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Incidence and risk factors of surgical site infection in dogs undergoing laparoscopy ovariectomy. Multicentric prospective cohort study

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ABSTRACT

Canine laparoscopic ovariectomy has become more popular due to several advantages including smaller incisions and faster recovery. However, surgical site infections (SSIs) remain a common complication that increases morbidity and mortality. The aim of this study was to describe the incidence of SSI and identify the factors associated with development of SSI in dogs undergoing laparoscopic ovariectomy. A multicentre, prospective cohort study was performed, including 208 female dogs undergoing surgery at seven veterinary hospitals in Spain between January 2022 and September 2023. SSI was diagnosed according to Centers for Disease Control and Prevention (CDC) criteria, with active surveillance consisting of clinical evaluations on postoperative days 5–7 and 10–12, and follow-up telephone conversation at 30 days. SSIs were identified in 15 dogs (7.2 %) of which 12 were classified as superficial and 3 as deep infections. Duration of Surgery ($P < 0.001$) and Elizabethan collar ($P = 0.003$) were identified as risk factors of SSI. The incidence of SSI was identified in 7.2 % (IC 95 %: 4.1 %-11.6 %) of dogs and it was associated with surgical time exceeding 46 min and improper use of the Elizabethan collar. Prospective, standardised studies should test whether collar use and shorter surgical time reduce SSI after laparoscopy ovariectomy. Therefore, shorter surgical times and correct use of buster collar could reduce the incidence of SSI.

Introduction

Laparoscopic spaying in dogs has gained increasing popularity over the past 15 years (Buote, 2022; Monnet and Twedt, 2003). Compared to conventional open surgery, laparoscopy offer several advantages including smaller incisions, lower inflammation, reduced trauma and bleeding, faster return to activity, shorter hospital stay, and reduced postoperative complications (Culp et al., 2009; Del Romero et al., 2020; Devitt et al., 2005; Hancock et al., 2005; Lee & Kim, 2014). Despite these advantages, several specific complications have also been described including; related to surgical access to the abdominal cavity, bleeding associated with pedicle ligation, creation of subcutaneous emphysema or formation of adhesions to the abdominal wall (Case et al., 2011; Culp et al., 2009; Niranjana et al., 2013; Nylund et al., 2017; Shariati et al., 2014). Besides, selective T-cell dysfunction in uterine and other mucosal tissues may compromise early host–pathogen control and delay wound

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repair at trocar sites, providing a plausible mechanism for increased SSI susceptibility after laparoscopy ovariectomy (Kang et al., 2024). Therefore, the immune microenvironment strongly influences tissue healing (Wang et al., 2024).

Surgical site infections (SSIs) is a common complication of both open and laparoscopic procedures and results in increased morbidity and mortality, prolonged hospital stays, increased healthcare costs and adverse effects on the owners' emotional state (Beal et al., 2000; Brown et al., 1997; Espinel-Rupérez et al., 2019; Eugster et al., 2004; Frey et al., 2010; Nicholson et al., 2002; Stetter et al., 2021; Turk et al., 2014; Vasseur et al., 1988). Selective T-cell dysfunction in uterine and other mucosal tissues may compromise early host–pathogen control and delay wound repair at surgical sites, providing a plausible mechanism for increased SSI susceptibility after laparoscopy ovariectomy (Kang et al., 2024). In addition, metabolic dysregulation of ovarian pathways may modulate peri-operative inflammatory and reparative signalling, potentially shaping port-site healing after laparoscopy ovariectomy (Ruan et al., 2024). Systemic stress and heat-related tissue inflammation have also been linked to impaired wound repair (Gao et al., 2022). The incidence of SSI in open spay ranges from 2.7 % to 9.5 % (Berzon, 1979; Burrow et al., 2005; Dorn and Swist, 1977; Mayhew et al., 2012) and in laparoscopic spay ranges from 1 % to 15.9 %, however, these studies did not follow the current CDC recommendation for diagnosis and classification of SSI (Binder et al., 2018; CharlesworthSanchez,2019; Corriveau et al., 2017; Pope and Knowles, 2014). A retrospective study involving dogs and cats compared SSI between multiple clean or clean contaminate procedures performed minimally invasive or by open surgery and reported an incidence of 1.7 % and 5.5 %, respectively (Mayhew et al., 2012). However, confounding factors such as differences in surgery time and preoperative preparation were also identified in this study (Mayhew et al., 2012). Other risk factors of SSI described for clean procedures include surgical and anaesthetic time and the presence of concomitant endocrine disease (Beal et al., 2000; Nicholson et al., 2002; Stetter et al., 2021). Endocrine comorbidities (e.g., diabetes mellitus, hyperadrenocorticism) may plausibly increase SSI susceptibility after laparoscopy ovariectomy by compromising local immune control and early wound repair, consistent with selective T-cell dysfunction in uterine/mucosal tissues (Kang et al., 2024). In addition, metabolic dysregulation of ovarian pathways may modulate peri-operative inflammatory and reparative signalling, potentially shaping port-site healing (Ruan et al., 2024).

Prospective multicentre laparoscopy ovariectomy cohorts using CDC-based SSI definitions with active 30-day surveillance are scarce, and evaluations of modifiable factors are rarely standardised. We therefore conducted a multicentre prospective study to estimate SSI incidence after laparoscopy ovariectomy and to assess candidate modifiable risk factors under standardised surveillance. Therefore, the objectives of this study were (1) to describe the incidence of SSI in dogs undergoing laparoscopy ovariectomy and (2) to identify possible risk factors associated with SSI. We hypothesized that (1) the incidence of SSI following laparoscopy sterilization would be similar than following open clean surgical procedures and (2) the risk factors would be similar to previous studies that involves clean procedures in veterinary medicine such us longer operative time and absent Elizabethan-collar use.

Materials and methods

Study design and eligibility criteria

A prospective multicentric cohort study was performed. Female dogs older than 5-month-old and weighted more than 2 kg that underwent laparoscopic spay between January 2022 and September 2023 at seven Spanish veterinary hospitals were included in the study. Patients were excluded if they were diagnosed with an underlying pathology, had any abnormalities on physical examination, classified > 1 based on the American Society of Anaesthesiologists (ASA) classification, receiving any medical treatment, pregnant or lactating, in oestrus, had a recent (less than one year) history of abdominal surgery or required an additional surgical procedure. Aggressive patients, those with incomplete record or follow-up less than 30 days were also excluded.

