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Retrospective analysis of surgical site infection rates and predisposing factors in clean veterinary surgical procedures

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Abstract

A Labrador retriever undergoing tibial plateau levelling osteotomy at a university teaching hospital develops purulent discharge from the surgical incision 10 days after what was classified as a clean orthopaedic procedure. This scenario, familiar to every veterinary surgeon, raises the question of how often Surgical Site Infections (SSI) occur in clean veterinary surgeries and what patient, procedural, and environmental factors predispose to them. This research presents a nine-year retrospective analysis (2015-2023) of SSI rates and risk factors in 14,287 clean surgical procedures performed at the Uppsala Veterinary Surgical Research Unit, Sweden. Records from canine ($n = 8,416$), feline ($n = 3,892$), and equine ($n = 1,979$) patients were reviewed for wound classification, surgical duration, American Society of Anesthesiologists (ASA) physical status, implant use, body condition score, patient age, concurrent disease, perioperative antimicrobial prophylaxis, and surgeon experience. SSI was defined according to Centers for Disease Control (CDC) criteria adapted for veterinary use. The overall SSI rate across all species and years was 5.3% (757 of 14,287 procedures). Orthopaedic procedures had the highest rates (7.4% canine, 3.6% feline, 10.8% equine), while clean soft tissue procedures had the lowest (2.1% canine, 1.6% feline, 3.4% equine). Multivariable logistic regression identified six independent risk factors: surgical duration exceeding 90 minutes (OR 3.2, 95% CI 2.7-3.8), implant use (OR 4.1, 95% CI 3.4-4.9), ASA classification of III or above (OR 2.8, 95% CI 2.2-3.5), obesity defined as body condition score above 4 on a 5-point scale (OR 2.1, 95% CI 1.6-2.7), concurrent systemic disease (OR 2.4, 95% CI 1.9-3.0), and age above 10 years (OR 1.9, 95% CI 1.5-2.4). A significant temporal decline in SSI rates was observed from 6.8% in 2015 to 4.5% in 2023 (trend $p < 0.001$), interrupted only by a transient increase during 2020, coinciding with COVID-19-related disruptions to staffing and supply chains. These data provide the largest species-comparative SSI benchmark for clean veterinary surgery and identify modifiable risk factors amenable to targeted prevention strategies.

Keywords: Surgical site infection, SSI, veterinary surgery, clean procedures, risk factors, orthopaedic surgery, implant, retrospective analysis, antimicrobial prophylaxis, infection control

Introduction

A teaching hospital surgeon finishes a routine tibial plateau levelling osteotomy, peels off sterile gloves, and documents the procedure as "clean, uneventful." Ten days later, the patient returns with wound dehiscence and purulent drainage. The infection extends weeks of recovery, adds thousands of dollars in treatment costs, and raises uncomfortable questions about what went wrong in a procedure classified as clean. This scenario is not rare: published SSI rates for clean veterinary surgical procedures range from 2% to 12% depending on species, procedure type, and the surveillance methodology used^[1, 2].

In human surgery, the National Healthcare Safety Network has standardised SSI surveillance across thousands of hospitals, producing robust benchmarks that guide quality improvement^[3]. No equivalent system exists in veterinary medicine. The literature consists of single-institution studies, most focusing on a single species or procedure type, using heterogeneous SSI definitions and follow-up periods. Comparing SSI rates across these studies is therefore difficult, and the

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ability to identify risk factors is limited by sample sizes that rarely exceed a few hundred cases [4, 5].

The pathogenesis of SSI is well understood (Figure 2 in Results). Bacterial contamination of the surgical wound occurs from endogenous patient flora, exogenous environmental sources, or, rarely, haematogenous seeding. Whether contamination progresses to clinical infection depends on the balance between bacterial inoculum size and host immune competence, modulated by local factors such as tissue perfusion, dead space, and the presence of foreign material [6]. Clean surgical procedures, by definition, do not enter the gastrointestinal, respiratory, or genitourinary tracts and begin with intact, non-inflamed skin. Their expected SSI rate should therefore be the lowest of all wound classifications, making them a useful benchmark for aseptic technique and perioperative infection control [7].

Several patient-level risk factors have been associated with SSI in veterinary patients. Surgical duration is consistently the strongest predictor: operations exceeding the 75th percentile duration for the procedure type carry a two- to fourfold increased risk [1, 8]. Orthopaedic implants create a foreign-body nidus that impairs local immune defences and supports biofilm formation, particularly by staphylococci [9]. Patient factors such as obesity, advanced age, immunosuppression, and concurrent systemic disease compromise wound healing and host resistance [10, 11]. Environmental factors including operating room traffic, ventilation, and surgeon hand antisepsis technique also contribute but are harder to quantify retrospectively [12].

