

# Evaluation of Postceliotomy Peritoneal Drain Fluid Volume, Cytology, and Blood-to-Peritoneal Fluid Lactate and Glucose Differences in Normal Dogs

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**Objective:** To describe peritoneal drain fluid volume, fluid cytology, and blood-to-peritoneal fluid lactate and glucose concentration differences after exploratory celiotomy in normal dogs.

**Study Design:** Prospective study.

**Animals:** Healthy Beagle dogs (n = 10).

**Methods:** After exploratory celiotomy, a peritoneal drain was placed, and peritoneal fluid was recorded every 6 hours for 7 days. Fluid was submitted for cytologic examination, and fluid and blood glucose and lactate concentrations were recorded every 12 hours. On day 7, drains were removed and drain tips submitted for aerobic bacterial culture.

**Results:** Mean peritoneal fluid volume decreased from 2.8 mL/kg/day (day 1) to 0.6 mL/kg/day (day 7). All dogs had degenerate neutrophils in peritoneal fluid throughout the 7 days. Four dogs developed contaminated drains. Blood-to-peritoneal glucose concentration differences > 20 mg/dL occurred after day 4. By day 7, 5 of 7 dogs with patent drains had blood-to-peritoneal lactate concentration differences < -2 mmol/L.

**Conclusion:** After day 4, blood-to-peritoneal glucose concentration differences were consistent with septic effusion based on previously reported values used to diagnose septic peritonitis in dogs. Blood-to-peritoneal lactate concentration differences varied but after day 4, > 70% of dogs had differences consistent with septic peritonitis each day. Postoperative blood-to-peritoneal fluid glucose and lactate difference may not be reliable indicators of septic peritonitis when evaluating abdominal fluid collected with closed suction drains.

Septic peritonitis is a life threatening condition requiring emergency surgical intervention. Mortality rates in dogs and cats range from 20% to 80% depending on the nature and severity of the peritonitis.<sup>1-12</sup> The most common cause of septic peritonitis is disruption of the gastrointestinal tract and inoculation with endogenous bacteria.<sup>7,10,11,13</sup>

The incidence of postoperative gastrointestinal surgical wound dehiscence ranges from 7% to 15%.<sup>10-12</sup> Dehiscence of intestinal biopsy or resection and anastomosis sites most commonly occurs between 3 and 5 days postoperatively during the lag phase of wound healing when the strength of the gastrointestinal incision is provided solely by the fibrin clot and closure material.<sup>10-12,14,15</sup>

Diagnosis of septic peritonitis is based on the identification of degenerative neutrophils and intracellular bacteria within abdominal fluid.<sup>1,13</sup> Published reports indicate a range of 57-100% accuracy for fluid cytologic examination

in the preoperative diagnosis of septic peritonitis.<sup>1,4,8,9</sup> Peritoneal fluid cytology may fail to identify intracellular bacteria if the patient is on antibiotic therapy, if the peritoneal fluid is sampled from a pocket distant to the gastrointestinal wound, or if the slide is inadequately evaluated.<sup>1,4,8,9</sup> A positive culture result from the peritoneal fluid is the gold standard for the diagnosis of septic peritonitis. Considering that a culture requires several days to obtain a result, culture results are only used to augment the diagnosis of septic peritonitis, and to obtain information on antimicrobial susceptibility. The ability to quickly diagnose the loss of gastrointestinal incisional integrity is required to decrease postoperative morbidity and mortality by facilitating rapid intervention.

A progressive increase in peritoneal fluid lactate concentration occurs in dogs with segmental bowel strangulation and likely results from anaerobic metabolism from

both bacterial infection and tissue anoxia.<sup>16</sup> A peritoneal fluid lactate concentration  $>2.5$  mmol/L is 91% sensitive and 100% specific for diagnosis of septic peritonitis from peritoneal effusions obtained by abdominocentesis.<sup>9</sup> A concentration difference of  $>20$  mg/dL between blood and peritoneal fluid glucose concentrations is 100% sensitive and 100% specific for a diagnosis of septic peritonitis in dogs, and a concentration difference between blood and peritoneal fluid lactate of  $<-2.0$  mmol/L is 63% sensitive and 100% specific.<sup>8,9</sup>

