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A systematic review of complications related to laparoscopic and laparoscopic-assisted procedures in dogs

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Abstract

Objective: To evaluate and report the quality of the scientific literature reporting complications associated with laparoscopic and laparoscopic-assisted procedures in client-owned or healthy research dogs and to report and illustrate laparoscopic complications related to individual organ systems.

Study design: Systematic review.

Animals: Client-owned or healthy research dogs.

Methods: A literature review was performed by using PubMed and CAB abstracts for English-language studies providing descriptions of complications related to laparoscopic and laparoscopic-assisted procedures in dogs. Study selection used PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines. Quality assessment was performed by using a MINORS (Methodological Items for Non-Randomized Studies) scoring system and a grading scale of level of evidence. Descriptive statistics were used.

Results: In total, 741 manuscripts were identified, with 64 manuscripts eligible for data extraction and quality assessment. The most represented organ system was the female genital tract, represented by 22 (34.4%) studies. The most commonly reported intraoperative and postoperative complications were related to abdominal entry and portal incisions, respectively. In 53 of 54 non-randomized studies, high risk of bias was found. Forty-eight (75%) studies provided level III or IV evidence.

Conclusion: This report provides an updated review of complications related to laparoscopic and laparoscopic-assisted procedures in dogs, classified by organ system. The overall quality of evidence was low, limiting direct comparison of complication rates between studies.

Clinical significance: There is a need for implementation of standardized criteria for defining complications, study time frames and greater numbers of high quality prospective randomized trials in veterinary laparoscopy to permit comparison of complication and conversion rates between published studies and across organ systems.

1 | INTRODUCTION

The benefits of minimally invasive laparoscopic surgery compared with conventional open surgery are numerous and include increased diagnostic accuracy, improved visibility,[1] decreased patient stress and postoperative pain, faster patient recovery, reduced infection rate, and decreased morbidity and hospitalization stay.[2-8] The use of laparoscopic and laparoscopic-assisted techniques is becoming increasingly commonplace in small animal surgery, most notably for elective procedures including ovariectomy and elective gastropexy.[9-11] This is reflected in the rise in the number of publications pertaining to elective laparoscopic procedures. As a result of increasing experience with laparoscopy, additional publications in which more challenging procedures are described, including laparoscopic cholecystectomy and adrenalectomy, have also emerged within the last decade.[12-14]

Similarly to traditional open surgery, laparoscopy can be associated with specific perioperative complications and patient morbidity.[15,16] Recent research has been focused on reporting complications for various laparoscopic procedures.[17-20] A narrative literature review of complications associated with laparoscopic and thoracoscopic procedures was published in 2011.[15] However, most citations in this traditional review are of material published prior to 2008, with only 10 citations from 2008 through 2011, four of which are proceedings.[15] Furthermore, in a recently published textbook on surgical complications, the most recent citations in the chapter dedicated to laparoscopy are of material published in 2009 and 2010.[7,16,21]

On the basis of the rise in the number of publications related to laparoscopy within the past 10 years and emergence of descriptions of more advanced surgical procedures with greater surgeon experience, there is a requirement for an updated review to investigate and illustrate the types of complications associated with laparoscopic and laparoscopy-assisted procedures in dogs. Recently, systematic reviews dedicated to surgical treatments have been conducted in human and veterinary surgery by using non-randomized studies with adapted and validated quality assessment scales.[22-25] In contrast to a narrative review, a systematic review uses a more rigorous approach to reviewing the literature on a specific topic, including a comprehensive and systematic search strategy and the use of predefined strict inclusion and exclusive criteria.[26] Using a quality assessment scale adapted to non–randomized controlled trials (RCT) from the human literature,[25] we sought to apply a well-defined, evidence-based medicine approach to laparoscopic procedures in dogs. Therefore, the objective of this systematic review was to evaluate and report the quality of the scientific literature reporting complications associated with laparoscopic and laparoscopic-assisted procedures in client-owned or healthy research dogs and to report and illustrate laparoscopic complications related to individual organ systems.

2 | MATERIALS AND METHODS

2.1 | Search strategy

A comprehensive literature review was performed on October 1, 2018, by using PubMed and CAB abstracts databases. Search terms included ["laparoscopy" OR "laparoscopic" OR "laparoscopic-assisted"] AND ["dog" OR "dogs" OR "canine"] from January 1, 2008 through October 1, 2018. Potential additional references were hand searched, notably in the bibliographic sections within primary surgical textbooks.[2,16]

2.2 | Study selection

Inclusion criteria included English-language articles that provided description of intraoperative ± postoperative complications of laparoscopic or laparoscopic-assisted procedures in client-owned or healthy research dogs. Study types included were RCT, cohort studies, and case series including a minimum of three dogs. Exclusion criteria included studies that provided insufficient information regarding occurrence of intraoperative complications, review articles, editorials, studies involving the incorrect species, cadaveric studies, and reports that included fewer than three dogs. Studies that provided information regarding occurrence of intraoperative complications but did not provide any information relating to short- or long-term postoperative complications were not excluded. Studies that involved both dogs and cats but separated occurrence of complications by species were not excluded. From studies that compared open vs laparoscopic procedures, only the laparoscopic data were extracted. Finally, human experimental studies assessing a surgical technique not relevant to the veterinary surgical field were excluded.

This literature review followed the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) flowchart (Figure 1) and is based on its statement.[26] After the research strategy was applied, one author (M-P.M.) assessed the articles by title and abstract for inclusion for an initial screening. The full text of the identified articles was then assessed by the same author for inclusion, producing the final selection of articles included for review of complications and methodological assessment.

