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CLINICAL RESEARCH

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Clinical findings and prognostic factors for immediate survival in 33 dogs undergoing surgery for biliary peritonitis

Solène Renaud DVM[1] | Mila Freire DMV, PhD, DACVS (Small Animal)[1] | Elizabeth O'Toole BSc, DVM, DVSc, DACVECC[1] | Louis Huneault DMV, MSc, DACVS (Small Animal)[2] | Marie Llido DVM[2,3] | Brendon Ringwood DMV, MSc, DACVS[4] | Tristan Juette PhD[1] | Dominique Gagnon DMV, DVSc, DACVS (Small Animal)[1]

[1]Faculty of Veterinary Medicine, University of Montreal, Saint-Hyacinthe, Québec, Canada

[2]Centre Vétérinaire Rive-Sud, Brossard, Québec, Canada

[3]Centre Vétérinaire Laval, Laval, Québec, Canada

[4]Veterinary Emergency Clinic, Toronto, Ontario, Canada

Correspondence
Solène Renaud, Faculté de médecine vétérinaire (FMV), Université de Montréal, 3200 rue Sicotte, Saint-Hyacinthe, Québec, Canada.
Email: solenn.renaud@gmail.com

Abstract

Objective: To report demographics, clinical signs, physical examination, diagnostic test results, surgical findings, and prognostic factors for in-hospital postoperative mortality following biliary peritonitis surgery in dogs.

Study design: Retrospective, multi-institutional cohort study.

Animals: Thirty-three client-owned dogs.

Methods: The medical records of dogs that underwent surgery for biliary peritonitis between 2015 and 2021 were reviewed. Dogs were included if they had a definitive diagnosis of biliary peritonitis and a surgery report. Information on demographics, clinical signs and duration, physical examination findings, laboratory and diagnostic imaging results, surgery, perioperative medical treatment, and complications for each patient was obtained. Statistical analyses were performed to identify risk factors that affected survival.

Results: Cholecystectomy was the procedure most frequently performed (31/33, 94%). The overall mortality rate was 36% (12/33). Survival was affected negatively by hyperbilirubinemia ($p = .049$), administration of vasopressors ($p = .002$), renal dysfunction ($p = .008$), and number of postoperative complications ($p = .005$). A mortality rate of 50% was observed in dogs with a total bilirubin level greater than 60.5 μmol/L. There was no difference in mortality rate between septic and nonseptic biliary effusions.

Conclusion: New prognostic factors associated with in-hospital postoperative mortality in dogs treated surgically for biliary peritonitis were identified, while

Abbreviations: ALP, Alkaline phosphatase; ALT, Alanine aminotransferase; aPTT, Activated partial thromboplastin time; CT, Computed tomography; GBM, Gallbladder mucocele; GGT, Gamma-glutamyl transferase; PaO_2, Partial pressure of oxygen; PCV, Packed cell volume; PT, Prothrombin time; USG, Urine specific gravity.

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others that had been reported previously were confirmed. A preoperative bilirubin threshold value associated with a 50% mortality was identified.

Clinical significance: Additional information that could help to predict survival in dogs with biliary peritonitis has been provided. However, further research is warranted.

1 | INTRODUCTION

Biliary peritonitis is an inflammatory response to a localized or diffuse leakage of bile into the abdomen. Rupture of the gallbladder or any portion of the biliary system can result from blunt or penetrating abdominal trauma, biliary tract obstruction from choledocholithiasis or neoplasia, iatrogenic injury during surgery, or inflammation and/or infection. Bile salts are hyperosmolar and cytotoxic to the peritoneal mesothelial cells, resulting in increased vascular permeability, third-spacing of fluid into the abdomen, inflammation, hemolysis, and tissue necrosis.[1,2]

Biliary peritonitis is a life-threatening condition as it can lead to hypovolemic shock, systemic inflammatory response syndrome, multiple organ dysfunction, and death if prompt treatment is not provided quickly. Surgery is always indicated, and the specific treatment depends on the underlying disease process. Surgical treatment options include cholecystectomy, primary repair of the extrahepatic biliary tract, and biliary diversion.[1–3]

Information regarding clinical outcomes and mortality rates of dogs treated surgically for biliary peritonitis is scarce in the veterinary literature. Mehler et al. reported that 43% of dogs (26/60) undergoing extrahepatic biliary surgery had biliary peritonitis at the time of surgery, and the most common causes were necrotizing cholecystitis, blunt trauma, and extrahepatic biliary tract obstruction secondary to cholelithiasis.[4] Jaffrey et al. reported a cohort of 219 dogs diagnosed with a gallbladder mucocele (GBM) and found that dogs with biliary peritonitis following gallbladder rupture were 2.7 times more likely to die than those without biliary peritonitis.[5] A significant difference in survival was found when comparing septic biliary peritonitis (25% to 45%) versus nonseptic biliary peritonitis (87% to 100%) in dogs.[4,6] However, the correlation between survival and the presence of septic or nonseptic biliary peritonitis remains controversial, as other more recent studies did not find a significant difference between these two subpopulations.[5,7] Hyperlactatemia, hyperbilirubinemia, biliary peritonitis, sepsis, immediate postoperative hypotension, and prolongation of activated partial thromboplastin time (aPTT) have also been associated with decreased survival in dogs undergoing extrahepatic biliary surgery in various studies.[2,4,5,8–10] However, there is currently a lack of information regarding the outcomes of dogs undergoing surgery for biliary peritonitis specifically, and predictors of survival are largely unknown.

The aim of this study was to report demographics, clinical signs, physical examination, laboratory and diagnostic imaging results, and surgical findings of dogs treated surgically for biliary peritonitis, and to identify prognostic factors that affect survival in the immediate postoperative period. The hypothesis was that dogs with septic biliary peritonitis would not have a worse prognosis than dogs with nonseptic biliary effusion.

