A systematic review of the prevalence of post-operative complications after general anaesthesia in adult horses (2000-2023)

A systematic review of the prevalence of post-operative complications after general anaesthesia in adult horses (2000–2023)

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Abstract

Background: Equine post-operative morbidity represents a significant concern for both veterinary surgeons and horse owners. Objectives: To estimate the prevalence of post-operative complications in horses after elective/non-abdominal surgery or colic surgery. Study design: Systematic review. Methods: A database search identified eligible studies which reported the prevalence of equine post-operative complications published as a full paper in English in a peer-reviewed journal between 2000 and 2023. Studies were evaluated using the JBI Critical Appraisal Checklist for Prevalence Studies and GRADE (Grading of Recommendations, Assessment, Development and Evaluations) framework. Data for the most commonly reported complications were analysed using Chi-squared analysis of weighted means to answer 13 PICO (Population, Intervention, Comparator and Outcomes) questions. Results: Sixty-seven studies met inclusion criteria. Data for eight post-operative morbidities (colic, surgical site complications, myopathy/neuropathy, laminitis, diarrhoea/colitis, fever/pyrexia, jugular thrombophlebitis/thrombosis, respiratory complications) were sufficient to allow statistical analyses. The weighted mean of the overall proportion of post-operative complications after elective/non-abdominal surgery is 17.48%(95% confidence interval [95% CI]: 13.20–22.92), significantly increasing to 55.62%(95% CI: 45.79–65.03) after colic surgery (odds ratio [OR] 6.63; 95% CI: 5.83–7.56;$p < 0.001$). The most commonly reported morbidity was post-operative colic, with a weighted mean prevalence of 7.45% (95% CI: 4.83–11.76) after elective/non-abdominal surgery, significantly rising to 26.46% (95% CI: 19.11–35.97) after colic surgery (OR 4.11; 95% CI: 3.60–4.71; $p < 0.001$). The weighted mean prevalence of surgical site complications, laminitis, diarrhoea/colitis, fever/pyrexia, jugular thrombo-phlebitis/thrombosis and respiratory complications were significantly higher after colic surgery compared with elective/non-abdominal surgery. Myopathy/neuropathy was the only morbidity where prevalence was not different between groups(OR 1.86; 95% CI: 0.86–4.16; $p = 0.16$).Main limitations: The majority of studies were retrospective. Morbidity definitions, data collection periods, follow-up time and methods varied between studies.

Conclusions: Based on current evidence, the prevalence of post-operative colic, surgical site complications, laminitis, diarrhoea/colitis, fever/pyrexia, jugular thrombophlebitis/thrombosis and respiratory complications is significantly higher after colic surgery compared with elective/non-abdominal surgery under general anaesthesia. KEYWORDS anaesthesia, complication, equine, horse, morbidity, post-operative.

Equine perioperative mortality and morbidity are of interest to anaesthetists, practitioners, horse owners and insurance companies.1 While the incidence and risk factors for perioperative mortality

have been extensively investigated in the equine veterinary literature,2,3 postoperative morbidity has been largely overlooked.1,4 A number of single and multicentre studies report the prevalence and nature of equine post-operative complications, but study designs and populations vary significantly between studies. Furthermore, a key issue seems to be the lack of uniform consensus definitions of complications and morbidities. Post-operative complication rates may be as high as 25% in horses undergoing elective or non-abdominal surgery5 and rise as high as 93% in horses recovering from colic surgery.6 Postoperative morbidity continues to be a significant concern and may increase hospitalisation cost and time, can affect the future performance of the horse and, in worst case scenarios, can lead to euthanasia.1 A variety of equine post-operative complications are reported in the veterinary literature and the topic has attracted narrative review.1 However, to date, a systematic review of the prevalence of the most common equine post-operative complications is missing. For the purpose of this review, post-operative morbidities or complications have been defined as any reported deviation from the normal post-operative course.7 The primary objective of this systematic review was to analyse the reported prevalence of post-operative complications in adult horses undergoing elective/non-abdominal surgery or colic surgery. In order to achieve this, we aimed to evaluate published studies reporting equine post-operative complications using the JBI Critical Appraisal Checklist for Studies Reporting Prevalence Data8 and the GRADE (Grading of Recommendations, Assessment, Development and Evaluations) framework.9 The weighted mean proportion of each complication was calculated and compared between elective/non-abdominal surgery and colic surgery using the Chi-squared test. Secondly, and using this information, we also aimed to answer a series of clinical questions formulated using the PICO (Population, Intervention, Comparator and Outcomes) model.

2 | MATERIALS AND METHODS

2.1 | Search strategy

A literature search was performed, independently by two investigators (KL and JdG), in three databases (CAB abstracts, PubMed and

Europe Pubmed Central (Europe PMC)) to identify all relevant published studies using the following search terms: (equine OR horse OR pony) AND (surgery OR anaesthesia OR post operative) AND (morbidity OR complication). Automatic synonym search was enabled. Secondary search methods included Google Scholar and cross referencing two review papers1,11 identified during the database searches. The filter options differed between databases. Results from CAB abstracts were not filtered for study type as this was not offered. Results from PubMed were filtered for randomised controlled clinical trials, clinical trials, veterinary clinical trials, systematic reviews and meta-analyses using the database selection tool. The results from Europe PMC were filtered for research articles. The remaining results from all three databases were limited to studies published between 2000 and 2023 in the English language. The date of the final search was 14 December 2023. The search results from CAB abstracts and PubMed were tabulated by two investigators (KL and JdG) independently and assigned a code to indicate inclusion or exclusion (stating the particular reason). The tables were then compared and any differences were discussed by the two investigators until a conclusion was reached. The Europe PMC database results were screened for eligibility by one investigator (KL) and sample screened by the second investigator (JdG). These results were used to cross reference the retrieved studies from CAB abstracts and PubMed to ensure no eligible studies had been omitted and that sampling to redundancy had been achieved.

2.2 | Inclusion criteria

Inclusion criteria were: publication in a peer-reviewed journal between 2000 and 2023 as a full paper, written in English, clinical in design and reporting the prevalence of equine post-operative complications in adult horses after surgery under general anaesthesia (GA). The search results were independently screened for eligibility by KL and JdG following the guidelines of

the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA 2020).12 Exclusion criteria were: studies published before 2000, studies not exclusively involving horses (e.g., studies involving donkeys or mules), study outcome not relevant to review topic, studies reporting surgery or performance outcome rather than post-operative complication rate, study population not representative of general equine hospital population (e.g., foals), studies involving standing procedures, studies involving field procedures (e.g., castrations), studies involving imaging procedures rather than surgery under GA, studies reporting post-operative mortality only, studies not reporting post-operative complication rates, studies involving a population of fewer than 20 horses and studies in formats other than full papers published in a peer-reviewed veterinary journal.

