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Antimicrobial prophylaxis in companion animal surgery: A scoping review for European Network for Optimization of Antimicrobial Therapy (ENOVAT) guidelines

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ABSTRACT

Surgical antimicrobial prophylaxis (SAP) is widely used to reduce the risk of surgical site infections (SSI), but there is uncertainty as to what the proportion of SSI reduction is. Therefore, it is difficult for surgeons to properly weigh the costs, risks and benefits for individual patients when deciding on the use of SAP, making it challenging to promote antimicrobial stewardship in primary practice settings. The objective of this study was to map the veterinary evidence focused on assessing the effect of SAP on SSI development and in order to identify surgical procedures with some research evidence and possible knowledge gaps. In October 2021 and December 2022, Scopus, CAB Abstracts, Web of Science Core Collection, Embase and MEDLINE were systematically searched. Double blinded screening of records was performed to identify studies in companion animals that reported on the use of SAP and SSI rates. Comparative data were available from 34 out of 39123 records screened including: eight randomised controlled trials (RCT), 23 cohort studies (seven prospective and 16 retrospective) and three

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retrospective case series representing 12476 dogs and cats in total. Extracted data described peri- or post-operative SAP in nine, and 25 studies, respectively. In the eight RCTs evaluating SAP in companion animals, surgical procedure coverage was skewed towards orthopaedic stifle surgeries in referral settings and there was large variation in SAP protocols, SSI definitions and follow-up periods. More standardized data collection and agreement of SSI definitions is needed to build stronger evidence for optimized patient care.

Introduction

Surgical antimicrobial prophylaxis (SAP) is administered to minimise the risk of developing a surgical site infection (SSI). In recent EU legislation (Regulation 2019/6, Article 105), prophylaxis has been defined as 'the administration of a medicinal product to animals or a group of animals before clinical signs of a disease, in order to prevent the occurrence of disease or infection' (EU, 2022). In the context of SAP, this relates to the administration of antimicrobials to animals undergoing a surgical procedure to prevent development of an SSI and does not include preoperative decolonisation or treatment of established infections.

To be coherent with principles of antimicrobial stewardship (AMS), SAP should significantly reduce the morbidity and/or mortality associated with SSI development and balance the negative effects of antimicrobial use, including costs, adverse drug reactions and impacts on antimicrobial resistance and the bacterial microbiota (Menz et al., 2021; Stavroulaki et al., 2023). In human medicine SAP accounts for 11–40% of in-patient antimicrobial prescription (Zarb et al., 2012; Magill et al., 2014; Pereira et al., 2020; Labi et al., 2021; Levy Hara et al., 2022; Shaikh et al., 2022) with only 12–57% of its use deemed appropriate across a variety of healthcare settings (Testa et al., 2015; Ierano et al., 2019; Levy Hara et al., 2022; Morioka et al., 2022; Viel-Thériault et al., 2022). In these studies, inappropriate SAP administration included unjustified continuation beyond 24 hours post-surgery, unjustified re-start of post-operative prophylaxis, selection of an antimicrobial with an incorrect spectrum of activity, or inappropriate timing or dosing of antimicrobials according to local, national or international antimicrobial use guidelines.

Current SAP practice in veterinary medicine is largely unknown and likely varies greatly with the clinical setting, nature of surgical workload and geographical region. Several published retrospective studies on surgical procedure outcomes have described relatively high (63–100%) rates of peri- or post-operative SAP, or a combination thereof (Vasseur et al., 1988; Billings et al., 1990; Launcelott et al., 2019; Cockburn et al., 2022). Current antimicrobial use guidelines do not recommend peri-operative SAP in most sterile settings and clean procedures and state that post-operative SAP is rarely indicated (Jessen, 2018; Frey et al., 2022). Nonetheless, surveys of companion animal veterinarians have described limited compliance with antimicrobial use guidelines for common procedures including castrations, ovariohysterectomy and dermal mass removal (Knights et al., 2012; Hardefeldt et al., 2017), highlighting the possibility of widespread over-prescription in this context. Any antimicrobial use carries a risk of adverse effects (Branch-Elliman et al., 2019) and, importantly, can potentiate and drive antimicrobial resistance (AMR). Therefore, further prescriber education is paramount to reduce unnecessary antimicrobial use and to optimise the timing of administration and duration of SAP, particularly in clean procedures. Surgeons have the responsibility to weigh the benefit of SSI-risk reduction for the individual patient afforded by prophylactic antimicrobial administration against the broader societal risk from such use.

Recent European legislation aims to reduce antimicrobial use including avoiding SAP and stipulates that 'antibiotic medicinal products should not be used for prophylaxis other than in exceptional cases only for the administration to an individual animal' (EU, 2022). However, no clear definition of exceptional cases is available and SAP is still permitted in individual animals. Veterinarians therefore require evidence of benefit for specific surgical procedures and settings to support and substantiate rational decision making.

This scoping review aims to identify all published studies relating to dogs and cats that provide an assessment of the impact of SAP on SSI development. The results will provide evidence to inform the Surgical Prophylaxis Guidelines of the European Network for Optimization of Antimicrobial Therapy (ENOVAT, 2023) and European Society of Clinical Microbiology and Infectious Diseases (ESCMID) Study Group for Veterinary Microbiology (ESGVM, 2023).

Table 1
Definitions applied in the scoping review to categorize studies based on timing of surgical antimicrobial prophylaxis administration.

Antimicrobial timing	Definition
No administration	No antimicrobials administered before, during or after surgery.
Pre-operative administration	Administration earlier than 2 hours before procedure initiation.
Peri-operative administration	Administration from 2 hours before procedure initiation to 24 hours after procedure completion.
Post-operative administration	Administration from 24 hours after procedure completion.

Methods

This scoping review was reported according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) statement (Tricco et al., 2018).

Protocol and registration

The protocol was drafted *a priori* using the Preferred Reporting Items for Systematic Reviews and Meta-analysis Protocols (PRISMA-P) (Moher et al., 2015), and was revised by the ENOVAT SAP drafting group members. The final protocol was registered prospectively with the Systematic Reviews for Animals & Food (SYREAF, 2023) on 19th October 2021.

Eligibility criteria

To meet the objective of mapping the published evidence on SAP in companion animal surgery, studies needed to report on antimicrobial administration and SSI occurrence. Papers were eligible for inclusion if they provided an abstract in English, involved surgical procedures on companion animals (defined as dogs and/or cats) and described antimicrobial administration and postoperative infections for treated and untreated animals separately. Original studies including prospective studies, retrospective studies, and case series including a minimum of 10 animals were considered eligible. Fewer than 10 animals in the population were deemed to provide very low certainty of evidence by the research group.