Closed-suction drains are used to provide postoperative drainage for dogs with septic peritonitis.<sup>4,13,17</sup> We commonly use these drains in dogs at risk for gastrointestinal dehiscence because fluid production, cytology, and blood-to-fluid glucose and lactate concentration differences can be readily monitored while the drain is in place. However, to our knowledge there are no studies that assess the validity of using cytology, or blood-to-peritoneal drain fluid glucose and lactate concentration differences to determine if dehiscence has occurred. Additionally, the volume of abdominal fluid production that can be expected from the presence of a drain within the peritoneal cavity is unknown.

Our purposes were to evaluate the volume of peritoneal fluid production, fluid cytology, and blood-to-peritoneal drain fluid glucose and lactate concentration differences in normal dogs after exploratory celiotomy and placement of a closed suction drain. We hypothesized that blood-to-peritoneal drain fluid glucose and lactate concentration differences in healthy dogs after celiotomy would be consistent with a nonseptic effusion based on previously reported values.

## MATERIALS AND METHODS

### Dogs

Ten healthy (5 female, 5 male), purpose-bred adult Beagles (6.5–11.5 kg) were studied. Dogs were kept in individual runs, fed adult maintenance food twice daily, and had access to water *ad libitum*.

### Anesthesia

Dogs were premedicated with acepromazine (0.025 mg/kg intravenously [IV]) and hydromorphone (0.05 mg/kg IV) 30 minutes before induction. Anesthesia was induced with thiopental (15 mg/kg IV) and maintained with isoflurane in oxygen. At induction, each dog was administered carprofen (2 mg/kg subcutaneously). Dogs were positioned in dorsal recumbency and the abdomen clipped from the xiphoid to the pubis, and aseptically prepared. Lactated Ringer's solution (10 mg/kg/h IV) was administered for the duration of the procedure. Dogs were monitored continuously by use of an ECG, indirect blood pressure manometry, and pulse oximetry.

### Surgical Procedure

After draping a 20 cm ventral median incision was made through the skin and *linea alba* starting just caudal to the xiphoid process. Balfour retractors were placed and a standard abdominal exploration was performed for 10 minutes using gentle manual retraction of the viscera to observe all abdominal organ systems. The abdomen was lavaged with 500 mL sterile saline (0.9% NaCl) solution and lavage fluid was removed with suction until the peritoneal cavity was visibly free of fluid. A skin stab incision was made 5–8 cm lateral to the ventral midline with a #15 scalpel blade and a silicone peritoneal drain (Jackson-Pratt, Cardinal Health, McGraw Park, IL) inserted through the body wall into the peritoneal cavity. The portion of the drain within the abdominal cavity was 10 mm wide  $\times$  220 mm long. The external tubing of the drain was connected to the grenade-type compressible reservoir (Cardinal Health) and secured to the skin with 2-0 nylon suture using a finger-trap pattern.

The *linea alba* was closed with 2-0 polydioxonone in a simple continuous pattern. Bupivacaine (0.25%, 1 mg/kg) was then injected dorsal to the ventral rectus abdominus fascia around the *linea alba*. The subcuticular and subcutaneous tissue layers were closed with 3-0 polydioxonone using simple continuous patterns.

Before recovery from anesthesia, an 18 g jugular catheter was inserted aseptically and sutured to the skin with 3-0 nylon sutures. A body stocking (Surgisox<sup>®</sup>, Dogg-Leggs LLC, Reston, VA) and a neck collar (Bite Not<sup>®</sup>, San Francisco, CA) were applied to protect the drain and surgical site.

### Postoperative Care

Each dog was administered buprenorphine (0.02 mg/kg IV every 8 hours) for the first 24 hours postoperatively. Dogs were evaluated 4 times daily for pain for the duration of the study by palpation of the surgical incision and drain sites, monitoring of heart rate, respiratory rate, and activity level. Buprenorphine was administered as needed for analgesia.

