Non-dietary risk factors for gastric dilatation-volvulus in large and giant breed dogs

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Objective—To identify non-dietary risk factors for gastric dilatation-volvulus (GDV) in large breed and giant breed dogs.

Design—Prospective cohort study.

Animals—1,637 dogs 6 months old of the following breeds: Akita, Bloodhound, Collie, Great Dane, Irish Setter, Irish Wolfhound, Newfoundland, Rottweiler, Saint Bernard, Standard Poodle, and Weimaraner.

Procedure—Owners of dogs that did not have a history of GDV were recruited at dog shows, and the dog's length and height and the depth and width of its thorax and abdomen were measured. Information concerning the dog's medical history, genetic background, personality, and diet was obtained from the owners, and owners were contacted by mail and telephone at approximately 1-year intervals to determine whether dogs had developed GDV or died. Incidence of GDV, calculated on the basis of dog-years at risk for dogs that were or were not exposed to potential risk factors, was used to calculate the relative risk of GDV.

Results and Clinical Relevance—Cumulative incidence of GDV during the study was 6% for large breed and giant breed dogs. Factors significantly associated with an increased risk of GDV were increasing age, having a first-degree relative with a history of GDV, having a faster speed of eating, and having a raised feeding bowl. Approximately 20 and 52% of cases of GDV among the large breed and giant breed dogs, respectively, were attributed to having a raised feed bowl. (*J Am Vet Med Assoc* 2000;217:1492–1499)

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 cardiogenic shock. The risk of GDV can be high in some larger breed dogs. For example, in a recently completed 5-year prospective study of > 1,900 show dogs, incidences of GDV in 7 large (23 to 45 kg [50 to 99 lb]) and 4 giant (> 45 kg [> 99 lb]) breeds were 23 and 26 cases/1,000 dog-years at risk, respectively.[1] On the basis of this incidence, lifetime risks of developing GDV for large and giant breed dogs were estimated to be 24 and 22%, respectively. However, the lifetime risk of developing GDV in the largest breeds, such as the Great Dane, was 42%. The high incidence of GDV, together with a case-fatality rate of approximately 30%, results in GDV being a leading cause of death for large and giant breed dogs.

Until recently, retrospective studies have been the primary source of information regarding risk factors for GDV. These studies indicated that older, large, and giant purebred dogs with a deep and narrow thorax that had a first-degree relative with a history of GDV were at higher risk.[2] Results of retrospective case-control studies have also suggested that other risk factors for GDV include faster eating, being fed 1 meal daily, consuming a diet of dry food only, and having a nervous or fearful temperment.[3] In contrast, dogs reported by their owners to be happy and easygoing were at decreased risk of GDV. However, findings from retrospective studies must be interpreted with caution, because information about potential predisposing conditions is collected only after a dog has already suffered an episode of GDV. Responses from owners can be biased if they have preconceived ideas about the causes of GDV or if the accuracy of their recall differs systematically from the accuracy of recall by owners of nonaffected control dogs.[4] Such bias is best avoided by querying dog owners about the presence or absence of risk factors before the onset of GDV and following the dogs prospectively to determine which ones develop GDV. A recently completed 5-year prospective study of incidence of and breed-related risk factors for GDV in dogs[1] afforded us this opportunity. As a part of that study, an effort was made to determine the impact of management factors currently recommended to reduce the incidence of GDV such as raising the dog's feed bowl, restricting exercise before and after eating, and wetting dry food prior to feeding.[5] The purpose of the study reported here, therefore, was to identify non-dietary risk factors for GDV in large and giant breed dogs. The study was designed to examine potential risk factors for individual dogs and determine the proportion of cases of GDV attributed to each factor.

Materials and Methods

Recruitment of dogs and owners—Details of the study procedure have been reported.[1] Eleven national breed clubs, namely the Akita, Bloodhound, Collie, Great Dane, Irish Setter, Irish Wolfhound, Newfoundland, Rottweiler, Saint Bernard, Standard Poodle, and Weimaraner clubs, agreed to participate in, and partially fund, a prospective study of GDV at Purdue University. Beginning in June 1994 and ending in

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Funded in part by grants from the Morris Animal Foundation, the American Kennel Club Canine Health Foundation, and the Akita, Bloodhound, Collie, Great Dane, Irish Setter, Irish Wolfhound, Newfoundland, Rottweiler, Saint Bernard, Standard Poodle, and Weimaraner national breed clubs.

