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Citation for published version:
Glenn, OJ, Faux, I, Pratschke, KM & Blacklock, K 2023, 'Evaluation of a client questionnaire at diagnosing surgical site infections in an active surveillance system', *Veterinary Surgery*, pp. 1-10.
https://doi.org/10.1111/vsu.14011

Digital Object Identifier (DOI):
10.1111/vsu.14011

Link:
Link to publication record in Edinburgh Research Explorer

Document Version:
Peer reviewed version

Published In:
Veterinary Surgery

Title page

Evaluation of a client questionnaire at diagnosing surgical site infections in an active surveillance system

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Evaluation of a client questionnaire at diagnosing surgical site infections in an active surveillance system

Objective: To report sensitivity, specificity, predictive values and accuracy of a client questionnaire at diagnosing surgical site infections (SSIs) and describe the impact of active surveillance on SSI detection.

Study design: Prospective, cohort study.

Animals: Dogs and cats undergoing soft tissue or orthopedic surgery over a 12-month period at a referral hospital.

Methods: Clients were emailed a questionnaire 30 days post-operatively, or 90 days where an implant was used. Three algorithms were developed to diagnose SSIs using one or both of two criteria: 1)presence of any wound healing problems; 2)wound dehiscence or antibiotic prescription, and either purulent discharge or two or more clinical signs (redness, pain, heat, swelling, discharge). Algorithmic diagnoses were compared to gold standard diagnoses made by veterinarians.

Results: Of 754 surgical procedures, 309 responses were completed with 173 corresponding gold standard diagnoses. The most accurate algorithm determined “SSI” or “No SSI” from 90.2% of responses with 95.5%(92.4-98.6) accuracy, 82.6%(77-88.3) sensitivity, 97.7%(95.5-100) specificity, 86.4%(81.2-91.5) positive predictive value, and 97%(94.5-99.6) negative predictive value. “No SSI” was diagnosed in responses not meeting criterion 1, and “SSI” in responses meeting criteria 1 and 2. “Inconclusive” responses, comprising 9.8% of responses, met criterion 1 but not 2. Overall SSI rate was 62/754(8.2%) and 12/62(19.4%) SSIs were detected by active surveillance only.

Conclusions: Use of this client questionnaire accurately diagnosed SSIs; active surveillance increased SSI detection.

Clinical significance: Surveillance of SSIs should be active and can be simplified by using a client questionnaire and algorithmic diagnoses, allowing automated distribution, data collection and analysis.

Word count = 250

Keywords = Surgery, infection control, prospective, algorithm, wound infection, small animal, implant

Introduction

Surgical site infections (SSIs) are a major source of patient morbidity, mortality, and increased costs for clients and hospitals.[1-6] Whilst SSI existence may be ineradicable,[7-9] the rate is influenceable.[9-13] Surveillance of SSIs is needed to estimate rate, identify outbreaks, evaluate infection control programs, and benchmark against other hospitals and surgeons.

Passive surveillance is the retrospective review of data collected for reasons other than surveillance.[9] It is simple to perform but is poorly sensitive and underestimates SSI rates.[3,4,9,14] In a referral hospital, passive SSI surveillance is poorly sensitive because post discharge care is often performed by the referring veterinarian (RV), who may not report back to the referral hospital.[15,16] Therefore, SSI rates may be underestimated by the referral hospital because 92-100% of SSIs are diagnosed after discharge.[3,4]

Guidelines in human health care state that SSI surveillance should be active, patient-based and prospective.[17] Active surveillance requires scheduled, purposeful, and separate collection of post-operative data from clients or RVs.[9] It has been widely and routinely used in human surgery since 1974 and is often mandatory.[10,18,19] Two studies in veterinary patients have compared active and passive surveillance, finding that 27.8-35% of SSIs were only detected through active surveillance.[3,4] Active surveillance is more time consuming and expensive to perform because it typically uses telephone calls, in-person appointments, or manual review of questionnaires.[14,15,18] This is often undertaken by specialized infection control nurses in human hospitals, with a ratio of at least 1 nurse to 250 patients recommended.[10,20] However, this is not possible in many veterinary hospitals due to cost and smaller caseloads. Where patient-based surveillance is performed, standard definitions of SSIs[17,21] cannot be directly applied because of barriers created by medical jargon, the requirement for bacterial culture results, or interpretation of clinical signs. [22,23]

