Closed Suction Drainage for Treatment of Septic Peritonitis of Confirmed Gastrointestinal Origin in 20 Dogs

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Objective: To determine survival rate in dogs with septic peritonitis of confirmed gastrointestinal origin treated with closed suction drainage.
Study Design: Retrospective case series.
Animals: Dogs (n = 20) with septic peritonitis.
Methods: Medical records (2007–2010) of dogs with septic peritonitis of confirmed gastrointestinal origin treated by closed suction drainage were reviewed. Information on signalment, clinicopathologic abnormalities, underlying cause, surgical procedure performed, postoperative management, complications, and outcome was obtained.
Results: Dehiscence of a previous anastomosis was the most common source of contamination (80%). Drains remained in place, collecting fluid produced within the abdomen, for a median of 6 days (range, 2–11 days). Eighteen dogs received nutritional support, and 14 received plasma transfusions. Seventeen dogs (85%) survived to discharge.
Conclusions: Closed suction drainage together with resolution of the underlying cause of peritonitis and appropriate postoperative management is an effective technique for treatment of septic peritonitis of confirmed gastrointestinal origin in dogs.

Septic peritonitis is a potentially fatal condition characterized by inflammation of the peritoneum, secondary to bacterial contamination of the abdomen.[1] Bacterial contamination of the abdomen can occur from various sources such as the gastrointestinal tract, hepatobiliary system, reproductive tract, ruptured abscess, external penetrating injuries, or the source may be unknown. Gastrointestinal leakage is by far the most common source of contamination, accounting for 38–75% of secondary septic peritonitis cases,[2–6] and can often occur as a result of surgical wound dehiscence.[1]

Septic peritonitis is associated with a high mortality rate in dogs. Successful treatment involves hemodynamic support, surgical exploration to identify and control the source of contamination, and comprehensive postoperative management.[7] Controversy exists on whether the condition is better managed by open peritoneal drainage, primary closure, or closed suction drainage. Published survival rates from previous studies suggest there are no significant differences between treatments[5,6] although, because there are no prospective studies, there is often selection bias in these reports.

Many authors consider that continued drainage of the abdominal cavity is important as it facilitates the primary action of peritoneal defense, that is physically removing bacteria and inflammatory mediators from the abdominal cavity.[8] One study on the use of closed suction drainage systems for continued abdominal drainage after initial correction of the cause of peritonitis reported a survival rate of 70%.[5] This is comparable to survival rates of 52–89% reported using open peritoneal drainage,[2,6] and 54–67% reported using no drainage/primary closure.[6,9] The advantages of a closed suction drain compared to open peritoneal drainage include decreased potential for evisceration, minimal postoperative bandage care, and elimination of the need for a 2nd surgery to close the abdomen.[7] Another study reported on the use of vacuum-assisted peritoneal drainage to modify the open peritoneal drainage technique; however, a 2nd surgery was still required to close the abdomen and the survival rate was only 38%.[10]

One study had a 27% survival rate for surgical treatment of septic bile peritonitis[11] but we are unaware of results documenting surgical treatment of septic peritonitis originating from a purely gastrointestinal origin. Thus, our purposes were 3-fold: (1) to determine the outcome of dogs with septic peritonitis of a confirmed gastrointestinal origin treated with closed suction drainage after resolution of the underlying cause of peritonitis; (2) to identify any complications associated with this method; and (3) to describe details of postoperative management and support. We hypothesized that closed suction drainage would be effective at treating septic peritonitis of a confirmed gastrointestinal origin in dogs.

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MATERIALS AND METHODS

Medical records (January 2007–August 2010) of all dogs referred to Davies Veterinary Specialists that were diagnosed with septic peritonitis were retrospectively reviewed. Inclusion criteria were surgical treatment of the peritonitis with subsequent confirmation of gastrointestinal origin. Postoperative management of septic peritonitis with closed suction drainage has been the treatment of choice for all dogs in this hospital since 2007 and was therefore used in all dogs treated with this condition for this study. Dogs were excluded if they were euthanatized or died before completion of surgery and transfer to the recovery unit.

Data retrieved from the medical record included signalment, duration of hospitalization, change in weight between admission and discharge, and the results of all blood tests run in hospital. Cause of gastrointestinal contamination, intraoperative technique, length of anesthesia, and intraoperative complications were also recorded. Postoperative management data included detailed information on all drugs administered, intravenous (IV) fluid type and rate of administration, a record of all blood product transfusions, and any postoperative complications. Daily volumes of fluid collected from closed suction drains, the number of days drains remained in place, and drain fluid cytology and microbial culture results were all recorded. Postoperative nutrition was documented detailing the type of feeding tube placed, type and rate of supplementary feeding, diet being fed, and time until voluntary oral food intake was sufficient enough to not require supplementation.

