Identification of risk factors for septic peritonitis and failure to survive following gastrointestinal surgery in dogs

Janet A. Grimes, DVM; Chad W. Schmiedt, DVM, DACVS;
Karen K. Cornell, DVM, PhD, DACVS; MaryAnn G. Radlinksy, DVM, MS, DACVS

Objective—To identify risk factors for failure to survive and development of septic peritonitis following full-thickness gastrointestinal incision in dogs.

Design—Retrospective cohort study.

Animals—Dogs that underwent gastrointestinal surgery from 1998 through 2007 at the University of Georgia Veterinary Teaching Hospital.

Procedures—Medical records of dogs undergoing a full-thickness gastrointestinal incision were reviewed, and information regarding dog history, clinicopathologic findings, surgery characteristics, and outcome was collected.

Results—Records for 197 dogs (225 surgeries) were evaluated. In 35 (16%) surgeries, the dogs died prior to hospital discharge. After 28 (12%) surgeries, dogs developed septic peritonitis. For 45 (20%) surgeries, dogs had preoperative septic peritonitis; of those, approximately a third resulted in continued septic peritonitis (17/45; 38%) or death (15/45; 33%). Of the 180 surgeries performed in dogs lacking preoperative septic peritonitis, 11 (6%) resulted in development of septic peritonitis and 20 (11%) resulted in death. When all surgeries were considered, common risk factors for development of septic peritonitis included preoperative septic peritonitis, low preoperative serum albumin and plasma protein concentrations, and intraoperative hypotension. Presence of a foreign body was a protective factor.

Conclusions and Clinical Relevance—Multiple factors were associated with failure to survive and development of septic peritonitis after gastrointestinal surgery in dogs. Aggressive perioperative attempts to increase protein concentrations and intraoperative surgical strategies to decrease the chance of a poor outcome may be indicated in dogs with risk factors identified in this study. (*J Am Vet Med Assoc* 2011;238:486–494)

Gastrointestinal surgery is commonly performed in small animal veterinary practice for diagnostic or therapeutic reasons. Although gastrointestinal surgery may be routine, a risk of potentially fatal postoperative complications exists, the most important being leakage of ingesta at the surgical site resulting in postoperative septic peritonitis.

Factors associated with leakage or survival following gastrointestinal surgery in dogs have been reported.[1–4] Dogs and cats undergoing multiple procedures are less likely to survive than those undergoing 1 procedure because such animals are more likely than others to have a greater severity of illness and degree of surgical trauma; however, whether surgery involves the small or large intestine does not appear to influence mortality rates.[4] Abdominal trauma and gastrointestinal foreign bodies necessitating gastrointestinal surgery have also been identified as risk factors for anastomotic dehiscence.[1,2]

Presurgical diagnosis of septic peritonitis is an established risk factor for failure to survive and recurrence of anastomotic failure after surgery.[1,2,4] Mortality rates in dogs with perioperative septic peritonitis range from 37% to 85%.[1,2,4–7] Given the important historical influence of septic peritonitis on surgical outcomes, factors associated with survival and successful enteric closure should differ in dogs with or without septic peritonitis.

The association of preoperative plasma protein concentration, particularly plasma albumin concentration, with postoperative complications or failure to survive in dogs and cats undergoing gastrointestinal surgery is debatable.[1–4,8] One research group found that hypoalbuminemia (ie, ≤ 2.5 g of protein/dL) was a significant risk factor for anastomotic dehiscence.[2] Another group found that plasma albumin concentrations were lower in dogs with anastomotic dehiscence than in those without, but this finding was not significant.[1] In several other studies,[4,6,8,9] plasma albumin concentrations did not differ significantly between surviving and nonsurviving dogs that underwent intestinal surgery, nor were significant differences identified for dogs with dehiscence at the gastrointestinal surgical site.[3,8] This variability in significant differences contrasts with evidence regarding the consistent prognostic value of serum albumin concentration in human surgical patients.[10]

Abbreviations

CI	Confidence interval
OR	Odds ratio
TNF	Tumor necrosis factor

From the Department of Small Animal Medicine and Surgery, College of Veterinary Medicine, University of Georgia, Athens, GA 30602.
Address correspondence to Dr. Schmiedt (cws@uga.edu).

Correction or improvement of hypoproteinemia is a potential preoperative therapeutic goal in animals undergoing elective gastrointestinal surgery. The purpose of the study reported here was to identify risk factors for failure to survive and development of septic peritonitis following full-thickness gastrointestinal incision in dogs. Our hypothesis was that hypoalbuminemia and hypoproteinemia would be identified as risk factors for postoperative septic peritonitis and death and that the nature of the risk factors would vary with the presence of preoperative septic peritonitis and section of the gastrointestinal tract affected.

Materials and Methods

Animals—Medical records of all dogs undergoing exploratory celiotomies from 1998 through 2007 at the University of Georgia Veterinary Teaching Hospital were reviewed. Dogs and associated surgeries were included in the study when the surgery involved full-thickness incision of the stomach, small intestine, or large intestine. Multiple surgeries involving different anesthetic episodes in the same dog were treated as distinct surgeries. Dogs were excluded from the study if they died or were euthanized intraoperatively.

Data collection—Data collected from the medical record included dog age, sex, body weight, whether a relevant previous gastrointestinal surgery was performed (ie, abdominal exploratory surgery with gastrointestinal penetration; gastrotomy, enterotomy, or colotomy; or gastrointestinal resection and anastomosis), whether any surgery was performed within 72 hours before the relevant gastrointestinal surgery, and whether there was a diagnosis of preoperative septic peritonitis based on definitive cytologic evidence (ie, free or intracellular bacteria), an abdominal effusion-to-blood glucose concentration difference of > 20 mg/dL with subsequent intraoperative confirmation of gastrointestinal leakage, or a positive result of microbial culture of a swab or fluid specimen obtained from the peritoneal cavity. Whether a dog received NSAIDs or corticosteroids before or after surgery was also recorded. Preoperative hematologic findings including counts for RBCs, WBCs, and platelets were recorded from hemograms. When > 1 preoperative hemogram was available, data were collected from the one obtained closest to the time of anesthesia and surgery. General characteristics of the surgery were gathered including whether a biliary procedure was performed, surgery was performed solely for the purpose of obtaining gastrointestinal biopsies, neoplasia was diagnosed, a foreign body was discovered, or a feeding tube was placed. The anatomic location of surgery within the gastrointestinal tract (ie, stomach, small intestine, or large intestine) was also recorded.