Examples of active surveillance in veterinary literature have involved telephone calls and questionnaires to clients and RVs, with manual review of all responses.[4,5,24,25] These methods are time consuming and expensive in personnel hours, presenting barriers to implementation.[3,15,26,27] Additionally, diagnoses from client surveillance have not been compared to gold standard diagnoses, meaning the sensitivity, specificity, predictive values and accuracy of previously described methods are not known. Therefore, alternative methods utilizing automation with a client specific definition of SSI [18,19,23] and known sensitivity, specificity, predictive values and accuracy are needed if active surveillance of SSIs is to be widely implemented in veterinary hospitals as part of infection control programs.

The primary objective of this study was to evaluate a dedicated client questionnaire at diagnosing SSIs compared to gold standard diagnoses made by a veterinarian. The secondary objective was to describe the impact of an active surveillance system on the detection of SSIs. Our hypotheses were that a client questionnaire would be able to accurately diagnose SSIs and that active surveillance would increase the detection of SSIs compared to passive surveillance.

Materials and Methods

2.1 | Study design

All dogs and cats undergoing surgery by the soft tissue or orthopedic services of a single university veterinary teaching hospital between 3rd March 2021 and 3rd March 2022 were eligible for prospective enrolment. Exclusion criteria included surgical procedures performed by other departments, and procedures not performed in an operating theatre. Clients were informed of the study at the time of patient discharge and allowed to opt-out. Ethical approval was obtained from the institution's Human Ethical Review Committee (reference HERC_461_20).

2.2 | Data collection

Patient data prospectively collected from hospital medical records included signalment, date of surgery, use of implants, and alive or dead at time of follow-up. Retrospectively collected data included date of last hospital visit. Wound classification was retrospectively assigned based on the surgical procedure.[28]

2.3 | Surveillance

Passive surveillance was performed at least 30 days post-operatively, or 90 days where an implant was used, whereupon the hospital medical records were reviewed for diagnosis of an SSI. An implant was defined as an object permanently placed in the animal during a surgical procedure that was not suture material, vascular clips or staples.

A single questionnaire was developed for use in veterinary patients (Appendix 1) by making minor adaptations to a questionnaire used for post-discharge surveillance of SSIs in human patients.[19] Active surveillance involved emailing clients and referring veterinarians a link to the online questionnaire (Online Surveys, JISC, Bristol, UK) automatically scheduled through practice management software (Provet, Nordhealth Ltd, Helsinki, Finland) 30 days post-operatively, or 90 days where an implant was used. Data were downloaded as a spreadsheet for analysis. Those with incomplete questionnaires were sent an email reminder at least 30 days later. When patients underwent multiple surgical procedures, each procedure was actively surveilled separately. When a surgical site underwent a subsequent surgical procedure(s) at the same site within 30 days, or 90 days where an implant was used, only the most recent surgery was included in the active surveillance. Patients not alive at the time of follow-up were excluded from active surveillance.

2.4 | SSI definitions

A gold standard diagnosis of "SSI" or "No SSI" was made from hospital medical records or RV questionnaires using an established Centers for Disease Control and Prevention definition (Table 1).[21] A gold standard diagnosis of "SSI" was made if the criteria in Table 1 were met. A gold standard diagnosis of "no SSI" was made if the criteria in Table 1 were not met after a minimum of 30 days postoperatively, or 90 days where an implant was used.

Client questionnaires were analyzed using two separate criteria to identify clinical signs and prescriptions suggestive of SSI. These criteria were used to create 3 algorithms that defined SSI from client questionnaires (Figure 1). Criterion 1 was the presence of any wound healing problem. Criterion 2 was the presence of a) wound dehiscence or antibiotic prescription; and b) purulent discharge or two or more relevant clinical signs of SSI (redness, pain, heat, swelling, discharge). Wound healing problems, discharge, purulent discharge, redness, pain, heat, swelling, dehiscence and antibiotic prescription corresponded to questions 1, 2a, 2bii, 3i, 3ii, 3iii, 3iv, 3v and 6 respectively (Appendix 1). Algorithms were encoded as formulas in Excel (Excel 16.56, Microsoft, Redmond, Washington, United States). Returned diagnoses were compared to the gold standard diagnoses, and classified as true positive (TP), true negative (TN), false positive (FP) or false negative (FN).

