Evaluation of short-term outcomes and potential risk factors for death and intestinal dehiscence following full-thickness large intestinal incisions in dogs

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OBJECTIVE
To determine complication rates for dogs in which full-thickness large intestinal incisions were performed, assess potential risk factors for death during hospitalization and for intestinal dehiscence following these surgeries, and report short-term mortality rates for these patients.

ANIMALS
90 dogs.

PROCEDURES
Medical records of 4 veterinary referral hospitals were reviewed to identify dogs that underwent large intestinal surgery requiring full-thickness incisions. Signalment, history, clinicopathologic data, medical treatments, surgical procedures, complications, and outcomes were recorded. Descriptive statistics were calculated; data were analyzed for association with survival to discharge (with logistic regression analysis) and postoperative intestinal dehiscence (with Fisher exact or Wilcoxon rank sum tests).

RESULTS
Overall 7-day postoperative intestinal dehiscence and mortality rates were 9 of 90 (10%) and 15 of 90 (17%). Dogs with preoperative anorexia, hypoglycemia, or neutrophils with toxic changes and those that received preoperative antimicrobial treatment had greater odds of death than did dogs without these findings. Preexisting colon trauma or dehiscence, preexisting peritonitis, administration of blood products, administration of > 2 classes of antimicrobials, positive microbial culture results for a surgical sample, and open abdominal management of peritonitis after surgery were associated with development of intestinal dehiscence. Five of 9 dogs with intestinal dehiscence died or were euthanized.

CONCLUSIONS AND CLINICAL RELEVANCE
Factors associated with failure to survive to discharge were considered suggestive of sepsis. Results suggested the dehiscence rate for full-thickness large intestinal incisions may not be as high as previously reported, but several factors may influence this outcome and larger, longer-term studies are needed to confirm these findings. (*J Am Vet Med Assoc* 2019;255:915–925)

Intestinal surgery is commonly performed in dogs for a variety of diagnostic and therapeutic indications, although these procedures more commonly involve the small intestine than the large intestine.[1–3] In 1 study[3] of gastrointestinal surgeries performed in dogs at a single hospital, only 19 of 225 identified surgeries involved the large intestine. Although infrequently reported, large intestinal surgery is often considered for dogs with obstructive foreign bodies, neoplasia, and intussusception.[3–6] In 1 study,[6] foreign bodies found in the colon at the time of surgery accounted for 9 of 208 (4%) discrete foreign bodies detected throughout the gastrointestinal tract. The large intestine is a relatively common site for tumor development, accounting for 58 of 160 (36%) to 96 of 160 (60%) intestinal tumors in previous studies[7–9] of dogs, with adenocarcinoma being the most common nonhematopoietic neoplasm diagnosed. Intussusceptions can occur in dogs of various ages, and sometimes occur secondary to other processes such as neoplasia and foreign bodies. Intussusception is often found at the ileocolic junction, and surgical treatment is indicated to remove abnormal tissue and restore intestinal motility.[4,10–12] Large intestinal surgery may also be performed as treatment for colonic torsion; strictures; colonic duplication; colonic, cecal, and rectal perforations; and cecal inversion.[13–17] These disorders often require surgical intervention to allow resection of diseased or devitalized tissue and alleviation of clinical signs, and these procedures often result in enterocolic, colocolic, or colorectal anastomoses.[7,18,19]

Full-thickness small and large intestinal incisions in dogs have reported dehiscence rates of 28 of 225 (12%) to 42 of 295 (14%).[1,3,20] Reported risk factors for intestinal dehiscence, in general, include preexisting septic peritonitis, hypoalbuminemia, intraop-

ABBREVIATIONS

CI	Confidence interval
FFP	Fresh-frozen plasma

erative hypotension, and presence of an intestinal foreign body.[1–3,21] In addition, administration of corticosteroids in dogs undergoing surgery of the large intestine was associated with failure to survive in 1 report.[3] The consequences of intestinal dehiscence can be devastating, with mortality rates after intestinal dehiscence in dogs and subsequent septic peritonitis found to be as high as 22 of 29 (76%) to 11 of 13 (85%).[1,2,20,21] It has been theorized that dehiscence is more likely to develop in small animal patients after surgery of the large intestine than after surgery of the small intestine because of the poor collateral blood supply, high intraluminal pressure during passage of fecal boluses, and high bacterial load in the large intestine.[22] Dehiscence rates following surgery of the large intestine are infrequently reported in the veterinary literature. In 1 retrospective study[3] performed to evaluate risk factors for peritonitis and death after gastrointestinal surgery, 19 of 197 dogs had surgery involving the large intestine, and of those 19, 6 developed septic peritonitis.

In people, results of large investigations and meta-analyses indicate that rates for development of intestinal leakage following anastomoses involving the colon and rectum range from 3.8% to 23%; this factor is associated with a mortality rate of approximately 12.9%,[23–26] and the proportion of human patients with subclinical leakage detected with diagnostic imaging may be as high as 50%.[27,28] The incidence of subclinical anastomotic leakage in dogs has not been reported to the authors' knowledge.

There is a paucity of information available in the veterinary literature on colon surgery requiring full-thickness incisions and the risk factors associated with dehiscence and death in patients undergoing these procedures. The objectives of the study reported here were to determine the overall complication rate after full-thickness large intestine incisions in dogs at 4 veterinary referral facilities, to assess potential risk factors for death during initial hospitalization and intestinal dehiscence following these surgeries, and to report short-term mortality rates (up to 7 days after surgery) for these patients. We hypothesized that the dehiscence and mortality rates following full-thickness incisions of the large intestine would be similar to those reported elsewhere[1–3,21] for small intestinal surgery.

Materials and Methods

Case selection criteria

The study was designed as a multicenter, retrospective cohort study. Electronic and hardcopy medical records were obtained from 4 veterinary referral hospitals: the University of California-Davis William R. Pritchard Veterinary Medical Teaching Hospital (facility 1), University of Tennessee John and Ann Tickle Small Animal Hospital (facility 2), University of Georgia Veterinary Teaching Hospital (facility 3), and Virginia-Maryland College of Veterinary Medicine Veterinary Teaching Hospital (facility 4). Records from January 1, 1995, to December 31, 2016, were reviewed to identify dogs that underwent laparotomy for conditions that required full-thickness incision into the colon. Dogs were included in the study if follow-up information could be obtained during the period from the date of surgery to 7 days after surgery. Follow-up data were obtained from records of direct examination, communications with the owner, or communications with the primary care veterinarian. Dogs were excluded if follow-up information could not be obtained or if there was no description in the medical record of the intraoperative procedures performed.