The drain tube exit site was cleaned daily with 2% chlorhexidine solution and water, and triple antibiotic ointment was applied to the skin. On day 4, the drain grenade was replaced in all dogs. Each drain was removed on day 7. Before drain removal, the drain exit site was aseptically prepared. The drain was removed by cutting the finger-trap suture and applying gentle traction. The distal 1 cm of the drain was then cut with sterile scissors and placed in thioglycollate medium (Becton Dickinson Co., Sparks, MD). The tube site was covered with triple antibiotic ointment and a 4  $\times$  4 in. cotton gauze, covered with the body stocking for 3 days, and allowed to heal by second intention. The jugular catheter was removed at time of drain removal. Each dog's abdominal incisions were inspected once daily for swelling, discharge, or pain for an additional 7 days after drain removal.

### Monitoring

Suction grenades were emptied, and the volume of the drain fluid was recorded every 6 hours for 7 days. A fresh 0.5–1 mL sample of the fluid was collected from the drain and placed in an EDTA tube for cytology every 12 hours after wasting the fluid in the grenade. Peritoneal fluid glucose concentration was also measured on a fresh sample using a hand-held glucometer (AlphaTrak<sup>®</sup>, Abbott Laboratories, North Chicago, IL). The glucometer recorded values <20 mg/dL as low on the visual display, thus low readings were designated a value of 20 mg/dL. Peritoneal lactate concentration was similarly measured using a fresh sample with a portable lactate analyzer (Accutrend<sup>®</sup>, Roche Diagnostics, Indianapolis, IN). The lactate analyzer read values <1.7 mmol/L as low on the visual display, therefore, a low reading was designated as 1.7 mmol/L. The EDTA sample was stored at 35°C for cytologic analysis within 12 hours. Immediately after fluid collection, 3 mL blood was removed from the jugular catheter. Another 0.5 mL blood was then collected and blood glucose and lactate concentrations immediately measured using the same monitors. The original 3 mL was returned to the dog through the jugular catheter and the catheter was flushed with 2 mL heparinized saline.

Cytology was performed on all abdominal drain fluid samples within 12 hours of collection. For each fluid sample, an automated total nucleated cell count was performed using a hematology analyzer (Advia 120, GMI, Ramsey, MN) and total protein concentration and specific gravity were measured using a digital refractometer (Palm Abbe, MISCO, Cleveland, OH). Two cytocentrifuge specimens were made using a 50 and a 100  $\mu$ L aliquot. Samples were spun at 750 rotations/min for 5 minutes in a cytocentrifuge (Shandon Cytospin 4, Thermo Fisher Scientific, Waltham, MA) machine. The cytospin samples were then stained with Wright–Giemsa's stain using an automated slide stainer. A differential cell count on 100 cells and white blood cell morphology assessment was performed by a veterinary clinical pathologist (JN). The presence or absence of bacteria was noted.

The distal 1 cm of the drain in the thioglycollate medium was incubated at 37°C for 24 hours and then subcultured to Columbia blood agar (Becton Dickinson Co.) for 24–48 hours. Colonies were then isolated and identified.

### Statistical Analysis

Descriptive statistics were used to summarize peritoneal drain fluid volume, peritoneal fluid white blood cell count, peritoneal fluid neutrophil percentage, peritoneal fluid lactate and glucose concentration, blood lactate and glucose concentration, and blood-to-peritoneal lactate and glucose concentration difference for all dogs.

## RESULTS

Two dogs developed postoperative complications. Dog 1 developed erythema and mild purulent discharge along the

celiotomy incision on day 3. Amoxicillin with clavulanic acid (Clavamox<sup>™</sup>, Pfizer Animal Health, New York, NY, 13.75 mg/kg orally every 12 hours) was administered and the discharge resolved in 24 hours, but antibiotics were continued until the drain was removed on day 7. Because of antibiotic administration, the dog was removed from the study. Dog 2 developed mild inflammation around the peritoneal drain exit site on day 3 and this resolved in 48 hours without treatment. No bacteria were noted on cytology for either dog throughout the study. Two drains stopped producing fluid at 5 and 7 days, respectively. All dogs were healthy and abdominal incisions healed by day 14.

