Risk factors associated with short-term outcome and development of perioperative complications in dogs undergoing surgery because of gastric dilatation-volvulus: 166 cases (1992–2003)

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Objective—To evaluate risk factors associated with death and development of perioperative complications in dogs undergoing surgery for treatment of gastric dilatation-volvulus (GDV).

Design—Retrospective case series.

Animals—166 dogs.

Procedures—Records of dogs with confirmed GDV that underwent surgery were reviewed. Logistic regression was performed to identify factors associated with development of complications (ie, hypotension, arrhythmias, gastric necrosis necessitating gastrectomy, disseminated intravascular coagulation, peritonitis, sepsis, postoperative dilatation, postoperative vomiting, and incisional problems) and with short-term outcome (ie, died vs survived to the time of suture removal).

Results—Short-term mortality rate was 16.2% (27/166). Risk factors significantly associated with death prior to suture removal were clinical signs for > 6 hours prior to examination, combined splenectomy and partial gastrectomy, hypotension at any time during hospitalization, peritonitis, sepsis, and disseminated intravascular coagulation. Partial gastrectomy was not a significant risk factor for death but was for peritonitis, disseminated intravascular coagulation, sepsis, and arrhythmias. Age, gastrectomy, and disseminated intravascular coagulation were risk factors for development of hypotension. Use of a synthetic colloid or hypertonic saline solution was associated with a significantly decreased risk of hypotension.

Conclusions and Clinical Relevance—Results suggest that the prognosis for dogs undergoing surgery because of GDV is good but that certain factors are associated with an increased risk that dogs will develop perioperative complications or die. (*J Am Vet Med Assoc* 2006;229:1934–1939)

Abbreviations

GDV	Gastric dilatation-volvulus
DIC	Disseminated intravascular coagulation
OR	Odds ratio

Gastric dilatation-volvulus is an acute, life-threatening condition of dogs that requires immediate medical and surgical treatment. The syndrome is characterized by various degrees of volvulus of the stomach, resulting in intragastric accumulation of gas and increased intragastric pressure, which in turn leads to decreased venous return, portal hypertension, gastrointestinal tract ischemia, hypovolemia, hypotension, and often cardiogenic shock.[1,2] Death is imminent if appropriate treatment is not rapidly administered. However, even with appropriate treatment, mortality rates for dogs undergoing surgery because of GDV range from 15% to 33%.[1,3-5]

Although the exact etiology of GDV remains unclear, several studies[3,4] have concentrated on breed-related and environmental risk factors for development of the disease. Breeds at highest risk include the Great Dane, Gordon Setter, Irish Setter, Weimaraner, Saint Bernard, Standard Poodle, and Bassett Hound.[3,4] Possible predisposing factors include lean body condition,[6] increasing age,[7] increased thoracic depth-to-width ratio,[7-9] having a first-degree relative with GDV,[7,10] aggressive or fearful temperament,[8,11] decreased food particle size,[12] once-daily feeding,[13] histologic evidence of inflammatory bowel disease,[14] increased hepatogastric ligament length,[15] previous splenic torsion or splenectomy with a large splenic mass,[16] and stress.[12]

Several studies[1,3,5,17-20] have examined risk factors for death following treatment of GDV, but none, to our knowledge, have evaluated the incidence of or risk factors associated with specific complications following surgery. Moreover, improvements in surgery, anesthesia, and critical care may have had an impact on current morbidity and mortality rates. The purpose of the

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study reported here, therefore, was to determine incidences of and risk factors associated with death and development of various postoperative complications in dogs undergoing surgery because of GDV.

Criteria for Selection of Cases

Medical records of dogs examined at the Colorado State University Veterinary Medical Center because of GDV between 1992 and 2003 were reviewed. Dogs were included in the study if the diagnosis of GDV had been confirmed and surgery had been performed. Dogs with severe, underlying disease processes unrelated to GDV that could be expected to have substantially affected the treatment, prognosis, or outcome were excluded from the study. Dogs without radiographic or surgical confirmation of volvulus were also excluded.