2.3 | Data extraction and management The studies that met the inclusion criteria and were eligible for analysis were categorised according to the complication type(s) reported or the surgical procedure undertaken (Table 1). Allocation of each study to a category was based on the primary aim of the study. For example, studies reporting all post-operative complications after elective or non-abdominal surgery were allocated to Group A, studies reporting all post-operative complications after colic surgery were allocated to Group B, studies reporting a specific post-operative complication for example, post-operative colic, surgical site infection, diarrhoea, colitis, laminitis and so forth, were allocated to Group C and studies reporting complications after a specific surgical procedure for example, castration, were allocated to Group D. The characteristics and findings of each individual study are summarised in TableS1

2.4 | Assessment of quality of evidence The JBI Critical Appraisal Checklist for Studies Reporting Prevalence Data (https://jbi.global/critical-appraisal-tools) was used to evaluate individual studies. The checklist comprises nine questions (Appendix I) which assess factors including adequacy of sample size, appropriate data analysis, validity of study methods, reliability of condition measurement(s), appropriate statistical analysis, consideration of low response rates and appropriate management.8 The factors relevant to the checklist were tabulated for each study under the following headings to address each of the nine checklist questions; population of interest (Appendix I; Q1 and Q4), study design and sample size (Appendix I; Q2, Q3 and Q7), methodology, time frame of data collection, follow-up period and statistical analyses (Appendix I; Q5, Q6, Q8), estimate of prevalence (Appendix I; Q9). The GRADE (Grading of Recommendations, Assessment, Development, and Evaluations) framework9 was used to evaluate the quality of evidence offered by the published studies in each sub-group, independently by KL and JdG. GRADE considers sources of imprecision, inconsistency, indirectness and bias in order to evaluate the quality of evidence presented and ascertain the overall certainty that the conclusions drawn are valid. The level of certainty can be scored from very low to high.

2.5 | Data analysis The data relating to the reported proportions of post-operative complications were analysed using R software (version 4.4.0). The overall complications and the eight most common post-operative complications, namely post-operative colic, surgical site complications, myopathy/neuropathy, laminitis, diarrhoea/colitis, fever/pyrexia, jugular thrombophlebitis/thrombosis and respiratory complications, were described as counts and percentages. The mean prevalence (weighted mean prevalence) and 95% confidence intervals (95% CIs) were calculated for each category of post-operative complication, considering the unequal population size between studies. The Chi-square test was used to determine whether there was a statistically significant difference between the expected frequency and the observed frequencies in the number of horses affected by the studied complications between those who had undergone colic surgery and those who had undergone elective or non-abdominal surgery. The statistical significance was established at $p \leq 0.05$.

The PICO questions posed were:

i. What is the overall prevalence of post-operative complications in horses undergoing elective or non-abdominal surgery under GA?

ii. What is the overall prevalence of post-operative complications in horses undergoing colic surgery under GA?

iii. What is the reported prevalence of post-operative colic in horses undergoing elective or non-abdominal surgery compared with colic surgery under GA?

iv. What is the reported prevalence of post-operative surgical site complication (infection or drainage) in horses undergoing elective or non-abdominal surgery compared with colic surgery under GA?

v. What is the reported prevalence of post-operative lameness in horses undergoing surgery under GA?

vi. What is the reported prevalence of post-operative myopathy or neuropathy in horses undergoing elective or non-abdominal surgery compared with colic surgery under GA? vii. What is the reported prevalence of post-operative laminitis in horses undergoing elective or non-abdominal surgery compared with colic surgery under GA?

viii. What is the reported prevalence of post-operative diarrhoea or colitis in horses after elective or non-abdominal surgery compared with colic surgery under GA?

ix. What is the reported prevalence of post-operative fever or pyrexia in horses after elective or non-abdominal surgery compared with colic surgery under GA? x. What is the reported prevalence of post-operative jugular thrombophlebitis/thrombosis in horses after elective or non-abdominal surgery compared with colic surgery under GA?

xi. What is the reported prevalence of post-operative respiratory complications in horses undergoing elective or non-abdominal surgery compared with colic surgery under GA? xii. What is the reported prevalence of post-operative corneal abrasion after surgery under GA? xiii. What is the reported prevalence of post-operative peritonitis and post-operative ileus or reflux in horses after colic surgery? The number of retrieved studies relating to PICO questions (v) and (xii) were too few to be able to perform statistical analyses on a comparator group, so the results relating to each of these questions were reported as a single group. Similarly, no comparator group existed for studies relating to PICO question (xiii), therefore the results were reported for studies involving horses undergoing colic surgery only.

3 | RESULTS 3.1 | Study characteristics and groups The database search yielded a total of 2239 studies from CAB abstracts (n = 285), Pubmed (n = 196) and Europe PMC (n = 1758) of which 56 were eligible for inclusion (Figure 1). Apart from those, a total of 19 studies were identified via secondary search methods using cross referencing of review article reference lists and Google Scholar. After removal of eight duplicated studies, a total of 67 studies were eligible for inclusion in this systematic review. Of these, 55 were single centre studies, six were two centre studies and six were multi (three or more) centre studies. Fifty-three studies were retrospective in design, 13 studies were prospective and one study had both retrospective and prospective components. The time frame over which study data were collected ranged from 8 months to 21 years. The smallest sample size was n = 26, the largest sample size was n = 3500 and the median sample size was n = 190. Forty-seven studies involved horses undergoing colic surgery, 17 involved horses undergoing elective or

non-abdominal surgery, two involved horses undergoing all types of surgery and one study involved horses undergoing non-ocular surgery. Of the 2239 studies screened, the reasons for exclusion were: other species (humans or non-equine animals or donkeys/mules) (n = 1632); studies presented in another format, for example, case reports, case series <20 cases (n = 209); study topic not relevant (n = 123); studies reporting surgery or performance outcome only(n = 79); no post-operative complication rates reported (n = 63); studies involving standing procedures (n = 56); studies involving an equine subpopulation not typical of the general hospital population, for example, foals (n = 9); mortality studies (n = 6); studies involving imaging procedures (n = 3) and studies involving field procedures (n = 3) (Figure 1).

The final 67 studies eligible for inclusion were summarised (Table S1) and categorised into groups (A–D) according to the primary post-operative morbidity of interest reported and the surgical procedure undertaken (Table 1). Group A consists of studies which reported

Group B consists of studies which reported all post-operative complications for horses undergoing colic surgery (n = 29 studies). Group C consists of studies which reported the prevalence of a specific post-operative complication including postoperative colic after elective or non-abdominal surgery (n = 5 studies), post-operative colic in a combined population of all types of surgery (n = 1 study), abdominal incisional site infection/complication after colic surgery (n = 14 studies), surgical site infection/complication after elective or non-abdominal surgery (n = 3 studies), post-operative colitis (n = 1 study), post-operative corneal abrasion (n = 1 study), post-operative pneumonia or sinusitis (n = 1 study), post-operative thrombophlebitis (n = 1 study), post-operative lameness (n = 1 study) and post-operative laminitis (n = 1 study). Group D consists of studies which reported post-operative complications after a specific surgical procedure including castration/cryptorchidectomy (n = 3 studies).

