The Effect of Ingredients in Dry Dog Foods on the Risk of Gastric Dilatation-Volvulus in Dogs

Using dry dog food label information, the hypothesis was tested that the risk of gastric dilatation-volvulus (GDV) increases with an increasing number of soy and cereal ingredients and a decreasing number of animal-protein ingredients among the first four ingredients. A nested case-control study was conducted with 85 GDV cases and 194 controls consuming a single brand and variety of dry food. Neither an increasing number of animal-protein ingredients (*P*=0.79) nor an increasing number of soy and cereal ingredients (*P*=0.83) among the first four ingredients significantly influenced GDV risk. An unexpected finding was that dry foods containing an oil or fat ingredient (e.g., sunflower oil, animal fat) among the first four ingredients were associated with a significant (*P*=0.01), 2.4-fold increased risk of GDV. These findings suggest that the feeding of dry dog foods that list oils or fats among the first four label ingredients predispose a high-risk dog to GDV. **J Am Anim Hosp Assoc 2006;42:28-36.**

Malathi Raghavan, DVM, PhD

Nita W. Glickman, MPH, PhD

Lawrence T. Glickman, VMD, DrPH

RS

From the Department of Veterinary Pathobiology, School of Veterinary Medicine, Purdue University, West Lafayette, Indiana 47907-2027.

Funded in part by grants from the Morris Animal Foundation, the American Kennel Club Canine Health Foundation, and by the 11 national breed clubs that participated in the study.

Introduction

Gastric dilatation-volvulus (GDV) in dogs is characterized by rapid accumulation of air in the stomach, malposition of the stomach, increased intragastric pressure, and often hypovolemic shock.[1] Host risk factors for GDV include increasing age, large-breed size, a deep and narrow anatomic thorax, a family history of GDV, a nervous temperament, and a faster speed of eating.[1-4] Among management factors, feeding from a raised food bowl, feeding once daily, and feeding a large volume of food per meal have been associated with an increased risk of GDV.[2,4-6] Moistening of dry food prior to feeding increased the risk for GDV in large-breed dogs but not in giant-breed dogs.[2]

In 1974, Van Kruiningen *et al.* suggested there was an association between consumption of commercial dry dog foods and acute gastric dilatation.[7] Despite a shortage of scientific studies evaluating the role of dry food in GDV, published advice to prevent a first episode of GDV has often included avoidance of exclusively dry, expanded, cereal-based and soy protein-based commercial dog foods.[7-9] Burrows *et al.* reported that gastric motility and emptying in healthy, large-breed dogs were not affected by consumption of a cereal-based food.[10] However, the type of cereal and the proportion by weight or volume of the cereal in the food was not reported.[10] Articles in specialty dog magazines and scientific journals continue to caution the feeding of soy- and cereal-based commercial dry dog foods, and the question of an association between these ingredients and GDV risk continues to be raised.[11,12]

In addition, an epidemiological study found that Irish setters consuming a single food type were three times more likely to develop GDV than were Irish setters fed a mixture of food types.[5] This report was consistent with findings that the addition of table foods or canned foods to the predominantly dry food diet of large- and giant-breed dogs was associated with a 59% and 28% decreased risk of GDV, respectively.[4] Increasing

energy intake from carbohydrates was not associated with a higher GDV risk.[6] Increased particle size of food was, however, associated with a significantly decreased risk of GDV in Great Danes.[13]

