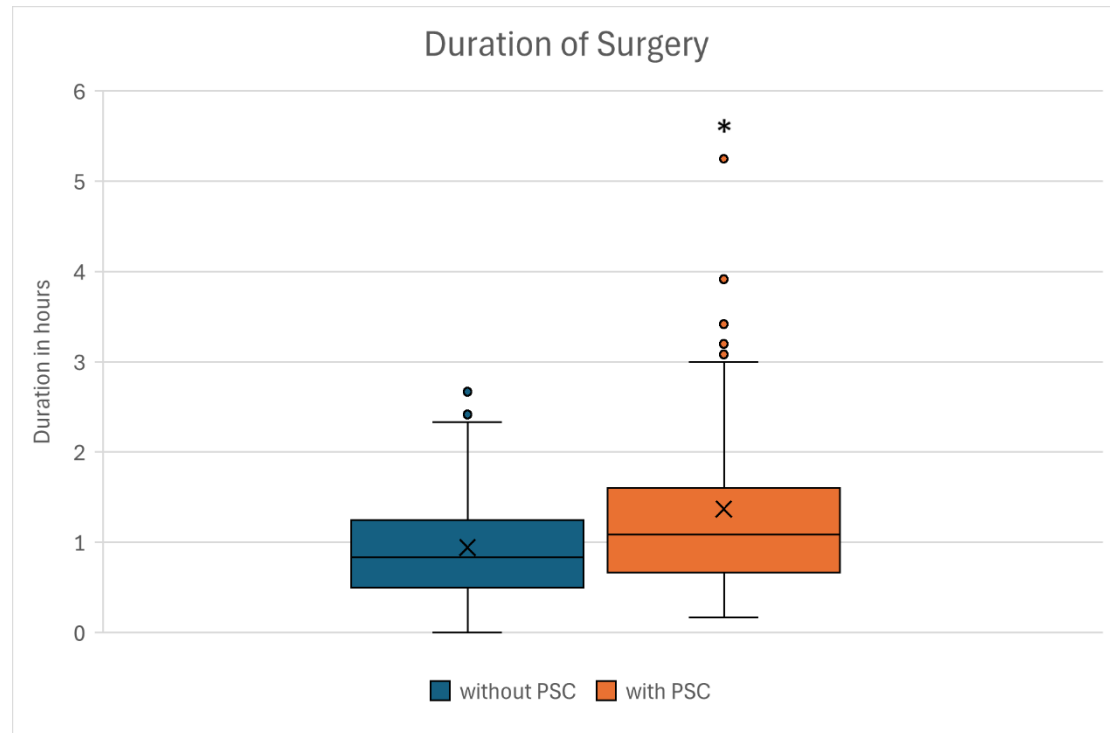
Variable (unit) (n)	Category	post-surgical complication		OR	95 % CI	p-value
		no	yes			
Procedure 1 (400)	Mass Removal	64.56 % (51)	35.44 % (28)	referent		0.0578 ^a
	Respiratory Tract/Middle Ear Surg.	28.57 % (2)	71.43 % (5)	4.55	0.83 - 25.01	0.081
	Tooth Extraction/Sinus Surg.	65.59 % (61)	34.41 % (32)	0.96	0.51 - 1.79	0.887
	Orthopedic	63.96 % (71)	36.04 % (40)	1.03	0.56 - 1.87	0.933
	Castration/Laparotomy/Laparoscopy/Penile Surg./Septic Funiculitis	50.54 % (47)	49.46 % (46)	1.78	0.96 - 3.30	0.065
	Ophthalmological	76.47 % (13)	23.53 % (4)	0.56	0.17 - 1.88	0.349
Procedure 2 (67)	Mass Removal	37.5 % (3)	62.5 % (5)	referent		0.515 ^a
	Respiratory Tract/Middle Ear Surg.	20.00 % (1)	80.00 % (4)	2.4	0.18 - 32.88	0.512
	Tooth Extraction/Sinus Surg.	55.56 % (25)	44.44 % (20)	0.48	0.10 - 2.26	0.353
	Orthopedic	25.00 % (1)	75.00 % (3)	1.8	0.12 - 26.20	0.667
	Castration/Laparotomy/Laparoscopy/Penile Surg./Septic Funiculitis	33.33 % (1)	66.67 % (2)	1.2	0.07 - 19.63	0.898
	Ophthalmological	50.00 % (1)	50.00 % (1)	0.6	0.03 - 13.58	0.748
ASA Status (225)	1	59.78 % (55)	40.22 % (37)	referent		0.824 ^a
	2	56 % (70)	44 % (55)	1.17	0.68 - 2.02	0.577
	3	62.5 % (5)	37.5 % (3)	0.89	0.20 - 3.96	0.88
GA (400)	no	64.41 % (114)	35.59 % (63)	referent		
	yes	58.74 % (131)	41.26 % (92)	1.27	0.85 - 1.91	0.249
SAP pre-surgery (400)	no	64.88 % (133)	35.12 % (72)	referent		
	yes	57.44 % (112)	42.56 % (83)	1.37	0.91 - 2.05	0.127
Time between Application of SAP and Start of Surgery (h) (165)		1.75 ± 0.71	1.59 ± 0.64	0.69	0.43 - 1.11	0.127
AM intra-surgery (400)	no	61.58 % (218)	38.42 % (136)	referent		
	yes	58.7 % (27)	41.30 % (19)	1.13	0.60 - 2.11	0.706
Duration anesthesia (h) (210)		1.90 ± 0.80	2.30 ± 1.18	1.51	1.13 - 2.03	0.006
Duration Surgery (h) (223)		0.95 ± 0.59	1.37 ± 1.02	1.95	1.35 - 2.82	<0.001
Complication intra-surgery (400)	no	64.16 % (179)	35.84 % (100)	referent		
	yes	54.55 % (66)	45.45 % (55)	1.49	0.97 - 2.30	0.071