Medical records review

Keywords for electronic searches included colon or colonic surgery, large intestine surgery, colonic or large intestine tumor, colon or large intestine foreign body, colotomy, colectomy, colonic resection and anastomosis, colon or large intestine dehiscence, and colon or large intestine biopsy. Records were reviewed and data were collected by multiple authors (CRL, JAG, MEB, and DBA), and 1 author (CNL) was responsible for collating and summarizing data into a single source.

Preoperative data collected and recorded in a commercially available spreadsheet[a] included age and body weight at the time of admission, breed, sex and reproductive status, clinical signs, duration of clinical signs, time from admission to surgery, clinicopathologic (PCV, Hct, or both; CBC and serum biochemical analysis [including serum lactate concentration]; prothrombin time; and partial thromboplastin time) results, and systolic blood pressure measurement (with Doppler or oscillometric techniques). Preoperative colon-cleansing procedures (when applicable) and treatments given immediately before surgery or during the hospitalization period, including administration of blood products and antimicrobials, were recorded. Treatments, including antimicrobial administration, were classified as preoperative (documented at hospital admission or administered any time prior to anesthesia for surgical intervention), perioperative or intraoperative (administered during the anesthetic episode for intestinal surgery or during the surgical procedure), or postoperative (administered after recovery from the surgical anesthetic episode). Preoperative diagnostic imaging findings were obtained from the medical records without retrospective review of stored images. Findings were documented on the basis of radiology reports finalized by board-certified veterinary radiologists at the respective institutions.

Specific hematologic variables were evaluated for association with outcome. These included thrombocytopenia (< 150 × 10^3 platelets/µL), anemia (PCV or Hct < 35%), neutrophilia (> 10 × 10^3 neutrophils/µL), leukocytosis (> 14 × 10^3 WBCs/µL), leukopenia (< 5 × 10^3 WBCs/µL), hyperproteinemia (total serum protein concentration > 8 g/dL), hypoproteinemia (total serum protein concentration < 5.5 g/dL), hypoalbu-

minemia (serum albumin concentration < 3.2 g/dL), hyperglycemia (serum glucose concentration > 135 mg/dL), hypoglycemia (serum glucose concentration < 80 mg/dL), and hyperlactatemia (serum lactate concentration > 2 mmol/L). These values were chosen on the basis of the corresponding author's institutional reference ranges at the beginning of the study and were distributed to all institutions. The means of upper and lower reference limits for the hematologic variables at all 4 institutions were calculated and reported following receipt of this information. Preoperative comorbidities were identified and recorded on the basis of previous clinical diagnosis reported in the medical record, response to previous treatment, or histopathologic diagnosis.

Indications for surgery were recorded from the medical records and surgical reports. Intraoperative data were collected from the surgical records or were obtained from the basic medical record if a surgical report was not available. Information recorded included overall surgical time (time from skin incision to completion of skin closure) and total anesthesia time (time from induction to extubation). The details of the surgical procedures, including intraoperative surgical complications, peritoneal drainage (closed suction or open abdominal drainage), and histopathologic and microbiologic results for collected samples, were also recorded. Histologic findings were recorded when a full report from a board-certified veterinary pathologist was available. The information recorded included final diagnosis and classification of that diagnosis as benign neoplasia, malignant neoplasia, inflammation, changes secondary to the indication for surgery, or normal. The condition that led to the dog requiring surgery of the large intestine was categorized as follows: megacolon, colonic mass, cecal or ileal mass, extracolonic mass with involvement of the colon, foreign body, biopsy, intussusception, trauma or dehiscence, and devitalization, abscessation, ulceration, or stricture of the colon. Peritonitis was defined by the presence of ≥ 2 of the following factors: peritoneal fluid biochemical and cytologic analyses consistent with peritonitis; ultrasonographic evidence of free abdominal fluid in addition to intestinal wall defect or inflammation of intestine and local tissues; gross evidence of petechiation, serosal inflammation, or contamination; or histopathologic, culture, or cytologic results in the record consistent with peritonitis for samples collected during surgery.

Surgeries were classified into 6 categories as follows for study purposes: colonic biopsy (full-thickness incision and collection of a large-intestine wall sample), partial colectomy (< 75% of the colon resected) with colocolonic anastomosis, partial colectomy with ileocolic junction resection and jejunocolic anastomosis, partial colectomy with ileocolic junction resection and ileocolic anastomosis, subtotal colectomy (≥ 75% but < 100% of the colon resected) with preservation of the ileocolic junction and colorectal anastomosis, and total colectomy (100% of the colon resected, including the ileocolic junction) with enterorectal anastomosis. In addition, the type of closure used for the biopsy site or anastomosis was documented. Augmentation of the intestinal closure was noted as either omental or serosal patching.

Recorded postoperative complications were classified as gastrointestinal (vomiting, diarrhea, regurgitation, or anorexia), aspiration pneumonia (documented in the medical record with radiographs confirming presence of disease evaluated by a board-certified veterinary radiologist), incisional (seroma, skin dehiscence, or evidence of infection at the incision site), cardiac arrhythmias, and cardiopulmonary arrest. A diagnosis of intestinal dehiscence at the incision site after surgery was recorded when there was documentation in the medical record consisting of septic abdominal effusion, confirmation of dehiscence at the time of a second procedure, or confirmation of dehiscence at the time of necropsy. If dogs with intestinal dehiscence underwent a second procedure for treatment of this complication, that information was documented as well as any microbial culture and susceptibility results for samples collected during the procedure.

For analysis purposes, survival from the time of surgery until discharge from the hospital was recorded. Additional short-term survival information was recorded from discharge up to 7 days after surgery. If death occurred or euthanasia was elected from the time of surgery up to 7 days after surgery, it was categorized as associated with the colonic surgery or with the medical indication for the surgery. Medical records were searched for communications with the owner or primary care veterinarian to confirm that dogs had follow-up for ≥ 7 days, and if outcome for this period could not be obtained from the records, the owners or veterinarians were contacted by telephone to obtain the information.