Studies were excluded if they did not fit into the conceptual framework of the review, e.g. there was insufficient data to determine whether SAP was administered or whether administration was pre-, peri- or post-operative. Definitions of the four categories of SAP timing are shown in Table 1. Studies reporting antimicrobial administration to treat established infection were also excluded as such administration of antimicrobials is considered therapeutic and not prophylactic. Studies solely

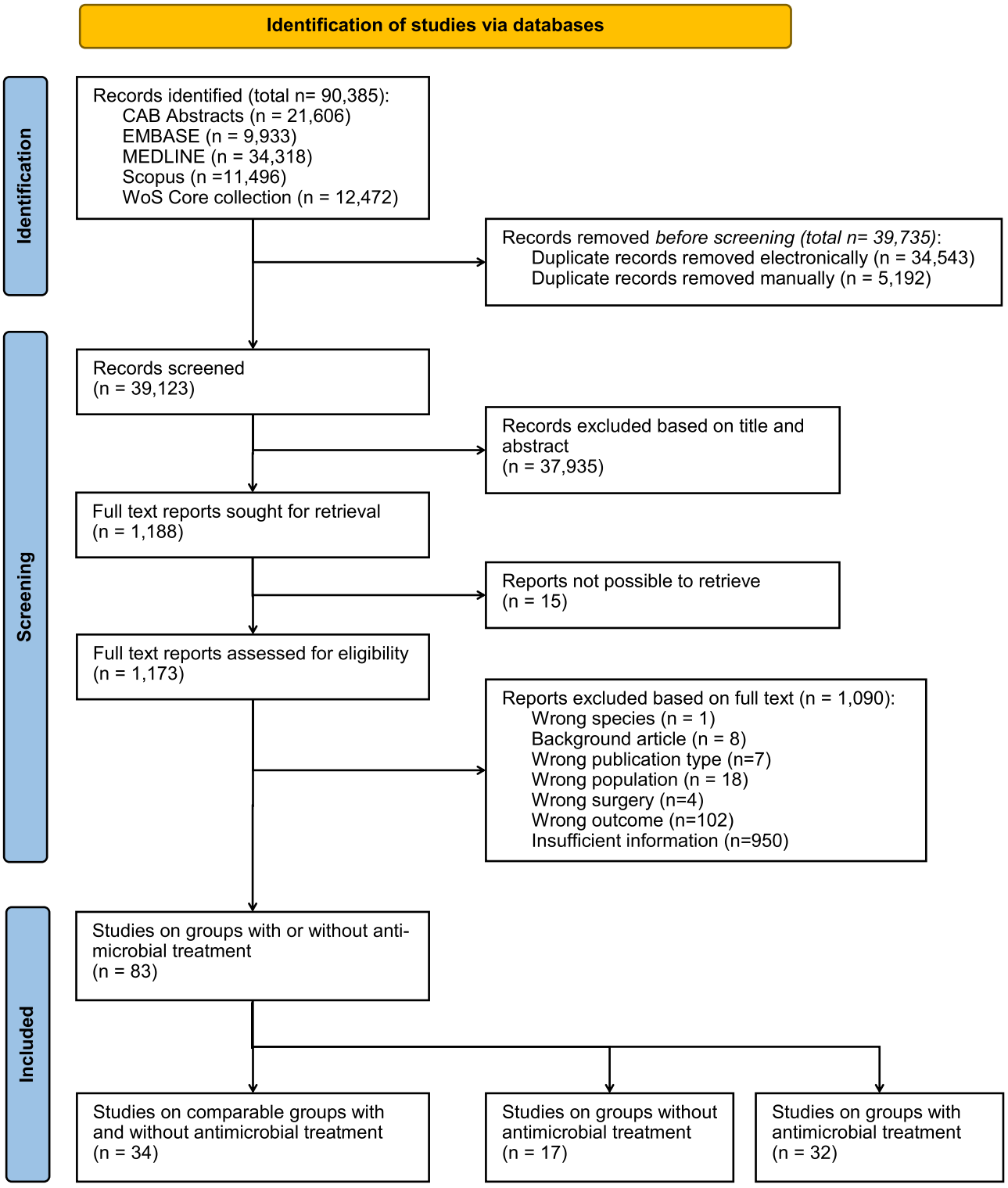

Fig. 1. Flow diagram showing the database search result, numbers of identified records, reasons for exclusions during the screening process and the final number of included studies for the scoping review.

reporting on dental or ophthalmic procedures were excluded from the review as SSI, along with the definitions of superficial and deep infections, differ in these locations compared to other surgeries with cutaneous incisions.

Information sources

The bibliographic databases Scopus, CAB Abstracts, Web of Science Core Collection, Embase, MEDLINE were searched through Scopus, CAB Direct, Web of Science interface, Ovid and PubMed, respectively (Grindlay et al., 2012). No restrictions were applied on publication year or language *a priori*. The search was not supplemented with screening of reference lists or other approaches to reach grey literature. An *a priori* list of 22 known relevant publications (Supplementary Table 1) was identified by the research group in order to validate the final search strategy. Initial database searches were performed on 15th-18th of

Table 2
Characteristics of 15 prospective studies reporting surgical site infections in both antimicrobial treated and untreated groups of animals (comparative groups).

Study	Design	Region	Center	Years	Population (*n*)	Surgery group
Peri-operative comparison						
Daude-Lagrave et al. (2001)	RCT	France	Single	NR	873 dogs and cats	Mixed
Holmberg (1985)	RCT	Canada	Single	NR	60 dogs	Ortho w/implant
Vasseur et al. (1985)	RCT	USA	Single	NR	128 dogs	Mixed
Whittem et al. (1999)	RCT	USA	Single	1996–1998	112 dogs	Ortho w/implant
Brown et al. (1997)	Cohort	USA	Single	1994–1995	930 dogs and cats	Mixed
Castro et al. (2022)	Cohort	Brazil	Single	NR	20 dogs	Soft
Stetter et al. (2021)	Cohort	Sweden	Multi	2017, 2018	511 dogs	Soft
Turk et al. (2015)	Cohort	Canada	Single	2010–2011	846 dogs	Mixed
Post-operative comparison						
Aiken et al. (2015)	RCT	UK	Single	2011–2012	400 dogs	Ortho w/implant
Chutipongvivate et al. (2022)	RCT	Thailand	Single	NR	492 cats	Soft
Pratesi et al. (2015)	RCT	UK	Single	2009–2010	97 dogs	Ortho w/implant
Spencer and Daye (2018)	RCT	USA	Single	2015–2017	120 dogs	Ortho w/implant
Andrade et al. (2016)	Cohort	USA	Single	2012–2013	100 dogs	Ortho w/implant
Espinel-Rupérez et al. (2019)	Cohort	Spain	Single	2013–2014	184 dogs	Soft
Nazarali et al. (2015)	Cohort	Canada, USA	Multi	2012–2014	153 dogs	Ortho w/implant

Mixed, both orthopaedic and soft tissue surgeries included in the study population; NR, Not reported; RCT, Randomized controlled trial; Soft, only soft tissue surgeries included in the study population; Ortho w/implant, only orthopedic surgeries with implants included in the study population.

October 2021, and last executed on 7th of December 2022 to include more recent publications.

Search

The search strategies were reviewed by an information specialist at the University of Copenhagen (Anne Cathrine Trumpy) and further refined through discussions with the research group. Veterinary or Animal filters were applied in all databases, except CAB Direct. The University of Copenhagen library access to CAB direct significantly decreased during the search period, and thus made a repeat search including filters impossible. The final search through Scopus and PubMed interfaces can be found in "Supplementary file 2".

Individual database search results were imported to EndNote™ 20 software (Clarivate, 2013) and duplicates removed both electronically and manually. The final reference list was imported to the internet based software program Rayyan® (Ouzzani et al., 2016) that facilitates blinded collaboration among reviewers during the study selection process. Another electronic duplicate removal phase was performed in Rayyan before the selection phase (Ouzzani et al., 2016).

Selection of sources of evidence

A reference screening manual was drafted to guide reviewers in the screening process and prioritisation of reasons for exclusion. To increase consistency among reviewers and test the screening manual ten reviewers screened the same 25 references in Rayyan, discussed the results and approved the screening manual before initiation of the screening process for this review (Supplementary table 2).

Fifteen reviewers collaboratively identified eligible studies from the search based on the title and abstracts. Each record was screened independently by two reviewers blinded to each other's decision. Full text documents were retrieved for review where uncertainty existed based on the title and abstract alone. A third reviewer resolved any conflicts where there were disagreements on study categorisation.