p^a – overall p-value for categorical data, based on logistic regression analysis

OR – odds ratio, CI – confidence interval, Surg. – Surgery, GA – general anesthesia, SAP – surgical antimicrobial prophylaxis, AM – antimicrobials.

Figure 5, duration of surgery (hours) in relation to PSC occurrence. Horizontal lines within the box represents the median duration of surgery, crosses within the box represents mean duration of surgery. Upper and lower limit of the box represent 75th and 25th percentiles, upper and lower limit of the bars represent the 90th and 10th percentiles. Dots represent outliers.

* Surgical duration was significantly longer for equids that developed PSC ($p < 0.001$)

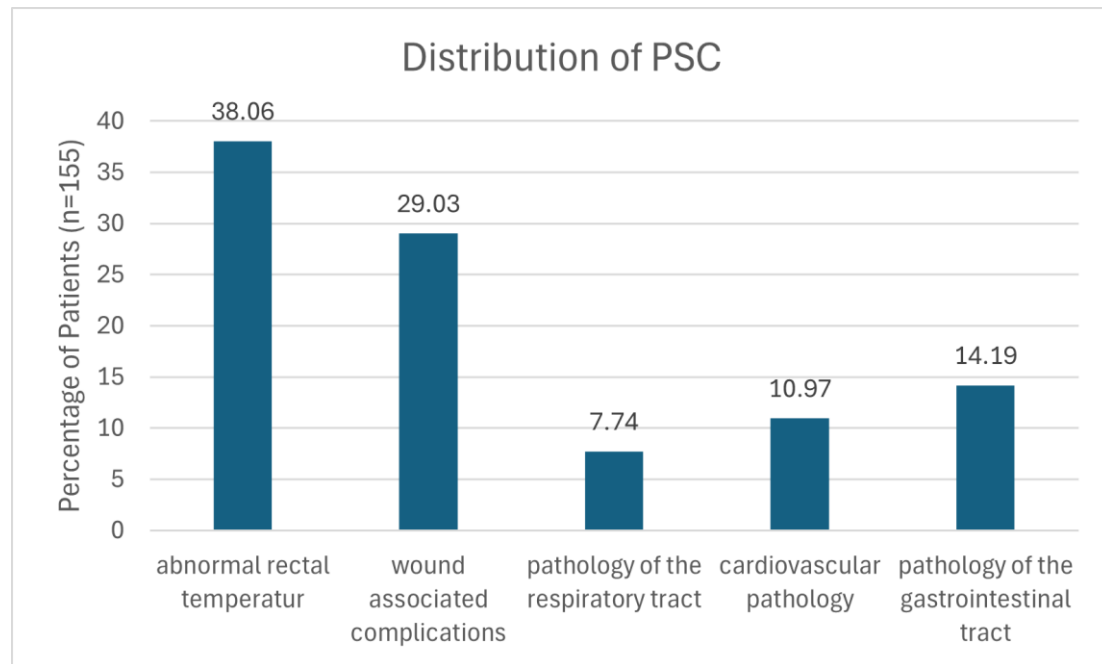


3.3 Postoperative parameters

Out of all 400 documented cases, 155 (38.75 %) developed PSC. The most common complication was a change in body temperature with 38.06 % (59/155). 15 (25.42 %) of those suffered from hypothermia and 44 (74.58 %) from pyrexia. If a patient had more than one kind of complication, only the most severe was documented, resulting in 71 out of 400 (17.75 %) cases having postsurgical fever overall. The mean peak temperature of fever was 39.15 ± 0.55 °C and had an average duration of 2.2 ± 1.9 days. A detailed description of the types of PSC can be found in Figure 6.

After surgery, 97.75 % (391/400) of equids received additional medication. The most common drug used as the first additional medication was flunixin, with 80.31 % (314/391) of patients being treated with it. Mean duration of application of the first additional medication was 4.34 ± 4.63 days. In 7.75 % (31/400) of patients, laboratory parameters were determined. Concerning the WBCC post-surgery, 35.48 % (11/31) showed leukocytosis and 19.35 % (6/31) showed leukopenia. Regarding the neutrophil count post-surgery, 38.71 % (12/31) had neutrophilia and 19.35 % (6/31) had neutropenia.

Figure 6, distribution of postsurgical complications in 155 equids undergoing elective surgery at the Equine Clinic of the University of Veterinary Medicine Vienna, November 2022 – June 2024.