Statistical analysis

Descriptive statistics were calculated. Normality tests for each variable were performed on the basis of skewness and kurtosis, and the results were combined into an overall test statistic. Normally distributed continuous variables are reported as the mean ± SD, and variables that were not normally distributed are reported as median and range. Categorical data are expressed as frequencies. Logistic regression analysis was performed to evaluate the association of 112 variables extracted from the medical records with the odds of survival to hospital discharge in the first hospitalization period of the study. The variables were extracted from the categories of history (including comorbidities) and clinical signs (including duration); physical examination, diagnostic imaging, and clinicopathologic analysis results; preoperative, perioperative or intraoperative, and postoperative treatments administered; indication for surgery, surgery classification, and intraoperative findings; results of histopathologic, microbial, and cytologic analysis for

submitted samples; and postoperative complications. Two-way interactions among the main effects were investigated. An interaction term was retained in the model on the basis of a P value < 0.05. Univariate analysis was initially performed, and factors with a P value < 0.20 were tested in the model. Factors with values of $P \leq 0.05$ were retained in the final model. There were too few cases of intestinal dehiscence in the 7-day follow-up time period to perform multivariable regression; therefore, a Fisher exact test (for categorical data) or Wilcoxon rank sum test (for ordinal or continuous data) was used to identify individual variables associated with intestinal dehiscence, with each dog included only once in a given analysis. Values of $P \leq 0.05$ were considered significant. All analyses were performed with commercially available statistical software.[b]

Results

Animals

Ninety dogs (11, 34, 31, and 14 dogs from facilities 1, 2, 3, and 4, respectively) met the inclusion criteria. Fifty of 90 (56%) dogs were male (20 sexually intact and 30 castrated), and 40 (44%) were female (7 sexually intact and 33 spayed). The median age was 96 months (range, 3 to 181.4 months), and median body weight was 18.6 kg (40.9 lb; range, 2.1 to 66.8 kg [4.6 to 147 lb]). The sample included mixed-breed dogs (n = 19), Labrador Retrievers (10), Golden Retrievers (8), Dachshunds (4), German Shepherd Dogs (3), Boxers (3), Shih Tzus (3), Staffordshire Terriers (not further specified; 3), Jack Russell Terriers (3), West Highland White Terriers (2), Miniature Schnauzers (2), Shetland Sheepdogs (2), English Bulldogs (2), Springer Spaniels (not further specified; 2), Beagles (2), and 1 dog each of the following: Chinese Shar-Pei, Brittany Spaniel, Coonhound (not further specified), Cocker Spaniel (not further specified), Weimaraner, Cane Corso, Bloodhound, Pomeranian, Great Dane, Maltese, Irish Setter, Lhasa Apso, Yorkshire Terrier, Siberian Husky, Bichon Frise, Boston Terrier, German Wirehaired Pointer, Border Collie, French Bulldog, Chesapeake Bay Retriever, Whippet, and Australian Shepherd.

Nine of 90 (10%) dogs developed intestinal dehiscence after surgery (5 during the hospitalization period and 4 after hospital discharge but ≤ 7 days after surgery). The mean ± SD time to the diagnosis of dehiscence was 3.4 ± 1.2 days (range, 2 to 6 days) after surgery. Seventy-seven (86%) dogs survived to hospital discharge, and 13 did not (including 2 that were euthanized during surgery). The median number of days from surgery to hospital discharge was 3 (range, 0 to 13 days). Of the 77 dogs that survived to hospital discharge, 75 survived for ≥ 7 days after surgery; the 2 dogs that did not survive this period developed intestinal dehiscence 3 and 6 days after being released to the owners. The overall survival rate for the study sample, including the 7-day follow-up period, was 75 of 90 (83%), with spontaneous death in 6 (7%) dogs and euthanasia in 9 (10%) dogs. The median number of days after surgery until death or euthanasia for dogs that had these outcomes was 2 (range, 0 to 6 days).

No signalment characteristics (age, sex, reproductive status, or breed) were significantly associated with intestinal dehiscence in dogs that survived the initial surgery (n = 88). Similarly, in the final multivariable analysis, none of these variables were significantly associated with survival to hospital discharge.

Preoperative findings

The most commonly reported clinical signs prior to surgery were diarrhea (42/90 [47%] dogs) and vomiting (42 [47%]), followed by hematochezia (32 [36%]), anorexia (25 [28%]), weight loss (20 [22%]), and constipation or obstipation (7 [8%]). The duration of clinical signs prior to surgery was < 1 week for 34 of 90 (38%) dogs, from 1 to 4 weeks for 32 (36%) dogs, from 4 weeks to 6 months for 21 (23%) dogs, and > 6 months for 17 (19%) dogs. Seven dogs with > 1 clinical sign had different durations of signs, resulting in dogs being classified into > 1 group. The sign with the greatest duration in these 7 dogs was present for 4 weeks to 6 months.

Diarrhea was the only preoperative clinical sign significantly ($P = 0.033$) associated with postoperative intestinal dehiscence, and the effect was negative; 1 of 41 (2%) dogs with diarrhea as a clinical sign had intestinal dehiscence, whereas 8 of 47 (17%) dogs without diarrhea had dehiscence. In the final multivariable analysis, dogs with clinical signs of anorexia prior to surgery had significantly ($P = 0.022$) greater odds of not surviving to discharge, compared with dogs that did not have this finding (OR, 8.6; 95% CI, 1.4 to 53.7). Overall, 8 of 25 (32%) dogs with anorexia did not survive to hospital discharge, whereas 5 of 65 (8%) dogs without anorexia did not survive to discharge. Comorbidities were identified in 2 dogs. These included cardiac disease (11/90 [12%]), pelvic trauma or spinal cord disease (6 [7%]), nephropathy (5 [6%]), hyperadrenocorticism (3 [3%]), hypothyroidism (2 [2%]), enteropathy (2 [2%]), diabetes mellitus (1 [1%]), hepatopathy (1 [1%]), and miscellaneous conditions such as epilepsy, osteoarthritis, and ophthalmic diseases (7 [8%]). A total of 12 dogs had > 1 comorbidity.