Data regarding blood protein concentration was gathered in 3 ways. Total plasma protein and albumin concentrations as reported from the clinical pathology laboratory were recorded for 2 and 1 days before surgery, the day of surgery (preoperatively or postoperatively), and 1 and 2 days after surgery. Total plasma protein concentration as recorded in the intensive care unit by use of refractometer was recorded for the same time points. Lastly, the presence of hypoproteinemia (total plasma protein concentration < 5 g/dL) or hypoalbuminemia (serum albumin concentration < 2.5 g/dL) within 2 days before or after surgery was recorded.

Intraoperative data included whether there was intraoperative hypotension (ie, mean arterial blood pressure < 60 mm Hg as measured via a direct or indirect method) and, if so, the duration of hypotension and the number of hypotensive episodes. Surgical and anesthetic durations were recorded as well as whether antimicrobials were administered intraoperatively, whether there was cardiac arrest during anesthesia, and whether the surgery was performed after hours (ie, between 5 PM and 8 AM).

Postoperative data included the number of days dogs were kept in the intensive care unit, days of hospitalization, whether fresh frozen plasma was administered, whether dogs became hyperthermic (ie, rectal temperature > 39.2°C [102.5°F]), whether septic peritonitis developed (as defined previously), whether the dog died or was euthanized, and whether corticosteroids or NSAIDs were administered. Strictly speaking, dogs with preoperative septic peritonitis likely had some degree of postoperative septic peritonitis; therefore, postoperative septic peritonitis, as defined here, did not include dogs in which preoperative septic peritonitis was effectively treated with surgery and peritoneal lavage and resolved in the postoperative period.

Each surgery was described and grouped. The first group included all surgeries, then surgeries were grouped according to whether preoperative septic peritonitis was present (2 groups: present and not present) and the anatomic location of surgery (3 groups: stomach, small intestine, and large intestine). Thus, there were 6 groups overall, and individual surgeries were included in multiple groups, when applicable. In all groups, risk factors for 2 outcomes (in-hospital death and postoperative development of septic peritonitis) were evaluated.

Statistical analysis—Relationships between putative preoperative, intraoperative, and postoperative risk factors and outcomes (development of postoperative septic peritonitis and failure to survive to discharge) in each of the 6 groupings were evaluated by means of logistic regression analysis with a statistical software package.[a] All hypothesis tests were 2-sided, and the significance level was set at a value of $P < 0.05$. If quasiseparation of data occurred, the Firth penalized maximum likelihood estimation method was used to reduce bias in logistic model parameter estimation. Odds ratios and 95% CIs were calculated for each factor. Factors identified as significant were further evaluated by use of multiple regression analysis. When insufficient data existed to evaluate all data within 1 multiple regression analysis, data were split into smaller, clinically related groups for analysis. Mean age was compared between groups with a 2-tailed Student *t* test. Data regarding risk factors for each outcome are reported as mean ± SD. Risk factors that were deemed not significant are not reported.

Results

Animals—Medical records of 197 dogs with a total of 225 gastrointestinal surgeries were identified for

analysis. The mean ± SD age of all dogs was 6.4 ± 4.0 years. Seventy-nine surgeries involved spayed females, 77 involved castrated males, 50 involved sexually intact males, and 19 involved sexually intact females. Of the 225 surgeries, 35 (16%) resulted in death while the affected dog was in the hospital; 28 (12%) surgeries resulted in postoperative development of septic peritonitis. Of the 35 dogs that did not survive to discharge from the hospital, 15 (43%) had postoperative septic peritonitis.

Risk factors involving all surgeries combined— Univariate logistic regression identified several risk factors for postoperative development of septic peritonitis and death (**Tables 1 and 2**). Low preoperative plasma protein concentration (assessed cage-side or via chemistry analyzer) and low serum albumin concentration were significantly associated with septic peritonitis and death after surgery. Surgeries involving dogs with preoperative septic peritonitis also had a significantly higher risk of postoperative septic peritonitis and death. Surgeries involving a gastrointestinal foreign body were significantly less likely to do the same. Seventy-three surgeries involved a gastrointestinal foreign body, and the age of these dogs (6.3 ± 4.2 years) did not differ significantly ($P = 0.60$) from the age of dogs with no foreign body (6.5 ± 3.9 years).

The Spearman correlation test revealed moderate correlation between hypoalbuminemia and hypoproteinemia ($\rho = 0.63$). Multivariate logistic regression to evaluate whether preoperative hypoalbuminemia (yes or no) and preoperative hypoproteinemia (yes or no) were associated with failure to survive after surgery identified preoperative hypoproteinemia as significant (OR, 5.4; 95% CI, 2.0 to 14.7; $P = 0.001$). However, when testing whether preoperative hypoalbuminemia and preoperative hypoproteinemia were significantly associated with postoperative development of septic peritonitis, neither factor was significant.

Multivariate logistic regression was used to test the following factors identified through univariate analysis as significant for relationships with failure to survive after surgery: history of gastrointestinal surgery within 72 hours prior to the relevant surgery, surgery involving the biliary system, diagnosis of a foreign body, and preoperative diagnosis of septic peritonitis. Of those 4 factors, biliary surgery (OR, 4.8; 95% CI, 1.2 to 20.0; $P = 0.03$) and diagnosis of preoperative septic peritonitis (OR, 3.4; 95% CI, 1.3 to 8.6; $P = 0.01$) were identified as significant risk factors, whereas diagnosis of a foreign body was protective (OR, 0.2; 95% CI, 0.0 to 0.7; $P = 0.01$).