FIGURE 1 Study selection flow chart [Color figure can be viewed at wileyonlinelibrary.com]
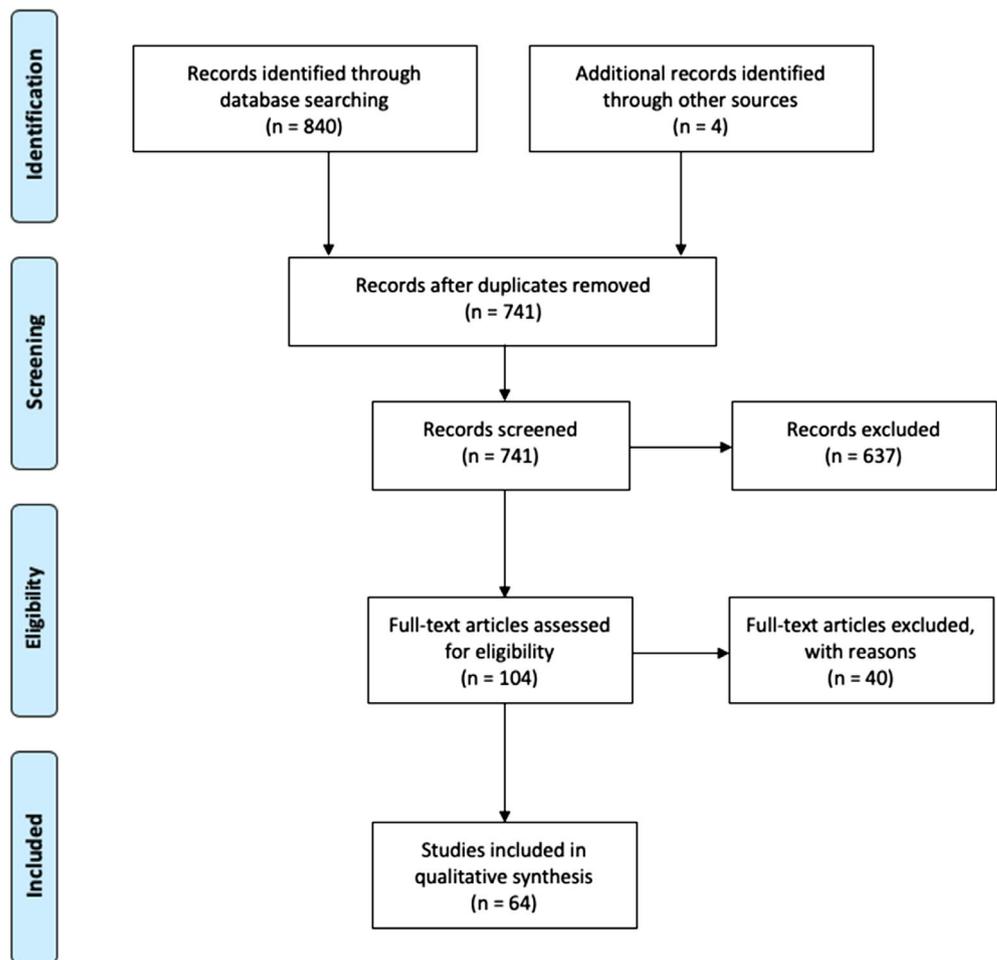
2.3 | Data and quality assessment

The following data were recorded from each study by two authors (M-P.M. and R.A.M.): study design, year of publication, surgical procedure, number of dogs included, abdominal entry technique (Veress needle, modified Hasson, or both), complication types, frequency of complications, hospitalization time (in days), follow-up, and mortality during hospitalization. Selected studies were divided into eight groups (female genital tract, urinary tract, stomach, intestinal tract, liver, adrenal glands, spleen, and other) representing different organ systems for presentation of surgical time, complications, follow-up, and mortality during hospitalization (Tables S1 and S2). The group designated "other" included studies that could not be classified as one organ system because they contained surgical procedures involving more than one organ system. Complications were classified as intraoperative or postoperative. No perioperative category was used because of inconsistency in its meaning within the literature. Intraoperative complications were defined as any unanticipated intraoperative event that did or did not require intervention to resolve and were subdivided into those

related to bleeding, organ damage, or other, such as a random technical problem (eg, the unanticipated requirement to enlarge a portal incision). Conversion events were reported separately from intraoperative complications and were subdivided into (1) because of an intraoperative complication (eg, hemorrhage or organ damage) and (2) because of a technical problem or limitation (eg, mesenteric adhesions precluding completion of a procedure laparoscopically).[8] Postoperative complications were subdivided into immediate postoperative (≤24 hours postoperatively), short term (≤6 weeks postoperatively), and long term (>6 weeks postoperatively). Postoperative complications were initially stratified as major (those that required medical or surgical treatment) or minor (those that did not require medical or surgical intervention).[27] However, because of inconsistencies in the description of complications within studies, this stratification could not be performed. Length of hospitalization, follow-up, and the method of follow-up were retrieved when available. The term *recheck* was used when follow-up was performed by a veterinarian, and the term *owner* was used when follow-up was retrieved through a questionnaire or telephone call with the owner. Mortality was defined as death or

TABLE 1 The revised and validated version of MINORS[25]

Methodological Items NOn-Randomised Studies (MINORS)	Score[a]
1 A clearly stated aim: the question addressed should be precise and relevant in the light of available literature	0-1-2
2 Inclusion of consecutive patients: all patients potentially for inclusion (satisfying the criteria inclusion) have been included in the study during the study period (no exclusion or details about the reasons for exclusion)	0-1-2
3 Prospective collection of data: data were collected according to a protocol established before the beginning of the study	0-1-2
4 Endpoints appropriate to the aim of the study: unambiguous explanation of the criteria used to evaluate the main outcome which should be in accordance with the question addressed by the study. Also, the endpoints should be assessed on an intention-to-treat basis.	0-1-2
5 Unbiased assessment of the study endpoint: blind evaluation of objective endpoints and double-blind evaluation of subjective endpoints. Otherwise the reasons for not blinding should be stated	0-1-2
6 Follow-up period appropriate to the aim of the study: the follow-up should be sufficiently long to allow the assessment of the main endpoint and possible adverse events	0-1-2
7 Loss to follow-up less than 5%: all patients should be included in the follow-up. Otherwise, the proportion lost to follow up should not exceed the proportion experiencing the major endpoint	0-1-2
8 Prospective calculation of the study size: information of the size of detectable difference of interest with a calculation of 95% confidence interval, according to the expected incidence of the outcome event, and information about the level for statistical significance and estimates of power when comparing the outcomes	0-1-2
Additional criteria in the case of comparative study	
9 An adequate control group: having a gold standard diagnostic test or therapeutic intervention recognized as the optimal intervention according to the available published data	0-1-2
10 Contemporary groups: control and studied group should be managed during the same time period (no historical comparison)	0-1-2
11 Baseline equivalence of groups: the groups should be similar regarding the criteria other than the studied endpoints. Absence of confounding factors that could bias the interpretation of the results	0-1-2