Systolic blood pressure was recorded for 13 of 90 (14%) awake dogs prior to surgery; the mean ± SD measurement was 138.15 ± 33.9 mm Hg. Preoperative diagnostic imaging was performed for 85 of 90 (94%) dogs. Procedures included abdominal ultrasonography (65/85 [76%] dogs), abdominal radiography (58 [68%]), thoracic radiography (46 [54%]), abdominal CT (4 [5%]), contrast-enhanced radiography of the colon, (4 [5%]), and abdominal MRI (1 [1%]). Colonoscopy was performed prior to surgical intervention for 21 of 90 (23%) dogs; only 1 dog had this procedure performed while hospitalized for surgery.

Results of the preoperative hematologic analyses and mean reference limits for the participating institutions were summarized **(Table 1)**. By use of cutoff values for the corresponding author's institution, anemia, leukopenia, and thrombocytopenia were present in 21 of 85 (25%), 4 of 79 (5%), and 4 of 69 (6%) dogs, respectively. Leukocytosis and neutrophilia were present in 40 of 79 (51%) and 40 of 76 (53%) dogs. A neutrophilic regenerative left shift was present in 19 of 66 (29%) dogs, and a degenerative left shift was present in only 1 of 66 (2%) dogs. Neutrophils with evidence of toxic changes (ie, toxic neutrophils) were reported for 7 of 76 (9%) dogs. Hypoalbuminemia, hypoproteinemia, and hyperproteinemia were identified in 51 of 78 (65%), 15 of 67 (22%), and 4 of 67 (6%) dogs, respectively. Hyperlactatemia was documented for 3 of 14 (21%) dogs. Hypoglycemia affected 8 of 87 (9%) dogs, and hyperglycemia affected 3 of 87 (3%) dogs.

No CBC or serum biochemical analysis findings were associated with development of intestinal dehiscence after surgery. Five of 7 dogs with toxic neutrophils died or were euthanized during the initial hospitalization, compared with 4 of 69 dogs that did not have this finding; in the final multivariable analysis, dogs with toxic neutrophils had significantly (P = 0.003) greater odds of not surviving to discharge (OR, 44.8; 95% CI, 3.6 to 552.3). Overall, 4 of 8 dogs with hypoglycemia and 9 of 79 dogs (11%) without hypoglycemia failed to survive to hospital discharge. Hypoglycemic dogs also had significantly (P = 0.023) greater odds of not surviving to hospital discharge, compared with nonhypoglycemic dogs (OR, 18.4; 95% CI, 1.5 to 224.2). No other hematologic variables were associated with this outcome.

Indications for surgery included presence of a colonic mass (29/90 [32%] dogs), intussusception (18 [20%]), ileal or cecal mass (14 [16%]), repair of traumatic colon injury or dehiscence (8 [9%]), megacolon (7 [8%]), biopsy (7 [8%]), extracolonic mass (5 [6%]), large intestine foreign body (3 [2%]), and other conditions (colonic stricture, devitalization, abscessation, or ulceration; 6 [7%]). Eight of 90 (9%) dogs had multiple indications for surgery (eg, a mass affecting the cecum and colon or a foreign body causing intussusception).

The only indication for surgery that was significantly associated with postoperative intestinal dehiscence was preexisting colonic trauma or dehiscence (P = 0.003); whereas 4 of 8 dogs that underwent colonic repairs for trauma or dehiscence had postoperative intestinal dehiscence, 5 of 80 (6%) dogs with other indications for surgery had this outcome. No indication for surgery was significantly associated with survival to discharge.

Medical treatments

Colon cleansing was performed prior to surgery for 17 of 90 (19%) dogs. These consisted of liquid ene-

Table 1—Summary of hematologic variables assessed prior to surgery for 90 dogs in a retrospective study to determine overall complication rates following full-thickness large intestinal incisions at 4 veterinary referral facilities, to assess potential risk factors for death during initial hospitalization and for intestinal dehiscence following these surgeries, and to report short-term mortality rates (≤ 7 days after surgery) for these patients.

Variable	No. of dogs	Measurement	Mean reference range values*
CBC			
PCV (%)	57	42 (5–70)	35–55
Hct (%)	85	41 ± 9.16	41–60
WBCs (X 10^3 cells/μL)	79	14.1 (1.3–64)	5.1–14
Lymphocytes (X 10^3 cells/μL)	76	1.35 (0.22–7.2)	1.1–4.6
Neutrophils (X 10^3 cells/μL)	76	11.1 (0.34–41.4)	2.6–9.8
Band neutrophils (X 10^3 cells/μL)	66	0 (0–8.1)	0–0.3
Platelets (X 10^3 cells/μL)	69	395.8 ± 177.9	150–423
Prothrombin time (s)	16	7.5 (5.9–15.1)	6.8–9.0
Partial thromboplastin time (s)	17	18.2 (9.4–78)	10.4–12.9
Serum biochemical analysis			
Lactate (mmol/L)	14	1.2 (0.8–2.4)	0–2
Total protein (g/dL)	67	6.4 ± 1.15	5.4–6.8
Albumin (g/dL)	78	2.85 (1.5–4.0)	3.2–4.1
Globulin (g/dL)	78	3.0 (1.4–5.6)	1.9–3.1
Serum glucose (mg/dL)	87	103 (66–316)	80–135
BUN (mg/dL)	86	12 (4–68)	7–26
Creatinine (mg/dL)	85	0.8 (0.2–3.3)	0.5–1.6
Alanine aminotransferase (U/L)	78	40 (8–265)	18–100
Alkaline phosphatase (U/L)	78	84.5 (11–1406)	13–240
Total bilirubin (mg/dL)	75	0.2 (0–4.4)	0.1–0.6
Sodium (mmol/L)	84	146.2 ± 5.29	141–147
Potassium (mmol/L)	85	4.23 ± 0.62	2.8–4.7

Measurement data represent median (range) or the mean ± SD for the study sample.

*Reference ranges from all institutions were noted, and upper and lower limits reported in the table represent mean values for the 4 institutions that participated in the study.

mas (13/17) and enteral administration of an osmotic laxative (11). Seven of the 17 dogs underwent 2 types of cleansing preparations.

