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Risk Factors for Dehiscence of Stapled Functional End-to-End Intestinal Anastomoses in Dogs: 53 Cases (2001–2012)

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Abstract

Objective: To identify risk factors for dehiscence in stapled functional end-to-end anastomoses (SFEEA) in dogs.

Study Design: Retrospective case series.

Animals: Dogs (n=53) requiring an enterectomy.

Methods: Medical records from a single institution for all dogs undergoing an enterectomy (2001–2012) were reviewed. Surgeries were included when gastrointestinal (GIA) and thoracoabdominal (TA) stapling equipment was used to create a functional end-to-end anastomosis between segments of small intestine or small and large intestine in dogs. Information regarding preoperative, surgical, and postoperative factors was recorded.

Results: Anastomotic dehiscence was noted in 6 of 53 cases (11%), with a mortality rate of 83%. The only preoperative factor significantly associated with dehiscence was the presence of inflammatory bowel disease (IBD). Surgical factors significantly associated with dehiscence included the presence, duration, and number of intraoperative hypotensive periods, and location of anastomosis, with greater odds of dehiscence in anastomoses involving the large intestine.

Conclusion: IBD, location of anastomosis, and intraoperative hypotension are risk factors for intestinal anastomotic dehiscence after SFEEA in dogs. Previously suggested risk factors (low serum albumin concentration, preoperative septic peritonitis, and intestinal foreign body) were not confirmed in this study.

Stapled functional end-to-end anastomosis (SFEEA) is reported to be a safe and effective technique for apposing intestinal segments in human and veterinary medicine.[1–4] Reported advantages over hand-sewn anastomosis include speed, consistency, repeatability, decreased tissue trauma, improved blood supply to the anastomosis site, superior strength during the lag phase of wound healing, immediate high burst strength, and the ability to appose 2

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DISCLOSURE

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portions of bowel with large differences in lumen diameter.[1,2,5–11] Previous studies have reported that stapled anastomoses can be efficiently and safely performed by nonexpert but trained surgeons,[12] and limited case series have reported staple repairs to be appropriate in situations with confirmed bacterial peritonitis.[1] However, unlike hand-sewn intestinal anastomoses, specific indications and risk factors for dehiscence associated with SFEEA are not well described in veterinary medicine.[13,14] Current evidence does not favor 1 technique over the other, and the choice is based on surgeon preference and cost.

A review of pertinent human literature yielded several studies comparing stapled and hand-sewn anastomosis in specific clinical situations. Multiple studies evaluating ileocolonic anastomoses have suggested a significantly decreased rate of dehiscence after a stapled anastomosis.[4,15–20] However, others have suggested an increased rate of dehiscence in emergency general surgery patients after a stapled anatomosis,[21,22] or no difference in outcome between techniques.[23] No comparative studies in veterinary medicine exist. Additionally, although several risk factors for dehiscence have been described for hand-sewn anastomosis in dogs, no studies have evaluated the risk factors for dehiscence after a SFEEA. This study aims to identify risk factors for dehiscence in SFEEA as a single technique in dogs.

MATERIALS AND METHODS

Medical records from a single institution (Colorado State University, College of Veterinary Medicine & Biomedical Sciences, Fort Collins, CO) for all dogs undergoing an enterectomy from January 2001 to September 2012 were reviewed. Cases or surgeries were included when gastrointestinal (GIA) and thoracoabdominal (TA) stapling equipment was used to create a functional end-to-end anastomosis of the duodenum, jejunum, ileum, colon, or any combination of the four. Multiple surgeries (separate surgical events over multiple days) involving the same animal were only considered for the first stapled resection and anastomosis. Animals were excluded from the study if they were euthanatized or died intraoperatively.

