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Intra-abdominal complications following intestinal anastomoses by suture and staple techniques in dogs

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Abstract

OBJECTIVE—To compare the incidence of intra-abdominal complications in dogs following resection and functional end-to-end stapled anastomosis (FEESA) versus anastomosis with an end-to-end sutured technique for treatment of enteric lesions.

DESIGN—Multicenter, retrospective descriptive cohort study.

ANIMALS—180 dogs.

PROCEDURES—Medical records of dogs undergoing intestinal resection and anastomosis at 3 nonaffiliated private practice specialty centers were retrospectively reviewed. Preoperative clinical

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variables, indication for surgery, surgical technique (sutured end-to-end anastomosis vs FEESA), and evidence of postoperative anastomosis site leakage (dehiscence) were recorded. Variables of interest were analyzed for associations with dehiscence.

RESULTS—Dehiscence rates of sutured and stapled anastomoses were 12 of 93 (13%) and 4 of 87 (5%), respectively; odds of postoperative dehiscence were significantly lower for dogs with FEESAs than for dogs with sutured anastomoses (OR, 0.28; 95% confidence interval, 0.09 to 0.94). Among dogs that underwent surgery for treatment of intestinal dehiscence after surgery at another facility, subsequent dehiscence developed in 3 of 5 with sutured anastomoses and 0 of 11 with stapled anastomoses. Dehiscence rates varied significantly among clinics. No other variable was associated with risk of dehiscence. Eleven of 16 dogs with dehiscence were euthanized without additional surgery. Impaction at the anastomosis site was identified months or years after surgery in 3 dogs (4 anastomosis sites) that had FEESAs.

CONCLUSIONS AND CLINICAL RELEVANCE—Odds for dehiscence were significantly greater for sutured end-to-end anastomoses than FEESAs, and dogs undergoing surgery for previous dehiscence were significantly more likely to experience a subsequent dehiscence with a sutured anastomosis. However, variability of procedure types and dehiscence rates among clinics suggested further research is needed to confirm these findings. Obstruction at the anastomosis site was identified as a potential long-term complication of FEESA.

Intestinal resection and anastomosis is commonly performed in veterinary patients for treatment of intestinal foreign bodies, intestinal perforation, devitalized tissue secondary to vascular compromise, intestinal neoplasia, or intussusception and in patients that require revision of prior intestinal surgery. One potential major complication of intestinal anastomosis is leakage at the anastomosis site, which typically occurs 3 to 5 days after surgery during the lag phase of healing when the tissue is weakest.¹ Anastomosis site leakage not only requires a second surgery for revision, but can also frequently result in death, with mortality rates reported to be as high as 14 of 19 to 11 of 13.^{2,3}

A variety of surgical techniques for intestinal anastomosis have been described and analyzed.^{4–12} Currently, both end-to-end sutured anastomoses and FEESAs are commonly accepted techniques. Various suture materials and patterns have been examined in the context of intestinal anastomoses.^{5–7,13–15} Single-layer appositional closures are preferred to inverting or everting patterns, as submucosal apposition has been shown to promote primary healing of the intestinal wall, whereas inverted or everted closures require second-intention healing and can increase the risk of luminal stenosis or anastomosis site leakage, respectively.^{14,16,17} Outcomes following the use of interrupted and continuous suture patterns have been evaluated, and the incidence of leakage is comparable between these methods (1/26 [4%] and 1/57 [2%], respectively).⁷ Several anastomotic techniques that include the use of surgical stapling devices have also been described, with advantages including the ability to easily appose intestinal segments of different diameters as well as decreased surgery time, decreased tissue handling and inflammation, increased stoma diameter, and increased bursting strength during the lag phase of healing, compared with sutured anastomoses.^{9–12,17–20} However, stapling may be associated with an increased risk of stenosis at the anastomosis site owing to the everting staple line's tendency to form adhesions; additionally, the risk of hemorrhage may be greater with this method because of

the staple design, which is intended to maintain patent microvasculature for more rapid healing.^{9,11,21}