The same procedure was used to test the following factors identified through univariate analysis as significant for relationships with postoperative septic peritonitis: prior abdominal surgery within 72 hours before the relevant surgery, diagnosis of a foreign body, large intestinal surgery, and preoperative diagnosis of septic peritonitis. Of those 4 factors, only preoperative diagnosis of septic peritonitis was significant (OR, 7.5; 95% CI, 2.9 to 19.5; $P < 0.001$).

Table 1—Significant results of univariate logistic regression analysis of variables associated with development of septic peritonitis after gastrointestinal surgery (n = 225 surgeries) in 197 dogs at a veterinary teaching hospital.

Variable	Value in group with postoperative peritonitis	Value in group without postoperative peritonitis	OR	95% CI	*P* value
Before surgery					
Abdominal surgery within 72 hours before relevant surgery*	6/28 (21)	12/196 (6)	4.2	1.4–12.3	0.009
Septic peritonitis*	17/28 (61)	27/194 (14)	9.2	3.9–21.7	< 0.001
Hypoproteinemia* (< 5.0 g/dL; RF)	8/16 (50)	35/112 (31)	2.4	1.0–5.4	0.041
TP on day 0 (g/dL; CA)	4.94 ± 1.30 (12/28)	5.79 ± 1.25 (85/196)	0.6	0.3–1.0	0.037
TP on day 0 (g/dL; RF)	5.24 ± 1.46 (17/28)	6.16 ± 1.41 (94/196)	0.6	0.4–0.9	0.018
Albumin on day 0 (g/dL)	2.32 ± 0.79 (13/28)	3.06 ± 0.78 (85/196)	0.3	0.1–0.7	0.005
During surgery					
Hypotension* (MAP < 60 mm Hg)	19/28 (68)	89/187 (48)	2.3	1.0–5.4	0.050
No. of hypotensive episodes	2.78 ± 2.44 (18/28)	1.42 ± 1.43 (106/196)	1.5	1.2–2.0	0.003
Foreign body*	4/28 (14)	68/196 (35)	0.3	0.1–0.9	0.039
Large intestinal surgery*	6/28 (21)	13/195 (7)	3.8	1.3–11.1	0.014
After surgery					
TP on day 1 (g/dL; RF)	4.54 ± 1.22 (23/28)	5.19 ± 1.06 (145/196)	0.5	0.3–0.9	0.008
TP on day 2 (g/dL; RF)	4.54 ± 1.12 (20/28)	5.45 ± 0.95 (115/196)	0.4	0.2–0.7	0.001
TP on day 2 (g/dL; CA)	3.62 ± 1.16 (10/28)	4.53 ± 1.09 (40/196)	0.4	0.2–0.9	0.033
Hypoproteinemia* (< 5.0 g/dL; RF)	25/28 (89)	100/164 (61)	5.3	1.6–18.4	0.008
Hypoalbuminemia* (< 2.5 g/dL)	23/23 (100)	63/91 (69)	21.1	1.2–377.8	0.038
Plasma administered after surgery*	21/28 (75)	58/195 (30)	7.1	2.9–17.6	< 0.001
Hyperthermia* (> 39.2°C)†	8/28 (29)	16/196 (8)	4.5	1.7–11.8	0.002
Days to ICU discharge	8.54 ± 4.35 (13/28)	3.65 ± 2.57 (176/196)	1.5	1.2–1.7	< 0.001
Days to hospital discharge	9.25 ± 4.22 (12/28)	4.93 ± 2.59 (174/196)	1.4	1.2–1.7	< 0.001

Values reported are proportion (%) of relevant surgeries for which data were available with the indicated characteristic for dichotomous (yes or no) variables or mean ± SD (proportion of relevant surgeries for which data were available) for continuous variables.

*Dichotomous (yes or no) variable. †To convert to Farenheit, multiply by 1.8 and add 32.

CA = Total protein value obtained from chemistry analyzer. ICU = Intensive care unit. MAP = Mean arterial blood pressure. RF = Total protein value obtained from refractometer. TP = Total protein.

Odds ratios refer to the fold increase in odds per unit increase of a particular risk factor (continuous variables) or the odds of having the outcome in dogs with versus without the risk factor. Values < 1 suggest dogs with the factor were less likely to have the outcome; values > 1 suggest dogs with the factor were more likely to have the outcome. Day 0 is the day of surgery, and days 1 and 2 are 1 and 2 days after surgery, respectively. A value of $P < 0.05$ was considered significant. Values for CIs may include 1 because of rounding.

Table 2—Significant results of univariate logistic regression analysis of variables associated with failure to survive to hospital discharge after gastrointestinal surgery (n = 225 surgeries) in 197 dogs at a veterinary teaching hospital.