An estimated sample size of 214 patients was calculated for an infection rate of 5.0 % based on previous studies including open clean procedures (Stetter et al., 2021). The established precision was $\pm$ 3 % age units and a confidence level of 95 %, with an expected replacement rate of 5 %. The study was approved by the Institutional Ethics Committee (reference number 29/2021; 21 January 2022) and all owners consented to participate in the study prior to the inclusion.

Procedure

All patients underwent complete preoperative physical examination. Preoperative haematology and serum biochemistry were recommended to all the patients. Similar anaesthetic protocol was used in all the patients with minor modifications based on the patient's characteristics and the anaesthesiologist's preference. Use of peri- and/or postoperative antibiotics was based on surgeon's preference. Patients were clipped from the xiphoid to the pubis in the induction room under premedication or anaesthetic induction. After induction, then the patient was moved to the operating room, and the surgical site was finally aseptically prepared using either chlorhexidine alone or interspersed with alcohol just before draping (Evans et al., 2009). All patients were placed in dorsal recumbency for the intervention. A previously described standard 2-port or 3-port midline technique was performed based on surgeon's preference (Dupré et al., 2009; Monnet & Twedt, 2003). Abdominal access was achieved using Veress needle technique or a modified Hasson technique (Bianchi et al., 2021). The abdomen was insufflated with carbon dioxide (CO_2) to a maximum pressure of 12 mmHg and maximum flow of 2 l/min, using a pressure-regulating mechanical insufflator. Cutaneous portal incisions were created using a number 15 scalpel blade. Trocar size used during the procedure include 5 mm and/or 10 mm. Bipolar vessel sealing device (Ligasure®; Medtronic) was used in all procedures for haemostasia and tissue transection. Standard two layers closure, muscle and skin, was performed. All dogs were discharged the day of surgery. Postoperative prescription of non-steroidal anti-inflammatory drugs (NSAIDs) depended on the surgeon's preference, although all patient received it. Owners were instructed about the postoperative wound care, use of Elizabethan collar and how to recognize common complications.

Data collection

Data were prospectively collected in an individual recording sheet from the medical records and during the procedure, hospital stay and follow-ups. Independent variables were classified as patient-related variable, surgical variables, and post-operative variables. Patient-related variables included signalment, institution, weight, body condition (9 points scale according to the World Small Animal Veterinary Association, Global Nutrition Committee; WSAVA, 2024), physical examination, haematology and serum biochemistry parameters. Surgical variables included daytime of the surgical procedure (morning or evening), surgeon's experience in laparoscopic surgery was classified following previous description (Pope and Knowles, 2014) as low experience (learning curve); less than 80 laparoscopic ovariectomies performed, moderate experience; 80–160 procedures performed, and high experience; more than 160 laparoscopic ovariectomies performed, intervention number of the day, clipping performed under pre-medication or after anaesthesia induction, number of stuff present in the operating room, type of surgical scrub of staff and patient, type of surgical drapes, technique of entry into the abdomen (Veress needle or modified Hasson technique), number of incisions, length of incisions (cm), diameter of ports used, local anaesthetics (splash block technique or direct on the ovarian pedicles), hypotension (mean arterial pressure

[MAP] < 60 mmHg [Turk et al., 2014]) hypothermia (body temperature < 36.5°C; [Brodeur et al., 2017]), use of active body warming method during anaesthesia (a warming blanket or warm air system), anaesthetic and surgical time (minutes), skin suture pattern, administration of perioperative antibiotics (preoperative, intraoperative and post-operative) and presence of intraoperative complications (classified according to (Follette et al., 2020) criteria) classified as grade 1 or mild complication (any deviation from the ideal operative course without the need for any additional treatment or intervention), grade 2 or moderate complication (requires pharmacologic treatment with drugs other than those allowed for minor complication) and grade 3 or severe complication (require reoperation as well as complications resulting in failure of one or more organ systems). Postsurgical variables included the use of Elizabethan collar (classified as appropriate use if it was used continuously throughout the postoperative period and as inappropriate use if it was not recommended or used intermittently during the postoperative period), and postoperative complications other than SSI (classified according to Follette et al. 2020 criteria).

Definition of SSI and SSI surveillance

Diagnosed of SSI was performed following the criteria of the Centers for Disease Control and Prevention (CDC) and classified as superficial, deep, or organ/space (Horan et al., 1992). Bacteriological culture and analysis were recommended in all the cases with suspected SSI.

An active surveillance system was used. Patients were checked twice by trained veterinary surgeons at the centre where the intervention was performed, between postoperative days 5–7 and between postoperative days 10–12. A final telephone follow-up was performed 30 days after surgery. Treatment of the SSI was decided based on the surgeon's preference.

Statistical analysis

Qualitative variables are described by their frequency distribution. Continuous variables were tested for normality using the Kormogorov-Smirnov normality test and the Shapiro-Wilk test. Normally and non-normally distributed continuous data are presented as mean and standard deviation (SD) and median and interquartile range (25th percentile-75th percentile), respectively. Incidence of SSI per 100 surgical procedures was calculated using the formula: (number of cases of SSI / total number of surgical procedures) * 100. Results are expressed as percentages with 95 % confidence intervals (CI) calculated using the exact binomial method.

Univariate logistic regression analysis was used to assess the association between the independent variables and the risk of SSI. To simplify the statistical analysis, the quantitative independent variables were divided into two groups, either using the median as the cut-off point (as the duration of surgery or anaesthesia) or previous published cut-off points. A multivariate logistic regression model was constructed using the forward stepwise method for variables with p-values < 0.100 and/or clinically relevant. The estimated effects and their 95 % confidence intervals are expressed as odds ratios (ORs) (Harrell, 2015; Steyerberg et al., 2001). The goodness-of-fit of the final model was assessed using the Hosmer-Lemeshow test. Discriminatory ability was assessed using receiver operating characteristic (ROC) curves and results are presented as area under the curve (AUC) with 95 % confidence intervals and associated p-values. Internal validation of the model was performed using bootstrap with a sample size of 100 and a difference of 0.03. In all cases, results were considered statistically significant if the p-value was < 0.050. Statistical analysis was performed using SPSS software for Windows, version 18.0, and Stata 13.0.

Results

Descriptive statistics

Two hundred fourteen dogs meet the initial inclusion criteria. However, five dogs were excluded due to lost follow-up. Therefore, 208 patients/interventions were included in the study.