Data charting process

A comprehensive data charting form to extract relevant information from included studies was drafted in Microsoft Excel based on the protocol. The form was tested by two reviewers for 27 references and adjusted before final data charting for all included studies was initiated. Four reviewers (FA, TMS, KAS, JER) blinded to each other's assessment participated in data charting resulting in double extractions on all studies. Any inconsistencies between two reviewers were resolved by a third reviewer or collective agreement among reviewers.

Non-English full texts were screened and charted by one reviewer where the language competence was available within the group (German, French, Spanish, Portuguese, Dutch, Italian). Other language texts were screened using Google translate (Google, 2023).

Data items

For all included studies data were extracted on study characteristics (country of origin, language, investigation years, design, setting and follow-up period), population characteristics (e.g. population and group size, species, surgical procedures, diagnoses), concept variables (e.g. reporting on antimicrobial prescription and timing in relation to surgery, pharmaceutical substance, administration, dose and duration), outcome variables and reported definitions thereof (e.g. number of SSIs, other complications, mortality, surrogate outcomes such as initiation of antimicrobial treatment), or P-values for SAP effect where no raw numbers were provided and follow-up information.

The study designs of included studies were evaluated based on the relevant outcomes for the scoping review and defined based on Royal College of Veterinary Surgeons (RCVS) Knowledge Evidence Based Veterinary Medicine (EBVM) Toolkit 3 (RCVS, 2023).

Summary of results

Studies were grouped based on timing of antimicrobial prescription, study design and surgical procedure group. Descriptive and demographic data from each included study were presented in tables and visual diagrams supplemented by a narrative to summarize the results.

Results

Selection of sources of evidence

The first and second database searches identified 83,060 and 7325 records, respectively (n=90,385 in total). A total of 39,123 records proceeded to screening after initial electronic and manual duplicate removal. Title and abstract screening excluded 37,935 records leaving 1188 records for full-text retrieval and assessment. Fifteen full texts could not be retrieved and most of the remaining 1173 full texts were excluded based on reasons listed in the PRISMA flow diagram (Fig. 1). Eighty-three studies reported sufficiently on antimicrobial treatment and SSI to identify treated and/or untreated groups of animals. Comparative data from treated and untreated animals were provided in 34 studies. The remaining 49 studies provided data from untreated (17

Table 3
Characteristics of 19 retrospective studies reporting surgical site infections in both antimicrobial treated and untreated groups of animals (comparative groups).

Study	Design	Region	Center	Years	Population (*n*)	Surgery group
Peri-operative comparison						
Vasseur et al. (1988)	Cohort	USA	Single	1984–1986	902 dogs & 198 cats	Mixed
Post-operative comparison						
Atwood et al. (2015)	Cohort	USA	Single	2006–2013	242 dogs	Ortho w/implant
Campbell et al. (2016)	Cohort	USA	Single	2005–2014	45 dogs	Ortho w/implant
Carwardine et al. (2021)	Cohort	UK	Multi	2012–2019	62 dogs (82 procedures)	Ortho w/implant
Etter et al. (2013)	Cohort	USA	Single	2005–2009	283 dogs	Ortho w/implant
Ferrell et al. (2019)	Cohort	USA	Single	2007–2011	1700 dogs	Ortho w/implant
Fitzpatrick and Solano (2010)	Cohort	UK	Single	2004–2009	1000 dogs	Ortho w/implant
Frey et al. (2010)	Cohort	USA	Single	2005–2006	808 dogs (902 procedures)	Ortho w/implant
Gatineau et al. (2011)	Cohort	Canada	Single	2004–2008	348 dogs (476 procedures)	Ortho w/implant
Hagen et al. (2020)	Cohort	Canada	Single	2011–2018	541 dogs (659 procedures)	Ortho w/implant
Hans et al. (2017)	Cohort	USA	Single	2011–2015	145 dogs	Ortho w/implant
Korytárová et al. (2022)	Cohort	Germany	Single	2018–2019	158 dogs	Ortho w/implant
Kuan et al. (2009)	Cohort	Australia	Single	2000–2006	249 dogs (300 procedures)	Ortho w/implant
Launcelott et al. (2019)	Cohort	USA	Single	2013–2016	302 dogs[a]	Soft
Solano et al. (2015)	Cohort	UK	Single	2003–2011	208 dogs	Ortho no/implant
Yap et al. (2015)	Cohort	UK	Single	2008–2013	186 dogs	Ortho w/implant
Armstrong et al. (2019)	Case series	UK, USA, Australia	Multi	2010–2016	32 dogs	Ortho w/implant
Chase et al. (2019)	Case series	UK	Single	2000–2009	19 dogs (26 procedures)	Ortho w/implant
Winter et al. (2022)	Case series	UK	Multi	2009–2020	22 dogs	Ortho w/implant

Mixed, both orthopedic and soft tissue surgeries included in the study population; Soft, only soft tissue surgeries included in the study population; Ortho no/implant, only orthopedic surgeries without implants included in the study population; Ortho w/implant, only orthopedic surgeries with implants included in the study population.
[a] 201 medical records (retrospective) & 101 prospective cases

Table 4
Reported outcomes of 15 prospective studies reporting surgical site infections in both antimicrobial treated and untreated groups of animals (comparative groups).

Author	Surgery	Follow-up	Peri-OP AM	Peri-OP Control	Post-OP AM	Post-OP Control	AM group SSI (%)	Control SSI (%)
Peri-operative comparison								
Daude-Lagrave et al. (2001)	Clean, clean-contaminated	12 days	446	427	0	0	38 (8.5)	40 (9.4)
Holmberg (1985)	Fractures (long bone and pelvic)	6 months	30	30	0	0	0 (0.0)	2 (6.7)
Vasseur et al. (1985)	Orthopedic(106) Soft (22)	7–10 days	64	64	0	0	1 (1.6)	0 (0.0)
Whittem et al. (1999)	Clean orthopedic surgeries	10–14 days	91	35	0	0	4 (4.4)	5 (14.3)
Brown et al. (1997)	Various with skin incision	14 days	167	763	0	0	5 (3.0)	38 (4.9)
Castro et al. (2022)	Orchiectomy	7 days	10	10	0	0	0 (0.0)	0 (0.0)
Stetter et al. (2021)	Castration	30 days	79	432	0	0	2 (2.5)	15 (3.5)
Turk et al. (2015)	Orthopedic (310) Soft (435) Neurologic (101)	30 days / 1 year[a]	802	44	0	0	24 (3.0)	2 (4.6)
Post-operative comparison								
Aiken et al. (2015)	Clean orthopedic surgeries	6 weeks	389	0	198	191	7 (3.5)	10 (5.2)
Chutipongvivate et al. (2022)	OHE	7 days	492	0	244	248	0 (0.0)	7 (2.8)
Pratesi et al. (2015)	Clean orthopedic surgeries	12 months	93	0	46	47	2 (4.4)	10 (21.3)
Spencer and Daye (2018)	TPLO	8 weeks	120	0	70	64	8 (11.4)	11 (17.2)[b]
Andrade et al. (2016)	TPLO and TTA	8 weeks	100	0	33	67	NR	NR[c]
Espinel-Rupérez et al. (2019)	Various soft tissue	30 days	184	0	126	58	13 (10.3)	3 (5.2)
Nazarali et al. (2015)	TPLO	8 weeks	153	0	79	74	7 (8.9)	18 (24.3)

AM, Antimicrobial; NR, Not reported; Peri-OP, Peri-operative; Post-OP, Post-operative; OHE, Overiohysterectomy; SSI, Surgical site infections; TPLO, Tibial plateau leveling osteotomy; TTA, Tibial tuberosity advancement.
[a] For implant surgery [b] P=0.94, [c] P=0.17

studies) or treated (32 studies) animals only and thus were considered suitable for baseline information only and not for direct treatment comparison purposes.

