# Diet-Related Risk Factors for Gastric Dilatation-Volvulus in Dogs of High-Risk Breeds

A nested case-control study was conducted among 1634 dogs with complete diet information in a 5-year prospective study to determine diet-related risk factors for gastric dilatation-volvulus (GDV). Cases included 106 dogs that developed GDV; controls included 212 dogs without GDV that were frequency matched to cases by year of GDV onset. Proportionate energy consumed from major food types and from carbohydrates was determined. Dogs were categorized as consuming either a low volume or high volume of food based on the median number of cups of food fed per kg of body weight per meal. Dogs fed a larger volume of food per meal were at a significantly ($P<0.05$) increased risk of GDV, regardless of the number of meals fed daily. For both large- and giant-breed dogs, the risk of GDV was highest for dogs fed a larger volume of food once daily. **J Am Anim Hosp Assoc 2004;40:192-203.**

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## Introduction

Gastric dilatation-volvulus (GDV) in dogs is characterized by rapid accumulation of air in the stomach, malpositioning of the stomach, increased intragastric pressure, and often hypovolemic shock.[1] The prevalence of GDV in 12 veterinary teaching hospitals in the United States increased more than twofold from 1980 to 1988.[1] The increasing frequency of GDV together with an overall case-fatality rate of approximately 15% to 30% explains why GDV is the second leading cause of death in large-breed dogs.[1,2] Host risk factors for GDV include increasing age, large-breed size, having a deep and narrow thorax, a family history of GDV, a nervous temperament, and a faster speed of eating.[1-4]

Consumption of commercial dry dog food is thought to play a role in the development of GDV.[5,6] Despite a shortage of scientific studies evaluating the role of dry food in GDV, advice to prevent a first episode of GDV often includes not feeding exclusively commercial diets, especially those made from highly processed cereals.[5,7] An epidemiological study found that Irish setters consuming a single food type were three times more likely to develop GDV than Irish setters fed a mixture of food types.[8] Inclusion of table foods in the diet of large- and giant-breed dogs was associated with a 59% decreased risk of GDV, while inclusion of canned foods was associated with a 28% decreased risk.[4]

Among other diet-related factors investigated, increased particle size of food was associated with a significantly decreased risk of GDV in Great Danes.[9] Once-daily feeding and using a raised food bowl significantly increased GDV risk, while moistening of dry food prior to feeding significantly increased GDV risk for large-breed, but not for giant-breed, dogs.[2,4,8]

Most risk factor studies of GDV have been retrospective and, thus, subject to potential recall bias by owners.[4,8,9] Therefore, the authors used a recently completed 5-year prospective study to characterize owner-reported, daily diet-related risk factors for GDV.[10] The method of assessing past or present self-reported diets is used routinely in human epidemiological studies of risk factors for chronic diseases.[11] The specific hypotheses tested in the present study were that the risk of GDV increases with feeding dry, commercial dog food, with feeding an increased volume of food per meal, and when an increased proportion of carbohydrates is provided in the diet.

## Materials and Methods

### *Study Design*

Eleven breed clubs (i.e., Akita, bloodhound, collie, Great Dane, Irish setter, Irish wolfhound, Newfoundland, rottweiler, Saint Bernard, standard poodle, and Weimaraner) agreed to participate in and partially fund a prospective study of GDV at Purdue University. Eligible dogs were recruited between June 1994 and March 1997 at 27 national and specialty dog shows in the United States. Detailed methods have been previously reported.[2,10]

Within 30 days of entry into the study, owners were mailed an eight-page questionnaire about the type (e.g., dry, canned, semimoist, unprocessed, home-prepared, table scraps, treats), brand, variety, and amount (cups per meal) of commercial dog foods fed on a daily or weekly basis. Owners were not specifically given instructions on the size of a standard cup, but feeding guidelines on most bags of commercial dry dog foods are based on an 8-fl oz cup. Owners were asked to record the guaranteed analysis and first four ingredients printed on food labels or to submit the food labels with the completed questionnaire. If home-prepared foods or table scraps were fed, information was requested about the amount (i.e., cups or ounces) and form (i.e., raw or cooked) fed. Information was obtained on dietary supplements and feeding practices, such as frequency of feeding, moistening of dry food prior to feeding, and whether exercise or water was restricted pre- or postprandially. Owners scored their dog's speed of eating on a scale of 1 to 10, with 1 indicating slow and 10 indicating fast. Owners were asked to report any changes in their dog's diet during the course of the study, and if changes were reported, the most recent diet was always used in the risk-factor analysis.

Owners were mailed follow-up postcards with tear-off, prepaid response cards in July 1997, March 1998, and February 1999, and follow-up ended in December 2000. A detailed description of the follow-up procedures has been published.[10] Dogs ≥6 months of age at the time of enrollment were included in the present study, provided information on vital status (i.e., whether alive or dead) and whether GDV had occurred was obtained at least once after recruitment, and complete diet information was reported at the start of the study.