2 | MATERIALS AND METHODS

2.1 | Study population

This was a multi-institutional retrospective cohort study of dogs that underwent surgery for the treatment of biliary peritonitis between January 2015 and December 2021, at one academic and three private practice institutions. Medical records were reviewed, and dogs were included if they had a definitive diagnosis of biliary peritonitis confirmed intraoperatively, based on a surgery report. The study excluded dogs with biliary peritonitis that did not survive prior to surgical intervention, as well as those that did not undergo surgery or had peritonitis of other etiologies.

2.2 | Data collection

Information was extracted from medical records when available. Complete data could not be obtained for each dog as the diagnostic tests and treatments provided were performed at the discretion of the veterinarians in charge of each case.

2.2.1 | Demographics

Demographic data (age, breed, sex, and body weight) were recorded for each dog.

2.2.2 | Clinicopathological parameters

Clinical signs and physical examination

The presenting complaint, clinical signs (lethargy, anorexia, nausea, vomiting and diarrhea) and duration, vital parameters (temperature, heart rate, respiratory rate and systolic blood pressure), and physical examination findings (icterus and abdominal pain) were documented.

Laboratory

The laboratory data collected at presentation included results of serum lactate levels, complete blood count (packed cell volume or PCV; absolute neutrophil count; band neutrophil count, and platelet count), serum biochemistry profile (creatinine, albumin, total bilirubin, and liver enzymes, including alkaline phosphatase or ALP; alanine aminotransferase or ALT; and gamma-glutamyl transferase or GGT), urinary sediment analysis (urine specific gravity or USG, and bilirubinuria), and coagulation profile (prothrombin time or PT; aPTT).

Abdominocentesis fluid sample analysis

Data from the preoperative analysis of the recorded abdominocentesis fluid samples included results of cytology, bacterial culture and susceptibility testing (aerobic and anaerobic), and the measurement of glucose, lactate and bilirubin concentrations in the peritoneal effusion.

2.2.3 | Diagnostic imaging

Diagnostic imaging results, detailing the findings of abdominal radiography, ultrasound and/or computed tomography, were collected.

2.2.4 | Surgery

Surgical findings were recorded (site of biliary tract perforation and leakage, surgical treatment performed, results of aerobic and anaerobic intraoperative bacterial culture and susceptibility testing before and/or after abdominal lavage, number of closed suction drains placed before closure, and the duration in days of active drainage). Septic biliary peritonitis was defined as a positive bacterial culture when samples were collected intraoperatively. All bacterial cultures were submitted to a reference laboratory for analysis.

2.2.5 | Perioperative medical treatments

Perioperative medical treatments (oxygen therapy, antimicrobials, vasopressors, fluid therapy with isotonic crystalloids and/or colloids and transfusions with blood products) administered to each patient were also documented.

2.2.6 | Complications

Perioperative complications were categorized into two groups: intraoperative and postoperative. Intraoperative complications included events that occurred between skin incision and closure, whereas postoperative complications were those that occurred between recovery from general anesthesia and discharge or death of the dog.

Intraoperative complications

The following intraoperative complications were defined *a priori*: hemorrhage—more than10% blood loss requiring one or more transfusions of blood product; hypotension—systolic blood pressure below 90 mmHg; hypothermia—body temperature below 36.5°C; and cardiopulmonary arrest—cardiac and respiratory arrest requiring resuscitation therapy. The number of intraoperative complications was recorded for each dog.

Postoperative complications

The following postoperative complications were defined *a priori* and characterized to reflect substantial dysfunction of major body systems: cardiovascular—systolic blood pressure below 90 mmHg requiring treatment with vasopressors; coagulation—platelet count below 100×10^9/L confirmed by a blood smear and/or prolonged coagulation time with PT and aPTT more than 25% of the upper normal reference limit, which required one or more transfusions with plasma and/or platelet-rich plasma; hematologic—PCV below 25% requiring transfusions of red blood cells; renal—creatinine above140 mmol/L or an increase of more than 26.4 mmol/L within 48 h of presentation despite medical treatment; and respiratory dysfunction —oxygen support of any type required if oxygen saturation was below 95% on pulse oximetry or arterial partial pressure of oxygen (PaO_2) was below 80 mm Hg. The number of postoperative complications was recorded for each dog.

2.2.7 | Duration of hospitalization and outcomes

The total duration (in days) of hospitalization, the dog's status following surgery (whether it was dead or alive and whether death was due to humane euthanasia), and the findings of the postmortem examination, if applicable, were also documented.

2.3 | Statistical analysis

R software, version 4.0.3, was used to perform all statistical analyses.[11] Data were analyzed to identify risk factors affecting the survival of dogs surgically treated for biliary peritonitis. The dependent variable was binomial (survival or not), so statistical results were provided using generalized linear models, specifying that data followed a binomial distribution. The results were used to determine the estimate, standard error, z-value, and *p*-value. Significance was set as $p < .05$. Descriptive statistics were generated and presented in tables, describing medians and ranges (from minimum to maximum) as well as estimates, standard errors, z-values and *p*-values for the explanatory variables. The *survival* package was used to construct Cox proportional hazard models. The proportional hazard assumption was confirmed by nonsignificant, independent scaled Schoenfeld residuals.

3 | RESULTS

3.1 | Demographics

Thirty-three dogs met the inclusion criteria. Age, body weight, clinical signs, and duration were documented for each dog at the time of presentation. Seventeen dogs (17/33, 52%) were females, of which 16 (94%) were spayed and one (6%) was intact. Sixteen dogs (16/33, 48%) were males, of which 13 (81%) were neutered and three (19%) were intact. There were 16 purebreds and two mixed-breed dogs. Purebreds represented were Chihuahua (6/33, 18%), pug (4/33, 12%), Yorkshire terrier (4/33, 12%), schapendoes (2/33, 6%), American Cocker spaniel (2/33, 6%), miniature poodle (2/33, 6%), miniature schnauzer (2/33, 6%) and one of each breed (1/33, 3%) Bernese mountain dog, dachshund, English bull terrier, French spaniel, Jack Russell terrier, keeshond, Portuguese water dog, shih tzu and standard poodle. In this study population, survival in dogs was not affected by demographics (Table 1).