Characteristics of individual sources of evidence from 34 comparative studies

The 34 comparative studies were performed in five continents starting in the 1980 s, encompassing 12476872 dogs and cats. The majority (n=13) were conducted in the United States of America as single centre studies. There were 15 prospective and 19 retrospective studies including eight randomized controlled trials (RCT), 23 cohort studies and three case series. The population consisted mainly of dogs, with a total of 30 comparative studies in dogs, one in cats and three in a mixed dog and cat population (Tables 2–3).

Summary of results from 34 comparative studies

Administration of peri- or post-operative antimicrobial prophylaxis represented the intervention in four of the included RCTs whereas SAP

Table 5
Reportted outcomes of 19 retrospective studies reporting surgical site infections in both antimicrobial-treated and untreated groups of animals (comparative groups).

Author	Surgery	Follow-up	Peri-OP AM	Peri-OP Control	Post-OP AM	Post-OP Control	AM group SSI (%)	Control SSI (%)
Peri-operative comparison								
Vasseur et al. (1988)	OHE (350) Castration (128) Simple mass (26) Mixed (596)	14 days	797	303	0	0	13 (1.6)	14 (4.6)
Post-operative comparison								
Atwood et al. (2015)	TPLO	14 days	242	0	166	140	12 (7.2)	21 (15.0)
Campbell et al. (2016)	CWO	8 weeks	45	0	34	21	5 (14.7)	3 (14.3)
Carwardine et al. (2021)	Transcondylar screw placement	0–2481 days	70	0	30	40	NR	NR[a]
Etter et al. (2013)	TPLO	Until healing	283	0			NR	NR[b]
Ferrell et al. (2019)	TTA	12 months	1700	0	1293	475	63 (4.9)	19 (4.0)
Fitzpatrick and Solano (2010)	TPLO	6 months	1000	0	750	250	NR	NR[c]
Frey et al. (2010)	TPLO or ECLS	6 months	808	0	771	131	39 (5.1)	14 (10.7)
Gatineau et al. (2011)	TPLO	24 months	476	0	208	268	2 (1.0)	12 (4.5)
Hagen et al. (2020)	TPLO	12 months	541	0	455	204	30 (6.6)	41 (20.1)
Hans et al. (2017)	TPLO	6 weeks	54	0	34	20	6 (17.7)	8 (40.0)
	TTA	6 weeks	91	0	84	6	13 (15.3)	1 (16.7)
Korytárová et al. (2022)	Spinal surgery	4–6 weeks	158	0	92	66	1 (1.1)	1 (1.5)
Kuan et al. (2009)	TWO	≥ 1 month	300	0	56	244	2 (3.6)	17 (7.0)
Launcelott et al. (2019)	Foreign body removal	2 weeks	302	0	189	113	34 (18.0)	18 (16.0)
Solano et al. (2015)	TPLO	6 weeks	208	0	90	108	3 (3.3)	37 (34.3)
Yap et al. (2015)	TTA	90–1837 days	186	0	173	51	9 (5.2)	3 (5.9)
Armstrong et al. (2019)	Fracture repair	NR	28	0	20	5	1 (5.0)	2 (40.0)
Chase et al. (2019)	Transcondylar screw placement	6–18 weeks	19	0	8	11	3 (37.5)	8 (50.0)
Winter et al. (2022)	Fracture repair	4–46 weeks	22	0	5	17	0 (0.0)	2 (11.8)

AM, Antimicrobial; CWO, Tibial closing wedge osteotomy; ECLS, Extracapsular lateral suture; NR, Not reported; Peri-OP, Peri-operative; Post-OP, Post-operative; OHE, Ovariohysterectomy; SSI, Surgical site infections; TPLO, Tibial plateau levelling osteotomy; TTA, Tibial tuberosity advancement; TWO, Tibial wedge osteotomy.
[a] P=0.34, [b] P=0.15, [c] P=0.06.

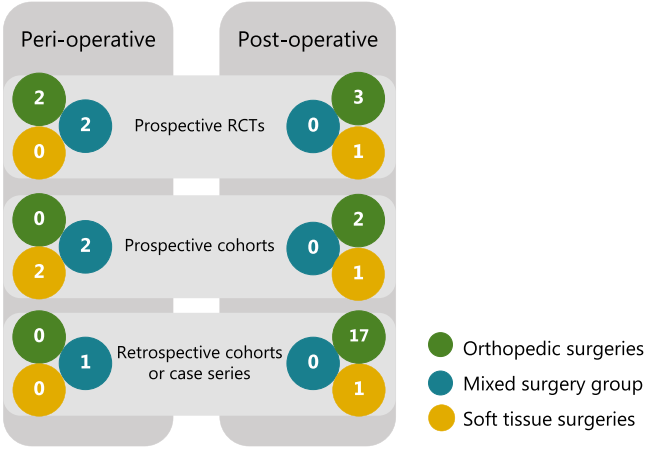

Fig. 2. Comparative studies included in the scoping review. Illustration of peri- or post-operative surgical antimicrobial prophylaxis, study designs and surgical procedures covered in the 34 included studies.

was not the subject of investigation in the other four. In the observational studies, SAP was the main topic in 4 out of 26 studies. The data reporting allowed discrimination between SSI rates in SAP treated animals and untreated animals in all 34 studies (Table 4–5). Orthopaedic surgery was investigated in 24 studies, soft tissue surgery in five studies (including three studies on elective neutering procedures) and the remaining five studies investigated mixed groups of surgeries, some of which were only categorised as clean or clean-contaminated surgeries without further definition or specification in the publications (Fig. 2).

Beta-lactam antimicrobials (primarily first-generation cephalosporins) were reported in the 34 comparative studies for both peri- and post-operative use (Tables 6–7). There was no consistency across studies regarding the timing and frequency of peri-operative antimicrobial prophylaxis, whereas post-operative prophylaxis was of relatively uniform duration (5–7 days in the prospective studies) (Tables 6–7). There was also considerable variability in the definition of SSI applied from documenting inflammatory signs or wound dehiscence to following standards set by the US Centers for Disease Control and Prevention (CDC) and performing routine bacterial cultures (only two of the prospective comparative studies). Post-operative follow-up period also varied considerably (from 7 days to 12 months) across the included studies (Table 4-5).

Characteristics of individual sources of evidence and summary of results from 49 uncontrolled studies

Study characteristics and reported SSI rates from the 17 studies of untreated animals and the 32 studies of treated animals are available in supplementary file 1 Table 3-5. Baseline SSI risk, representing 4529 dogs and cats, can be extracted from the 17 studies where no SAP was administered at any time point during the studies. A range of orthopaedic, neurological and soft tissue procedures were reported in these studies (Supplementary file 1 Table 3) with SSI rates ranging from 0.0% to 28.6% in individual studies. In the 28 studies of animals receiving peri-operative SAP, representing 6220 dogs and cats, the SSI risk ranged from 0.0% to 35.3% (Supplementary file 1 Table 4-5).

Discussion

This scoping review identified 34 primary studies, published between 1985 and 2022, investigating or reporting on the administration of SAP and related SSI frequencies. Eight RCT publications on SAP were identified predominantly describing orthopaedic procedures. Although elective procedures (e.g., ovariohysterectomy, castration) and cutaneous mass removals are likely the most performed in veterinary

Table 6
Reported antimicrobial treatments (intervention) and surgical site infection definitions (outcome) in the 15 prospective comparative studies included in the review.