SSIs were divided into "superficial", "deep" and "organ space" where sufficient clinical information was available.[21]

2.5 | Statistical analysis

Descriptive statistics were calculated in Excel. Continuous data were assessed for normality. Normally distributed data are presented as mean with standard deviation and non-normally distributed data as median with range. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy were calculated as previously described.[29]

Results

3.1 | Study population

Patients undergoing 754 surgical procedures met the inclusion criteria and were eligible for passive surveillance. Of these procedures, 666 were undertaken in dogs and 88 were in cats. Multiple surgical procedures were performed in 44 dogs and three cats, giving 698 unique patients. The median age of dogs was 63.4 months (1.8 – 169) and 62.8 months (5.1 - 198) for cats.

Forty-four patients undergoing 45 surgical procedures died before 30 days (or 90 days where an implant was used), 12 patient records did not have a valid client email address, and 6 surgical sites were re-operated on within 30 days (or 90 days where an implant was used). Therefore, 63 surgical procedures were excluded from active surveillance, leaving 691 surgical procedures eligible for active surveillance (Figure 2).

3.2 | Surveillance

Medical records for 230 surgical procedures had a follow-up consultation at least 30 days post-operatively, or 90 days where an implant was used, or a recorded SSI event. These occurred at a median of 116 days post-operatively (3-440) and permitted passive surveillance for these procedures.

RV questionnaires were completed for 224 surgical procedures. Twenty-five were excluded due to early completion, leaving 199 questionnaires suitable for inclusion. RV questionnaires were completed at a median of 108 days post-operatively (30-705).

Hospital medical records or RV questionnaires gave a gold standard diagnosis for 366 surgical procedures.

Client questionnaires were completed for 309 surgical procedures. Fifteen were excluded due to early completion, leaving 294 questionnaires suitable for inclusion. Client questionnaires were completed at a median of 64.5 days post-operatively (30-693). Response rate was 37.9% higher for clients than RVs. Client questionnaires from 173 surgical procedures had a corresponding gold standard diagnosis.

The diagnoses "SSI" or "No SSI" from each algorithm were compared to gold standard diagnoses (Table 2) and used to calculate sensitivity, specificity, PPV, NPV and accuracy (Table 3). Algorithm 1 was the most sensitive (87.1%) compared to algorithm 2 (61.3%) and algorithm 3 (82.6%). Algorithm 2 was the most specific (97.9%) compared to algorithm 1 (91.5%) but very similar to algorithm 3 (97.7%). Algorithm 3 was the most accurate (95.5%) compared to algorithms 1 (90.8%) and 2 (91.3%). It was able to classify "SSI" or "No SSI" from 156/173 (90.2%) of responses, leaving 17/173 (9.83%) responses as "Inconclusive". Of the "Inconclusive" responses, 9/17 (52.9%) had an SSI and 8/17 (47.1%) did not.

3.3 | SSIs

A gold standard diagnosis of SSI was identified in 62 of 754 surgical procedures (8.22%). Wound classification data are shown in Table 4. Surgical procedures with implants accounted for 16/62 (25.8%) SSIs. Revision surgery was undertaken in 21 of all 62 SSIs (33.9%) and 7 of the 16 SSIs (43.8%) involving implants.

Passive surveillance identified 50/62 (80.6%) SSIs, while active surveillance identified an additional 12/62 (19.4%) SSIs that were not detected by passive surveillance. Active surveillance increased the SSI rate by 24% compared with passive surveillance alone.

Using algorithm 3 to analyze the remaining client questionnaires identified one additional likely SSI and 3 “inconclusive” responses.

Clinical signs of SSI were noted by clients or referring veterinarians at a median of 8 days post-operatively (range 1-201). Of the 57 SSIs with this data, 27 (47.4%) showed clinical signs within seven days post-operatively, 46 (80.7%) within 14 days post-operatively, 52 (91.2%) within 30 days post-operatively and 55 (96.5%) within 90 days post-operatively. Two SSIs occurred after 90 days, at 115 and 201 days post-operatively. Both late SSIs occurred following surgical procedures with implants.