TABLE 1 (Continued)

Methodological Items NOn-Randomised Studies (MINORS)	Score[a]
12 Adequate statistical analyses: whether the statistics were in accordance with the type of study with calculation of confidence intervals or relative risk	0-1-2

[a]0 = not reported, 1 = reported but inadequate, and 2 = reported and adequate. The global ideal score is 16 for noncomparative studies and 24 for comparative studies.

TABLE 2 Grading scheme for quality of evidence scoring[23,29]

Level of evidence	Study designs
I	Randomized controlled trial
II	Prospective cohort study (patients compared with a control group of patients treated at the same time and institution) Poor-quality RCT; eg, <80% follow-up
III	Case control study Retrospective cohort study
IV	Case series, no control group or historical control group
V	Expert opinion

euthanasia during surgery or the postoperative hospitalization period.[28] If an animal was reported to have died after hospital discharge and death was deemed directly related to the laparoscopic/laparoscopy-assisted procedure by the author(s) of that study, this was recorded here as a short-term or long-term postoperative complication, depending on the time frame in which the complication occurred.

The selected studies methodological quality and level of evidence were assessed by using the MINORS (Methodological Items for NOn-Randomized Studies) scoring system,[25] which comprises eight items for non-comparative studies and four additional items for comparative studies. The items are scored 0 when information is not reported, 1 when information is reported but inadequate, and 2 when information is reported and adequate. The global ideal score is 16 for non-comparative studies and 24 for comparative studies, whereas 0 is the weakest score (Table 1). No modifications to the initial questions included in the MINORS scoring tool were required. The MINORS score was calculated only for non-randomized studies and could not be applied to the RCT. In addition, all studies were assessed for level of evidence (Table 2) and classified on a scale of I-IV by using a classification

proposed by Wright et al[29] for therapeutic studies that has been previously applied in systematic reviews published in the veterinary literature.[23,24,29] Level I evidence is the strongest and includes high quality RCT, whereas evidence with the least strength is expert opinion, level V (Table 2). Expert opinion, as well as editorials, were not included in this review.

3 | RESULTS

In total, 840 articles were identified through database searching, and four were added from the manual search. After duplicates were removed, 741 manuscripts remained and were screened, leaving 104 studies that met the inclusion criteria for this systematic review. Forty studies were excluded after the full text was assessed, and 64 studies were eligible for data extraction and quality assessment (Figure 1). The most common reason for exclusion was insufficient reporting of intraoperative complications (n = 21). Additional reasons for exclusion included the presence of review articles, abstracts, reports with less than three dogs, non–English-language articles, and human experimental studies describing surgeries not applicable to veterinary surgery (n = 19).

3.1 | Study characteristics

Study characteristics are presented in Table S3. Description of the study method or design was incomplete or not mentioned in many instances and had to be assigned by the primary author. Among the 64 studies selected, there were 35 (54.7%) case series, 10 (15.6%) RCT, nine (14.1%) cohort studies, six (9.4%) experimental studies, two (3.1%) case reports including a minimum of three dogs, and two (3.1%) studies that included clinical and experimental cases. Data collection was retrospective in 37 (57.8%) studies, prospective in 25 (39.1%) studies, and the two studies that included both experimental and clinical cases were retrospective and prospective. In total, 2428 dogs were described within 64 studies, with a median of 16 (range, 3-618) dogs per study. Fourteen (21.9%) studies included a control population, with a median of 18 (range, 10-60) dogs. Thirty-two (50%) studies described a modified Hasson technique, 13 (20.3%) described a Veress needle technique, nine (14.1%) described both techniques, and 10 (15.6%) did not specify entry technique (Table S1).

All studies specified occurrence of intraoperative complications and conversion events. Forty (62.5%) studies did not mention at least one temporal category of postoperative complications; among these 40 studies, five (12.5%) did not mention immediate postoperative complications, 25 (62.5%) did not mention short-term complications, and 39 (97.5%) did not describe long-term complications. Surgical time was not reported in three (4.7%) studies. Hospitalization time was not reported in 27 (42.2%) studies, and follow-up was not mentioned in seven (10.9%) studies. Because of variation in normality of continuous data such as surgical time, hospitalization time, and follow-up time within individual reports and absence of this information in others, it was not possible to summarize these data in an accurate manner.

3.2 | Classification of studies by organ system

Classification of studies by organ system is presented in Tables S1 and S2. Numbers of studies and participants were reported within each organ/system group including female genital tract (22 studies [n = 1407 dogs]),[1,7,11,20,30-47] urinary tract (7 studies [n = 114]),[3,48-53] stomach (9 studies [n = 250]),[10,18,54-59] intestinal tract (5 studies [n = 48]),[60-64] liver (5 studies [n = 288]),[12,17,65-67] adrenal gland (5 studies [n = 62]),[13,28,68-70] spleen (7 studies [n = 111]),[19,71-76] and other (4 studies that included gastropexy and ovariectomy procedures [n = 148]).[9,77-79] One experimental study, in which colopexy in seven male dogs was described, was classified as intestinal tract even though these dogs were also sterilized during the surgical procedure because this study reported only complications and outcomes related to colopexy.[63] Seventeen (26.6%) studies included laparoscopic-assisted procedures. The most common intraoperative complication was splenic laceration, which was recorded 84 times in 24 (37.5%) studies and across all organ systems (Table S2). Ten (11.9%) of the 84 incidents of splenic laceration required conversion to an open procedure. Incidence of splenic laceration for each study and organ system group is listed in Table S2. Conversion to an open procedure was required and reported 47 times in total in 20 (31.3%) studies and reported across all organ systems (Table S1). The conversion rate across all studies ranged from 0% to 30%. Conversion rates within each group are listed in Table S1. The group with the lowest rate of conversion was the female genital tract (0.7%), whereas the group with the highest rate of conversion was the intestinal tract (8.3%). The highest conversion rate was described in a case series of 20 dogs undergoing cholecystectomy.[17] In this study, six cases required a conversion, three because of technical challenges. The most commonly reported postoperative complications, recorded 192 times in 20 (31.3%) studies and across all organ systems, were wound related and included emphysema, inflammation, infection, swelling, seroma, discharge, and incisional