Study	Intervention	Control	Timing & Duration	SSI definition
Peri-operative comparison				
Daude-Lagrave et al. (2001)	Cefalexin 30 mg/kg IV	Placebo NaCl IV	At induction and 4 h later	Wound drainage and/or body temp >39,5, wound characteristics (redness, heat, swollen, local induration, possible oozing)
Holmberg (1985)	Penicillin procaine 40,000 U/kg IM and IV and 50,000 U/kg Topical	No treatment	At induction IM & IV, at closure topical	NR
Vasseur et al. (1985)	Ampicillin 20 mg/kg	Placebo NaCl IV	At induction and 4 h later	Wound drainage
Whittem et al. (1999)	Cefazolin 20 mg/kg IV or Penicillin G 40,000 U/kg IV	Placebo NaCl IV	30 min pre-surgery and q90m	NR
Brown et al. (1997)	NR	NR	NR	Purulent discharge
Castro et al. (2022)	Cefalothin 30 mg/kg IM	NR	pre-OP	NR
Stetter et al. (2021)	NR	NR	NR	Purulent discharge/ positive culture/ one or more inflammation signs OR reoperation
Turk et al. (2015)	NR	NR	NR	Purulent discharge/ positive culture/ one or more inflammation signs OR reoperation
Post-operative comparison*				
Aiken et al. (2015)	Cephalexin 20 mg/kg PO BID	No treatment	5 days	Purulent discharge/ spontaneous dehiscence with serous drainage & at least 2 inflammation signs, joint sepsis or discharging sinus. Infected implants diagnosed as persistent lameness & 2 inflammation signs or radiographic signs ofosteomyelitis.
Chutipongvivate et al. (2022)	Cephalexin 22.2 mg/kg PO BID	No treatment	7 days	Wound score and antimicrobial intervention
Pratesi et al. (2015)	Cephalexin 15–25 mg/kg or AMC 12.5 mg/kg PO BID	No treatment	7 days	Deterioration after surgery for no other recognized reason & positive microbial culture or considered present based on appropriate clinical signs and/or cytology.
Spencer and Daye (2018)	Cefpodoxime 5–10 mg/kg PO SID	Placebo PO SID	7 days	Purulent discharge +/- laboratory confirmation, or ≥3 criteria (redness, pain, swelling, heat at the incision).
Andrade et al. (2016)	Various	No treatment	10–14 days	Positive culture (joint/wound), purulent drainage, abscess, fistula or spontaneous dehiscence with serous drainage. All drainage wounds underwent bacteriologic culture.
Espinel-Rupérez et al. (2019)	NR	No treatment	NR	CDC criteria
Nazarali et al. (2015)	NR	No treatment	Median 10 days (12 hours −21 days)	CDC criteria

AMC: Amoxicillin+clavulanic acid or potentiated amoxicillin; BID: twice daily; CDC: Center for Disease Control and Prevention; IV: Intravenous; NR: Not reported; PO: per oral; SC: subcutaneous

* All treated peri-operative

practices worldwide and are still subject to routine SAP in some areas (Otero Balda et al., 2023), these procedures rarely featured in the retrieved literature. This reflects skewing of data towards the caseload of referral hospitals where more advanced procedures are typically undertaken (e.g. Tibial Plateau Levelling Osteotomy (TPLO)). The lack of RCTs on SAP in common surgical procedures is a key gap in the veterinary literature highlighted by this scoping review. Decision making on peri-operative or post-operative antimicrobial use for specific procedures is best informed by direct evidence from properly conducted RCTs investigating the population, setting and procedures in question. However, not all procedures are equally important to investigate and research should be prioritized for procedures where reduction in SSI rates would truly be perceived as clinically relevant or where antimicrobial use is common despite likely low benefit. For procedures where baseline SSI rates (without the use of antimicrobial prophylaxis) are deemed acceptable to practitioners it may be justifiable to adopt non-treatment practices without pursuit of a RCT (Smith and Pell, 2003). The same rationale may be used to support a recommendation not to use post-operative antimicrobial therapy (more than 24 hours after surgery). Baseline SSI rates for several procedures can be calculated from the control groups of comparative studies and observational data summarized in this scoping review (Table 4, 5 and supplementary tables 4) and may assist the veterinary research community in selecting which procedures should be prioritized for future RCTs on SAP and/or post-operative antimicrobial administration, e.g. ovariohysterectomy, enterotomy/enterectomy and non-implant orthopaedic surgeries. Additional tasks for the veterinary research community are to investigate what core outcomes matter to veterinary practitioners, technicians and animal owners and to identify what constitutes an acceptable SSI rate for various types of surgery. Not all SSI are equivalent and development of a superficial SSI will be less consequential than one that is implant-associated. Some SSI can be managed with topical wound management while others may necessitate implant removal, limb amputation or even lead to the euthanasia of the animal. Awareness of these different outcomes, and an appreciation of the relative value attributed by different stakeholders will add important context to any decision to use (or withhold) SAP.

The range of SSI rates reported in this study broadly mirrors previous summaries of the literature (Weese, 2008; Burgess, 2019). Differences in SSI rates between groups with and without SAP are presented in Table 4 and 5, but the authors advise caution when interpreting these data. Critical assessment of the different methodologies and reporting criteria is essential to contextualise any recommendations derived from this dataset.

Although the chosen search strategy was very sensitive and wide and identified a very large number of candidate records, careful screening and detailed review of this body of evidence led to the exclusion of over 99% of the original records. This study highlights the challenge in collating veterinary evidence for systematic reviews and meta-analysis. Given the expected paucity of RCTs evaluating the impact of SAP, observational studies (prospective and retrospective) were also included. While offering a lower certainty of evidence, such studies remain the largest source of evidence upon which guideline recommendations can be made in the absence of suitable RCTs for certain surgical procedures.

Of the articles selected for more detailed consideration (and therefore classified according to procedure type), a majority (24/34) related to orthopaedic procedures and in particular to dogs with cranial cruciate ligament disease (16/34). The over-representation of two procedures (TPLO and tibial tuberosity advancement (TTA)) in this scoping review may be a reflection of them being relatively common and standardised procedures and the ongoing controversy around the use of post-operative SAP in the field. A recent systematic review (Budsberg et al., 2021) found little evidence to support the use of postoperative antimicrobials to reduce the risk of SSIs in dogs after TPLO. However, the authors lamented the absence of prospective trials upon which they could base their conclusions and the lack of a consistent definition of 'post-operative', as any antimicrobial use (even that confined to the 24 h peri-operative window) would be considered post-operative in some studies. The use of antimicrobials beyond 24 hours after the end of the procedure (post-operatively) in orthopaedic surgery in people is not recommended even when implants are placed (Bratzler et al., 2013). Nonetheless, the high cost of these procedures and potentially catastrophic implications of SSI may contribute to a tendency for orthopaedic surgeons to search for justification for post-operative prophylaxis (Charani et al., 2019).

A secondary outcome from this scoping review is the recognition that many potentially eligible studies were excluded due to missing information including the omission of a statement when no antimicrobials were administered or insufficient detail to determine whether animals that developed SSIs had (or had not) received SAP. The authors encourage reporting of key details relating to antimicrobial use in a standardised manner to facilitate future comparison. Key details should include the timing of antimicrobial administration with respect to first incision and surgical wound closure, dose and antimicrobial agent used, route of administration, number of doses administered and at what interval. Authors should also specifically state if no antimicrobials were used in a particular procedure. Further, considerable ambiguity remains concerning the definition of SSI. Although effective definitions have not been compared in the present veterinary study a systematic review on prospective SSI rates in human healthcare settings highlighted the use of 41 different versions of SSI definitions amongst 90 different studies (Bruce et al., 2001). We therefore recommend researchers and future authors to use established referenced SSI definitions such as CDC when designing studies. The present authors also encourages editorial boards of scientific journals to require routine inclusion of information around SAP, complication rates and complication severity in journal submissions (even in supplementary materials). This will help grow the bank of comparable data and generate more robust evidence upon which future recommendations can be made.