Dogs were classified as either survivors or nonsurvivors. Survivors were defined as those dogs that survived to discharge. Nonsurvivors included all dogs that died or were euthanatized while hospitalized. Long-term follow up was obtained by telephone communication with the owners, $\geq$6 months after surgery.

Surgical Procedures

Ventral median celiotomies extending from xiphoid to pubis were performed and surgical suction used to remove any free abdominal fluid. Complete exploration of the abdomen was performed. Any adhesions were gently broken down by finger dissection or blunt dissection using DeBakey forceps, bipolar diathermy, or Metzenbaum scissors; this allowed the entire length of the intestinal tract to be examined by running the bowel between the fingers. The source of the gastrointestinal contamination was located and surgically corrected. Further support for the completed repair of the bowel was provided by omentalization in 14 dogs and serosal patching in 6 dogs. Before closure of the abdomen, the peritoneal cavity was lavaged with ~200 mL/kg of warm sterile saline (0.9% NaCl) solution. Abdominal lavage fluid was removed by suction until the peritoneal cavity was visibly free of fluid after which surgical gloves, instruments, and drapes were changed.

A Jackson-Pratt style closed suction drainage system (closed wound vacuum drain [silicone], SurgiVet, Waukesha, WI) was then placed cranially, between the liver and the diaphragm. A paramedian abdominal stab incision was then made and a hemostatic forceps was pushed through this into the abdomen to grasp the end of the drain and withdraw it out of the abdomen. If a 2nd drain was placed, a 2nd paramedian stab incision was made and the drain placed caudally, alongside the bladder, or beside the enteric surgery site depending on surgeon preference. Drains were secured using a purse string suture through the skin converting up into a finger-trap suture along the drain.

Gastrostomy tubes (Freka® PEG set Gastric, Fresenius Kabi AG, Germany), in selected dogs, were also placed at this time. The abdomen was closed in 3 layers. Indwelling urinary catheters were placed in most dogs and esophageal feeding tubes in a select few. A suction grenade (continuous suction bulb, SurgiVet) was attached to the drain creating a vacuum when compressed and secured to the dog using either a soft elastic net bandage (K-lite Vet, URGO Medical, Loughborough, UK) or a crepe knit bandage (Surgifix, FRA Production, Cisterna d'Asti, Italy) tied around the abdomen. Two sizes of suction grenade were used: 150 mL for dogs weighing <15 kg and 400 mL grenades for dogs $\geq$15 kg. Abdominal wound and drain sites were covered with adhesive dressings (Primapore, Smith & Nephew Medical Limited, Hull, UK), and changed daily for site assessment purposes.

All dogs were admitted to the intensive care unit after surgery. Suction grenades were emptied when fully expanded or at regular time intervals as directed by the attending clinician, and thus varied during the course of hospitalization, ranging from as often as half hourly in the immediate postoperative period to every 6 hours later in the course of treatment.

Postoperative hemodynamic support with IV crystalloids was provided for all dogs and tailored to individual needs based on clinical assessment and ongoing fluid losses from the drains. An assessment of colloid osmotic pressure (COP) to estimate appropriate colloid support with hydroxyethyl starch was performed for each dog based on measurements of total protein concentration, the volumes of fluid lost from the drains, and clinical signs of edema. Fresh frozen plasma transfusions were used to help maintain COP when doses of hydroxyethyl starch exceeded 20 mL/kg/day, but also used when serum albumin was <2.6 g/dL and for coagulopathic dogs in combination with cryoprecipitate transfusions.

The criteria supporting a decision to remove a drain included some or all of the following: (1) a favorable overall clinical assessment of the dog including hematology/serum biochemistry assessment; (2) only nondegenerate neutrophils seen with no evidence of intracellular bacteria, on cytology of fluid collected from the grenade; and (3) a downward trend or marked reduction in daily drain fluid production from immediate postoperative values.

Statistical Analysis

Descriptive statistics were used to summarize the volumes of fluid collected from the closed suction drains, time of drain removal, rates of postoperative hemodynamic support, rates of fresh frozen plasma transfusions, serum albumin concentrations, length of required nutritional support, hospitalization period, and outcome. The volume of fluid collected from the closed suction drains on day 0 (day of surgery) was adjusted to allow for surgery at different times of day.

RESULTS

Data Retrieval

Thirty cases of septic peritonitis of a confirmed gastrointestinal origin presented within the study period. Six dogs were euthanatized after initial investigations and received no further treatment. The remaining 24 dogs all had surgical intervention; 4 were euthanatized during surgery, leaving 20 dogs that met the study inclusion criteria.