Information for the following preoperative factors was recorded: age, breed, sex, neuter status, body weight, duration of gastrointestinal signs (> or <4 weeks), presence of inflammatory bowel disease (IBD; based on previous clinical diagnosis and response to treatment or definitive histopathologic diagnosis), previous gastrointestinal surgery (within 10 days of enterectomy), and presence of free peritoneal fluid (preoperative or intraoperative). Dogs identified as having preoperative septic peritonitis either had definitive cytological evidence (free or intracellular bacteria), intraoperative confirmation of gastrointestinal leakage, or a positive microbial culture of a swab or fluid specimen obtained from the peritoneal cavity (cases where perforation was suspected intraoperatively, but there were no obvious signs of peritonitis and a negative microbial culture were excluded). Preoperative hematologic parameters collected include red blood cell (RBC) and reticulocyte counts, white blood cell counts, presence of a left shift (band neutrophils >0.3 $10^3/\mu L$), and lymphocyte and platelet counts. Preoperative serum chemistry parameters collected include glucose, albumin, blood urea nitrogen, creatinine, phosphorus, total calcium, total protein, globulin, total bilirubin, and bicarbonate. Hematologic and serum

biochemistry parameters were included when they were collected within the 48 hours preceding the enterectomy. If multiple samples were obtained in that time frame, the sample collected closest to the time of surgery was included. Additionally, whether an animal received nonsteroidal anti-inflammatory drugs, corticosteroids, or chemotherapeutic drugs within 4 weeks preceding surgery or within 1 week postoperatively was recorded.

Recorded characteristics of the surgical procedure included location of anastomosis, whether the margins of the enterectomy were normal (visual inspection or histopathology when available), placement of a suture at the "crotch" of the GIA staple line, presence of a serosal or omental patch (TA or GIA staple line), oversew of TA staple line, length and location of the resected segment, performance of additional enterotomies, gastrotomies or intestinal biopsies, feeding tube placement (jejunostomy, gastrotomy, or gastrostomy–jejunostomy tube), presence of a closed suction peritoneal drain, whether the abdomen was left open, performance of additional surgeries (within 5 days before enterectomy) or biopsies of liver, pancreas, spleen, or lymph nodes, presence of a foreign body (classified as linear or nonlinear based on surgical description) or an intestinal mass (and evidence of metastasis based on histopathology taken from surgical biopsies), involvement of the biliary system, perforation of the bowel present intraoperatively, intraoperative bacterial culture, and appropriateness of perioperative antibiotic choices based upon intraoperative bacterial culture and susceptibility.

Additional intraoperative data collected include anesthesia time (induction to extubation), surgical procedure time (surgical procedures performed during the same anesthetic event), intraoperative hypotension (mean or systolic arterial blood pressure <60 mmHg measured via indirect or direct methods). If hypotension was recorded, the total duration, number of events, and lowest recorded value were collected.

Postoperative data included whether fresh frozen plasma or blood products (packed RBCs or whole blood) were administered and whether the animal died within 14 days. Cases in which septic peritonitis occurred were classified into 3 groups: preoperative peritonitis that healed after treatment, preoperative peritonitis that did not heal after treatment, and postoperative peritonitis that developed after surgery. Gastro-intestinal surgical dehiscence was defined as leakage between the stapled edges of the anastomosis or immediately adjacent to the staple line. The location of dehiscence in relation to the stapled line was recorded (GIA or TA). All cases of dehiscence were confirmed via direct visualization (during abdominal re-exploration or postmortem exam).

Statistical Analysis

Dogs were assigned to either the dehiscence or nondehiscence group. Variables with >50% missing values were excluded from analysis. Univariate analyses exploring associations between risk factors and outcome of interest (anastomosis dehiscence) were evaluated (α=0.05) using a 2-sided Fisher's exact test for categorical variables and Mann–Whitney *U*-test for continuous variables. Odds ratios were calculated for selected variables. All statistical analyses were performed using commercial software (R version 3.0, R Foundation for Statistical Computing, Vienna, Austria, http://www.r-project.org/).[24]

RESULTS

Fifty-three cases met the inclusion criteria. All anastomoses were performed with a 30 mm or 55 mm reusable linear stapler (TA 30/55, Covidien, Dublin, Ireland) and a 50 mm or 90 mm reusable linear cutting stapler (GIA 50/90 Premium Reusable Stapler, Covidien) with disposable cartridges. A disposable GIA cartridge with a 3.8 mm staples was used in all cases to create a functional end-to-end anastomosis of the intestinal segments. TA staple type used to close the stoma created by the side-to-side anastomosis was not always specifically recorded in the medical record; however, in 52/53 cases, either 3.5 mm or 4.8 mm staples were used. A vascular cartridge with 2.5 mm staples was used to close the stoma in the remaining case.