Regional differences were evident in the antimicrobial used for SAP. Cefazolin, a first-generation cefalosporin, was predominantly used in studies from North America and Europe, while cefuroxime, a second-generation cefalosporin predominated in the UK. From a survey published in 2012, cefalexin, a first-generation cefalosporin, was the most widely used antibiotic in surgical prophylaxis in France (Darles, 2012). This difference could merely reflect drug availability and national clinical practices. However,given the differences in spectrum of activity and expected duration, the level of SSI protection provided may differ depending on the particular cefalosporin used (Ahmed et al., 2022).

Conclusions

Despite the widespread use of SAP in dogs and cats there is remarkably limited high-quality data evaluating the need for SAP and comparing different regimens for different surgical procedures. This study identified eight RCTs evaluating SAP in companion animals but surgical procedure coverage is largely skewed towards orthopaedic stifle surgeries from referral settings, with no comparative data available for the vast majority of surgical procedures relevant for primary practice. There is large variation in SAP protocols, SSI definitions and follow-up periods which challenge comparisons and synthesis of results across identified studies and therefore highlights a need for the veterinary community to adhere to established definitions when designing studies.

Table 7
Reported antimicrobial treatments (intervention) and surgical site infection definitions (outcome) in 19 retrospective comparative studies included in the review.

Author	Intevention	Control	Timing & duration	SSI definition
Peri-operative comparison				
Vasseur et al. (1988)	Ampicillin (693), Oxacillin (88) or Cefazolin (16)	No treatment	NR	Purulent discharge / spontaneous dehiscence and inflammation
Post-operative comparison*				
Atwood et al. (2015)	Various	No treatment	NR	Veterinary adaptation of CDC definitions
Campbell et al. (2016)	NR	No treatment	NR	Presence of inflammation or discharge around/ from the surgical site.
Carwardine et al. (2021)	Cefalexin 15–30 mg/kg	No treatment	5–10 days	Purulent drainage / organisms isolated from fluid, tissue or an implant / pain and lameness that improves with antibiotics following cytological suspicion of infection
Etter et al. (2013)		No treatment		Positive culture / drainage > 48 hours post-surgery / abscess / fistula / dehiscence
Ferrell et al. (2019)	Various	No treatment	NR	Based on CDC definitions
Fitzpatrick and Solano (2010)	Cefalexin	No treatment	14 days	Veterinary adaptation of CDC definitions
Frey et al. (2010)	Various	No treatment	NR	Purulent wound drainage / abscessation / fistulation / ≥ 3 inflammation signs or serous wound drainage or dehiscence / joint effusion / moderate to severe lameness / pain over the implants.
Gatineau et al. (2011)	Cefalexin	No treatment	10 days	Purulent drainage / abscess / wound dehiscence associated with pain and swelling together with severe lameness / positive bacterial culture. Negative culture did not preclude diagnosis of infection if the other criteria were met.
Hagen et al. (2020)	Various	No treatment	NR	Veterinary adaptation of CDC definitions
Hans et al. (2017)	Cephlaexin 22 mg/kg PO	No treatment	q8h at surgeon's discretion	
Korytárová et al. (2022)	AMC (84), various	No treatment	NR	NR
Kuan et al. (2009)	AMC 20 mg/kg or Cefalexin 30 mg/kg PO BID	No treatment	NR	Inflammation signs in the soft tissue around the site of the ostectomy or the tibialsections involved in the ostectomy or implant or both
Launcelott et al. (2019)	NR	No treatment		
Solano et al. (2015)	Various	No treatment	NR	Veterinary adaptation of CDC definitions
Yap et al. (2015)	Cefalexin 15–20 mg/kg or AMC 10–20 mg/kg PO BID	No treatment	5–10 days	Veterinary adaptation of CDC definitions
Armstrong et al. (2019)	NR	No treatment	NR	NR
Chase et al. (2019)	Not stated	No treatment	NR	Initiation of antimicrobial treatment
Winter et al. (2022)	AMC (3), Cefalexin (2)	No treatment	5–7 days	NR

AMC: Amoxicillin+clavulanic acid or potentiated amoxicillin; BID: twice daily; CDC: Center for Disease Control and Prevention; IV: Intravenous; NA: Not applicable; NR: Not reported; PO: per oral; SC: Subcutaneous;
* All treated peri-operative

Broader studies with more granular and standardized data collection and clear SSI definitions are needed for development and refinement of effective SAP guidance that optimizes patient care and minimizes risks, including development of antimicrobial resistance.

Conflict of interest statement

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Supplementary material

The published protocol is available at https://sid.erda.dk/share_redirect/HAR2r8D8mN.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.tvjl.2024.106101.

References

Ahmed, N.J., Haseeb, A., Alamer, A., Almalki, Z.S., Alahmari, A.K., Khan, A.H., 2022. Meta-analysis of clinical trials comparing cefazolin to cefuroxime, ceftriaxone, and cefamandole for surgical site infection prevention. Antibiotics 11.

Aiken, M.J., Hughes, T.K., Abercromby, R.H., Holmes, M.A., Anderson, A., A, 2015. Prospective, randomized comparison of the effect of two antimicrobial regimes on surgical site infection rate in dogs undergoing orthopedic implant surgery. Veterinary Surgery 44, 661–667.

Andrade, N., Schmiedt, C.W., Cornell, K., Radlinsky, M.A.G., Heidingsfelder, L., Clarke, K., Hurley, D.J., Hinson, W.D., 2016. Survey of intraoperative bacterial contamination in dogs undergoing elective orthopedic surgery. Veterinary Surgery 45, 214–222.

Armstrong, A.J., Bruce, M., Adams, R., Kulendra, E., Pease, T., Perry, K.L., 2019. Injuries involving the central tarsal bone in nonracing dogs: Short-term outcomes and prognostic factors. Veterinary Surgery 48, 524–536.

Atwood, C., Maxwell, M., Butler, R., Wills, R., 2015. Effects of incision closure method on infection prevalence following tibial plateau leveling osteotomy in dogs. The Canadian Veterinary Journal = Louisiana Revue Veterinaire Canadienne 56, 375–381.

Billings, L., Vasseur, P.B., Fancher, C., Miller, M., Nearenberg, D., 1990. Wound infection rates in dogs and cats after use of cotton muslin or disposable impermeable fabric as barrier material: 720 cases (1983-1989). Journal of the American Veterinary Medical Association 197, 889–892.

Branch-Elliman, W., O'Brien, W., Strymish, J., Itani, K., Wyatt, C., Gupta, K., 2019. Association of duration and type of surgical prophylaxis with antimicrobial-associated adverse events. Journal of the American Medical Association Surgery 154, 590–598.

Bratzler, D.W., Dellinger, E.P., Olsen, K.M., Perl, T.M., Auwaerter, P.G., Bolon, M.K., Fish, D.N., Napolitano, L.M., Sawyer, R.G., Slain, D., et al., 2013. Clinical practice guidelines for antimicrobial prophylaxis in surgery. American Journal of Health-System Pharmacy 70, 195–283.

Brown, D.C., Conzemius, M.G., Shofer, F., Swann, H., 1997. Epidemiologic evaluation of postoperative wound infections in dogs and cats. Journal of the American Veterinary Medical Association 210, 1302–1306.

Bruce, J., Russell, E.M., Mollison, J., Krukowski, Z.H., 2001. The quality of measurement of surgical wound infection as the basis for monitoring: A systematic review. Journal of Hospital Infection 49, 99–108.

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. Veterinary Surgery 50, 729–739.