Several potential risk factors have been proposed for anastomotic dehiscence in veterinary patients, including hypoalbuminemia, preoperative peritonitis, presence of a foreign body, intraoperative hypotension, preexisting inflammatory bowel disease, and involvement of large intestine.^{2,22} To the authors' knowledge, 2 studies^{23,24} have provided a direct comparison of dehiscence rates following anastomosis by suture-versus staple-based techniques in veterinary patients. In one study,²³ no significant difference was identified. The other²⁴ found that patients with stapled anastomoses were less likely to experience dehiscence than those with sutured anastomoses, particularly in the presence of preoperative septic peritonitis. Reports^{25–29} on this topic in the human medical literature have conflicting results. In light of the high mortality rates associated with intra-abdominal complications in veterinary patients, and considering the financial burden to owners when a second surgery is required, it is desirable to identify the anastomotic technique with the lowest rate of intra-abdominal complications regardless of differences in preoperative variables, pathogenesis of the condition that necessitates surgery, or anatomic site of the anastomosis. The purpose of the study reported here was to compile a large number of cases in which intestinal anastomoses were performed by board-certified surgeons and to compare intra-abdominal complication rates between FEESAs and end-to-end anastomoses that were hand-sewn with monofilament absorbable suture. We hypothesized that anastomoses completed by use of gastrointestinal anastomosis and thoracoabdominal surgical stapling devices would have a lower incidence of intra-abdominal complications, given that colotomies performed with thoracoabdominal staplers in dogs had greater bursting strength during the lag phase of intestinal healing than did those performed with Czerny-Lembert suture lines.²⁰

Materials and Methods

Case selection

Electronic medical records of 3 unaffiliated private practice veterinary specialty centers (clinics A, B, and C) were retrospectively searched to identify all dogs that underwent intestinal resection and anastomosis between January 1, 2005, and October 1, 2015 (clinic A); between January 1, 2010, and October 1, 2015 (clinic B); and between January 1, 2013, and October 1, 2015 (clinic C). Records were reviewed by 1 veterinarian at each practice. Any patient for which both surgical stapling devices and suture were used was excluded from the study, with the exception of the described anchoring suture at the base of the staple line inherent to the FEESA procedure.¹⁰ For any dog that underwent a subsequent anastomosis at the same veterinary center, only the first procedure was included in the analysis to prevent confounding of the statistical analysis that would occur if an animal was included multiple times. Dogs that underwent multiple concurrent anastomoses, those lost to follow-up (with information regarding outcomes 10 days after surgery not available either by review of the medical record or through telephone contact with the referring veterinarian), and those that died or were euthanized in the postoperative period for reasons unrelated to anastomotic failure were also excluded.

Medical records review

Information collected included signalment (age, sex, and breed), body weight, the condition for which the procedure was indicated, preoperative serum albumin concentration, anatomic location of the resection, whether peritonitis was present at the time of surgery (grossly or on cytologic examination), the technique used to complete the anastomosis, and whether there was evidence of leakage from the anastomosis site in the postoperative period (ie, up to 10 days after surgery).

Procedures

All surgeries were performed by 1 of 11 board-certified surgeons. The analgesic and anesthetic protocols used were determined at the discretion of the attending surgeon responsible for the patient. All stapled anastomoses were completed with gastrointestinal anastomosis^a or thoracoabdominal^b surgical staplers containing staples with 3.8-mm^c and 3.5-mm^d open leg lengths, respectively. Removal of skin sutures was recommended 10 to 14 days after surgery. All patients deemed healthy on evaluation of postoperative history and physical examination findings recorded at the time of suture removal were considered to have recovered without anastomosis site leakage.

Patients with gross leakage from the anastomosis site or juxta-anastomotic abscess confirmed through a second surgery were categorized as having postoperative dehiscence. Dogs that had clinical signs or diagnostic results consistent with septic peritonitis or sepsis in the postoperative period but were euthanized despite recommendations for a second surgery were also included in this group on the assumption that the observed clinical signs were attributable to failure of the anastomosis. Clinical signs and diagnostic findings consistent with septic peritonitis or systemic sepsis included extreme weakness and signs of depression, intractable vomiting or regurgitation, hypoglycemia and associated first-time seizures, and abdominal effusion with intracellular bacteria present.

The primary focus of the study was to determine whether the incidence of postoperative dehiscence differed between surgical techniques (stapling vs suturing) and whether the risk of this outcome for each technique was altered by additional patient-specific variables, including indication for surgery (ie, pathological findings), anatomic site of the resection, reproductive status (sexually intact or neutered), serum albumin concentration, and presence of peritonitis. Indications for surgery were categorized as dehiscence of a previous surgical site (eg, enterotomy or resection and anastomosis), foreign body, blunt or penetrating trauma, presence of a mass, intestinal incarceration or intussusception, and other (eg, stricture, ischemic injury, evisceration, or perforation secondary to ulceration). Anastomosis location was characterized as enteric only, colonic only, or enterocolic. Dogs for which peritonitis was not indicated as present or absent in the medical record were used in analyses where possible but were excluded from analyses specifically evaluating the relationship between peritonitis and outcome.