hernia. Thirteen (21%) studies had no complication that was encountered during the study period.

3.3 | Quality assessment

Quality assessment is presented in Table S3. The overall mean MINORS score (applicable to non-randomized studies only) was 7.3 of 16 (median, 8; range, 3-12) for non-comparative studies and 14.5 of 24 (median, 14; range, 8-21) for comparative studies. The interpretation of the mean MINORS score led to high risk of bias for 52 (96.3%) of 54 studies. A moderate risk of bias was identified in only one experimental study.[37] The second assessment scale allowing quality assessment of all studies revealed that only two (3.1%) studies provided level I evidence,[7,56] 14 (21.9%) studies provided level II evidence, nine (14.1%) studies provided level III evidence, and 39 (60.9%) studies provided level IV evidence.

4 | DISCUSSION

Within the past decade, there has been a rise in the number of publications pertaining to laparoscopic and laparoscopic-assisted procedures in dogs, along with the emergence of descriptions of more advanced minimally invasive procedures.[13,14,80] This systematic review evaluated the available scientific literature pertaining to laparoscopic and laparoscopic-assisted procedures in dogs over the past decade. Grouping of studies by individual organ systems illustrates types of complications related to minimally invasive surgery involving these organ systems (Tables S1 and S2). Most studies included in our review were case series, with only 10 RCT. The proportion of prospective studies (almost 40%) is encouraging; however, most studies were retrospective. We interpret mean MINORS score for non-randomized studies, which accounted for 62.5% of all included studies, as evidence of a high risk of bias for just over 95% of such studies. Forty-eight (75%) studies provided level III or IV evidence. These findings highlight the design limitations inherent to published studies over the past 10 years. With this in mind, the authors of the present systematic review advise caution in overinterpretation of comparison of complication rates between studies.

The most commonly reported intraoperative complication in our review was splenic laceration and was most commonly related to abdominal entry technique and intracorporeal instrument handling.[81] The highest incidence (9.9%) was observed in the spleen group and appeared related to injury to this organ during intracorporeal manipulation rather than abdominal entry

technique. Within this group, the highest incidence (27.3%) was in a study by Mayhew et al.[19] The lowest rate was in the liver group, in which the highest incidence was 1.9%.[65] Apparent lower rates of splenic puncture were identified within groups/organ systems containing more complex procedures such as cholecystectomy and adrenalectomy compared with elective procedures such as ovariectomy and gastropexy (Table S2). These data may provide evidence that, with increasing laparoscopic experience, surgeons performing more complex procedures may be less likely to commit a basic technical error. When comparisons between groups in this systematic review are made, it should be borne in mind that the reporting of complication rates and types (eg, bleeding from the spleen or ovarian pedicle) within studies depends on the authors' definitions of what constitutes a complication and the study design (ie, prospective vs retrospective), which impacts the accuracy and completeness of the medical records.

Our systematic review revealed a preponderance of use of the modified Hasson technique compared with the Veress needle technique during the past decade. The reasons for this are unknown but are likely related to surgeon preference.[30] Although it was not included in our systematic review, a Ternamian visual entry technique has been described in dogs and in man.[81] A previous study showed a higher risk of splenic puncture and general visceral or vascular complications secondary to a blind entry technique.[15,77] The authors of a recent study evaluated the prevalence of and risk factors for complications related to three different entry techniques, the modified Hasson, Veress needle, and Ternamian visual entry techniques.[81] In that study, complications were five and 28 times higher with modified Hasson (26%) and Veress needle entry (60%) techniques, respectively, compared with Ternamian visual entry (9%) technique. While complications related to entry technique were encountered in approximately 20% of procedures overall, just over 90% of these complications were considered minor.[81] Conversely, Pope and Knowles[11] identified no significant difference in the incidence of splenic laceration with Veress or open technique. The true rate of complications related to abdominal entry technique in small animal laparoscopic surgery is most likely underreported,[82] and there is a requirement for large prospective RCT to determine the superiority of one technique over another.[81]

The most commonly reported postoperative complication identified in this review was portal incision related. Despite a lower reported rate of surgical site infection and shorter incision lengths with laparoscopy compared with open surgical technique,[6,37] fairly high rates of incisional-related complications have been reported with certain laparoscopic procedures.[11,83] In the study by Pope and

Knowles,[11] postoperative incisional complications (inflammation, seroma, herniation) occurred in approximately 16% of dogs. In a recent multi-institutional study not included in this review, approximately one in five dogs undergoing laparoscopic-assisted gastropexy experienced a postoperative incision-related complication. These included seroma in just over 12% of dogs and surgical site infection in approximately 4% of dogs.[83] Finally, 30% of dogs experienced postoperative incisional complications in a study involving laparoscopic-assisted gastropexy.[18] Some of these complications may have been related to the location of the ports (eg, midline vs paramedian), abdominal entry technique, and the type of port used, with the modified Hasson technique and single-incision laparoscopic surgery port requiring more soft tissue dissection compared with the Veress technique and single-port cannula assemblies, respectively. Other factors such as requirement to extend the size of portal incisions (eg, laparoscopic-assisted ovariohysterectomy) may also be responsible for some of these incisional complications within studies.