### *Cases and Controls*

A nested case-control study is one in which cases and controls belong to a defined cohort.[11] Dogs that developed GDV during follow-up were defined as cases. For control selection, the cases were divided into six strata corresponding to the calendar year they developed GDV (i.e., from 1994 up to 2000). Potential controls were dogs enrolled in the study that were alive at the time the cases developed GDV and did not themselves develop GDV anytime during the study. This method of control selection ensured that diet histories for cases and controls were collected at comparable time periods. Twice as many controls as GDV cases were randomly selected from the pool of each calendar year using a frequency matching computer program.[a]

### *Assessment of Nutrient Intake*

Guaranteed analysis and the first four label ingredients for each variety of owner-reported dry and canned foods fed were compared with those in published references for the same time period to verify that the information was consistent.[12,13] If a discrepancy was found, it was noted in the database by use of an indicator variable, and the owner-reported information alone was used in subsequent analyses. The energy density (defined as metabolizable energy [ME] per 8-fl oz cup or ME per gm); the percentage of ME derived from macronutrients, carbohydrates, fat, and protein; and the density (weight per 8-fl oz cup) of each commercial food were obtained from these references. The total ME, expressed in kilocalories (Kcal) and derived from a specific commercial food (e.g., $ME_{dry}$), was calculated as energy density per cup of commercial food × number of cups fed per meal × number of meals the food was fed per day. The absolute ME derived from each macronutrient from a commercial food was calculated (e.g., $ME_{dry} \times \% \ ME_{carbohydrates\ in\ dry\ food} \div 100$).

Pet food companies not listed in the references were contacted to obtain nutrient values of commercial food varieties manufactured at the time the dogs' diets were reported. When only the energy density, but not the percentage of ME from the different macronutrients, was available for a given food, the percent ME was calculated based on weight of dry matter using modified Atwater coefficients of 3.5 kcal/gm for carbohydrates and protein and 8.5 kcal/gm for fat.[14] If the value for dry matter was not available, the guaranteed analysis was used after adjusting for moisture content, to estimate the percentage of ME derived from carbohydrate, fat, and protein from the food type. For dogs that consumed home-prepared foods, table scraps, or store-bought foods meant for human consumption, the ME derived from these foods and the ME derived from each nutrient were calculated using a nutrient database and modified Atwater coefficients.[14,15]

To standardize food intake, the total volume of all food types fed on a daily basis was divided by the weight (kg) of the dog. To estimate the amount of food fed per meal, volume was divided by the number of meals fed per day. The weight of each food type fed was given by the number of cups of food type fed × density of food per cup. To estimate the weight of food fed per meal, the total weight of all food types fed was divided by the weight of the dog and by the number of meals fed per day.

The total ME per day derived from each food type was calculated to obtain the proportion derived from each food type (e.g., % ME from dry = $ME_{dry} \div ME_{total} \times 100$) and from each nutrient (e.g., % ME from carbohydrates = $ME_{carbohydrates} \div ME_{total} \times 100$). The proportion of ME derived from carbohydrates, protein, and fat was adjusted for body weight, because larger dogs consumed proportionately more carbohydrates.[16] The primary food type (i.e., the food type contributing >50% of the total dietary ME) and the primary nutrient (i.e., the nutrient providing the largest proportion of ME in the diet) were identified for each dog. Finally, the energy density of all foods consumed per day was calculated as $ME_{total}$ ÷ total number of cups of all food types fed daily.

### *Data Analysis*

Data was entered using epidemiological software[b] and was analyzed using SAS System for Windows.[a] A nutritional profile for each dog was entered into a spreadsheet database[c] and exported to SAS[a] and compared between cases and controls using chi-square ($\chi^2$), independent samples t-test (for normal distributions), and Mann-Whitney test (for nonnormal distributions). Each potential risk factor was examined for an association with GDV risk using unconditional logistic regression[d] and the method of maximum likelihood.[17] The measure of association between GDV and each putative risk factor was expressed as the odds ratio (OR) and 95% confidence interval (CI). A linear trend in the OR (either an increase or decrease in GDV risk), associated with increasing levels of a risk factor, was calculated.[b]

A multivariate logistic regression model included those risk factors having a *P* value of <0.20 in univariate analyses. To control for unmeasured factors relating to breed- or size-specific characteristics, breed size was included in the multivariate model regardless of the *P* value. Ordered categorical factors were included in the final model only if the test for trend in the univariate analysis satisfied the *P* value criterion. Interaction terms were included based on known or suspected biological relationships between variables. Risk factors for GDV in the final model were considered significant at a *P* value of <0.05. The fit of the final model was determined using the Pearson $\chi^2$ and Hosmer and Lemeshow statistics.[18] A larger *P* value indicates a better fit.