Among the 45 animals that died within 30 days post-operatively, or 90 days where an implant was used, one developed an SSI and euthanasia was elected in preference to further wound management.

Discussion

We found in this study that a client questionnaire diagnosed SSIs with clinically useful levels of sensitivity, specificity, PPV, NPV and accuracy, and that active surveillance increased the detection of SSIs compared to passive surveillance. Therefore, we accepted both hypotheses.

Algorithm 1 had a sensitivity and NPV of 87.1% and 97% respectively, making it useful in identifying possible SSIs. However, the PPV of 69.2% was insufficiently reliable. Algorithm 1 could be used as a “rule-out” test to identify animals in need of further follow-up for possible SSIs. Algorithm 2 had a specificity and PPV of 97.9% and 86.4%, making it useful in diagnosing SSIs. However, the sensitivity of 61.3% meant a significant proportion of SSIs were missed. Algorithm 2 could be used as a “rule-in” test to diagnose SSIs but would require manual review of “No SSI” responses to identify false negatives. Algorithm 3 had a sensitivity, specificity, PPV, NPV and accuracy of 82.6%, 97.7%, 86.4%, 97% and 95.5% respectively, making it clinically useful in diagnosing both SSIs and no-SSIs. Use of algorithm 3 means manual review was only required for the 9.83% of responses associated with “Inconclusive” results. Using algorithm 3 with manual review of “Inconclusive” responses, assuming all inconclusive responses were correctly diagnosed, would combine the sensitivity and NPV of algorithm 1 with the specificity and PPV value of algorithm 2. In the authors’ experience, “Inconclusive” responses often required only manual review of the final free text question of the questionnaire, without telephone or RV follow-up, to define the response into “SSI” or “No SSI”. Hospitals wishing to create an active surveillance system for SSIs with this client questionnaire could choose an algorithm to match their requirements and resources available.

Detailed analysis of the reasons for each incorrect algorithmic SSI diagnosis was outside the design of this study. Subjective assessment of responses suggested that clients may have forgotten SSIs, over-interpreted clinical signs, or misappropriated clinical signs to the wrong surgical procedure when multiple surgical procedures were performed. Surveying clients at multiple time points could increase sensitivity by reducing false negatives due to forgotten SSIs, whilst educating clients on wound healing expectations and signs associated with SSIs could help increase specificity by reducing false positives due to over-interpretation of clinical signs.

A similar questionnaire was investigated in human surgery for post-discharge surveillance, which assigned numerical scores as cut-off points to define SSIs.[23] It reported similar sensitivity and specificity for individual scores as algorithms 1 and 2 in the current study.

Client questionnaires were completed for 37.9% more surgical procedures than RV questionnaires. This suggests that clients may be more motivated or available to provide post-discharge surveillance so surveilling them could increase the response rate, and therefore sensitivity, of an active surveillance system compared to RV surveillance alone.

This study differed from previous examples of active surveillance by i) using a questionnaire with a client-specific definition of SSI, and ii) defining questionnaire sensitivity, specificity, predictive values and accuracy. [3-5,11,24,25,30-35] This methodology allowed questionnaire distribution and data collection to be automated through existing practice management software and online questionnaire platforms, and data analysis to be automated through algorithms encoded as formulae into a spreadsheet. This process minimizes the cost and time requirement compared to telephone surveillance or manually reviewed questionnaires and maximizes response rate compared to RV surveillance alone.

The authors' institution now uses this automated method to continuously actively surveil SSIs.

Passive surveillance failed to detect 19.4% of SSIs in this study. Although this was lower than the 27.8 – 35% previously reported,[3,4] it underestimated the SSI rate by 24% and shows the importance of active surveillance. Active surveillance has been shown to reduce the incidence of SSIs,[36-38] and when combined with an effective infection control program was shown to reduce SSIs by 40.5% in human hospitals.[10] With the rise of multidrug resistant SSIs,[15] the importance of SSI prevention is paramount. Active surveillance of SSIs in veterinary surgery could reduce the incidence of SSIs and therefore should play an important role in hospital infection control programs.