We were surprised to find that comparable conversion rates were identified in this review among studies involving the female genital tract (0.7%) and those reporting more complex surgical procedures involving the adrenal glands (2.3%) and liver (4.9%) organ systems.[20,28] However, not all studies followed this trend. For example, in a study by Scott et al[51] involving 20 dogs that underwent laparoscopic cholecystectomy, 30% of dogs experienced intraoperative complications that required conversion to open technique. It may be anticipated that the more experienced laparoscopist, proficient and comfortable with complex laparoscopic procedures, would tolerate more adverse situations for a longer time before converting to an open procedure. Other factors such as careful case selection are also very likely to influence intraoperative conversion rates.[12,36,40]

The term *perioperative* was not employed as a time period in this review because it was considered ambiguous. Instead, complications were divided into intraoperative, immediate postoperative, short-term, and long-term.[27] Because of the absence of standardized definitions of study time frames in small animal soft tissue surgery, comparison of complication rates between studies is challenging. In a very recent systematic review of criteria used to report complications in soft tissue and oncologic surgery, the term *perioperative* was found to refer to time frames ranging from *during anesthesia* to *within 14 days postoperatively*.[84] The authors of that systemic review discouraged the use of the term *perioperative* because of its variable meaning. Instead, the authors recommended use of preoperative, intraoperative, and postoperative, with the latter capable of being subdivided into during hospitalization, short-term, and long-term. Standardization

of definitions and criteria for reporting complications will improve our ability to compare results between studies.

Systematic reviews preferentially include studies with high levels of evidence-based medicine such as RCT and prospective cohort studies. Only 25.9% of studies included in this review provided level I or II evidence. Specific difficulties in conducting randomized trials in human and veterinary surgery are recognized. Research is therefore mainly based on observational or non-randomized studies.[25] Even by using a validated scale specific to observational studies, careful interpretation of results is required in this specific surgical field. Minimally invasive surgery, particularly laparoscopy, may be particularly vulnerable to selection bias within observational studies. For instance, patients with fewer comorbidities may be more frequently selected for laparoscopic procedures, and randomized studies are more likely performed by experienced laparoscopic surgeons, limiting the comparability of their reported outcomes.[85] Systematic reviews do not result in improvement in the scientific evidence. If RCT are associated with specific challenges in veterinary surgery, an effort should be made to conduct good quality observational studies. Just as the CONSORT (CONsolidated Standards Of Reporting Trials) statement provides guidance on reporting RCT, the STROBE (Strengthening The Reporting of OBservational studies in Epidemiology) statement provides recommendations for improving common observational clinical designs (cohort, case–control, and cross-sectional studies).[86] This statement, currently not used in veterinary surgery, should be considered.

Numerous considerations and limitations must be acknowledged in this systematic review. A controlled, thorough electronic and manual search of manuscripts was performed following the PRISMA guidelines.[26] However, it is possible that some reports may have been excluded from this review if the title or abstract did not contain a relevant search term. Important data might also have been omitted because only studies in the English language were included. Most studies included in this systematic review were retrospective in nature. Therefore, the accuracy of data such as recording of complications within studies will have relied heavily upon the completeness of the medical records. Differences in study design within groups (eg, retrospective case series vs RCT) and lack of standardized criteria for what constitutes a complication make comparison of complication rates between studies and overall groups difficult. In addition, small case series may be biased toward successful outcomes. Rates of complications and conversion within studies, particularly those relating to more complex surgical procedures, are expected to be related to surgeon experience and expertise and may not be reproducible by less experienced laparoscopists. The

inclusion of laparoscopic-assisted procedures, which accounted for 25% of all included studies, may have contributed to an underestimation of complications, particularly intraoperative complications in which the technique becomes comparable to an open procedure after organs are exteriorized (eg, laparoscopy-assisted gastrointestinal biopsies, laparoscopy-assisted ovariohysterectomy). However, these studies also included the entry technique and abdominal exploration aspect of the laparoscopic procedure and were therefore included. Finally, studies in which laparoscopic-assisted gastropexy was described, which accounted for most laparoscopic-assisted studies, very commonly included ovariectomy or other procedures performed intracorporeally and had to be classified in the group "other" in this review. This likely affected the overall frequency of complications related to these individual procedures and groups in our review.

By summarizing the scientific literature of the past decade, we have provided a systematic review that is an extensive and thorough overview of complications related to laparoscopic and laparoscopic-assisted surgery in dogs. This review highlights that most of the veterinary literature reporting on laparoscopic and laparoscopic-assisted procedures has a low level of evidence, which limits formulation of strong conclusions and comparison of complication rates between studies. The consistent reports of splenic puncture identified in this systematic review justifies the recent interest in entry technique related complications. There is a requirement for implementation of standardized criteria for defining complications and study time frames and greater numbers of prospective RCT or high-quality observational studies in veterinary laparoscopic surgery to permit comparison of complication and conversion rates between published studies and across organ systems.