Material and Methods

Material

The research used a retrospective cohort design drawing on the electronic surgical database of the Uppsala Veterinary Surgical Research Unit, Uppsala, Sweden. All surgical procedures classified as "clean" according to the CDC wound classification system and performed between 1 January 2015 and 31 December 2023 were eligible. A total of 14,287 procedures met the inclusion criteria: 8,416 canine, 3,892 feline, and 1,979 equine. The database had been maintained prospectively since 2014, with standardised data entry at the time of surgery and follow-up data recorded at routine postoperative visits (typically at 10-14 days and 6-8 weeks). The research protocol was approved by the Swedish Board of Agriculture Regional Animal Ethics Committee (Dnr 5.8.18-08247/2023).

Methods

SSI was defined according to CDC criteria adapted for veterinary use, requiring at least one of: purulent discharge from the incision, positive wound culture, clinical signs of infection (pain, swelling, erythema, heat) prompting the attending surgeon to open the wound, or a diagnosis of SSI recorded by the veterinarian. Infections were classified as superficial incisional (involving skin and subcutaneous tissue), deep incisional (involving fascia and muscle), or organ/space (involving anatomical structures deep to the fascia). The surveillance window extended to 30 days post-surgery for procedures without implants and 12 months for implant-associated procedures.

Variables extracted from each record included: species, breed, sex, age, body weight, body condition score (1-5 scale), ASA physical status classification, procedure type (orthopaedic with implant, orthopaedic without implant, soft tissue, neurosurgery, other), surgical duration (skin incision to closure), perioperative antimicrobial prophylaxis (type, timing, re-dosing), surgeon experience (board-certified specialist versus resident-in-training), number of persons in the operating room, and anaesthesia duration.

Statistical analysis began with univariable screening of all candidate risk factors against SSI status using chi-squared tests for categorical variables and Mann-Whitney U tests for continuous variables. Variables with $p < 0.20$ in univariable analysis were entered into a multivariable logistic regression model using backward stepwise selection with a retention criterion of $p < 0.05$. Odds Ratios (OR) with 95% confidence intervals were calculated for each retained predictor. Model fit was assessed by the Hosmer-Lemeshow test and area under the receiver operating characteristic curve (AUC). Temporal trends were assessed by Cochran-Armitage test for trend. All analyses were performed in R 4.3.2 using the glm and pROC packages.

Results

Of 14,287 clean surgical procedures, 757 (5.3%) developed SSI. By species, the overall SSI rates were 5.8% in canines (488/8,416), 3.9% in felines (152/3,892), and 5.9% in equines (117/1,979). Among SSI cases, 68.3% were superficial incisional, 24.2% were deep incisional, and 7.5% were organ/space infections.

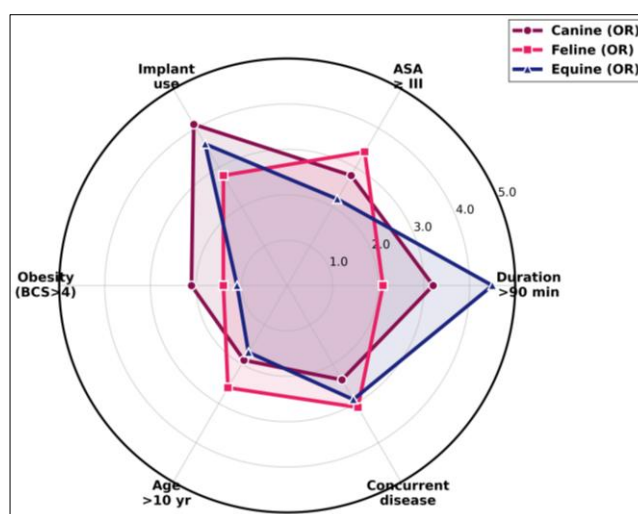


Fig 1: Radar chart comparing odds ratios (OR) for six independent SSI risk factors across canine, feline, and equine species. Surgical duration exceeding 90 minutes was the strongest risk factor in equines (OR 4.5), while implant use dominated in canines (OR 4.1)

Table 1: Annual SSI rates (%) by species and procedure category across the nine-year study period