The overall SSI rate of 8.22% using active surveillance was within the 2.83% – 12.9% range reported by other studies evaluating multiple surgical procedures, as was the SSI rate of each surgical wound classification.[3-5,11,24,25,30-35]. Comparing SSI rates between hospitals and studies is difficult due to different caseloads, SSI definitions, durations of follow-up, and surveillance methods. Many studies used an SSI definition of 14 days or less which likely reduced their sensitivity.[11,24,35-38] In the present study, 11/57 (19.3%) SSIs would have been missed with this definition. Standardization of SSI definitions and the use of risk-adjusted SSI rates have been recommended.[14,17,39] The use of this questionnaire-based method would allow comparison of SSI rates between institutions.

This study had several limitations, including the incomplete response rate. It was possible there could have been a reporting bias, where clients were more or less likely to respond if their animal had an SSI. However, the 44.7% response rate was comparable to other questionnaires in the veterinary literature. [34,40-43] Patients who died before follow-up were excluded from contact for active surveillance due to ethical concerns about causing unnecessary distress to clients. SSIs within this group were still recorded by passive surveillance, but it was possible some were missed due to the lack of active surveillance. The gold standard diagnoses partially relied on referring veterinarian assessment of wounds and diagnosis of SSI. Even with a uniform SSI definition, there is some subjectivity in the interpretation of wounds meaning that false positive and false negative gold standard diagnoses could have occurred.

Surgical procedures involving implants were followed up 90 days post-operatively in this study. This was based upon CDC guidelines,[17] but means some implant-related SSIs that developed clinical signs after 90 days could have been missed. Studies on SSIs following veterinary orthopedic surgery found that SSIs were detected within a median of 18-21 days,[25,44] and that 75-100% of SSIs were detected within 90 days.[25,34,44] Only 2 SSIs were known to have occurred after 90 days in our study and were detected by passive surveillance. This suggests that the majority of implant-related SSIs were detected with the 90-day surveillance.

As deep or implant-related SSIs can have few external clinical signs, these could have been undetected by the questionnaire because all algorithms required a ‘wound healing problem’ to be considered for SSI diagnosis. This format was chosen to make the questionnaire quick to complete to increase the response rate but may have resulted in reduced sensitivity to SSIs not associated with superficial wound healing problems (e.g., deep infections). An 8-12 week post-operative radiographic follow-up of patients that underwent orthopedic surgeries was routinely performed during the study period, therefore we believe deep SSIs in this cohort would likely have been detected by passive surveillance of hospital records.

Together, these limitations mean the SSI rate reported was likely still an underestimation of the true SSI burden.

This questionnaire could not be used to identify the type of SSI (superficial, deep, organ space). While the additional free text information provided by clients in some cases was sufficient to suggest the type of SSI, the accuracy was not assessed. We believe this differentiation is likely beyond the capability of client wound assessment.

In conclusion, this questionnaire was able to diagnose SSIs from client responses for dogs and cats that underwent soft tissue or orthopedic surgery, with clinically useful sensitivity, specificity, predictive values and accuracy. Active surveillance increased the detection of SSIs compared to passive surveillance. This client questionnaire could be used to create an active surveillance system for SSIs with automated distribution, data collection and semi-automated analysis, reducing barriers to implementation. Further research is warranted to evaluate its impact on SSI rate.

Word count = 2984

Acknowledgments

Author contributions:

Glenn OJ, BVMS MRCVS AFHEA: Conception, design, data collection, data analysis, manuscript preparation, manuscript review.

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Disclosure statement

Funding information: No funding was used or awarded for this research.

Conflict of interest: The authors declare no conflicts of interest related to this report.

Previous presentations: Preliminary results of this research were presented as an abstract at the 31st ECVS Annual Scientific Meeting; July 7-9, 2022; Porto, Portugal

