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The effect of peri- and postoperative antibiotic prophylaxis on surgical site infection in surgeries with elective antibiotic administration

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ABSTRACT

The aim of this study was to investigate the effect of peri- and postoperative antimicrobial prophylaxis (AMP) on surgical site infection (SSI) in surgeries with elective antibiotic administration in a large university hospital with a high volume of people in the operating room. In this retrospective study, 1060 cats and dogs belonging to private owners were analysed for the occurrence of SSI over a period of almost 5 years, except during the COVID pandemic. Both the patient files were included, and the patient owners were contacted by questionnaire. The type of surgery, the use and type of AMP, as well as the occurrence, time, type and treatment of an SSI were documented. The overall SSI rate was 7.8 % (66/841). The use of an AMP did not lead to a significant reduction in risk in any of the surgeries analysed. Postoperative continuation of antibiotic prophylaxis showed no significant difference compared to perioperative prophylaxis alone. When interpreting the results, the retrospective nature of the study should be considered, as well as the fact that some of the results are based on a survey of patient owners.

Introduction

The occurrence of surgical site infection (SSI) is a natural complication of surgery that is associated with increased costs for the owner and suffering for the patient (Barnett, 2007; Nicoll et al., 2014). One goal in human and veterinary medicine is to minimise the rate of SSI and the prophylactic administration of antibiotics is one way of reducing this (Eugster et al., 2004; Howe and Boothe, 2006; Välkki et al., 2020; Vasseur et al., 1985; Whittem et al., 1999). While antibiotics are part of the treatment for contaminated and infected surgical wounds, the use of antimicrobial prophylaxis (AMP) in clean and clean-contaminated procedures is at the discretion of the surgeon (Barie and Eachempati, 2005; Howe and Boothe, 2006; Nelson, 2011). In addition to the type of surgery, potential risk factors such as the patient's American Society of Anesthesiologists (ASA) status, the expected duration of the procedure and anaesthesia or the use of implants are used as a decision-making aid for the administration of AMP (Beal et al., 2000; Brown et al., 1997; Culver et al., 1991; Eugster et al., 2004; Nicholson et al., 2002; Whittem et al., 1999). It is important to note that although antibiotics can reduce the risk of infection, they do not reduce the risk factors (Boothe and Boothe, 2015). Guidelines in human medicine state that AMP should be administered at least 60 minutes before surgery and not beyond 24 hours (Allegranzi et al., 2016; Control, 2013). There are no such guidelines in veterinary medicine, but the principles are adopted. Postoperative continuation of prophylaxis is common practice in veterinary medicine and its benefits are debated (Nelson, 2011; Pratesi et al., 2015; Välkki et al., 2020). The evidence is strongest for tibial plateau levelling osteotomy (TPLO), with a 2021 review by Budsberg et al. documenting a lack of evidence for the benefit of postoperative antibiotics (Budsberg et al., 2021). A 2012 survey from England showed that veterinarians extend AMP postoperatively in a variety of surgeries, not just orthopaedic procedures (Knights et al., 2012). In order to further reduce the administration of antibiotics in veterinary medicine, it is necessary to investigate whether and for which surgeries prophylactic perioperative or postoperative administration makes sense and whether postoperative prolongation can have a positive influence. There is a lack of studies on this in the available veterinary literature. The aim of this retrospective study was therefore to investigate elective AMP in common surgeries at a small animal teaching hospital with many staff and students in the operating theatre. The aim was to examine whether

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prophylaxis has an influence on the occurrence of SSI in these surgeries and whether postoperative extension can have an additional positive influence.

Material and methods

Data collection

Patient data was collected retrospectively in the period from 01/01/2016–01/08/2022. The period between 11 March 2020 and 12 September 2021 was not included due to the COVID pandemic and its impact on the daily routine in the clinic where the study took place. Surgeries on dogs and cats were categorised according to the type of procedure and selected based on the number of cases, at least 20 procedures, and the non-routine use of an AMP. The resulting surgical catalogue included the following procedures: internal facture repair of closed fractures, hemilaminectomy, ventral slot, patellar luxation surgery (treatment using various techniques, possibly simultaneous extracapsular suture), femoral head and neck excision (FHNE), amputation of a limb, caesarean section, splenectomy, skin tumour resection (excluding complex skin flap techniques), enucleation and thoracotomies. All patients that had undergone one of the above-mentioned operations during the study period were included. The data from these patients was checked for the occurrence of surgical wound infections in the digital patient management system (Vetera®, Vetera GmbH, Eltville am Rhein). The follow-up period was 30 days or 90 days if an implant was inserted according to the criteria of the European Centre of Disease Controls (ECDC) (ECDC, 2016). In patients who underwent independent surgeries with a suitable time interval (30 or 90 days) between them, each procedure was evaluated separately. Patients who died or were euthanised during the study period, not due to a wound infection, who underwent additional surgery that was not used to treat an SSI, who had an unusual bacterial contamination (e.g. infected ulcerated tumour) and therefore an indication for antibiotic therapy, or who had already been administered antibiotics before surgery for various other reasons, were excluded. The patella luxation surgeries were divided into those with and without metal implants, as the observation period changed accordingly from 30 to 90 days. Owners of patients for whom the occurrence of an SSI could not be clearly diagnosed from the medical records, as they neither returned early because of an SSI nor had a record 30 or 90 days after the respective surgery, were contacted by letter and/or e-mail and asked to complete a special questionnaire (Appendix A-D) relating to wound healing. If the questionnaire was not returned, an attempt was made to contact the patient owners by telephone and ask them accordingly. The survey was voluntary and was not carried out if the owner did not wish to be interviewed. The questions were asked in such a way that a wound infection could be distinguished from an inflammatory reaction using the definitions of SSI in Table 1, and the patient's manipulation of the wound was also taken into account. The questionnaire was based on the prospective study by Turk et al. with the aim of determining the incidence of SSI on the basis of the survey (Turk et al., 2015). Patients who, according to the owner, traumatized the wound themselves were documented but not included in the analysis, as no reliable statement could be made about the condition of the wound before the trauma. The criteria for diagnosis and categorisation of an SSI into superficial, deep and body cavity/organ-associated, according to ECDC guidelines, are shown in Table 1 (ECDC, 2016). The data collected for each patient included the species (dog, cat), age, sex, body weight, type of surgery, type of AMP (categorised as perioperative group, postoperative group, none) and condition of the wound at the time of suture removal and after 30 and 90 days. Patients in the perioperative AMP group were given prophylactic antibiotics immediately before (30 min - 1 h) the operation, prolonged during the operation and up to a maximum of 24 h after the operation. Any further postoperative administration beyond this was allocated to the postoperative AMP group. Additionally, patients without preoperative AMP, who received antibiotics after more than 24 hours postoperatively for no apparent reason other than the operation were also assigned to the postoperative AMP group. In the case of an SSI, a distinction was made between the type of SSI, the treatment of the SSI (conservative/surgical) and whether antibiotic therapy was necessary. The ethics committee of the Faculty of Veterinary Medicine reviewed and approved the study design. (AZ 342–27–11–2022)