†Deceased.

March 1997, the investigators visited 27 national or specialty dog shows held throughout the United States. Owners were told of the nature of the study and asked to enroll any of their dogs that were in attendance. Owners who agreed to participate were requested to provide their name, address, and telephone number, the American Kennel Club's registered name of their dog, weight of their dog, and information regarding whether their dog or any of its first-degree relatives (ie, siblings, offspring, and parents) had ever had GDV. Owners also gave written permission allowing the investigators to contact them periodically by telephone or mail. Confidentiality of all information provided by owners was emphasized. Dogs were measured at the show using a standardized protocol. These measurements included length (humeral deltoid tuberosity to ischium), height at the top of the withers, depth and width of the thorax at the level of the costal arch, and depth and width of the abdomen at the level of the umbilicus. Body condition (eg, thin, lean, optimum, overweight, obese) was also recorded. Procedures used in this study were approved by the Committee on the Use of Human Research Subjects and the Animal Care and Use Committee of Purdue University.

Data collection—Within 30 days after enrollment, owners were mailed an 8-page questionnaire designed to gather information concerning their dogs' current vital status and history of GDV. A detailed description of the questionnaire and follow-up procedures has been published.[1] Dogs that had developed GDV prior to enrollment in the study were excluded.

Data management and analysis—Data were analyzed with a statistical software program.[a] Incidence of GDV and associated 95% **confidence limits (CL)** were calculated for the 4 giant (body weight > 45 kg [> 99lb]) breeds combined (Great Dane, Irish Wolfhound, Newfoundland, Saint Bernard) and for the 7 large (23 to 45 kg [50 to 99 lb]) breeds combined (Akita, Bloodhound, Collie, Irish Setter, Rottweiler, Standard Poodle, Weimaraner), as described.[1] This same approach was used to calculate incidence of GDV for dogs that had or had not been exposed to potential host-related, morphometric, personality or temperament, and environmental or management risk factors for GDV. The relative risk and its 95% CL and *P* value were calculated for each potential risk factor (univariate analysis) by dividing the incidence of GDV among dogs that had been exposed to the risk factor by the incidence among dogs that had not been exposed. The population attributable risk for potentially modifiable risk factors for GDV was calculated on the basis of the prevalence of these risk factors and their relative risk.[6]

Risk factors associated with GDV in univariate analyses at $P < 0.2$ were included in a multivariate Cox proportional hazards regression analysis.[7] Separate hazards models were created for host, morphometric, personality or temperament, and environmental or management factors. Risk factors for which the *P* value was < 0.1 were entered into a final proportional hazards model for large and giant breed dogs combined. Risk factors for GDV in the final model were considered to be significant if *P* was < 0.05. Because there were differences among the 11 breeds in regard to size and body shape and between males and females within a breed, morphometric measurements and indices were standardized by breed and sex for the risk factor analysis. This was done by calculating the mean and SD for each measurement or index by breed and sex. Values for each dog were classified as low (> 1 SD less than the mean), medium (between 1 SD less than the mean and 1 SD greater than the mean), or high (> 1 SD greater than the mean).

Results

Signalment of dogs enrolled—Owners of 1,991 dogs answered the initial questions at dog shows, but 77 (3.9%) dogs were excluded, because they had a history of GDV. Of the remaining 1,914 dogs that were enrolled in the prospective study, vital status information was obtained for 1,843 (96.3%) at least once during the follow-up period, and the detailed questionnaire was completed for 1,660 (86.7%). Of these 1,660 dogs, 23 (1.4%) were < 6 months old at the time of enrollment in the study and were excluded from further analysis. Thus, 1,637 (82.2%) of the 1,991 dogs initially enrolled in the study were available for characterization of risk factors for GDV.