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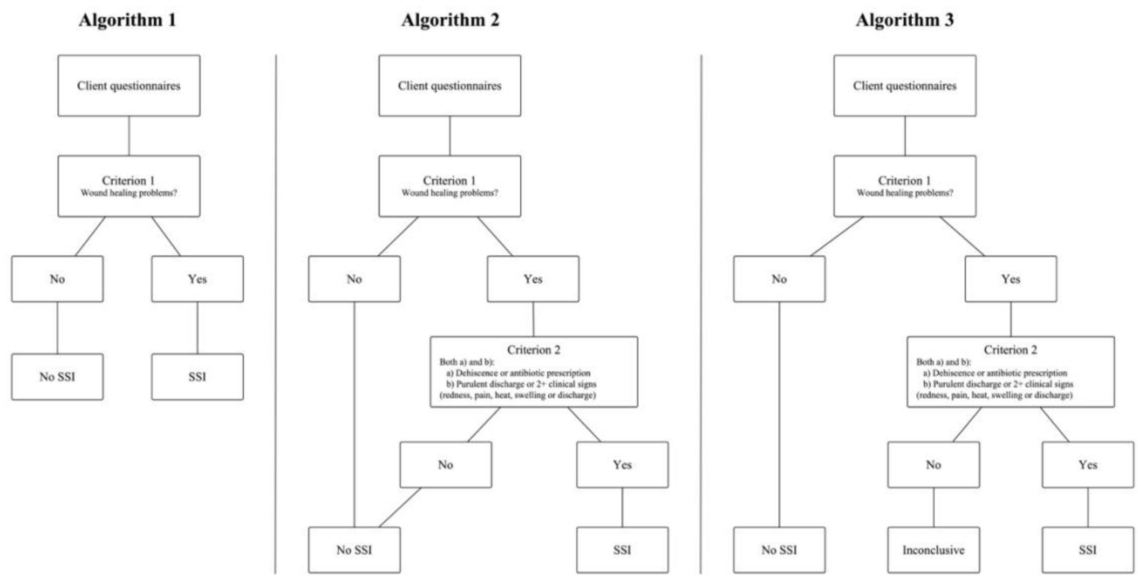
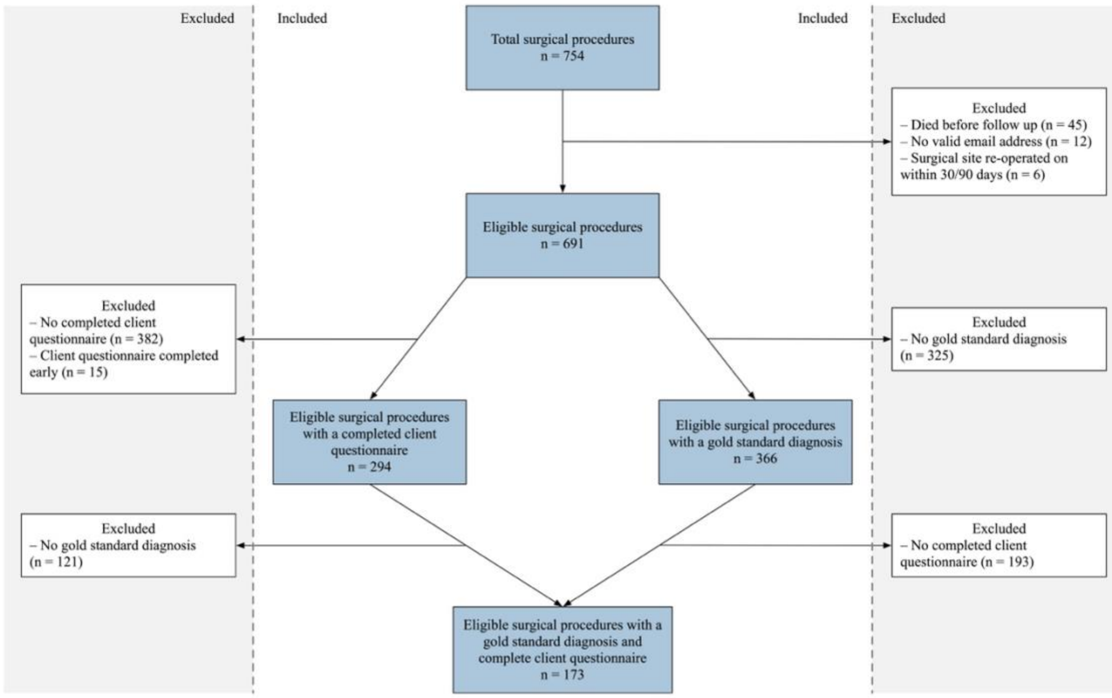
Figure legend

Figure 1: Flow diagrams depicting the method of surgical site infection definition from client questionnaires using algorithm 1, algorithm 2 and algorithm 3.