Five peritoneal drain tips had positive bacterial cultures at the end of the study. Four dogs had 1 isolate and 1 dog had 2 isolates. Culture results were as follows: *Staphylococcus intermedius* (n = 1), coagulase-negative *Staphylococcus* (1), *Bacillus* sp. and *S. intermedius* (1), *Pasteurella multocida* (1), and *Corynebacterium* sp. (1).

### Peritoneal Fluid Volume and Cytology

Mean peritoneal fluid volume decreased from  $2.8 \pm 1.2$  mL/kg on day 1 to  $0.6 \pm 0.5$  mL/kg on day 7 (Table 1).

Both intracellular and extracellular bacteria were observed in the peritoneal fluid of 4 of 5 dogs with positive cultures. Bacteria were first observed on days 2, 4, 5, and 7 for each of the 4 dogs, respectively. Once bacteria were observed, they were present on all cytology slides for the remainder of the study. The *Corynebacterium* culture was considered a contaminant at time of drain removal because there was no evidence of bacteria on cytology during the study.

Mean peritoneal white blood cell counts were highest on day 3 and 4 at  $13.3 \pm 36.8 \times 10^3$  and  $14.5 \pm 26.0 \times 10^3$  cells/ $\mu$ L, respectively (Table 1). A spike in the mean white blood cell count corresponded to the time dog 2 developed incisional inflammation. This dog had a peritoneal fluid white blood cell count of  $150.0 \times 10^3$  cells/ $\mu$ L with 96% degenerate neutrophils on day 3. The dog continued to have increased peritoneal fluid white blood cell counts of  $63.6 \times 10^3$  and  $84.1 \times 10^3$  cells/ $\mu$ L for the next 24 hours, but then decreased to  $27.5 \times 10^3$  cells/ $\mu$ L with 88% degenerate neutrophils by day 5 when inflammation around the drain site decreased.

Degenerate neutrophils were the predominant cell type on cytology of all dogs each day. The mean percentage of neutrophils decreased from  $89.5 \pm 8.3\%$  to  $66.7 \pm 12.2\%$  by day 7.

### Blood and Peritoneal Fluid Glucose

Mean peritoneal drain fluid glucose concentration decreased from  $125 \pm 39.7$  mg/dL on day 1 to  $20 \pm 1.4$  mg/dL by day 7 (Table 1). On day 1, 4 of the 9 dogs had blood-to-peritoneal fluid glucose concentration differences > 20 mg/dL. On days 2 and 3, 3 dogs had blood-to-peritoneal glucose concentration differences > 20 mg/dL. By