^aGIA 50 stapling device, Covidien, Dublin, Ireland.

^bTA 55 stapling device, Covidien, Dublin, Ireland.

^cPremium GIA 50, 3.8-mm reload, Covidien, Dublin, Ireland.

^dPremium TA 55, 3.5-mm reload, Covidien, Dublin, Ireland.

Statistical analysis

Patients were compared on the basis of key demographics (signalment, anatomic site of resection, serum albumin concentration, and presence or absence of peritonitis) to ensure equivalent groups with respect to surgical technique and clinic. Continuous variables (age, weight, and serum albumin concentration) were compared with Student *t* tests (between surgical techniques) and 1-way ANOVA (among clinics), with no indication of unequal variance for these data. Categorical variables (all others) were compared with χ^2 tests. Resulting *P* values were adjusted with a step-up Bonferroni³⁰ adjustment.

The rates of anastomosis site dehiscence among dogs categorized by clinic, by indication for surgery, and by surgical technique within an indication-for-surgery category were compared with the Fisher exact or χ^2 test as appropriate. Similar statistical analysis was performed for dogs with intestinal foreign bodies to compare dehiscence rates between those with linear and nonlinear foreign bodies. The Breslow-Day test for homogeneity of odds ratios was used to compare dehiscence rates between surgical techniques separately for dogs with and without serum albumin concentration data recorded.

A logistic regression was fit to the outcome of dehiscence with surgical technique as the key predictor. The need to incorporate clinic or surgeon as random effects was assessed with the Akaike information criterion adjusted for small sample size.³¹ Patient age was retained as a statistical control variable owing to the confounding of age with clinic. The change in OR for technique was qualitatively evaluated when additional variables were added to the model to address whether this estimate was altered by the presence of additional control or explanatory variables.

A Fisher exact test was used to compare postoperative dehiscence rates between dogs that underwent surgery for dehiscence following a previous intestinal surgery and those that had other indications for the procedure. Because the number of dogs in this category was small, a logistic regression was fit with the Firth penalized likelihood approach and a single predictor (weight, age, anastomosis site, reproductive status, serum albumin concentration, presence or absence of peritonitis, or surgical technique, controlling for age and weight).³²

All analyses were performed with statistical software.^e Values of *P* < 0.05 (following adjustment as necessary) were considered significant.

Results

The medical records review identified 291 dogs that underwent intestinal resection and anastomosis during the predefined study periods for each hospital. Of these, 180 (101, 27, and 52 from clinics A, B, and C, respectively) met the inclusion criteria and were included in the analyses. Eighty-seven of these dogs underwent FEESA (85, 2, and 0 from clinics A, B, and C, respectively), and 93 (16, 25, and 52 from clinics A, B, and C, respectively) had sutured end-to-end anastomoses performed. Indications for surgery included foreign body (*n* = 72), presence of a mass (36), intestinal incarceration or intussusception (21), dehiscence of

^eSAS, version 9.4 (SAS/STAT 13.1), SAS Institute Inc, Cary, NC.

a previous enteric surgery performed elsewhere (16), and blunt or penetrating trauma (9). Twenty-six dogs underwent the surgery for other causes. Anatomic sites were classified as enteric in 153 dogs, colonic in 9, and enterocolic in 15; anatomic location was not noted in the records of 3 dogs.

Patient signalment was similar across clinics with the exception of age; clinic B had a significantly ($P < 0.001$) older population of patients than did the other study sites (Table 1). The remaining analyzed patient variables, including body weight, serum albumin concentration, anastomotic location, sex, reproductive status, and preoperative presence of peritonitis, did not differ significantly between dogs grouped by surgical technique (stapled vs sutured anastomosis) or among clinic populations. The overall dehiscence rates ranged from 0 of 27 (0%) to 11 of 52 (21%) and differed significantly ($P = 0.001$; Fisher exact test) among clinics.

Overall dehiscence rates following anastomoses with suture and staple techniques were 12 of 93 (13%) and 4 of 87 (5%), respectively. Indications for surgery varied among dogs that developed postoperative dehiscence, including foreign body ($n = 7$), dehiscence following a previous enteric surgery (3), intestinal incarceration or intussusception (3), and neoplasia (1); 2 dogs were categorized as having other findings. The patient with neoplasia had a histologic diagnosis of colorectal adenocarcinoma with clean surgical margins but marked invasion into the local mesentery, vessels, and lymph nodes. Surgical indications classified as other among these patients included entrapment and strangulation of a portion of the midjejunum secondary to adhesions from a previous abdominal surgery ($n = 1$) and ulcerative enteritis with duodenal perforation (1). Anatomic site of the anastomosis also varied among patients with subsequent dehiscence, with enteric ($n = 13$), enterocolic (2), and colonic (1) anastomoses represented.