Procedures

Data collected from the medical records of dogs included in the study consisted of signalment, treatment, and complications. Time between the onset of clinical signs and examination at the veterinary teaching hospital was recorded, when available, as ≤ or > 6 hours. Complications evaluated included hypotension, cardiac arrhythmias, gastric necrosis necessitating partial gastrectomy, DIC, peritonitis, sepsis, postoperative dilatation, postoperative vomiting, and incisional problems. The postoperative period was defined as the time from surgery until suture removal.

Dogs were considered to have DIC if they had at least 3 of the following 5 signs: thrombocytopenia, prolonged prothrombin time, prolonged activated partial thromboplastin time, low plasma fibrinogen concentration, and high serum fibrin degradation products concentration.[21] In addition, dogs were considered to have DIC if they had 2 of these signs in conjunction with clinical (ie, ecchymoses or petechiae, excessive bleeding during surgery, or excessive thrombosis during surgery) or necropsy (ie, multiple thrombi with end-organ necrosis, microthrombi, hemorrhage in multiple organs, and ecchymoses or petechiae[21,22]) evidence of DIC. Sepsis was diagnosed if an animal had a known focus of infection and at least 2 of the following signs: body temperature > 39.7°C (103.5°F) or < 37.8°C (100.0°F), heart rate > 160 beats/min, respiratory rate > 20 breaths/min or $Paco_2$ < 32 mm Hg, WBC count > 12,000 cells/µL or < 4,000 cells/µL, and band neutrophil fraction > 3%.[23-25] Hypotension was defined as systolic blood pressure < 80 mm Hg or mean arterial pressure < 60 mm Hg at any time during hospitalization.[26] Cardiac arrhythmias identified in the medical record were recorded, including ventricular premature contractions, ventricular tachycardia, atrioventricular block, atrial fibrillation, and ventricular fibrillation. The presence of the R-on-T phenomenon was also recorded.

Short-term outcome was defined as outcome (ie, died vs survived) at the time of suture removal 10 to 14 days after surgery. Short-term mortality rate was defined as the proportion of dogs that died prior to the time of suture removal.

Statistical analysis—Logistic regression was used to obtain ORs and their 95% confidence limits and probability values for risk factors potentially associated with development of complications and short-term outcome. Logistic regression was also used to determine the effect of surgery date and duration of clinical signs on development of complications and short-term outcome. Data analysis was performed with standard software.[a] The χ^2 test was used to compare breed distribution between the study group and the hospital population during the same time period. Data are reported as mean ± SD. Values of $P < 0.05$ were considered significant.

Results

During the period of the study (January 1992 through December 2003), 378 dogs were admitted because of gastric dilatation or GDV. Of these, 166 met the criteria for inclusion in the study.

Of the 166 dogs included in the study, 22 (13.3%) were mixed-breed dogs, 23 (13.9%) were German Shepherd Dogs, 15 (9.0%) were Great Danes, 13 (7.8%) were Standard Poodles, 12 (7.2%) were Golden Retrievers, 10 (6.0%) were Collies, 8 (4.8%) were Akitas, 6 (3.6%) were Bloodhounds, 6 (3.6%) were Labrador Retrievers, and 5 (3.0%) were Mastiffs. The remaining dogs represented 22 breeds with ≤ 4 dogs/breed. German Shepherd Dogs, Great Danes, Collies, Bloodhounds, Akitas, Saint Bernards, Mastiffs, Standard Poodles, and Labrador Retrievers were significantly ($P < 0.05$) overrepresented, compared with the hospital population during the study period.

There were 42 (25.3%) spayed females, 23 (13.9%) sexually intact females, 71 (42.8%) castrated males, and 30 (18.1%) sexually intact males. Mean ± SD age at the time of examination was 7.3 ± 3.50 years (range, 0.3 to 16.5 years).

Eight of the 166 (4.8%) dogs were euthanized during surgery, and 19 (11.4%) died while hospitalized, including 2 that died while anesthetized. The remaining 139 (83.7%) were discharged from the hospital, and all dogs discharged from the hospital survived to the time of suture removal. The short-term mortality rate, therefore, was 16.3% (27/166). Short-term mortality rate for dogs > 10 years old was 21% (9/42).