SFEEA was performed in 20 dogs after removal of intestinal foreign material with questionable intestinal viability and 13 dogs after removal of intestinal neoplasia. SFEEA was also performed in 13 dogs because of complications from prior intestinal surgery (hand-sewn resection and anastomosis dehiscence [7 dogs], enterotomy dehiscence [4], small intestinal biopsy dehiscence [1], and gross intestinal leakage from a previous gastroduodenal ulceration repair and serosal patch [1]). SFEEAwas performed in remaining dogs for iatrogenic trauma (n=1), intussusception (1), intestinal volvulus (1), distal duodenal perforation (1), severely plicated bowel (1), and intestinal incorporation within a mesenteric abscess (1). Enterectomy was performed within the duodenum (2), from duodenum to jejunum (12), within the jejunum (31), from jejunum to ileum (4), from jejunum to colon (3), and from ileum to colon (1). Median length of the resected segment was 20 cm (range; 4 cm to >100 cm).

Six of 53 cases (11%) were confirmed to have dehiscence associated with the stapled anastomosis at the time of subsequent exploratory laparotomy or postmortem examination. One additional case had an area of dehiscence located along a transgastric feeding tube, but there was no evidence of leakage from the anastomosis site. Location of the dehisced enterectomy was within the duodenum (1), within the jejunum (3), and jejunal-colic (2). Dehiscence was noted along the GIA staple line in 2 cases, the TA line in 2 cases, and the exact location was not recorded in the remaining 2 cases. Median time from surgery to identification of dehiscence was 4 days (range; 2–5 days). In 2 cases, the staple line remained grossly intact, with an area of devitalized tissue approximately 2 mm from the staple line, both associated with the GIA staple line in a jejunal-colic anastomosis. The devitalized area was on the jejunal side in 1 case and the colonic side in the other. Three of the 6 cases had additional areas of dehiscence (enterotomy, duodenal biopsy, and a transgastric jejunal feeding tube site). In cases with multiple areas of dehiscence, 2 cases (duodenal biopsy and transgastric jejunal feeding tube dehiscence) had pre-existing septic peritonitis and a previous diagnosis of IBD. The 3rd case (enterotomy dehiscence) received a SFEEA, gastrotomy, and 2 enterotomies for removal of a linear foreign body.

Preoperative septic peritonitis was noted in 27/53 cases, with intraoperative intestinal leakage identified in 23/27 cases. In the remaining 4 cases, no evidence of intestinal leakage was noted intraoperatively; however, a positive aerobic bacterial culture was obtained in

surgery. The indications for obtaining a culture and sensitivity were not reported in these cases. Anastomotic dehiscence occurred in 3/27 cases with preoperative septic peritonitis.

A closed suction peritoneal drain was placed in 12 cases, all of which had preoperative septic peritonitis. Intraoperative intestinal leakage was noted in 10/12 cases where a peritoneal drain was placed, with a subsequent mortality rate of 58% (7/12). Dehiscence occurred in 3 of 12 cases in which a closed suction peritoneal drain was placed. Seven of 12 cases receiving a peritoneal drain experienced intraoperative hypotension. Each of these cases had preoperative septic peritonitis (mortality rate 85%; 6/7). Two of 7 cases with a peritoneal drain, intraoperative hypotension, and septic peritonitis developed postoperative anastomotic leakage.