Detailed dietary information was collected as part of a 5-year prospective study of GDV in large- and giant-breed dogs that were thought to be at an increased lifetime risk of GDV.[2,6,14] For 89% of the dogs in that study, ≥75.0% of the metabolizable energy (ME) in the daily diet was derived from dry dog food.[6] Fifty percent of the dogs in the study derived ≥96.5% of their ME from dry dog food.[6] The homogeneity of this study population with respect to the type (i.e., dry dog food) and amount of foods consumed provided an opportunity to evaluate the first four label ingredients in dry foods for a possible association with GDV risk. The first four label ingredients were of plant or animal origin and typically contributed to the protein, fat, or carbohydrate content of the food. Ingredients were listed in descending order by weight.[15] Therefore, the listing of an ingredient (e.g., soy) among the first four label ingredients was considered an indicator of the increased amount by weight of that ingredient in the food. Conversely, the absence of an ingredient among the first four label ingredients was considered an indicator of the decreased amount by weight of that ingredient in the food. The cut-off point of four ingredients was decided based on the need to balance accuracy, ease, and convenience in data collection with the need to collect data that would be meaningful and informative.

While a previous study analyzed the percent of ME from carbohydrates, protein, or fat for an association with GDV risk, the origin of these nutrients in the dog's diet was not studied.[6] Therefore, the purpose of this study was to identify any association between the type of ingredients among the first four label ingredients (e.g., whether of meat-based protein or soy-based protein) and the risk of GDV in dogs. The specific hypothesis tested was that the risk of GDV increases with the increasing number of plant-protein ingredients such as soy, wheat, rice, and corn, and with the decreasing number of animal-protein ingredients, among the first four label ingredients. An additional purpose of this paper was to determine if there was any association between dry food manufacturing technology and the risk of GDV.

Materials and Methods

Study Design

Dogs in this nested case-control study belonged to a defined cohort that was recruited between June 1994 and March 1997 (start of study) at 27 national and specialty dog shows in the United States and followed until December 2000 (end of study). Detailed methods have been previously published.[2,6,14] The cohort was represented by 11 breeds thought to be at elevated risk of GDV (i.e., Akita, bloodhound, collie, Great Dane, Irish setter, Irish wolfhound, Newfoundland, rottweiler, Saint Bernard, standard poodle, and Weimaraner).[1]

Immediately after recruitment, owners completed a detailed, eight-page questionnaire. A section of the questionnaire focused on the dog's diet, including brand and variety of commercial dry dog foods fed on a daily or weekly basis.[2,6,14] Owners recorded the guaranteed analysis and first four ingredients printed on food labels, or they submitted the food labels with the completed questionnaire. At periodic 1-year intervals, owners provided information on their dog's vital status (i.e., whether alive or dead) and whether their dog had developed GDV at any time since the last contact. The date and cause of death and date of GDV occurrence, if applicable, were requested. No effort was made to determine the onset of other diseases during the study period.

Cases and Controls

Dogs that developed GDV by the end of the study in December 2000 were defined as cases. Details of selection of controls have been published previously.[6] Participation in the present study was restricted to cases and controls that consumed a single brand and variety of commercial dry dog food.

Dry Food Ingredients

All dry foods evaluated in this study contained at least one ingredient of plant origin and one ingredient of animal origin among the first four label ingredients. Dry foods were therefore grouped by the numbers (i.e., 1, 2, or 3) of ingredients of plant and animal origin among the first four label ingredients. The foods were then grouped by the numbers (i.e., 1, 2, or 3) of animal-protein ingredients (e.g., meat, poultry, by-products, by-product meal) and plant-protein ingredients listed among the first four label ingredients. Ingredients of plant origin that could potentially provide some amount of protein in the diet were considered plant-protein ingredients.[16] These included soy-based and all cereal-based ingredients and did not include ingredients such as beet pulp, potato, and peanut hulls. All dry foods evaluated in the study contained at least one plant protein and one animal protein among the first four label ingredients. Ingredients contributing only fat content to the final formulation (e.g., animal fat, canola oil) were not included in the grouping by origin of protein ingredients.