Canine blood products were administered to 19 of 90 (21%) dogs in the preoperative period or during the perioperative or intraoperative period. Six of 19 dogs received > 1 type of blood product. Blood products administered included FFP (17/19), packed RBCs (8), and fresh whole blood (2). An additional 2 of 90 (2%) dogs received human albumin in the postoperative time period.

Antimicrobials were administered to 26 of 90 (29%) dogs in the preoperative period, most commonly metronidazole (10/26 [38%]), enrofloxacin (8 [31%]), and amoxicillin–clavulanic acid (3 [12%]). Perioperative or intraoperative antimicrobial administration was recorded for 79 of 90 (88%) dogs, most commonly cefazolin (42/79 [53%]), cefoxitin (22 [28%]), and ampicillin-sulbactam (10 [13%]). Postoperative administration of antimicrobials was recorded for 62 of 90 (69%) dogs, with metronidazole (34/62 [55%]), enrofloxacin (26 [42%]), and ampicillin-sulbactam (14 [23%]) most often selected for these patients. Twenty-four of 90 (27%) dogs received antimicrobials of > 2 classes; these combinations consisted of aminopenicillins with β-lactamase inhibitors, enrofloxacin, and metronidazole (n = 7 dogs); cephalosporins, metronidazole, and enrofloxacin (6); aminopenicillins with β-lactamase inhibitors and enrofloxacin (6); and cephalosporins and metronidazole (5).

Treatment with colon-cleansing procedures was not significantly associated with postoperative intestinal dehiscence or failure to survive to hospital discharge. Administration of > 2 classes of antimicrobials was significantly (P = 0.001) associated with intestinal dehiscence, as was administration of blood products (P = 0.002). Seven of 24 dogs that were administered > 2 classes of antimicrobials had intestinal dehiscence, and 2 of 64 dogs that did not receive > 2 classes of antimicrobials had dehiscence. A total of 6 of 19 dogs that received blood products had intestinal dehiscence versus 3 of 69 (4%) dogs that did not receive blood products. In the final multivariable analysis, dogs that received antimicrobials in the preoperative period had significantly (P = 0.025) greater odds of failure to survive to hospital discharge than did dogs that did not receive antimicrobials during this period (OR, 8.1; 95% CI, 1.3 to 50.9). Overall, 8 of 26 (31%) dogs that did and 5 of 64 (8%) dogs that did not undergo this treatment died or were euthanized during hospitalization.

Surgical procedures and outcomes

The surgery report was available for review in the records of 87 of 90 (97%) dogs, and the 3 dogs that did not have surgery reports available had summarized notes regarding the surgery present in the general medical record. The most frequently performed procedure was partial colectomy with ileocolic junction resection and jejunocolic anastomosis (24/90 [27%]), followed by partial colectomy with ileocolic junction resection and ileocolic anastomosis (23 [26%]); for these dogs, closure of the anastomosis was performed with an interrupted suture pattern (n = 19 and 20, respectively), a continuous suture pattern (2 each), or a surgical stapling device (3 and 1, respectively). Partial colectomy with colocolonic anastomosis was performed for 21 (23%) dogs that had the anastomosis closed with an interrupted (n = 17) or continuous (4) suture pattern. Fourteen (16%) dogs underwent colonic biopsy, and the site was closed with an interrupted suture pattern in 10 and a continuous suture pattern in 4. The least frequently performed procedures were total colectomy (5 [6%]) and subtotal colectomy (3 [3%]); for these dogs, the anastomosis was most commonly closed with an interrupted (n = 3 and 2, respectively) or continuous (1 each) suture pattern. One dog that underwent total colectomy had the anastomosis closed with a surgical stapling device. Augmentation of the intestinal closure was performed in 12 dogs by serosal patching (6/90 [7%]) or omental patching (6 [7%]). The mean ± SD times for surgery and anesthesia were 140.2 ± 43.1 minutes and 208.9 ± 58.3 minutes, respectively.

Overall, 35 intraoperative complications were reported in the medical records; 7 of 90 (8%) dogs had ≥ 1 intraoperative complication. Intraoperative complications reported in the surgical or medical records included hypotension (25/90 [28%] dogs), hypothermia (4 [4%]), hemorrhage (3 [3%]), and iatrogenic fecal contamination of the abdomen (3 [3%]). Eighty-eight of 90 (98%) dogs survived the initial surgery, and 2 were euthanized during surgery.

No surgery type, closure method, or type of augmentation was significantly associated with postoperative intestinal dehiscence or with failure to survive to hospital discharge. In addition, no intraoperative complication was significantly associated with either of these outcomes.

Peritonitis was present in 15 of 90 (17%) dogs at the time of the initial surgery. This was confirmed by preoperative fluid analysis in 2 dogs, gross evidence during surgery in 10 dogs, and cytologic or histologic evaluation of surgical samples in 11 dogs, and it was suspected on the basis of ultrasonographic results in 4 dogs. Confirmation was made by > 1 method reported for 12 of 15 dogs. A sample of abdominal tissue or fluid was collected for microbial culture during the first surgery in 19 of 90 (21%) dogs, and culture results were positive for 15. The most commonly isolated bacteria were *Enterococcus* spp (n = 10 dogs), *Escherichia coli* (9), and *Clostridium* spp (4). Abdominal drainage was performed for treatment of peritonitis in 10 of 15 (67%) dogs and consisted of an active suction drain for 6 (40%) dogs and open abdominal management for 4 (27%) dogs.

A second surgery was performed for 7 of 88 (8%) dogs. The indications for a second surgery included dehiscence of the intestinal surgery site (n = 5), intussusception of a distant jejunal segment (1), and exploration and lavage prior to abdominal closure after open abdominal management (1). Two of 7 dogs that

had a second surgery were discharged after the initial surgery and readmitted for the second procedure. Six of 7 dogs that had a second surgical procedure survived the subsequent procedure and were discharged from the hospital. A sample of abdominal fluid or tissue was collected during surgery for 6 of these 7 dogs for microbial culture, with positive culture results in all cases. The most common bacterial isolates from the second surgery were *Enterococcus* spp (n = 3 dogs), *Streptococcus* spp (2), and *E coli* (2).