3.4 Outcome and overall clinical course parameters

The results of all parameters concerning the outcome and overall clinical course are displayed in Table 3. 61.75 % (247/400) received systemic AM therapy at some point during hospitalization. This increased the risk for PSC significantly ($p < 0.001$) and resulted in a doubling of PSC risk. A detailed display of this result can be found in Figure 7. When looking at local or systemic AM treatment during hospitalization, the proportion of patients receiving it rises to 69.25 % (277/400). Similarly, this was also significantly associated with a higher chance of PSC ($p = 0.01$) and resulted in a 2.58-fold increase of PSC occurrence. Out of all patients, 11.25 % (45/400) needed a follow-up procedure. The need for a follow-up surgery was significantly linked to higher odds of developing PSC ($p = 0.016$). 25 patients (55.56 %) who had a follow-up procedure ended up having complications, compared to 20 patients (44.44 %) who had a convalescence without complications even though they had to have a follow-up surgery. The mean duration from admission to the first procedure was 2.35 ± 4.01 days. The mean for patients who developed complications compared to those who did not was 2.97 ± 5.52 days and 1.96 ± 2.59 days, respectively. The period between admission and the first surgery was significantly linked to higher odds of complication, with an 8 % higher chance of complication for each additional day ($p = 0.026$). Furthermore, the mean time of hospitalization was 12.66 ± 12.65 days. Equids with PSC stayed for an average of 16.63 ± 15.35 days, in contrast to 10.14 ± 9.83 days for those without PSC. A longer total hospitalization was significantly associated with a higher complication risk ($p < 0.001$). Out of all patients, 1 % (4/400) was euthanized and 2.25 % (9/400) were readmitted. Animals that were readmitted to

the clinic were 13.28 times more likely to develop complications in comparison to those who were not readmitted ($p=0.015$).