Variable	Value in group that failed to survive	Value in group that survived	OR	95% CI	*P* value
Before surgery					
Any previous surgery*	8/35 (23)	19/188 (10)	2.6	1.05–6.67	0.039
Septic peritonitis*	15/35 (43)	29/186 (16)	3.8	1.82–8.30	0.001
RBC count ($\times 10^6$ cells/μL)	5.44 ± 1.69 (32/35)	6.71 ± 3.19 (172/188)	0.7	0.58–0.90	0.004
TP on day –1 (g/dL; CA)	4.69 ± 1.53 (14/35)	6.08 ± 1.22 (51/188)	0.5	0.27–0.76	0.003
TP on day 0 (g/dL; CA)	4.72 ± 1.18 (12/35)	5.82 ± 1.24 (85/188)	0.5	0.27–0.82	0.008
TP on day 0 (g/dL; RF)	5.39 ± 1.58 (23/35)	6.20 ± 1.37 (87/188)	0.7	0.45–0.93	0.019
Hypoproteinemia* (< 5.0 g/dL; CA)	20/33 (61)	42/170 (25)	4.8	2.13–10.20	< 0.001
Albumin on day –1 (g/dL)	2.23 ± 0.81 (16/35)	3.21 ± 0.82 (51/188)	0.2	0.09–0.52	< 0.001
Albumin on day 0 (g/dL)	2.28 ± 0.61 (13/35)	3.07 ± 0.80 (85/188)	0.3	0.10–0.62	0.003
Hypoalbuminemia* (< 2.5 g/dL)	15/33 (45)	44/169 (26)	2.4	1.10–5.10	0.028
During surgery					
Foreign body*	2/35 (6)	70/188 (37)	0.1	0.02–0.44	0.002
Biliary surgery*	4/35 (11)	5/188 (3)	4.8	1.20–20.0	0.026
Hypotension* (MAP < 60 mm Hg)	23/33 (70)	84/181 (46)	2.6	1.19–5.88	0.016
Total duration of hypotension (min)	73.95 ± 72.96 (19/35)	34.94 ± 42.31 (64/188)	1.0	1.00–1.02	0.013
No. of hypotensive episodes	2.28 ± 2.07 (25/35)	1.46 ± 1.53 (98/188)	1.3	1.02–1.69	0.034
Surgery duration (min)	154.24 ± 75.39 (33/35)	127.26 ± 51.38 (186/188)	1.0	1.00–1.01	0.014
After surgery					
TP on day 0 (g/dL; RF)	4.21 ± 1.00 (27/35)	4.82 ± 1.01 (78/188)	0.5	0.3–0.9	0.010
TP on day 1 (g/dL; RF)	4.41 ± 0.94 (26/35)	5.24 ± 1.08 (141/188)	0.4	0.3–0.7	< 0.001
TP on day 2 (g/dL; RF)	4.38 ± 1.08 (19/35)	5.48 ± 0.93 (115/188)	0.3	0.2–0.6	< 0.001
TP on day 2 (g/dL; CA)	3.59 ± 1.10 (10/35)	4.54 ± 1.09 (40/188)	0.4	0.2–0.9	0.027
Albumin on day 2 (g/dL)	1.64 ± 0.58 (9/35)	2.34 ± 0.67 (38/188)	0.1	0.0–0.6	0.013
Hypoproteinemia* (< 5.0 g/dL; RF)	29/33 (88)	95/158 (60)	4.8	1.6–14.3	0.005
Plasma administered*	24/35 (69)	54/187 (29)	5.3	2.4–11.1	< 0.001

Day –1 refers to 1 day before surgery.
See Table 1 for remainder of key.

Because of incomplete availability of data, other meaningful multiple logistic regression analyses could not be performed in this or other surgical groups.

Risk factors involving preoperative septic peritonitis—Forty-five of the 225 (20%) surgeries involved dogs with preoperative septic peritonitis. Of those 45, 17 (38%) dogs went on to have postoperative septic peritonitis and 15 (33%) dogs died. Eight of 17 (47%) surgeries involving dogs with both preoperative and postoperative septic peritonitis resulted in failure to survive to hospital discharge. Twenty of the 180 (11%) surgeries involving dogs without preoperative septic peritonitis resulted in death. Eleven of the 180 (6%) surgeries involved dogs that developed postoperative septic peritonitis; 5 of the 11 dogs died.

Univariate logistic regression identified significant relationships between several variables and outcomes in both of these groups (**Tables 3 and 4**). No dogs with preoperative septic peritonitis had surgery associated with biliary surgery or postoperative NSAID administration, so these risk factors were not evaluated for surgeries involving dogs with preoperative septic peritonitis.

Preoperative hypoproteinemia was a significant risk factor for failure to survive after surgery in dogs with and without preoperative septic peritonitis. In surgeries involving dogs with preoperative septic peritonitis, a low preoperative RBC count and high preoperative WBC count were also significant risk factors for death. In surgeries involving dogs without preoperative septic peritonitis, presence of a foreign body was identified as protective against failure to survive after surgery; however, increased surgical duration and having gastrointestinal surgery in combination with biliary surgery were significant risk factors. Postoperative administration of corticosteroids was associated with failure to survive in dogs with preoperative septic peritonitis. In 21 of 180 (12%) surgeries, dogs received corticosteroids after surgery; of these, 6 (29%) dogs died.

No significant preoperative risk factors for having postoperative septic peritonitis were identified in surgeries involving dogs with preoperative septic peritonitis. During surgery, existence of hypotension increased the odds of postoperative septic peritonitis and administration of antimicrobials reduced the odds. Similarly, for surgeries involving dogs without preoperative septic peritonitis, no preoperative or intraoperative risk factors for postoperative development of septic peritonitis were identified. After surgery, plasma protein and serum albumin concentrations increased the odds of developing septic peritonitis, as did hyperthermia.

Risk factors involving gastric surgery—One hundred two surgeries involved the stomach, and 40 of these involved the stomach alone. Of those 40 surgeries, 4 (10%) resulted in septic peritonitis and none of the affected dogs died. After 3 of the 40 (8%) surgeries, the affected dog died. Sixty-one surgeries involved the stomach and small intestine. Afterward, 6 (10%) dogs developed septic peritonitis, and 4 of those 6 dogs died. Of all dogs that underwent both gastric and small intestinal surgeries, 6 (10%) dogs died. No surgery involved both the stomach and large intestine. One surgery involved the stomach, small intestine, and large intestine; the affected dog did not develop septic peritonitis but did not survive to discharge from the hospital.

Table 3—Significant results of univariate logistic regression analysis of variables associated with failure to survive to hospital discharge after gastrointestinal surgery (n = 225 surgeries) in dogs with and without preoperative septic peritonitis at a veterinary teaching hospital.