Thirty-four of the 166 (20.5%) dogs had gastric necrosis necessitating partial gastrectomy; 9 (26%) of these dogs died or were euthanized. In 10 of the 34 dogs with gastric necrosis, the cardia was affected, and 4 of the 10 dogs with necrosis of the cardia died or were euthanized. A gastrotomy was performed in 12 of the 166 (7.2%) dogs to remove excessive food or foreign bodies. Splenectomy was performed in 26 (15.7%) dogs, and a combination of splenectomy and partial gastrectomy was performed in 15 (9.0%).

Belt-loop gastropexy was performed in 111 (66.9%) dogs, circumcostal gastropexy was performed in 22 (13.3%), incisional gastropexy was performed in 21 (12.7%), and tube gastropexy was performed in 2 (1.2%). The remaining 2 dogs died while anesthetized, prior to undergoing gastropexy.

Postoperative complications occurred in 126 (75.9%) dogs. Cardiac arrhythmias developed in 84 (50.6%) dogs, and 44 of the 84 received antiarrhythmic therapy. Twelve of the 84 dogs developed arrhythmias prior to surgery, 43 developed arrhythmias during surgery, and 29 developed arrhythmias after surgery.

Table 1—Analysis of factors potentially associated with death prior to the time of suture removal in dogs undergoing surgery because of gastric dilatation-volvulus.

Factor	OR	95% Confidence limits	*P* value
Age (y)	1.053	0.932–1.189	0.407
Female (male as reference)	1.082	0.467–2.507	0.854
Sexually intact (neutered as reference)	1.912	0.824–4.439	0.131
Clinical signs > 6 hours	3.250	1.322–7.987	0.010
Partial gastrectomy	2.280	0.918–5.663	0.076
Combined partial gastrectomy and splenectomy	3.156	1.154–8.635	0.025
Hypotension	6.516	2.698–15.737	< 0.001
Gastrotomy	0.448	0.055–3.619	0.451
Splenectomy	0.630	0.175–2.270	0.480
Necrosis of the gastric cardia	4.000	0.956–16.740	0.058
Gastropexy technique (belt-loop gastropexy as reference)			
Incisional gastropexy	1.515	0.384–5.974	0.553
Circumcostal gastropexy	0.909	0.187–4.420	0.906
Arrhythmias	1.827	0.782–4.270	0.164
Onset of arrhythmias (preoperative onset as reference)			
Intraoperative onset	1.031	0.236–4.510	0.967
Postoperative onset	0.346	0.059–2.034	0.240
No arrhythmias	0.423	0.098–1.828	0.249
Type of arrhythmia (no arrhythmias as reference)			
Ventricular premature contractions	1.145	0.406–3.229	0.797
Ventricular tachycardia	2.571	0.762–8.682	0.128
Other	14.400	1.194–173.710	0.036
Atrial fibrillation	7.200	0.417–124.461	0.175
R-on-T phenomenon	1.619	0.661–3.967	0.292
Treatment of arrhythmias	0.673	0.277–1.634	0.382
Type of arrhythmia treatment (none as reference)			
Lidocaine	1.926	0.749–4.949	0.174
Procainamide	0.963	0.109–8.481	0.973
Blood transfusion	5.432	1.906–15.477	0.002
Plasma transfusion	3.125	1.124–8.691	0.029
Colloid or hypertonic saline solution administered	0.486	0.197–1.201	0.118
Hypoproteinemia	0.891	0.331–2.403	0.820
Postoperative vomiting	0.744	0.159–3.487	0.708
Postoperative dilatation	1.847	0.352–9.700	0.468
Disseminated intravascular coagulation	5.388	1.649–17.600	0.005
Sepsis	17.250	1.722–172.837	0.015
Peritonitis	10.794	2.4–48.541	0.002

Unless otherwise specified, absence of the specific factor was used as the reference category. The OR represents the odds that a dog with the specified factor would die prior to the time of suture removal 10 to 14 days after surgery, compared with the odds that a dog without the reference category would die during this period.