Table 3, univariable association between variables concerning the outcome and overall clinical course, and the occurrence of postoperative complications in 400 equids undergoing elective surgery at the Equine Clinic of the University of Veterinary Medicine Vienna, November 2022 – June 2024, based on simple logistic regression models.

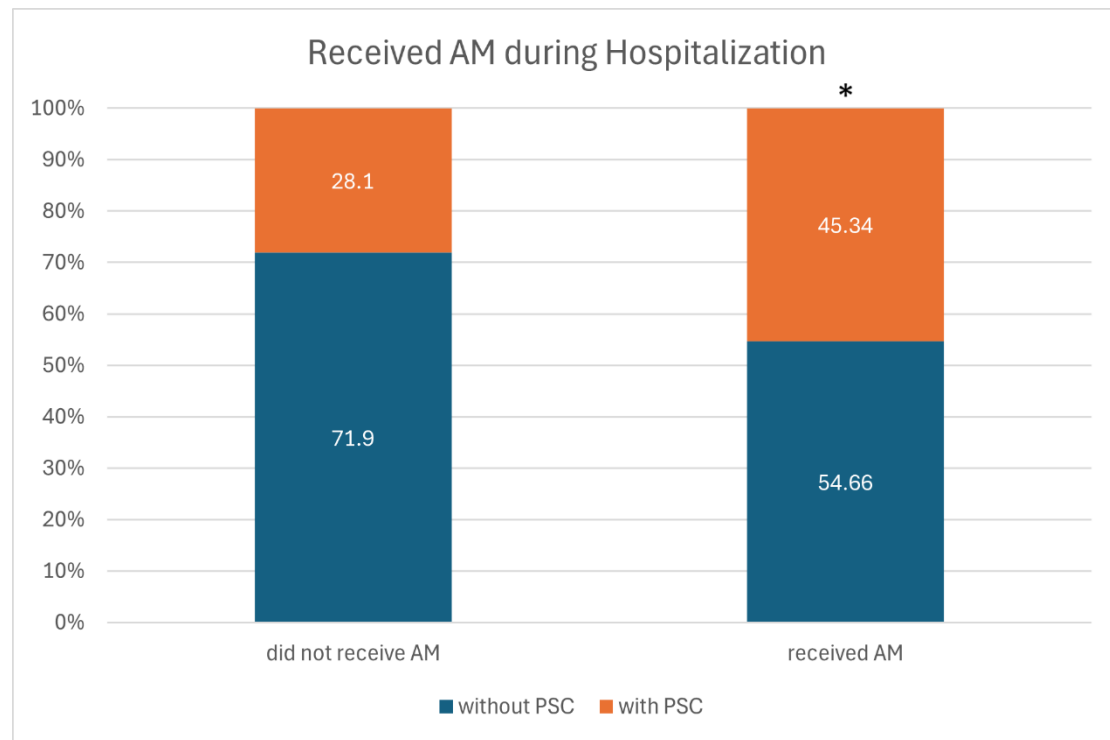
Variable (unit) (n)	Category	post-surgical complication		OR	95 % CI	p-value
		no	yes			
Received systemic AM at Clinic (400)	no	71.90 % (110)	28.10 % (43)	referent		
	yes	54.66 % (135)	45.34 % (112)	2.12	1.38 - 3.27	0.001
Follow-up Surgery (400)	no	63.38 % (225)	36.62 % (130)	referent		
	yes	44.44 % (20)	55.56 % (25)	2.16	1.16 - 4.05	0.016
Received local or systemic AM (400)	no	70.73 % (87)	29.27 % (36)	referent		
	yes	57.04 (158)	42.96 % (119)	1.82	1.15 - 2.87	0.01
Admission until 1 st Procedure (days) (400)		1.96 ± 2.59	2.97 ± 5.52	1.08	1.01 - 1.16	0.026
Admission until Discharge (days) (400)		10.14 ± 9.83	16.63 ± 15.35	1.05	1.03 - 1.07	<0.001
Readmission (400)	no	62.40 % (244)	37.60 % (147)	referent		
	yes	11.11 % (1)	88.89 % (8)	13.28	1.64 - 107.24	0.015

p^a – overall p-value for categorical data, based on logistic regression analysis

OR – odds ratio, CI – confidence interval, AM – antimicrobials

Figure 7, proportion of equids with and without PSC in relation to whether they have received AM during hospitalization or not.