Dry foods were also classified by the presence of individual types of plant ingredients such as soy, corn, wheat, rice, barley, etc., and by the number of times (i.e., 0, 1, 2, or 3) they were listed in different forms. No attempt was made to distinguish between the different forms of an ingredient type; in other words, forms used primarily as a source of protein (e.g., corn gluten meal) were not differentiated from forms used primarily as a source of carbohydrates (e.g., ground corn) or fiber (e.g., corn bran).[17] Similarly, foods were also classified as those containing meat-based, poultry-based, rendered (i.e., dry proteins such as meat meal, poultry by-product meal), or nonrendered (i.e., wet proteins such as lamb meat, poultry by-products) animal-protein ingredients.[17] No further attempt was made to distinguish animal-protein ingredients by their protein or ash content. Apart from protein, the only other energy nutrient that could potentially be derived from either plant or animal source

would be fat. Therefore, fat ingredients such as canola oil, beef tallow, and animal fat were also categorized as being of plant or animal origin.

An example of the ingredient classification is as follows: if the food label indicated ground corn, wheat gluten meal, corn bran, and animal fat as the first four label ingredients, then the food was classified as containing one ingredient of animal origin; three ingredients of plant origin; no animal-protein ingredient; three cereal ingredients; two corn-based ingredients; one wheat-based ingredient; no soy- or rice-based ingredient; and one fat ingredient of animal origin.

Methods used to calculate proportion of ME from different food types and from the different energy nutrients have been published previously.[6]

Data Analysis

Data were entered using epidemiological software[a] and analyzed using SAS System for Windows.[b] Ingredient profiles were compared between cases and controls using chi-square, independent samples *t*-test (for normal distributions), and Mann-Whitney test (for nonnormal distributions). Each potential risk factor for GDV was examined using unconditional logistic regression analysis.[c,18] The measure of association between GDV and each putative risk factor was expressed as the odds ratio (OR) and 95% confidence interval (CI). An OR >1.0 indicated an increased risk of GDV, and an OR <1.0 indicated a decreased risk of GDV associated with the factor, compared with the reference group (reference OR=1.0). A test for a linear trend in the OR (either an increase or decrease in GDV risk) associated with increasing levels of a risk factor was also calculated.[a] A multivariate logistic regression model was developed using ingredient-related risk factors satisfying a screening criterion with a *P* value ≤0.10 in univariate analyses. The multivariate ORs were also adjusted for known host risk factors for GDV, such as age, breed size, family history of GDV, and body condition. Risk factors for GDV in the final model were considered significant at a *P* value ≤0.05. The fit of the final model was evaluated by regression diagnostics.[19]

Results

Of 1634 dogs with information available on vital status and diet in the prospective study, 106 dogs that developed GDV were potential cases, and 212 dogs without GDV were potential controls.[6] Of these, only 85 dogs with GDV (cases) and 194 dogs without GDV (controls) consumed a single brand and variety of commercial dry dog food and were eligible for inclusion in this report as the study population. Reasons for excluding 38 dogs from the present report were as follows: diet did not include any dry commercial dog food (1 control dog); dry food information was incomplete (1 control dog); and two or more brands or varieties of dry dog food were consumed (21 case dogs, 16 control dogs). Eighty-five (100%) case dogs and 185 (95.4%) control dogs were fed extruded dry foods, while the remaining nine (4.6%) control dogs were fed pelleted or baked dry foods (*P*=0.06).

The mean ± standard deviation (SD) ages for cases and controls were 6.1±2.8 and 5.4±2.5 years, respectively (*P*=0.04). Thirty-four percent of the case dogs had died by the end of the study period compared with only 8.8% of the control dogs (*P*<0.0001). Case and control dogs were not significantly different with respect to gender, height, and weight.

The primary food type (i.e., the food type contributing >50% of the total dietary ME) was determined to be dry dog food for all 279 dogs in this study. The medians (ranges) in ME derived from dry food for case and control dogs were 95.0% (59.5% to 100.0%) and 97.1% (51.0% to 100.0%), respectively (*P*=0.64).

Effects of Ingredients

All dry foods evaluated contained at least one ingredient of plant origin and one ingredient of animal origin among the first four ingredients listed. Increasing numbers of ingredients of animal origin among the first four label ingredients (regardless of the major nutrient they contributed to the final formulation), and vice versa, decreasing numbers of ingredients of plant origin, were not associated with the risk of GDV (*P* value for trend=0.92).