Table 2—Factors associated with development of various complications among dogs undergoing surgery because of gastric dilatation-volvulus.

	Peritonitis		DIC		Sepsis		Arrhythmias	
Factor	OR	*P* value	OR	*P* value	OR	*P* value	OR	*P* value
Partial gastrectomy	7.33	0.009	7.75	< 0.001	12.58	0.031	5.00	< 0.001
Splenectomy	6.09	0.015	5.66	0.004	NS	NS	6.91	< 0.001
Necrosis of the gastric cardia	6.87	0.025	NS	NS	8.38	0.047	NS	NS
Clinical signs > 6 hours	NS	NS	NS	NS	NS	NS	3.60	< 0.001

NS = Not significant.

Ventricular tachycardia and intermittent ventricular premature contractions were seen in 70 dogs, the R-on-T phenomenon was documented in 43 dogs, atrioventricular block was seen in 6 dogs, atrial fibrillation was seen in 2 dogs, and ventricular fibrillation was seen in 2 dogs. Both dogs with ventricular fibrillation died as a result.

Thirteen (7.8%) dogs were treated for DIC. Peritonitis was diagnosed in 8 dogs (4.8%), and hypotension was diagnosed in 41 (24.7%). Sepsis was documented in 4 (2.4%) dogs. Eighteen (10.8%) dogs required at least 1 blood transfusion, and 21 (12.7%) were treated with at least 1 unit of plasma. A synthetic colloid (ie, dextran or hetastarch) or hypertonic saline solution was administered in 129 (77.7%) dogs.

Risk factors significantly associated with death prior to suture removal included clinical signs for > 6 hours prior to examination, combined splenectomy and partial gastrectomy, hypotension at any time during hospitalization, peritonitis, sepsis, DIC, administration of a blood transfusion, and administration of a plasma transfusion (**Table 1**). Administration of a synthetic colloid solution was not significantly associated with short-term outcome. Serum concentration of fibrin degradation products, prothrombin time, activated partial thromboplastin time, and platelet count were not significantly associated with short-term outcome when analyzed individually or together by means of multivariate logistic regression.

Several risk factors were found to be significantly associated with development of DIC, sepsis, peritonitis, and arrhythmias (**Table 2**). Serum concentration of fib-

rin degradation products, prothrombin time, activated partial thromboplastin time, and platelet count were not found to be significantly associated with development of DIC regardless of whether these variables were included in logistic regression analyses as continuous or dichotomous (normal vs abnormal) values.

Dogs that had had clinical signs for > 6 hours prior to examination (n = 45 [27.1%]) had significantly increased risks of requiring partial gastrectomy (OR, 2.6; $P = 0.024$), developing arrhythmias (OR, 3.6; $P < 0.001$), and requiring splenectomy (OR, 2.9; $P = 0.023$).

Age (OR, 1.13; $P = 0.03$), partial gastrectomy (OR, 2.7; $P = 0.017$), and DIC (OR, 4.0; $P = 0.018$) were risk factors for development of hypotension. There were significant associations between administration of a blood or plasma transfusion and hypotension (OR, 6.1 [$P < 0.001$] and 6.7 [$P < 0.001$], respectively). The use of a synthetic colloid solution or hypertonic saline solution was associated with a significantly decreased risk of hypotension (OR, 0.06; $P < 0.001$).

Discussion

Results of the present study suggest that although the overall prognosis for dogs undergoing surgery because of GDV is favorable, several factors affect the risk of whether dogs will develop perioperative complications or die. In particular, significant risk factors for death included clinical signs for > 6 hours prior to examination, hypotension at any time, peritonitis, DIC, and development of sepsis.