Signalment

Four dogs were Labrador Retrievers and the other 16 represented 14 different breeds. Median age was 5 years 6 months (range, 8 months to 12 years) with 8 sexually intact males, 5 castrated males, 3 intact females, and 4 spayed females. Median weight was 23.0 kg (range, 3.8–50.0 kg).

Cause of Abdominal Contamination

Sixteen dogs (80%) had developed septic peritonitis secondary to dehiscence of an anastomosis or enterotomy. In 7 of these cases, surgery at the referring hospitals to treat septic peritonitis secondary to dehiscence of an anastomosis or enterotomy had been attempted before referral to Davies Veterinary Specialists. Repeat evidence of dehiscence and leakage of gastrointestinal contents into the abdomen for the second time had prompted referral. Other causes of septic peritonitis included rupture of gastrointestinal ulceration suspected to be secondary to nonsteroidal anti-inflammatory drug use (n = 2, 1 duodenal and 1 colonic), rupture of a gastric wall abscess (n = 1), and multiple perforations caused by a linear foreign body (n = 1). The most common anatomic origin of contamination was the jejunum (n = 11; 55%), but other origins included the stomach, duodenum, ileocecal junction, and colon. Two dogs had leakage from both stomach and jejunum.

Surgery

Median duration of anesthesia was 3 hours (range, 2–4.5 hours). Correction of the underlying cause of septic peritonitis was performed in all 20 dogs. Correction of gastric contamination (n = 4) was performed by resection of the compromised gastrotomy site and layered sutured closure in 3 dogs and by debridement and omentalization of a gastric wall abscess in 1 dog. Correction of duodenal contamination (n = 2) was performed by resection and end-to-end anastomosis in 1 dog and by local debridement and primary suture repair, because of proximity of the common bile duct, in the other dog. Correction of jejunal contamination (n = 11) was performed by resection and sutured end-to-end anastomosis in all but 1 dog where a functional end-to-end anastomosis stapling technique[12] was performed instead. Correction of contamination from the ileocecal junction (n = 3) was performed by resection and jejunocolic anastomosis in all 3 dogs. Correction of colonic contamination (n = 2) was performed by resection and end-to-end anastomosis in 1 dog and by local debridement and primary suture repair in the other dog, to preserve colonic length where a previously large section of colon had already been removed.

Complications

Presurgical serum albumin concentrations were available for 11 dogs and all were hypoalbuminemic (serum albumin <2.6 g/dL) with a mean of 1.83 ± 0.28 g/dL. Intraoperative hypotension (systolic blood pressure <90 mmHg) was recorded in 13 dogs (65%). Positive inotrope therapy was administered to 3 of these dogs during surgery. One dog was administered dopamine (1–10 μg/kg/min IV), 1 ephedrine hydrochloride (0.05–0.2 mg/kg IV every 5–15 minutes), and 1 dobutamine (1–20 μg/kg/min IV). Other intraoperative complications included hypertension (systolic blood pressure >180 mgHg, n = 3), gastroesophageal reflux (n = 2), cardiac arrhythmias (n = 1), and significant blood loss (n = 1). Postoperative complications are summarized in Table 1.

Drain Management

All 20 dogs had Jackson-Pratt closed suction drains placed; 5 (25%) dogs had 2 drains placed. Two dogs died with drains still in place; for the other 18 dogs, drains remained in place a median of 6 days (range, 2–11 days). Three of the 5 dogs with 2 drains placed had staged removal of the drains with the 1st drain being removed after a median of 7 days (range, 5–8 days), and the 2nd drain after a median of 8 days (range, 6–11 days). Mean adjusted fluid collection on day 0 (day of surgery) was 46.66 ± 25.95 mL/kg/day. One dog died 10 hours after surgery and was excluded from this analysis as the volume of fluid collected in the drain during this period was excessive, and calculated to be equivalent to 129.77 mL/kg/day. Drain fluid collection for the remaining 19 dogs is summarized in Table 2.

All dogs had a marked decrease in daily fluid collected from the closed suction drains over time, although 2 dogs had a mild increase in the volume of fluid collected in the last day that the drains were in place of <2 mL/kg/day. One of those 2 dogs developed a relapse of septic peritonitis 6 days later and was euthanatized. All drains were able to be removed with dogs conscious. One drain had to be re-sutured at the skin interface, and leakage of abdominal fluid at the drain exit site occurred in 2 dogs. No other complications with the drains were recorded. Cytology at the time of drain removal was documented for only 5 dogs, all of which had low numbers of nondegenerate neutrophils, with no bacteria seen.