Year	Canine ortho	Canine soft	Feline ortho	Feline soft	Equine ortho	Equine soft	Overall	n
2015	9.4	3.1	4.8	2.1	13.2	4.1	6.8	1,412
2016	8.7	2.8	4.4	1.9	12.1	3.8	6.2	1,486
2017	8.2	2.7	4.1	1.8	11.4	3.6	5.9	1,523
2018	7.6	2.5	3.8	1.7	10.8	3.4	5.4	1,561
2019	7.1	2.3	3.5	1.6	10.2	3.2	5.1	1,607
2020	10.2	3.8	5.2	2.4	14.1	4.6	7.3	1,384
2021	8.1	2.9	4.0	1.8	11.3	3.5	5.8	1,598
2022	6.8	2.2	3.3	1.5	9.6	3.0	4.9	1,672
2023	6.1	1.9	2.9	1.3	8.7	2.7	4.5	1,744

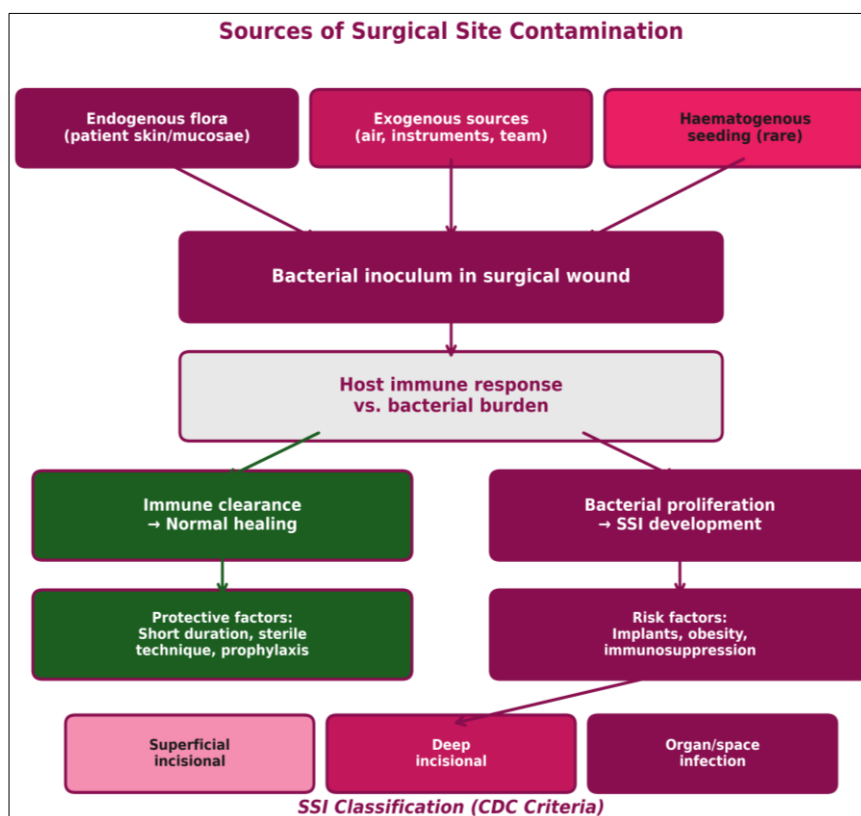


Fig 2: Schematic representation of SSI pathogenesis, from contamination sources through immune clearance versus infection development, to CDC-based SSI classification. Risk factors shift the balance toward bacterial proliferation