* Equids which received AM were significantly more likely to develop PSC ($p=0.001$).



3.5 Multivariable logistic regression model

The results of the multivariable logistic regression analysis are shown in detail in Table 4. Equids with an orthopedic diagnosis were significantly less likely to develop PSC compared to those with a soft tissue pathology ($p=0.001$). Also, an ophthalmological diagnosis was approaching significance compared to soft tissue diagnosis ($p=0.051$). Patients which received treatment in the field before being admitted to the clinic were at a 12.54 times higher risk for complications ($p=0.024$) and with every additional hour of surgery, the chance of PSC increased by 2.32 ($p<0.001$). Those in need of a follow-up procedure were significantly more likely of having PSC ($p=0.044$).

Table 4, multivariable association between selected variables and the occurrence of post-operative complications in 223 equids undergoing elective surgery at the Equine Clinic of the University of Veterinary Medicine Vienna, November 2022 – June 2024, based on a multivariable logistic regression model.

Variable (unit)	Category	OR	95 % CI	p-value
Diagnosis	soft tissue	referent		<0.001 ^a
	orthopedic	0.32	0.16 - 0.61	0.001
	ophthalmological	0.06	0.004 - 1.015	0.051
	oral	0.46	0.01 - 22.00	0.695
	cavity/respiratory tract/middle ear			
Previous Treatment	no	referent		
	yes	12.54	1.40 - 112.56	0.024
Duration surgery (h)		2.32	1.52 - 3.55	<0.001
Follow-up Surgery	no	referent		
	yes	5.57	1.05 - 29.60	0.044

p^a – overall p-value for categorical data, based on logistic regression analysis

OR – odds ratio, CI – confidence interval

4 Discussion

The prevalence of PSC after elective surgeries at the Equine Clinic of the University of Veterinary Medicine Vienna was at 38.75 % and thereby higher than the observed results of multiple other studies, where the complication rates ranged from 13.7 % - 25 %, (21, 20, 22). However, Stöckle et al. found that the occurrence of PSC to be at 39.1 %, which is similar to the results of the present study (23). Reasons as to why the PSC occurrence differs when comparing our data to other studies, can be diverse. One possible explanation could be that the categorization is different in each study design, or that the limit at which something is considered to be a complication might not have been the same in every study.

In this study, we identified several factors that were associated with the development of PSC at our institution. In the univariable logistic regression analysis, patients which received AM treatment at any point during hospitalization were at a significantly higher risk of suffering from complications. However, the application of SAP pre-surgery did not have an influence on the occurrence of PSC. In the final multivariable model, the duration of surgery, the diagnosis which was the reason for admission and the surgical procedure, previous treatment in the field and the need for a follow-up surgery were associated with an increased risk to develop complications after a surgical procedure.

The duration of surgery had a significant influence on the development of PSC, with every additional hour of surgery leading to a doubling of risks. This corresponds well with the findings of previous studies (24–26), even though there are studies which were unable to reproduce this result (27). Prolonged surgical duration can result in increased wound margin desiccation, which can in turn elevate the risk of infection (28). Additionally, Cheng et al. stated that longer operative time is linked to more complex procedures, and has therefore a negative impact on the development of PSC (19). An increase of surgical duration also leads to more time under GA, which has already been shown to have a negative influence on the development of PSC in previous studies (20). A combination of these different aspects linked to prolonged surgical time could be a possible explanation for this finding.