CONFLICT OF INTEREST

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

REFERENCES

1. van Nimwegen SA, Van Goethem B, de Gier J, Kirpensteijn J. A laparoscopic approach for removal of ovarian remnant tissue in 32 dogs. *BMC Vet Res*. 2018;14(1):333.
2. Johnston SA, Tobias KM. *Veterinary Surgery: Small Animal*. 2nd ed. Philadelphia, PA: Elsevier; 2018.
3. Singh A, Hoddinott K, Morrison S, et al. Perioperative characteristics of dogs undergoing open versus laparoscopic-assisted cystotomy for treatment of cystic calculi: 89 cases (2011-2015). *J Am Vet Med Assoc*. 2016;249(12):1401-1407.
4. Monnet E, Twedt DC. Laparoscopy. *Vet Clin North Am Small Anim Pract*. 2003;33(5):1147-1163.
5. Nowicki M, Rychlik A, Nieradka R, Kander M, Depta A, Chrzastowska M. Usefulness of laparoscopy guided renal biopsy in dogs. *Pol J Vet Sci*. 2010;13(2):363-371.
6. Mayhew PD, Freeman L, Kwan T, Brown DC. 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 Assoc*. 2012;240(2):193-198.
7. Culp WT, Mayhew PD, Brown DC. The effect of laparoscopic versus open ovariectomy on postsurgical activity in small dogs. *Vet Surg*. 2009;38(7):811-817.
8. Barry KS, Case JB, Winter MD, Garcia-Pereira FL, Buckley G, Johnson MD. Diagnostic usefulness of laparoscopy versus exploratory laparotomy for dogs with suspected gastrointestinal obstruction. *J Am Vet Med Assoc*. 2017;251(3):307-314.
9. Gandini M, Giusto G. Laparoscopic single-port ovariectomy and gastropexy in dogs. *Schweiz Arch Tierheilkd*. 2016;158(11): 755-758.
10. Takacs JD, Singh A, Case JB, et al. Total laparoscopic gastropexy using 1 simple continuous barbed suture line in 63 dogs. *Vet Surg*. 2017;46(2):233-241.
11. Pope JF, Knowles TG. Retrospective analysis of the learning curve associated with laparoscopic ovariectomy in dogs and associated perioperative complication rates. *Vet Surg*. 2014;43 (6):668-677.
12. Mayhew PD, Mehler SJ, Radhakrishnan A. Laparoscopic cholecystectomy for management of uncomplicated gall bladder mucocele in six dogs. *Vet Surg*. 2008;37(7):625-630.
13. Jimenez Pelaez M, Bouvy BM, Dupre GP. Laparoscopic adrenalectomy for treatment of unilateral adrenocortical carcinomas: technique, complications, and results in seven dogs. *Vet Surg*. 2008;37(5):444-453.
14. Mayhew PD. Advanced laparoscopic procedures (hepatobiliary, endocrine) in dogs and cats. *Vet Clin North Am Small Anim Pract*. 2009;39(5):925-939.
15. Mayhew PD. Complications of minimally invasive surgery in companion animals. *Vet Clin North Am Small Anim Pract*. 2011;41(5):1007-1021. vii-viii.
16. Griffon D, Hamaide A. *Complications in Small Animal Surgery*. 1st ed. Hoboken, NJ: John Wiley & Sons; 2016.
17. Scott J, Ameet S, Mayhew PD, et al. Perioperative complications and outcome of laparoscopic cholecystectomy in 20 dogs. *Vet Surg*. 2016;45(S1):O49-O59.
18. Loy Son NK, Singh A, Amsellem P, et al. Long-term outcome and complications following prophylactic laparoscopic-assisted gastropexy in dogs. *Vet Surg*. 2016;45(S1):O77-O83.
19. Mayhew PD, Sutton JS, Singh A, et al. Complications and short-term outcomes associated with single-port laparoscopic splenectomy in dogs. *Vet Surg*. 2018;47(S1):O67-O74.
20. Nylund AM, Drury A, Weir H, Monnet E. Rates of intraoperative complications and conversion to laparotomy during laparoscopic ovariectomy performed by veterinary students: 161 cases (2010-2014). *J Am Vet Med Assoc*. 2017;251(1):95-99.
21. Fiorbianco V, Skalicky M, Doerner J, Findik M, Dupre G. Right intercostal insertion of a Veress needle for laparoscopy in dogs. *Vet Surg*. 2012;41(3):367-373.
22. Cerciello S, Corona K, Morris BJ, Santagada DA, Maccauro G. Early outcomes and perioperative complications of the arthroscopic latarjet procedure: systematic review and meta-analysis. *Am J Sports Med*. 2019;47(9):2232-2241.
23. Bergh MS, Budsberg SC. A systematic review of the literature describing the efficacy of surgical treatments for canine hip dysplasia (1948-2012). *Vet Surg*. 2014;43(5):501-506.

24. Bergh MS, Sullivan C, Ferrell CL, Troy J, Budsberg SC. Systematic review of surgical treatments for cranial cruciate ligament disease in dogs. *J Am Anim Hosp Assoc.* 2014;50(5):315-321.

25. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (MINORS): development and validation of a new instrument. *ANZ J Surg.* 2003;73(9):712-716.

26. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med.* 2009;6(7):e1000097.

27. Cook JL, Evans R, Conzemius MG, et al. Proposed definitions and criteria for reporting time frame, outcome, and complications for clinical orthopedic studies in veterinary medicine. *Vet Surg.* 2010;39(8):905-908.

28. Mayhew PD, Culp WT, Hunt GB, et al. Comparison of perioperative morbidity and mortality rates in dogs with noninvasive adrenocortical masses undergoing laparoscopic versus open adrenalectomy. *J Am Vet Med Assoc.* 2014;245(9):1028-1035.

29. Wright JG, Swiontkowski MF, Heckman JD. Introducing levels of evidence to the journal. *J Bone Joint Surg Am.* 2003;85(1):1-3.

30. Dupré G, Fiorbianco V, Skalicky M, Gültıken N, Ay SS, Fındık M. Laparoscopic ovariectomy in dogs: comparison between single-portal and two-portal access. *Vet Surg.* 2009;38 (7):818-833.

31. Case JB, Marvel SJ, Boscan P, Monnet EL. Surgical time and severity of postoperative pain in dogs undergoing laparoscopic ovariectomy with one, two, or three instrument cannulas. *J Am Vet Med Assoc.* 2011;239(2):203-208.

32. Ohlund M, Hoglund O, Olsson U, Lagerstedt AS. Laparoscopic ovariectomy in dogs: a comparison of the LigaSure and the SonoSurg systems. *J Small Anim Pract.* 2011;52(6):290-294.

33. Manassero M, Leperlier D, Vallefuoco R, Viateau V. Laparoscopic ovariectomy in dogs using a single-port multiple-access device. *Vet Rec.* 2012;171(3):69.

34. Adamovich-Rippe KN, Mayhew PD, Runge JJ, et al. Evaluation of laparoscopic-assisted ovariohysterectomy for treatment of canine pyometra. *Vet Surg.* 2013;42(5):572-578.