Table 1 Recorded Postoperative Complications

Postoperative Complications	Dogs Affected
Common postoperative complications	
Hypoproteinemia (TP < 54 g/dL)	18 (90%)
Anemia (PCV <35%)	17 (85%)
Vomiting/regurgitation	15 (75%)
Diarrhea	12 (60%)
Edema	11 (55%)
Patient removed central line	5 (25%)
Perianal inflammation secondary to diarrhea	5 (25%)
Ileus	4 (20%)
Uncommon postoperative complications	
Abdominal wound seroma	1
Acute hypovolemic shock secondary to abdominal hemorrhage	1
Aspiration pneumonia	1
Cardiac arrhythmias	1
Chewing gastrostomy tube	1
Decompensatory septic shock	1
Emphysema around left antebrachium—secondary to trauma to central line	1
Hypersalivation	1
Hypertension (systolic blood pressure >180 mmHg)	1
Hypoglycemia (blood glucose <3.5 mmol/L)	1
Leakage of fluid from drain sites	2
Leakage of stomach contents around gastrostomy tube site	1
Necrotizing pancreatitis causing pyloric obstruction	1
Patient chewed central line	2
Patient removed esophageal feeding tube	1
Significant gastrointestinal hemorrhage—melena and hematochezia	1
Urinary incontinence	1

Table 1 Recorded Postoperative Complications

Postoperative Hemodynamic Support

All dogs were administered Hartmann's solution for crystalloid support for a median of 6 days (range, 1–12 days), and 17 dogs received potassium supplementation during this period tailored to individual needs. Mean rate of crystalloid support after surgery on day 0 was 5.45 ± 3.87 mL/kg/h. For the following 3 days, dogs received a mean of 3.57 ± 1.43 mL/kg/h, reducing to a mean of 2.69 ± 1.02 mL/kg/h thereafter. Up to 3 days after surgery, 18 dogs were still receiving crystalloids, but this number more than halved over the next 3 days and on day 7, only 5 dogs were still receiving IV crystalloids.

Thirteen dogs (65%) also received hydroxyethyl starch for colloid support for a median of 3 days (range, 1–9 days). Mean rate of colloid support after surgery on day 0 was 13.64 ± 12.63 mL/kg/day. Over the following 3 days, dogs received a mean of 8.21 ± 5.38 mL/kg/day and the numbers receiving colloids during this time dropped to 6. After this point (day 4 onwards), only 3 dogs continued to receive colloid support, which was administered at a mean of 10.45 ± 3.34 mL/kg/day.

Nineteen dogs (95%) had an indwelling urinary catheter (IDUC) placed at the end of surgery, and these remained in place for a median of 3 days (range, 1–7 days). A central line was placed in 18 dogs (90%), and remained in place for a median of 6 days (range, 1–14 days). These lines allowed the effectiveness of initial fluid therapy to be regularly assessed and changed in conjunction with the trend of central venous pressure (CVP) measurements and individual urinary output values. Fluid replacement rates were titrated to maintain CVP between 0 and 10 cm H_2O and urinary output at >1 mL/kg/h.

Table 2 Drain Fluid Collection Analysis

Time After Surgery	Number of Dogs With Drains Still in Place	Mean ± SD Daily Fluid Collection From Drain(s) (mL/kg/Day)	Range (mL/kg/Day)
Day 0 (day of surgery—time adjusted)	19	46.66 ± 25.95	(6.32–107.22)
Day 1	19	30.05 ± 14.71	(3.17–63.25)
Day 2	19	19.79 ± 10.51	(2.29–51.98)
Day 3	18	18.15 ± 9.06	(4.58–40.47)
Day 4	18	17.71 ± 11.61	(1.85–46.47)
Day 5	17	10.43 ± 8.85	(0.38–30.19)
Day 6	12	10.80 ± 9.36	(2.04–31.00)
Day 7	8	8.39 ± 6.06	(1.01–19.64)
Day 8	2	13.43 ± 8.17	(5.26–21.60)
Day 9	1	14.38	—
Day 10	1	7.42	—
Day 11	1	1.04	—

Transfusion Medicine

Fourteen dogs (70%) received a total of 27 FFP transfusions at a mean dose of 12.72 ± 6.27 mL/kg per transfusion and a mean total dose of 24.52 ± 9.66 mL/kg per dog during hospitalization. Thirteen of these received FFP transfusions on the day of surgery, 8 of which were started during surgery. One dog did not receive plasma until 2 days after surgery. FFP transfusions were administered on a median of 1 day only (range, 1–6 consecutive days) and were supplementary to synthetic colloid support in 9 dogs.