3.2 | Clinicopathological parameters

3.2.1 | Clinical signs and physical examination

The most common clinical signs were lethargy (29/33, 88%) and anorexia (29/33, 88%), followed by vomiting (26/33, 79%), abdominal pain (26/33, 79%), and nausea (25/33, 76%). Approximately one-fifth of the dogs had jaundice (7/33, 21%) and diarrhea (7/33, 21%). Other clinical signs documented were dehydration, dyspnea, abdominal distension, and polyuria/polydipsia. Sixteen dogs (16/33, 48%) had one or more concomitant health problems such as tracheal collapse, diabetes mellitus, urolithiasis, extrahepatic portosystemic shunt, chronic kidney disease, cholelithiasis, heart murmur, and hypothyroidism. All dogs had their vital parameters recorded upon physical examination. Seven dogs (7/33, 21%) had hyperthermia with a rectal body temperature >39.5°C and two (2/33, 6%) had hypothermia with a temperature <37.5°C. Four dogs (4/40, 20%) that had their blood pressure recorded on admission had systemic hypertension with a systolic blood pressure >160 mmHg, and five (5/20, 25%) had hypotension with a systolic blood pressure <80 mmHg. Survival in dogs was not affected by clinical signs, their duration, or the vital parameters (Table 1).

3.2.2 | Laboratory

Thirty-two dogs (32/33, 97%) had a complete blood count and serum biochemistry profile performed. Two dogs (2/32, 6%) were anemic with a PCV < 35%; 27 (27/32, 84%) had a mature neutrophilia with an absolute segmented neutrophil count $>9.80 \times 10^9$/L; two (2/32, 6%) were neutropenic with an absolute segmented neutrophil count $<2.7 \times 10^9$/L; seven (7/32, 22%) had a mature left shift with an absolute nonsegmented or band neutrophil count $>0.3 \times 10^9$/L and four dogs (4/32, 13%) were thrombocytopenic with an absolute platelet count $<153 \times 10^9$/L. Four dogs (4/32, 13%) had elevated creatinine concentrations with creatinine levels >140 μmol/L; 11 dogs (11/32, 34%) had hypoalbuminemia with albumin levels <25 g/L; and 25 dogs (25/32, 78%) had hyperbilirubinemia with bilirubin levels >8.8 μmol/L. A threefold increase in normal serum hepatic enzyme activity was documented in 21 dogs (21/32, 65%) for ALP, in 17 dogs (17/32, 53%) for ALT and in one dog (1/32, 3%) for GGT. Serum lactate levels were analyzed in 27 dogs (27/32, 84%), and seven (7/27, 26%) had elevated lactate >2.5 mmol/L. Ten dogs (10/33, 30%) had a urinalysis performed and bilirubinuria was documented in four of them (4/10, 40%). A coagulation profile (PT/aPTT) was performed in 16 dogs (16/33, 48%). Activated partial thromboplastin time was increased in 11 dogs (11/16, 69%), and PT was increased in three dogs (3/16, 19%). Serum bilirubin levels ($p = .049$) had an impact on survival (Table 1). The predictive value was calculated using a linear regression model and a threshold value associated with a 50% probability of survival was determined. Specifically, the threshold value for hyperbilirubinemia,

TABLE 1 Descriptive and inferential statistics for the explanatory variables associated with survival. The values of the explanatory variables for surviving and deceased dogs are given, along with the number of dogs considered for each variable. The results of univariate Cox models testing the effect of these explanatory variables on the probability of survival are reported.

Explanatory variable	*n*	Mean deceased (±SE)	Mean surviving (±SE)	LR test	Df	*p*
Demographics						
Age (year)	33	9.0 (1.0)	8.9 (0.7)	0.00	1	.959
BCS	24	5.0 (0.6)	5.0 (0.5)	0.00	1	1.000
Body mass (kg)	33	8.3 (1.7)	12.4 (2.3)	0.46	1	.498
Sex	33	F: 0%	F: 5%	1.13	3	.763
		FS: 58%	FS: 43%			
		M: 16%	M: 5%			
		MC: 25%	MC: 47%			
Clinical signs						
Duration (days)	33	8.8 (6.5)	3.3 (0.5)	1.10	1	.295
Lethargy	33	100.0% (0.0)	81.0%(8.8)	0.73	1	.394
Icterus	33	33.3%(14.2)	14.3% (7.8)	0.66	1	.416
Abdominal pain	33	75.0% (13.1)	81.0% (8.8)	0.06	1	.810
Anorexia	32	90.9% (9.1)	90.5% (6.6)	0.00	1	.982
Nausea	33	75.0% (13.1)	76.2% (9.5)	0.00	1	.964
Vomiting	33	75.0% (13.1)	81.0% (8.8)	0.06	1	.810
Diarrhea	33	8.3% (8.3)	28.6% (10.1)	0.58	1	.448
Vital parameters						
Temperature (°C)	33	38.2 (0.4)	39.0 (0.2)	1.93	1	.165
Heart rate (bpm)	32	150.9 (10.5)	139.8 (8.9)	0.22	1	.641
Respiratory rate (rpm)	27	38.6 (2.9)	41.2 (4.2)	0.07	1	.788
Systolic blood pressure (mmHg)	17	138.0 (14.2)	142.0 (8.2)	0.03	1	.853
Blood work						
Packed cell volume	33	48.5 (2.6)	47.0 (2.0)	0.07	1	.790
Neutrophils	31	18.4 (4.2)	16.2 (1.3)	0.26	1	.610
Bands	33	A: 75%	A: 67%	0.53	2	.766
		P: 25%	P: 19%			
		Suspect: 0%	Suspect: 14%			
Platelets	29	388.0 (54.4)	326.0 (44.4)	0.23	1	.634
Creatinine	31	172.8 (70.2)	69.7 (8.3)	2.53	1	.112
Lactatemia	27	2.77 (0.48)	1.78 (0.27)	1.53	1	.216
Albumin	30	24.4 (1.9)	29.9 (1.5)	1.46	1	.228
Total bilirubin	**31**	**66.8 (13.3)**	**26.0 (5.5)**	**4.53**	**1**	**.049**[a]
Alkaline phosphatase (ALP)	32	1596 (358)	1207 (374)	0.15	1	.700
Alanine aminotransferase (ALT)	32	669.2 (207.0)	392.3 (83.7)	1.12	1	.289
Gamma-glutamyl transferase (GGT)	27	41.3 (17.9)	12.7 (2.8)	2.82	1	.093
Prothrombin time (PT)	16	23.6 (9.2)	11.6 (1.1)	1.38	1	.240
Activated partial thromboplastin time (aPTT)	16	99.6 (40.0)	103.3 (33.6)	0.00	1	.955
Abdominocentesis fluid sample						
Bilirubin concentration	6	216.6 (93.7)	183.7 (127.0)	0.02	1	.886