Variable, by condition	Value in group that failed to survive	Value in group that survived	OR	95% CI	*P* value
Without peritonitis, before surgery					
TP on day –1 (g/dL; CA)	4.98 ± 1.35 (9/20)	6.18 ± 1.12 (45/157)	0.4	0.2–0.8	0.014
Hypoproteinemia* (< 5.0 g/dL; CA)	9/18 (50)	33/143 (23)	3.3	1.2–9.1	0.019
Albumin on day –1 (g/dL)	2.47 ± 0.80 (9/20)	3.26 ± 0.76 (45/157)	0.2	0.1–0.7	0.011
Without peritonitis, during surgery					
Biliary surgery*	4/20 (20)	5/157 (3)	7.7	1.9–33.3	0.005
Foreign body*	2/20 (10)	66/157 (42)	0.2	0.1–0.7	0.016
Surgery duration (min)	152.15 ± 91.61 (20/20)	123.22 ± 48.53 (156/157)	1.0	1.0–1.0	0.035
Without peritonitis, after surgery					
TP on day 1 (g/dL; RF)	4.62 ± 0.96 (16/20)	5.31 ± 1.08 (115/157)	0.5	0.3–0.9	0.013
TP on day 2 (g/dL; RF)	4.53 ± 1.26 (11/20)	5.54 ± 0.91 (90/157)	0.4	0.2–0.7	0.003
Plasma administered*	9/20 (45)	33/156 (21)	3.0	1.2–7.7	0.021
With peritonitis, before surgery					
RBC count ($\times 10^6$ cells/μL)	4.53 ± 1.17 (15/15)	6.04 ± 1.55 (27/30)	0.6	0.4–0.9	0.012
WBC count ($\times 10^6$ cells/μL)	26.45 ± 15.18 (15/15)	18.53 ± 8.99 (28/30)	1.1	1.0–1.1	0.047
Hypoproteinemia* (< 5.0 g/dL; CA)	11/15 (73)	9/26 (35)	5.3	1.3–21.3	0.021
With peritonitis, during surgery					
Total duration of hypotension (min)	112.50 ± 83.79 (8/15)	47.50 ± 37.28 (16/30)	1.0	1.0–1.0	0.049
With peritonitis, after surgery					
TP on day 1 (g/dL; RF)	4.07 ± 0.85 (10/15)	4.93 ± 1.07 (25/30)	0.4	0.2–1.0	0.041
TP on day 2 (g/dL; RF)	4.17 ± 0.82 (8/15)	5.27 ± 1.03 (24/30)	0.3	0.1–0.8	0.022
Corticosteroids administered*	4/15 (27)	1/30 (3)	10.0	1.0–100.0	0.045

See Tables 1 and 2 for key.

Table 4—Significant results of univariate logistic regression analysis of variables associated with septic peritonitis after gastrointestinal surgery (n = 225 surgeries) in dogs with and without preoperative septic peritonitis at a veterinary teaching hospital.

Variable, by condition	Value in group with peritonitis	Value in group without peritonitis	OR	95% CI	*P* value
Without preoperative peritonitis, after surgery					
Hypoproteinemia* (< 5.0 g/dL; RF)	11/11 (100)	77/138 (56)	18.3	1.0–323.3	0.048
TP on day 1 (g/dL; RF)	4.40 ± 1.36 (11/11)	5.28 ± 1.04 (121/167)	0.4	0.2–0.8	0.008
TP on day 2 (g/dL; RF)	4.22 ± 1.16 (9/11)	5.53 ± 0.91 (93/167)	0.2	0.1–0.6	0.001
TP on day 2 (g/dL; CA)	2.98 ± 0.68 (4/11)	4.61 ± 1.10 (31/167)	0.1	0.0–0.9	0.043
Albumin on day 2 (g/dL)	1.50 ± 0.41 (4/11)	2.39 ± 0.74 (31/167)	0.1	0.0–0.9	0.043
Plasma administered*	6/11 (55)	37/166 (22)	4.2	1.2–14.5	0.024
Hyperthermia* (> 39.2°C)†	3/11 (27)	9/167 (5)	6.6	1.5–29.1	0.013
Second surgery*	8/11 (73)	3/167 (1.2)	145.8	25.3–839.4	< 0.001
Days to ICU discharge	8.83 ± 4.62 (6/11)	3.41 ± 2.35 (152/167)	1.6	0.0–0.5	0.009
Days to hospital discharge	10.60 ± 3.91 (5/11)	4.79 ± 2.37 (150/167)	1.7	1.2–2.1	< 0.001
With preoperative peritonitis, during surgery					
No. of hypotensive episodes	3.82 ± 2.44 (11/17)	1.81 ± 1.78 (21/28)	1.6	1.1–2.4	0.024
Perioperative antimicrobial administration*	11/17 (65)	25/27 (93)	0.2	0.0–0.8	0.032

Second surgery refers to dogs that had a second surgery to repair dehiscence or investigate continued or recurrent peritonitis.
See Table 1 for key.

When data from all surgeries involving a gastrotomy were analyzed via univariate logistic regression, significant risk factors were identified for postoperative death and postoperative septic peritonitis (**Tables 5 and 6**). A diagnosis of foreign body in affected dogs was protective against failure to survive after surgery. Low plasma protein and serum albumin concentrations, preoperative septic peritonitis, and intraoperative hypotension were also significant in the postoperative development of septic peritonitis.

Risk factors for dogs undergoing small intestinal surgery—One hundred eighty surgeries involved the small intestine, and 104 of these involved the small intestine alone. Overall, dogs failed to survive to hospital discharge in 17 of the 104 (16%) small intestinal surgeries. Twelve (12%) dogs that underwent surgery involving only the small intestine developed septic peritonitis, and 4 of these dogs died. Fourteen surgeries involved the small and large intestines. Two of these 14 dogs failed to survive to hospital discharge. Five dogs developed septic peritonitis, and of those, 2 died.

Several significant risk factors were identified involving surgeries of the small intestine (**Tables 7 and 8**). Preoperative protective factors against postoperative death included diagnosis of foreign body, increasing plasma protein or serum albumin concentration, and increasing RBC counts. On the other hand, surgeries

Table 5—Significant results of univariate logistic regression analysis of variables associated with failure to survive after gastric surgery (n = 102 surgeries) in dogs at a veterinary teaching hospital.