One dog was known to have von Willebrand disease and was given FFP in conjunction with cryoprecipitate presurgery. This dog required 2 further cryoprecipitate transfusions and 2 packed red blood cell transfusions because of persistent hemorrhage into the gastrointestinal tract. Another dog developed acute hypovolemic shock, shortly after surgery, characterized by a sudden increase in hemorrhagic effusion into the abdominal cavity, which was drained using the closed suction drain. Initial stabilization with volume replacement fluid therapy was successful, but the event repeated itself within a very short time span. Further investigation revealed a significantly prolonged buccal mucosal bleeding time (>7 minutes) with adequate numbers of platelets on a blood smear, consistent with a platelet adhesion abnormality. Treatment consisted of a transfusion of both packed red blood cells and cryoprecipitate, in combination with desmopressin acetate (2 μg/kg IV). No further hemorrhagic episodes occurred.

Drug Therapy

All dogs received perioperative IV antibiotics with either cefuroxime (22 mg/kg every 2 hours; n = 6) or amoxicillin and clavulanate (20 mg/kg every 2 hours; n = 14). These were continued postoperatively (every 6–8 hours) in combination with metronidazole (10 mg/kg IV twice daily) in 19 dogs, 13 of which were also administered enrofloxacin (10 mg/kg IV once daily).

Low molecular weight heparin, dalteparin sodium (Fragmin, Pfizer, Inc., New York, NY; 100 U/kg subcutaneously, twice daily), was administered to 7 dogs. Postoperative vomiting and regurgitation was treated with oral or subcutaneous ranitidine (2 mg/kg every 8–12 hours; n = 17), oral sucralfate (0.25–2 g every 6–8 hours; n = 16) and subcutaneous maropitant citrate (Cerenia, Zoetis, Kalamazoo, MI; 1 mg/kg once daily; n = 8) as required. Three dogs were administered omeprazole (0.75–1.5 mg/kg orally once daily). Metoclopramide (1–2 mg/kg IV over 24 hours) was given as a constant rate infusion (CRI) to aid gastrointestinal motility in 14 dogs.

Postoperative pain was managed with methadone (0.1–0.3 mg/kg IM every 4–6 hours) as standard, reducing to buprenorphine (0.01–0.02 mg/kg every 6–8 hours IV, IM or subcutaneously) as pain reduced. Seventeen dogs (85%) required additional pain management. IV CRI lidocaine (20–40 μg/kg/min) was administered in 16 dogs; 2 dogs also had CRI morphine sulfate (0.15–0.2 mg/kg/h), and 1 of those 2 also received ketamine CRI (2–5 μg/kg/min). A ketamine infusion was also administered to 1 other dog not receiving lidocaine.

Drain Fluid Microbial Culture and Susceptibility Testing

Abdominal fluid was submitted for culture and susceptibility in only 4 dogs; all yielded bacterial growth. In 3 dogs, *Escherichia coli* was isolated as a single organism, and the other dog had a mixed fecal growth. Isolates from 2 dogs showed some resistance but all empirical antibiotic choices were appropriate. In dogs where culture and susceptibility was not performed, all responded appropriately to treatment, and only 1 dog had recurrence of septic peritonitis, which was because of breakdown of an enterotomy site and gross re-contamination.

Nutritional Support

Eighteen dogs (90%) received supplementary nutrition using a high protein diet (Formula V® EnteralCare HLP, Pet AG, Hampshire, IL) after surgery. Nine of these were fed via a gastrostomy tube placed at surgery, 7 via an esophagostomy tube, and 2 were syringe fed orally. Two of these dogs died before any appetite returned. The remainder of these dogs did not have any appetite for a median of 3 days (range, 1–10 days) and required supplementary nutrition for a median of 4 days (range, 1–11 days) to ensure they met their daily maintenance energy requirement. The remaining 2 dogs were eating adequate quantities of high protein oral food (Prescription Diet® i/d®, Hill's, Topeka, KS) after surgery and required no supplementary nutrition.

Recommendations were given to remove gastrostomy tubes after 10–14 days, but because of owner compliance problems, they remained in place for a median of 17.5 days (range, 7–36 days). Esophagostomy tubes remained in place for a median of 6 days (range, 1–13 days). All supplementary feeding was carried out by interval feeds, except in 6 dogs that were trickle fed as bolus feeding was associated with vomiting or regurgitation. Trickle feeding consisted of receiving a slow constant administration of liquid food by feeding tube using a syringe driver over a period of 6–8 hours repeated 2–3 times/day. This was performed through a gastrostomy tube in 5 dogs and an esophageal tube in 1 dog.