SSI, surgical site infection

Figure 2: Flow diagram illustrating study enrollment and exclusion. Gold standard diagnoses were made by a veterinarian according to CDC criteria.[21]



n, number

Tables

Table 1: Surgical site infection (SSI) definitions.[21]

Superficial SSI	Infection occurs within 30 days after the operative procedure and involves only skin and subcutaneous tissue of the incision ***and*** patient has at least 1 of the following: a. purulent drainage from the superficial incision b. organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision c. at least 1 of the following signs of infection: pain or tenderness, localized swelling, redness, or heat, ***and*** superficial incision is deliberately opened by a veterinarian ***and*** is culture positive or not cultured. A culture-negative finding does not meet this criterion. d. diagnosis of superficial incisional SSI by the surgeon or attending veterinarian.
Deep SSI	Infection occurs within 30 days after the operative procedure if no implant is left in place or within 1 year if implant is in place ***and*** the infection appears to be related to the operative procedure ***and*** involves deep soft tissues (e.g., fascial and muscle layers) of the incision ***and*** patient has at least 1 of the following: a. purulent drainage from the deep incision but not from the organ/space component of the surgical site b. a deep incision spontaneously dehisces or is deliberately opened by a veterinarian ***and*** is culture-positive or not cultured when the patient has at least 1 of the following signs: fever or localized pain or tenderness. A culture-negative finding does not meet this criterion. c. an abscess or other evidence of infection involving the deep incision is found on direct examination, during reoperation, or by histopathologic or radiologic examination d. diagnosis of a deep incisional SSI by a surgeon or attending veterinarian.
Organ/space SSI	Infection occurs within 30 days after the operative procedure if no implant is left in place or within 1 year if implant is in place and the infection appears to be related to the operative procedure ***and*** infection involves any part of the body, excluding the skin incision, fascia, or muscle layers, that is opened or manipulated during the operative procedure ***and*** patient has at least 1 of the following: a. purulent drainage from a drain that is placed through a stab wound into the organ/space

	b. organisms isolated from an aseptically obtained culture of fluid or tissue in the organ/space c. an abscess or other evidence of infection involving the organ/space that is found on direct examination, during reoperation, or by histopathologic or radiologic examination d. diagnosis of an organ/space SSI by a surgeon or attending veterinarian.

Table 2: Comparison of algorithm surgical site infection diagnoses from client questionnaires to gold standard diagnoses.

Algorithm defining SSI	True positive	True negative	False positive	False negative
Algorithm 1	27	130	12	4
Algorithm 2	19	139	3	12
Algorithm 3	19	130	3	4

Note: Results for algorithm 3 excluded 17 “Inconclusive” results.

Table 3: Descriptive statistics of algorithm surgical site infection diagnoses from client questionnaires compared to gold standard diagnoses.

Algorithm defining SSI	*Sensitivity (95% CL)*	*Specificity (95% CL)*	*PPV (95% CL)*	*NPV (95% CL)*	*Accuracy (95% CL)*
Algorithm 1	87.1% (82.1-92.1)	91.5% (87.4-95.7)	69.2% (62.4–76.1)	97% (94.5–99.6)	90.8% (86.4–95.1)
Algorithm 2	61.3% (54–68.5)	97.9% (95.7–100)	86.4% (81.2–91.5)	92.1% (88–96.1)	91.3% (87.1–95.5)
Algorithm 3	82.6% (77–88.3)	97.7% (95.5–100)	86.4% (81.2–91.5)	97% (94.5–99.6)	95.5% (92.4–98.6)

CL = confidence limit, PPV = positive predictive value, NPV = negative predictive value.

Table 4: Number and incidence of SSIs for each surgical wound category.[28]

Wound category	Number of surgical procedures	Number of SSIs	SSI rate	Use of implants
Clean	426	34	7.98%	Implant = 187 No implant = 239
Clean-contaminated	204	12	5.88%	Implant = 3 No implant = 201
Contaminated	30	3	10%	Implant = 6 No implant = 24
Dirty	94	13	13.8%	Implant = 5 No implant = 89
Total	**754**	**62**	**8.22%**	**Implant = 201** **No implant = 553**

SSI = surgical site infection

Appendix 1: Flow diagram of client questionnaire used to identify surgical site infections.