This study included seven veterinary centres, all of which employed veterinary surgeons with an extensive experience in laparoscopic surgery. No statistically significant associations were found between the centres and the risk of developing ISQ (see supplementary material). Patient median age was 1.5 (IQR: 1.1–2.3) years and median bodyweight was 12.9 (IQR: 7.1–24.7) kg with a median body condition of 5 (IQR: 5.0–5.0). Most common breeds included crossbreed (31.3 %), Border Collie (6.7 %) and Labrador Retriever (7.2 %). Preoperative physical examination was normal in all patients. Haematology and serum biochemistry were performed in 139 (66.8 %) patients and were within the established reference ranges in all cases.

Surgeries were routinely performed in the morning in 183 (88.0 %) cases and in the afternoon in 25 (12.0 %) cases. Procedures were classified as the first, second, third, fourth and fifth intervention of the day in 51.9 %, 29.3 %, 11.5 %, 5.3 % and 1.9 % respectively. Regarding the experience of the surgeons, 65 (31.3 %) surgeries were performed by low-experience surgeons, 24 (11.5 %) by moderate-experience surgeons and 119 (57.2 %) by high-experience surgeons. Clipping was performed in 89 (42.8 %) patients under pre-medication and in 119 (57.2 %) patients after induction of anaesthesia. The median number of persons present in the operating theatre was 4 (IQR 3–4), with a minimum of 3 and a maximum of 14 persons. In 194 (93.3 %) patients, 70° alcohol was used in combination with 1 % chlorhexidine for surgical site preparation, and in 14 (6.7 %) patients only chlorhexidine soap (1 %) was used. For all procedures, surgeons used chlorhexidine digluconate 40 mg/ml (Hibiscrub®) as a hand wash without brush in 136 (65.4 %) procedures and with brush in 72 (34.6 %) procedures. In addition, surgeons used hydroalcoholic gel (Sterillium®) in 118 (56.7 %) operations. Disposable drapes were used in 184 procedures (88.5 %) and reusable drapes in 24 (11.5 %) procedures. The abdominal entry technique was the modified Hasson technique in 170 (81.7 %) patients and the Veress needle in 38 (18.3 %) patients (Table 1).

Two incisions (craneal and sub-umbilical) were made in 28.8 % of the procedures and three incisions (cranial, sub-umbilical and caudal) were made in 71.2 % of the procedures. Minilap® forceps were used in 126 (60.6 %) of the procedures. Sutures or hooks placed outside the abdominal wall to secure the ovary were used in 60 (28.8 %) procedures. For the cranial incision, a 5 mm trocar was used in 81.7 % of operations and a 10 mm trocar in 18.3 %. For the subumbilical incision, a 5 mm trocar was used in 95.7 % of operations and a 10 mm trocar in 9 (4.3 %) patients. Finally, for procedures using the three-incision technique, a third 5 mm trocar was used in 10.6 % of cases. The mean length of cranial and subumbilical incisions were 1.4 cm (SD: 0.3; range between 0.7 and a 2.5 cm) and 1.3 cm (SD: 0.4; range between 0.7 and 3.8 cm), respectively. Of the 148 patients who underwent the third incision, the caudal incision, a 5 mm trocar was used in 22 patients and minilap® forceps in 126 patients. The mean length of the caudal incision was 0.4 cm (SD 0.3; range between 0.2 and 2.0 cm) (Table 1).

In 11 (5.3 %) patients, bupivacaine was administered subcutaneously in the area of the surgical incisions just before the start of surgery. Local anaesthetics were given in the abdomen in 70 (33.7 %) patients. Of these, 26 (12.5 %) patients received bupivacaine in the pedicles, 35 patients (16.8 %) received bupivacaine in the abdomen using the splash block technique, and 9 (4.3 %) patients received lidocaine in the pedicles. Blood pressure was recorded during surgery in 152 patients (73.1 %) of the 208. Hypotension was noted in 21 of the 152 (12.5 %) patients, all were successfully treated with medical treatment. Intraoperative temperature was monitored in 181 patients and included mild or moderate hypothermia in 21 (10.1 %). All patients with hypothermia

Table 1
General, surgical and postsurgical variables.

General variables		
Variable	N	%
Age (years)	1.5†	1.1–2.3††
Weight (kg)	12.9†	7.1–24.7††
Body Score Condition (1/9)	5†	5.0–5.0†
Surgical variables		
Variable	N	%
Time of the day that surgery was performed		
Morning	183	88.0
Afternoon	25	12.0
Experience of the surgeons		
Little (< 80 surgeries)	65	31.3
Medium (between 80 and 160 surgeries)	24	11.5
Great (> 80 surgeries)	119	57.2
Number of people in the operating theatre	4†	3–4††
Order in which the procedures were performed		
First shift	108	51.9
Second shift	61	29.3
Third shift	24	11.6
Fourth shift	11	5.3
Fifth shift	4	1.9
Clipping		
Before induction	89	42.8
After induction	119	57.2
Patient́s surgical scrub		
Alcohol 70° combined with chlorhexidine 1 %.	194	93.3
Chlorhexidine 1 %.	14	6.7
Staffs scrub use of brush		
Yes	72	34.6
No	136	65.4
Staffs scrub use of hydroalcoholic gel		
Yes	118	56.7
No	90	43.3
Disposable drapes		
Yes	184	88.5
No	24	11.5
The abdominal entry technique		
Veress	170	81.7
Hasson	38	18.3
Number of surgical incisions		
2	60	28.8
3	148	71.2
Use of Minilap® forceps		
Yes	82	39.4
No	126	60.6
Use of ovarian hook/suture		
Yes	60	28.8
No	158	71.2
Size of trocar used in cranial incision		
5 mm	170	81.7
10 mm	38	18.3
Size of the trocar used in sub-umbilical incision		
5 mm	199	95.7
10 mm	9	4.3
Size of the trocar used in the caudal incision		
No used	186	89.4
5 mm	22	10.6
Length of cranial incision	1,4*	0.3**
Length of the sub-umbilical incision	1,3*	0.4**
Length of the caudal incision	0,4*	0.3**
Use of bupivacaine in the surgical incision		
Yes	11	5.3
No	197	94.7
Use of locoregional analgesia techniques in the abdomen		
No	138	66.3
Yes	70	33.7
Hypotension		
Yes	21	12.5
No	131	87.5
Hypothermia		
Yes	21	10.1
No	160	89.9
Duration of surgery	46,4*	14.3**
Duration of anaesthesia	72,5*	22.3**
Suture pattern used for skin closure		
Simple stitches	14	6.7
Intradermal	194	93.3
Use of tissue adhesive		
Yes	127	61.1
No	81	38,0
Preoperative antimicrobials		
Yes	124	59.6
No	84	40.4
Postoperative antimicrobials		
Yes	48	23.1
No	160	76.9
Presence of intraoperative complications		
Yes	14	6.7
No	194	93.3
Instrument-related complications		
Yes	11	5.2
No	197	94.8
More than two unsuccessful attempts to enter the peritoneal cavity		
Yes	2	1,0
No	206	99,0
Spleen laceration		
Yes	1	0.5
No	207	99.5
Postsurgical variables		
Variable	N	%
Use of Elizabethan Collar		
Yes	36	17.3
No	172	82.7
Surgical site infection		
Variable	N	%
Presence of SSI		
Yes	15	7.2
No	193	92.8
Typo of ISQ		
ISQ superficial	12	80,0
ISQ deep	3	20,0
ISQ organ/space	0	0,0