The mortality rate for patients with postoperative dehiscence was 11 of 16 (69%). All 11 nonsurvivors were euthanized on diagnosis of sepsis or septic peritonitis, despite recommendations for additional surgery. Of the 5 patients that underwent a second surgery because of postoperative dehiscence, all survived, with only 1 requiring a third surgery for treatment of a second dehiscence.

The statistical model of dehiscence as a function of the surgical procedure revealed that the odds of dehiscence for dogs with a FEESA were about one-quarter of those for dogs with sutured anastomoses (OR, 0.28; 95% confidence interval, 0.09 to 0.94; $P = 0.040$). Additionally, incorporation of other individual predictors into this base model, with the exception of serum albumin concentration, did not significantly alter this difference in dehiscence rates between the 2 surgical techniques (Table 2). When serum albumin concentrations were incorporated into the model, there was no longer a significant relationship between surgical technique and dehiscence rate (OR for stapled vs sutured anastomoses, 0.49; 95% confidence interval, 0.14 to 1.75; $P = 0.267$). However, information regarding serum albumin concentration was not available for 75 of the 180 (42%) dogs included in the analysis. No differences were identified between patients with and without serum albumin measurements on record with respect to anatomic location of the

anastomosis, presence of peritonitis at the time of surgery, indication for surgery, sex, reproductive status, or body weight.

Patients for which the surgery in the study was performed for treatment of dehiscence following surgery elsewhere were not more likely to have a subsequent dehiscence than patients that had other indications for the surgery (OR, 0.373; 95% confidence interval, 0.094 to 1.479; $P = 0.157$). However, for this subset of 16 patients, the dehiscence rate of sutured revisions (3/5) was significantly ($P = 0.018$) higher than that of stapled revisions (0/11). None of the other variables evaluated for this subset of patients (presence of peritonitis, serum albumin concentration, anatomic location of the anastomosis, reproductive status, body weight, or age) was significantly associated with subsequent dehiscence (data not shown). Conclusions could not be drawn about the cause for dehiscence of the initial surgery in these patients because the initial surgical procedures had been performed at referring clinics, and data regarding the initial surgery were not consistently available for analysis.

Of the 72 dogs categorized as having a foreign body prior to surgery, 14 (19%) were classified as having linear foreign bodies. There was no significant ($P = 0.332$) difference in dehiscence rates between dogs with linear (0/14) and nonlinear (7/58) foreign bodies.

Three dogs that underwent FEESAs were known to have developed impaction at previous anastomosis sites (4 incidents) in the months following the initial surgery. The shortest time between initial surgery and development of impaction was approximately 2 months; the longest was 1 year. The remaining 2 impactions were identified approximately 6 months after the initial procedure.

Discussion

Intestinal healing is a complex process. Inflammatory responses anywhere within the bowel cause an increase in collagenase activity throughout the gastrointestinal tract.¹⁴ This collagenase activity decreases the collagen content of the submucosa, which is the holding layer for intestinal apposition. Collagen content reaches a nadir during the lag phase of healing, approximately 3 days after surgery, and the decreased collagen concentration weakens the tissue and delays healing.^{14,20} Intestinal enterotomy and anastomosis sites are therefore most susceptible to dehiscence during the lag phase. Our follow-up criteria for successful anastomotic healing included apparent health of the dog at the time of skin suture removal, because it has been shown that the anastomosis site retains its bursting strength without the presence of sutures 14 days after surgery and can therefore be considered to have healed without complication if no clinical signs of dehiscence are noted by that time.¹

Despite the results of research and adjustments in anastomotic techniques, similar dehiscence rates have been reported for sutured and stapled intestinal anastomoses in veterinary patients. Ralphs et al² reported rates of 13 of 90 (14%) in dogs and 0 of 25 (0%) in cats that underwent anastomoses with a suture technique. Allen et al³ reported dehiscence in 16 of 100 (16%) dogs with sutured anastomoses, and a comparison of interrupted and continuous suture patterns in dogs reported by Weisman et al⁷ revealed dehiscence rates of 1

of 26 (4%) and 1 of 57 (2%), respectively. A clinical evaluation of the FEESA technique in 20 dogs and 4 cats by Ullman et al¹⁰ identified dehiscence in 3 of 24 (13%) patients, and all affected animals were dogs. Evaluation of a modified functional end-to-end anastomosis method that included 2 gastrointestinal anastomosis staple lines found no incidents of dehiscence in 15 dogs.¹² Jardel et al¹⁸ reported dehiscence in 2 of 30 (7%) dogs following FEESAs performed by nonexpert surgeons. A report by Snowdon et al²² on complication rates of FEESAs identified an overall dehiscence rate of 6 of 53 (11%) for these procedures in dogs. When Deull et al²³ directly compared the 2 techniques, dehiscence rates of 21 of 134 (16%) and 8 of 71 (11%) were found for sutured and stapled anastomoses, respectively. Taken together, although not standardized, these studies suggested estimated overall dehiscence rates of 52 of 432 (12.0%) and 19 of 193 (9.8%) for sutured and stapled anastomoses, respectively.