All dry foods contained at least one soy- or cereal-based ingredient and one animal-protein ingredient among the first four ingredients listed. With respect to type of plant ingredients, corn-based ingredients were the most common. At least one corn-based ingredient (such as corn meal, corn gluten meal, ground yellow corn, ground corn grits, corn bran, and kibbled corn) was present among the first four label ingredients in dry foods consumed by 67% of the dogs in the study. Rice-based ingredients and wheat-based ingredients were present among the first four ingredients in 63% and 39% of dry foods, respectively. Soy-based ingredients were relatively less common. Only about 7% of the dry foods in this study had at least one soy-based ingredient listed among the first four ingredients. Dry foods fed to cases and controls did not differ significantly with respect to the presence of individual types of plant-protein ingredients such as corn (*P*=0.16), soy (*P*=0.69), wheat (*P*=0.61), rice (*P*=0.25), barley (*P*=0.28), sorghum (*P*=0.35), oatmeal (*P*=0.17), and millet (*P*=0.35) among the first four ingredients [Table 1]. Dry foods fed to cases and controls also did not differ significantly with respect to the presence of animal-protein ingredients that were rendered (*P*=0.15), nonrendered (*P*=0.69), poultry based (*P*=0.59), or meat based (*P*=0.72) among the first four ingredients.

Ninety-three (33.3%) dry foods contained a fat ingredient among the first four ingredients. Two (0.7%) dry foods contained an oil, 92 (33%) contained fats of animal origin, and one (0.4%) contained both an oil and an animal fat among the first four label ingredients. The presence of an oil or fat among the first four ingredients was differentially distributed between the case and control groups. Significantly more cases (44.7%) than controls (28.4%) were fed a dry food that contained an oil or fat ingredient among the first four label ingredients (*P*=0.008). Specifically, significantly

Table 1

Type and Frequency of the First Four Label Ingredients in Dry Dog Foods Consumed by Gastric Dilatation-Volvulus Cases and Control Dogs

	Cases		Controls	
Plant-Origin Ingredients	**No. of Dogs**	**%**	**No. of Dogs**	**%**
Protein, carbohydrate, and fiber sources*	85	100.0	194	100.0
Corn	62	72.9	125	64.4
Rice	49	57.6	126	64.9
Wheat	31	36.5	77	39.7
Barley	10	11.8	15	7.7
Soy	5	5.9	14	7.2
Sorghum	4	4.7	5	2.6
Oatmeal	2	2.4	1	0.5
Beet pulp	2	2.4	3	1.5
Millet	1	1.2	6	3.1
Brewer's yeast	1	1.2	1	0.5
Potato	1	1.2	1	0.5
Peanut hulls	0	0.0	1	0.5
Oils and fats	2	2.4	0	0.0
Canola oil†	1	1.2	0	0.0
Sunflower oil	1	1.2	0	0.0
Animal-Origin Ingredients				
Rendered	70	82.4	172	88.7
Nonrendered	23	27.1	57	29.4
Protein and fat sources	85	100.0	194	100.0
Poultry	49	57.6	105	54.1
Poultry by-product meal	23	27.1	67	34.5
Poultry meat	19	22.4	43	22.2
Poultry meal	12	14.1	22	11.3
Poultry by-products	4	4.7	14	7.2
Mammalian	37	43.5	89	45.9
Meat meal	22	25.9	67	34.5
Meat and bone meal	15	17.6	23	11.9
Meat	2	2.4	9	4.6
Fish/fish meal	1	1.2	4	2.1
Egg	0	0.0	1	0.5

(Continued on next page)

Table 1 (cont'd)

Type and Frequency of the First Four Label Ingredients in Dry Dog Foods Consumed by Gastric Dilatation-Volvulus Cases and Control Dogs