**Table 1** Summary of Mean  $\pm$  SD (Range) Blood and Peritoneal Drain Fluid Values

Day	Peritoneal fluid			Blood		Blood-peritoneal fluid glucose concentration difference		Peritoneal fluid		Blood		Blood-peritoneal fluid lactate concentration difference	
	Volume (mL/kg/day)	WBC ( $\times 10^6$ cells/ $\mu$ L)	Glucose (mg/dL)	Glucose (mg/dL)	Glucose (mg/dL)	Glucose (mg/dL)	Glucose (mg/dL)	Lactate (mmol/L)	Lactate (mmol/L)	Lactate (mmol/L)	Lactate (mmol/L)	Lactate (mmol/L)	Lactate (mmol/L)
1	2.8 $\pm$ 1.2 (1.2-5.2)	15.1 $\pm$ 12.5 (0.3-43.2)	125 $\pm$ 39.7 (20-181)	125 $\pm$ 49.4 (84-263)	0 $\pm$ 63.0 (-73-148)	1.8 $\pm$ 1.8 (0.7-7.2)	1.4 $\pm$ 0.7 (0.7-3.4)	-0.4 $\pm$ 2.0 (-5.6-3.4)					
2	1.4 $\pm$ 1.0 (0.1-2.9)	3.2 $\pm$ 3.0 (0.3-13.4)	124 $\pm$ 39.5 (36-179)	120 $\pm$ 13.0 (92-148)	0.2 $\pm$ 36.1 (-40-93)	3.2 $\pm$ 2.1 (0.7-7.0)	1.6 $\pm$ 0.6 (0.7-2.6)	-1.9 $\pm$ 1.9 (-5.2-1.2)					
3	1.3 $\pm$ 0.9 (0.3-2.9)	13.3 $\pm$ 36.8 (0.5-149.8)	72 $\pm$ 47.8 (20-190)	119 $\pm$ 11.7 (104-148)	47.0 $\pm$ 46.0 (-55-107)	5.9 $\pm$ 3.5 (0.8-12.4)	1.5 $\pm$ 0.8 (0.7-2.9)	-4.4 $\pm$ 3.3 (-11.4-0.1)					
4	1.2 $\pm$ 1.5 (0.4-5.1)	14.5 $\pm$ 26.0 (0.4-84.1)	43 $\pm$ 31.4 (20-104)	119 $\pm$ 11.9 (100-140)	70.4 $\pm$ 39.0 (-4-114)	6.1 $\pm$ 3.2 (1.3-15.7)	1.3 $\pm$ 0.5 (0.7-2.3)	-5.0 $\pm$ 3.1 (-13.6-0.2)					
5	0.9 $\pm$ 0.6 (0.01-1.6)	8.5 $\pm$ 7.1 (1.3-27.5)	28 $\pm$ 12.7 (20-54)	120 $\pm$ 24.4 (91-204)	87.8 $\pm$ 32.1 (35-184)	5.2 $\pm$ 2.3 (0.1-8.4)	1.5 $\pm$ 0.7 (0.7-3.3)	-4.1 $\pm$ 1.7 (-6.5-0.5)					
6	0.7 $\pm$ 0.6 (0.01-1.7)	4.8 $\pm$ 3.4 (0.4-12.0)	22 $\pm$ 5.8 (20-42)	104 $\pm$ 12.6 (79-125)	83.1 $\pm$ 14.1 (55-105)	5.9 $\pm$ 3.1 (0.7-10.5)	1.5 $\pm$ 0.6 (0.7-2.5)	-4.4 $\pm$ 3.1 (-8.9-0.6)					
7	0.6 $\pm$ 0.5 (0-1.5)	7.7 $\pm$ 7.7 (1.3-29.0)	20 $\pm$ 1.4 (20-25)	101 $\pm$ 10.9 (82-124)	80.7 $\pm$ 11.0 (60-104)	5.7 $\pm$ 4.2 (0.7-12.2)	1.9 $\pm$ 1.7 (0.7-3.3)	-4.1 $\pm$ 3.9 (-9.9-1.7)					

WBC, white blood cell.

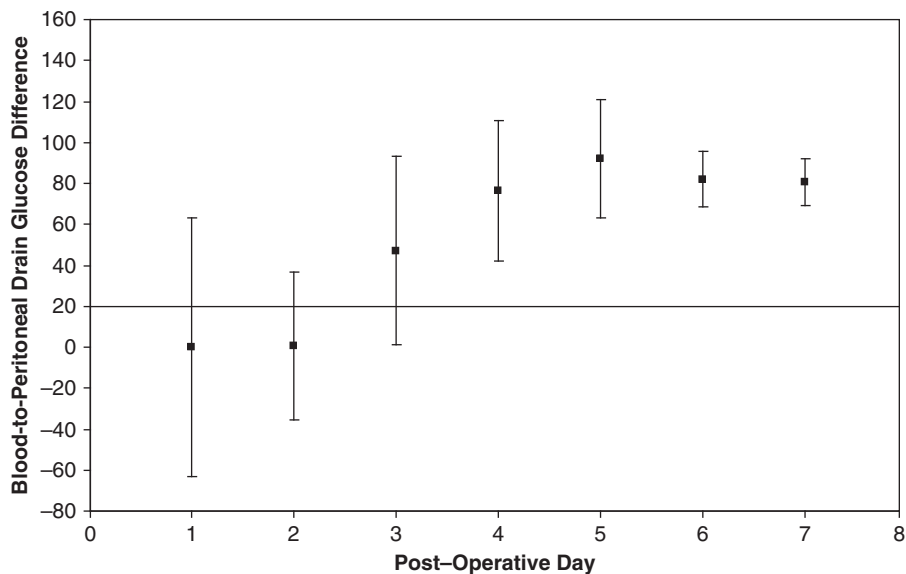
day 4, 8 of the 9 dogs had blood-to-peritoneal fluid glucose concentration differences  $>20$  mg/dL. After day 4 all dogs with drains that continued to produce fluid had a glucose difference  $>20$  mg/dL until the end of the study (Fig 1).