3.2 | Types and frequency of morbidities reported Within the 67 studies included in this review, 71 different types of post-operative morbidity were reported (Table 2). The seven most frequently reported post-operative complications affecting horses undergoing elective surgery or colic surgery were: colic (n = 36 reports); surgical site complication (infection or drainage) (n = 35); lameness (total n = 31; non-specific lameness n = 4, laminitis n = 19 and myopathy or neuropathy n = 8); diarrhoea or colitis (n = 30); fever/pyrexia (n = 26), jugular thrombophlebitis/thrombosis (n = 17) and respiratory complications (n = 15). Post-operative reflux or ileus (n = 26) and peritonitis (n = 10) were only reported in horses after colic surgery (Table 2).

3.3 | PICO question analysis The data collected from the individual studies was appraised and statistically analysed and this information was used to answer the following series of PICO questions.

3.3.1 | PICO: What is the overall prevalence of post-operative complications in horses undergoing elective or non-abdominal surgery under GA? Six studies reported an overall proportion of post-operative complications in horses undergoing elective or non-abdominal surgery (Table 3). The studies involved a heterogenous population in terms of surgical procedure and the time period from which data were collected was quite wide ranging (1–21 years), which may influence results. Four of the studies were retrospective which may limit the level of evidence offered; however, all but one of the studies reported consistent findings (Table S2). Therefore, there is low to moderate certainty that the overall proportion of post-operative complications in horses undergoing elective or non-abdominal surgery is between 4.3% and 25.0% (Table S2). The weighted mean proportion of overall complications, which accounts for variable population size between studies, is 17.48% (95% CI: 13.20–22.92) (Table 4, Figure 2). The lowest incidence of overall post-operative complications (4.3%) was reported by a study involving horses undergoing elective arthroscopy15 while a higher rate of

post-operative complications (25%) was reported in horses undergoing non-abdominal surgery.5 The heterogeneity of surgical procedures included in this sub-group (elective arthroscopy, non-abdominal surgery, cryptorchidectomy, elective surgery and synovial endoscopy) may have contributed to the variation in results. Borland et al. compared post-operative morbidity from two different time periods, with the authors testing the null hypothesis that prevalence and type of post-operative morbidity would not change over time in a single centre.5 In fact, the overall prevalence of morbidities actually increased as did some individual morbidities such as: colic, thrombophlebitis, pyrexia, lameness, neuropathy and myopathy. However, the incidence of diarrhoea, respiratory distress and wounds sustained in recovery decreased.5 The authors discussed that the reason for the overall increase was likely to be multifactorial and may include better recording practices, a change in the population of horses or a change in clinical practice over time.5 Another important finding in that study was the doubling (7.7%– 18.5%) of the prevalence of post-operative colic between the two time frames.5 The reason for this increase remained unknown; however, the follow-up time for the detection of colic was different between the two data sets; 72 h post-anaesthesia versus time until discharge which, as the authors discuss, may explain, in part, the increased rate.5 This point is highly relevant for our review as a whole. If the follow-up time varies between studies, it can be expected to affect the opportunity for complication detection and thereby influence reported rates and introduce bias.

3.3.2 | PICO: What is the overall prevalence of post-operative complications in horses undergoing colic surgery under GA? Fifteen studies reported an overall proportion of post-operative complications in horses undergoing colic surgery (Table 5). Eleven of the studies had sample sizes less than 200 and there was inconsistency between studies in the findings reported, with five of the studies reporting complication prevalence equal to or less than 42% while the rest of the studies yielded complication percentages from 47% to 93%. Surgical procedure heterogeneity was also significant and all but one of the studies were retrospective in design (Table S3). Therefore, based on current evidence, there is low certainty that the overall prevalence of post-operative complications for horses undergoing colic surgery is between 31.0% and 93.18% (Table S3). The weighted mean proportion of overall complications was 55.62% (95% CI: 45.79– 65.03) (Table 4, Figure 2). This is significantly higher than the weighted mean of the overall prevalence of post-operative complications in horses undergoing elective/non-abdominal surgery which was 17.48% with a 95% CI: 13.20–22.92 (OR 6.63; 95% CI: 5.83–7.56; $p < 0.001$) (Table 4). The heterogeneity in the precise surgery performed may contribute to the variation in reported outcomes. Two studies involving horses undergoing large colon surgery reported very different complication rates (42% vs. 93%).6,32 However, the nature of the surgical lesion and hence the surgical procedure performed may explain these findings, as horses undergoing large colon resection and anastomosis surgery attracted a higher percentage of complications compared with non-strangulating large colon lesions.6,32 Similarly, the lowest proportion of complications reported from the group as a whole was associated with horses undergoing small intestinal surgery where resection was not performed.21 Complexity of the surgical procedure may affect surgery duration which may also influence results. In a population of horses undergoing pedunculated lipoma surgery, the risk of complication was increased when duration of surgery exceeded 150 min.23 The only prospective study in the group analysed serial post-anaesthetic venous lactate measurements and found that horses were twice as likely to develop post-operative complications when venous lactate was >5 mmol/L.29

3.3.3 | PICO: What is the reported prevalence of post-operative colic in horses undergoing elective or non-abdominal surgery compared with colic surgery under GA? Our review identified 36 studies reporting the prevalence of postoperative colic. Of those, 13 involved horses undergoing nonabdominal or elective surgery, 22 involved horses undergoing colic surgery and one study13