	Cases		Controls	
Animal-Origin Ingredients (cont'd)	**No. of Dogs**	**%**	**No. of Dogs**	**%**
Oils and fats‡	37	43.5	55	28.4
Animal fat (unspecified)§	19	22.4	28	14.4
Poultry fat†	11	12.9	25	12.9
Beef tallow	5	5.9	1	0.5
Lamb fat	2	2.4	1	0.5

* Includes different forms of cereals. For example, corn includes corn gluten meal, corn bran, ground yellow corn, etc. Rice includes rice flour, rice bran, ground brown rice, etc.
† One case dog consumed a dry food that listed both canola oil and poultry fat among the first four label ingredients.
‡ Differential distribution between cases and controls (P=0.01)
§ Differential distribution between cases and controls (P=0.04)

more cases (43.5%) than controls (28.4%) were fed a dry food containing a fat of animal origin (P=0.01).

Foods with oils or fats among the first four label ingredients were found to differ significantly from foods without such ingredients among the first four, with respect to the percent of ME derived from fat (mean ± SD, 33.6%±8.3% and 31.2%±6.4%, respectively; P=0.02); the medians (ranges) for the two groups were 36.6% (20.4% to 55.0%) and 31.8% (15.4% to 46.1%), respectively. Among foods that contained an oil or fat ingredient among the first four label ingredients, 49.4% had fat rather than carbohydrates as their primary energy nutrient (i.e., the nutrient providing the highest percent of ME in the dog's dry food diet). In contrast, among foods not containing an oil or fat ingredient among the first four ingredients, only 15.2% had fat as the primary energy nutrient (P<0.0001).

Risk of GDV was not significantly (P=0.57) increased by a higher number of soy- and cereal-based ingredients among the first four ingredients in dry foods. Risk of GDV was significantly (P=0.03) decreased by a higher number of animal-protein ingredients among the first four label ingredients [Table 2]. Presence of oils and fats among the first four label ingredients was significantly associated with an increased GDV risk (P=0.008). Compared with foods containing no corn (reference OR=1.0), the presence of one corn-based ingredient (OR=1.42; P=0.24) or two corn-based ingredients (OR=1.94; P=0.15) among the first four label ingredients increased the risk of GDV, but this trend of increased risk was not significant (P for trend=0.11). Risk of GDV was not increased with an increasing number of soy-, wheat-, or rice-based ingredients.

Potential risk factors associated with GDV in univariate analyses at $P \leq 0.10$ were included in multivariate logistic regression analysis [Table 3]. Although the increasing number of plant-protein ingredients did not satisfy the criterion for entry into the multivariate model, the factor was forced in the analysis because of its reciprocal relationship with the number of animal ingredients. Neither a higher number (i.e., >1 versus 1) of animal-protein ingredients nor a higher number (i.e., >1 versus 1) of plant-protein ingredients among the first four ingredients was significantly associated with the risk of GDV. However, the presence of an oil or fat among the first four ingredients was associated with a 2.4-fold increased risk of GDV (P=0.01). The fit of the multivariate model was found to be acceptable.[19]

Discussion

It has been suggested that feeding dry, cereal-based commercial dog food is causally related to GDV in large- and giant-breed dogs.[7-9] In a previous epidemiological study, no association was found between GDV risk and the percentage of ME in the diet from dry dog food.[6] However, this may have resulted from the low statistical power of that study to detect such an association.[6] The purposes of the present study, therefore, were to identify any association between the predominance of soy- and cereal-based ingredients in dry foods and the risk of GDV in dogs, and to

Table 2

Effects of Increasing Plant- or Animal-Origin Ingredients on the Risk of Gastric Dilatation-Volvulus in Dogs