Ten of the 53 cases reported in our study were treated with corticosteroids in the perioperative period (within 4 weeks preceding surgery or within 1 week postoperatively). Three of these cases had dehiscence of the stapled repair. In all 3 cases, a diagnosis of IBD was made preoperatively and treatment with corticosteroids was initiated before surgery. Histopathology of the resected bowel segments in those 3 cases revealed diagnoses of plasmacytic, lymphocytic, and eosinophilic enteritis with evidence of chronic inflammation, transmural lymphangiectasia with mild-to-moderate lymphoplasmacytic and neutrophilic enteritis, and necrosuppurative enteritis with bacteria and transmural necrosis with normal anastomotic ends.

Intraoperative hypotension (mean or systolic arterial blood pressure <60 mmHg) was recorded in 17/52 (33%) cases. Four cases (24%) experienced dehiscence of the stapled anastomosis. Mean (±SD) duration of hypotension in cases with stapled anastomosis dehiscence was 23.3±12.4 minutes compared to 8.2±2.7 minutes in cases without hypotension. Mean number of hypotensive episodes in cases experiencing dehiscence was 2.0±1.0 compared to 0.7±0.2 in cases without hypotension. Septic peritonitis was present in 15/17 (88%) cases with intraoperative hypotension.

Partial or complete mechanical obstruction from foreign material was noted in 23/53 dogs, with a linear component in 8/23 cases. Septic peritonitis was present in 11/23 cases, with 5/11 due to a linear foreign body. Dehiscence of the SFEEA occurred in 2 cases (1 linear and 1 discrete foreign body). Pre-existing septic peritonitis was not present in either case of dehiscence.

Fifteen of 53 (28%) dogs died within the postoperative recovery period (14 days). Five of 15 (33%) were associated with confirmed dehiscence of the stapled repair. Overall mortality rate in cases with confirmed dehiscence was 83% (5/6), compared to 21% (10/47) in cases without dehiscence. Mortality in cases without confirmed dehiscence was attributed to multiple factors (systemic inflammatory response syndrome, disseminated intravascular coagulation, cardiac arrest).

Dogs experiencing intestinal dehiscence were 46 times more likely to have had pre-existing IBD (95%CI; 3.6–590, P=.003). Dogs experiencing intestinal dehiscence were 13 times more likely to have intraoperative hypotension (95%CI; 1.4–120, P=.026). Surgical risk factors for dehiscence included the presence (P=.011), duration (P=.040), and number (P=.

033) of hypotensive episodes, and the location of anastomosis (*P* .033), with an 11 times greater odds of dehiscence in anastomoses involving the large intestine (95% CI; 1.2–100, *P*=.03). Few additional continuous variables reached statistical significance (Table 1).

DISCUSSION

None of the significant risk factors identified in our study (IBD, location of anastomosis, and intraoperative hypotension) have previously been identified as risk factors for dehiscence in canine studies. Only intraoperative hypotension has previously been implicated in the development of septic peritonitis and failure to survive.[25] Furthermore, in our subset of cases, none of the previously suggested risk factors for intestinal dehiscence in small animal surgery (low serum albumin, intestinal foreign body, and preoperative septic peritonitis) were significant in our univariate analysis.

We identified an overall dehiscence rate of 11% in cases with a SFEEA. This is similar to previous studies in canine hand-sewn anastomoses that have reported a rate of dehiscence of 14% and 16%.[13,14] Previous studies with stapled anastomoses have reported rates of dehiscence of 0%, 10%, and 3%.[1,2,12] Direct comparison between previous studies are difficult to make; however, case selection bias is a possible explanation for the difference in our results and previously reported dehiscence rates in SFEEA. At our institution, a stapled anastomosis was generally reserved for cases where supposed pre-existing risk factors (predominantly low serum albumin and septic peritonitis) were present and/or when the anesthesia risk was high. This may predispose the present study to a higher overall dehiscence rate when compared to a random sample. However, results of our study provide additional information regarding risk factors for dehiscence in a SFEEA that may be useful to surgeons when selecting an anastomosis technique.