Our study identified dehiscence rates of 12 of 93 (13%) and 4 of 87 (5%) for sutured and stapled anastomoses, respectively. The dehiscence rate following anastomoses with the suture technique was comparable to previously reported values, although the rate following anastomoses with the staple technique was lower than in most other studies.^{2,3,10,12,18,23} Our findings that sutured anastomoses were 3.6 times as likely to develop dehiscence as FEESAs were in agreement with data reported by Davis et al,²⁴ who found the risk of dehiscence for sutured anastomoses was 3.3 times that for stapled anastomoses when all dogs that had the procedure were considered, and 3.8 times that for stapled anastomoses in dogs with preoperative septic peritonitis. Our findings could have been attributable to any combination of the reported advantages of surgical stapling devices, including preservation of local blood supply; reduced tissue trauma, compared with that resulting from apposition by suture; or greater bursting strength during the lag phase of healing, compared with the strength of sutured anastomoses.^{11,20,21} The finding that significance of the difference in dehiscence rates between procedures was lost when serum albumin concentration was added to the statistical model was interesting; however, as previously mentioned, albumin measurements were not available for 75 of 180 dogs included in this analysis. In most of these cases, the records were older and hematologic test results for those patients might have been performed but were not accessible.

Preexisting peritonitis, hypoalbuminemia, blood product administration, supplemental nutrition, male sex, traumatic injuries, and intestinal foreign bodies have all been associated with an increased risk of dehiscence for sutured anastomoses.^{2,3,24,33} However, a recent analysis of FEESAs did not identify these variables as significant risk factors for dehiscence.²² Instead, preexisting inflammatory bowel disease, intraoperative hypotension, and anastomoses involving the large intestine were found to be associated with a greater risk of dehiscence following this procedure.²² In our study population, hypoalbuminemia, preoperative peritonitis, presence of a foreign body, and anatomic location of the anastomosis were not found to be risk factors for dehiscence. However, among dogs that underwent revision surgery for a previous dehiscence, the rate of subsequent dehiscence was significantly greater when the suture technique was used than when the staple technique was used (3/5 vs 0/11). This finding was in agreement with a previous report²⁴ in which dogs with preoperative septic peritonitis were more likely to experience dehiscence following sutured anastomoses than following stapled anastomoses. It stands to reason that all dogs

experiencing dehiscence develop septic peritonitis prior to their revision surgery. Surgery and anesthesia times, whether intraoperative hypotension developed, and presence of preexisting comorbidities were not evaluated in our study.

A few of the patients in our study that underwent FEESAs (3 dogs [with 4 affected anastomosis sites]) were known to have been evaluated months to years after the procedure included in the study because of impaction of material at the previous anastomosis site. Typically, the impacted material was such that it would have been expected to pass normally through unaltered intestine (grass, straw, and fur), although one contained wood chips and another included a laundry dryer sheet. One dog that had undergone 2 concurrent FEESA procedures developed an impaction at the distal anastomosis site and then developed another at the proximal site several months later. No such impactions were identified in dogs treated with sutured end-to-end anastomoses. It is of note that all 3 of these patients underwent a second resection and anastomosis, with 2 sites closed by suture and 2 closed by staples. None of these developed dehiscence, and to the authors' knowledge, none developed impaction at these sites a second time. It is possible that other dogs developed similar long-term complications but that follow-up did not involve the study hospital.

Although delayed aboral transit of ingesta across side-to-side anastomoses (compared with that through end-to-end anastomoses) has been reported, it has been shown that intestinal motility in either conformation is not significantly different from that of healthy dogs that have not undergone intestinal surgery.^{34,35} Trichobezoar obstruction at a circular end-to-end stapled anastomosis site has been reported and was presumed to result from entanglement with the exposed regions of staples in the intestinal lumen.³⁶ These reports, along with the occurrence of impactions at some of the previously stapled anastomosis sites for dogs in our study that required additional surgery, may indicate the need for development of absorbable staple materials to decrease the risk of this complication.