involved two groups of horses undergoing either colic or non-colic surgery (Table 6). Findings were generally consistent among the studies, although there was considerable surgical type heterogeneity and variation in follow-up periods which may introduce bias and influence results (Table S4). Therefore, based on the existing body of evidence, there is a low to moderate degree of certainty that the prevalence of post-operative colic in horses undergoing elective or non-abdominal surgery is between 0.22% and 18.5% and between 4.67% and 60.9% after colic surgery (Table S4). The weighted mean proportion of post-operative colic after colic surgery (26.46%; 95% CI: 19.11–35.97) is significantly higher than after elective/non-abdominal surgery (7.45%; 95% CI: 4.83–11.76) (OR 4.11; 95% CI: 3.60–4.71; $p < 0.001$) (Table 4, Figure 2). The recent large retrospective study by Skrzypczak et al. which involved horses undergoing all types of surgery (colic and non-colic), reported a post-operative colic prevalence of 2.6% after non-colic procedures and 26.7% after colic surgery.13 In that study, the prevalence of colic after non-colic procedures was a little lower than the 95% confidence interval (4.83%–11.76%) we calculated, based on the studies included in this review; however, the heterogeneity of surgical procedures may explain this variation. The proportion of horses experiencing post-operative colic after colic surgery reported by Skrzypczak et al. is consistent with the mean complication percentage calculated from the findings of the studies included in this review (26.46%; 95% CI: 19.11–35.97). The aetiology of colic is likely to differ in horses after elective or non-abdominal surgery compared with colic surgery, therefore, the risk factors for each group have been considered separately. Risk factors for colic after elective or non-abdominal surgery were investigated by six separate studies.5,17,35,36,38,39 Surgical duration was associated with an increased risk of colic in one study ($p = 0.05$)5 and a surgery duration >60 min was also associated with an increased risk of reduced faecal output (OR 2.7; 95% CI: 1.2–6.1) in another retrospective study.34 When a combined population of horses undergoing either non-colic or colic surgery was analysed retrospectively, procedure time >2 h remained as an independent risk factor for post-operative colic (OR 4.13; 95% CI: 1.52–11.22; $p = 0.006$).13 The effect of surgical procedure on post-operative colic risk was analysed by several studies. Orthopaedic surgery was associated with an increased risk of colic in one study (OR 3.9; 95% CI: 1.3–12.2; $p < 0.05$)39 and reduced faecal output (≤3 defecations per 24-h period after surgery) (OR 3.1; 95% CI: 1.1–9.2) in another.34 Interestingly, in the same study, of the horses which showed signs of colic, all had reduced faecal output, but 73% of the horses that developed reduced faecal output did not show signs of colic.34 Several studies investigated the influence of drug administration on post-operative colic risk. Morphine administration was associated with a fourfold increase in risk of colic (OR 4.11; 95% CI: 1.39–12.2; $p = 0.01$) versus butorphanol or no opioid administration in horses undergoing orthopaedic surgery.38 However another study found no such association ($p = 0.5$).35 Both studies used morphine doses within a similar range of 0.1–0.17 mg/kg. The recent retrospective study investigating the association between post-operative colic and perianaesthetic hydromorphone administration in horses undergoing non-colic or colic surgery identified no effect (OR 1.61; 95% CI: 0.71–3.62; $p = 0.3$).13 Regarding other drugs, one study found an increased risk of postoperative colic after administration of sodium benzylpenicillin (NaBP) compared with alternative antimicrobials (mainly enrofloxacin) (OR 2.77; 95% CI: 1.69–4.50).17 When faecal output was specifically analysed, the absence of administration of phenylbutazone postoperatively was associated with a fivefold increase in the risk of postoperative reduced faecal output (OR 5.7; 95% CI: 1.8–18.0).34 The authors of that study discussed that it is probable that surgically induced pain contributes to the development of post-operative reduced faecal output.34 One retrospective study involving horses undergoing elective surgery, investigated risk factors for post-anaesthetic gastrointestinal dysfunction and found five significant factors; breed (OR 0.80; 95% CI: 0.63–1.01; $p = 0.05$), intraoperative peripheral blood lactate (OR 1.38; 95% CI: 1.04–1.83; $p = 0.02$), right lateral recumbency (OR 1.34; 95% CI: 0.80–2.25; $p = 0.04$), post-anaesthetic rectal temperature (OR 0.63;

95% CI: 0.43–0.92; p = 0.03) and hours to first passage of faeces (OR 1.11; 95% CI: 1.02–1.20; p < 0.01).36 Opioids were administered to horses in this study but the specific type of opioid was not stated.36 One other study also found that breed influenced colic risk and reported that Thoroughbred horses compared with non-Thoroughbred horses were at an increased risk of postoperative colic (OR 2.93; 95% CI: 1.73–4.96; p < 0.001).17 The only multicentre study in the current evidence base which investigated colic after elective surgery reported a significant difference between centres in colic prevalence.39 This finding highlights the differences which may exist between institutions in perioperative management, post-operative monitoring, the methods employed to detect colic and the employed definition of colic, making it difficult to accurately compare studies. In the current evidence base, most commonly, post-operative colic was reported without a specific diagnosis made (33%–57%), but when a diagnosis was made, large colon impaction was the most common finding as a complication after non colic procedures (16.7%–21.4%).36,39 With regards to reporting the presence of colic after colic surgery, three studies explored this occurrence.26,30,50 Stephen et al. reported an overall complication percentage after colic surgery but not for specific complications.30 Instead, that study explored risk factors in depth and found that in horses undergoing surgery for small intestinal volvulus, resection at surgery (p = 0.003), involvement of the ileum at surgery (p = 0.022) and performance of a jejunoca ecostomy at surgery (p = 0.02) all increased the risk of repeat colic.30 In horses undergoing all types of colic surgery, Mair and Smith found that the prevalence of post-operative pain was significantly higher after intestinal resection (OR 3.71; 95% CI: 2.02–6.81; p < 0.001) compared with no resection, small intestinal distension at surgery compared with none (OR 3.23; 95% CI: 1.72–6.91; p < 0.0008), ischaemic intestine left in the abdomen compared with not (OR 3.68; 95% CI: 1.24–11.63; p = 0.006), post-operative ileus compared with no ileus (OR 6.45; 95% CI: 3.07–13.85; p < 0.001) and post-operative peritonitis compared with no peritonitis (OR 13.6; 95% CI: 1.59–629.12; p = 0.002).26 Immonen et al. reported relaparotomy in the short post-operative term due to either continuous pain, colic, reflux, or incisional dehiscence, and therefore the percentage of colic per se could not be included in the current analysis.50 However, that study did explore risk factors for repeat colic and found that the odds of post-operative colic was 3.3-fold higher (OR 3.27; 95% CI: 1.31–8.19; p = 0.01) following surgery for large intestinal lesions compared with small intestinal lesions.50 Regarding follow-up periods, Proudman et al. followed cases for up to 500 days post-operatively and found that the majority of first colic episodes occurred within 100 days of surgery but that they can occur up to 1 year post-operatively.45 Theirs was one of the longest follow-up periods of the studies examined, but interestingly, Mair and Smith, reported a very similar colic rate, about 30%, in a comparable population of horses (similar sample size and surgery type) within a much shorter follow-up period, being time to hospital discharge.

3.3.4 | PICO: What is the reported prevalence of post-operative surgical site complications (infection or drainage) in horses undergoing elective or nonabdominal surgery compared with colic surgery under GA? A total of 35 studies reported post-operative surgical site complications (infection or drainage), of which five studies involved horses undergoing elective or non-abdominal surgery and 30 involved horses undergoing colic surgery (Table 7). A small number of studies were retrieved which involved horses undergoing elective or non-abdominal surgery and while they reported consistent findings, all studies were retrospective in design which may limit the level of evidence offered. A larger number of studies were retrieved for horses undergoing colic surgery; however, the time period from which data were collected and follow-up periods varied significantly between studies (Table S5). Therefore, there is low to moderate certainty that the prevalence of surgical site complications after elective or non-abdominal surgery is 1.35%–3.7%, while there is moderate certainty that the prevalence of surgical site complications after colic surgery is between 5.0% and