Table 1
Overview definition of SSI according to ECDC(ECDC, 2016). Classification into superficial, deep and body cavity/organ SSI.

Type of SSI	Time period/ relevant structures	Criteria (1 applicable)
Superficial SSI	Within 30 days Regarding: superficial incision (skin and subcutis)	– Purulent discharge – Positive aseptic culture obtained – One of the symptoms: pain or tenderness, localised swelling, redness or increased warmth AND opening of the incision by a surgeon EXCEPT a negative culture – Diagnosis was made by the attending surgeon or physician
Deep SSI	Within 30 days or 90 days for implants Regarding: Tissue of the deep incision (e.g. fascia, muscles) in the surgical field	– Purulent discharge – Spontaneous dehiscence or opening of the deep incision by a surgeon with clinical symptoms such as: Fever, localised pain or tenderness, EXCEPT a negative culture – Abscess or other evidence in direct, histopathological, radiological examination or re-surgery – Diagnosis by the attending surgeon or physician
Body cavities/ organ SSI	Within 30 days or 90 days for implants Regarding: anatomical structures (organs, body cavities) in the surgical field	– Purulent discharge from drainage – Positive aseptic culture obtained – Abscess or other evidence in direct, histopathological, radiological examination or re-surgery – Diagnosis by the attending surgeon or physician

Pre- and postoperative procedure

The patients were treated according to the clinic's established standard procedure. Firstly, premedication was administered in accordance with the ASA status, the planned procedure and the patient. Intubation followed the induction. After intubation, all imaging measures that were important for the operation and could not be carried out while the patient was awake were performed. Immediately before the operation, the operating area was generously shaved and washed. Before transferring the patient to the operating theatre, the skin was disinfected for the first time. The exception to this were the patients who underwent a caesarean section. In this case, the patients were prepared for the operation while awake and anaesthetised in the operating theatre in order to keep the anaesthesia time as short as possible with regard to the puppies. The surgeons and assistants performed a standard surgical hand wash and disinfection. The operation was performed in compliance with sterility standards. Cephazolin (20 mg/kg) or amoxicillin/clavulanic acid (20 mg/kg) was administered intravenously as AMP approx. 30–60 min before incision of the skin, depending on the operation and the surgeon's decision, and given again every 90 min depending on the duration of the operation. After the operation, the wound was covered with a plaster. The owner was usually instructed to change the plaster at home after contamination and to check the wound at least once a day. The stitches were typically removed after 10–14 days in the clinic or by the vet. Patients were given a neck collar and/or bodysuit immediately after the operation in the recovery phase.

Statistical analysis

The collected data was statistically analysed in Excel (Microsoft Corporation, Redmond) and RStudio (PBC, Boston). Association between variables was determined using logistic regression models using the R package 'arm'(Gelman, 2022) with the bayesglm function for Bayesian logistic regression, with correction for multiple testing according to Holm (Holm, 1979). Two hypotheses were tested. 1. The use of an AMP does not influence the occurrence of an SSI in the individual operations. For this hypothesis, patients with AMP and without AMP were compared within the individual operations. 2. There is no difference regarding the occurrence of an SSI whether an AMP was only used perioperatively or extended postoperatively. The last hypothesis was tested by comparing only the patients who received AMP for each individual operation. The rates of the perioperative group were compared with those of the postoperative group. A value of $p \leq 0.05$ and $q \leq 0.05$ is assumed to be statistically significant.