The 1,637 dogs included in the study consisted of 96 Akitas, 105 Bloodhounds, 174 Collies, 160 Great Danes, 231 Irish Setters, 170 Irish Wolfhounds, 262 Newfoundlands, 91 Rottweilers, 112 Standard Poodles, 151 Saint Bernards, and 85 Weimaraners (**Table 1**). Median age of all dogs at the time of enrollment in the study was 2.3 years (range, 0.5 to 14.6 years). There were 743 (45.4%) males and 894 (54.6%) females. Eighty-five (11.4%) of the males and 163 (18.2%) of the

Table 1—Demographics of large breed (23 to 45 kg [50 to 99 lb]) and giant breed (> 45 kg [> 99 lb]) dogs included in a study of non-dietary risk factors for gastric dilatation-volvulus (GDV)

Breed	No. of dogs enrolled	No. of males	No. of females	Median age in years (range)	Median duration of follow-up in years (maximum)
Large breed dogs					
Akita	96	54	42	2.3 (0.5–10.7)	2.0 (2.5)
Bloodhound	105	40	65	2.0 (0.5–10.9)	2.6 (2.8)
Collie	174	81	93	2.1 (0.5–12.1)	2.9 (2.9)
Irish Setter	231	96	135	3.3 (0.5–13.6)	3.0 (4.8)
Rottweiler	91	36	55	3.0 (0.6–10.3)	2.7 (2.8)
Standard Poodle	112	56	56	2.4 (0.5–14.2)	2.7 (2.8)
Weimaraner	85	35	50	2.2 (0.5–14.6)	2.5 (2.6)
Subtotal	**894**	**398**	**496**	**2.4 (0.5–14.6)**	**2.6 (4.8)**
Giant breed dogs					
Great Dane	160	63	97	2.1 (0.5–8.0)	3.3 (4.4)
Irish Wolfhound	170	75	95	2.5 (0.5–8.0)	2.8 (2.9)
Newfoundland	262	118	144	2.8 (0.5–12.1)	1.9 (2.0)
Saint Bernard	151	89	62	1.7 (0.5–8.5)	2.1 (2.5)
Subtotal	**743**	**345**	**398**	**2.3 (0.5–12.1)**	**2.0 (4.4)**
Total	**1,637**	**743**	**894**	**2.3 (0.5–14.6)**	**2.4 (4.8)**

Table 2—Univariate analysis of host risk factors for GDV in large breed and giant breed dogs