Our study suffers from limitations inherent in retrospective studies where data have been collected in a clinical context and we make no direct comparison to cases in which a hand-sewn anastomosis was performed. In addition, although this study represents the largest case series involving intestinal stapling to date in veterinary medicine, we only identified 6 cases of surgical dehiscence in 53 cases of a SFEEA. In contrast, similar studies and meta-analyses in human medicine have evaluated risk factors with sample populations with much greater numbers.[4,19,26,27] Future studies of risk factors associated with SFEEA should include multi-institutional collaboration to obtain larger sample populations.

Canine IBD is described as a heterogeneous group of idiopathic, chronic, relapsing inflammatory disorders of the GIA tract that are immune mediated.[28] They are often characterized by moderate transmural thickening of the intestinal wall with lymphocytic plasmacytic, eosinophilic, granulomatous, or mixed infiltrates.[29–31] Current therapy revolves around some combination of dietary modification, prebiotics, antimicrobials, and immunosuppressive doses of corticosteroids that aim to decrease intestinal mucosal inflammation and reduce clinical signs.[32,33]

Several possible explanations exist for the observed increased risk of dehiscence associated with IBD, including small sample size. Only 4 cases with IBD were identified in our study,

with 3 of those cases resulting in dehiscence of the stapled repair. Conclusions cannot be made with such a small sample size. Additionally, histopathology from the resected segment in 1 case was not consistent with chronic inflammatory disease at the time of surgery (necrosuppurative enteritis with bacteria and transmural necrosis with normal anastomotic ends). The clinical signs associated with this patient's inflammatory disease resolved with prior corticosteroid therapy and intestinal biopsies obtained 3 months before SFEEA revealed lymphoplasmacytic suppurative enteritis and lymphangiectasia, consistent with chronic IBD. Whether inflammatory disease was present in this patient at the time of surgery is debatable. However, in people, there is some evidence to suggest that proinflammatory cytokines are synthesized at an increased rate in patients with inflammatory disease, even in segments of the bowel without inflammation.[34–37] This may lead to an increased risk of dehiscence in the presence of macroscopically normal margins.[38]

Mechanical and ischemic causes for stapled anastomotic dehiscence in canine IBD must be considered. Unfortunately, detailed information describing the exact location and appearance of intestinal dehiscence was not consistently reported. Of important note is that staplers were designed for bowel of normal thickness in people and that failure to properly select the correct staple size in veterinary patients may lead to improper closure and subsequent dehiscence of the repair. This is especially important in conditions such as IBD, in which the thickness of the bowel may be increased. Normal canine small intestinal thickness ranges from 2.06 mm to 3.13mm.[39] Although no definitive measurements are diagnostic for IBD, measurements obtained from ultrasound examinations of dogs with IBD have been reported to be >6 mm and >4.7 mm in the duodenum and jejunum, respectively.[40] However, the accuracy of these ultrasono-graphic measurements in surgical patients has not been validated. Studies investigating intestinal anastomoses in emergency general surgery in people have suggested that stapled anastomoses in trauma patients may be prone to failure because of the edematous nature of injured bowel.[21,22] In a canine study, severely edematous bowel in 2 cases of SFEEA caused failure of the TA staple line and required conversion to a hand-sewn closure of the stoma.[12] In our study, dehiscence in patients with IBD may be attributed in part to inappropriate size of the staple cartridge, leading to suboptimal staple morphology and/or poor staple purchase. Longer staples with a larger closed staple height (4.8 mm staples) are often recommended for thickened hollow organ tissue in people and may be a more appropriate choice for grossly thickened bowel in a canine SFEEA.[41]

Additionally, a vascular cartridge with 2.5 mm staples was used to close the stoma in a single case after foreign body removal in a small breed dog (Yorkshire terrier). In this dog, dehiscence of the stapled repair was noted postoperatively. Vascular cartridges are designed for the complete occlusion of small arteries and veins and may result in compromised blood flow and impairments to wound healing when used in the intestine.[42] Endoscopic staplers of appropriate size are commonly used in pediatric human patients,[43–45] and may represent a more appropriate choice when traditional stapling instrumentation is oversized in small dogs; however, their use has not been evaluated in veterinary medicine. Based on the severity of potential complications, the authors suggest avoiding the use of vascular staplers for SFEEA.