Findings that were significantly associated with intestinal dehiscence after surgery included presence of peritonitis at the time of the initial surgery (P = 0.006), positive microbial culture results at the time of the initial surgery (P < 0.001), and open abdominal management of peritonitis after the initial surgery (P = 0.048). Of the 15 dogs with peritonitis at the initial surgery, 5 had intestinal dehiscence, whereas 4 of 73 (5%) dogs without preexisting peritonitis had intestinal dehiscence. Two of 4 dogs with open abdominal management of peritonitis after surgery had colonic dehiscence, compared with 7 of 84 (8%) dogs that did not have this treatment. Presence of peritonitis at the initial surgery, positive microbial culture results, and requirement for a second abdominal surgery were not significantly associated with survival to discharge.

Eighty-five of 90 dogs had histologic reports available and findings recorded in the general medical record. Two dogs had > 1 histologic diagnosis. Thirty-one of 85 (36%) dogs with data available had malignant disease. The most common malignancies were adenocarcinoma (12/29 dogs with colonic masses) and cecal gastrointestinal stromal tumor or leiomyosarcoma (classified together because these were not differentiated by immunohistochemical analysis in many cases; 7/14 dogs with cecal or ileal masses). Additional malignancies noted were colonic lymphosarcoma (n = 3), colonic leiomyosarcoma (2), small intestinal lesions requiring removal of large intestine tissue (large cell lymphoma [2], adenocarcinoma [1], and gastrointestinal stromal tumor [1]), metastatic apocrine gland anal sac adenocarcinoma (1), cecal carcinoid tumor (1), and cecal peripheral nerve sheath tumor (1). Malignant disease was identified in dogs with intussusception (1/18), preexisting colonic trauma or dehiscence (1/8), or an extracolonic mass (1/5) and in dogs that had surgery for purposes of colon biopsy (2/7). Benign diseases were reported for 12 dogs (7/29 with colonic masses, 2/5 with extracolonic masses, 1/14 with ileal or cecal masses, 1/8 with preexisting colonic trauma or dehiscence, and 1/7 that underwent surgery for biopsy) and included leiomyoma (n = 7), adenomatous polyp (4), and plasmacytoma (1). Inflammatory disease was identified in 21 dogs that had colonic masses (6/29), intussusception (3/18), ileal or cecal masses (3/14), megacolon (3/7), or extracolonic masses (2/5) or surgery for colon biopsy (3/7). Inflammatory disease was most commonly lymphoplasmacytic in character (reported for 9/13 dogs). No histologic diagnosis was associated with failure to survive to discharge or intestinal dehiscence.

Overall, 10 of 88 dogs had ≥ 1 postoperative complication. The most common postoperative complication was presence of gastrointestinal signs (56/88 [64%] dogs, including 44, 13, and 9 dogs with diarrhea, vomiting, and anorexia, respectively). Other postoperative complications included cardiac arrhythmias (7/88 [8%] dogs), aspiration pneumonia (4 [5%]), cardiopulmonary arrest (3 [3%]), and incisional complications (cellulitis from subcutaneous infection and seroma formation; 2 [2%]). No postoperative complication was associated with intestinal dehiscence or failure to survive to discharge.

Of the 5 dogs that developed postoperative intestinal dehiscence during the initial hospitalization, 2 did not survive to discharge (both dogs were euthanized). Of the 4 dogs that developed dehiscence after being released from the hospital, 2 underwent a successful second surgery and survived for ≥ 7 days after the second surgery. The remaining 2 dogs died spontaneously. The diagnosis of dehiscence was confirmed by surgical exploration or necropsy in 7 of the 9 dogs, and the remaining 2 had cytologic findings consistent with septic peritonitis together with clinical and hematologic examination findings suggestive of systemic sepsis.

Of the 13 of 90 (14%) dogs that failed to survive to hospital discharge (including 1 dog that had a second surgery during the initial hospitalization), cardiopulmonary arrest occurred in 4 and was attributed to development of pneumonia (n = 1), progression of preoperative sepsis (1), or unknown causes (2). In addition to the 2 dogs euthanized during surgery (because of the extent of disease), 7 dogs were euthanized after surgery for the following reasons: confirmation of septic peritonitis and intestinal dehiscence (n = 2 following the first surgery and 1 after the second surgery), failure to improve clinically with biopsy results confirming lymphoma (2), occurrence of disseminated intravascular coagulation or multiple organ dysfunction (identified on the basis of notation in the medical record; 1), and development of jejunal intussusception after surgery (1).

Discussion

Previous information regarding outcome and complications following large intestine surgery with full-thickness incisions in dogs is sparse and consists of small numbers of animals, with results often admixed with those for dogs undergoing small intestinal surgery.[2,3,18,20,29] To the authors' knowledge, the present multi-institutional, retrospective study of 90 dogs was the largest study to date to assess risk factors and outcome data following full-thickness incisions of the large intestine. Factors significantly associated with the development of postoperative intestinal dehiscence included perioperative administration of blood products, administration of ≥ 2 classes of antimicrobials, preexisting colon trauma or dehiscence, the presence of peritonitis at surgery, a positive culture result for abdominal tissue or fluid collected at the time of surgery, and treatment of peritonitis that included open abdominal management. Presence of the clinical sign of diarrhea prior to surgery was negatively associated with

intestinal dehiscence. Factors that were significantly associated with failure to survive to discharge included clinical signs of anorexia prior to surgery, presence of toxic neutrophils, preoperative hypoglycemia, and preoperative antimicrobial administration. The overall dehiscence and mortality rates for the first week after surgery were 9 of 90 (10%) and 15 of 90 (17%), respectively.