Factor	Large breed dogs				Giant breed dogs			
	No. of dogs	Incidence of GDV* (95% CI)	Relative risk (95% CI)	*P* value	No. of dogs	Incidence of GDV* (95% CI)	Relative risk (95% CI)	*P* value
Breed size	894	24 (18–30)	NA	NA	743	27 (19–35)	NA	NA
Age (y)	NA				NA			
0.5–2.9		19 (9–29)	1.00	NA		9 (1–17)	1.00	NA
3.0–4.9		9 (2–16)	0.50 (0.20–1.26)	0.18		24 (11–37)	2.81 (1.01–7.80)	0.04
≥ 5.0		42 (28–56)	2.24 (1.18–4.25)	0.01		56 (34–78)	6.52 (2.50–17.04)	0.00
Sex								
Male	398	28 (18–38)	1.00	NA	345	26 (14–38)	1.00	NA
Female	496	20 (12–28)	0.73 (0.43–1.24)	0.27	398	28 (17–39)	1.07 (0.59–1.95)	0.88
Reproductive status								
Sexually intact male	356	29 (18–40)	1.00	NA	302	28 (15–41)	1.00	NA
Castrated male	42	19 (–7–45)	0.64 (0.15–2.70)	0.76	43	12 (–12–36)	0.43 (0.06–3.21)	0.72
Sexually intact female	408	19 (11–27)	1.00	NA	323	25 (13–37)	1.00	NA
Spayed female	88	30 (6–54)	1.60 (0.64–3.97)	0.29	75	43 (11–75)	1.70 (0.71–4.07)	0.30
Body condition								
Thin or lean	51	40 (5–75)	1.72 (0.68–4.31)	0.23	52	48 (10–86)	1.76 (0.74–4.16)	0.17
Optimum	801	23 (16–30)	1.00	NA	651	27 (18–36)	1.00	NA
Overweight or obese	42	11 (–11–33)	0.46 (0.06–3.36)	0.72	40	0	0.00	0.27
Type of breeding								
Inbreeding	42	18 (–7–43)	0.95 (0.22–4.10)	1.00	15	0	0.00	0.62
Line breeding	452	29 (19–39)	1.49 (0.84–2.65)	0.21	399	24 (13–35)	0.73 (0.39–1.34)	0.35
Outcross	373	19 (10–28)	1.00	NA	293	33 (19–47)	1.00	NA
History of GDV in any first-degree relative								
No	600	17 (10–24)	1.00	NA	500	23 (14–32)	1.00	NA
Yes	210	40 (23–57)	2.33 (1.32–4.11)	0.01	170	41 (22–60)	1.75 (0.94–3.27)	0.08
History of GDV in any parent								
No	615	21 (14–28)	1.00	NA	510	26 (16–36)	1.00	NA
Yes	147	32 (15–49)	1.49 (0.79–2.84)	0.21	135	37 (16–58)	1.40 (0.71–2.75)	0.35
History of GDV in any sibling								
No	591	17 (10–24)	1.00	NA	493	26 (16–36)	1.00	NA
Yes	79	63 (29–97)	3.60 (1.85–7.01)	0.00	46	72 (22–122)	2.81 (1.28–6.19)	0.02
History of GDV in any offspring								
No	348	19 (10–28)	1.00	NA	274	31 (17–45)	1.00	NA
Yes	24	106 (13–199)	5.62 (2.07–15.23)	0.00	17	106 (2–210)	3.45 (1.17–10.20)	0.04
Speed of eating								
1–3	159	13 (2–24)	1.00	NA	111	36 (12–60)	1.00	NA
4–6	346	23 (13–33)	1.82 (0.68–4.82)	0.29	273	29 (15–43)	0.79 (0.35–1.77)	0.53
7–10	379	30 (19–41)	2.36 (0.91–6.12)	0.09	354	22 (12–32)	0.62 (0.27–1.38)	0.26
Weight of dog at 4 months								
Below average	62	18 (–2–38)	0.78 (0.24–2.51)	1.00	44	35 (1–69)	1.34 (0.47–3.80)	0.55
Approximately average	702	23 (16–30)	1.00	NA	557	26 (17–35)	1.00	NA
Above average	55	31 (1–61)	1.35 (0.48–3.76)	0.55	97	29 (6–52)	1.11 (0.46–2.66)	0.82
Puppy feeding regimen								
Maximize growth	61	13 (–5–31)	0.53 (0.13–2.17)	0.58	30	43 (–6–92)	1.72 (0.52–5.72)	0.43
Attain average growth	673	25 (18–32)	1.00	NA	456	25 (15–35)	1.00	NA
Slow growth	72	14 (–2–30)	0.55 (0.17–1.78)	0.48	209	31 (15–47)	1.24 (0.64–2.40)	0.60
Major or chronic problems during first year of life								
Yes	91	16 (0–32)	1.00	NA	93	47 (16–78)	1.00	NA
No	765	25 (18–32)	1.58 (0.57–4.38)	0.52	619	23 (15–31)	0.50 (0.24–1.04)	0.09
Major or chronic medical problems after first year of life								
Yes	119	25 (8–42)	1.00	NA	102	50 (19–81)	1.00	NA
No	721	23 (16–30)	0.93 (0.44–1.97)	0.84	579	25 (16–34)	0.51 (0.25–1.03)	0.07
Dog has eructations								
Yes	417	22 (13–31)	0.85 (0.50–1.46)	0.59	365	32 (20–44)	1.54 (0.82–2.87)	0.22
No	473	26 (17–35)	1.00	NA	371	21 (11–31)	1.00	NA
Frequency of eructations								
Rarely	169	19 (6–32)	1.00	NA	103	26 (5–47)	1.00	NA
Occasionally	167	22 (8–36)	1.16 (0.45–2.99)	0.81	172	31 (13–49)	1.23 (0.46–3.27)	0.81
Often	73	27 (3–51)	1.47 (0.48–4.50)	0.55	79	41 (11–71)	1.60 (0.54–4.76)	0.41
Dog has flatulence								
Yes	482	23 (14–32)	0.96 (0.56–1.64)	0.89	356	30 (18–42)	1.35 (0.73–2.49)	0.36
No	402	24 (15–33)	1.00	NA	376	22 (12–32)	1.00	NA
Frequency of flatulence								
Rarely	205	25 (11–39)	1.00	NA	174	23 (8–38)	1.00	NA
Occasionally	197	22 (9–35)	0.91 (0.41–2.03)	0.84	121	36 (14–58)	1.57 (0.64–3.87)	0.36
Often	72	18 (–2–38)	0.72 (0.21–2.54)	0.78	52	41 (5–77)	1.82 (0.61–5.43)	0.34
Post-prandial abdominal distention								
Yes	60	26 (1–51)	1.08 (0.39–3.00)	0.79	34	74 (15–133)	3.16 (1.33–7.50)	0.02
No	815	24 (17–31)	1.00	NA	691	24 (16–32)	1.00	NA

*No. of cases/1,000 dog-years at risk.
CI = Confidence interval. NA = Not applicable. Relative risk of GDV in giant breed vs large breeds dogs was 1.15 (95% CI, 0.77–1.71; $P = 0.54$).