* Mean ** SD
† Median †† IQR

were successfully treated using a warming blanket in 185 (88.9 %) patients and a warm air system in 23 (11.1 %) patients. Mean (SD) surgical and anaesthetic time was 46.4 (14.3) minutes and 72.5 (22.3) minutes, respectively. An intradermal pattern was used to close the skin in 194 (93.3 %) procedures and simple sutures in 14 procedures (6.7 %). In addition, tissue adhesive was also used in 127 (61.1 %) procedures (Table 1).

Perioperative antimicrobials were administered intravenous (cefazolin) or subcutaneous (amoxicillin-clavulanic), in 40.4 %. Oral antimicrobials (amoxicillin-clavulanate) were administered in the postoperative period in 160 patients (76.9 %) for a duration of seven days. Intraoperative complications were encountered in 14 (6.7 %) patients, all of them classified as grade I. Instrument-related complications were observed in 11 (5.2 %) procedures, including breakage of the laparoscopic forceps during removal of the ovary resulting in the ovary falling out, rupture of the vessel seal tip and insufflator malfunction (incorrect insufflation). In two (1 %) cases, more than two unsuccessful attempts to enter the peritoneal cavity with the Veress needle were recorded. A laceration of the spleen was reported in one patient resulting in minor bleeding which resolved with local pressure using a swab grasped with forceps. No conversion to open surgery was required in any patient (Table 1). All the patients were discharged the same day of the surgical intervention with anti-inflammatory medication for 3–5 days.

The Elizabethan Collar was correctly used throughout the postoperative period in 36 (17.3 %) patients and incorrectly (omitted or discontinued use) in 172 (82.7 %) patients. Postoperative complications (including SSI) were encountered in 18 (8.7 %) patients. Apart from SSIs, three (16.7 %) of these 18 patients experienced a Grade I postoperative complication, including subcutaneous emphysema (n = 1), haematoma (n = 1) and swelling (n = 1).

Surgical site infection

During the study period, SSI was diagnosed in 15 patients. Therefore, the calculated incidence of SSI was 7.2 % (IC 95 %: 4.1 %-11.6 %). Of those, 12 (80 %) SSI were classified as superficial and 3 (20 %) as deep SSIs. No organ/space infections were diagnosed (Table 1). All SSIs were diagnosed at the first post-surgical check-up, except for one diagnosed 21 days post-surgery.

Bacteriological cultures were performed in two of the 15 patients in which SSI was diagnosed and were positive in both cases. A *Staphylococcus pseudintermedius* and *Staphylococcus aureus* were isolated. The antibiogram did not show a multidrug-resistant pattern in any of the isolated strains.

Superficial wound flush with diluted chlorhexidine (1 %) was recommended twice daily for 10 days. All patients with SSI were followed up at least once more at the institution where the intervention was performed. In 6 of the 15 patients were prescribed with prophylactic antimicrobials for 7 days. In 12 of the 15 patients, the previously prescribed anti-inflammatory treatment was extended for at least another 7 days. All the SSI resolved following the prescribed treatment.

Univariate and multivariate analysis

There were no statistically significant associations between the general variables (age, weight or body condition) and the risk of developing SSI (Supplementary data).

A statistically and clinically relevant trend was observed between the risk of developing an SSI and the duration of anaesthesia at or above the median (73.0 min) (OR 3.0; 95 %CI 0.9–9.6; p = 0.071), and a significant association with the duration of surgery at or above the median (46 min) (OR 6.7; 95 %CI 1.8–24.6; p = 0.023). Other variables such as intraoperative complication of more than two failed abdominal entries (OR 13.7; 95 %CI 0.8–23.1; p = 0.069), and size of trocar for subumbilical incision (OR 4.1; 95 %CI 0.8–21.7; p = 0.098) had no statistically significant associations with the risk of developing SSI although also showed a statistical trend. The use of the Elizabethan collar was not found to make a significant difference in the univariate statistical study, although the magnitude of the effect was clinically relevant, so it was included in the multivariate analysis (Supplementary data).

These variables were included in the multivariate analysis, and the duration of surgery and Elizabethan collar retained in the final multivariate model. An association was observed between duration of surgery longer than 46 min (OR 6.5; 95 % CI 0.8–52.6; p = 0.003) and the non-use of the Elizabethan Collar (OR 9.1; 95 % CI 2.4–33.9; p = <0.001) with the risk of developing SSI (Table 2). The Hosmer and Lemeshow goodness of fit test result was not statistically significant (p = 0.981). The AUC was 0.760 (95 % CI 0.634–0.885; p = 0.001).

Discussion

In this study, we identified (1) an incidence of SSI in female dogs undergoing laparoscopic ovariectomy of 7.2 % (IC 95 %: 4.1 %-11.6 %), and (2) surgery time and Elizabethan collar were risk factors associated with the development of SSI.

The incidence described in the current study is slightly higher than the incidence described in a previous prospective (Stetter et al., 2021) and retrospective (Beal et al., 2000; Nicholson et al., 2002;) studies of open clean surgery, ranging from 4.8 % to 5.9 %. Additionally, it is also higher than the incidence described in a prospective laparoscopic study (1.7 %) that included different laparoscopic procedures (Mayhew et al., 2012). Therefore, we rejected our initial hypothesis. Stetter et al. (2021) reported a slightly lower incidence of infection (5.5 %) than in the current study. This small difference may be because almost half of the patients were not followed up in the clinic by a veterinarian and that some patients were followed up by telephone during the 30-day postoperative period (Stetter et al., 2021). The possible discrepancy in SSI rates between the current study and Mayhew (2012), could be due to the criteria used to identify SSIs, as the latter is based on the presence of purulent discharge from the incision, which could underestimate SSIs compared to the current study, which follows the CDC criteria (Berríos-Torres et al., 2017; Horan et al., 1992). In the present study all patients were actively followed-up in hospital by veterinarians, which might have improved the detection rate, as previously described (Stetter et al., 2021).