## Results

Of 1634 dogs with information on vital status and diet in the prospective study, 106 dogs that developed GDV were included as cases in the nested case-control study. Dogs without GDV (n=212; 13.9%) were selected as controls. The case and control dogs were not significantly different with respect to body size, breed, gender, and reproductive status. Significantly more case dogs had a first-degree relative (i.e., sire, dam, sibling, or offspring) with a history of GDV (*P*<0.001) or were in thin (lean) body condition (*P*=0.02). The mean±standard deviations (SD) for ages of cases and controls were 5.9±2.7 years and 5.0±2.4 years, respectively (*P*=0.01); the age medians (ranges) for cases and controls were 5.9 (1.4 to 12.3) years and 4.9 (1.6 to 12.4) years, respectively. Thirty-six percent of the case dogs were dead at the end of the study period compared to only 8% of the control dogs (*P*<0.0001).

### *Nutrient Profiles*

Case and control dogs did not differ with respect to the food types fed daily [Figure 1]. The medians (ranges) of percent ME derived from dry food for cases and controls were 96.1 (59.5 to 100) and 97.1 (0 to 100), respectively (*P*=0.99). One hundred and thirty (41.0%) dogs in the study consumed canned food on a daily basis. The medians (ranges) of percent ME in the daily diet derived from canned food for cases and controls were 0 (0 to 35.4) and 0

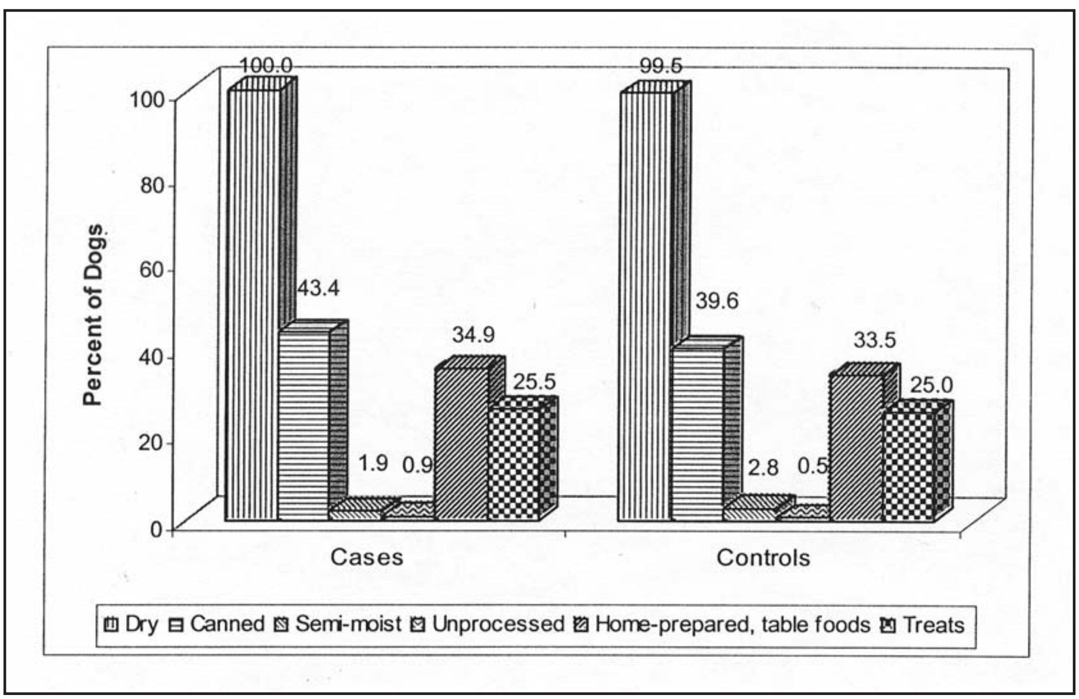


***Figure 1***—Food types consumed daily by 106 dogs with gastric dilatation-volvulus (GDV) (cases) and 212 dogs without GDV (controls).

(0 to 43.9), respectively (*P*=0.60). One hundred and forty-six (45.9%) dogs in the study were fed home-prepared foods, table scraps, and store-bought human foods daily. The medians (ranges) of percent ME derived from these foods for cases and controls were 0 (0 to 30.5) and 0 (0 to 59.0), respectively (*P*=0.94). The primary food type (i.e., the food type providing >50% of ME in the total diet) was dry, commercial dog food for all cases and for all but two controls. Cases and controls also did not differ significantly with respect to the proportion of ME derived from carbohydrates (*P*=0.95), fat (*P*=0.89), or protein (*P*=0.59) [Figure 2].

### Univariate Analyses

Among host-related factors, increasing age, a history of GDV in first-degree relatives, being thin (lean), and a history of major or chronic health problems in the first year of life were associated (*P*<0.20) with GDV risk in univariate analyses [Table 1].

Among diet-related factors, an increasing number of cups of food fed per kg of body weight per meal or per day was associated with an increasing risk of GDV (*P* values for trends were 0.04 and 0.17, respectively) [Table 2]. Weight of food fed per meal per kg of body weight was positively correlated with the volume of food fed (correlation coefficient [*r*], 0.93; *P*<0.001). Energy density of all foods fed daily was weakly correlated with the total number of cups of food fed on a daily basis (*r*, -0.11; *P*=0.08).