Table 3—Univariate analysis of morphometric risk factors for GDV in large breed and giant breed dogs

Factor	Large breed dogs				Giant breed dogs			
	No. of dogs	Incidence of GDV (95% CI)	Relative risk (95% CI)	*P* value	No. of dogs	Incidence of GDV (95% CI)	Relative risk (95% CI)	*P* value
Height								
Low	138	23 (7–39)	0.85 (0.40–1.81)	0.86	101	13 (–2–28)	0.46 (0.14–1.49)	0.26
Medium	619	27 (19–35)	1.00	NA	536	29 (19–39)	1.00	NA
High	130	9 (–1–19)	0.35 (0.11–1.14)	0.07	102	36 (11–61)	1.25 (0.58–2.71)	0.53
Weight								
Low	114	13 (0–26)	0.48 (0.17–1.34)	0.17	113	16 (0–32)	0.53 (0.19–1.50)	0.29
Medium	662	27 (19–35)	1.00	NA	529	30 (20–40)	1.00	NA
High	118	14 (0–28)	0.51 (0.19–1.43)	0.23	101	27 (5–49)	0.91 (0.38–2.17)	1.00
Body mass index*								
Low	126	15 (2–28)	0.55 (0.22–1.39)	0.25	115	27 (7–47)	1.02 (0.45–2.34)	1.00
Medium	629	27 (19–35)	1.00	NA	509	26 (16–36)	1.00	NA
High	132	16 (2–30)	0.58 (0.23–1.45)	0.33	115	35 (12–58)	1.34 (0.63–2.85)	0.41
Thoracic depth								
Low	152	15 (3–27)	0.56 (0.24–1.33)	0.21	107	17 (0–34)	0.58 (0.21–1.64)	0.39
Medium	590	26 (18–34)	1.00	NA	530	29 (19–39)	1.00	NA
High	144	24 (7–41)	0.93 (0.43–1.98)	1.00	98	28 (6–50)	0.98 (0.41–2.33)	1.00
Thoracic width								
Low	124	24 (6–42)	1.00 (0.45–2.24)	1.00	132	13 (0–26)	0.43 (0.15–1.22)	0.11
Medium	640	23 (16–30)	1.00	NA	496	31 (20–42)	1.00	NA
High	124	24 (6–42)	1.03 (0.46–2.30)	0.84	108	26 (5–47)	0.85 (0.35–2.02)	0.84
Thoracic depth-to-width ratio								
Low	134	29 (11–47)	1.22 (0.61–2.45)	0.57	102	29 (6–52)	1.03 (0.43–2.45)	1.00
Medium	620	23 (16–30)	1.00	NA	520	28 (18–38)	1.00	NA
High	132	19 (4–34)	0.81 (0.34–1.92)	0.84	113	20 (2–38)	0.72 (0.28–1.85)	0.67
Abdominal depth								
Low	137	24 (7–41)	1.11 (0.52–2.41)	0.84	117	15 (0–30)	0.54 (0.19–1.52)	0.29
Medium	608	22 (15–29)	1.00	NA	513	28 (18–38)	1.00	NA
High	140	33 (13–53)	1.53 (0.77–3.01)	0.24	106	38 (12–64)	1.34 (0.61–2.91)	0.51
Abdominal width								
Low	136	11 (0–22)	0.39 (0.14–1.10)	0.07	120	27 (7–47)	0.85 (0.38–1.92)	0.84
Medium	619	28 (20–36)	1.00	NA	504	31 (21–41)	1.00	NA
High	133	16 (2–30)	0.56 (0.22–1.42)	0.26	112	9 (-3–21)	0.27 (0.07–1.13)	0.08
Abdominal depth-to-width ratio								
Low	139	14 (2–26)	0.56 (0.22–1.43)	0.33	106	9 (-3–21)	0.31 (0.07–1.28)	0.11
Medium	603	25 (17–33)	1.00	NA	525	28 (18–38)	1.00	NA
High	143	27 (10–44)	1.09 (0.55–2.20)	0.86	105	43 (15–71)	1.53 (0.73–3.20)	0.28
Thoracic depth-to-abdominal depth ratio								
Low	132	26 (9–43)	1.18 (0.57–2.45)	0.69	109	27 (5–49)	0.99 (0.41–2.38)	1.00
Medium	623	22 (15–29)	1.00	NA	518	28 (18–38)	1.00	NA
High	130	27 (8–46)	1.19 (0.55–2.55)	0.68	108	25 (5–45)	0.92 (0.39–2.21)	1.00