TABLE 1 (Continued)

Explanatory variable	*n*	Mean deceased (±SE)	Mean surviving (±SE)	LR test	Df	*p*
Surgery						
Bacterial culture	28	14.3% (14.3)	43.9% (11.1)	1.28	1	.258
Closed suction drain	33	75.0% (13.1)	71.4% (10.1)	0.02	1	.897
Duration of active drainage (days)	23	3.89 (2.13)	3.79 (0.32)	0.00	1	.947
Perioperative medical treatment						
Antimicrobials	32	91.7% (8.3)	100% (0.0)	0.60	1	.437
Oxygen therapy	32	36.4% (15.2)	9.5% (6.6)	1.61	1	.205
Vasopressors	32	90.9% (9.1)	23.8% (9.5)	**9.59**	**1**	**.002**[a]
Fluid boluses with isotonic crystalloids	32	90.9% (9.1)	52.4% (11.2)	3.49	1	.062
Fluid boluses with colloids	32	36.4% (15.2)	23.8% (9.5)	0.39	1	.583
Blood products	32	72.7% (14.1)	33.3% (10.5)	1.54	1	.214
Type of blood products	14	Plasma: 63%	Plasma: 83%	0.26	1	.612
		RBC: 37%	RBC: 17%			
Hospitalization						
Duration (days)	33	4.2 (1.8)	5.1 (0.5)	0.14	1	.699
Intraoperative complications						
Hemorrhage	33	16.7% (11.2)	14.3% (7.8)	0.01	1	.913
Hypotension	33	83.3% (11.2)	61.9% (10.9)	0.54	1	.464
Hypothermia	33	66.7% (14.2)	52.4% (11.2)	0.22	1	.641
Cardiopulmonary arrest	33	58.3% (14.9)	38.1% (10.9)	0.44	1	.505
Number of complications	33	1.8 (0.2)	1.3 (0.3)	0.32	1	.569
Postoperative complications						
Cardiovascular dysfunction	33	33.3% (14.2)	14.3% (7.8)	0.82	1	.367
Coagulation dysfunction	33	33.3% (14.2)	4.8% (4.8)	2.09	1	.149
Hematologic dysfunction	33	8.3% (8.3)	19.0% (8.8)	0.45	1	.504
Renal dysfunction	**33**	**58.3% (14.9)**	**0.0% (0.0)**	**6.97**	**1**	**.008**[a]
Respiratory dysfunction	33	33.3% (14.2)	28.6% (10.1)	0.03	1	.865
Number of complications	**33**	**2.5 (0.4)**	**0.6 (0.2)**	**7.88**	**1**	**.005**[a]

Abbreviations: bpm, beats per minute; rpm, respirations per minute.
[a]This explanatory variable was related to decreased survival in dogs. A $p < .05$ was considered significant (in bold).

at which 50% of dogs survived postoperatively, was found to be 60.5 μmol/L. Survival was otherwise not affected by the other clinicopathologic parameters assessed (Table 1).

3.2.3 | Abdominocentesis fluid sample analysis

Fourteen dogs underwent diagnostic abdominocentesis before surgery for various analyses (14/33, 42%). Cytology was performed in 13 of them (13/14, 93%). All samples were interpreted by a board-certified clinical pathologist. A cytological diagnosis of biliary peritonitis was obtained in four dogs (4/13, 31%) by direct visualization of bile pigments, while septic suppurative inflammation was observed in seven dogs (7/13, 54%). Bacterial culture and susceptibility testing from peritoneal effusion was performed in eight dogs (8/33, 57%), and four of them (4/8, 50%) were positive. The microorganisms isolated were *Escherichia coli* (2/4, 50%), *Klebsiella pneumoniae* (1/4, 25%), and *Staphylococcus intermedius* (1/4, 25%). Three dogs (3/14, 21%) had their glucose and lactate concentrations quantified on peritoneal effusion, and six dogs (6/14, 43%) had their bilirubin concentrations compared with serum. Four dogs (4/14, 29%) had a diagnosis of biliary peritonitis based on twice the concentration of bilirubin in the peritoneal effusion as in the serum. Survival in dogs was not affected by peritoneal bilirubin concentration (Table 1).

3.3 | Diagnostic imaging

All dogs underwent diagnostic imaging of the abdomen prior to surgery. Thirty-two dogs (32/33, 97%) had an ultrasound performed and 13 (13/33, 39%) had radiographs. The dog that had only abdominal radiographs had evidence of effusion, and cytology confirmed the presence of bile pigments. Peritoneal effusion was the most common finding observed in 28 abdominal ultrasounds (28/32, 88%) and in six radiographic studies (6/13, 46%). No abnormalities specifically related to the biliary system were identified in any of the dogs that underwent radiographs. On abdominal ultrasound, GBM was diagnosed in 20 dogs (20/32, 63%) and cholelithiasis was reported in five (5/32, 16%). Ultrasound findings consistent with extrahepatic biliary tract rupture—characterized by gallbladder wall discontinuity, distortion of its oval shape, and surrounding free fluid, along with secondary biliary peritonitis—were identified in 12 of 32 dogs (38%). Of these, 10 dogs (10/12, 83%) had a GBM, and two had cholelithiasis (2/12, 17%). Abdominal ultrasonography had a sensitivity of 38% in accurately identifying cases of extrahepatic biliary tract rupture.