The postoperative dehiscence rate in the present study was lower than previously reported large intestinal dehiscence rates. In 1 retrospective study,[29] 4 of 53 (8%) dogs with stapled end-to-end anastomosis had surgical sites that included the colon, and the overall dehiscence rate in that study was 6 of 53 (11%). However, when surgery included the large intestine, odds of dehiscence were 11 times those for dogs that had intestinal surgery that did not involve the large intestine, with dehiscence in 2 of the 4 dogs.[29] In an investigation to evaluate risk factors for death and for development of septic peritonitis in dogs that had gastrointestinal surgery, 19 of 225 surgeries involved the large intestine.[3] The dehiscence rate following surgeries that involved the large intestine in that study[3] was 6 of 19. In the present study, it was possible that some cases of intestinal dehiscence occurred after the 7-day follow-up period or that some dogs that did not survive and did not undergo necropsy had undiagnosed dehiscence; the lack of necropsy or antemortem evaluation for intestinal dehiscence for some dogs and short follow-up period were limitations of the retrospective study. Additionally, it is possible that subclinical leakage, as reported in people,[27,28] could have occurred, although the relevance of this in the clinical setting is unknown. In 2 evaluations of veterinary patients that underwent surgery of the large intestine, 0 of 7 dogs had dehiscence, and 1 of 8 dogs had septic peritonitis following surgery but did not have confirmed dehiscence.[17,18] Another retrospective study[2] performed to assess morbidity and mortality rates for dogs and cats that had small and large intestinal surgery found that the probability of intestinal dehiscence after small intestinal surgery is not significantly different from that after large intestinal surgery. Additionally, colonic anastomoses performed on healthy dogs in a laboratory setting have had favorable results.[30,31]

Colon-cleansing procedures were performed infrequently in our study sample of dogs (17/90 [19%]). The goal with colon-cleansing procedures is generally to reduce the overall population of bacteria in the colon and the rate of postoperative peritonitis.[32] However, these procedures are controversial and not routinely performed, as studies[32,33] in human medicine have shown that these techniques do not decrease the risk of anastomotic leakage and may increase the risk of intraoperative contamination resulting from spillage of liquid with fecal contents. Colon-cleansing procedures were not significantly associated with postoperative intestinal dehiscence in dogs of the present study, although a more thorough evaluation of this topic with a larger group of dogs would be necessary prior to making clinical recommendations.

The only surgical indication that was associated with postoperative intestinal dehiscence in the present study was previous dehiscence of a large intestine surgery site or colon trauma. Peritonitis at the time of surgery and factors associated with preoperative peritonitis, including positive results of microbial culture and open abdominal management of septic peritonitis, were also significant risk factors for the development of dehiscence in the present study. An experimental study in rats[34] showed that septic peritonitis can impair anastomotic healing through increased collagenase activity, which increases the risk of leakage. Investigators of human studies[35,36] have determined that matrix metalloproteinases and collagen are essential for normal tissue remodeling and intestinal healing. However, upregulation of matrix metalloproteinases occurs after initial intestinal injury and can contribute to inflammation and tissue destruction.[36] Inhibition of these enzymes has been shown to increase the strength of intestinal anastomoses.[35–37] Research has also revealed that in rabbits and rats, the large intestine has more extensive collagen loss and weaker synthesis of collagen during healing, compared with the small intestine.[38,39]

The strength of colonic anastomoses is limited during the first 3 to 4 days after surgery, coinciding with the lag phase of healing.[40,41] The mean ± SD time to the diagnosis of postoperative intestinal dehiscence for the 9 dogs that had this outcome in the present study was 3.4 ± 1.2 days after surgery, consistent with previous reports[42] described for small intestinal dehiscence. This result suggested that dehiscence following colon surgery may be expected to develop in the same postoperative time frame as that for the small intestine. Results of previous investigations support that trauma to the intestinal tract[21] and dehiscence of a prior gastrointestinal surgery site[1,3,20,21] are risk factors for postoperative intestinal dehiscence, similar to the results of the present study. Previously reported risk factors for gastrointestinal dehiscence, such as low serum albumin concentration,[20,21] intraoperative hypotension,[3,29] and presence of a foreign body,[20,21] were not associated with dehiscence after colon surgery in the present study. However, it is important to consider that the aforementioned studies[3,20,21,29] predominantly evaluated small intestine healing. There are inherent differences in small versus large intestine healing, and such factors were beyond the scope of the present study. Hypoalbuminemia was found to have no association with intestinal dehiscence in some studies[29,43] of intestinal healing in dogs, and other studies[3,20] in which this variable was reported as a risk factor for intestinal dehiscence defined the cutoff value for hypoalbuminemia as much lower than typical laboratory reference ranges (≤ 2.5 mg/dL). It is possible that hypoalbuminemia was not a significant risk factor for dehiscence in our study because of population differences from those in other studies, the low overall number of dogs that developed dehiscence, or the definition of hypoalbuminemia, which was determined on the basis of laboratory reference ranges for serum biochemical values.

Anorexia prior to surgery was associated with failure to survive to discharge in the present study. This finding may have been associated with chronicity of disease processes prior to surgery and the potential for

these dogs to have nutritional deficiencies that were not evaluated specifically. Additionally, severely ill dogs may be less likely to eat, suggesting that these dogs may have been affected with more severe disease states (eg, septic peritonitis) than other study dogs. Diarrhea was negatively associated with intestinal dehiscence in this group of dogs, suggesting dogs with diarrhea were less likely to have intestinal dehiscence. Previously, it was postulated that liquid with fecal contents resulting from colon-cleansing procedures was suspected to increase the risk of anastomotic leakage and intraoperative contamination.[32,33] Although the clinical relevance of this finding was unclear, our data appeared to refute that conclusion.

The only clinicopathologic findings associated with failure to survive to discharge were the presence of toxic neutrophils and hypoglycemia. Cytoplasmic changes in neutrophils consistent with toxic effects occur in the bone marrow and include diffuse basophilia, foamy vacuolation, granulation, and the presence of Döhle bodies.[44] The presence of toxic changes in neutrophils has been linked to systemic processes including bacteremia, septicemia, and severe inflammatory processes.[45,46] In a previous study,[44] dogs with toxic neutrophils were significantly more likely to have peritonitis or septicemia, as well as several other systemic diseases, than were dogs without this finding. Additionally, presence of toxic neutrophils was associated with a significantly higher mortality rate in that study sample of dogs.[44] We considered it very likely that hypoglycemia and the presence of toxic neutrophils in dogs of the present study were likely associated with sepsis, given the association with failure to survive to discharge; however, this was not strictly assessed in the investigation. In a study[47] to compare clinical findings in dogs with sepsis to those in dogs with suspected anaphylaxis, patients in both groups fit the criteria for systemic inflammatory response syndrome, and those with hypoglycemia were significantly more likely to have sepsis than were those with anaphylaxis. In addition, blood glucose concentration is included in the 5-variable acute patient physiologic and laboratory evaluation score for stratification of illness severity in hospitalized dogs, though hyper- and hypoglycemia were noted to change the score.[48]