The incidence described in the current study is within the range of previous studies in laparoscopy ovariectomy ranging from 1.3 % to 3.2 % (CharlesworthSanchez,2019; Corriveau et al., 2017) and slightly lower compared with others ranging from 12.9 % to 14 % (Binder et al., 2018; Pope and Knowles, 2014). A retrospective study that followed the CDC criteria for SSI description described a SSI incidence of 5.6 % for open surgery compared with 3.2 % for laparoscopic ovariectomy (CharlesworthSanchez,2019). However, patients of that study were only followed-up for 14 days. Another retrospective study including 278 patients, 131 (47.0 %) laparoscopic ovariectomy and 147 (54.0 %) laparoscopic-assisted ovariohysterectomy, described postoperative complications in 15 patients (6.7 %), although the incidence of infection was only 1.3 % (3 patients) (Corriveau et al., 2017). In addition, a retrospective study of 614 dogs that underwent laparoscopic ovariectomy reported an incidence of infection/inflammation of 14 % (87 patients). In that study, they grouped infection and inflammation and no description of the criteria for diagnosis was provided (Pope and Knowles, 2014). Possible differences in SSI rates between the current study and these studies could be due to their retrospective nature, shorter follow-up times, unclear SSI definition without following CDC criteria and lack of an active surveillance system. This may have contributed to a possible underestimation or overestimation of the incidence of SSI compared to the current study. Therefore, comparison of the reported SSI incidence it is difficult.

In this study, surgical time was significative associated with SSI (P < 0.001) and surgeries longer than 46 min had an increased risk of nine times. However, the duration of anaesthesia was not observed as a risk factor for the development of SSI. In a prospective study comparing SSI rates in dogs and cats after minimally invasive versus open surgery, surgeries longer than 90 min had an increased risk of 2.1 times for SSI (Mayhew et al., 2012). In that study, median surgical time of the minimally invasive procedures was 75 (25−245) minutes, however, surgical times in the current study were shorter than 90 min. Therefore, we decided to use the median of the surgical time as a cutting point to create both groups of comparison. Several studies in general open surgery has suggested that both surgical and anaesthesia time are associated with an increased risk of SSI (Beal et al., 2000; Eugster et al., 2004; Nicholson et al., 2002) (Espinel-Rupérez et al., 2019; Eugster et al., 2004; Nicholson et al., 2002; Rigby et al., 2021; Stetter et al., 2021; Thieman Mankin & Cohen, 2020). Some reasons for this association has been suggested in the current literature including longer exposure to operating room microorganisms (Cruse and Foord, 1980) or the greater immunosuppressive effect of anaesthetics (Salo, 1992).

Additionally, incorrect use of Elizabethan collar was also

Table 2
Multivariate model of risk factors for surgical site infection.

Variables	OR (CI 95 %)	p
Use of Elizabethan Collar		
No	6,5 (0,8−52,6)	
Yes	1	0,003
Duration of surgery		
≤ 46 min	1	
> 46 min	9,1 (2,4−33,9)	< 0,001

significantly associated with SSI. In this study, the recommendation to use this collar in the postoperative period was based on surgeon preferences and some surgeons did not recommend it to any patient. This finding has not been previously described in laparoscopic surgery; however, it was previously described as a risk factor in one prospective study including open surgery in dogs (Espinel-Rupérez et al., 2019). To the authors knowledge, only one study described the use of Elizabethan collar during the postoperative period following laparoscopic surgery (Pope and Knowles, 2014). Elizabethan collar is commonly recommended to avoid self-mutation (Tobias and Johnston, 2018). Numerous bacteria are presented in the mouth of canine (Rodrigues Hoffmann et al., 2016) and they could be transferred to the surgical site while self-mutation and predispose SSI. Even if a subjective survey reported that 77.4 % owners of dogs using this collar reported a poorer quality of life in their companion animals while the collar was worn (Shenoda et al., 2020), findings of the current study suggest that the improper use of the collar is a risk factor for SSI. Therefore, further studies evaluating advantages and disadvantages of the use of this collar are needed.

We accepted our second hypothesis because risk factor for SSI identified in this study were previously described in studies involving clean procedures. However, other risk factors previously described in other studies, such as the length of the surgical incision (Thieman Mankin & Cohen, 2020), the number of people in the operating room (Eugster et al., 2004), and clipping before anaesthesia (Brown et al., 1997; Mayhew, et al., 2012), were not identified in our study. One of the possible reasons could be that other studies describing these factors were retrospective and/or did not use the CDC criteria for classification of SSI and did not have active surveillance for 30 days postoperatively. Beyond surgical variables, lncRNA mediated regulation of inflammatory, proliferative and extracellular matrix remodelling pathways in reproductive tissues may modulate early port site healing and inter individual recovery trajectories (Zhu et al., 2024).

In this study, there was no association between increased risk of SSI and preoperative surgical antimicrobial prophylaxis. The use of preoperative chemoprophylaxis has been extensively studied in human medicine and its administration is commonly based on the degree of contamination of the surgical procedure. Like this study, a study involving clean laparoscopic surgery in veterinary medicine did not identify a protection effect of preoperative antimicrobial against SSI (Mayhew, et al., 2012). Although the available evidence is limited (Sørensen et al., 2024), some studies in open surgery also suggest that preoperative antimicrobial prophylaxis may not provide significant benefit in clean procedures (Brown et al., 1997; Daude-Lagrave et al., 2001; Espinel-Rupérez et al., 2019; Hardefeldt et al., 2018; Vasseur et al., 1988; Weese, 2008). In dogs and cats, prophylactic antimicrobial therapy has been associated with a low risk of SSI for clean procedures lasting more than 90 min, but no difference for procedures lasting less than 90 min (Vasseur et al., 1988). Other studies suggest that appropriate use of perioperative antibiotics is a factor that reduces the likelihood of developing SSI (Brown et al., 1997; Eugster et al., 2004; Turk et al., 2014). Therefore, the result of this study supports the no use of prophylactic antimicrobials in laparoscopic spay. Mechanistically, local wound healing after minimally invasive surgery may be influenced by intrinsic regulatory pathways analogous to those reported in reproductive tissues, for example the lncRNA RHPN1 AS1–miR 485 5p–TOP2A axis regulating proliferative and proliferation, survival and migratory programmes (S. Zhou et al., 2021; Y. Zhou et al., 2021), which offers a biological rationale for the limited incremental benefit of routine prophylaxis in this clean laparoscopic setting, where our adjusted data indicate that risk is better mitigated by non-antibiotic measures (shorter operative time and correct Elizabethan collar use)

Additionally, no decreased risk of developing an SSI was associated with the use of postoperative surgical antimicrobial prophylaxis in this study. This finding support the current recommendation of the guidelines of non-use of antibiotics in the postoperative period in clean procedures (Mangram et al., 1999; Sørensen et al., 2024). In this study, 23.1 % of patients in this study were prescribed antibiotics for a postoperative period of 7 days. These results are consistent with those recently published in a survey of perioperative antibiotic use in Spain (Otero Balda et al., 2023) and in other countries (Gómez-Beltrán et al., 2021; Knight et al., 2013).