3.4 | Surgery

For the dogs without a definitive preoperative diagnosis, surgery was recommended based on clinical signs, physical examination findings, and diagnostic results. All surgical procedures were performed by a board-certified veterinary surgeon or resident under direct supervision. Each dog was confirmed to have biliary peritonitis at the time of surgery either through visualization of a bile-like effusion in the peritoneal cavity and/or identification of a defect in the extrahepatic biliary system.

A detailed description of the surgical procedure, including the specific site of biliary tract perforation, was available in 32 surgery reports (32/33, 97%). Twenty-four perforations were located to the gallbladder wall (24/32, 75%), six to the cystic duct (6/32, 19%), and two to the common bile duct (2/32, 6%). Twenty dogs (20/32, 63%) had GBM confirmed macroscopically as suspected on abdominal ultrasound. The type of surgical procedure performed was specifically documented for all 33 dogs. Cholecystectomy was the most common (31/33; 94%). Two dogs (2/33, 6%) underwent choledochal stenting via duodenotomy in addition to cholecystectomy; one dog (1/33, 3%) had a cholecystoduodenostomy performed, and another dog (1/33, 3%) required revision surgery to ligate a leaking cystic duct from a previous cholecystectomy. Bacterial culture and susceptibility testing were performed on peritoneal effusion in 27 dogs (27/33, 82%) intraoperatively, with 15 samples (15/27, 56%) collected before abdominal lavage at the beginning of surgery, and 12 (12/27, 44%) collected after the final lavage at the end of surgery. None of the dogs had bacterial culture performed both before and after abdominal lavage during surgery. Intraoperatively, bacterial culture was positive in nine dogs (9/27, 33%); six samples (6/9, 67%) were taken before abdominal lavage and three (3/9, 33%) were performed after lavage. Out of the eight dogs that had a bacterial culture performed preoperatively, seven (7/8, 88%) also had another bacterial culture performed during the surgical procedure. Only one of these dogs (1/7, 14%) had a negative preoperative bacterial culture that was positive when cultured again at the time of surgery, the remaining dogs showed consistent microbial results and antimicrobial susceptibility. The dog that only had preoperative bacterial culture performed tested negative.

Overall, 10 of the 28 dogs (36%) that had perioperative bacterial cultures performed on their peritoneal effusion were septic. Of these dogs, one (1/7, 14%) died postoperatively, and 9/21 (43%) survived. The microorganism most cultured was *E. coli* identified in eight dogs (8/10, 80%). A closed suction drain was placed in 24 dogs (24/33, 73%) before abdominal closure. The median number of days the drain was in left *in situ* was 3.8 days (range, 1–7 days). There was no difference in the mortality rate between septic and nonseptic biliary effusions in this study population, between dogs that had a closed abdominal drain and those that did not, or in the duration of active drainage (Table 1).

3.5 | Perioperative medical treatments

Overall, during surgery and hospitalization, 32 dogs (32/33, 97%) received broad-spectrum prophylactic antimicrobial treatment intravenously. One dog (1/33, 3%) did not receive it because of severe hypotension at the time of surgery. The antimicrobials most commonly administered were ampicillin (28/32, 88%), enrofloxacin (22/32, 69%), and metronidazole (8/32, 25%). Twenty-four dogs (24/32, 75%) received more than one antimicrobial simultaneously. Twenty-one dogs (21/33, 64%) received fluid boluses with isotonic crystalloids and nine (9/33, 27%) received colloids. Fifteen dogs (15/33, 45%) required vasopressors and nine (9/33, 60%) received more than one type of vasopressors. Norepinephrine was the most commonly administered molecule (13/15, 87%). Dopamine ($n = 4$), dobutamine ($n = 3$), phenylephrine (n = 3), ephedrine ($n = 2$), epinephrine ($n = 1$), and vasopressin (n = 1) were also used. Except for epinephrine, all vasopressors were use intraoperatively and postoperatively. Fourteen dogs (14/33, 42%) were transfused with blood products, nine of which (9/14, 64%) received plasma and the remaining five (5/14, 36%) received plasma combined with packed red blood cells. Six dogs (6/33, 18%) required oxygen therapy. The use of vasopressors was associated ($p = .002$) with decreased survival in dogs (Table 1). Other perioperative medical treatments administered did not have an impact on the dogs' outomes (Table 1).

3.6 | Complications

3.6.1 | Intraoperative complications

Intraoperative complications reported included hypotension (19/33, 58%), hemorrhage (14/33, 42%), hypothermia (5/33, 15%) and cardiopulmonary arrest (1/33, 3%). Nine dogs (9/33, 27%) had no intraoperative complications but most dogs (24/33, 73%) experienced at least one intraoperative complication. Four dogs (4/24, 17%) had one complication, 16 (16/24, 67%) had two complications, and four (4/24, 17%) had three complications. The dog that was severely hypotensive and did not receive broad-spectrum prophylactic antimicrobial treatment was euthanized intraoperatively. The type and number of intraoperative complications did not have an impact on survival (Table 1).

3.6.2 | Postoperative complications

Postoperative complications reported included cardiovascular dysfunction (13/32, 41%), respiratory dysfunction (6/32, 19%), hematologic dysfunction (4/32, 13%), coagulation dysfunction (4/32, 13%) and renal dysfunction (4/32, 13%). One dog (1/33, 3%) had no information on the postoperative complications evaluated. Fifteen dogs (15/32, 47%) had no postoperative complications, 17 (17/32, 53%) had at least one recorded. Seven dogs (7/17, 41%) had one complication; one dog (1/17, 6%) had two complications; seven (7/17, 41%) had three complications, and two dogs (2/17, 12%) had four complications. Eleven dogs (11/32, 34%) died postoperatively, seven of which (7/11, 64%) were euthanized. The type of complication was associated with decreased survival, specifically renal dysfunction ($p = .008$) and an increase in the number of postoperative complications ($p = .005$) (Table 1).