Variable	Value in group that failed to survive	Value in group that survived	OR	95% CI	*P* value
Before surgery					
Septic peritonitis*	5/12 (42)	8/87 (9)	7.1	1.8–25.0	0.005
Albumin on day –1 (g/dL)	2.27 ± 0.81 (6/12)	3.16 ± 0.92 (23/88)	0.3	0.1–1.0	0.048
TP on day 0 (g/dL; RF)	4.99 ± 1.11 (7/12)	6.42 ± 1.44 (37/88)	0.4	0.2–0.9	0.025
During surgery					
Foreign body*	1/12 (8)	41/88 (47)	0.1	0.0–0.8	0.032
Hypotension* (MAP < 60 mm Hg)	9/12 (75)	35/84 (42)	4.4	1.1–16.7	0.037
No. of hypotensive episodes	2.11 ± 1.36 (9/12)	0.98 ± 1.20 (46/88)	1.9	1.1–3.2	0.026
After surgery					
TP on day 2 (g/dL; RF)	4.38 ± 1.11 (7/12)	5.64 ± 0.81 (55/88)	0.2	0.1–0.6	0.007
Plasma administered*	7/12 (58)	17/88 (19)	6.3	1.8–20.0	0.005

See Tables 1 and 2 for key.

Table 6—Significant results of univariate logistic regression analysis of variables associated with development of septic peritonitis after gastric surgery (n = 102 surgeries) in dogs at a veterinary teaching hospital.

Variable	Value in group with peritonitis	Value in group without peritonitis	OR	95% CI	*P* value
Before surgery					
Septic peritonitis*	5/10 (50)	8/90 (9)	10.3	2.4–43.1	0.001
During surgery					
Hypotension (MAP < 60 mm Hg)	8/10 (80)	37/87 (43)	5.6	1.1–27.7	0.037
Surgery duration (min)	170.80 ± 74.49 (10/10)	129.86 ± 53.23 (91/91)	1.0	1.0–1.0	0.037
After surgery					
TP on day 2 (g/dL; RF)	4.52 ± 1.08 (9/10)	5.63 ± 0.82 (54/91)	4.1	1.5–10.9	0.005
Hypoproteinemia* (< 5.0 g/dL; RF)	10/10 (100)	41/76 (53.9)	18.4	1.0–338.8	0.050
Plasma administered*	7/10 (70)	18/91 (20)	10.0	2.4–42.8	0.002
Hyperthermia* (> 39.2°C)†	3/10 (30)	5/91 (5)	7.3	1.4–37.0	0.017
Days to ICU discharge	8.00 ± 4.16 (4/10)	3.36 ± 2.10 (85/91)	0.6	0.4–0.9	0.005
Days to hospital discharge	10.00 ± 3.00 (3/10)	4.55 ± 2.23 (83/91)	0.5	0.3–0.8	0.008

See Table 1 for key.

Table 7—Significant results of univariate logistic regression analysis of variables associated with failure to survive after small intestinal surgery (n = 180 surgeries) in dogs at a veterinary teaching hospital.

Variable	Value in group that failed to survive	Value in group that survived	OR	95% CI	*P* value
Before surgery					
Septic peritonitis*	13/31 (42)	23/147 (16)	3.8	1.7–9.1	0.002
RBC count (× 10^6 cells/μL)	5.57 ± 1.54 (29/31)	6.90 ± 3.42 (138/148)	0.7	0.5–0.9	0.006
TP on day –1 (g/dL; CA)	4.72 ± 1.59 (13/31)	6.07 ± 1.33 (39/148)	0.5	0.3–0.8	0.009
TP on day 0 (g/dL; CA)	4.63 ± 1.26 (10/31)	5.78 ± 1.20 (71/148)	0.5	0.2–0.8	0.013
Hypoproteinemia* (< 5.0 g/dL; CA)	18/30 (60)	36/136 (26.5)	4.2	1.8–9.1	0.001
Albumin on day –1 (g/dL)	2.29 ± 0.85 (14/31)	3.21 ± 0.88 (39/148)	0.3	0.1–0.7	0.006
Albumin on day 0 (g/dL)	2.21 ± 0.57 (12/31)	3.08 ± 0.75 (71/148)	0.1	0.0–0.5	0.002
During surgery					
Biliary surgery*	4/31 (13)	5/148 (3)	4.2	1.1–16.7	0.041
Foreign body*	2/31 (6)	51/148 (34)	0.2	0.0–0.6	0.007
Total duration of hypotension (min)	71.00 ± 70.23 (15/31)	33.68 ± 43.01 (56/148)	1.0	1.0–1.0	0.030
Anesthesia duration (min)	230.77 ± 93.53 (30/31)	201.32 ± 59.40 (145/148)	1.0	1.0–1.0	0.031
Surgery duration (min)	154.14 ± 78.86 (29/31)	126.77 ± 47.65 (146/148)	1.0	1.0–1.0	0.017
After surgery					
TP on day 0 (g/dL; RF)	4.16 ± 0.96 (24/31)	4.79 ± 1.07 (63/148)	0.53	0.3–0.9	0.017
TP on day 1 (g/dL; RF)	4.30 ± 0.94 (23/31)	5.19 ± 1.13 (111/148)	0.40	0.2–0.7	0.001
TP on day 2 (g/dL; RF)	4.32 ± 1.08 (18/31)	5.43 ± 0.96 (97/148)	0.33	0.2–0.6	0.000
TP on day 2 (g/dL; CA)	3.38 ± 1.12 (8/31)	4.50 ± 1.07 (30/148)	0.29	0.1–0.9	0.024
Hypoproteinemia* (< 5.0 g/dL; RF)	9/23 (39)	25/82 (30)	5.56	1.6–20.0	0.007
Albumin on day 2 (g/dL)	1.61 ± 0.62 (8/31)	2.32 ± 0.71 (30/148)	0.10	0.0–0.7	0.024
Corticosteroids administered*	6/31 (19)	10/148 (7)	3.33	1.1–10.0	0.031
Plasma administered*	21/31 (68)	46/147 (31)	4.76	2.0–11.1	0.000
Second surgery*	7/31 (23)	8/148 (5)	5.0	1.7–14.3	0.004

See Tables 1 and 2 for key.