Hospitalization

Median duration of hospitalization for surviving dogs was 8 days (range, 3–13 days). During hospitalization, dogs lost a mean of 2.26 ± 2.44 kg, which was equivalent to a mean loss of 9.62 ± 6.70% of their body weight since being admitted to the hospital. Dogs lost a mean of 1.03 ± 0.71% bodyweight/day of hospitalization.

Outcome

Seventeen dogs (85%) survived to discharge and all were still alive at 6-month follow up; no complications or issues relating to their previous surgeries were reported. Median time of death after surgery was 114 hours (range, 10–288 hours). The first dog entered decompensatory septic shock during surgery, averaging systolic blood pressures of 40 mmHg despite inotrope infusions. This dog also developed severe metabolic derangements and acidosis despite aggressive IV fluid management. The dog then died from cardiopulmonary arrest 10 hours after surgery. The 2nd dog was euthanatized 5 days after surgery because of necrotizing pancreatitis (diagnosed on intraoperative biopsies), which was also causing complete pyloric obstruction. The drain cytology at this time was consistent with normal postoperative fluid suggesting a resolution from the septic peritonitis. The 3rd dog deteriorated 12 days after surgery, showing signs of recurrence of septic peritonitis with gross contamination and was euthanatized.

DISCUSSION

Our results show that closed suction drainage in addition to management of the cause of peritonitis is very effective as a means of treatment for septic peritonitis of gastrointestinal origin in dogs. Although we only focused on septic peritonitis of gastrointestinal origin, and thus our study is not directly comparable, the mortality rate of 15% does compare favorably to previously reported mortality rates and drainage methods used to treat septic peritonitis from all causes which range from

11% to 48%.[2,6] Further, our mortality rate is lower than the 73% reported for septic bile peritonitis.[11] This large difference suggests the need to perform investigation of survival rates associated with other causes of septic peritonitis.

One of the primary responses of the peritoneum to infection is the physical removal of bacteria from the abdominal cavity through lymphatic drainage.[8] This mechanism was impaired in an experimental model of septic peritonitis induced in conscious sheep.[13] In a dog model of experimentally induced septic peritonitis, there was a marked increase in mortality in the presence of lymphatic blockage by thoracic duct ligation.[14] This may be further illustrated by the higher mortality rates (33[6]–46%[9]) reported with primary closure of the abdomen after surgical treatment of septic peritonitis. These mortality rates may actually be moderated by a degree of selection bias inherent within these reports and thus may underestimate mortality without postoperative drainage. The purpose therefore of postoperative abdominal drainage is to facilitate the peritoneal defensive mechanism by physically removing fluid, and with it bacteria, from the abdominal cavity.

Successful continued drainage of the abdomen has traditionally been challenging. Active closed suction drains provide effective and prolonged periods of postoperative abdominal drainage while allowing closure of the abdomen, which decreases the potential for evisceration, and eliminates the need for a 2nd surgical procedure to close the abdomen as is needed with open peritoneal drainage.[5] Use of an external vacuum source to create an active pressure gradient into the collection grenade means they are potentially independent of intraperitoneal circulation.[5] Although not documented ultrasonographically, none of the drains in our dogs appeared to occlude, nor were occluded with fibrin on removal. Drains remained in place and continued to collect peritoneal fluid for up to 11 days (mean, 6.17 ± 1.80 days), almost twice as long as previously reported.[5] However, although fluid was collected throughout the time the drains were in place, it was impossible, retrospectively, to determine whether the drains were effectively removing all fluid produced within the entire abdominal cavity.

Open peritoneal drainage was previously considered the drainage technique of choice because it provided successful drainage of the entire peritoneal cavity with survival rates ranging from 52%[2] to 89%.[6] However, it is difficult to monitor ongoing fluid losses with this technique, which relies on nursing-intensive bandage changes. By comparison, closed-suction drainage systems allow the easy monitoring of the rate and nature of fluid the peritoneum is producing. When used in conjunction with urine production metrics obtained from IDUC, an estimation of fluid loss can be calculated and compared against fluid replacement. CVP measurements and blood pressure monitoring can also be factored in, to tailor hemodynamic support to the individual dog's needs as often as necessary. Recording these figures in an "ins and outs" table can give a better idea of temporal trends. An additional advantage of active closed-suction drainage systems is that the suction grenade, because of its active nature, acts as a proxy for processes occurring within the peritoneum as they occur. This allows a near constant monitoring and response system for fluid balance. For example, this system allowed detection and subsequent expedient treatment of a suspected platelet adhesion abnormality characterized by a sudden increase in hemorrhagic abdominal effusion in 1 dog in our study. The use of vacuum-assisted peritoneal drainage as described by Cioffi et al.[10] rectifies the problem of monitoring ongoing fluid losses with standard open peritoneal drainage. However, a 38%[10] survival rate is disappointing regardless of the drainage technique used.