The median (range) numbers of cups of food fed per kg of body weight for dogs fed one or two meals a day were 0.11 (0.06 to 0.22) and 0.06 (0.02 to 0.17), respectively. The median number of cups was used to categorize dogs as either consuming a low or high volume of food per meal. The mean±SD energy density of foods fed in lower volumes (whether in one or two meals) was 365.3±51.1 kcal/cup, and this was not significantly higher than the energy density of foods fed in higher volumes (359.7±53.6 kcal/cup; *P*=0.36). There was, however, an interaction between the number of meals fed daily and the volume of food fed per meal. For example, when dogs were grouped into those fed either one or two meals a day, dogs fed a higher volume of food and one meal a day were at a significantly increased risk of GDV (OR, 2.47; CI, 1.01 to 6.04; *P*=0.05) compared to dogs fed a lower volume of food and two meals a day. Dogs fed a higher volume of food and two meals a day (OR, 1.42; CI, 0.83 to 2.44; *P*=0.20) and those fed a lower volume of food and one meal a day (OR, 1.08; CI, 0.41 to 2.86; *P*=0.88) did not have a significantly increased risk of GDV compared to dogs fed a lower volume of food and two meals a day. Seven dogs fed more than two meals a day were excluded from these analyses.

### Multivariate Analyses

Potential risk factors associated with GDV in univariate analyses at *P*<0.20 were further analyzed by multivariate logistic regression [Table 3]. The number of cups of food fed per kg of body weight per meal and per day could not be included in the same multivariate model because of high colinearity. Among host-related risk factors, only increasing age (OR per year, 1.15; CI, 1.03 to 1.29) was significantly (*P*<0.05) associated with GDV risk. Having a history of a major or chronic health problem during the first year of life was marginally associated with an increased risk of GDV (OR, 2.20; CI, 1.00 to 4.81). Dogs fed a higher volume of food per meal were more likely to develop GDV (OR, 1.82; CI, 1.02 to 3.23) than dogs fed a lower volume of food, regardless of the number of meals fed per day. The fit of the

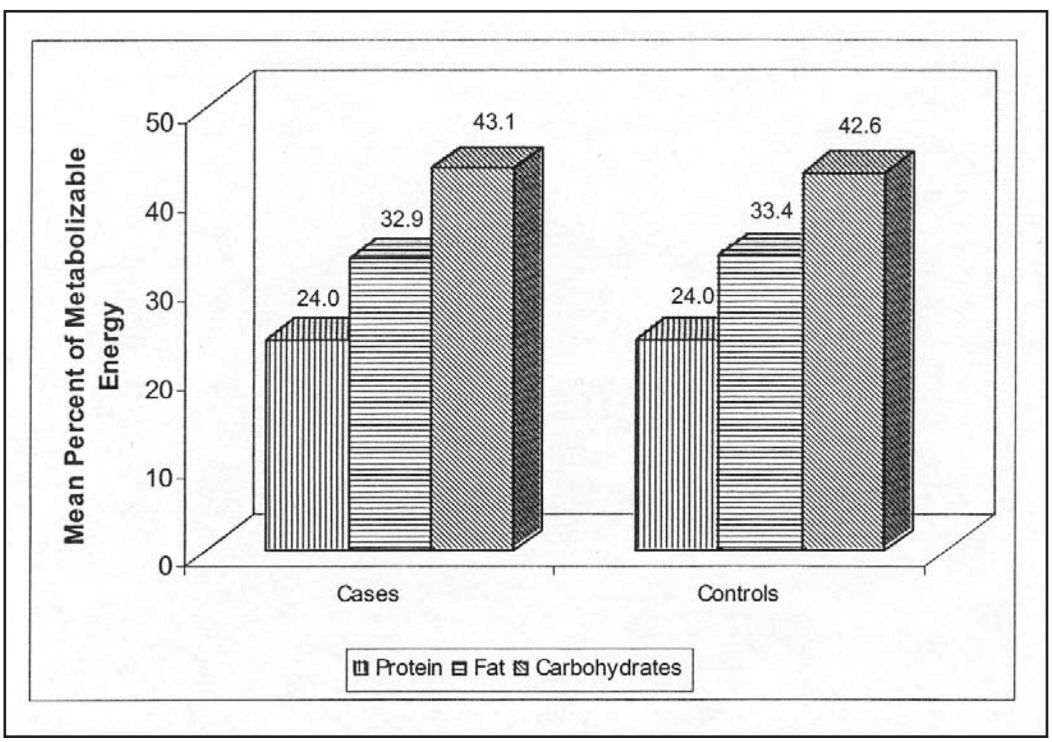


***Figure 2***—Proportion of metabolizable energy derived from macronutrients daily for 106 dogs with gastric dilatation-volvulus (GDV) (cases) and 212 dogs without GDV (controls).