42.2% (Table S5). The weighted mean proportion of surgical site complications after colic surgery (18.03%; 95% CI: 12.93–25.29) is significantly higher than after elective/non-abdominal surgery (2.07%; 95% CI: 0.82–5.33) (OR 11.48; 95% CI: 7.97–17.09; p < 0.001) (Table 4, Figure 2). Of the 30 studies that involved horses undergoing colic surgery, seven also reported the following rates of incisional hernia development; 2.2%,62 3.2%,40 5.7%,49 5.8%,63 6.9%,55 8.4%45 and 10%.6 One study commented that the prevalence of incisional hernia development was higher in horses with an incisional site infection compared with those without.63 Salciccia et al. found that the odds for horses undergoing repeat laparotomy to develop an incisional infection compared with horses undergoing single laparotomy were increased 6.5-fold (OR 6.51; 95% CI: 2.67–15.88; p < 0.001).67 In a multicentre retrospective study, intraoperative hypercapnia (OR 1.05; 95% CI: 1.001–1.11; p = 0.04), placement of an abdominal bandage (OR 11.9; 95% CI: 2.6–54; p = 0.001) and previous celiotomy (OR 4.6; 95% CI: 1.5–14.8; p = 0.009) were associated with incisional site herniation risk.62 The risk factors for incisional site infection have been reviewed in detail elsewhere by Salem et al. and Kelmer and readers are referred to these reviews

3.3.5 | PICO: What is the overall reported prevalence of post-operative lameness in horses undergoing surgery under GA? Four studies reported the prevalence of post-operative lameness5,14,18,37 (Table 8). In horses after non-abdominal surgery, two studies reported a lameness prevalence of 0.6% and 3% which also included cases of post-operative myopathy and neuropathy.5,14 Two studies involving horses undergoing elective orthopaedic surgery reported post-operative lameness rates of 0.74% and 11.0%.18,37 Preexisting lameness status was not stated by either study. Still, with this evidence, the weighted mean proportion of general lameness was reported to be 3.89% (95% CI: 2.37–6.91) (Table 4, Figure 2). It is difficult to draw conclusions relating to post-operative lameness from the findings of just four studies with a heterogenous surgical population but as a larger number of studies specifically reported post-operative myopathy, neuropathy and laminitis, these complications were analysed separately with the following two PICO questions.

3.3.6 | PICO: What is the reported prevalence of post-operative myopathy or neuropathy in horses undergoing elective or non-abdominal surgery compared with colic surgery under GA? Six studies reported the prevalence of post-operative myopathy or neuropathy with two involving horses undergoing elective or nonabdominal surgery and four involving horses undergoing colic surgery (Table 9). The small number of studies and retrospective study design limited the level of evidence offered for studies involving elective or non-abdominal surgery. Studies involving horses undergoing colic surgery were also sparse in number but there were consistent findings between studies together with similar data collection time frames and follow-up periods (Table S6a). Therefore, there is low certainty that the prevalence of post-operative myopathy or neuropathy in horses undergoing elective or non-abdominal surgery is between 0.84% and 3.30% and low to moderate certainty that it is between 0.4% and 3.7%. after colic surgery (Table S6a). The weighted mean proportion of myopathy or neuropathy after colic surgery (1.78%; 95% CI: 0.74–5.00) is not significantly different to that after elective/non-abdominal surgery (2.08%; 95% CI: 0.68–6.48) (OR 1.86; 95% CI: 0.86–4.16; p = 0.16) (Table 4, Figure 2). The fact that reported prevalence of post-operative myopathy or neuropathy was similar for horses undergoing elective or nonabdominal surgery compared with colic surgery, may be due to the heterogeneity of the procedures involved and the small number of studies available. Despite the small number of studies, in this evidence base, a number of risk factors for post-operative lameness have been reported. In the study by Laurenza et al., the risk factors for post-anaesthetic neuromuscular complications included increased bodyweight (OR 1.26; 95% CI: 1.00–1.63) for each 100 kg increase, duration of anaesthesia (OR 1.35; 95% CI: 1.05–1.71) for every additional hour of time, senior surgeon (OR 2.1; 95% CI: 1.1.0–4.44) and decreased blood pressure

(OR 1.25; 95% CI: 0.95–1.63) for every 10 mmHg decrease in blood pressure.4 In that study, the risk was reduced when the surgery was an arthroscopy (OR 0.55; 95% CI: 0.26–1.06)

3.3.7 | PICO: What is the reported prevalence of post-operative laminitis in horses undergoing elective or non-abdominal surgery compared with colic surgery under GA? Post-operative laminitis was reported by 19 studies, all but one of which, involved horses undergoing colic surgery (Table 10). Findings were consistent across the studies but data collection time frames and follow-up periods were variable which may introduce bias and affect results (Table S6b). Therefore, there is low to moderate certainty that the prevalence of post-operative laminitis is 0.4%–12.0%. (Table S6b). The weighted mean proportion of laminitis after colic surgery (3.57%; 95% CI: 1.72–7.72) is significantly higher than after elective/non-abdominal surgery (0.66%; 95% CI: 0.44–0.98) (OR 4.30; 95% CI: 2.79–6.91; $p < 0.001$) (Table 4, Figure 2). It must be reiterated that there was only one study contributing prevalence data for the elective/non-abdominal group. The demographic of the horses affected may indicate that the aetiology of laminitis in this population is likely to be toxaemia/endotoxaemia-associated rather than contra-lateral limb weight-bearing as may occur after some orthopaedic procedures. Cohen et al. reported that the prevalence of laminitis in their prospective case control study of horses undergoing colic surgery, was significantly higher in horses that experienced post-operative ileus compared with those that did not ($p = 0.05$).54 One retrospective study examined several variables as risk factors for laminitis after colic surgery and found that only the absence of low molecular weight heparin administration, used for its anti-inflammatory properties, was a significant risk factor (OR 0.27; 95% CI: 0.092–0.77; $p = 0.02$).72 Few other studies explored risk factors associated with the development of laminitis, possibly due to the low numbers affected

3.3.8 | PICO: What is the reported prevalence of post-operative diarrhoea or colitis in horses after elective or non-abdominal surgery compared with colic surgery under GA? Thirty studies reported the prevalence of post-operative diarrhoea or colitis, of which six involved horses undergoing elective or nonabdominal surgery and 24 involved horses undergoing colic surgery (Table 11). Findings were generally consistent across the studies; however, surgical procedure heterogeneity and a wide-ranging time frame from which data was collected may influence results (Table S7) Therefore, there is low to moderate certainty that the prevalence of post-operative diarrhoea or colitis in horses after elective or nonabdominal surgery is between 0.6% and 10.0% and between 1.1% and 69.7% in horses undergoing colic surgery (Table S7). The weighted mean proportion of diarrhoea or colitis after colic surgery (18.72%; 95% CI: 12.77–27.40) is significantly higher than after elective/non-abdominal surgery (2.84%; 95% CI: 1.33–6.27) (OR 12.50; 95% CI: 9.15–17.57; $p < 0.001$) (Table 4, Figure 2). The study by Cribb et al. involved horses undergoing elective cryptorchidectomy and reported an inconsistently high percentage of postoperative diarrhoea compared with the other studies in the group.16 However, cryptorchidectomy involves abdominal entry which may explain the disparity in findings. The two studies reporting the highest prevalence of post-operative diarrhoea or colitis involved horses undergoing colic surgery specifically affecting the large colon.6,74 Importantly, the definition of diarrhoea varied between the studies included in this review. Some studies simply stated that diarrhoea was defined as 'passage of soft or liquid faeces with increased volume and frequency'. 5 Other studies included specific frequencies and duration, including 'persistent watery or loose faeces for more than 24 h duration', 42 'on more than 2 consecutive occasions' 27 or 'more than one loose bowel movement during the post-operative period'. 48 The study by Givan et al. specifically examined risk factors associated with the development of colitis after colic surgery and clearly defined colitis as post-operative diarrhoea with one or more of the following criteria: fever, leucopenia, or ultrasonographic evidence of colon inflammation (colon wall thickness >4 mm).24 This retrospective study found that post-operative