Results

Study population and SSI rate

After an initial search of the operations performed in the hospital information system, a total of 1060 operations were available for evaluation. 50 % (533/1060) of the patients could be analysed on the basis of the clinical records, as they presented again as part of a follow-up examination. Of the remaining 50 % (527/1060) patients, 61 % (322/527) of the owners answered the questionnaire. 14 patients were excluded due to manipulation of the wound (12 of the clinical records, two of the questionnaires). This resulted in a total study population of 841 surgeries analysed. The population consisted of 75 % (632/841) dogs and 25 % (209/841) cats. The sexes were almost equally distributed. The median body weight of the dogs was 13 kg (IQR = 7.0, 27) and that of the cats was 4.3 kg (IQR = 3.5, 5.3). The median age of the dogs was 6.9 years (IQR = 4.0, 9.9), the cats were in median 4.2 years (IQR = 1.2, 10.6) old. The exact composition of the study population is shown in Table 2. SSI occurred in 7.8 % (66/841) of patients, with 84 % (51/66) diagnosed up to suture removal and 16 % (15/66) after suture removal. The SSI rate of the patients analysed by clinical record was 9.8 % (51/521), while 4.7 % (15/320) of the patients had an SSI identified by questionnaire. Of the 66 patients with SSI, 68 % (45/66) were superficial, 24 % (16/66) deep, 6.1 % (4/66) a combination of both and one developed a body cavity SSI (septic peritonitis). 39 % (26/66) of infections were treated surgically and 61 % (40/66) conservatively. 83 % (55/66) of patients with an SSI received antibiotic therapy. Caesarean section had the highest SSI rate at 19 % (10/53). In case of enucleation, FHNE and patellar luxation surgery without implants, there were no infections documented. The proportions of surgeries with an SSI for the individual operations are shown in Fig. 1 and Table 3.

AMP regardless of the timing

32 % (271/841) of patients did not receive prophylactic antibiotics. The infection rates in relation to the AMP of the individual surgeries, the odds and results of logistic regression are shown in Table 4. The logistic regression showed no significant difference between the AMP and no AMP-group for each individual surgery.

Difference between perioperative and postoperative group

AMPs were only administered perioperatively to 28 % (159/570) of patients, while the remaining 72 % (411/570) patients were assigned to the postoperative group. 5.6 % (9/159) of the surgeries in the perioperative group developed an SSI, compared to 5.8 % (24/411) of the surgeries in the postoperative group. Logistic regression showed no differences in SSI rates between the two groups for the individual surgeries (Table 5).

Discussion

The aim of this study was to investigate the occurrence of SSI in frequently performed, clean and clean-contaminated surgeries in a larger university hospital with a high number of people in the operating theatre. Surgeries were selected that were performed frequently ($n \geq 20$) during the study period and in which AMP was not used as standard in order to investigate the effect of this on the SSI rate. In addition, the focus was placed on whether there was a difference if the AMP was only administered perioperatively or additionally extended postoperatively.

The infection rate in the overall study population regardless of antibiotic administration was 7.8 %, higher than in older studies of clean surgeries (Beal et al., 2000; Brown et al., 1997; Eugster et al., 2004; Heldmann et al., 1999; Turk et al., 2015; Vasseur et al., 1988, 1985; Whittem et al., 1999). However, the earlier studies used inconsistent definitions and follow-up intervals. A study from 2015 with similar criteria to the present study found an infection rate of 3.2 % in clean surgery and 3.8 % in clean-contaminated surgery (Turk et al., 2015). A recent study from 2021 also showed a higher rate of SSI than in previous studies, with an SSI rate of 5.5 % (Stetter et al., 2021). Possible reasons for the increased infection rate in the present study may have been longer anaesthesia/surgery times (Beal et al., 2000; Brown et al., 1997) or increased traffic in the operating rooms (Alexander et al., 2013; Eugster et al., 2004), as well as the fact that some of the surgeries were performed by inexperienced surgeons in training (Culver et al., 1991; Vasseur et al., 1988). These factors were not documented in detail in the present study. However, the surgeries took place in a teaching hospital, so the presence of students and the training of veterinary staff can be assumed to influence these factors. The selection of surgeries for our study may also play a role, as they do not represent the totality of clean surgeries. In veterinary medicine, there are only individual publications on selected surgeries and their reported SSI rates, which vary greatly. A study by Dyall et al., for example, reported an SSI rate of 0.6 % for hemilaminectomy without AMP (Dyall and Schmökel, 2018). Spare et al. reported an SSI rate of 8,9 % for mastectomies without AMP (Spåre et al., 2021) and Dacanay et al. reported a rate of 5.0 % for enucleations regardless of AMP (Dacanay et al., 2023). In the present study, however, hemilaminectomies resulted in an SSI in 3.9 % of cases and enucleations in none of the cases. In our own study, mastectomy was included in the group of skin tumour removals, which had an SSI rate of 13 %. The reason for these differences cannot be explained more precisely on the basis of the studies and shows the complexity of the topic under investigation. The surgeries included in our study were intended to be performed more frequently and not to require the routine use of antibiotics, so that surgeries that were administered AMP as standard (e.g. TPLO) and surgeries that were not administered AMP without exception (e.g. castrations) were not included.

The observation period in our own study also played a role in the higher incidence of SSI. In most older studies, patients were examined for the occurrence of an SSI for 7–14 days or until suture removal (Beal et al., 2000; Brown et al., 1997; Eugster et al., 2004; Vasseur et al., 1988, 1985; Whittem et al., 1999). In the present study population, 16 % (15/66) of SSIs occurred after suture removal. Thus, the infection rate before suture removal was only 6.0 % (51/841). In addition, not all of the original 1060 patients could be reached in this study.