This prospective study has several limitations. One of the main limitations of this study is the participation of several centers and the inherent limitation of variations in the protocols of each institution. Although in general all institutions followed relatively similar surgical protocol, there was some important differences in the use of antimicrobials and postoperative use of Elizabethan collar. The use of multilevel logistic regression or mixed effects models to adjust for centre was initially considered. However, this option was rejected due to the limited number of events and insufficient sample size for this purpose. Another important limitation of the study was that some patients were prescribed antibiotics in the post-operative period. Despite guidelines did not recommends the use of antibiotics in the perioperative period, this practice is still common among some veterinarians. However, our results show that their use does not lead to significant differences in the risk of developing SSI. These findings reinforce the importance of promoting the need to avoid inappropriate use of antibiotics in veterinary medicine, as this practice contributes to the increase in antimicrobial resistance. Even if we recommended perform microbiologic culture in all the cases with a suspicion of SSI, only two owners agree to perform culture of the wound. Even if microbiologic culture is not mandatory based on the CDC definitions, it is recommended, and we could underestimate the incidence of SSI. Moreover, a detail description of the bacteria involving in the SSIs was not included. Only healthy patients were including to this study, therefore results should be evaluated carefully, as the systemic immune balance can play an important role during the postoperative period (Yang et al., 2025). Further studies in patients with any disease are needed to assess the incidence and risk factors.

In conclusion, the incidence of SSI in female dogs undergoing laparoscopic ovariectomy was 7.2 % (IC 95 %: 4.1 %-11.6 %), similar or slightly higher than previously reported incidences of SSI in dogs undergoing laparoscopy or undergoing open clean procedures. Surgical procedures exceeding 46 min and improper use of Elizabethan collars were significantly associated with SSI.

CRediT authorship contribution statement

M. Fuertes-Recuero: Writing – review & editing. **J. Espinel Rupérez:** Writing – review & editing. **M. Abal-Flores:** Writing – review & editing. **G. Gonzalez-Matellano:** Writing – review & editing. **M. Gardoqui-Arias:** Writing – original draft. **A. Rubio Guivernau:** Writing – original draft, Resources. **D. Carrero Escolar:** Writing – original draft. **C. Sánchez-Collado:** Writing – original draft. **D. Calzado-Barranco:** Writing – original draft. **J. C. Fontanillas-Pérez:** Writing – original draft. **G. Ortiz-Diez:** Writing – original draft. **A. Fraile-Fernandez:** Writing – original draft, Resources.

Animal ethic statement

The study was approved by the Institutional Ethics Committee (reference number 29/2021; 21 January 2022) and all owners gave their informed consent prior to the inclusion of their dogs in the study.

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

No generative AI or AI-assisted technologies were used in the writing process.

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Declaration of Competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.tvjl.2025.106496.

Data Availability

The data that support the findings of this study are available on request from the
corresponding author.

References

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. Veterinary Surgery 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., for the Healthcare Infection Control Practices Advisory Committee, 2017. Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017JAMA Surg15278479110.1001/jamasurg.2017.0904.

Berzon, J.L., 1979. Complications of elective ovariohysterectomies in the dog and cat at a teaching institution: clinical review of 853 cases. Veterinary Surgery 8, 89–91. https://doi.org/10.1111/j.1532-950X.1979.tb00615.x.

Bianchi, A., Collivignarelli, F., Vignoli, M., Scaletta, L., Cuomo, A., Falerno, I., Paolini, A., Tamburro, R., 2021. A comparison of times taken for the placement of the first portal and complication rates between the Veress needle technique and the modified Hasson technique in canine ovariectomy laparoscopic surgery. Animals 11, 2936. https://doi.org/10.3390/ani11102936.

Binder, C., Katić, N., Aurich, J.E., Dupré, G., 2018. Postoperative complications and owner assessment of single portal laparoscopic ovariectomy in dogs. Vet Rec 183, 745. https://doi.org/10.1136/vr.104950.

Brodeur, A., Wright, A., Cortes, Y., 2017. Hypothermia and targeted temperature management in cats and dogs. J Vet Emerg Crit Care (Sanoma Antonio) 27, 151–163. https://doi.org/10.1111/vec.12572.

Brown, Conzemius, M.G., Shofer, F., Swann, H., 1997. Epidemiologic evaluation of postoperative wound infections in dogs and cats. Sci Rep 5.

Buote, N.J., 2022. Updates in laparoscopy. Veterinary Clinics of North America Small Animal Practice Soft Tissue Surgery 52, 513–529. https://doi.org/10.1016/j.cvsm.2021.12.007.

Burrow, R., Batchelor, D., Cripps, P., 2005. Complications observed during and after ovariohysterectomy of 142 bitches at a veterinary teaching hospital. Vet Rec 157, 829–833. https://doi.org/10.1136/vr.157.26.829.

Case, J.B., Marvel, S.J., Boscan, P., Monnet, E.L., 2011. Surgical time and severity of postoperative pain in dogs undergoing laparoscopic ovariectomy with one, two, or three instrument cannulas. javma 239, 203–208. https://doi.org/10.2460/javma.239.2.203.

CharlesworthSanchez, 2019. A comparison of the rates of postoperative complications between dogs undergoing laparoscopic and open ovariectomy. J Small Anim Pract 60, 218–222. https://doi.org/10.1111/jsap.12993.

Corriveau, K.M., Giuffrida, M.A., Mayhew, P.D., Runge, J.J., 2017. Outcome of laparoscopic ovariectomy and laparoscopic-assisted ovariohysterectomy in dogs: 278 cases (2003–2013). javma 251, 443–450. https://doi.org/10.2460/javma.251.4.443.

Cruse, P.J., Foord, R., 1980. The epidemiology of wound infection. A 10-year prospective study of 62,939 wounds. Surg Clin North Am 60, 27–40. https://doi.org/10.1016/s0039-6109(16)42031-1.