**Table 1**

Univariate Analyses of Host-Related Factors With Gastric Dilatation-Volvulus (GDV) Risk for 106 Case and 212 Control Dogs

| **Host-Related Factor**[*] | **Cases (No.)**[†] | **Controls (No.)**[†] | **Odds Ratio (95% Confidence Interval)** | ***P* Value**[‡] | ***P* Value for Trend**[§] |
|---|---|---|---|---|---|
| Age (y) | 106 | 212 | 1.14 (1.04-1.26) | 0.01 | |
| Breed size | | | | | |
| Large breed (>23 to ≤45 kg)[∥] | 58 | 120 | 1.00 | NA | |
| Giant breed (>45 kg) | 48 | 92 | 1.08 (0.68-1.73) | 0.75 | |
| Gender | | | | | |
| Male[∥] | 50 | 108 | 1.00 | NA | |
| Female | 56 | 104 | 1.16 (0.73-1.86) | 0.53 | |
| Gender and reproductive status | | | | | |
| Sexually intact male[∥] | 47 | 94 | 1.00 | NA | |
| Castrated male | 3 | 14 | 0.43 (0.12-1.57) | 0.20 | |
| Sexually intact female[∥] | 41 | 82 | 1.00 | NA | |
| Spayed female | 15 | 22 | 1.36 (0.64-2.90) | 0.42 | |
| History of GDV in first-degree relative | | | | | |
| No[∥] | 55 | 141 | 1.00 | NA | |
| Yes | 43 | 53 | 2.08 (1.25-3.46) | <0.001 | |
| Body condition | | | | | |
| Thin or lean | 12 | 9 | 2.81 (1.14-6.91) | 0.02 | |
| Optimum[∥] | 91 | 192 | 1.00 | NA | 0.02 |
| Overweight or obese | 3 | 11 | 0.58 (0.16-2.11) | 0.41 | |
| Height | | | | | |
| 1st tertile[∥] | 30 | 77 | 1.00 | NA | |
| 2nd tertile | 35 | 58 | 1.55 (0.85-2.81) | 0.15 | 0.30 |
| 3rd tertile | 40 | 75 | 1.37 (0.77-2.42) | 0.28 | |
| Weight | | | | | |
| 1st tertile[∥] | 36 | 73 | 1.00 | NA | |
| 2nd tertile | 37 | 66 | 1.14 (0.65-2.00) | 0.66 | 0.77 |
| 3rd tertile | 33 | 73 | 0.92 (0.52-1.63) | 0.77 | |

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## Table 1 (cont'd)

Univariate Analyses of Host-Related Factors With Gastric Dilatation-Volvulus (GDV) Risk for 106 Case and 212 Control Dogs

| Host-Related Factor* | Cases (No.)† | Controls (No.)† | Odds Ratio (95% Confidence Interval) | *P* Value‡ | *P* Value for Trend§ |
|---|---|---|---|---|---|
| Speed of Eating Score (1-10) | | | | | |
| Large-breed dogs (>23 to ≤45 kg) | | | | | |
| 1 to 3 | 5 | 17 | 0.63 (0.21-1.91) | 0.41 | |
| 4 to 6\ | 23 | 49 | 1.00 | NA | 0.21 |
| ≥7 | 30 | 51 | 1.25 (0.64-2.45) | 0.51 | |
| Giant-breed dogs (>45 kg) | | | | | |
| 1 to 3 | 9 | 15 | 1.17 (0.43-3.18) | 0.76 | |
| 4 to 6\ | 18 | 35 | 1.00 | NA | 0.74 |
| ≥7 | 21 | 42 | 0.97 (0.45-2.11) | 0.94 | |
| Major or chronic health problems during first year of life | | | | | |
| No\ | 84 | 184 | 1.00 | NA | |
| Yes | 17 | 19 | 1.96 (0.97-3.96) | 0.06 | |
| Major or chronic gastrointestinal problems during dog's life | | | | | |
| No\ | 89 | 181 | 1.00 | NA | |
| Yes | 8 | 10 | 1.63 (0.62-4.27) | 0.32 | |

* Tertiles of height and weight were determined separately for each breed-gender combination. This was necessary because of large differences in the average weight and height between breeds in this study.
† Totals may not add up to 106 cases and 212 controls because of unknown or missing information
‡ NA=not applicable
§ A test for linear trend in the odds ratio (either an increase or decrease in GDV risk) associated with increasing levels of a potential risk factor
\ Reference group

## Table 2

Univariate Analyses of Diet-Related Factors With Gastric Dilatation-Volvulus (GDV) Risk for 106 Case and 212 Control Dogs