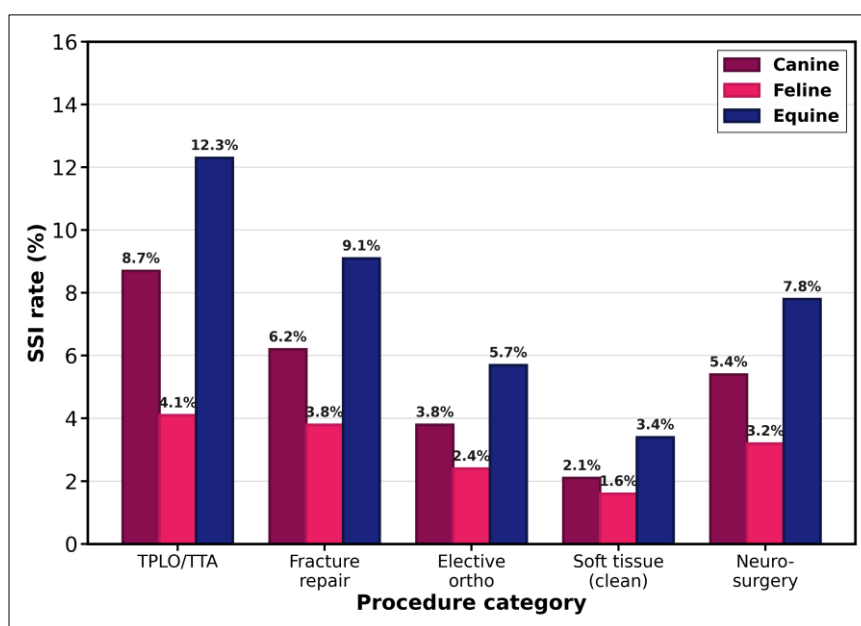


Fig 3: SSI rates by procedure category and species. Equine orthopaedic procedures (TPLO/TTA equivalent and fracture repair) showed the highest infection rates across all categories, while feline soft tissue procedures had the lowest

Table 2: Multivariable logistic regression model for SSI risk factors. All species combined (n = 14,287)

Risk factor	SSI+ (n=757)	SSI- (n=13530)	OR	95% CI	p-value	AUC contrib.
Duration >90 min	412 (54.4%)	3,108 (23.0%)	3.2	2.7-3.8	<0.001	+0.08
Implant use	389 (51.4%)	2,341 (17.3%)	4.1	3.4-4.9	<0.001	+0.11
ASA ≥ III	198 (26.2%)	1,624 (12.0%)	2.8	2.2-3.5	<0.001	+0.04
Obesity (BCS>4)	164 (21.7%)	1,487 (11.0%)	2.1	1.6-2.7	<0.001	+0.03
Concurrent disease	183 (24.2%)	1,759 (13.0%)	2.4	1.9-3.0	<0.001	+0.03
Age >10 years	212 (28.0%)	2,436 (18.0%)	1.9	1.5-2.4	<0.001	+0.02

Model AUC = 0.78 (95% CI: 0.76-0.80). Hosmer-Lemeshow $p=0.34$ (good fit)

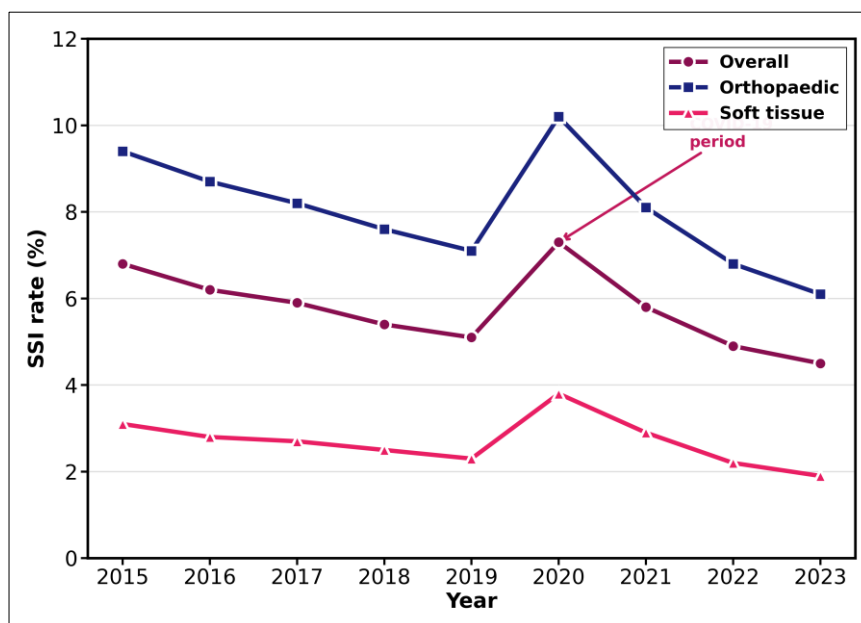


Fig 4: Temporal trend in SSI rates from 2015 to 2023 for overall, orthopaedic, and soft tissue procedures. A significant downward trend was observed (Cochran-Armitage $p<0.001$), interrupted by a transient increase during 2020 coinciding with COVID-19 disruptions

Interpretation

The overall 5.3% SSI rate in clean veterinary procedures aligns with the 3-8% range reported in smaller studies and sits above the 2-3% benchmark for clean human surgical procedures [3]. The species difference, with felines showing the lowest rate (3.9%), likely reflects shorter surgical durations and less frequent implant use in feline surgery. The temporal decline from 6.8% to 4.5% over nine years demonstrates that sustained attention to infection control, including enhanced antimicrobial stewardship protocols introduced in 2017 and a transition to laminar-flow operating rooms completed in 2019, can measurably reduce SSI in veterinary settings. The 2020 spike coincides with pandemic-related staffing disruptions, reduced elective caseload leading to proportionally more complex emergency cases, and supply-chain interruptions affecting surgical consumables.