Interestingly, soft tissue surgeries such as skin tumour removal, splenectomy or caesarean section had a higher incidence of wound infection in this study population than the included patellar luxation surgeries with implant or internal fracture repair after closed fractures. This corresponds to the result of a 2021 study in which soft tissue surgery had a marginally higher infection rate compared to the included orthopaedic surgery (Stetter et al., 2021). In contrast, in previous

Table 2
Overview of the study population categorised by surgery. The number and proportion of dogs and cats, as well as gender and neutering status are shown. The weight and age of the patient population is shown in the median and the interquartile range (IQR).

Study population by ordered type of surgery	**Amputation**, N = 43	**C-Section** N = 53	**Enucleation**, N = 45	**FHNE**, N = 17	**Hemilaminectomy**, N = 153	**Internal fracture repair**, N = 164	**Patellaluxation implant**, N = 53	**Patellaluxation no implants**, N = 26	**Skintumor**, N = 174	**Splenectomy**, N = 53	**Thoracotomy**, N = 21	**Ventral slot**, N = 39
Species, n (%)												
Cat	22 (51)	15 (28)	27 (60)	4 (24)	5 (3.3)	97 (59)	2 (3.8)	5 (19)	26 (15)	0 (0)	5 (24)	1 (2.6)
Dog	21 (49)	38 (72)	18 (40)	13 (76)	148 (97)	67 (41)	51 (96)	21 (81)	148 (85)	53 (100)	16 (76)	38 (97)
Sex, n (%)												
m	6 (14)	0 (0)	4 (8.9)	6 (35)	47 (31)	40 (24)	11 (21)	8 (31)	43 (25)	16 (30)	7 (33)	16 (41)
m.k.	15 (35)	0 (0)	18 (40)	3 (18)	38 (25)	56 (34)	9 (17)	4 (15)	42 (24)	15 (28)	4 (19)	13 (33)
w	7 (16)	40 (75)	14 (31)	3 (18)	35 (23)	44 (27)	13 (25)	8 (31)	39 (22)	9 (17)	6 (29)	7 (18)
w.k.	15 (35)	13 (25)	9 (20)	5 (29)	33 (22)	24 (15)	20 (38)	6 (23)	50 (29)	13 (25)	4 (19)	3 (7.7)
Dogs Weight (kg), Median (IQR)	22 (15 – 34)	9 (4 – 10)	19 (7 – 35)	9 (6 – 15)	5 (5 – 16)	6 (3 – 11)	10 (7 – 15)	8 (3 – 18)	29 (17 – 35)	25 (16 – 33)	12 (4 – 21)	13 (10 – 16)
Dogs Age (a), Median (IQR)	9.1 (6.7 – 9.9)	5.7 (3.6 – 6.5)	10.1 (7.0 – 12.5)	7.0 (2.5 – 10.2)	6.5 (4.6 – 9.3)	1.2 (0.4 – 4.9)	3.1 (2.3 – 7.1)	7.1 (2.8 – 9.9)	8.7 (6.3 – 10.6)	10.3 (8.7 – 11.8)	4.2 (0.2 – 7.9)	7.8 (5.7 – 9.9)
Cats Weight (kg), Median (IQR)	4.45 (3.63 – 5.28)	3.50 (3.50 – 5.10)	3.90 (3.50 – 4.55)	4.80 (3.60 – 5.35)	2.95 (2.30 – 3.48)	5.00 (5.00 – 5.00)	6.40 (5.50 – 7.20)	4.00 (3.20 – 5.00)	5.50 (4.78 – 6.15)	NA (NA – NA)	5.30 (3.70 – 5.70)	6.90 (6.90 – 6.90)
Cats Weight (kg), Median (IQR)	4.45 (3.63 – 5.28)	3.50 (3.50 – 5.10)	3.90 (3.50 – 4.55)	4.80 (3.60 – 5.35)	2.95 (2.30 – 3.48)	5.00 (5.00 – 5.00)	6.40 (5.50 – 7.20)	4.00 (3.20 – 5.00)	5.50 (4.78 – 6.15)	NA (NA – NA)	5.30 (3.70 – 5.70)	6.90 (6.90 – 6.90)