| Diet-Related Factor | Cases (No.)* | Controls (No.)* | Odds Ratio (95% Confidence Interval) | *P* Value† | *P* Value for Trend‡ |
|---|---|---|---|---|---|
| No. of meals fed per day | | | | | |
| 1 | 19 | 28 | 1.42 (0.75-2.69) | 0.29 | |
| 2§ | 81 | 169 | 1.00 | NA | 0.26 |
| ≥3 | 6 | 15 | 0.84 (0.31-2.23) | 0.72 | |
| Food type fed | | | | | |
| Percentage of ME[\] from dry food | | | | | |
| <75 | 5 | 17 | 0.54 (0.19-1.53) | 0.24 | |
| ≥75 to <100§ | 57 | 104 | 1.00 | NA | 0.75 |
| 100 | 40 | 82 | 0.89 (0.54-1.46) | 0.65 | |
| Percentage of ME from canned food | | | | | |
| 0§ | 61 | 128 | 1.00 | NA | |
| >0 to ≤10 | 31 | 54 | 1.21 (0.70-2.06) | 0.50 | 0.69 |
| >10 | 13 | 26 | 1.05 (0.51-2.18) | 0.87 | |
| Percentage of ME from home-cooked foods | | | | | |
| 0§ | 69 | 141 | 1.00 | NA | |
| >0 to ≤10 | 22 | 44 | 1.02 (0.57-1.84) | 0.94 | 0.86 |
| >10 | 12 | 23 | 1.07 (0.50-2.27) | 0.87 | |
| Volume of food fed | | | | | |
| No. of cups of food/day/kg of body weight | | | | | |
| 1st tertile | 27 | 77 | 0.50 (0.28-0.92) | 0.02 | |
| 2nd tertile§ | 39 | 56 | 1.00 | NA | 0.17 |
| 3rd tertile | 35 | 65 | 0.77 (0.43-1.38) | 0.38 | |
| No. of cups of food/meal/kg of body weight | | | | | |
| 1st tertile | 24 | 69 | 0.65 (0.35-1.20) | 0.17 | |
| 2nd tertile§ | 37 | 69 | 1.00 | NA | 0.04 |
| 3rd tertile | 40 | 60 | 1.24 (0.71-2.19) | 0.45 | |
| Daily energy consumption | | | | | |
| ME (Kcal)/kg of body weight | | | | | |
| 1st tertile | 27 | 71 | 0.64 (0.35-1.18) | 0.15 | |

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**Table 2 (cont'd)**

Univariate Analyses of Diet-Related Factors With Gastric Dilatation-Volvulus (GDV) Risk for 106 Case and 212 Control Dogs

| Diet-Related Factor | Cases (No.)* | Controls (No.)* | Odds Ratio (95% Confidence Interval) | *P* Value† | *P* Value for Trend‡ |
|---|---|---|---|---|---|
| Daily energy consumption (cont'd) | | | | | |
| ME (Kcal)/kg of body weight (cont'd) | | | | | |
| 2nd tertile§ | 36 | 61 | 1.00 | NA | 0.25 |
| 3rd tertile | 35 | 64 | 0.93 (0.52-1.66) | 0.80 | |
| Energy density of food consumed daily | | | | | |
| ME (Kcal)/cup of food | | | | | |
| 1st tertile | 36 | 60 | 1.50 (0.81-2.77) | 0.20 | |
| 2nd tertile§ | 26 | 65 | 1.00 | NA | 0.59 |
| 3rd tertile | 36 | 71 | 1.27 (0.69-2.32) | 0.44 | |
| Nutrient composition | | | | | |
| Primary energy nutrient in the total diet¶ | | | | | |
| Fat§ | 33 | 58 | 1.00 | NA | |
| Carbohydrates | 65 | 138 | 0.83 (0.49-1.39) | 0.48 | |
| Primary energy nutrient in dry food# | | | | | |
| Fat§ | 26 | 49 | 1.00 | NA | |
| Carbohydrates | 77 | 158 | 0.92 (0.53-1.59) | 0.76 | |
| Percent ME from carbohydrates from all food types** | | | | | |
| 1st tertile | 36 | 62 | 1.67 (0.91-3.09) | 0.10 | |
| 2nd tertile§ | 25 | 72 | 1.00 | NA | 0.92 |
| 3rd tertile | 37 | 62 | 1.72 (0.93-3.17) | 0.08 | |
| Percent ME from carbohydrates in dry food** | | | | | |
| 1st tertile | 38 | 67 | 1.28 (0.71-2.28) | 0.41 | |
| 2nd tertile§ | 31 | 70 | 1.00 | NA | 0.59 |
| 3rd tertile | 34 | 70 | 1.08 (0.60-1.95) | 0.80 | |

* Totals may not add up to 106 cases and 212 controls because of unknown or missing information
† NA=not applicable
‡ A test for linear trend in the odds ratio (either an increase or decrease in GDV risk) associated with increasing levels of a potential risk factor
§ Reference group
\ ME=metabolizable energy
¶ Nutrient providing the largest proportion of ME derived from all food types in dog's daily diet
# Nutrient providing the largest proportion of ME derived from dry food in dog's daily diet
** Adjusted for body weight (see text)

**Table 3**

Multivariate Analyses of Host- and Diet-Related Factors With Gastric Dilatation-Volvulus (GDV) Risk for 92 Case and 174 Control Dogs*

| Risk Factors | Odds Ratio | 95% Confidence Interval | *P* Value |
|---|---|---|---|
| Age (y) | 1.15 | 1.03-1.29 | 0.01 |
| Breed size (giant vs large†) | 1.25 | 0.72-2.17 | 0.44 |
| History of GDV in first-degree relative (yes vs no†) | 1.68 | 0.97-2.92 | 0.06 |
| Body condition (thin or lean vs optimum or overweight or obese†) | 2.44 | 0.87-6.88 | 0.09 |
| Major or chronic health problems during first year of life (yes vs no†) | 2.20 | 1.00-4.81 | 0.05 |
| Volume of food fed per meal‡ (high vs low†) | 1.82 | 1.02-3.23 | 0.04 |