Mean peritoneal drain fluid lactate increased from  $1.8 \pm 1.8$  mmol/L on day 1 to  $5.7 \pm 4.2$  mmol/L by day 7 (Table 1). On day 1, 3 of the 9 dogs had blood-to-peritoneal fluid lactate concentration differences  $<-2$  mmol/L. By postoperative day 4, 7 dogs had differences  $<-2$  mmol/L. On postoperative day 5, 1 dog stopped producing peritoneal fluid, thus 7 of the remaining 8 dogs had blood-peritoneal lactate concentration differences  $<-2$  mmol/L. Six of 8 dogs on day 6, and 5 of 7 dogs with patent peritoneal drains on day 7 had blood-peritoneal lactate concentration differences  $<-2$  mmol/L (Fig 2).

## DISCUSSION

Previous research on peritoneal fluid obtained by abdominocentesis has shown that a blood-peritoneal fluid glucose difference  $>20$  mg/dL and a blood-to-peritoneal lactate difference  $<-2$  mmol/L are reliable indicators of preoperative abdominal sepsis.<sup>8,9,16</sup> It was proposed that bacterial utilization of peritoneal fluid glucose, and anaerobic bacterial metabolism combined with tissue anoxia resulted in lower fluid glucose, and higher fluid lactate concentrations relative to blood. We found that blood-to-peritoneal drain fluid glucose concentration difference increased to  $>20$  mg/dL in all dogs after day 4. The decreased peritoneal drain fluid glucose concentration could be because of red or white blood cell glucose uptake, and metabolism because peritoneal fluid was resident in the tubing between recordings. Peritoneal lactate concentration was more variable compared with glucose concentration, but by day 4, 7 of 9 dogs with patent peritoneal drains had blood-to-peritoneal lactate concentration differences  $<-2$  mmol/L. Although further study in postoperative clinical patients is warranted, it appears that a large blood-to-peritoneal fluid glucose or lactate concentration difference is not a reliable indicator of septic effusion if the peritoneal fluid is collected in the manner reported here.

Mean drain fluid production was  $2.8 \pm 1.2$  mL/kg on day 1. This initial high fluid production was likely because of residual saline solution in the peritoneal cavity. Within 24 hours, mean drain fluid volume decreased to  $1.4 \pm 1.0$  mL/kg and steadily decreased to  $0.6 \pm 0.5$  mL/kg by day 7. There was also variability in fluid volume between dogs on any given day, and within each individual dog between volume recordings. Two drains also stopped suctioning peritoneal fluid on day 6 and 7, respectively. Factors such as degree of local inflammation, omental interference, activity level, and drain position within the peritoneal space between recordings could have contributed to the high variability.<sup>18,19</sup> In a previous study in 40 dogs and cats with septic peritonitis, all grenade suction drains remained patent despite remaining in place for as



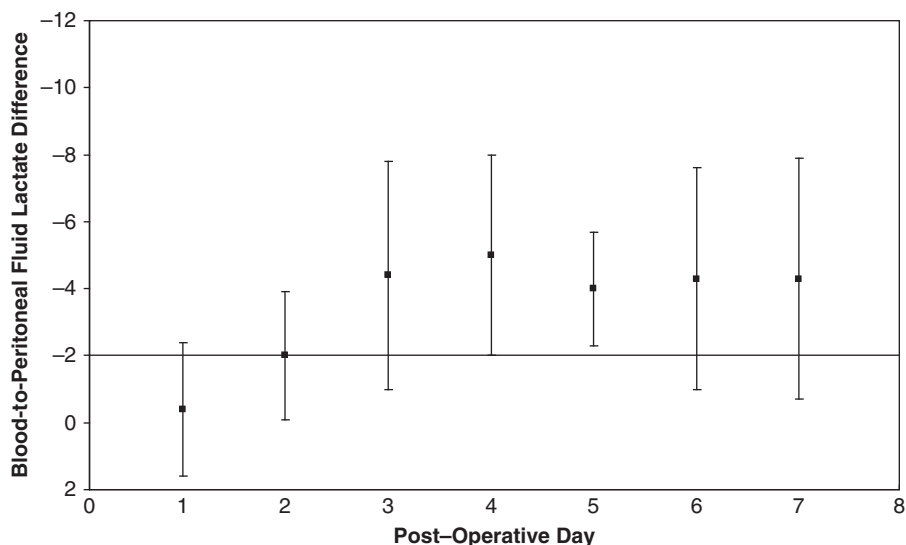
**Figure 1** Mean (± SD) blood-to-peritoneal drain fluid glucose concentration differences per day. Previous preoperative studies suggested that differences > 20 are indicative of septic peritonitis.<sup>8</sup>