Horses and other equids diagnosed with orthopedic conditions were significantly less likely to experience PSC compared to those with soft tissue pathologies. Additionally, animals admitted due to ophthalmological pathologies showed a lower risk of developing PSC, approaching statistical significance when compared to those with soft tissue pathologies. The influence of this parameter is less frequently explored in other studies, as they tend to focus on the type of procedure conducted rather than the underlying diagnosis. The effect of procedure type on the occurrence of PSC is still inconclusive in scientific literature, with some publications reporting a significant impact (21), whereas others found no association between the two parameters (29), the latter being in agreement with the findings of the present study. A possible explanation

for the significant impact of diagnosis at the time of admission observed here is that soft tissue pathologies often lead to procedures that involve the abdominal cavity, such as certain castration techniques, hernia repairs or nephrosplenic space closures. The involvement of the abdomen is known to carry a higher risk of postoperative morbidity (30). Additionally, cases involving sarcoid removals were included within this category. These procedures frequently involve multiple excision sites, which could be another explanation for the significant association with increased chances of PSC seen in this category. Furthermore, cases of the soft tissue diagnosis group include two different types of procedures following admission, one being “mass removal” and the other “castration, laparotomy, laparoscopy, penile surgery and septic funiculitis”. This variety of procedure types within the soft tissue diagnosis group could be a reason why only the latter was proven to have a significant effect on the patient’s outcome regarding PSC.

Treatment in the field before clinic admission showed a significant association with the occurrence of PSC resulting in a 12.54-fold increase in risk. To the authors knowledge, this is the first study that identified this parameter as a significant influence on the postoperative course. An explanation for this finding may be multifactorial. A wrong, suboptimal or inconsistent therapy could have negative effects on the further development of the patient and could possibly result in delayed referral. It could also indicate that those cases were more chronic in nature and perhaps already had multiple invasive procedures (e.g. venous catheters) prior to referral. Over 60 % of equids which received treatment previous to clinic admission were treated with AMs or a combination of AMs and pain medication. An unsuitable AM therapy can have adverse effects on the outcome of therapy. Moreover, it can contribute to the development of AMR, if the chosen AM regimen was not suited for treating the present problem (9). Future research could focus on investigating this relation more, as data concerning the exact line of treatment before admission was limited in our retrospective study design.

The fourth significant variable of the multifactorial analysis was the need for an additional surgery. Follow-up procedures could be indicators that the underlying cause, which was the reason for the first surgery, was not fully resolved or that complications related to the initial intervention were so severe that another procedure was necessary. Furthermore, an additional surgery results in more time where the patient is exposed to anesthetic drugs and in surgery, which has already been discussed in this study as a significantly negative impact on the patients convalescence (26). Similarly, repeated surgery leads to an increase of surgical manipulation of tissue, which results in it being more prone to inflammation and poor healing (31). Moreover, it has been proven multiple times that the need for a second procedure has negative effects on the development of PSC in the context of equine colic surgery as well (32,

33). Additionally, a follow-up procedure may result in a longer hospitalization period, which was already linked to a higher risk of nosocomial infections by previous studies (34).

The administration of AM therapy at any point during hospitalization was associated with a significantly higher rate of PSC in the univariable analysis. Animals that received antibiotics were twice as likely to develop complications compared to those who did not. This aligns with existing literature suggesting that prolonged and inappropriate use of antimicrobials may contribute to adverse postoperative outcomes (9). For instance, a study by Brown et al. observed that patients with clean surgical wounds had a higher chance of PSC if they received antibiotics post-surgery compared to those who did not (35). Furthermore, even if AM therapy is indicated, there are side effects to its use. Antibiotics are known to influence the guts microbiome, and can result in further PSC due to the development of dysbiosis or diarrhea (36).