FHNE = femoral head and neck excision

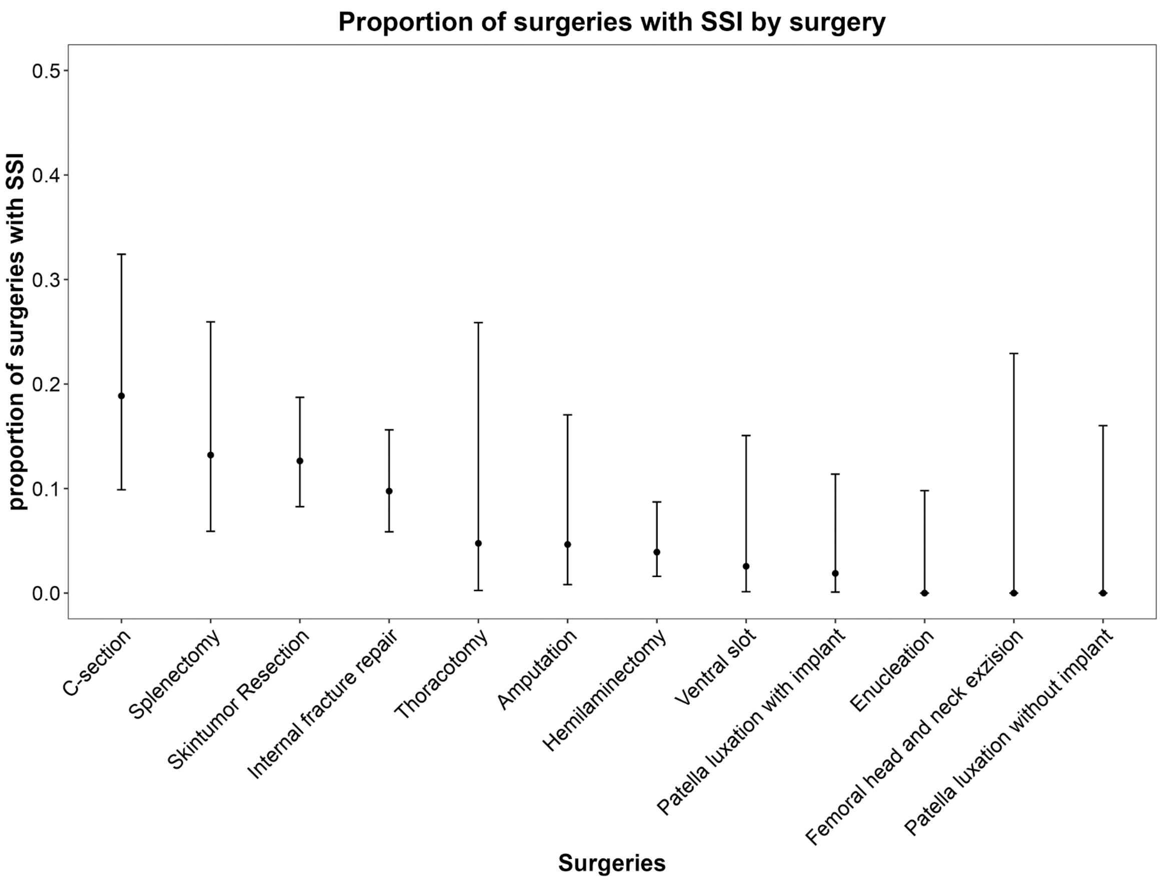

Fig. 1. Proportion of surgeries with SSI with 95 %-confidence intervals. Surgeries ordered from highest proportion to lowest.

Table 3
Proportions and absolute numbers of SSI occurrences ordered by surgery performed.

Surgery	N	SSI % (n)	95 % CI[a]
C-Section	53	19 % (10)	9.9 %, 32 %
Splenectomy	53	13 % (7)	5.9 %, 26 %
Skin tumor resection	174	13 % (22)	8.3 %, 19 %
Internal fracture repair	164	9.8 % (16)	5.9 %, 16 %
Thoracotomy	21	4.8 % (1)	0.25 %, 26 %
Amputation	43	4.7 % (2)	0.81 %, 17 %
Hemilaminectomy	153	3.9 % (6)	1.6 %, 8.7 %
Ventral slot	39	2.6 % (1)	0.13 %, 15 %
Patella luxation surgery with implant	53	1.9 % (1)	0.10 %, 11 %
Enucleation	45	0 % (0)	0 %, 10 %
Patella luxation surgery without implant	26	0 % (0)	0 %, 16 %
FHNE	17	0 % (0)	0 %, 23 %

[a] CI = Confidence Interval

studies, the insertion of an implant increased the risk of wound infection, which is why this was considered an indication for AMP (Turk et al., 2015).

In this study, caesarean section showed the highest proportion of surgeries with wound infection compared to the other surgeries considered, without the influence of AMP. Due to the incision in the urogenital tract, the caesarean section can, by definition, be assigned to the clean-contaminated wound classification, which in the literature showed a higher SSI rate independent of an AMP (Brown et al., 1997; Turk et al., 2015; Vasseur et al., 1985). In the available literature, the SSI rate of a caesarean section in small animal medicine is not further investigated. In human medicine, special measures are recommended for this surgery, which can reduce the comparably higher risk of infection. These measures include perioperative AMP (Berríos-Torres et al., 2017), preoperative irrigation of the vagina with a povidone-iodine solution and spontaneous detachment of the placenta (Martin et al., 2018). In our study population, the use of an AMP had no significant effect, which may again be due to the sample size being too small. An additional potential risk factor for an SSI could be the difficult aftercare of the wound, as these are under almost constant manipulation by the newborn puppies; in addition, the wound is somewhat more difficult for the pet owner to access and therefore more difficult to care for. At the clinic where our study took place, patients were prepared for surgery while awake and induced on the operating table to reduce anaesthesia time in terms of foetal safety. The extent to which this can influence the risk of SSI needs to be investigated in further studies.

In our study, patients who manipulated the wound were excluded. It should be noted that manipulation of the wound may also have taken place due to an existing SSI and therefore the proportion of operations with an SSI would be slightly higher.

The use of an AMP did not significantly reduce the risk of wound infection in the individual surgeries analysed, regardless of the time of application. There are controversial results on this in the literature. Some studies showed a protective effect with regard to the occurrence of an SSI (Eugster et al., 2004; Vasseur et al., 1988; Whittem et al., 1999). Other studies found no difference with regard to the benefit of an AMP (Daude-Lagrave et al., 2001; Stetter et al., 2021; Välkki et al., 2020). These studies mostly only examined orthopaedic surgery or generally clean to clean-contaminated surgery. Due to the study design in our study, the protective effect of an AMP can be obscured. It is more likely that AMP will be used for operations with a higher SSI risk and, due to the potential protective effect, reduce the SSI rate to that of operations with a lower SSI risk without AMP. The potential protective effect cannot be determined in our study in this situation and requires a

Table 4
Univariable Logistic regression models for the association between SSI occurrence and the use of prophylactic antibiosis, by surgery performed.