colitis risk was higher in patients after pelvic flexure enterotomy (OR 3.7; 95% CI: 1.7–7.9; p = 0.001), with post-operative leucopenia or leucocytosis (OR 21.2; 95% CI: 9.7–46.7; p < 0.001) or with a plasma lactate 2.0–4.0 mmol/L (OR 3.0; 95% CI: 1.3–6.7; p < 0.008). The same study also reported that patients diagnosed with colitis had a longer median length of hospitalisation (9 days; range 2–21) compared with patients that did not develop colitis (7 days; range 2–25, p < 0.001), but that survival to discharge was similar between groups (95% vs. 93%).24 Another retrospective study reported that in horses undergoing surgery for small intestinal volvulus, increased venous blood pH was associated with a decreased risk of diarrhoea (p < 0.027) and increased serum total plasma protein was associated with an increased risk of diarrhoea (p = 0.03).30 The presence of diarrhoea 48 h post-operatively was identified as a risk factor for the development of incisional site infection in one prospective blinded controlled clinical trial in horses following colic surgery (OR 20; 95% CI: 1.5–277; p = 0.02).

3.3.9 | PICO: What is the reported prevalence of post-operative fever or pyrexia in horses after elective or non-abdominal surgery compared with colic surgery under GA? A total of 26 studies reported the prevalence of post-operative fever/ pyrexia, of which nine involved horses undergoing elective or nonabdominal surgery and 17 involved horses undergoing colic surgery (Table 12). Findings were consistent across the studies, but surgical type heterogeneity and variable time frames from which data were collected limited the level of evidence offered (Table S8). Therefore, based on the existing literature, there is low to moderate certainty that the prevalence of fever/pyrexia in horses after elective or nonabdominal surgery is between 0.28% and 23.7% and between 3.0% and 85.0% after colic surgery (Table S8). The weighted mean proportion of fever or pyrexia after colic surgery (38.45%; 95% CI: 30.57– 47.18) is significantly higher than after elective/non-abdominal surgery (6.99%; 95% CI: 4.26–11.77) (OR 17.97; 95% CI: 14.58–22.39; p < 0.001) (Table 4, Figure 2). Across the studies, there were nine different numerical definitions of fever/pyrexia, with a discrepancy of 1.4C. The temperature above which fever/pyrexia was diagnosed included >38.0C,74 >38.3C,23,57 >38.4C,33 >38.5C,40,48,73,75 >38.6C,6,17,24,27,29,37,43,49 >38.89C,42 >38.9C,44 >39.0C5,14 and >39.4C.28 The numerical definition of fever/pyrexia was not stated in five studies.15,16,18,22,47 This wide variation in the numerical limit at which fever/pyrexia is diagnosed influences overall results for prevalence. Furthermore, the duration of fever/ pyrexia required for inclusion as a morbidity differed between studies with some studies making the diagnosis after a single pyrexic episode (>38.3C) measured at any time point during hospitalisation,57 while others considered pyrexia of >38.5C to be a post-operative complication only if the duration was >48 h.75 Age is a risk factor for the development of fever/pyrexia after certain procedures. Kummer et al. reported a relatively high prevalence of fever after castration using an inguinal approach and found that 27% of horses aged 1–4 years were febrile compared with 18% and 8% of horses aged 5–10 years and more than 10 years respectively, (p = 0.07).33 Although these numbers failed to reach statistical significance, there was a non-significant trend for a higher proportion of post-castration fever in younger horses (10 years). Similarly, in another study involving horses undergoing castration using an open technique, all horses that experienced fever/pyrexia were <4 years of age, while overall patient age in

this study ranged from 9 months to 13 years From all the studies identified in this review, Freeman et al. reported the highest prevalence (85%) of post-anaesthetic pyrexia in horses after colic surgery and defined pyrexia as >38.3 C...

measured at any point during hospitalisation in the post-operative period.57 The authors of this study concluded that post-operative pyrexia is common after colic surgery but the presence of pyrexia is not necessarily always associated with impending bacterial infection.57 The intensity of

the pyrexia was categorised in a way which allowed further analysis of the results and it was identified that a peak temperature of >39.2C was associated with an increased risk of post-operative infection (OR 5.06; 95% CI: 2.10–12.20; p < 0.001).57 Interestingly, Gazzerro et al. also stratified the intensity or severity of fever, differentiating fever (>38.6C) from high fever (>39.4C).43 This study found that in horses undergoing all types of colic surgery, fever >38.6C was associated with colic (p < 0.001) and repeat laparotomy (p = 0.03) and high fever (>39.4C) was associated with diarrhoea (p = 0.039), colic (p = 0.037), repeat laparotomy (p = 0.01) and laminitis (p = 0.01).43 Finally, the study by Stephen et al. identified, in horses undergoing surgery for small intestinal volvulus that longer duration of pain (p = 0.014), the presence of reflux before surgery (p = 0.019) and flunixin administration (p = 0.046) before referral decreased the risk of post-anaesthetic fever identified via univariate analysis.

3.3.10 | PICO: What is the reported prevalence of post-operative jugular thrombophlebitis/thrombosis in horses after elective or non-abdominal surgery compared with colic surgery under GA? Seventeen studies reported post-operative jugular vein thrombophlebitis/thrombosis, of which two studies involved horses undergoing elective or non-abdominal procedures and 15 involved horses undergoing colic surgery (Table 13). Only two studies were retrieved involving elective/non-abdominal surgery; however, both studies reported consistent findings, were prospective in design and represented the general hospital surgical population. A larger number of studies were retrieved involving horses undergoing colic surgery, also reporting consistent findings; however, the time frame from which data were collected was wide-ranging and varying definitions of thrombophlebitis were used which may introduce reporting bias and affect findings (Table S9). There is low to moderate certainty that the prevalence of jugular vein thrombophlebitis/thrombosis in horses undergoing elective or non-abdominal procedures is 0.9%–2.0% and between 4.8% and 18.4% after colic surgery (Table S9). The weighted mean prevalence of jugular vein thrombophlebitis/thrombosis after colic surgery (9.34%; 95% CI: 5.46–15.87) is significantly greater than after elective/non-abdominal surgery (1.55%; 95% CI: 0.53–4.70) (OR 9.15; 95% CI: 5.11–18.55; p < 0.001) (Table 4, Figure 2) Varying clinical definitions were used for jugular thrombophlebitis by the 17 studies included in this review. Four studies stated detailed definitions of thrombophlebitis, which included:

• Clinical signs (swelling over the affected vein, with or without occlusion of the vein) and results of ultrasonographic evaluation. Septic thrombophlebitis was diagnosed if there was heat and pain on palpation, fever, neutrophilic leucocytosis and ultrasonographic evidence of cavitation within the thrombus.