Few studies have been performed to evaluate the performance and reliability of surgical staplers in veterinary medicine, though a few cases of surgical stapler malfunction have been reported in people.[46,47] It is widely believed that under-sizing the staple cartridge increases the risk for inadequate staple formation and/or excessive tissue compression.[48] However, guidelines regarding the staple size in comparison to bowel thickness are merely estimations and clinical judgment of staple morphology and anastomotic configuration must be made intraoperatively by the surgeon. A strong correlation between precompression time and optimal staple formation was reported using a linear stapler with 3.5 mm staples in several portions of the porcine gastric wall ranging in thickness from 2.5 mm to 6 mm.[49] Staple morphology was inadequate when used on tissue that was excessively thick, regardless of precompression time.[49] Precompression takes advantage of the biphasic or viscoelastic properties of soft tissues that allows a change in thickness over time with a constant mechanical stress. Current manufacturer recommendations for precompression time is 15 seconds, which is based on the work of Astafiev in 1967.[50] Very little followup data have been performed to date, though the above porcine work shows that optimal staple formation may be improved by a longer precompression time.[49] The significance this may have on healing in intestinal anastomoses has not been evaluated.

Recent advances in stapling technology have not made their way into mainstream veterinary medicine, but they may help alleviate some of the complications associated with staple malformation. In situations where the tissue is difficult to penetrate or thickened, the staple may not form in the proper shape. In these situations, the tissue margin may not be secure, contributing to dehiscence. Directional Stapling Technology™ (DST, Covidien) has been developed to help in this situation by incorporating alterations in staple shape that allows staples to bend more consistently in the desired plane. In order to decrease the incidence of staple line failure, 3 rows of height progressive staples, rather than the conventional 2, are utilized in the Tri-Staple™ (Covidien). By providing varied staple heights within the same firing, there is reportedly less stress on the tissue along the outer staple line.[51,52] Ethicon-Endo Surgery, Inc. (Cincinnati, OH) has recently introduced the EES Linear Cutter™, which employs a novel 3D staple using a single cartridge containing 3 different staple heights, enabling the surgeon to select staple height without switching cartridges. A literature search of this method produced a single study that reported that the stapler was as safe as a standard linear cutter and produced less bleeding along the anastomosis in people.[53] The clinical effect these innovations may impart on intestinal anastomoses is unclear; however, they may represent an important area of future research.

Corticosteroids have long been associated with negative effects on wound healing. These depressant effects are presumed to be associated with alteration of the normal inflammatory response, including fibroblast proliferation and collagen synthesis.[54] No definitive conclusions have been made regarding their deleterious effects on intestinal anastomoses. All cases in our study with IBD in which dehiscence occurred received corticosteroids; however, corticosteroids alone were not associated with an increased risk of dehiscence. This is in agreement with studies evaluating Crohn's disease and ulcerative colitis in people, where increased surgical complication rates associated with corticosteroid therapy have not been demonstrated.[55–59] A larger retrospective review or prospective analysis of intestinal

healing in canine IBD is necessary to establish the effect clinical doses of corticosteroids and other immunosuppressive or anti-inflammatory drugs may have on intestinal healing.

Intestinal foreign bodies cause varying degrees of trauma to the intestinal wall as they move through the intestinal tract. They have been reported to decrease mesenteric blood flow oral to and increase mesenteric blood flow aboral to the obstruction.[60] Dilation of the intestinal lumen by foreign material may lead to venous stasis and intestinal wall edema followed by vascular compromise and subsequent intestinal necrosis.[61,62] This effect is not limited to the level of the mechanical obstruction, as hydrostatic pressure in the bowel orad to the obstruction can reach 44 mmHg, leading to capillary congestion and intestinal wall edema.[62] Previous studies evaluating hand-sewn anastomoses in veterinary medicine have suggested that the presence of an intestinal foreign body is associated with an increased risk of dehiscence.[13,14,63] However, these studies make no distinction between the variability of cases with intestinal foreign material and the surgeon's own criteria about the location and amount of intestine to resect. In our study, the presence of a foreign body was not a significant risk factor for dehiscence. The exact reason for this discrepancy is unknown; however, any of the previously stated benefits of stapled anastomoses may be contributing. Or like previous studies, the surgeon's own criteria about the location and amount of intestine to resect may play a role in intestinal healing.