	Cases		Controls					
	No. of Dogs	%	No. of Dogs	%	Unadjusted Odds Ratio	95% Confidence Interval	*P* Value	*P* Value for Trend
No. of Plant-Protein Ingredients*								0.57
1	3	3.5	11	5.7	1.00	—	—	
2	48	56.5	93	47.9	1.89	0.50, 7.10	0.35	
3	34	40.0	90	46.4	1.38	0.36, 5.27	0.63	
No. of Animal-Protein Ingredients*								0.03
1	72	84.7	143	73.7	1.00	—	—	
2	12	14.1	42	21.7	0.57	0.28, 1.14	0.11	
3	1	1.2	9	4.6	0.22	0.03, 1.78	0.16	
No. of Oils and Fats*								NA‡
0	47	55.3	139	71.7	1.00	—	—	
1 or 2†	38	44.7	55	28.4	2.04	1.20, 3.47	0.008	

* Among the first four label ingredients
† Most case dogs (n=37) and control dogs (n=55) consumed foods containing one oil or fat, and one case dog consumed a food containing two oils among the first four label ingredients.
‡ NA=not applicable

Table 3

Multivariate Analysis of Ingredient-Related Risk Factors for Gastric Dilatation-Volvulus (GDV) in Dogs

Risk Factors	Adjusted Odds Ratio†	95% Confidence Interval	*P* Value
No. of animal-protein ingredients* (>1 vs 1)	0.89	0.38, 2.10	0.79
No. of plant-protein ingredients* (>1 vs 1)	1.19	0.26, 5.37	0.83
Presence of oils or fats* (yes vs no)	2.36	1.22, 4.58	0.01

* Among the first four label ingredients
† Adjusted for the other two factors and also for age, breed size, body condition, and family history of GDV

determine any association between GDV risk and the method of manufacture of dry food.

The widespread practice of extruding dry dog food began in 1957.[17] An epidemic of GDV in dogs was reported in the United States from 1965 to 1995.[20] Extrusion is currently the most common processing method used to produce dry dog foods; high temperature and short time are used to fully cook and shape dry kibbles.[17] In the study reported here, all case dogs and all but nine control dogs consumed dry foods that were extruded.

Dry foods that contain soy- or cereal-based proteins have been implicated in the etiology of GDV.[7-9] In the present study, the total number of plant-protein ingredients among the first four ingredients and the presence of individual types of plant ingredients were not associated with an increased risk of GDV. An increasing trend in the risk for GDV was observed with an increasing number of corn-based ingredients; however, this trend was not significant in univariate analysis. In contrast, the risks of GDV were decreased (OR <1.0) with an increasing number of soy-, wheat-, and rice-based ingredients.

A linear decrease in the total number of plant-protein ingredients did not directly translate into a linear increase in the total number of animal-protein ingredients, mainly because of the presence of oils and fats among the first four ingredients. Initially, a significant reduction in the risk of GDV was expected with an increasing total number of animal-protein ingredients and a decreasing total number of plant-protein ingredients. Such associations, after adjustment for other factors in the multivariate model, were not statistically significant. However, plant-protein and animal-protein ingredients contain nonprotein substances such as fiber, carbohydrates, and fat that were not accounted for in the data analysis. By classifying plant ingredients based on the type of ingredient and not by form, the present study did not make any distinctions with regard to the major nutrient contribution of the soy- and cereal-based ingredients to the final formulation. Also, no distinctions were made with respect to potential differences in ingredient quality.