3.7 | Duration of hospitalization and outcomes

The overall perioperative mortality rate was 36% (12/33). Eight dogs (8/12, 67%) were euthanized and the other four (4/12, 33%) died. One dog was euthanized during the intraoperative period, and the remaining seven were euthanized postoperatively due to clinical deterioration despite medical management (respiratory distress ($n = 2$), acute kidney failure ($n = 2$), sepsis ($n = 2$), severe hypotension ($n = 1$)). Of the four dogs that died, two died from sepsis and two from cardiopulmonary arrest. There were no pre-incision complications. The duration of hospitalization did not have an effect on survival (Table 1).

3.8 | Global effects of explanatory variables on individual survival probabilities

In univariate models, preoperative hyperbilirubinemia, the use of perioperative vasopressors, renal dysfunction, and the number of postoperative complications were associated with survival in dogs (Table 2). The hazard ratios of these four variables are significantly less than 1, indicating that an increase in these variables would reduce the probability of survival. For instance, an increase of 1 μmol/L in bilirubin would lead to a 1% reduction in the probability of survival (Figure 1A). The presence of vasopressors and renal dysfunction would lead to a 71% and 66% reduction in the probability of survival, respectively. Finally, each additional complication

TABLE 2 Detailed univariate Cox proportional hazard model results for the four significant explanatory variables related to the survival probabilities of dogs.

Factor	Regression coefficient	HR	HR 95% CI	p
Total bilirubin	−0.01	0.99	[0.98; 0.99]	.049[a]
Vasopressors	−1.23	0.29	[0.14; 0.64]	.002[a]
Renal dysfunction	−1.07	0.34	[0.15; 0.81]	.008[a]
Number of postoperative complications	−0.36	0.70	[0.54; 0.91]	.005[a]

Abbreviation: HR, hazard ratio.

[a]This explanatory variable was related to decreased survival in dogs.

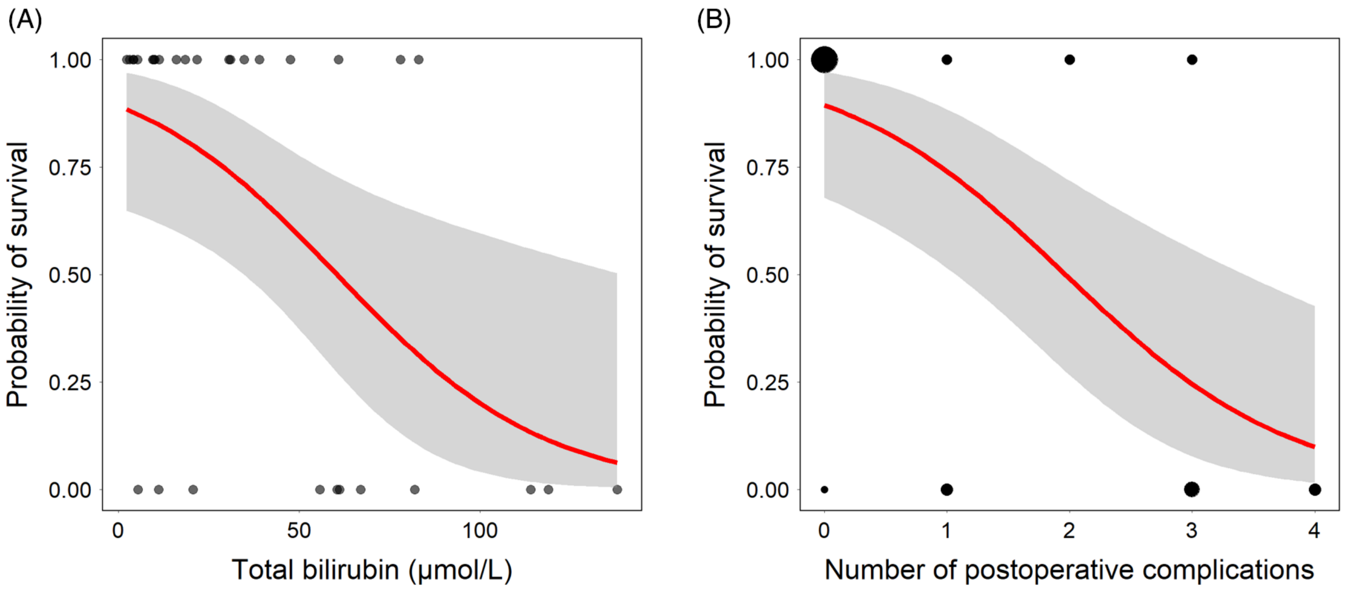

FIGURE 1 Prediction of the survival probability of dogs (± 95% confidence interval in gray). On (A) total bilirubin and (B) the number of postoperative complications. In the graph of postoperative complications, the size of each point represents the number of cases per complication.

TABLE 3 Multivariate Cox proportional hazard model results after stepwise selection.

Factor	Regression coefficient	HR	HR 95% CI	*p*
Total bilirubin	−0.01	0.99	[0.98; 0.99]	.015[a]
Vasopressors	−0.36	0.70	[0.24; 2.05]	.514
Renal dysfunction	0.08	1.09	[0.24; 4.85]	.911
Number of postoperative complications	−0.43	0.65	[0.49; 0.86]	.002[a]

Abbreviation: HR, hazard ratio.
[a]This explanatory variable was related to decreased survival in dogs.

would result in a reduction of approximately 30% in the probability of survival per complication (Figure 1B).

To achieve a more comprehensive explanatory model for survival, these four explanatory variables were combined in a multivariate model. Following a stepwise model selection, it was found that preoperative hyperbilirubinemia and the number of postoperative complications together provided a better explanation for the probability of survival of dogs (Table 3). Hyperbilirubinemia and the number of postoperative complications may be redundant with the presence of vasopressors and renal dysfunction, which have shown better explanatory power for dogs' survival. It is therefore suggested that the latter variables be excluded within a global model.