Hypoalbuminemia (<2.5 g/dL) was not a significant risk factor for dehiscence in this study. Nineteen cases with low serum albumin within 24 hours preceding surgery were identified of which 3 cases had dehiscence of the repair, whereas 3/28 with an albumin of >2.5 g/dL had dehiscence. This is in agreement with a previous study in dogs, for which hypoalbuminemia was not a significant risk factor for leakage after intestinal biopsy.[64] However, another study found low serum albumin to be a significant risk factor for dehiscence of canine hand-sewn anastomoses.[14] It is unclear whether the difference is related to the benefits a stapled repair may provide (e.g., higher immediate bursting strength, superior strength during the lag phase of wound healing, and improved blood supply to the anastomosis) or a result of our small sample size.[5,10,11,41] SFEEA does not appear to be contraindicated in the face of low serum albumin based on our results.

Septic peritonitis has been reported to delay or impair enteric wound healing,[65,66] and has been identified in previous studies as a risk factor for hand-sewn anastomotic dehiscence.[13,14,67] In our study, SFEEA dehiscence was not significantly associated with preoperative septic peritonitis. The criteria are in agreement with previous studies evaluating septic peritonitis[25,68–71]; however, no attempt was made to classify the severity of peritonitis. Few studies have evaluated the clinical distinction between generalized and localized septic peritonitis. An experimental model of septic peritonitis in rats reported that animals with large volume fecal contamination experience increased mortality.[72] A retrospective study in people with primary anastomosis of the left colon reported no significant difference in dehiscence rates between patients with localized and generalized peritonitis. However, no patients in the localized peritonitis group (n=38) died or suffered dehiscence of their repair compared to 2 deaths and 1 case of dehiscence in the diffuse peritonitis group (n=23).[73] Further studies are necessary to elicit the differences between localized and diffuse septic peritonitis, and their effects on intestinal wound healing.

Three of the 6 cases of intestinal dehiscence in our study had additional areas of leakage (enterotomy, duodenal biopsy, and a transgastric feeding tube site). In a previous study evaluating gastrointestinal foreign bodies in dogs and cats, the presence of multiple gastrointestinal incisions was associated with increased mortality,[74] which was attributed to poor healing related to septic peritonitis, though confirmed dehiscence was not obtained. It is unclear whether the cases presented in our study represent a systemic cause for poor healing, the presence of multiple gastrointestinal incisions, or complications associated with comorbidities (e.g., septic peritonitis, foreign body, IBD).

Intraoperative hypotension was significantly associated with the development of a postoperative anastomotic leakage in our study. This has been noted before in previous studies in people and has been attributed to local ischemia at the anastomosis site.[75,76] Similarly, in a retrospective canine study evaluating risk factors for mortality in septic peritonitis, intraoperative hypotension was significantly associated with postoperative development of septic peritonitis and death.[25] In our study, it is difficult to determine if the level of intraoperative hypotension experienced by dogs contributed directly to intestinal dehiscence or served as a marker for more severe systemic disease, such as septic peritonitis.

Although it is generally agreed that prevention of intraoperative hypotension is important clinically, a recent study in people has associated the use of perioperative vasopressors with increased risk of anastomotic dehiscence.[77] Vasopressors increase mean arterial blood pressure by constriction of medium sized arteries and arterioles, leading to a reduction of local blood flow to tissues. Intestinal anastomoses are dependent on local splanchnic blood flow for adequate tissue oxygenation and constriction of these vessels can lead to shunting of the microcirculation, local hypoxia, and a decreased anastomotic bursting strength.[78–80] The effect of vasopressors was not evaluated in our study, though it may represent an important area of future research.