35. Niranjana C, Ganesh R, Jayaprakash R, Cecilia J, Arun PA, Mishra AK. Two different port placement models and ovarian pedicle hemostasis techniques in laparoscopic-assisted ovariohysterectomy—bitches. *Int J Vet Sci.* 2013;2(4):155-160.

36. Naiman JH, Mayhew PD, Steffey MA, Culp WT, Runge JJ, Singh A. Laparoscopic treatment of ovarian remnant syndrome in dogs and cats: 7 cases (2010-2013). *J Am Vet Med Assoc.* 2014;245(11):1251-1257.

37. Shariati E, Bakhtiari J, Khalaj A, Niasari-Naslaji A. Comparison between two portal laparoscopy and open surgery for ovariectomy in dogs. *Vet Res Forum.* 2014;5(3):219-223.

38. Guizzo-Júnior N, Feranti JPS, Bairros MC, et al. Ultrasonic shears and bipolar vessel-sealing system for three-port laparoscopic ovariohysterectomy in dogs. *Arq Bras Med Vet Zootec.* 2015;67(1):55-61.

39. Sanchez-Margallo FM, Tapia-Araya A, Diaz-Guemes I. Preliminary application of a single-port access technique for laparoscopic ovariohysterectomy in dogs. *Vet Rec Open.* 2015;2(2): e000153.

40. Wallace ML, Case JB, Singh A, Ellison GW, Monnet E. Single incision, laparoscopic-assisted ovariohysterectomy for mucometra and pyometra in dogs. *Vet Surg.* 2015;44(Suppl 1):66-70.

41. Becher-Deichsel A, Aurich JE, Schrammel N, Dupre G. A surgical glove port technique for laparoscopic-assisted ovariohysterectomy for pyometra in the bitch. *Theriogenology.* 2016;86(2):619-625.

42. Bruckner M. Laparoscopy for the treatment of ovarian remnant syndrome in four dogs and two cats. *Tierarztl Prax Ausg K Kleintiere Heimtiere.* 2016;44(2):86-92.

43. Phipps WE, Goodman AR, Sullivan M. Ovarian remnant removal using minimally invasive laparoscopic techniques in four dogs. *J Small Anim Pract.* 2016;57(4):214-216.

44. Corriveau KM, Giuffrida MA, Mayhew PD, Runge JJ. Outcome of laparoscopic ovariectomy and laparoscopic-assisted ovariohysterectomy in dogs: 278 cases (2003-2013). *J Am Vet Med Assoc.* 2017;251(4):443-450.

45. Granados JR, Uson-Casaus J, Martinez JM, Sanchez-Margallo F, Perez-Merino E. Canine laparoscopic ovariectomy using two 3- and 5-mm portal sites: a prospective randomized clinical trial. *Can Vet J.* 2017;58(6):565-570.

46. Keeshen TP, Case JB, Runge JJ, et al. Outcome of laparoscopic ovariohysterectomy or ovariectomy in dogs with von Willebrand disease or factor VII deficiency: 20 cases (2012-2014). *J Am Vet Med Assoc.* 2017;251(9):1053-1058.

47. Spillebeen AL, Janssens S, Thomas RE, Kirpensteijn J, van Nimwegen SA. Cordless ultrasonic dissector versus advanced bipolar vessel sealing device for laparoscopic ovariectomy in dogs. *Vet Surg.* 2017;46(4):467-477.

48. Brun MV, Oliveira ST, Messina SA, Stedile R, Oliveira RP. Laparoscopic cystotomy for urolith removal in dogs: three case reports. *Arq Bras Med Vet Zootec.* 2008;60(1):103-108.

49. Zhang JT, Wang HB, Shi J, Zhang N, Zhang SX, Fan HG. Laparoscopy for percutaneous tube cystostomy in dogs. *J Am Vet Med Assoc.* 2010;236(9):975-977.

50. Kim YK, Park SJ, Lee SY, et al. Laparoscopic nephrectomy in dogs: an initial experience of 16 experimental procedures. *Vet J.* 2013;198(2):513-517.

51. Mayhew PD, Mehler SJ, Mayhew KN, Steffey MA, Culp WT. Experimental and clinical evaluation of transperitoneal laparoscopic ureteronephrectomy in dogs. *Vet Surg.* 2013;42(5): 565-571.

52. Pinel CB, Monnet E, Reems MR. Laparoscopic-assisted cystotomy for urolith removal in dogs and cats—23 cases. *Can Vet J.* 2013;54 (1):36-41.

53. Shariati E, Bakhtiari J, Aminsharifi A, Niasari-Naslaji A, Shariati E. Comparison of laparoscopic versus conventional open partial nephrectomy in dogs. *Iran J Vet Surg.* 2014;9(2):51-56.

54. Mayhew PD, Brown DC. Prospective evaluation of two intracorporeally sutured prophylactic laparoscopic gastropexy techniques compared with laparoscopic-assisted gastropexy in dogs. *Vet Surg.* 2009;38(6):738-746.

55. Urbanová L, Crha M, Raušer P, Nečas A. Clinical results and complications of preventive laparoscopic assisted gastropexy in 17 dogs: preliminary study. *Acta Vet Brno.* 2011;80(1):93-99.

56. Spah CE, Elkins AD, Wehrenberg A, et al. Evaluation of two novel self-anchoring barbed sutures in a prophylactic laparoscopic gastropexy compared with intracorporeal tied knots. *Vet Surg.* 2013;42(8):932-942.

57. Coleman KA, Adams S, Smeak DD, Monnet E. Laparoscopic gastropexy using knotless unidirectional suture and an articulated endoscopic suturing device: seven cases. *Vet Surg.* 2016;45 (S1):O95-O101.

58. Stiles M, Case JB, Coisman J. Elective gastropexy with a reusable single-incision laparoscopic surgery port in dogs: 14 cases (2012-2013). *J Am Vet Med Assoc.* 2016;249(3): 299-303.