*Body mass index = Weight (kg)/[height (cm)]^2.

For each factor, the mean and SD were calculated by breed and sex. Values for each dog were then classified as low (> 1 SD less than the mean), medium (between 1 SD less than the mean and 1 SD greater than the mean), or high (> 1 SD greater than the mean).

See Table 2 for key.

females were neutered. Median duration of follow-up for the 1,637 dogs was 2.4 years (maximum, 4.8 years).

Death rate—During the follow-up period, 182 (11.1%) of the 1,637 dogs died (93/894 large breed dogs [10.4%] and 89/743 giant breed dogs [12.0%]). Of the 182 dogs that died, 29 (15.9%) died of GDV. Other common causes of death included cancer (46 dogs) and neurologic diseases (9 dogs). Twenty-four dogs died of unknown causes. Death rate for the 894 large breed dogs was 41 deaths/1,000 dog-years at risk (95% CL, 33 to 49 deaths/1,000 dog-years at risk) versus a rate of 56 deaths/1,000 dog-years at risk (95% CL, 44 to 68 deaths/1,000 dog-years at risk) for the 743 giant breed dogs ($P = 0.05$).

Incidence of GDV—Overall, 98 dogs included in the study developed GDV. We did not detect a significant ($P = 0.54$) difference between incidence of GDV among large breed dogs (24 cases of GDV/1,000 dog-years at risk; 95% CL, 18 to 30 cases/1,000 dog-years at risk) and incidence among giant breed dogs (27 cases/1,000 dog-years at risk; 95% CL, 19 to 35 cases/1,000 dog-years at risk). During the study, 21 (2.4%) of 894 large breed dogs and 20 (2.7%) of 743 giant breed dogs had at least 1 episode of GDV for each year of observation. Of the 98 dogs that developed GDV, 29 (30%) died. The cumulative incidence of GDV during the study was 6.0% for the large breed and giant breed dogs.

Risk factor analysis—In univariate analyses of potential host risk factors for GDV, increasing age and a history of GDV in any first-degree relative, or specifically in a sibling or offspring, were associated with an increased risk of GDV ($P < 0.2$) in large breed and giant breed dogs (**Table 2**). An increased speed of eating was associated with an increased risk of GDV in large breed, but not giant breed, dogs. Host factors associated with an increased risk of GDV in giant breed, but not large breed, dogs were having a thin or lean body condition, a history of chronic medical problems, and postprandial abdominal distention.

Table 4—Univariate analysis of personality and temperament risk factors for GDV in large breed and giant breed dogs