Limitations of the present study included those inherent to any retrospective study. Information was obtained from review of medical records, some of which did not contain data for all of the variables of interest. Although single-layer closure with monofilament absorbable suture was used in all sutured anastomoses, the suture patterns used (eg, simple interrupted, simple continuous, modified Gambee) could not be determined from several records and could therefore not be evaluated for association with outcomes of interest in this study. A multicenter study was pursued to obtain a desirable sample size and to establish a study population that might be more representative of the general pet population than the one derived from a single clinic's database. It is of note, however, that surgeons at one location performed sutured anastomoses only and surgeons at another site performed only 2 FEESAs, with the remaining 25 procedures from that clinic performed with the suture technique. Therefore, most (85/87 [98%]) of the FEESAs in our analyses were performed at 1 clinic, and the analysis may have been affected by interclinic differences rather than true differences between the surgical techniques. Another limitation was the broad classification scheme used to classify anatomic locations of the anastomoses as enteric, colonic, or enterocolic. An attempt was made to further specify the anastomosis sites in the small intestine as duodenal, duodenojejunal, jejunal, and jejunoileal locations, but despite the

inclusion of multiple clinics in the study, the numbers of dogs in these groups were insufficient for statistical analysis.

Another limitation of the study was the assumption that patients with clinical signs and diagnostic findings consistent with sepsis or septic peritonitis in the postoperative period had dehiscence of the anastomosis site, even when leakage was not visualized. All dogs in the study were client-owned animals, and as such, diagnostic test options and the decision to pursue a second surgery were at the clients' discretion. These patients had been noted to have clinical improvement after the resection and anastomosis, followed by a decline in condition. No necropsies were performed, and although dehiscence was the most likely cause for delayed decline in clinical status, it was possible that some of these patients could have had other pathological changes such as perforation at another site in the gastrointestinal tract, thromboembolic events, or other undefined conditions. Therefore, the dehiscence rates could have been slightly overestimated.

The short-term outcomes for most patients in the present study were good, with 164 of 180 (91%) dogs having no evidence of dehiscence in the postoperative period. Because procedure types and dehiscence rates varied among clinics in this multi-institutional study, further investigation is needed to confirm the association between end-to-end sutured anastomosis and increased risk of dehiscence in dogs. Although the number of dogs in this study that underwent revision surgery for dehiscence of a previous anastomosis site was small, it should be considered that all such dogs with subsequent dehiscence had been treated with resection and sutured end-to-end anastomosis, suggesting that the use of staples may result in a better short-term outcome for revision surgery.

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ABBREVIATIONS

FEESA	Functional end-to-end stapled anastomosis
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References

1. Jönsson K, Jiborn H, Zederfelt B. Breaking strength of intestinal anastomoses. *Am J Surg* 1983;145:800–803. [PubMed: 6859418]
2. Ralphs SC, Jessen CR, Lipowitz AJ. Risk factors for leakage following intestinal anastomosis in dogs and cats: 115 cases (1991–2000). *J Am Vet Med Assoc* 2003;223:73–77. [PubMed: 12839067]
3. Allen DA, Smeak DD, Schertel ER. Prevalence of small intestinal dehiscence and associated clinical factors: a retrospective study of 121 dogs. *J Am Anim Hosp Assoc* 1992;28:70–76.
4. Coolman BR, Ehrhart N, Marretta SM. Use of skin staples for rapid closure of gastrointestinal incisions in the treatment of canine linear foreign bodies. *J Am Anim Hosp Assoc* 2000;36:542–547. [PubMed: 11105893]