Closed-suction drainage systems also allow easy collection of samples of abdominal fluid for daily cytologic evaluation, which is important for determining the appropriate timing of drain removal. Unfortunately, because our study was retrospective and also because cytologic analysis was performed by individual clinicians rather than clinical pathologists, this information was often not documented or lacked sufficient detail. This may explain why degenerate neutrophils were not reported at the time of drain removal as might be expected from normal post celiotomy drain fluid.[15] However, all dogs in our study were being administered antibiotics at time of drain removal, which may act as a confounding factor and make these results incomparable.

In acute life-threatening surgical infections requiring immediate institution of antimicrobial therapy such as those reported in our study, initial antibiotic treatment must be empirical. Ideally, all dogs would have preoperative abdominal fluid microbial culture and susceptibility testing performed to evaluate effectiveness of empirically chosen antibiotics postoperatively, but this was not routinely done. The polymicrobial nature of the gastrointestinal tract requires that the antibiotics selected cover aerobic, facultative, and anaerobic organisms. Thus more than 1 antibiotic is required for adequate coverage of common intra-abdominal pathogens, as was done in all but 1 dog in our study. For those 4 dogs that had abdominal fluid cultured, all empirically chosen antibiotics were appropriate despite some bacterial resistance. In 1 report, there was no significant difference in survival rates of animals treated with appropriate versus inappropriate antimicrobials,[5] thus emphasizing the importance of controlling the source of infection and possibly questioning the necessity for culture and susceptibility testing. A meta-analysis of human antibiotic regimens for secondary peritonitis of gastrointestinal origin had similar conclusions, being unable to make specific recommendations for the first line treatment of secondary peritonitis with antibiotics, as all regimens showed equivocal efficacy, with no particular antibiotic regimen resulting in significant difference in terms of mortality from infection.[16]

In the other dogs where culture and susceptibility testing was not performed, all responded appropriately to treatment and only 1 dog had a reoccurrence of septic peritonitis. That dog had a breakdown of an enterotomy site with gross contamination. Nosocomial infection is, however, a potential complication and has been reported with closed suction peritoneal drains,[5,15] but as abdominal fluid samples were not routinely submitted for culture before and after surgical correction, the risks of nosocomial infection could not be determined in our study. Open peritoneal drainage is also complicated by the risk of nosocomial infection of the peritoneum[4,17] but in comparison, the risk of nosocomial infection with closed suction would be expected to be lower given the closed nature of the drainage, and the active pressure gradient. Despite this, standard barrier nursing techniques should still be implemented when handling or emptying the drains to further minimize potential risks of nosocomial infection.

Postoperative hypoproteinemia was the most commonly documented complication (90%). This has been previously reported with abdominal drainage, but has not been associated with higher mortality rates.[18] However, proteins, and in particular albumin, have several important functions including drug carrying capacity, blood pH buffering, and mediation of coagulation and wound healing.[19] Although total protein concentration has not been associated with increased mortality, deficits in albumin have. Increased morbidity and mortality in both people and animals have been correlated with hypoalbuminemia,[20,21] and have been associated with delayed healing of gastrointestinal surgery sites.[22] Albumin synthesis is depressed during periods of inadequate nutrition, and can decrease by as much as 50% after an 18- to 24-hour fast.[23] In addition, animals with septic peritonitis enter a severe catabolic state resulting from a 25% increase in metabolic rate coupled with massive protein loss into the peritoneal cavity.[24,25] Therefore, particular attention was paid to analgesia to eliminate painful stimuli suppressing appetite, and early postoperative nutritional support, to provide amino acid sources necessary for albumin synthesis and wound healing. Early nutritional support where consistent caloric intake occurs within 24 hours postoperatively has recently been associated with shorter hospitalization in dogs with septic peritonitis.[26] Enteral nutrition also directly stimulates enterocytes, which helps prevent intestinal mucosal atrophy and subsequent bacterial translocation, both of which can contribute to sepsis and systemic inflammatory response syndrome (SIRS).[19] However, despite attempts to provide adequate supplementary nutrition, our dogs still lost a mean of $9.62 \pm 6.70\%$ of their body weight during hospitalization, although this could in part relate to resolution of fluid accumulation within the abdomen.