The population of dogs in the present study was similar to populations reported in previous studies[1,3,5] relative to breed, sex, and age.[1,3,5] Although the Golden Retriever was the fourth most common breed in the present study, Golden Retrievers were not overrepresented, compared with the hospital population during the study period. Similarly, the Golden Retriever has not been found to be a high-risk breed in other studies.[1,4,5,8]

Having clinical signs for > 6 hours prior to examination at the veterinary teaching hospital was a significant risk factor for death in the present study, but it was not a significant risk for development of sepsis, peritonitis, or DIC. In contrast, previous studies[3,5] that examined the duration of clinical signs have not found a significant effect on risk of death. Subjectively, it appeared to us prior to the present study that dogs that were examined early in the morning seemed to have a poorer prognosis. Therefore, we chose 6 hours as the cutoff for duration of clinical signs, reasoning that this was the approximate time that dogs would have been unobserved by their owners overnight. Lantz et al[27] demonstrated that in dogs with experimentally induced GDV, damage to the stomach progressively worsened with time, such that by 8 hours after induction of 360° gastric volvulus, severe serosal hemorrhage developed in the body and fundus of the stomach. Results of the present study were similar, in that dogs with a history of clinical signs for > 6 hours prior to examination had a significantly higher risk of having gastric necrosis requiring partial gastrectomy.

Hypotension was diagnosed in 41 (24.7%) of the dogs in the present study and was significantly associated with risk of death, regardless of when it occurred. Similarly, hypotension has been reported to be associated with outcome in dogs with generalized peritonitis.[28-30] In the present study, administration of plasma and administration of blood were also associated with the risk of death. However, it is likely that this does not indicate a true cause-and-effect relationship but likely reflects the fact that dogs requiring plasma or blood transfusions had more severe disease in general and were not responsive to other first-line treatments. Synthetic colloids and hypertonic saline solutions were commonly administered to dogs in the present study. Hypertonic saline and synthetic colloid solutions were grouped together for purposes of statistical analysis, even though hypertonic saline solution is not a synthetic colloid solution. However, hypertonic saline solution has initial osmotic effects similar to those seen with hetastarch and dextran. In the present study, the use of synthetic colloid or hypertonic saline solution was associated with a significantly decreased risk of hypotension, suggesting that use of these solutions may be associated with a better outcome. Analysis of individual solutions was beyond the scope of the present study.

Previous studies[2,3,5,17] have shown partial gastrectomy to be a negative risk factor for survival in dogs with GDV. In contrast, partial gastrectomy was not found to be a significant risk factor for death in the present study. One reason for this finding may be that during the time of the study, partial gastrectomy was consistently performed with stapling equipment, which has been associated with a better outcome.[31] On the other hand, partial gastrectomy was significantly associated with the risk of postoperative complications, including sepsis, peritonitis, arrhythmias, and DIC. An improved ability to recognize and treat these complications during the period of the study may help account for why partial gastrectomy was not significantly associated with a poor outcome.

Four of 10 dogs with necrosis of the cardia in the present study died. This high mortality rate most likely was reflective of the technical difficulties associated with resecting this portion of the stomach, especially if the distal portion of the esophagus is involved. In addition, dogs with necrosis of the cardia are frequently euthanized at the time of surgery because of a perception that they are likely to develop severe long-term postoperative complications associated with resection of the cardia. As previously demonstrated by Brourman et al,[1] the combination of partial gastrectomy and splenectomy was associated with a poor outcome in the present study, suggesting that dogs that undergo partial gastrectomy and splenectomy probably have a more advanced stage of disease. Splenectomy alone was not a negative risk factor for survival in the present study, but was a risk factor for development of DIC and cardiac arrhythmias. It has previously been demonstrated that patients undergoing splenectomy have an increased risk of cardiac arrhythmias.[32,33] It has also been established that GDV is associated with an increased risk of systemic inflammatory response syndrome and DIC.[22,24,34-36] The increased risk of DIC and

arrhythmias in dogs requiring splenectomy and partial gastrectomy was most likely related to the increased risk and severity of systemic inflammatory response syndrome in these patients.