Culp, W.T.N., Mayhew, P.D., Brown, D.C., 2009. The effect of laparoscopic versus open ovariectomy on postsurgical activity in small dogs. Veterinary Surgery 38, 811–817. https://doi.org/10.1111/j.1532-950X.2009.00572.x.

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. https://doi.org/10.1055/s-0038-1632689.

Del Romero, A., Cuervo, B., Peláez, P., Miguel, L., Torres, M., Yeste, M., Rivera del Alamo, M.M., Rubio, C.P., Rubio, M., 2020. Changes in acute phase proteins in bitches after laparoscopic, midline, and flank ovariectomy using the same method for hemostasis. Animals 10, 2223. https://doi.org/10.3390/ani10122223.

Devitt, C.M., Cox, R.E., Hailey, J.J., 2005. Duration, complications, stress, and pain of open ovariohysterectomy versus a simple method of laparoscopic-assisted ovariohysterectomy in dogs. javma 227, 921–927. https://doi.org/10.2460/javma.2005.227.921.

Dorn, A., Swist, R., 1977. Complications of canine ovariohysterectomy. J Am Anim Hosp Assoc 13, 720–724.

Dupré, G., Fiorbianco, V., Skalicky, M., Gültiken, N., Ay, S.S., Findik, M., 2009. Laparoscopic ovariectomy in dogs: comparison between single portal and two-portal access. Veterinary Surgery 38, 818–824. https://doi.org/10.1111/j.1532-950X.2009.00601.x.

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. Vet Rec Open 6, e000233. https://doi.org/10.1136/vetreco-2017-000233.

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.

Evans, L.K.M., Knowles, T.G., Werrett, G., Holt, P.E., 2009. The efficacy of chlorhexidine gluconate in canine skin preparation - practice survey and clinical trials. J Small Anim Pract 50, 458–465. https://doi.org/10.1111/j.1748-5827.2009.00773.x.

Follette, C.M., Giuffrida, M.A., Balsa, I.M., Culp, W.T.N., Mayhew, P.D., Oblak, M.L., Singh, A., Steffey, M.A., 2020. A systematic review of criteria used to report complications in soft tissue and oncologic surgical clinical research studies in dogs and cats. Vet Surg 49, 61–69. https://doi.org/10.1111/vsu.13279.

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). J Am Vet Med Assoc 236, 88–94. https://doi.org/10.2460/javma.236.1.88.

Gao, Y., Wang, C., Wang, K., He, C., Hu, K., Liang, M., 2022. The effects and molecular mechanism of heat stress on spermatogenesis and the mitigation measures. Syst Biol Reprod Med 68, 331–347. https://doi.org/10.1080/19396368.2022.2074325.

Gómez-Beltrán, D.A., Schaeffer, D.J., Ferguson, D.C., Monsalve, L.K., Villar, D., 2021. Antimicrobial prescribing practices in dogs and cats by Colombian veterinarians in the city of Medellin. Vet. Sci. 8, 73. https://doi.org/10.3390/vetsci8050073.

Hancock, R.B., Lanz, O.I., Waldron, D.R., Duncan, R.B., Broadstone, R.V., Hendrix, P.K., 2005. Comparison of postoperative pain after ovariohysterectomy by harmonic scalpel-assisted laparoscopy compared with median celiotomy and ligation in dogs. Veterinary Surgery 34, 273–282. https://doi.org/10.1111/j.1532-950x.2005.00041.x.

Hardefeldt, L.Y., Gilkerson, J.R., Billman-Jacobe, H., Stevenson, M.A., Thursky, K., Bailey, K.E., Browning, G.F., 2018. Barriers to and enablers of implementing antimicrobial stewardship programs in veterinary practices. J Vet Intern. Med. 32, 1092–1099. https://doi.org/10.1111/jvim.15083.

Harrell, F.E., 2015. Regression Modeling Strategies: With Applications to Linear Models, Logistic and Ordinal Regression, and Survival Analysis. Springer Series in Statistics. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-19425-7.

Horan, T.C., Gaynes, R.P., Martone, W.J., Jarvis, W.R., Emori, T.G., 1992. CDC definitions of nosocomial surgical site infections, 1992: a modification of CDC definitions of surgical wound infections. Am. J. 4.

Kang, S., Jin, S., Mao, X., He, B., Wu, C., 2024. CD4+T and CD8+T Cells in Uterus Exhibit Both Selective Dysfunction and Residency SignaturesJ. Immunology. Res.2024558215110.1155/2024/5582151.

Knight, S.M., Radlinsky, M.G., Cornell, K.K., Schmiedt, C.W., 2013. Postoperative complications associated with caudectomy in brachycephalic dogs with ingrown tails. J. Am. Anim.Hosp. Assoc. 49, 237–242. https://doi.org/10.5326/JAAHA-MS-5858.

Lee, J.Y., Kim, M.C., 2014. Comparison of oxidative stress status in dogs undergoing laparoscopic and open ovariectomy. J. Vet. Med. Sci. 76, 273–276. https://doi.org/10.1292/jvms.13-0062.

Mangram, A.J., Horan, T.C., Pearson, M.L., Silver, L.C., Jarvis, W.R., 1999. Guideline for prevention of surgical site infection. Infect. Control Hosp Epidemiol 20, 36.

Mayhew, P.D., Freeman, L., Kwan, T., Brown, D.C., 2012. Comparison of surgical site infection rates in clean and clean-contaminated wounds in dogs and cats after minimally invasive versus open surgery: 179 cases (2007–2008). J. Am. Vet. Med. 240, 193–198. https://doi.org/10.2460/javma.240.2.193.

Monnet, E., Twedt, D.C., 2003. Laparoscopy. Veterinary Clinics of North America Small Animal Practice Gastroenterology 33, 1147–1163. https://doi.org/10.1016/S0195-5616(03)00058-5.

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. Surgery 31, 577–581. https://doi.org/10.1053/jvet.2002.34661.