• Inflammation of a vein with blood clot formation inside the vein at the site of inflammation. Clinical signs: hardening, redness, warmth, pain along a superficial vein (worse when pressure is applied). Diagnosis on basis of clinical signs or ultrasonography.14 • Swelling over the vein with varying degrees of vein occlusion diagnosed by palpation and ultrasonographic evaluation.64 • Inflamed vein with in vivo blood clot formation with diagnosis made on basis of physical signs (venous hardening, redness, warmth and/or pain), or ultrasonography

Two studies stated simpler definitions of thrombophlebitis: • Thrombosis of the jugular vein requiring treatment (yes/no).43 • Thickening and purulent exudate at the catheter insertion site, swelling, tenderness, warmth, presence of a cord-like vein, or pain response.73 Eleven studies did not define thrombophlebitis.19,20,22,23,27,28,42,44,45,49,67 Not all studies used ultrasonography in their diagnosis of thrombophlebitis, which may have led to underreporting.73 When considering the risk factors for thrombophlebitis in horses undergoing nonabdominal surgery, the study by Borland et al. found that geldings showed lower odds (OR 0.12; 95% CI: 0.02–0.84) of developing

catheter site swelling, while the likelihood of thrombophlebitis increased (OR 1.20; 95% CI: 1.01–1.41; p = 0.04) for every year of life.5 The effect of age was investigated elsewhere; however, no difference was detected in thrombophlebitis prevalence between geriatric (8%) and non-geriatric (11%) horses undergoing colic surgery (p = 0.4).43 Lankveld et al. specifically investigated the prevalence of post-operative jugular thrombophlebitis when comparing two catheter types in horses undergoing colic surgery.73 Their study reported the highest prevalence of thrombophlebitis, 18.4%, and found that postoperative fever (p = 0.008) and diarrhoea (p = 0.002) were associated with thrombophlebitis development.73 Using data from Proudman et al. in horses undergoing colic surgery,45 French et al. reported a linear relationship between preoperative packed cell volume (PCV) and jugular thrombosis development (OR 1.07; 95% CI: 1.01–1.14; p = 0.022).76 The same study identified that a heart rate (HR) at presentation >60 beats per minute was another risk factor for jugular thrombosis (OR 2.50; 95% CI: 1.10–6.17; p = 0.04) suggesting a predisposing role of hypovolaemia.76 Similarly, Mair and Smith reported that the proportion of jugular vein thrombosis/thrombophlebitis was significantly higher in horses demonstrating post-operative pain compared with those that did not (OR 3.13; 95% CI: 1.15–8.79; p = 0.01), and in horses that developed post-operative shock compared with those that did not (OR 3.63; 95% CI: 1.13–10.56; p = 0.007).26 The administration of glyceryl guaiacol ether (GGE) was hypothesised by French et al. to be associated with the development of jugular thrombosis, but no such association was found (p = 0.23)

3.3.11 | PICO: What is the reported prevalence of post-operative respiratory complications in horses undergoing elective or non-abdominal surgery compared with colic surgery under GA? Thirteen studies reported post-operative respiratory complications with four involving horses undergoing elective or non-abdominal procedures, eight involving horses undergoing colic surgery and one study involving horses undergoing all types of surgeries (emergency and elective) (Table 14). While findings were consistent across studies, there was variation in the nature of the respiratory morbidities reported and all but one of the studies were retrospective in design which limits the level of evidence offered (Table S10). Therefore, there is low certainty that the prevalence of post-operative respiratory complications in horses undergoing elective or non-abdominal surgery is 0.3%–2.1% and 0.9%–19.2% after colic surgery (Table S10). The weighted mean proportion of respiratory complications after colic surgery (5.44%; 95% CI: 3.02–10.22) was significantly higher than after elective/non-abdominal surgery (1.11%; 95% CI: 0.47–2.62) (OR 4.96; 95% CI: 3.01–8.63; p < 0.001) (Table 4, Figure 2). Between all the studies evaluated, there was large variation in the definition of individual respiratory morbidities and consequently the frequency of conditions reported. Seven studies specifically reported the prevalence of pneumonia or pleuro-pneumonia after colic surgery with consistent findings between 0.9% and 7.0%.23,24,43,44,57,59,77 Using a control population, one study reported that horses with pneumonia were significantly more likely to have postoperative fever and perioperative reflux than matched controls.77 The study by Jago et al. was the only study that report tracheal mucosa sloughing which occurred in four horses in their study population.17 However, since this diagnosis requires airway endoscopy, the true prevalence of this complication may be unknown. In the retrospective study by Laurenza et al. of all horses undergoing GA (for non-colic and colic surgeries), the odds of respiratory complications was increased 1.71 times (95% CI: 0.91–3.06) for every 10 years of age, by 1.57 times (95% CI: 1.08–2.42) with every 100 kg bodyweight increase, 1.49 times (95% CI: 1.12–1.94) for each additional hour of anaesthesia and 2.58 times (95% CI: 1.04– 7.79) when the surgeon was a senior.4 The odds were reduced (OR 0.66; 95% CI: 0.47–0.92) when the arterial oxygen tension/fractional inspired oxygen tension (PaO_2/FiO_2) ratio was one unit greater

3.3.12 | PICO: What is the reported prevalence of post-operative corneal abrasions after surgery under GA? Corneal ulceration or keratitis was reported retrospectively in only four studies which

found a percentage between 0.19% and 0.37% in horses after elective or non-abdominal surgery17,18 and 0.5%–1.2% after colic surgery.22,28 However, a prospective study involving 40 horses which specifically investigated perioperative corneal trauma, reported the presence of corneal abrasion in 17.6% of horses but corneal ulceration in none.78 These results may indicate that corneal abrasions may be clinically under-diagnosed unless fluorescein stain is routinely applied post-operatively. In that study, the development of corneal abrasion was significantly associated with duration of GA ($p = 0.027$), total duration of recumbency ($p = 0.04$) and intraoperative recumbency position (dorsal vs. lateral) (OR 0.06; 95% CI: 0.01–0.45; $p = 0.008$), lateral recumbencies having a higher risk of developing corneal abrasions.78

3.3.13 | PICO: What is the reported prevalence of post-operative peritonitis and post-operative ileus or reflux in horses after colic surgery Post-operative peritonitis and post-operative ileus or reflux were reported by 10 and 26 studies respectively, all involving horses undergoing colic surgery. The prevalence of post-operative peritonitis was 0.8%,24 1.8%,27 3.1%,26 4.3%,42 7%,23,47,74 7.2%,50 10.9%44 and 18.5%.64 The reported prevalence of post-operative ileus or reflux was; 3.3%,6 7.1%,42 9.6%,40,45 10.7%,24 11%,21 13.7%,26 14.7%,22,27 15.2%,69 16%,19 17.6%,25 18.7%,54 20.4%,49 20.9%,66 22.6%,43 26%,29 27.2%,50 29.9%,20 31%,46,64 34%,23 34.6%,67 46.7%,44 47.3%48 and 53%.47 Since no reports of peritonitis or post-operative ileus or reflux were found in studies involving horses undergoing elective or non-abdominal surgery, comparisons could not be made between surgery groups so further analysis was not performed.