* Numbers do not add up to 106 cases and 212 controls because of missing information on one or more factors
† Reference group
‡ High vs low volume of food fed was defined based on median number of cups of food per kg body weight per meal (see text)

final logistic model was found to be acceptable based on the large *P* value for the Hosmer and Lemeshow statistic ($P$=0.97).

When dogs were grouped by the number of meals fed per day, the dogs that were fed a higher volume of food (whether in one or two meals a day) were at an increased risk of GDV [Table 4]. However, at highest risk were dogs fed a higher volume of food once daily (OR, 3.18; CI, 1.15 to 8.79). This relationship between the volume of food fed per meal, the number of meals fed per day, and GDV risk was further explored by grouping dogs based on breed size. The increased risk of GDV associated with being fed a higher volume of food once daily was more pronounced for giant-breed dogs (OR, 11.16; CI, 1.66 to 75.18) than large-breed dogs (OR, 3.63; CI, 0.95 to 13.80).

## Discussion

The present study indicated that feeding dogs a larger volume of food per meal, regardless of the number of meals fed per day, significantly increased their risk of GDV nearly twofold, compared to risk levels for dogs fed a smaller volume of food per meal. Moreover, feeding a larger volume of food once daily significantly increased a dog's risk of GDV threefold, compared to risk levels for dogs fed a smaller volume of food twice daily. A similar association between volume fed per meal and GDV risk was observed for dry food consumption alone. This was expected, considering that for a majority of the dogs in the study, over 75% of the daily ME was derived from dry foods. The present findings support current recommendations to prevent GDV by avoiding feeding single, large meals and to feed two to three small meals a day.[5-7,19]

The association between a high volume of food fed in one meal a day and GDV risk was more pronounced in giant-breed dogs than in large-breed dogs, possibly because the size of the digestive tract relative to body weight is reported to be less for giant-breed dogs (2.8%) than for large-breed dogs (3.3%).[20,21] Using cinefluoroscopy, it has been shown that postprandially, the stomachs of healthy dogs fed commercial dry dog food once daily for at least 1 year were larger than the stomachs of healthy dogs fed commercial dry foods three times daily and larger than the stomachs of dogs fed meat-and-bone ration either once or three times daily in the same time period.[19] At autopsy 2 hours following a complete meal, dogs fed commercial dry dog food once daily also had a significantly higher volume and weight of postprandial food residue, a greater length of the greater curvature of the stomach, and a higher gastric weight compared to any of the other three groups of dogs.[19] Dogs fed commercial dry dog food once daily also had the heaviest stomachs, when expressed as a percentage of body weight, while those fed meat-and-bone ration three times a day had the lightest.[19] It appears, therefore, that a high volume of food fed once daily can increase the risk of GDV by distending and weighing down the stomach, thus stretching its supporting ligaments over time. The lengths of hepatogastric ligaments

**Table 4**

Volume of Food Per Meal, Number of Meals Per Day, Breed Size, and Gastric Dilatation-Volvulus (GDV) Risk for 90 Case and 169 Control Dogs*

| | No. of Meals Fed Per Day | Volume of Food Fed Per Meal† | Cases (No.) | Controls (No.) | Odds Ratio‡ | 95% Confidence Interval | *P* Value |
|---|---|---|---|---|---|---|---|
| All dogs | | | | | | | |
| | 2 | Low§ | 31 | 73 | 1.00 | — | — |
| | 1 | Low | 7 | 13 | 1.77 | 0.61-5.13 | 0.29 |
| | 2 | High | 41 | 72 | 1.88 | 0.99-3.59 | 0.06 |
| | 1 | High | 11 | 11 | 3.18 | 1.15-8.79 | 0.03 |
| Breed size | | | | | | | |
| Large-breed (>23 to ≤45 kg) dogs only | | | | | | | |
| | 2 | Low\ | 10 | 35 | 1.00 | — | — |
| | 1 | Low | 4 | 8 | 2.74 | 0.63-11.99 | 0.18 |
| | 2 | High | 29 | 45 | 3.48 | 1.37-8.84 | 0.01 |
| | 1 | High | 6 | 9 | 3.63 | 0.95-13.80 | 0.06 |
| Giant-breed (>45 kg) dogs only | | | | | | | |
| | 2 | Low | 21 | 38 | 2.39 | 0.93-6.15 | 0.07 |
| | 1 | Low | 3 | 5 | 3.15 | 0.60-16.59 | 0.18 |
| | 2 | High | 12 | 27 | 2.29 | 0.77-6.80 | 0.14 |
| | 1 | High | 5 | 2 | 11.16 | 1.66-75.18 | 0.01 |

* Numbers do not add up to 106 cases and 212 controls because of missing information on one or more factors. Seven dogs fed >2 meals a day are not included in these analyses.