4 | DISCUSSION

Biliary peritonitis is a surgical emergency associated with a high mortality rate in dogs, ranging between 28% and 50%.[4–7] In our study, a perioperative mortality rate of 36% was reported. The most common surgical finding leading to biliary peritonitis was gallbladder rupture secondary to GBM. Gallbladder mucocele is a well known risk factor for biliary peritonitis and surgery is generally recommended in most cases to prevent and avoid this life-threatening complication. The incidence of gallbladder rupture associated with GBM in dogs has been previously reported, ranging from 21% to 61%.[5,7,9,12–14] The risk of death was 2.7 times higher in dogs with biliary peritonitis than in those without gallbladder rupture in a large cohort of 219 dogs diagnosed with GBM.[5] The high mortality associated with surgery of the extrahepatic biliary tract in general, and sustained in our study, is likely related to the complex pathophysiology of hepatobiliary disease, impacting wound healing, hemostasis, and sepsis.[1,15] Bile salts and constituents of the bile are cytotoxic to the organs of the abdominal cavity and cause extravasation of fluids, loss of protein, and bacterial translocation. This highly inflammatory state can then lead to shock, severe hypotension, and death if adequate treatment is not provided.[1,2,15]

The most widely used imaging diagnostic tool for determining the location of the biliary tract rupture and origin of the biliary peritonitis before surgery is abdominal ultrasound. Reported sensitivity and specificity of abdominal ultrasound to document such findings range from 56% to 86% and 81% to 100%, respectively.[5,7,10,12–14,16–18] In this cohort of dogs, abdominal ultrasonography had a sensitivity of 38% to identify extrahepatic biliary tract rupture specifically preoperatively, which is lower than previously reported. Several factors, including patient populations, imaging protocols, and the sonographer's level of experience, could have contributed to this lower sensitivity. Advances in imaging technology, including contrast-enhanced ultrasound and computed tomography (CT), have improved the accuracy of diagnosing bile leakage and assessing the severity of peritonitis. Bargellini et al. found contrast-enhanced ultrasonography to be 100% sensitive and specific in identifying gallbladder wall necrosis and rupture in dogs.[16]

Cytologically, bile peritonitis is characterized by the presence of green, gold, or black-brown pigments surrounded or phagocytized by macrophages, and sometimes bacterial microorganisms.[19,20] A peritoneal fluid bilirubin concentration that is more than twice the serum bilirubin concentration confirms a diagnosis of biliary peritonitis. Thirty-one percent of the dogs that had cytological analysis of peritoneal effusion prior to surgery were diagnosed with biliary peritonitis, and 12% were diagnosed using the peritoneal bilirubin to serum bilirubin ratio. In all these cases, the diagnosis of biliary peritonitis was also suspected based on abdominal ultrasound.

There are few reports that address prognostic factors associated with survival from biliary peritonitis in dogs specifically. Hyperlactatemia, hyperbilirubinemia, increased serum creatinine concentration, alkaline phosphatase activity, hyperphosphatemia, sepsis, immediate postoperative hypotension, and prolonged aPTT have been described as prognostic factors associated with decreased survival in dogs undergoing extrahepatic biliary surgery.[2,4–6,8–10] In our study population, preoperative hyperbilirubinemia, the need for perioperative vasopressors, postoperative renal dysfunction, and a higher number of postoperative complications were associated with a poorer prognosis. The threshold value for hyperbilirubinemia at which 50% of dogs survived postoperatively was determined; hyperbilirubinemia, with total bilirubin levels greater than 60.5 μmol/L, was associated with decreased survival.

Information regarding the status of septic or nonseptic biliary peritonitis on survival is controversial in dogs. Septic biliary effusion was previously associated with a poorer outcome.[4,6] In 1997, Ludwig et al. reported a survival rate of 100% for dogs with nonseptic biliary peritonitis, compared with 27% for those with septic biliary peritonitis.[6] In our study, 36% of dogs had a septic effusion yet we did not find a difference in survival between dogs with septic and nonseptic biliary peritonitis. Among the deceased dogs, only a minority had septic effusion in comparison with those that survived. Specifically, 14.3% of the dogs that died had a positive culture, compared to 43.9% of the survivors. This finding is consistent with the results of two recent retrospective studies.[5,7] As mentioned in these studies, the increased survival rate over the years is most likely secondary to a combination of improved diagnostic imaging, emergency care, and perioperative management of these dogs. The microorganism most commonly cultured from peritoneal effusion was *E. coli*, identified in 80% of the dogs for which bacterial culture was performed. *E. coli* and *Enterococcus* spp. are the bacteria most frequently found in dogs with extrahepatic biliary tract disease, as they are naturally present in the intestinal microbiota.[3,21,22] Antimicrobials selected based on bacterial culture and susceptibility testing are often used in the treatment of biliary peritonitis, and their appropriate application is essential to achieve an effective therapeutic outcome and prevent the development of antimicrobial resistance.

In this study, although valuable insights were obtained regarding biliary peritonitis in dogs, it is important to acknowledge—in addition to the inherent limitations associated with a retrospective study—that the small sample size of 33 dogs represents an important limitation. Indeed, the restricted number of cases reduced the statistical power of our analysis, making it challenging to detect important relationships or assess accurately the impact of various factors on the prognosis of biliary peritonitis in dogs. The small sample size also increased the potential for selection bias, as the characteristics of the dogs may not be representative of the entire population of dogs with biliary peritonitis, limiting the validity of our findings. Consequently, our results should be interpreted with caution and consideration.

In conclusion, despite advancements in veterinary medicine, biliary peritonitis remains a serious condition with a substantial risk of complications and mortality in dogs. Early diagnosis and appropriate surgical and medical intervention improve the chances of a positive outcome. New factors associated with in-hospital postoperative mortality in dogs treated surgically for biliary peritonitis were identified, whereas others that had been reported previously were confirmed. A preoperative bilirubin threshold value associated with 50% mortality has been identified, providing valuable insights into the prognosis of this pathology. Hyperbilirubinemia, with total bilirubin levels greater than 60.5 μmol/L, was associated with decreased survival in dogs. Further investigation of biliary peritonitis in dogs with a larger sample size and considering alternative study designs could help address the limitations identified.

AUTHOR CONTRIBUTIONS

All authors contributed substantially to the design of this project and the acquisition of data, drafted and/or revised it critically for important intellectual content, approved the final version to be published, and agreed to be accountable for all aspects of the work by ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Drs Renaud, Freire, O'Toole and Gagnon also participated in the analysis and interpretation of the data with the University of Montreal's statistician, Tristan Juette.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this report.