Table 8—Significant results of univariate logistic regression analysis of variables associated with development of septic peritonitis after small intestinal surgery (n = 180 surgeries) in dogs at a veterinary teaching hospital.

Variable	Value in group with peritonitis	Value in group without peritonitis	OR	95% CI	*P* value
Before surgery					
Abdominal surgery within 72 hours before relevant surgery*	6/23 (26)	10/157 (6)	5.2	1.7–16.0	0.004
Any previous surgery	6/23 (26)	17/157 (11)	3.0	1.0–8.4	0.042
Septic peritonitis*	14/23 (61)	22/156 (14)	9.5	3.7–24.5	0.000
RBC count ($\times 10^6$ cells/μL)	5.67 ± 1.40 (23/23)	6.82 ± 3.38 (145/157)	1.4	1.0–1.8	0.035
TP on day 0 (g/dL; CA)	4.85 ± 1.32 (11/23)	5.77 ± 1.21 (70/157)	1.8	1.0–3.2	0.036
Hypoproteinemia* (< 5.0 g/dL; CA)	12/23 (52.2)	43/144 (29.9)	2.5	1.0–6.2	0.041
TP on day 0 (g/dL; RF)	5.16 ± 1.46 (16/23)	6.06 ± 1.38 (77/157)	1.7	1.1–2.6	0.025
Albumin on day 0 (g/dL)	2.34 ± 0.82 (12/23)	3.06 ± 0.74 (71/157)	4.2	1.5–12.1	0.008
During surgery					
No. of hypotensive episodes	2.67 ± 2.66 (15/23)	1.55 ± 1.48 (87/157)	0.7	0.6–1.0	0.032
After surgery					
TP on day 2 (g/dL; RF)	4.34 ± 1.12 (16/23)	5.39 ± 0.98 (100/157)	2.8	1.5–5.1	0.001
Hypoproteinemia* (< 5.0 g/dL; RF)	20/23 (87)	85/135 (63)	3.5	1.1–11.6	0.040
Plasma administered*	18/23 (78)	50/156 (32)	7.8	2.7–22.2	0.000
Hyperthermia* (> 39.2°C)†	6/23 (26)	14/157 (9)	3.6	1.2–10.6	0.021
Second surgery*	11/23 (48)	4/157 (3)	31.2	8.8–110.5	0.000
Days to ICU discharge	7.89 ± 4.94 (9/23)	3.87 ± 2.72 (140/157)	0.8	0.7–0.9	0.001
Days to hospital discharge	8.75 ± 4.95 (8/23)	5.12 ± 2.75 (139/157)	0.8	0.6–0.9	0.003

See Table 1 for key.

involving biliary surgery and preoperative septic peritonitis had greater odds of failure to survive. Hypotension during surgery and increased surgery and anesthesia duration were also significant risk factors for death. Low postoperative protein and albumin concentrations were also identified as significantly associated with postoperative death.

Risk factors for postoperative septic peritonitis included previous abdominal surgery, preoperative septic peritonitis, and low plasma protein and serum albumin concentrations.

Risk factors involving large intestinal surgery— Nineteen surgeries involved the large intestine. Four involved surgery of the large intestine alone, 1 of which resulted in septic peritonitis; none of the dogs died. For all 19 surgeries involving the large intestine, postoperative corticosteroid administration was significantly associated with failure to survive after surgery (OR, 100.0; 95% CI, 1.6 to 3,448; $P = 0.029$), and requirement for a second surgery was associated with postoperative septic peritonitis (OR, 48.6; 95% CI, 1.4 to 1,695; $P = 0.032$).

Discussion

In the study reported here, variables were examined for associations with failure to survive and development of septic peritonitis following full-thickness gastrointestinal incision in dogs. We identified a mortality rate of approximately 15% following various gastrointestinal surgeries in dogs, and septic peritonitis was diagnosed after 12% of surgeries. The probability of death tripled when dogs had septic peritonitis before surgery; 11% of surgeries involving dogs without preoperative septic peritonitis were followed by death, compared with 33% of surgeries involving dogs with preoperative septic peritonitis. Low preoperative plasma protein and serum albumin concentrations, as well as the presence of preoperative septic peritonitis, were significantly associated with both failure to survive and postoperative development of septic peritonitis in dogs following gastrointestinal surgery.

The strong association between preoperative septic peritonitis and the risk of postoperative septic peritonitis and death existed when all surgeries were considered together as well as when surgeries involving various segments of the gastrointestinal tract were evaluated independently. In dogs with preoperative septic peritonitis, we were unable to identify specific preoperative risk factors for postoperative development of septic peritonitis. In such situations, a lower preoperative RBC count, a higher WBC count, and hypoproteinemia were all significantly associated with nonsurvival. These factors were likely markers for more severe systemic disease.

Enteric healing is impaired when septic peritonitis is present.[11,12] Collagen synthesis is an important aspect of wound healing: it imparts wound strength and seals small tissue defects to prevent leakage after closure. In rodents, peritonitis results in weaker anastomotic bursting pressure and less total collagen content of the anastomosis site than in unaffected rodents.[12] This reduction in collagen coincides with reduction of new collagen and total protein synthesis at the anastomotic site, potentially due to depletion of amino acid substrate and energy stores.[11] In addition, septic peritonitis results in high amounts of TNF-α, which is a proinflammatory cytokine.[13] In turn, TNF-α has been shown to reduce gene expression of collagen α1(I) and of transforming growth factor-β, which is a profibrotic cytokine.[14] Additionally, an increase in collagen destruction associated with collagenases can occur with septic peritonitis. For example, in humans with septic peritonitis, active matrix metalloproteinase-8, which is a collagenase of neutrophil origin, is of higher concentration in the serum and urine than in people without the condi-

tion.[15] The concentration of matrix metalloproteinase-8 is also substantially higher in the peritoneal fluid than in the blood in humans with septic peritonitis.[15] Thus, the presence of septic peritonitis provides a challenging environment for enteric healing because impaired collagen synthesis and increased collagen destruction both can occur.