Niranjana, C., Ganesh, R., Jayaprakash, R., Joseph, C., Arun, P.A., Mishra, A.K., 2013. Two different port placement models and ovarian pedicle hemostasis techniques in

laparoscopic-assisted ovariohysterectomy - bitches. Int. J. Veterinary Sci. 2, 155–160.
Nylund, A.M., Drury, A., Weir, H., Monnet, E., 2017. Rates of intraoperative complications and conversion to laparotomy during laparoscopic ovariectomy performed by veterinary students: 161 cases (2010–2014). javma 251, 95–99. https://doi.org/10.2460/javma.251.1.95.
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. https://doi.org/10.3390/ani13152475.
Pope, J.F.A., Knowles, T.G., 2014. Retrospective analysis of the learning curve associated with laparoscopic ovariectomy in dogs and associated perioperative complication rates. Vet. Surg. 43, 668–677. https://doi.org/10.1111/j.1532-950X.2014.12216.x.
Rigby, B.E., Malott, K., Hetzel, S.J., Soukup, J.W., 2021. Incidence and risk factors for surgical site infections following oromaxillofacial oncologic surgery in dogs. Front Vet. Sci. 8, 760628. https://doi.org/10.3389/fvets.2021.760628.
Rodrigues Hoffmann, A., Proctor, L.M., Surette, M.G., Suchodolski, J.S., 2016. The microbiome: the trillions of microorganisms that maintain health and cause disease in humans and companion animals. Vet. Pathol. 53, 10–21. https://doi.org/10.1177/0300985815595517.
Ruan, L.-L., Lv, X.-Y., Hu, Y.-L., Chen, M.-X., Jing-Tang, null, Zhong, Z.-H., Bao, M.-H., Fu, L.-J., Luo, X., Yu, S.-M., Wan, Q., Ding, Y.-B., 2024. Metabolic landscape and pathogenic insights: a comprehensive analysis of high ovarian response in infertile women undergoing in vitro fertilization. J Ovarian Res. 17, 105. https://doi.org/10.1186/s13048-024-01411-6.
Salo, M., 1992. Effects of anaesthesia and surgery on the immune response. Acta Anaesthesiol Scand 36, 201–220. https://doi.org/10.1111/j.1399-6576.1992.tb03452.x.
Shariati, E., Bakhtiari, J., Khalaj, A., Niasari-Naslaji, A., 2014. Comparison between two portal laparoscopy and open surgery for ovariectomy in dogs. Veterinary Research. Forum 5, 2019, 223.
Shenoda, Y., Ward, M.P., McKeegan, D., Fawcett, A., 2020. "The cone of shame": welfare implications of Elizabethan collar use on dogs and cats as reported by their owners. Animals 10, 333. https://doi.org/10.3390/ani10020333.
Sørensen, T.M., Scahill, K., Ruperez, J.E., Olejnik, M., Swinbourne, F., Verwilghen, D.R., Nolff, M.C., Baines, S., Marques, C., Vilen, A., Duarte, E.L., Dias, M., Dewulf, S., Wichtowska, A., Valencia, A.C., Pelligand, L., Broens, E.M., Toutain, P.L., Alishani, M., Brennan, M.L., Weese, J.S., Jessen, L.R., Allerton, F., from European Network for Optimization of Antimicrobial Therapy (ENOVAT) guidelines and theESCMID Study Group for Veterinary Microbiology (ESGVM), 2024. Antimicrobial prophylaxis in companion animal surgery: A scoping review for European Network for Optimization of Antimicrobial Therapy (ENOVAT) guidelines. Vet. J. 304, 106101. https://doi.org/10.1016/j.tvjl.2024.106101.
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.
Steyerberg, E.W., Harrell, F.E., Borsboom, G.J.J.M., Eijkemans, M.J.C., Vergouwe, Y., Habbema, J.D.F., 2001. Internal validation of predictive models: Efficiency of some procedures for logistic regression analysis. J. Clinical Epidemiology 54, 774–781. https://doi.org/10.1016/S0895-4356(01)00341-9.
Thieman Mankin, K.M., Cohen, N.D., 2020. Randomized, controlled clinical trial to assess the effect of antimicrobial-impregnated suture on the incidence of surgical site infections in dogs and cats. J. Am. Vet. Med. Assoc. 257, 62–69. https://doi.org/10.2460/javma.257.1.62.
Tobias, K., Johnston, S., 2018. Veterinary Surgery Small Animal. Elsevier Saunders, St. Louis.
Turk, R., Singh, A., Weese, J.S., 2014. Prospective surgical site infection surveillance in dogs: prospective surgical site infection surveillance. Vet. Surg. 2–8. https://doi.org/10.1111/j.1532-950X.2014.12267.x.
Vasseur, P.B., Levy, J., Dowd, E., Eliot, J., 1988. Surgical wound infection rates in dogs and cats data from a teaching hospital. Vet Surgery 17, 60–64. https://doi.org/10.1111/j.1532-950X.1988.tb00278.x.
Wang, Z.-B., Zhang, X., Fang, C., Liu, X.-T., Liao, Q.-J., Wu, N., Wang, J., 2024. Immunotherapy and the ovarian cancer microenvironment: Exploring potential strategies for enhanced treatment efficacy. Immunology 173, 14–32. https://doi.org/10.1111/imm.13793.
Weese, J.S., 2008. A review of post-operative infections in veterinary orthopaedic surgery. Vet Comp Orthop Traumatol 21, 99–105. https://doi.org/10.3415/vcot-07-11-0105.
WSAVA, 2024. Nutrition Committee [WWW Document]. URL ⟨https://wsava.org/committees/global-nutrition-committee/⟩ (accessed 5.16.24).
Yang, J., Yao, Y.-L., Lv, X.-Y., Geng, L.-H., Wang, Y., Adu-Gyamfi, E.A., Wang, X.-J., Qian, Y., Chen, M.-X., Zhong, Z.-H., Li, R.-Y., Wan, Q., Ding, Y.-B., 2025. The Safety and Efficacy of inactivated COVID-19 vaccination in couples undergoing assisted reproductive technology: A prospective cohort study. Vaccine 45, 126635. https://doi.org/10.1016/j.vaccine.2024.126635.
Zhou, S., Deng, F., Zhang, J., Chen, G., 2021. Incidence and risk factors for postoperative delirium after liver transplantation: a systematic review and meta-analysis. Eur. Rev. Med. Pharmacol. Sci. 25, 3246–3253. https://doi.org/10.26355/eurrev_202104_25733.
Zhou, Y., Li, J., Yang, X., Song, Y., Li, H., 2021. Rhophilin rho GTPase binding protein 1-antisense RNA 1 (RHPN1-AS1) promotes ovarian carcinogenesis by sponging microRNA-485-5p and releasing DNA topoisomerase II alpha (TOP2A). Bioengineered 12, 12003–12022. https://doi.org/10.1080/21655979.2021.2002494.
Zhu, Q., Sun, J., An, C., Li, X., Xu, S., He, Y., Zhang, X., Liu, L., Hu, K., Liang, M., 2024. Mechanism of LncRNA Gm2044 in germ cell development. Front Cell Dev. Biol. 12. https://doi.org/10.3389/fcell.2024.1410914.