Surgery	AMP SSI/no SSI (SSI/N %)		noAMP SSI/no SSI (SSI/N %)		OR (95 % CI)[a]	p-value	q-value[b]
Amputation	1/36	(2.7 %)	1/5	(17 %)	0.27 (0.02–3.11)	0.29	>0.99
C-Section	2/7	(22 %)	8/36	(18 %)	1.23 (0.25–5.99)	0.80	>0.99
Hemilaminectomy	1/97	(1.0 %)	5/50	(9.1 %)	0.16 (0.03–0.91)	**0.039**	0.35
Internal fracture repair	15/129	(10 %)	1/19	(5.0 %)	1.85 (0.33–10.4)	0.48	>0.99
Patellaluxation with implant	1/48	(2.0 %)	0/4	(0.0 %)	1.34 (0.03–67.1)	0.88	>0.99
Skin tumour Resection	8/75	(9.6 %)	14/77	(15 %)	0.61 (0.25–1.48)	0.27	>0.99
Splenectomy	4/36	(10 %)	3/10	(23 %)	0.44 (0.09–2.00)	0.28	>0.99
Thoracotomy	1/19	(5.0 %)	0/1	(0.0 %)	1.23 (0.02–77.5)	0.92	>0.99
Ventral slot	0/28	(0.0 %)	1/10	(9.0 %)	0.18 (0.01–3.93)	0.27	>0.99

[a] OR = Odds Ratio, CI = Confidence Interval
[b] Holm correction for multiple testing

Table 5
Univariable logistic regression models for the association between time of receiving AMP (perioperative or postoperative group) and the odds of SSI occurrence, by surgery performed. Only animals receiving antibiosis are included in these analyses.

Surgery	perioperative SSI/no SSI (SSI/N %)		postoperative SSI/no SSI (SSI/N %)		OR (95 % CI)[a]	p-value	q-value[b]
Amputation	0/9	(0.0 %)	1/27	(3.6 %)	1.95 (0.07–57.7)	0.70	>0.99
C-section	0/2	(0.0 %)	2/5	(28 %)	2.89 (0.11–73.7)	0.52	>0.99
Hemilaminectomy	0/41	(0.0 %)	1/57	(1.8 %)	2.66 (0.11–63.2)	0.54	>0.99
Internal fracture repair	4/27	(13 %)	11/102	(9.7 %)	0.75 (0.24–2.40)	0.63	>0.99
Patellaluxation with implant	0/10	(0.0 %)	1/38	(2.6 %)	1.80 (0.06–57.1)	0.74	>0.99
Skin tumor resection	3/37	(7.5 %)	5/38	(12 %)	1.51 (0.38–5.99)	0.56	>0.99
Splenectomy	1/8	(11 %)	3/28	(9.7 %)	0.90 (0.12–6.80)	0.92	>0.99
Thoracotomy	1/0	(100 %)	0/19	(0 %)	0.01 (0.00–0.68)	0.034	0.30

[a] OR = Odds Ratio, CI = Confidence Interval
[b] Holm correction for multiple testing

prospective approach.

In human medicine, the use of an AMP is considered a protective factor with regard to the development of an SSI (Allegranzi et al., 2016). It should be emphasized that no evidence of the benefit of postoperative antibiotic prophylaxis could be demonstrated, contrary to the use in common practice (Knights et al., 2012; Nelson, 2011; Pratesi et al., 2015; Välkki et al., 2020). Any use of an antibiotic increases the risk of resistance development (Guardabassi et al., 2018), therefore, according to the results of our study, this use should be minimized.

The fact that 39 % (26/66) of wound infections in the present study had to be treated in a second surgery shows that the effects of an SSI are a burden for humans and animals. This meant a second general anaesthesia for the patient and additional costs for the patient owner. 83 % (55/66) of SSIs were successfully treated with antibiotics in this study.

In our study, dogs and cats were analysed together. This was done to increase the sample size and statistical power. There are animal-specific differences between the two species. Nevertheless, the analysis was carried out together, as the literature available to the authors does not indicate an increased risk of SSI on one side or the other. A second argument in favour of this is that the surgical techniques do not differ. Previous studies have also used a similar approach (Beal et al., 2000; Brown et al., 1997; Daude-Lagrave et al., 2001; Eugster et al., 2004; Nicholson et al., 2002; Schmökel et al., 2021).

It is important to consider the retrospective nature of the study and the use of pet owner surveys as a data source, which could influence the results. The SSI rate of 9.8 % (51/521) of patients analysed from the clinical records was very different from 4.7 % (15/320) of patients analysed by questionnaire. This could be explained by the fact that patients who develop complications during the wound healing process are more likely to return for treatment and are therefore more easily recorded in this study design. It can be assumed that the animals of patient owners who were not reached at all potentially had an even lower SSI rate. It should also be noted that pet owners were not trained to interpret signs of inflammation and could over- or underestimate signs.