Location of the anastomosis was a significant risk factor for dehiscence in our study, with greater odds of dehiscence in anastomoses involving the large intestine. One of 2 cases in which a duodenal anastomosis was performed, and 2 of 4 dogs in which a jejunal-colic or ilial-colic anastomosis was performed experienced dehiscence. In cases undergoing colonic anastomosis, leakage occurred ~2 mm from the GIA staple line. These cases were classified as a dehiscence because of the close proximity of their pathology to the staple line. To the authors' knowledge, this pattern of dehiscence has not previously been reported in veterinary medicine and did not occur in cases involving only the small intestine. The pattern is consistent with localized intestinal ischemia and infarction; however, histopathology of the affected segments was not obtained. Blood flow to the anastomosis in these cases may have been compromised by overcompression of the staple line because of an undersized staple cartridge or from inadequate mobilization of tissues leading to increased tension along the anastomosis.[81,82] Tension should generally be avoided when creating an intestinal anastomosis; however, it appears to be least tolerated in the large intestine.[80] Surgical error, including inappropriate identification of healthy intestine and/or poor tissue handling, must also be considered, especially in the duodenum and large intestine, which can be more technically difficult because of the decreased mobility of the intestinal segments.

IBD, location of anastomosis, and intraoperative hypotension were identified as risk factors for intestinal anastomotic dehiscence after SFEEA in our study. Previously suggested risk factors (low serum albumin concentration, preoperative septic peritonitis, and intestinal foreign body) were not confirmed in our study. These factors should be considered when choosing a surgical technique for intestinal anastomosis in dogs.

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Table 1

Univariate Analysis of Continuous Variables With (n = 6) and Without Anastomotic Leakage (n = 47)

	Dehiscence (Mean±SD)		
	No	**Yes**	***P*-Value**
Age at surgery (years)	6.4±3.6	9.3±2.2	.079
Weight at surgery (kg)	26.2±12.4	19.3±10.2	.251
White blood cells ($\times 10^3/\mu L$)	15.0±8.7	16.4±11.6	.919
Segmented neutrophils ($\times 10^3/\mu L$)	12.4±8.2	13.8±11.2	.942
Band neutrophils ($\times 10^3/\mu L$)	0.5±1.2	0.1±0.1	.800
Lymphocytes ($\times 10^3/\mu L$)	1.1±1.0	0.8±0.8	.590
Monocytes ($\times 10^3/\mu L$)	0.9±0.7	1.4±1.0	.245
Reticulocytes ($\times 10^3/\mu L$)	36.6±11.5	11.9±22.0	.652
Red blood cells ($\times 10^6/\mu L$)	6.4±1.5	6.7±1.8	.673
Platelets ($\times 10^3/\mu L$)	283.6±152.8	345.5±128.1	.233
Glucose (mg/dL)	108.7±46.0	110.2±40.3	.511
Urea nitrogen (mg/dL)	18.9±18.2	36.5±50.4	.260
Creatinine (mg/dL)	0.9±0.6	1.1±0.5	.301
Phosphorus (mg/dL)	4.65±2.1	6.0±2.3	.081
Total calcium (mg/dL)	9.1±1.4	9.0±1.2	.673
Total bilirubin (mg/dL)	0.4±0.6	0.2±0.2	.738
Total protein (g/dL)	5.0±1.3	4.5±2.0	.610
Albumin (g/dL)	2.7±85.0	2.5±1.1	.694
Globulin (g/dL)	2.3±0.7	2.0±0.9	.411
Bicarbonate (mmol/L)	20.8±4.4	23.1±1.4	.213
Hypotension (minutes)	8.3±18.1	23.3±30.4	.040
Hypotensive episodes (no. of dogs)	0.7±1.6	2.0±2.5	.038
Anesthesia (minutes)	205.4±63.0	203.7±23.1	.492
Surgical time (minutes)	130.4±50.0	122.7±22.3	.856