3.3.14 | Other post-operative morbidities A number of other post-operative morbidities were reported by several studies but the frequency of reporting was too low to allow meaningful analysis (Table 2).

3.4 | Limitations 3.4.1 | Study design The first limitation is that the majority of the studies (53 out of 67) evaluated in this systematic review were retrospective in design. Retrospective studies rely on data collection systems that may not have been designed to accurately obtain the data required by the study.79 Therefore, this type of study offers a relatively low level of evidence due to their tendency to suffer from reporting inaccuracies, missing data and non-standardised anaesthetic or treatment protocols. Furthermore, when data is collected from a long time interval this may introduce bias due to a tendency for evolving patient management, changes in veterinary personnel, and updated facilities to influence outcome. Even in prospective studies, while a longer time frame of data collection is likely to result in a larger sample size and therefore an increase in the quality of evidence offered, it may also introduce reporting fatigue and affect accurate data acquisition. Finally, follow up periods were different between studies which may heavily influence results as a shorter period of post-operative monitoring for complications is likely to result in underreporting of those issues.

3.4.2 | Defining post-operative morbidities The definitions used for the various post-operative complications varied widely between the studies examined in this review. For example, Robson et al. clearly defined their criteria for an incisional complication in terms of positive bacterial culture or the physical appearance/ characteristics of the incision,65 while other studies adopted a different approach and defined an incisional complication as any incisional drainage present from 12h or longer after surgery56 or any discharge from the wound. The results of a recent scoping review of post-operative complications in equine colic surgery also reported that the definitions of most

complications used in individual studies were highly variable, with as many as 20 different definitions stated for one morbidity.80 Accurate comparison between studies evaluating post-operative colic for example is difficult because of the lack of a clear consensus on what specific symptoms and severity justify a diagnosis of colic and objective measures of pain are rarely used.11 In the current review, the variation in morbidity definitions also extended to those complications that would have arguably quantifiable scales such as pyrexia/fever, where there was up to 1.4C variation in cut-off temperatures used across studies. Therefore, we can say that differences in definitions are likely to introduce some bias and influence the reported prevalence. The lack of homogeneous and consistent definitions for common postoperative complications in horses makes it difficult to interpret data on complication rates, resulting in risks of underestimating or overestimating the safety of a specific treatment.80 It would appear that establishing consensus definitions of post-operative complications in horses is a simple step that is urgently needed to reduce study heterogeneity and improve risk estimation. A second limitation in morbidity definition was the different stratification between studies. Severity of fever, for example, was graded in some studies yet not others. Implementing a grading scale to evaluate the severity of complications may have identified further significant differences.27 Complication classification systems and grading criteria have been proposed, but the results of another equine literature review of post-operative complications also concluded there was a lack of reference to previously proposed defining and grading systems in the studies analysed

3.4.3 | Diagnosing post-operative morbidities Limitations in diagnostic methods or the desire (or financial ability) to investigate is another factor which may influence the reported prevalence of certain morbidities. For example, Garcia-Seco et al. reported 3% gastric ulceration detected by gastroscopy, in horses after undergoing colic surgery for pedunculated lipoma.23 However, the true prevalence of post-operative gastric ulceration may be unknown since gastroscopy is rarely performed routinely post-operatively and furthermore, it may be possible that the gastric ulceration identified was pre-existing. Another example is that some studies were able to detect leucopenia or elevated serum creatinine presumably by testing post-operatively. However, the true prevalence of these conditions may be hard to determine as few studies employed the diagnostics required to detect them.

3.4.4 | Study populations Another limitation of our review is the use of different population inclusion and exclusion criteria used by the studies included, which differ depending on the primary objective of the paper. For example, Robson et al. excluded records without arterial blood gas data as this was required to fulfil their primary objective,65 while other investigations would not necessarily require this data resulting in a different study population. A number of studies selected specific subpopulations according to specific types of surgery for example, castration, large colon resection and anastomosis. This makes comparison between studies more challenging and limits the directness of the evidence when applying the findings to a more general surgical caseload. Furthermore, in order to gain larger sample sizes, those studies requiring a specific surgery type tend to collect data over longer time frames which may introduce bias since anaesthetic and surgical management, personnel and equipment tend to change over time and this may affect outcome.

3.4.5 | Sample size calculations A final set of limitations is posed by the infrequent inclusion of sample size calculations. Sample size calculations were performed in only 8 of the 67 studies examined17,38,39,41,56,58,64,68; A common theme to the problem of underpowered studies is that the prevalence of postoperative complications is assumed to be low therefore requiring a large sample size to reach statistical power. Senior et al. performed their sample size calculations based on a lower prevalence of postoperative colic of approximately 2.8%38,39 and estimated that

approximately 45 cases would be encountered during a 2-year study period covering approximately 1600 anaesthetic procedures. They reached 45 colic cases before reaching their proposed 1600 cases. In contrast, Jago et al. calculated that based on assumptions of an overall incidence of colic of 10%, with an exposure rate of 60%, the required sample size to have at least 80% power to identify odds ratios of 2 or more, with 95% confidence, was 1022.17 Gustafsson et al. refined their sample size calculations mid-way through data collection when they detected a difference in the prevalence of incisional infection between control and treatment groups of 24% and 4% respectively, allowing a reduction in estimated sample size from 146 to 90 horses.58 One study comparing an intervention, performed their power calculations based on detecting a statistically significant, clinically meaningful outcome, defined as an expected reduction in complications from 26% to 4 |

CONCLUSION According to our initial objectives, this review identified and evaluated the relevant studies on this topic published between 2000 and 2023 and estimated overall post-operative complication rates for horses undergoing elective or non-abdominal surgery compared with colic surgery. Secondly, with our proposed PICO questions and with the use of the JBI Critical Appraisal Checklist for Prevalence Studies and the GRADE framework, we found sufficient evidence to conclude that there is an increased prevalence of post-operative complications overall in horses after colic surgery compared with elective/non-abdominal surgery. Specifically, there is an increased prevalence of post-operative colic, surgical site complications, laminitis, diarrhoea or colitis, fever/pyrexia, jugular thrombophlebitis/thrombosis and respiratory complications in horses after colic surgery compared with elective or non-abdominal surgery (Figure 2). Overall, our application of the GRADE framework showed that the body of published studies reporting prevalence of equine postoperative complications offers a low to moderate degree of certainty that the conclusions reached are valid. The current evidence base for the prevalence of equine post-operative complications is sizeable but notably heterogeneous in terms of population sampled and morbidity definitions used. The studies in our review were mainly retrospective, and although sample sizes were generally relatively large, this type of study design limits the quality of evidence offered (Figure 3).

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