Burgess, B.A., 2019. Prevention and surveillance of surgical infections: A review. Veterinary Surgery 48, 284–290.

Campbell, K.A., Payne, J.T., Doornink, M.T., Haggerty, J., 2016. Outcome of tibial closing wedge osteotomy in 55 cranial cruciate ligament-deficient stifles of small dogs (<15 kg). Veterinary Surgery 45, 1056–1062.

Carwardine, D., Burton, N.J., Knowles, T.G., Barthelemy, N., Parsons, K.J., 2021. Outcomes, complications and risk factors following fluoroscopically guided transcondylar screw placement for humeral intracondylar fissure %j journal of small animal practice. Journal of Small Animal Practice 8.

Castro, A.G.R., Magalhães, C.S., Sala, P.L., Borges, T.B., Zaniolo, M.M., Tramontin, R.S., Quessada, A.M., 2022. Autohemotherapy in dogs' orchiectomy. Ciência Animal 32, 17–27.

Charani, E., Ahmad, R., Rawson, T.M., Castro-Sanchez, E., Tarrant, C., Holmes, A.H., 2019. The differences in antibiotic decision-making between acute surgical and acute medical teams: An ethnographic study of culture and team dynamics. Clinical Infectious Diseases 69, 12–20.

Chase, D., Sul, R., Solano, M., Calvo, I., Joslyn, S., Farrell, M., 2019. Short- and long-term outcome after transcondylar screw placement to treat humeral intracondylar fissure in dogs. Veterinary Surgery 48, 299–308.

Chutipongvivate, P., Lampang, K.N., Punyapornwithaya, V., Thongkorn, K., 2022. Incidence of short-term complications after sterilization between pre-operative antibiotic versus pre- and post-operative antibiotic administration in female cats. Veterinary Integrative Sciences 20, 379–389.

Cockburn, E., Janovec, J., Solano, M.A., L'Eplattenier, H., 2022. Marginal excision of cutaneous mast cell tumors in dogs was not associated with a higher rate of complications or prolonged wound healing than marginal excision of soft tissue sarcomas. Journal of the American Veterinary Medical Association 260, 741–746.

Darles, E. 2012. Antibioprophylaxie en chirurgie vétérinaire: Bilan sur les données actuelles. Thesis, Doctor of Veterinary Medicine, Université Paul-Sabatier de Toulouse, France. https://oatao.univ-toulouse.fr/8624/ (Accessed 2 JAnuary, 2024.

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. Veterinary and Comparative Orthopaedics and Traumatology 14, 146–150.

ENOVAT, 2023. The european network for optimization of veterinary antimicrobial treatment. https://enovat.eu/ (Accessed 2 January, 2024).

ESGVM, 2023. European society of clinical microbiology and infectious diseases (escmid) study group for veterinary microbiology https://www.escmid.org/research-projects/study-groups/study-groups-o-z/veterinary-microbiology (Accessed 2 January, 2024).

Espinel-Rupérez, J., Martín-Ríos, M.D., Salazar, V., Baquero-Artigao, M.R., Ortiz-Díez, G., 2019. Incidence of surgical site infection in dogs undergoing soft tissue surgery: Risk factors and economic impact. Veterinary Record Open 6, e000233.

Etter, S.W., Schaeffer, D.J., Ragetly, G.R., Bennett, R.A., 2013. Effect of using triclosan-impregnated suture for incisional closure on surgical site infection and inflammation following tibial plateau leveling osteotomy in dogs. Journal of the American Veterinary Medical Association 242, 355–358.

EU, 2022. Regulation (eu) 2019/6 of the european parliament and of the council of 11 december 2018 on veterinary medicinal products and repealing directive 2001/82/ec (text with eea relevance). https://eur-lex.europa.eu/eli/reg/2019/6 (Accessed 2 January, 2024).

Ferrell, C.L., Barnhart, M.D., Herman, E., 2019. Impact of postoperative antibiotics on rates of infection and implant removal after tibial tuberosity advancement in 1,768 canine stifles. Veterinary Surgery 48, 694–699.

Fitzpatrick, N., Solano, M.A., 2010. Predictive variables for complications after tplo with stifle inspection by arthrotomy in 1000 consecutive dogs. Veterinary Surgery 39, 460–474.

Frey, E., Costin, M., Granick, J., Kornya, M., Weese, J.S., 2022. 2022 aafp/aaha antimicrobial stewardship guidelines. Journal of the American Animal Hospital Association 58, 1–5.

Frey, T.N., Hoelzler, M.G., Scavelli, T.D., Fulcher, R.P., Bastian, R.P., 2010. Risk factors for surgical site infection-inflammation in dogs undergoing surgery for rupture of the cranial cruciate ligament: 902 cases (2005-2006). Journal of the American Veterinary Medical Association 236, 88–94.

Gatineau, M., Dupuis, J., Plante, J., Moreau, M., 2011. Retrospective study of 476 tibial plateau levelling osteotomy procedures: Rate of subsequent 'pivot shift', meniscal tear and other complications. Veterinary and Comparative Orthopaedics and Traumatology 24, 333–341.

Google, 2023. Google translate. https://translate.google.ca/ (Accessed 2 January, 2024).

Hagen, C.R.M., Singh, A., Weese, J.S., Marshall, Q., Linden, A.Z., Gibson, T.W.G., 2020. Contributing factors to surgical site infection after tibial plateau leveling osteotomy: A follow-up retrospective study. Veterinary Surgery 49, 930–939.

Hans, E.C., Barnhart, M.D., Kennedy, S.C., Naber, S.J., 2017. Comparison of complications following tibial tuberosity advancement and tibial plateau levelling osteotomy in very large and giant dogs 50 kg or more in body weight. Veterinary and Comparative Orthopaedics and Traumatology 30, 299–305.

Hardefeldt, L.Y., Browning, G.F., Thursky, K., Gilkerson, J.R., Billman-Jacobe, H., Stevenson, M.A., Bailey, K.E., 2017. Antimicrobials used for surgical prophylaxis by companion animal veterinarians in australia. Veterinary Microbiology 203, 301–307.

Holmberg, D.L., 1985. The use of prophylactic penicillin in orthopedic surgery. A clinical trial. Veterinary Surgery 14, 160–165.

Ierano, C., Thursky, K., Marshall, C., Koning, S., James, R., Johnson, S., Imam, N., Worth, L.J., Peel, T., 2019. Appropriateness of surgical antimicrobial prophylaxis practices in australia. Journal of the American Medical Association Network Open 2, e1915003.

Jessen, 2018. Antimicrobial use guidelines for companion animals. https://www.ddd.dk/media/2175/assembled_final.pdf (Accessed 9 March, 2024).

Knights, C.B., Mateus, A., Baines, S.J., 2012. Current british veterinary attitudes to the use of perioperative antimicrobials in small animal surgery. The Veterinary Record 170, 646.

Korytárová, N., Kramer, S., Schnepf, A., Kreienbrock, L., Volk, H.A., 2022. Rate of surgical site and urinary tract infections in dogs after cessation of antibiotics following spinal surgery. The Veterinary Record. 2022;e2340.

Kuan, S., Smith, B., Black, A., 2009. Tibial wedge ostectomy: Complications of 300 surgical procedures. Australian Veterinary Journal 87, 438–444.

Labi, A.K., Obeng-Nkrumah, N., Dayie, N., Egyir, B., Sampane-Donkor, E., Newman, M.J., Opintan, J.A., 2021. Antimicrobial use in hospitalized patients: A multicentre point prevalence survey across seven hospitals in ghana. The Journal of Antimicrobial Chemotherapy - Antimicrobial Resistance 3, dlab087.