REFERENCES

1. Mayhew PD, Weisse C. Chapter 95: liver and biliary system. In: Johnston SA, Tobias KM, eds. *Veterinary Surgery: Small Animal*. 2nd ed. St. ed. Elsevier; 2018:4245-4306.
2. Thompson BJ, Sherman RA. Comprehensive review of biliary peritonitis. *Top Companion Anim Med*. 2021;44:100532. doi:10.1016/j.tcam.2021.100532
3. Mehler SJ, Bennett RA. Canine extrahepatic biliary tract disease and surgery. *Compendium on Continuing Education for the Practicing Veterinarian*; Compendiumvet.com; 2006:302-315.
4. Mehler SJ, Mayhew PD, Drobatz KJ, Holt DE. Variables associated with outcome in dogs undergoing extrahepatic biliary surgery: 60 cases (1988–2002). *Vet Surg*. 2004;33(6):644-649. doi:10.1111/j.1532-950X.2004.04087.x
5. Jaffey JA, Graham A, VanEerde E, et al. Gallbladder Mucocele: variables associated with outcome and the utility of ultrasonography to identify gallbladder rupture in 219 dogs (2007–2016). *J Vet Intern Med*. 2018;32(1):195-200. doi:10.1111/jvim.14898
6. Ludwig LL, McLoughlin MA, Graves TK, Crisp MS. Surgical treatment of bile peritonitis in 24 dogs and 2 cats: a retrospective study (1987–1994). *Vet Surg*. 1997;26(2):90-98. doi:10.1111/j.1532-950X.1997.tb01470.x
7. Crews LJ, Feeney DA, Jessen CR, Rose ND, Matise I. Clinical, ultrasonographic, and laboratory findings associated with gallbladder disease and rupture in dogs: 45 cases (1997–2007). *J Am Vet Med Assoc*. 2009;234(3):359-366. doi:10.2460/javma.234.3.359
8. Amsellem PM, Seim HB, MacPhail CM, et al. Long-term survival and risk factors associated with biliary surgery in dogs: 34 cases (1994–2004). *J Am Vet Med Assoc*. 2006;229(9):1451-1457. doi:10.2460/javma.229.9.1451
9. Malek S, Sinclair E, Hosgood G, Moens NMM, Baily T, Boston SE. Clinical findings and prognostic factors for dogs undergoing cholecystectomy for gall bladder Mucocele: cholecystectomy for gall bladder Mucocele. *Vet Surg*. 2013;42(4):418-426. doi:10.1111/j.1532-950X.2012.01072.x
10. Parkanzky M, Grimes J, Schmiedt C, Secrest S, Bugbee A. Long-term survival of dogs treated for gallbladder mucocele by cholecystectomy, medical management, or both. *J Vet Intern Med*. 2019;33(5):2057-2066. doi:10.1111/jvim.15611
11. R Core Team. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. 2021. https://www.R-project.org/.
12. Choi J, Kim A, Keh S, Oh J, Kim H, Yoon J. Comparison between ultrasonographic and clinical findings in 43 dogs with gallbladder mucoceles: Ultrasonographic features of Gb Mucocele in dogs. *Vet Radiol Ultrasound*. 2014;55(2):202-207. doi:10.1111/vru.12120
13. Pike FS, Berg J, King NW, Penninck DG, Webster CRL. Gallbladder mucocele in dogs: 30 cases (2000–2002). *J Am Vet Med Assoc*. 2004;224(10):1615-1622. doi:10.2460/javma.2004.224.1615
14. Worley DR, Hottinger HA, Lawrence HJ. Surgical management of gallbladder mucoceles in dogs: 22 cases (1999–2003). *J Am Vet Med Assoc*. 2004;225(9):1418-1422. doi:10.2460/javma.2004.225.1418
15. Mehler SJ. Complications of the extrahepatic biliary surgery in companion animals. *Vet Clin North Am Small Anim Pract*. 2011;41(5):949-967. doi:10.1016/j.cvsm.2011.05.009
16. Bargellini P, Orlandi R, Paloni C, et al. Evaluation of contrast-enhanced ultrasonography as a method for detecting gallbladder necrosis or rupture in dogs: Ceus of Gallbladder Wall lesions. *Vet Radiol Ultrasound*. 2016;57(6):611-620. doi:10.1111/vru.12404
17. Guess SC, Harkin KR, Biller DS. Anicteric gallbladder rupture in dogs: 5 cases (2007–2013). *J Am Vet Med Assoc*. 2015;247(12):1412-1414. doi:10.2460/javma.247.12.1412
18. Wilson K, Powers D, Grasperge B, Liu C, Granger LA. Dogs with biliary rupture based on ultrasound findings may have normal total serum bilirubin values. *Vet Radiol Ultrasound*. 2021;62(2):236-245. doi:10.1111/vru.12937
19. Gupta RK, Johnston PS, Naran S, Lallu S, Fauck R. Cytological findings in a sample of peritoneal aspirate from a case of bile peritonitis. *Diagn Cytopathol*. 2005;32(1):35-37. doi:10.1002/dc.20136
20. Owens SD, Gossett R, McElhaney MR, Christopher MM, Shelly SM. Three cases of canine bile peritonitis with mucinous material in abdominal fluid as the prominent cytologic finding. *Vet Clin Pathol*. 2003;32(3):114-120. doi:10.1111/j.1939-165X.2003.tb00324.x
21. Harrison JL, Turek BJ, Brown DC, Bradley C, Callahan CJ. Cholangitis and cholangiohepatitis in dogs: a descriptive study of 54 cases based on histopathologic diagnosis (2004–2014). *J Vet Intern Med*. 2018;32(1):172-180. doi:10.1111/jvim.14866
22. Tamborini A, Jahns H, McAllister H, et al. Bacterial cholangitis, cholecystitis, or both in dogs. *J Vet Intern Med*. 2016;30(4):1046-1055. doi:10.1111/jvim.13974

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