Conclusions

The results of this study showed that extension of prophylactic administration in the postoperative phase showed no further benefit in reducing the risk of SSI.

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CRediT authorship contribution statement

Andrea Meyer-Lindenberg: Writing – review & editing, Validation, Supervision, Resources, Project administration, Conceptualization. **Yury Zablotski:** Writing – review & editing, Visualization, Validation, Methodology, Formal analysis. **Nico Paeckel:** Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used DeepL in order to translate the original draft of the paper from German into English. After using this tool, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the published article.

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None

Appendix

A. *Questionnaire in German*
B. *Questionnaire in English*
C. *Questionnaire for Implant in German*
D. *Questionnaire for Implant in English*

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.tvjl.2024.106267.

References

Alexander, J.W., Van Sweringen, H., Vanoss, K., Hooker, E.A., Edwards, M.J., 2013. Surveillance of bacterial colonization in operating rooms. Surg. Infect. 14, 345–351. https://doi.org/10.1089/sur.2012.134.

Allegranzi, B., Bischoff, P., de Jonge, S., Kubilay, N.Z., Zayed, B., Gomes, S.M., Abbas, M., Atema, J.J., Gans, S., van Rijen, M., Boermeester, M.A., Egger, M., Kluytmans, J., Pittet, D., Solomkin, J.S., 2016. New WHO recommendations on preoperative measures for surgical site infection prevention: an evidence-based global perspective. Lancet Infect. Dis. 16, e276–e287. https://doi.org/10.1016/S1473-3099(16)30398-X.

Barie, P.S., Eachempati, S.R., 2005. Surgical site infections. Surg. Clin. North Am. 85, 1115–1135. https://doi.org/10.1016/j.suc.2005.09.006.

Barnett, T.E., 2007. The not-so-hidden costs of surgical site infections. AORN J. 86, 249–258. https://doi.org/10.1016/j.aorn.2007.03.012.

Beal, M.W., Brown, D.C., Shofer, F.S., 2000. The effects of perioperative hypothermia and the duration of anesthesia on postoperative wound infection rate in clean wounds: a retrospective study. Vet. Surg. 29, 123–127. https://doi.org/10.1111/j.1532-950X.2000.00123.x.

Berríos-Torres, S.I., Umscheid, C.A., Bratzler, D.W., Leas, B., Stone, E.C., Kelz, R.R., Reinke, C.E., Morgan, S., Solomkin, J.S., Mazuski, J.E., Dellinger, E.P., Itani, K.M.F., Berbari, E.F., Segreti, J., Parvizi, J., Blanchard, J., Allen, G., Kluytmans, J.A.J.W., Donlan, R., Schecter, W.P., Committee, for the H.I.C.P.A., 2017. Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017. JAMA Surg. 152, 784–791. https://doi.org/10.1001/jamasurg.2017.0904.

Boothe, D.M., Boothe, H.W., 2015. Antimicrobial considerations in the perioperative patient. Vet. Clin. North Am. Small Anim. Pract. 45, 585–608. https://doi.org/10.1016/j.cvsm.2015.01.006.

Brown, D.C., Conzemius, M.G., Shofer, F., Swann, H., 1997. Epidemiologic evaluation of postoperative wound infections in dogs and cats. J. Am. Vet. Med. Assoc. 210, 1302–1306.

Budsberg, S.C., Torres, B.T., Sandberg, G.S., 2021. Efficacy of postoperative antibiotic use after tibial plateau leveling osteotomy in dogs: a systematic review. Vet. Surg. 50, 729–739. https://doi.org/10.1111/vsu.13603.

Control, E.C. for D.P. and, Meyer, E., Haag, L., Gebhardt, S., Magiorakos, A., Gastmeier, P., Zweigner, J., 2013. Systematic review and evidence-based guidance on perioperative antibiotic prophylaxis. Publications Office. https://doi.org/doi/10.2900/85936.

Culver, D.H., Horan, T.C., Gaynes, R.P., Martone, W.J., Jarvis, W.R., Emori, T.G., Banerjee, S.N., Edwards, J.R., Tolson, J.S., Henderson, T.S., Hughes, J.M., National Nosocomial Infections Surveillance System, 1991. Surgical wound infection rates by wound class, operative procedure, and patient risk index. Am. J. Med. 91. https://doi.org/10.1016/0002-9343(91)90361-Z.

Dacanay, S.J., Barber, R.M., Diehl, K.A., Myrna, K.E., 2023. Incidence and risk factors for surgical site infection following enucleation in dogs. Front. Vet. Sci. 9, 1086956. https://doi.org/10.3389/fvets.2022.1086956.

Daude-Lagrave, A., Carozzo, C., Fayolle, P., Viguier, E., Viateau, V., Moissonnier, P., 2001. Infection rates in surgical procedures: a comparison of cefalexin vs. a placebo. Vet. Comp. Orthop. Traumatol. 14, 146–150. https://doi.org/10.1055/s-0038-1632689.

Dyall, B.A.R., Schmökel, H.G., 2018. Surgical site infection rate after hemilaminectomy and laminectomy in dogs without perioperative antibiotic therapy. Vet. Comp Orthop. Traumatol. 31, 202–213. https://doi.org/10.1055/s-0038-1639365.

ECDC, 2016. Surveillance of surgical site infections and prevention indicators in European hospitals - HAI-Net SSI protocol version 2.2, ECDC Technical Document.