long as 8 days.<sup>4</sup> In dogs and cats with peritonitis, volume changes would likely be more dramatic, and the massive fluid production may help to maintain drain patency. Omentum may also become adhered to other sites away from the drain in patients with septic peritonitis. Further study in clinical patients is indicated.

All dogs had degenerate neutrophils in their peritoneal fluid postoperatively. An aseptic inflammatory response should consist primarily of nondegenerate neutrophils.<sup>13</sup> Previous research has shown that nondegenerative neutrophils predominate in peritoneal lavage fluid 1–3 days after uncomplicated intestinal anastomosis in dogs.<sup>20</sup> The presence of de-

generate neutrophils in this study may be related in part to the presence of the drain inciting a localized peritonitis and should not be interpreted as an indicator of sepsis.

The dog with the incisional complication developed increased peritoneal drain fluid total white blood cell counts and neutrophil percentages on the same postoperative day the dog clinically developed an inflamed surgical wound. The peritoneal drain fluid neutrophil percentage decreased as the wound inflammation subsided. These findings suggest that an acute increase in neutrophil count in peritoneal drain fluid may be a useful indicator of a potential problem with the surgical wounds.



**Figure 2** Mean (± SD) blood-to-peritoneal drain fluid lactate differences per day. Previous preoperative studies suggested that differences < -2 are indicative of septic peritonitis.<sup>8,9</sup>

Drain contamination rate was 44%. A potential source of peritoneal drain contamination could come from migration of bacteria around the silicone tubing and into the abdomen. Migration of bacteria around tubing is one of the suggested causes of catheter associated urinary tract infections.<sup>21</sup> Another possibility could be that the closed-suction drainage system did not completely guard against ascending contamination within the tube lumen, as it was necessary to open the drain grenade to empty contents and reestablish suction. Constant negative pressure generated by the suction drain minimizes potential for retrograde flow of bacteria and fluid, but if suction decreases or stops as the closed system fills, this protective effect is lost.<sup>17</sup> Although the grenade has a 1 way valve to prevent fluid reflux, it cannot prevent bacteria from migrating in the fluid within the drain tubing.<sup>22</sup> The amount of time the drains were in place also increased the likelihood of them becoming contaminated. It has been shown that 50–63% of urinary catheters become culture positive after 4 days of placement.<sup>19,23</sup> These findings need to be taken into consideration when using similar drains in clinical patients in the postoperative period, and stresses the importance of maintaining aseptic technique when emptying the drain reservoir. Also, cytology of fluid collected from the grenade of a closed suction drain may be misleading because of the possibility of drain contamination,

A limitation of our study is its small sample size, but it is important to note that after day 4 all dogs would have been considered to have septic effusions according to the previously published blood-to-peritoneal drain fluid glucose concentration differences. Furthermore all dogs had degenerative neutrophils in the drain fluid throughout the study, and intracellular bacteria present if the drains became contaminated. Therefore, the presence of intracellular bacteria, blood-to-peritoneal glucose, and lactate concentration differences reported for diagnosing septic peritonitis in clinical patients may not be useful in postceliotomy patients with closed-suction drains. Further clinical studies are warranted to determine if these findings are consistent in canine and feline patients postoperatively.

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