Launcelott, Z.A., Lustgarten, J., Sung, J., Samuels, S., Davis, S., Davis, G.J., 2019. Effects of a surgical checklist on decreasing incisional infections following foreign body removal from the gastrointestinal tract in dogs. The Canadian veterinary Journal = Louisiana Revue veterinaire canadienne 60, 67–72.

Levy Hara, G., Rojas-Cortés, R., Molina León, H.F., Dreser Mansilla, A., Alfonso Orta, I., Rizo-Amezquita, J.N., Santos Herrera, R.G., Mendoza de Ayala, S., Arce Villalobos, M., Mantilla Ponte, H., et al., 2022. Point prevalence survey of antibiotic use in hospitals in latin american countries. Journal of Antimicrobial Chemotherapy 77, 807–815.

Magill, S.S., Edwards, J.R., Beldavs, Z.G., Dumyati, G., Janelle, S.J., Kainer, M.A., Lynfield, R., Nadle, J., Neuhauser, M.M., Ray, S.M., et al., 2014. Prevalence of antimicrobial use in us acute care hospitals, may-september 2011. Journal of the American Veterinary Medical Association 312, 1438–1446.

Menz, B.D., Charani, E., Gordon, D.L., Leather, A.J.M., Moonesinghe, S.R., Phillips, C.J., 2021. Surgical antibiotic prophylaxis in an era of antibiotic resistance: Common resistant bacteria and wider considerations for practice. Infection and Drug Resistance 14, 5235–5252.

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L.A., 2015. Preferred reporting items for systematic review and meta-analysis protocols (prisma-p) 2015 statement. Systematic Reviws 4 (1).

Morioka, H., Ohge, H., Nagao, M., Kato, H., Kokado, R., Yamada, K., Yamada, T., Shimono, N., Nukui, Y., Yoshihara, S., et al., 2022. Appropriateness of surgical antimicrobial prophylaxis in japanese university hospitals. Journal of Hospital Infection 129, 189–197.

Nazarali, A., Singh, A., Moens, N.M., Gatineau, M., Sereda, C., Fowler, D., Kim, S.E., Kisiel, A., Reynolds, D., Ringwood, B.R., et al., 2015. Association between methicillin-resistant staphylococcus pseudintermedius carriage and the development of surgical site infections following tibial plateau leveling osteotomy in dogs. Journal of the American Veterinary Medical Association 247 (test suppl), 909–916.

Otero Balda, I., Fuertes-Recuero, M., Penelo Hidalgo, S., Espinel Rupérez, J., Lapostolle, B., Ayllón-Santiago, T., Ortiz-Díez, G., 2023. A spanish survey on the perioperative use of antimicrobials in small animals. Animals 13, 2475.
Ouzzani, M., Hammady, H., Fedorowicz, Z., Elmagarmid, A., 2016. Rayyan—a web and mobile app for systematic reviews. Systematic Reviws 5, 210.
Pereira, L.B., Feliciano, C.S., Siqueira, D.S., Bellissimo-Rodrigues, F., Pereira, L.R.L., 2020. Surgical antibiotic prophylaxis: Is the clinical practice based on evidence? Einstein (Sao Paulo) 18 eAO5427.
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. Veterinary Surgery 44, 653–660.
RCVS, 2023. Royal college of veterinary surgeons - knowledge ebvm toolkit 3 https://knowledge.rcvs.org.uk/document-library/ebvm-toolkit-3-introduction-to-levels-of-evidence-and-study (Accessed 2 January, 2024).
Shaikh, Q., Sarfaraz, S., Rahim, A., Hussain, A., Behram, S., Kazi, A.S., Hussain, M., Salahuddin, N., 2022. Who point prevalence survey to describe the use of antimicrobials at a tertiary care center in pakistan: A situation analysis for establishing an antimicrobial stewardship program. Antibiotics (Basel) 11, 1555.
Smith, G.C.S., Pell, J.P., 2003. Parachute use to prevent death and major trauma related to gravitational challenge: Systematic review of randomised controlled trials. British Medical Journal 327, 1459–1461.
Solano, M.A., Danielski, A., Kovach, K., Fitzpatrick, N., Farrell, M., 2015. Locking plate and screw fixation after tibial plateau leveling osteotomy reduces postoperative infection rate in dogs over 50 kg. Veterinary Surgery 44, 59–64.
Spencer, D.D., Daye, R.M., 2018. A prospective, randomized, double-blinded, placebo-controlled clinical study on postoperative antibiotherapy in 150 arthroscopy-assisted tibial plateau leveling osteotomies in dogs. Veterinary Surgery 47, E79–E87.
Stavroulaki, E.M., Suchodolski, J.S., Xenoulis, P.G., 2023. Effects of antimicrobials on the gastrointestinal microbiota of dogs and cats. The Veterinary Journal 291, 105929.
Stetter, J., Boge, G.S., Gronlund, U., Bergstrom, A., 2021. Risk factors for surgical site infection associated with clean surgical procedures in dogs. Research in Veterinary Science 136, 616–621.
SYREAF, 2023. Systematic reviews for animals & food. www.syreaf.org/protocols/ (Accessed 2 January, 2024).
Testa, M., Stillo, M., Giacomelli, S., Scoffone, S., Argentero, P.A., Farina, E.C., Zotti, C.M., 2015. Appropriate use of antimicrobial prophylaxis: An observational study in 21 surgical wards. BMC Surgery 15, 63.
Tricco, A.C., Lillie, E., Zarin, W., O'Brien, K.K., Colquhoun, H., Levac, D., Moher, D., Peters, M.D.J., Horsley, T., Weeks, L., et al., 2018. Prisma extension for scoping reviews (prisma-scr): Checklist and explanation. Annals of Internal Medicine 169, 467–473.
Turk, R., Singh, A., Weese, J.S., 2015. Prospective surgical site infection surveillance in dogs. Veterinary Surgery 44, 2–8.
Vasseur, P.B., Levy, J., Dowd, E., Eliot, J., 1988. Surgical wound infection rates in dogs and cats. Data from a teaching hospital. Veterinary Surgery 17, 60–64.
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. Journal of the American Veterinary Medical Association 187, 825–827.
Viel-Thériault, I., Agarwal, A., Bariciak, E., Le Saux, N., Thampi, N., 2022. Antimicrobial prophylaxis use in the neonatal intensive care unit: An antimicrobial stewardship target that deserves attention! American Journal of Perinatology 39, 1288–1291.
Weese, J.S., 2008. A review of post-operative infections in veterinary orthopaedic surgery. Veterinary and Comparative Orthopaedics and Traumatology 21, 99–105.
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 perioperatiye prophylactic antimicrobial treatment in dogs undergoing elective orthopedic surgery. Journal of the American Veterinary Medical Association 215, 212–216.
Winter, J., Meeson, R.L., Egan, P., Langley-Hobbs, S., Belch, A., 2022. Management of proximal metaphyseal curvilinear tibial fractures in 25 skeletally immature dogs (2009 to 2020). Journal of Small Animal Practice 63, 542–549.
Yap, F.W., Calvo, I., Smith, K.D., Parkin, T., 2015. Perioperative risk factors for surgical site infection in tibial tuberosity advancement: 224 stifles. Veterinary and Comparative Orthopaedics and Traumatology 28, 199–206.
Zarb, P., Coignard, B., Griskeviciene, J., Muller, A., Vankerckhoven, V., Weist, K., Goossens, M., Vaerenberg, S., Hopkins, S., Catry, B., et al., 2012. The european centre for disease prevention and control (ecdc) pilot point prevalence survey of healthcare-associated infections and antimicrobial use. Euro surveillance: Bulletin Europeen sur les maladies transmissibles 17, 20316.