Serum lactate concentrations were obtained from medical records of dogs included in the present study, when available. However, this test was not available at our hospital until 1995. Thus, values were not available for a sufficient number of dogs to allow for statistical analysis of potential associations between serum lactate concentration and postoperative complications or death. High serum lactate concentration has previously been shown to be associated with gastric necrosis and poor outcome in patients with sepsis and GDV.[17]

Sepsis and peritonitis were both associated with a poor short-term outcome in the present study, regardless of whether these conditions developed before or after surgery. This is consistent with results of other studies[28,29,37-39] of peritonitis, in which mortality rates ranged from 29% to 68%. The risks of peritonitis and sepsis were significantly increased by partial gastrectomy in the present study. In dogs with GDV, peritonitis may result from perforation of the stomach or dehiscence following partial gastrectomy. Prolonged portal hypertension resulting from compression of the portal vein by the dilated stomach may lead to severe congestion of the gastrointestinal tract and result in bacterial translocation into the systemic circulation and peritoneal cavity. In the present study, 5 of the 8 dogs with generalized peritonitis underwent partial gastrectomy. In 1 of the remaining 3 dogs with peritonitis, necrosis of the cardia was reported, but partial gastrectomy was not performed, and the dog died < 24 hours after surgery because of leakage, generalized peritonitis, and sepsis. Sepsis was diagnosed in 4 dogs in the present study. Two of the 4 dogs had generalized peritonitis and underwent partial gastrectomy, 1 had generalized peritonitis but did not undergo partial gastrectomy, and 1 underwent partial gastrectomy but did not have peritonitis. In a previous study[20] of 21 dogs with GDV, 43% reportedly developed bacteremia. However, the prevalence of sepsis in conjunction with bacteremia was not evaluated, and bacteremia was not diagnosed in the 1 dog that died. Bacteremia is not necessary for a diagnosis of sepsis,[23-26,40] and criteria used in the present study have been shown to be 97% sensitive in the diagnosis of sepsis.[23] Sepsis has been associated with mortality rates of 31% to 50% in other studies.[24-26,40]

The diagnosis of DIC is complicated, and treatment is controversial. On the basis of previously described criteria,[21] DIC was diagnosed in 13 dogs in the present study. However, prothrombin time, activated partial thromboplastin time, platelet count, and serum concentration of fibrin degradation products were not significant risk factors for the development of DIC. In a previous study[34] of dogs with GDV, the likelihood of gastric necrosis was accurately predicted by abnormalities in 3 of 5 hemostatic indices. Use of newer diagnostic tests (eg, antithrombin and D-dimer concentrations)[35] and more inclusive criteria for the diagnosis of DIC would likely have changed the number of dogs in which DIC was diagnosed. However, these tests were only recently available at our hospital. Because DIC was found to be a significant risk factor for death in the present study, treatment and prevention are crucial. Although treatment for DIC remains controversial, the mainstay of treatment is correction of the underlying cause.[21,22,35]

Limitations of this study are primarily related to its retrospective nature. Dogs were treated by multiple surgeons with different degrees of experience. Initial treatment regimens were determined by the attending intern and resident and varied widely. In addition, perioperative treatment methods changed over the course of the study. Although surgery date was not significantly associated with outcome in the present study, overall mortality rate decreased over the course of the study period.

In conclusion, the prognosis for dogs with GDV appears to be favorable if medical and surgical treatment is instituted as soon as possible. In the present study, partial gastrectomy performed with various stapling devices was not a significant risk factor for death. However, it was associated with various postoperative complications, and the impact of this procedure should not be underestimated. Intensive perioperative monitoring should allow for early detection and appropriate treatment of potentially catastrophic complications. A key element to successful treatment of this syndrome appears to be prevention or early treatment of hypotension because hypotension at any time was a significant risk factor for death.

a. StatView, version 5.0, SAS Institute Inc, Cary, NC.