Although circulating blood albumin concentrations are intimately associated with nutritional state, they are also regulated by COP.[19] The effect of plasma on COP is less than that of synthetic colloids[27] and alone is an ineffective means of increasing intravascular protein concentrations, particularly if ongoing loss is occurring.[27] Thus the use of plasma alone to increase COP is expensive and often cost prohibitive; therefore, combination fluid therapy was used. All dogs were administered crystalloids to increase interstitial and intravascular volume, in combination with hydroxyethyl starch in 14 dogs to increase intravascular volume and maintain COP. FFP transfusions were used to help maintain COP when doses of synthetic colloids reached 20 mL/kg/day in an attempt to avoid potential coagulopathies associated with excessive colloid use.[28] FFP was also used to provide additional albumin primarily during the immediate perioperative period. The goal of albumin supplementation should be to raise plasma albumin to 2.0–2.5 g/dL[19] and for those dogs where this was measured, mean albumin concentrations of 1.83 ± 0.28 g/dL presurgery indicated a supplementation requirement of 0.17 to 0.67 ± 0.28 g/dL. To increase plasma albumin by 0.5 g/dL, ~22.5 mL/kg of plasma is required.[29] Dogs in our study were administered a mean total dose of 24.52 ± 9.66 mL/kg, which should equate to an estimated mean increase in plasma albumin of 0.54 ± 0.21 g/dL. However, as albumin levels were not routinely monitored postoperatively, and ongoing losses would occur through continued drainage of peritoneal fluid, the effectiveness of albumin supplementation could not be evaluated.

Because of the prevalence of disseminated intravascular coagulation in sepsis[30] and recent clinical experiences with thromboembolic disease, low molecular weight heparin was administered to 7 dogs (35%) at clinician discretion. Monitoring and assessment of treatment efficacy was not performed as equipment required to do this is expensive and was not available on site. Although none of these dogs or any of the remaining dogs in the study had postoperative complications consistent with thromboembolic disease, neither the prevalence, nor the potential for thromboembolic episodes could be assessed.

Our study has a number of other limitations, primarily because of its retrospective nature and small population size. This infers an inherent selection bias in patient data collection, although actual case selection bias in this study was avoided as all dogs presented within the study period were treated in the same manner with closed suction drainage. The small population size limits the power of the study and thus the results should be extrapolated cautiously. An attempt at retrospectively performing a risk stratification to provide a multivariate analysis of disease severity using the survival prediction index 2 (SPI2) reported by King et al.[31] was attempted but failed because of incomplete medical records and lack of standardized data collection. However, this would be worth considering in future prospective studies to allow comparison of disease severity between reports. Larger-scale multicenter prospective studies therefore will likely be necessary to demonstrate any statistically significant improvement in survival between drainage techniques, or sources of contamination.

Although not directly reported, on evaluation of data from a previous study on the use of closed suction drains to treat septic peritonitis,[5] the survival rate of dogs where this was of gastrointestinal origin was similar to our study. This could indicate that septic peritonitis of a purely gastrointestinal origin has a good survival rate, and previous reported survival rates have been reduced by the inclusion of septic peritonitis from sources of contamination associated with higher mortality. However, this survival rate compares favorably with previous reported survival rates using alternative or no drainage methods postoperatively. This improved outcome, therefore, could be an indication that standards of emergency and critical care are improving as most previously reported survival rates are from the late 1980s and 1990s. However, 1 study comparing dogs with septic peritonitis between 2 time periods (1988–1993 and 1999–2003)[31] contradicts this suggestion, as no significant difference in survival rates was found between the 2 periods despite an increased level of care. Similarly, despite the recent rapid progression of emergency and critical care, by far the highest published survival rate for septic peritonitis (89%)[6] describes cases treated between 1993 and 1999.

The ability to directly compare survival rates between different reports is difficult, because of the heterogeneity of the patient population, the lack of suitable comparisons of disease severity between studies, and likely variations in nursing protocols and critical care experiences at different institutions. Whereas it is possible that 85% survival rate in our study is simply because of less severely ill dogs being selected for treatment, the mean preoperative serum albumin was 1.83 ± 0.28 g/dL. In a previous study, nonsurvivors had mean preoperative serum albumin of 1.9 ± 0.9 g/dL.[32]

Despite the debate, improvements in emergency and critical care with particular regard for the management of hypoalbuminemia may have had significant impact upon survival rates, and it seems likely that the benefits of closed suction drainage have not only facilitated this care, but have also played an active role in the favorable survival rates reported in our study. In our opinion, further work investigating the differences in survival rates for septic peritonitis from specific causes would also be worthwhile. In this cohort of dogs, closed suction drainage with appropriate postoperative management was a very effective technique for treatment of septic peritonitis of confirmed gastrointestinal origin.

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DISCLOSURE

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