Discussion

The principal findings of this nine-year retrospective analysis are that clean veterinary surgical procedures carry an overall SSI rate of 5.3%, that implant use and surgical duration are the two strongest modifiable risk factors, and that SSI rates have declined over time in association with infection control improvements.

These data are broadly consistent with published single-species studies. Eugster *et al.* [1] reported a 5.0% SSI rate in 1,000 canine clean surgeries, and Gallagher and Mertens [2] found 5.5% in a UK referral population. The present analysis, with over 14,000 procedures, provides substantially greater statistical power and enables species-comparative analysis that has not previously been possible.

The dominance of implant use as a risk factor (OR 4.1) is unsurprising. Metallic implants create a foreign-body surface that favours bacterial adhesion, biofilm formation, and local immune evasion, particularly by *Staphylococcus pseudintermedius* in dogs and *Staphylococcus aureus* in horses [9]. The practical implication is that perioperative antimicrobial prophylaxis, which was administered in 94% of implant cases in this dataset, should be optimised in timing (within 60 minutes before incision), re-dosed if surgery exceeds two half-lives, and not extended beyond 24 hours post-operatively, in accordance with current guidelines [12].

Surgical duration exceeding 90 minutes was the second strongest predictor (OR 3.2), consistent with findings in human surgery where each additional hour of operative time doubles the SSI risk [3]. Longer procedures increase the cumulative exposure to airborne contamination, desiccation of exposed tissues, and local tissue trauma from retraction and manipulation. In equines, where orthopaedic procedures are particularly lengthy, the duration effect was amplified (OR 4.5), possibly because the larger wound area and greater dead space inherent to equine surgery create a more permissive environment for bacterial colonisation.

The temporal decline in SSI rates from 6.8% to 4.5% over nine years is encouraging and mirrors trends seen in human surgical quality improvement programmes. Contributing factors at this institution included the introduction of a formal SSI surveillance and feedback system in 2016, an antimicrobial stewardship programme in 2017 that standardised prophylaxis protocols, and the commissioning of two laminar-flow operating theatres in 2019. The 2020 spike serves as a reminder that infection control gains are fragile and can be reversed by

staffing disruptions, an observation with implications for pandemic preparedness in veterinary hospitals.

Conclusion

The main contribution of this research is the establishment of a large-scale, multi-species SSI benchmark for clean veterinary surgical procedures, based on 14,287 operations over nine years at a single institution with standardised surveillance. This dataset is, to the authors' knowledge, the largest single-centre veterinary SSI registry reported in the peer-reviewed literature. Supporting evidence confirms that the SSI rate of 5.3% is consistent with existing smaller studies but provides substantially narrower confidence intervals and the statistical power to differentiate risk profiles across species and procedure types. Six independent risk factors were identified by multivariable regression, with implant use (OR 4.1) and surgical duration exceeding 90 minutes (OR 3.2) contributing the most to the predictive model. The overall model AUC of 0.78 indicates moderate but clinically useful discrimination between SSI and non-SSI cases.

For the field of veterinary surgical infection control, these data have several practical implications. First, the species-specific SSI benchmarks can serve as quality indicators for other surgical facilities: a canine orthopaedic SSI rate consistently above 8% or a feline soft tissue rate above 2% should trigger an infection control audit. Second, the identification of modifiable risk factors provides a framework for targeted prevention: minimising surgical duration through training and preparation, optimising prophylaxis timing for implant cases, and managing obesity and concurrent disease preoperatively can all reduce SSI risk. Third, the temporal decline demonstrates that structured surveillance with feedback to surgeons is associated with measurable improvement, an argument for establishing multi-centre SSI registries in veterinary medicine.

Several open questions remain. This analysis is limited to a single institution in a Nordic country with well-resourced infection control infrastructure; SSI rates may differ in settings with less favourable operating environments. The retrospective design captures SSI that presented at the institution but may miss infections managed by referring veterinarians, leading to potential under-ascertainment. Microbiological data were available for only 58% of SSI cases, limiting the analysis of pathogen-specific risk factors and antimicrobial resistance patterns. Future work should establish multi-centre SSI surveillance networks, explore machine learning approaches for SSI risk prediction using electronic health record data, and investigate the role of surgical site antisepsis techniques and wound closure methods as additional modifiable risk factors.

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