† High vs low volume of dry food was defined based on median number of cups of food fed per kg body weight (0.11 cup for those fed one meal a day and 0.06 cup for those fed two meals a day).

‡ Odds ratios have been adjusted for age, history of GDV in first-degree relatives (i.e., sire, dam, sibling, or offspring), thin (lean) body condition, and history of major or chronic health problems during dog's first year of life through multivariate logistic regression analysis

§ Reference group

\ Reference group for both large- and giant-breed dogs in dogs with GDV have been reported to be significantly longer than those in dogs without GDV; the median (range) lengths were 7.0 (5.0 to 9.5) cm and 5.0 (3.0 to 7.5) cm, respectively, for the two groups.[22] This mechanism would be further supported if feeding lower energy-density foods was associated with an increased risk of GDV. However, the study reported here did not support this relationship, possibly because the volume of food fed was not linearly related to energy density (data not shown).

It has been suggested that feeding dry, cereal-based commercial dog foods plays a role in GDV.[5,6] In the present study, however, the authors were not able to determine if GDV risk was associated with consumption of commercial dry dog food, because all but one dog consumed dry food daily. For 89% of the dogs in the study, >75% of the ME in the daily diet was derived from dry dog food; the median ME from dry food was 96.5%. This diet pattern is in agreement with findings by Glickman, *et al*., that large-breed dogs are fed proportionately more dry dog food than smaller breed dogs.[16] In the present study, the pattern of the weekly diet was similar to that of the daily diet (data not shown). For this reason, the power of the present study to detect a difference between cases and controls with respect to the amount of dry food consumed was low (<15%).[b]

Carbohydrates in commercial dry foods have been suspected to play a role in GDV.[5,7] In the present study, neither the percentage of ME from carbohydrates from all food types (range, 18.4% to 70.1%), nor the percentage of ME from carbohydrates from dry foods alone (range, 18.4% to 69.8%) were associated with GDV risk. The percentage of ME from carbohydrates was adjusted for body weight, because dogs consume proportionately more carbohydrates with increasing breed size.[16]

Being thin (lean) and having a history of a major or chronic health problem during the first year of life were significantly associated with an increased risk of GDV in the univariate analyses. These findings are consistent with results of Glickman, *et al*., who reported that being underweight significantly increased a dog's risk of GDV.[4] A possible association between GDV and inflammatory bowel disease was raised in a study of 23 dogs with GDV, in which an intestinal biopsy was performed at the time of surgery for GDV.[23] Fourteen (61%) biopsies indicated the presence of an underlying inflammatory disease, and 12 (86%) of the 14 dogs had histories of prior gastrointestinal disturbances.[23] However, poorer body condition and a history of chronic health problems may not be causally related to GDV. Instead, being lean or having a history of a major or chronic health problem in the first year of life may result from the same underlying gastrointestinal pathology that ultimately causes GDV.

The present case-control study was nested within a larger prospective study of GDV. The prospective approach to dietary exposure assessment is considered to be an advantage methodologically, because the diet for each dog was assessed prior to the development of GDV, thus reducing the chances for recall bias.[11] 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. However, changes in diet during the study were voluntarily reported by owners of 28 dogs. When such a change in diet was reported, the latest reported diet was used in the analyses.

Dry-food formulations may change over time. In order to minimize errors arising from such changes, food label information reported by owners was verified using published references.[12,13] If differences were found between the two sources of information, only the label information reported by owners was used for risk-factor analysis. However, any discrepancies between what was reported by owners and information in published references should have been nondifferential (i.e., unbiased) with respect to case and control status. Frequency matching of controls to cases on calendar year of GDV was done to ensure that their diet information was obtained for comparable time periods. Finally, the definition of a standard cup was not specified on the questionnaire, and this could lead to inconsistent reporting by owners. However, any errors that did occur in reporting the total volume of food fed daily should have been nondifferential with respect to case and control status and, therefore, unbiased.

## Conclusion

The results of this study suggest that dogs at higher risk of developing GDV by nature of their size or breed should be fed a lower volume of food at each meal and multiple (at least two) meals per day. Increasing energy intake from carbohydrates in the diet was not found to be associated with GDV risk. Given the homogeneity of the study population with respect to the types of foods consumed, the authors were unable to definitively answer the question of whether feeding dry food increases the risk of GDV. The answer to this question requires further investigation, using a different type of study design.

[a] SAS version 8.2; SAS Institute, Inc., Cary, NC
[b] Dean AG, Dean AJ, Coulombier D, *et al*. Epi Info, Version 6; a word processing, database, statistics program for public health on IBM-compatible microcomputers. Center for Disease Control and Prevention, Atlanta, GA, 1995
[c] Excel 2000; Microsoft Corporation, Richmond, WA
[d] Proc Logistic; SAS Institute, Inc., Cary, NC

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