The administration of blood products has been previously reported as a risk factor for postoperative intestinal dehiscence in dogs,[20] consistent with the findings in the present study. Blood product transfusions are thought to result in immunosuppression and thus impair intestinal healing; this has been reported to increase the risk of postoperative intestinal dehiscence in people and rats.[49,50] Additionally, there is controversy related to administration of FFP transfusions for indications other than coagulopathy because FFP transfusions often do not significantly change circulating albumin concentrations, there is a risk of anaphylaxis with such products, and there is evidence of transfusion-related acute lung injury in human patients.[51] On evaluation of our study results, it was difficult to postulate how this variable was significantly associated with intestinal dehiscence. The decision to administer these products may have reflected that these dogs were more critically ill or more severely affected by the indication for surgery, and these or other factors that could not be controlled for in the statistical analysis might have contributed to the significantly higher frequency of dehiscence in these patients than in those not receiving such products.

Dogs that received preoperative antimicrobial treatment had significantly greater odds of failure to survive to discharge, compared with the odds for dogs that did not have this treatment, and administration of > 2 classes of antimicrobials was associated with a higher frequency of postoperative intestinal dehiscence, compared with that for dogs that did not receive > 2 classes of antimicrobials in the present study. Previous studies[52,53] performed to investigate empirical use of antimicrobials in dogs with bacterial pneumonia and septic peritonitis found no significant difference in survival rates between dogs administered appropriate and inappropriate antimicrobials. However, results of both studies[52,53] also revealed that dogs that had been given antimicrobials ≤ 4 weeks prior to hospitalization were significantly more likely to have received inappropriate empirical antimicrobial treatment. The greater odds of nonsurvival in dogs that received preoperative antimicrobial treatment in the present study may have been related to inappropriate antimicrobial selection, leading to a delay in the selection and administration of appropriate drugs and possibly antimicrobial resistance. In people, inappropriate antimicrobial use is associated with greater odds of death,[54] as is a delay in administering appropriate antimicrobials.[55] Determination of the exact timing of antimicrobial administration as well as the appropriateness of the chosen drug or drugs was beyond the scope of our study. We also considered that dogs with systemic signs of sepsis or severe infection were more likely to have been administered antimicrobials in the preoperative period and to have received antimicrobials of > 2 classes than were other dogs, and that underlying sepsis may have predisposed these dogs to postoperative intestinal dehiscence or death, rather than the antimicrobial selection alone.

Limitations of the present study included those common to all retrospective evaluations, including incomplete medical record information, lack of consistent preoperative and postoperative laboratory analyses, and differences in documentation of preoperative and postoperative care and patient follow-up. In addition, in-depth evaluation of specific factors that were significantly associated with failure to survive to discharge could not be performed, making it difficult to determine the clinical relevance of some of the results. Despite the relatively large number of dogs that underwent colon surgery in this multiinstitutional study, the number of patients that developed postoperative intestinal dehiscence was small, and multivariable regression could not be performed to assess risk factors for this outcome. The required follow-up time for study inclusion was 7 days after surgery; it was possible that dogs died or were euthanized after this period, and those results were outside the scope of the study. It is also important to consider that mortality

rates in any such retrospectively evaluated study sample will be affected by owner decisions made on the basis of factors such as financial limitations, prognostic information, and other concerns, and thus mortality rates can be influenced by variables other than disease progression or prognosis.

The results of the present study supported the hypothesis that postoperative dehiscence and short-term mortality rates following colon surgery requiring full-thickness incisions in dogs would be similar to those reported after small intestinal surgery in this species. Although the dehiscence and mortality rates in this study were 10% and 17%, respectively, it is important to consider that most (5/9) dogs that developed postoperative intestinal dehiscence in the present study died or were euthanized. This study provided more information to support other published data[1,2,20,21] that dogs with intestinal dehiscence have a lower rate of survival because of euthanasia or death, compared with dogs that do not develop intestinal dehiscence. The information in this report may help to guide veterinarians in determining prognosis and treatment recommendations for dogs with diseases of the colon requiring surgery.

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The authors declare that there were no conflicts of interest.

Footnotes

a. Excel 2016, Microsoft Corp, Redmond, Wash.
b. Stata, version 13.0, StataCorp, College Station, Tex.

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From this month's *AJVR*

Effect on urine specific gravity of the addition of glucose to urine samples of dogs and cats

Ellen N. Behrend et al

OBJECTIVE
To evaluate effects of the addition of glucose to dog and cat urine on urine specific gravity (USG) and determine whether glucosuria affects assessment of renal concentrating ability.

SAMPLE
Urine samples from 45 dogs and 35 cats.

PROCEDURES
Urine for each species was pooled to create samples with various USGs. Glucose was added to an aliquot of each USG pool (final concentration, 2,400 mg/mL), and serial dilutions of the glucose-containing aliquot were created for each pool. The USG then was measured in all samples. The difference in USG attributable to addition of glucose was calculated by subtracting the USG of the unaltered sample from the USG of the sample after the addition of glucose. The relationship between the difference in USG and the USG of the unaltered, undiluted sample was evaluated by the use of linear regression analysis.

RESULTS
Addition of glucose to urine samples increased the USG. There was a significant relationship between USG of the undiluted sample and the difference in USG when glucose was added to obtain concentrations of 300, 600, 1,200, and 2,400 mg/dL in canine urine and concentrations of 600, 1,200, and 2,400 mg/dL in feline urine. The more concentrated the urine before the addition of glucose, the less change there was in the USG. Changes in USG attributable to addition of glucose were not clinically important.

CONCLUSIONS AND CLINICAL RELEVANCE
Substantial glucosuria resulted in minimal alterations in specific gravity of canine and feline urine samples. Thus, USG can be used to assess renal concentrating ability even in samples with glucosuria. (*Am J Vet Res* 2019;80:907–911)

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