59. Haraguchi T, Kimura S, Itoh H, et al. Comparison of postoperative pain and inflammation reaction in dogs undergoing preventive laparoscopic-assisted and incisional gastropexy. *J Vet Med Sci.* 2017;79(9):1524-1531.

60. Tavakoli A, Bakhtiari J, Khalaj AR, Gharagozlou MJ, Veshkini A. Single-layer versus double-layer laparoscopic intracorporeally sutured gastrointestinal anastomoses in the canine model. *JSLS.* 2010;14(4):509-515.

61. Case JB, Ellison G. Single incision laparoscopic-assisted intestinal surgery (SILAIS) in 7 dogs and 1 cat. *Vet Surg.* 2013;42(5): 629-634.

62. Mitterman L, Bonczynski J, Hearon K, Selmic LE. Comparison of perioperative and short-term postoperative complications of gastrointestinal biopsies via laparoscopic-assisted technique versus laparotomy. *Can Vet J.* 2016;57(4):395-400.

63. Mathon DH, Palierne S, Meynaud-Collard P, et al. Laparoscopic-assisted colopexy and sterilization in male dogs: short-term results and physiologic consequences. *Vet Surg.* 2011;40 (4):500-508.

64. Otomo A, Singh A, Valverde A, et al. Comparison of outcome in dogs undergoing single-incision laparoscopic-assisted intestinal surgery and open laparotomy for simple small intestinal foreign body removal. *Vet Surg.* 2019;48(S1):O83-O90.

65. McDevitt HL, Mayhew PD, Giuffrida MA, Brown DC, Culp WT, Runge JJ. Short-term clinical outcome of laparoscopic liver biopsy in dogs: 106 cases (2003-2013). *J Am Vet Med Assoc.* 2016;248(1):83-90.

66. Petre SL, McClaran JK, Bergman PJ, Monette S. Safety and efficacy of laparoscopic hepatic biopsy in dogs: 80 cases (2004-2009). *J Am Vet Med Assoc.* 2012;240(2):181-185.

67. Kanai H, Hagiwara K, Nukaya A, Kondo M, Aso A. Short-term outcome of laparoscopic cholecystectomy for benign gall bladder diseases in 76 dogs. *J Vet Med Sci.* 2018;80(11): 1747-1753.

68. Naan EC, Kirpensteijn J, Dupre GP, Galac S, Radlinsky MG. Innovative approach to laparoscopic adrenalectomy for treatment of unilateral adrenal gland tumors in dogs. *Vet Surg.* 2013;42(6):710-715.

69. Ko J, Jeong J, Lee S, Son H, Kweon OK, Kim WH. Feasibility of single-port retroperitoneoscopic adrenalectomy in dogs. *Vet Surg.* 2018;47(S1):O75-O83.

70. Pitt KA, Mayhew PD, Steffey MA, et al. Laparoscopic adrenalectomy for removal of unilateral noninvasive pheochromocytomas in 10 dogs. *Vet Surg.* 2016;45(S1):O70-O76.

71. Al-Hasan AM, Al-Heani WA. Laparoscopic partial splenectomy in dogs. *J Anim Vet Adv.* 2009;8(11):2232-2240.

72. Stedile R, Beck CAC, Schiochet F, et al. Laparoscopic versus open splenectomy in dogs. *Pesq Vet Bras.* 2009;29(8): 653-660.

73. Khalaj A, Bakhtiari J, Niasari-Naslaji A. Comparison between single and three portal laparoscopic splenectomy in dogs. *BMC Vet Res.* 2012;8:161.

74. Radhakrishnan A, Mayhew PD. Laparoscopic splenic biopsy in dogs and cats: 15 cases (2006-2008). *J Am Anim Hosp Assoc.* 2013;49(1):41-45.

75. Shaver SL, Mayhew PD, Steffey MA, Hunt GB, Mayhew KN, Culp WT. Short-term outcome of multiple port laparoscopic splenectomy in 10 dogs. *Vet Surg.* 2015;44(Suppl 1):71-75.

76. Wright T, Ameet S, Mayhew PD, et al. Laparoscopic-assisted splenectomy in dogs: 18 cases (2012-2014). *J Am Vet Med Assoc.* 2016;248(8):916-922.

77. Gonzalez-Gasch E, Monnet E. Comparison of single port access versus multiple port access systems in elective laparoscopy: 98 dogs (2005-2014). *Vet Surg.* 2015;44(7):895-899.

78. Rivier P, Furneaux R, Viguier E. Combined laparoscopic ovariectomy and laparoscopic-assisted gastropexy in dogs susceptible to gastric dilatation-volvulus. *Can Vet J.* 2011;52(1):62-66.

79. Runge JJ, Mayhew PD. Evaluation of single port access gastropexy and ovariectomy using articulating instruments and angled telescopes in dogs. *Vet Surg.* 2013;42(7):807-813.

80. Mayhew PD. Recent advances in soft tissue minimally invasive surgery. *J Small Anim Pract.* 2014;55(2):75-83.

81. Anderson SJ, Fransson BA. Complications related to entry techniques for laparoscopy in 159 dogs and cats. *Vet Surg.* 2019; 48(5):707-714.

82. Monnet E. Laparoscopic entry techniques: what is the controversy? *Vet Surg.* 2019;48(S1):O6-O14.

83. Baron JK, Casale SA, Monnet E, et al. Paramedian incisional complications after prophylactic laparoscopy-assisted gastropexy in 411 dogs. *Vet Surg.* In press.

84. Follette CM, Giuffrida MA, Balsa IM, et al. A systematic review of criteria used to report complications in soft tissue and oncologic surgical clinical research studies in dogs and cats. *Vet Surg.* 2020;49(1):61-69.

85. Antoniou SA, Antoniou GA, Granderath FA. Comparing systematic reviews and meta-analyses of randomized clinical trials with cohort studies: a paradigm of single-incision laparoscopic surgery. *Hernia.* 2016;20(1):13-14.

86. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Int J Surg.* 2014;12(12):1495-1499.

SUPPORTING INFORMATION

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