An unexpected finding in the current study was the significantly increased risk of GDV associated with the presence of an added oil or fat ingredient among the first four label ingredients. The foods listing oils or fats among the first four label ingredients were found to provide a significantly higher proportion of ME from fat compared with foods not listing oils or fats among the first four label ingredients. In a previous study, no significant differences were reported between the percent ME derived from fat in dogs that developed GDV versus dogs that did not develop GDV.[6] However, in that study, energy nutrient distribution provided by commercial pet food manufacturers was determined from guaranteed analysis for about 60% of dog foods and not from "as fed" nutrient information.[6,16,21] The guaranteed analysis provides the minimum percent of crude protein and fat and the maximum percent of moisture and crude fiber in the food. These values, reported on the label by pet food manufacturers, are on an "as is" or "as fed" basis.[21] The "as fed" values are determined by the manufacturer after analyzing the final food product in the laboratory and applying some standardized calculations.[21] Use of guaranteed analysis to calculate energy nutrient distribution tends to underestimate the ME derived from fat and may partly explain the difference in findings between the two studies. In the present study, 90 (32.3%) dogs were fed dry foods for which "as fed" values were available. Among these 90 dogs, the risk of GDV associated with fat as the primary energy nutrient (rather than carbohydrates) was increased by 96% (P=0.14). In contrast, GDV risk associated with fat as the primary energy nutrient in all dogs was increased by only 15% (P=0.64) after adjustment for the method of calculation of macronutrient distribution.

Gastric emptying is known to be partially affected by the macronutrient composition of food.[22] Carbohydrates and protein are emptied faster from the stomach than fat.[23] Fat slows gastric emptying into the duodenum.[22,23] A delay in gastric emptying of liquids following surgical treatment for and recovery from GDV has been documented in some dogs.[24] The gastric emptying rate, following a circumcostal gastropexy, was significantly increased in dogs recovered from GDV compared to healthy dogs.[23] It has been suggested that delayed gastric emptying may cause chronic gastric distention and could consequently stretch the hepatogastric ligament, allowing partial or complete volvulus of the stomach.[23] Dietary management to increase the gastric emptying rate includes the feeding of foods with a liquid consistency, a high carbohydrate content, or <15% dry-matter fat.[23,25] Delayed gastric emptying aggravated by added fats in the diet may, over time, predispose dogs to GDV. Because dietary fats are also present in animal proteins (e.g., meats, meat meals, and meat and bone meals), it is not clear if added oils and fats influence GDV risk by increasing the proportion of calories from this macronutrient or by providing a fat that differs qualitatively from fat bound within animal-protein ingredients.

The present case-control study was nested within a larger prospective study of GDV. A prospective versus a retrospective approach to dietary exposure assessment was considered an advantageous methodology in nutritional epidemiology, because the diet for each dog was assessed prior to the development of GDV, which decreases bias.[26] A weakness of this method, however, was that diet and other risk factor information was collected systematically only once at the start of the study. Major changes in diet during the study were voluntarily reported by owners of 28 dogs. When such a change in diet was reported, the most recent diet was used in the data analyses.

Other weaknesses of the study were also identified. Ingredients of dry dog foods and the order in which they were listed may have varied over time. Therefore, some ingredients listed by owners at the time of study enrollment may not have adequately reflected the composition of the same foods consumed by these dogs later in life. The process of control selection was characterized by frequency-matching controls to cases by year, primarily to ensure that diet information from controls was obtained at approximately the same time periods as diet information was obtained from the GDV cases.[6] Finally, the presence of fat ingredients among the first four label ingredients did not directly indicate the actual fat content of the food.

Conclusion

The results of this nested case-control study suggested that dry foods containing fats or oils among the first four label ingredients predispose high-risk dogs to GDV, but soy- or cereal-based ingredients do not. Plant-protein ingredients such as soy, wheat, corn, and rice were not associated with an increased risk of GDV regardless of the number of times they were listed among the first four label ingredients. Despite a lack of statistical significance, there was a trend toward decreased risk of GDV with a higher number of protein ingredients of animal origin.