References

1. Brourman JD, Schertel ER, Allen DA, et al. Factors associated with perioperative mortality in dogs with surgically managed gastric dilatation-volvulus: 137 cases (1988–1993). *J Am Vet Med Assoc* 1996;208:1855–1858.
2. Monnet E. Gastric dilatation-volvulus syndrome in dogs. *Vet Clin North Am Small Anim Pract* 2003;33:987–1005.
3. Brockman DJ, Washabau RJ, Drobatz KJ. Canine gastric dilatation/volvulus syndrome in a veterinary critical care unit: 295 cases (1986–1992). *J Am Vet Med Assoc* 1995;207:460–464.
4. Glickman LT, Glickman NW, Perez CM, et al. Analysis of risk factors for gastric dilatation and dilatation-volvulus in dogs. *J Am Vet Med Assoc* 1994;204:1465–1471.
5. Glickman LT, Lantz GC, Schellenberg DB, et al. A prospective study of survival and recurrence following the acute gastric dilatation-volvulus syndrome in 136 dogs. *J Am Anim Hosp Assoc* 1998;34:253–259.
6. Raghavan M, Glickman N, McCabe G, et al. Diet-related risk factors for gastric dilatation-volvulus in dogs of high-risk breeds. *J Am Anim Hosp Assoc* 2004;40:192–203.
7. Glickman LT, Glickman NW, Schellenberg DB, et al. Incidence of and breed-related risk factors for gastric dilatation-volvulus in dogs. *J Am Vet Med Assoc* 2000;216:40–45.
8. Schellenberg D, Yi Q, Glickman NW, et al. Influence of thoracic conformation and genetics on the risk of gastric dilatation-volvulus in Irish Setters. *J Am Anim Hosp Assoc* 1998;34:64–73.
9. Schaible RH, Ziech J, Glickman NW, et al. Predisposition to gastric dilatation-volvulus in relation to genetics of thoracic conformation in Irish Setters. *J Am Anim Hosp Assoc* 1997;33:379–383.
10. Elwood CM. Risk factors for gastric dilatation in Irish Setter dogs. *J Small Anim Pract* 1998;39:185–190.
11. Glickman LT, Glickman NW, Schellenberg DB, et al. Nondietary risk factors for gastric dilatation-volvulus in large and giant breed dogs. *J Am Vet Med Assoc* 2000;217:1492–1499.
12. Theyse LF, van de Brom WE, van Sluijs FJ. Small size of

food particles and age as risk factors for gastric dilatation volvulus in Great Danes. *Vet Rec* 1998;143:48–50.

13. Glickman LT, Glickman NW, Schellenberg DB, et al. Multiple risk factors for the gastric dilatation-volvulus syndrome in dogs: a practitioner/owner case-control study. *J Am Anim Hosp Assoc* 1997;33:197–204.

14. Braun L, Lester S, Kuzma AB, et al. Gastric dilatation-volvulus in the dog with histological evidence of preexisting inflammatory bowel disease: a retrospective study of 23 cases. *J Am Anim Hosp Assoc* 1996;32:287–290.

15. Hall JA, Willer RL, Seim HB, et al. Gross and histologic evaluation of hepatogastric ligaments in clinically normal dogs and dogs with gastric dilatation-volvulus. *Am J Vet Res* 1995;56:1611–1614.

16. Millis DL, Nemzek J, Riggs C, et al. Gastric dilatation-volvulus after splenic torsion in two dogs. *J Am Vet Med Assoc* 1995;207:314–315.

17. de Papp E, Drobatz KJ, Hughes D. Plasma lactate concentration as a predictor of gastric necrosis and survival among dogs with gastric dilatation-volvulus: 102 cases (1995–1998). *J Am Vet Med Assoc* 1999;215:49–52.

18. Schertel ER, Allen DA, Muir WW, et al. Evaluation of a hypertonic saline-dextran solution for treatment of dogs with shock induced by gastric dilatation-volvulus. *J Am Vet Med Assoc* 1997;210:226–230.

19. Schober KE, Cornand C, Kirbach B, et al. Serum cardiac troponin I and cardiac troponin T concentrations in dogs with gastric dilatation-volvulus. *J Am Vet Med Assoc* 2002;221:381–388.

20. Winkler KP, Greenfield CL, Schaeffer DJ. Bacteremia and bacterial translocation in the naturally occurring canine gastric dilatation-volvulus patient. *J Am Anim Hosp Assoc* 2003;39:361–368.