Serum albumin concentration in dogs and cats has been identified as a significant predictor of anastomotic complications[2]; however, other veterinary studies[1,3] have not confirmed this relationship. Collection of intestinal biopsy specimens from hypoalbuminemic dogs reportedly results in no enteric healing complications.[8] In contrast, human studies[10,16–21] have consistently demonstrated albumin concentration to be a predictor of postoperative complications as well as of death, even when the concentration varies within reference limits. In 1 human study,[16] the increase in the estimated odds of death ranged from 24% to 56% for every 2.5 g/L reduction in albumin concentration. Although albumin is not an essential element of wound healing, it serves as a marker for disease and nutritional status, maintains oncotic pressure, and binds proteins and other substances critical in wound healing.[16,22]

Other than albumin, proteins considered important in wound healing are collagen, acute-phase proteins (eg, interleukins, C-reactive protein, TNFs, and haptoglobin), protease inhibitors, ceruloplasmin, and fibrinogen.[22] Taken as a group, plasma proteins exert substantial influence over inflammation and progression of wound healing. Also, because plasma protein concentration often varies with plasma albumin concentration, considerable perturbation in either may be a marker of general systemic abnormalities.[23]

In the present study, multivariate regression analysis was used to delineate covariation between total protein and albumin concentrations. In 1 analysis, preoperative hypoproteinemia (yes or no) was a significant risk factor for failure to survive to discharge when included with preoperative hypoalbuminemia (yes or no), which was not significant. However, preoperative serum albumin concentration was significant in several univariate logistic regression analyses.

In contrast to findings of other retrospective studies,[1,2] diagnosis of a gastrointestinal foreign body was consistently protective across several surgical groups in our analysis. This protective effect was evident even after multiple regression analysis. When all surgeries and surgeries involving the stomach alone were considered, having a foreign body was protective against postoperative death and development of septic peritonitis. When surgeries involving the small intestine alone were considered independently, diagnosis of foreign body was protective against postoperative death but had no relationship with postoperative development of septic peritonitis. Although young, healthy dogs are classically believed to acquire foreign bodies more often than older dogs, age did not differ significantly between dogs with and without foreign bodies in our study. Additionally, each surgery was treated as a distinct entity, which meant that a dog that developed septic peritonitis after foreign body removal may have had additional surgeries, but these additional surgeries would not have been recorded as related to a foreign body because the foreign body had been removed during the first surgery.

In a previous study,[1] foreign bodies were associated with 28% of the anastomotic dehiscences when 19 dogs with small intestinal dehiscence were compared with 102 dogs without dehiscence. This percentage was significantly greater than that for dehiscence associated with intussusception, hernia, neoplasia, abscess, or other. The authors postulated the cause may have been loss of small intestinal integrity or missed diagnoses of small intestinal perforations at the time of surgery. Another study[2] also revealed intestinal foreign bodies were a risk factor for leakage following intestinal anastomosis. That study involved comparison of 13 dogs with intestinal leakage to 77 dogs with intestinal surgery that did not leak. Dehiscence occurred in 26% of foreign body surgeries, and the authors considered that an increase in dehiscence may have been associated with intestinal vascular thrombosis or bowel wall edema.[2] In other studies,[9,24] the association of foreign bodies with dehiscence was evaluated, but the studies involved low numbers of affected dogs, so valid conclusions regarding risk of leakage after foreign body removal could not be determined. In the study reported here, of the 28 dogs that developed septic peritonitis, 4 (14%) had foreign bodies. When only intestinal surgeries were considered, of the 20 dogs that died postoperatively, 1 had surgery for a foreign body. The discrepancy between our results and those of previous reports may be attributable to the larger number of surgeries included in our study.

When gastrointestinal surgery was performed in conjunction with surgery of the extrahepatic biliary system in the present study, the odds of death increased. Death associated with biliary surgery alone is high, particularly when compared with death associated with routine gastrointestinal surgery[25]; thus, this risk factor was likely associated with hepatobiliary disease more than intestinal complications. Similarly, intraoperative hypotension was significantly associated with postoperative development of septic peritonitis and death. It is difficult to ascertain whether hypotension was a marker for other systemic injury or whether it directly impaired enteric healing secondary to poor perfusion and low tissue oxygenation. Regardless, intraoperative hypotension may represent an important therapeutic target to maximize clinical success.

Although the study reported here involves the largest number of gastrointestinal surgeries in the veterinary literature, the numbers are still relatively small. Additionally, to standardize analysis as much as possible, distinction was maintained during analysis between plasma total protein concentrations measured via 2 sources (refractometer vs laboratory chemistry analyzer) and the exact point at which they were measured. However, the historical records were incomplete with respect to these data. Additionally, there was covariability in the data, as some values may have fluctuated depending on others. For example, variation in serum albumin concentration may cause variation in plasma total protein concentration to become a significant factor. Multiple regression analysis was attempted, but because of the problems described, fully complete data sets were too few in number to yield valid results.

Lastly, specific surgical procedures (eg, resection and anastomosis vs enterotomy) were not completely distinguished in our analysis.

The findings of the present study confirmed that preoperative septic peritonitis and hypoalbuminemia are significant predictors of outcomes of gastrointestinal surgery. Importantly, other therapeutic targets were identified, including intraoperative blood pressure and pre- or postoperative serum protein concentration. Surgeons should be aware of these risk factors when planning surgery by contemplating additional surgical strategies that may increase the odds of success, considering prognoses, and caring for patients before, during, and after gastrointestinal surgery.

a. SAS, version 9.1, SAS Institute Inc, Cary, NC.

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