---

[a] Dean AG, Dean AJ, Coulombier D, *et al*. Epi Info, Version 6; Centers for Disease Control and Prevention, Atlanta, GA 30333

[b] SAS version 8.2; SAS Institute, Inc., Cary, NC 27513

[c] Proc Logistic; SAS Institute, Inc., Cary, NC 27513

References

1. 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.
2. Glickman LT, Glickman NW, Schellenberg DB, *et al*. Non-dietary risk factors for gastric dilatation-volvulus in large and giant breed dogs. J Am Vet Med Assoc 2000;217:1492-1499.
3. Glickman LT, Emerick T, Glickman NW, *et al*. Radiological assessment of the relationship between thoracic conformation and the risk of gastric dilatation-volvulus in dogs. Vet Radiol Ultrasound 1996;37:174-180.
4. 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.
5. Elwood CW. Risk factors for gastric dilatation for Irish setter dogs. J Small Anim Prac 1998;39:185-190.
6. Raghavan M, Glickman NW, 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. Van Kruiningen HJ, Gregoire K, Meuten DJ. Acute gastric dilatation: a review of comparative aspects, by species, and a study in dogs and monkeys. J Am Anim Hosp Assoc 1974;10:294-324.
8. Kronfeld D. Common questions about the nutrition of dogs and cats. Compend Contin Educ Prac Vet 1979;1:33-42.
9. Morgan RV. Acute gastric dilatation-volvulus syndrome. Compend Contin Educ Prac Vet 1982;4:677-682.
10. Burrows CF, Bright RM, Spencer CP. Influence of dietary composition on gastric emptying and motility in dogs: potential involvement in acute gastric dilatation. Am J Vet Res 1985;46:2609-2612.
11. Rugh KS. Feed your collie right. Popular Dog Series: Collies 2004;35:84-93.
12. Sullivan M, Yool DA. Gastric disease in the dog and cat. Vet J 1998;156:91-106.
13. Theyse LFH, van de Brom WE, van Sluijs FJ. Small size food particles and age as risk factors for gastric dilatation volvulus in Great Danes. Vet Rec 1998;143:48-50.
14. 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.
15. Roudebush P, Dzanis DA, Debraekeleer J, *et al*. Pet food labels. In: Hand MS, Thatcher CD, Remillard RL, *et al.*, eds. Small Animal Clinical Nutrition. 4th ed. Topeka, KS: Mark Morris Institute, 2000:147-161.
16. Coffman HD. The Dry Dog Food Reference. Nashua, NH: PigDog Press, 1995.
17. Cowell CS, Stout NP, Brinkmann MF, *et al*. Making commercial pet foods. In: Hand MS, Thatcher CD, Remillard RL, *et al.*, eds. Small Animal Clinical Nutrition. 4th ed. Topeka, KS: Mark Morris Institute, 2000:127-146.
18. SAS, SAS/STAT user's guide: version 8. Cary, NC: SAS Institute, Inc., 1999:1903-2042.
19. Hosmer DW, Taber S, Lemeshow S. The importance of assessing the fit of logistic regression models: a case study. Am J Public Health 1991;81:1630-1635.

20. Glickman LT. Epidemiology of gastric dilatation-volvulus in dogs. In: Proceedings. Twenty-First Congress of the World Small Animal Veterinary Association. Jerusalem, Israel, 1996:81-83.
21. Coffman HD. Coffman's Comparative Reference Guide to Dog Food. Nashua, NH: PigDog Press, 1998.
22. Groff JL, Gropper SS. The digestive system: mechanism for nourishing the body. In: Advanced Nutrition and Human Metabolism. 3rd ed. Belmont, CA: Wadsworth/Thomson Learning, 2000:24-49.
23. Hall JA. Canine gastric dilatation-volvulus update. Semin Vet Med Surg Small Anim 1989;4:188-193.
24. Funkquist B, Garmer L. Pathogenetic and therapeutic aspects of torsion of the canine stomach. J Small Anim Pract 1967;8:523-532.
25. Davenport DJ, Remillard RL, Simpson KW, *et al*. Gastrointestinal and exocrine pancreatic disease. In: Hand MS, Thatcher CD, Remillard RL, *et al.*, eds. Small Animal Clinical Nutrition. 4th ed. Topeka, KS: Mark Morris Institute, 2000:725-810.
26. Margetts BM, Nelson M. Design Concepts in Nutritional Epidemiology. 2nd ed. New York: Oxford University Press, 1997:105-414.