The administration of preoperative SAP had no significant influence on the development of PSC after elective surgeries. This result is in accordance with previous studies in both veterinary and human medicine, where the necessity and effectiveness of SAP in elective procedures has been under debate (6, 8). The present study did not investigate the influence of preoperative SAP administration compared to the different subcategories of procedures and their postsurgical chance of complication. However, recent studies which only focused on one type of elective procedure came to the same conclusion. These studies focused on castration, overall clean orthopedic procedures or elective arthroscopies, and stated that the use of SAP does not influence the rate of complications (18, 23, 17). Additionally, for SAP to be correctly administered, it should be given no more than 60 minutes before the first incision. This ensures that the tissue's drug concentration is higher than the minimum inhibitory concentration at the start of the procedure (8). In this study, the mean time between the SAP administration and the start of surgery was at 1.59 ± 0.64 hours for patients who did develop complications and 1.75 ± 0.71 for those who did not. Thus, SAP was administered too early to have the intended effect. These numbers could be distorted due to the retrospective design of our study, as the actual timing of administration was not always recorded in the medical record system, especially in cases where the procedure was delayed for a couple of hours. Therefore, future research should look more into the efficiency of SAP in elective procedures with a strong focus on the standardized conditions and proper administration protocols.

These findings highlight an interesting contrast. While AM treatment during hospitalization was significantly associated with an increased risk of PSC, preoperative SAP appeared to have no influence. Given that nearly 50 % of patients in our study received SAP before surgery, it is plausible to assume a potential association between them. An unnecessary use of AM, which includes SAP given prior to clean elective procedures, may contribute to an environment where

antibiotic treatment becomes more necessary. It has been proven in previous studies that prolonged or repeated AM administration can select for more resistant bacterial populations. This can result in more severe complications due to AM resistant bacterial pathogens and especially increase the risk of nosocomial infections (37). Thus, aggressive AM therapy may become necessary to treat these infections, which were nursed by the prior improper SAP use. However, this AM treatment comes with side effects as well, having a negative impact on the equid's gastrointestinal tract, leading e.g. to dysbiosis or diarrhea, and might also lead to negative effects on its systemic health, resulting in further PSC (36). This in turn is then reflected in the significant association between the administration of AM in general and the occurrence of PSC in the univariable logistic regression analysis.

Explanations as to why the parameter of AM therapy during hospitalization was no longer significant when compared to the occurrence of PSC in the multivariable model can be diverse. Possibly, the study's retrospective design led to the significant association with PSC in the univariable analysis because of reverse causality. This means that since there are cases where the AM therapy was started as a response to signs of PSC, AM administration was not the cause for the occurring complication, but the other way around (38). Since the multivariable model takes other parameters into account as well, it could be possible that they capture the true underlying risk factors and therefore eliminate AM administration as an independent risk factor.

There are several limitations to the present study due to its retrospective design. For instance, certain parameters, such as the timing of SAP application pre-surgery, were not always recorded accurately in the medical record system. Additionally, long-term follow-up of the equid's recovery at home was in general not possible. Exceptions were rare cases where owners called after discharge and the patient's health status was noted. On top of that, a more detailed work up of the patient's medical history prior to hospital admission would be beneficial to future research. This should include the documentation of specific drugs, their dosages and the duration of treatment to better evaluate the influence of pre-admission medication on the development of PSC. Finally, future research may benefit from focusing on a specific type of surgical procedure to have more precise insights into the risk factors for PSC and the role of SAP in its prevention.

This study identified several factors associated with the development of complications following elective surgery. Patients which had prolonged surgical duration, were diagnosed with soft tissue pathologies, were treated in the field previous to hospital admission or were in need of a follow-up procedure should be monitored more closely for signs of PSC. We have also found that AM treatment during hospitalization results in a significantly higher risk of PSC in the univariable analysis. The lack of significance in the multivariable model suggests

potential reverse causality, meaning that AM treatment may often be a response to complications rather than their cause. Furthermore, the use of SAP pre-surgery had no influence on PSC development. This ineffectiveness could be linked to suboptimal timing of administration, as it was often given too early to achieve the intended prophylactic effect. However, this result could be distorted due to the retrospective study design. It is possible that the improper or unnecessary use of SAP is also creating an environment where AMR can thrive. Therefore, it might be making AM treatment postoperatively more necessary as the occurrence of severe complications increase. This highlights the importance of correct antimicrobial stewardship and SAP guidelines. Future prospective studies should investigate these relationships further under standardized conditions to clarify the role of these parameters in preventing PSC.

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