5. Bernis-Filho WO, Wouters F, Wouters AA, et al. Comparative study of cotton, polyglactin, and polyglecaprone sutures in intestinal anastomoses in dogs. *Arq Bras Cir Dig* 2013;26:18–26. [PubMed: 23702865]
6. Polglase AL, Hughes ES, McDermott FT, et al. A comparison of end-to-end staple and suture colorectal anastomosis in the dog. *Surg Gynecol Obstet* 1981;152:792–796. [PubMed: 7017978]
7. Weisman DL, Smeak DD, Bichard SJ, et al. Comparison of a continuous suture pattern with a simple interrupted pattern for enteric closure in dogs and cats: 83 cases (1991–1997). *J Am Vet Med Assoc* 1999;214:1507–1510. [PubMed: 10340077]
8. Coolman BR, Ehrhart N, Pijanowski G, et al. Comparison of skin staples with sutures for the anastomosis of the small intestine in dogs. *Vet Surg* 2000;29:293–302. [PubMed: 10917278]
9. Ullman SL. Surgical stapling of the small intestine. *Vet Clin North Am Small Anim Pract* 1994;24:305–322. [PubMed: 8197672]
10. Ullman SL, Pavletic MM, Clark GN. Open intestinal anastomosis with surgical stapling equipment in 24 dogs and cats. *Vet Surg* 1991;20:385–391. [PubMed: 1369520]
11. Tobias KM. Surgical stapling devices in veterinary medicine: a review. *Vet Surg* 2007;36:341–349. [PubMed: 17547597]
12. White RN. Modified functional end-to-end stapled intestinal anastomosis: technique and clinical results in 15 dogs. *J Small Anim Pract* 2008;49:274–281. [PubMed: 18373543]
13. Samel ST, Heinrich A, Becker H, et al. Continuous single-layer anastomoses with monofilament poliglecaprone sutures in abdominal surgery. *Eur J Surg* 1999;165:710–711. [PubMed: 10452268]
14. Ballantyne GH. The experimental basis of intestinal suturing. Effect of surgical technique, inflammation, and infection on enteric wound healing. *Dis Colon Rectum* 1984;27:61–71. [PubMed: 6360595]
15. Milovancev M, Weisman DL, Palmisano MP. Foreign body attachment to polypropylene suture material extruded into the small intestinal lumen after enteric closure in three dogs. *J Am Vet Med Assoc* 2004;225:1713–1715. [PubMed: 15626221]
16. Jansen A, Becker AE, Brummelkamp WH, et al. The importance of the apposition of the submucosal intestinal layers for primary wound healing of intestinal anastomosis. *Surg Gynecol Obstet* 1981;152:51–58. [PubMed: 7455891]
17. Thornton FJ, Barbul A. Healing in the intestinal tract. *Surg Clin North Am* 1997;77:549–573. [PubMed: 9194880]
18. Jardel N, Hidalgo A, Leperlier D, et al. One stage functional end-to-end stapled intestinal anastomosis and resection performed by nonexpert surgeons for the treatment of small intestinal obstruction in 30 dogs. *Vet Surg* 2011;40:216–222. [PubMed: 21223317]
19. Hansen LA, Smeak DD. In vitro comparison of leakage pressure and leakage location for various staple line offset configurations in functional end-to-end stapled small intestinal anastomoses of canine tissues. *Am J Vet Res* 2015;76:644–648. [PubMed: 26111095]
20. Ballantyne GH, Burke B, Rogers G, et al. Accelerated wound healing with stapled enteric suture lines. *Ann Surg* 1985;201:360–364. [PubMed: 3883920]
21. Smith CR, Cokelet GR, Adams JT, et al. Vascularity of gastrointestinal staple lines demonstrated with silicone rubber injection. *Am J Surg* 1981;142:563–566. [PubMed: 7030091]
22. Snowdon KA, Smeak DD, Chiang S. Risk factors for dehiscence of stapled functional end-to-end intestinal anastomoses in dogs: 53 cases (2001–2012). *Vet Surg* 2016;45:91–99. [PubMed: 26565990]
23. Duell JR, Theiman Mankin KM, Rochat MC, et al. Frequency of dehiscence in hand-sutured and stapled intestinal anastomoses in dogs. *Vet Surg* 2016;45:100–103. [PubMed: 26731599]
24. Davis DJ, Demianiuk RM, Musser J, et al. Influence of preoperative septic peritonitis and anastomotic technique on the dehiscence of enterotomy sites in dogs: a retrospective review of 210 cases. *Vet Surg* 2018;44:125–129.
25. Chassin JL, Rifkind KM, Sussman B, et al. The stapled gastrointestinal tract anastomosis. *Ann Surg* 1978;188:689–696. [PubMed: 718296]
26. West of Scotland and Highland Anastomosis Study Group. Suturing or stapling in gastrointestinal surgery: a prospective randomized study. *Br J Surg* 1991;78:337–341. [PubMed: 2021851]