21. Bateman SW, Mathews KA, Abrams-Ogg AC, et al. Diagnosis of disseminated intravascular coagulation in dogs admitted to an intensive care unit. *J Am Vet Med Assoc* 1999;215:798–804.

22. Slappendel RJ. Disseminated intravascular coagulation. *Vet Clin North Am Small Anim Pract* 1988;18:169–184.

23. Hauptman JG, Walshaw R, Olivier NB. Evaluation of the sensitivity and specificity of diagnostic criteria for sepsis in dogs. *Vet Surg* 1997;26:393–397.

24. Weeren FR, Muir WW III. Clinical aspects of septic shock and comprehensive approaches to treatment in dogs and cats. *J Am Vet Med Assoc* 1992;200:1859–1870.

25. de Laforcade AM, Freeman LM, Shaw SP, et al. Hemostatic changes in dogs with naturally occurring sepsis. *J Vet Intern Med* 2003;17:674–679.

26. Otto CM. Recognition and treatment of sepsis in the emergency patient. *Compend Contin Educ Pract Vet* 2000;22(suppl 3A):47–53.

27. Lantz GG, Bottoms GD, Carlton WW, et al. The effect of 360° gastric volvulus on the blood supply of the nondistended normal dog stomach. *Vet Surg* 1984;13:189–195.

28. King LG. Postoperative complications and prognostic indicators in dogs and cats with septic peritonitis: 23 cases (1989–1992). *J Am Vet Med Assoc* 1994;204:407–414.

29. Mueller MG, Ludwig LL, Barton LJ. Use of closed-suction drains to treat generalized peritonitis in dogs and cats: 40 cases (1997–1999). *J Am Vet Med Assoc* 2001;219:789–794.

30. Mehler SJ, Mayhew PD, Drobatz KJ, et al. Variables associated with outcome in dogs undergoing extrahepatic biliary surgery: 60 cases (1988–2002). *Vet Surg* 2004;33:644–649.

31. Clark GN, Pavletic MM. Partial gastrectomy with an automatic stapling instrument for treatment of gastric necrosis secondary to gastric dilatation-volvulus. *Vet Surg* 1991;20:61–68.

32. Tillson MD. Spleen. In: Henderson RA, Slatter DH, eds. *Textbook of small animal surgery*. 3rd ed. Philadelphia: WB Saunders Co, 2003;1046–1062.

33. Marino DJ, Matthiesen DT, Fox PR, et al. Ventricular arrhythmias in dogs undergoing splenectomy: a prospective study. *Vet Surg* 1994;23:101–106.

34. Millis DL, Hauptman JG, Fulton RB Jr. Abnormal hemostatic profiles and gastric necrosis in canine gastric dilatation-volvulus. *Vet Surg* 1993;22:93–97.

35. Smith SA. Identification of coagulation dysfunction in the ICU, in *Proceedings*. 10th Int Vet Emerg Crit Care Symp 2004;68–72.

36. Rasmussen L. Stomach. In: Tobias KM, Slatter DH, eds. *Textbook of small animal surgery*. 3rd ed. Philadelphia: WB Saunders Co, 2003;592–640.

37. Greenfield CL, Walshaw R. Open peritoneal drainage for treatment of contaminated peritoneal cavity and septic peritonitis in dogs and cats: 24 cases (1980–1986). *J Am Vet Med Assoc* 1987;191:100–105.

38. Lanz OI, Ellison GW, Bellah JR, et al. Surgical treatment of septic peritonitis without abdominal drainage in 28 dogs. *J Am Anim Hosp Assoc* 2001;37:87–92.

39. Staatz AJ, Monnet E. Open peritoneal drainage versus primary closure for the treatment of septic peritonitis in dogs and cats: 42 cases (1993–1999). *Vet Surg* 2002;31:174–180.

40. Swann H, Hughes D. Diagnosis and management of peritonitis. *Vet Clin North Am Small Anim Pract* 2000;30:603–618.