Eugster, S., Schawalder, P., Gaschen, F., Boerlin, P., 2004. A prospective study of postoperative surgical site infections in dogs and cats. Vet. Surg. 33, 542–550. https://doi.org/10.1111/j.1532-950X.2004.04076.x.

Gelman, A., S.Y., 2022. _arm: data analysis using regression and multilevel/Hierarchical Models_. R Package Version 1, 13-1.

Guardabassi, L., Apley, M., Olsen, J.E., Toutain, P.-L., Weese, S., 2018. Optimization of antimicrobial treatment to minimize resistance selection. Microbiol. Spectr. 6. https://doi.org/10.1128/microbiolspec.ARBA-0018-2017.

Heldmann, E., Brown, D.C., Shofer, F., 1999. The association of propofol usage with postoperative wound infection rate in clean wounds: a retrospective study. Vet. Surg. 28, 256–259. https://doi.org/10.1053/jvet.1999.0256.

Holm, S., 1979. A simple sequentially rejective multiple test procedure. Scand. J. Stat. 6, 65–70.

Howe, L.M., Boothe, H.W., 2006. Antimicrobial use in the surgical patient. Vet. Clin. North Am. Small Anim. Pract. 36, 1049–1060. https://doi.org/10.1016/j.cvsm.2006.05.001.

Knights, C.B., Mateus, A., Baines, S.J., 2012. Current British veterinary attitudes to the use of perioperative antimicrobials in small animal surgery. Vet. Rec. 170, 646. https://doi.org/10.1136/vr.100292.

Martin, E., Beckmann, M., Barnsbee, L., Halton, K., Merollini, K., Graves, N., 2018. Best practice perioperative strategies and surgical techniques for preventing caesarean section surgical site infections: a systematic review of reviews and meta-analyses. BJOG Int. J. Obstet. Gynaecol. 125, 956–964. https://doi.org/10.1111/1471-0528.15125.

Nelson, L.L., 2011. Surgical site infections in small animal surgery. Vet. Clin. North Am. Small Anim. Pract. 41, 1041–1056. https://doi.org/10.1016/j.cvsm.2011.05.010.

Nicholson, M., Beal, M., Shofer, F., Brown, D.C., 2002. Epidemiologic evaluation of postoperative wound infection in clean-contaminated wounds: A retrospective study of 239 dogs and cats. Vet. Surg. VS Off. J. Am. Coll Vet. Surg. 31, 577–581. https://doi.org/10.1053/jvet.2002.34661.

Nicoll, C., Singh, A., Weese, J.S., 2014. Economic impact of tibial plateau leveling osteotomy surgical site infection in dogs. Vet. Surg. 43, 899–902. https://doi.org/10.1111/j.1532-950X.2014.12175.x.

Pratesi, A., Moores, A.P., Downes, C., Grierson, J., Maddox, T.W., 2015. Efficacy of postoperative antimicrobial use for clean orthopedic implant surgery in dogs: a prospective randomized study in 100 consecutive cases. Vet. Surg. 44, 653–660. https://doi.org/10.1111/vsu.12326.

Schmökel, H., Skytte, D., Barsch, M., 2021. Infection rate treating radial and ulnar fractures using bone plate fixation without antibiotic prophylaxis. J. Small Anim. Pract. 62, 1079–1084. https://doi.org/10.1111/jsap.13407.

Spåre, P., Ljungvall, I., Ljungvall, K., Bergström, A., 2021. Evaluation of post-operative complications after mastectomy performed without perioperative antimicrobial prophylaxis in dogs. ACTA Veterinaria Sca. 63, 35. https://doi.org/10.1186/s13028-021-00600-3.

Stetter, J., Boge, G.S., Grönlund, U., Bergström, A., 2021. Risk factors for surgical site infection associated with clean surgical procedures in dogs. Res. Vet. Sci. 136, 616–621. https://doi.org/10.1016/j.rvsc.2021.04.012.

Turk, R., Singh, A., Weese, J.S., 2015. Prospective surgical site infection surveillance in dogs. Vet. Surg. 44, 2–8. https://doi.org/10.1111/j.1532-950X.2014.12267.x.

Välkki, K.J., Thomson, K.H., Grönthal, T.S.C., Junnila, J.J.T., Rantala, M.H.J., Laitinen-Vapaavuori, O.M., Mölsä, S.H., 2020. Antimicrobial prophylaxis is considered sufficient to preserve an acceptable surgical site infection rate in clean orthopaedic and neurosurgeries in dogs. ACTA Veterinaria. Sca 62, 1–10. https://doi.org/10.1186/s13028-020-00545-z.

Vasseur, P.B., Levy, J., Dowd, E., Eliot, J., 1988. Surgical wound infection rates in dogs and cats data from a teaching hospital. Vet. Surg. 17, 60–64. https://doi.org/10.1111/j.1532-950X.1988.tb00278.x.

Vasseur, P.B., Paul, H.A., Enos, L.R., Hirsh, D.C., 1985. Infection rates in clean surgical procedures: a comparison of ampicillin prophylaxis vs a placebo. J. Am. Vet. Med. Assoc. 825–827.

Whittem, T.L., Johnson, A.L., Smith, C.W., Schaeffer, D.J., Coolman, B.R., Averill, S.M., Cooper, T.K., Merkin, G.R., 1999. Effect of perioperative prophylactic antimicrobial treatment in dogs undergoing elective orthopedic surgery. J. Am. Vet. Med. Assoc. 215, 212–216.