27. Brundage SI, Jurkovich GJ, David C, et al. Stapled versus sutured gastrointestinal anastomoses in the trauma patient. *J Trauma* 1999;47:500–507. [PubMed: 10498304]
28. Witzke JD, Kraatz JJ, Morken JM, et al. Stapled versus hand sewn anastomoses in patients with small bowel injury: a changing perspective. *J Trauma* 2000;49:660–666. [PubMed: 11038083]
29. Neutzling CB, Lustosa SA, Proenca IM, et al. Stapled versus hand sewn methods for colorectal anastomosis surgery. *Cochrane Database Syst Rev* 2012;2:CD003144.
30. Hochberg Y A sharper Bonferroni procedure for multiple tests of significance. *Biometrika* 1988;75:800–802.
31. Burnham KP, Anderson DR. Model selection and multimodel inference: a practical information theoretic approach 2nd ed. New York: Springer-Verlag, 1988;488.
32. Hosmer DW, Lemeshow S, Sturdivant RX. Applied logistic regression 3rd ed. Hoboken, NJ: John Wiley & Sons, 2013;500.
33. Luján JJ, Németh ZH, Barrat-Stopper PA, et al. Factors influencing the outcome of intestinal anastomosis. *Am Surg* 2011;77:1169–1175. [PubMed: 21944626]
34. Cannon WB, Murphy FT IV. The movements of the stomach and intestines in some surgical conditions. *Ann Surg* 1906;43:512–536. [PubMed: 17861784]
35. Toyomasu Y, Mochiki E, Ando H, et al. Comparison of postoperative motility in hand-sewn end-to-end anastomosis and functional end-to-end anastomosis: an experimental study in conscious dogs. *Dig Dis Sci* 2010;55:2489–2497. [PubMed: 19915979]
36. Carobbi B, Foale RD, White RA. Trichobezoar obstruction after stapled jejunal anastomosis in a dog. *Vet Surg* 2009;38:417–420. [PubMed: 19573108]

Table 1 —

Descriptive comparisons of variables among 180 dogs categorized by surgical technique and clinic where surgery was performed in a study to compare the incidence of intra-abdominal complications in dogs following FEESA versus anastomosis with an end-to-end sutured technique for treatment of enteric lesions.

Variable	Technique			Clinic		
	FEESA (n = 87)	value (n = 93)	P value *	B (n = 27)	A (n = 101)	P value †
Signalment						
Age (y)	5.45 ± 4.33	6.41 ± 4.25	0.539	9.80 ± 4.00	5.05 ± 4.05	< 0.001
Body weight (kg) ‡	23.22 ± 11.96	19.11 ± 14.06	0.341	18.88 ± 16.58	21.96 ± 13.00	0.837
Female	33/87 (38)	46/93 (49)	0.539	10/27 (37)	41/101 (41)	0.837
Neutered	68/87 (78)	82/93 (88)	0.502	24/27 (89)	78/101 (77)	0.338
Anatomic site						
Colonic	1/84 (1)	8/93 (9)	0.219	2/27 (7)	1/99 (1)	0.133
Enterocolic	5/84 (6)	10/93 (11)	0.674	0/27 (0)	10/99 (10)	0.837
Enteric	79/84 (94)	74/93 (80)	0.167	25/27 (93)	88/99 (89)	0.837
Other						
Albumin (g/dL) §	2.93 ± 0.88	2.89 ± 0.82	0.802	2.95 ± 0.66	3.02 ± 0.91	0.837
Peritonitis	18/87 (21)	22/93 (24)	0.802	7/27 (26)	21/101 (21)	0.837

Continuous data are represented as mean ± SD, and categorical data are represented as proportion (%) of dogs. Not all dogs had all data available. Serum albumin concentration and presence of septic peritonitis reflect findings prior to surgery at the study hospital.

* Reflects results of a Student *t* test or χ^2 test for continuous and categorical variables, respectively.

† Reflects results of ANOVA or χ^2 test for continuous and categorical variables, respectively.

‡ Data unavailable for 2 and 0 dogs that underwent FEESA and end-to-end sutured anastomosis, respectively.

§ Data unavailable for 48 and 27 dogs that had FEESA and end-to-end sutured anastomosis, respectively.

Values of $P < 0.05$ (adjusted by the Bonferroni step-up method³⁰) were considered significant.

Table 2 —

Odds ratios for anastomosis site dehiscence following FEESA, compared with an end-to-end sutured technique, calculated by use of the base statistical model (logistic regression incorporating surgical technique and age) and by use of the same model with individual variables added as possible predictors for the same dogs as in Table 1.

Variable	OR (95% CI)	No. of dogs	P value of Variable added effect
Base model	0.28 (0.09–0.94)	177	—
Added predictor			
Reason for surgery	0.25 (0.07–0.88)	177	0.768
Septic peritonitis	0.29 (0.09–0.96)	177	0.250
Albumin concentration	0.49 (0.14–1.75)	104	0.501
Anatomic site	0.29 (0.09–0.99)	177	0.999
Reproductive status	0.29 (0.09–0.95)	177	0.846

P values are unadjusted owing to initial nonsignificance.

— = Not applicable.

See Table 1 for remainder of key.