Factor	Large breed dogs				Giant breed dogs			
	No. of dogs	Incidence of GDV (95% CI)	Relative risk (95% CI)	*P* value	No. of dogs	Incidence of GDV (95% CI)	Relative risk (95% CI)	*P* value
Activity score								
1–5	110	32 (11–53)	1.00	NA	157	46 (23–69)	1.00	NA
6–10	779	22 (15–29)	0.69 (0.33–1.41)	0.29	582	22 (14–30)	0.48 (0.26–0.90)	0.04
Excitability score								
1–3	90	22 (3–41)	1.00	NA	122	32 (10–54)	1.00	NA
4–10	797	24 (17–31)	1.10 (0.44–2.77)	1.00	612	26 (17–35)	0.81 (0.38–1.76)	0.53
Aggression toward dogs score								
1–5	725	23 (16–30)	1.00	NA	640	25 (17–33)	1.00	NA
6–10	164	28 (11–45)	1.23 (0.64–2.39)	0.48	98	39 (14–64)	1.55 (0.75–3.24)	0.28
Aggression toward people score								
1–2	784	22 (15–29)	1.00	NA	679	27 (19–35)	1.00	NA
3–10	103	37 (13–61)	1.71 (0.83–3.50)	0.18	61	26 (1–51)	0.96 (0.34–2.70)	1.00
Submission to dogs score								
1–5	717	27 (19–35)	1.00	NA	586	26 (17–35)	1.00	NA
6–10	170	14 (3–25)	0.51 (0.22–1.20)	0.13	151	26 (8–44)	0.99 (0.46–2.13)	1.00
Submission to people score								
1–7	665	28 (20–36)	1.00	NA	510	25 (16–34)	1.00	NA
8–10	217	14 (4–24)	0.51 (0.24–1.07)	0.09	225	29 (14–44)	1.14 (0.60–2.16)	0.74
Happiness score								
1–7	100	30 (9–51)	1.00	NA	83	70 (30–110)	1.00	NA
8–10	790	23 (16–30)	0.76 (0.36–1.61)	0.52	655	22 (14–30)	0.31 (0.16–0.61)	0.002
Easily upset by strangers or environmental changes score								
1–5	729	24 (17–31)	1.00	NA	591	24 (16–32)	1.00	NA
6–10	161	24 (9–39)	0.99 (0.50–1.98)	1.00	149	37 (16–58)	1.54 (0.79–2.99)	0.25
Fearfulness score								
1–4	730	24 (17–31)	1.00	NA	597	26 (17–35)	1.00	NA
5–10	157	25 (10–40)	1.03 (0.52–2.05)	0.86	142	33 (13–53)	1.28 (0.63–2.60)	0.44
Trainability score								
1–6	111	25 (6–44)	1.00	NA	79	34 (7–61)	1.00	NA
7–10	777	23 (16–30)	0.93 (0.42–2.05)	0.83	657	26 (18–34)	0.76 (0.32–1.81)	0.47

See Table 2 for key.

Morphometric factors associated with a decreased risk of GDV in large breed dogs were greater height, lower weight, and lower abdominal width, whereas morphometric factors associated with decreased risk of GDV in giant breed dogs were lower thoracic width, greater abdominal width, and a lower abdominal depth-to-width ratio (**Table 3**). The only personality or temperament factor associated with an increased risk of GDV in large breed dogs was aggression to people, whereas submission to other dogs or to people decreased the risk of GDV. In the giant breed dogs, a high activity level and a high level of happiness decreased the risk of GDV (**Table 4**). Among the environmental and management factors, having a raised feeding bowl and restricting water intake before and after eating increased the risk of GDV in large breed and giant breed dogs (**Table 5**). In large breed dogs, but not in giant breed dogs, having a rural residence, restricting exercise before and after eating, and moistening dry dog food prior to feeding increased the risk of GDV, whereas attending dog shows decreased the risk of GDV. In giant breed dogs, but not in large breed dogs, having an urban residence increased the risk of GDV.

The final proportional hazards risk model included 10 potential risk factors and 1 interaction term (speed of eating × breed size). Factors significantly ($P < 0.05$) associated with an increased risk of GDV, whether adjusted for the other terms in the model or not, were increasing age, having a first-degree relative with a history of GDV, having a faster speed of eating, and having a raised feed bowl (**Table 6**). Risks of GDV for dogs with a first-degree relative with a history of GDV, compared with dogs that did not have a first-degree relative with a history of GDV, were increased 89 and 63%, respectively, in the unadjusted and adjusted risk models. The risk of GDV increased by approximately 20% with each year of age and by 38% with each unit increase in speed of eating (speed of eating was scored on a scale from 1 to 10). However, the relative risk of GDV associated with speed of eating could not be directly interpreted because of the significant interaction between speed of eating and breed size. Therefore, the relationship between speed of eating and GDV incidence was examined separately for large breed and giant breed dogs. A faster speed of eating increased the risk of GDV in large breed dogs but decreased the risk of GDV in giant breed dogs (**Fig 1**). Factors in the final model not significantly associated with risk of GDV included breed size, thoracic depth-to-width ratio, body condition, place of residence, whether water intake was restricted prior to eating, number of meals fed daily, and activity level of the dog.

Results of the final proportional hazards risk model were used to calculate the population attributable risk of GDV for significant risk factors that owners could potentially modify. For large breed and giant breed dogs in the present study, 20.4 and 51.9%, respectively, of the cases of GDV could be attributed[8] to using a raised feed bowl (**Table 7**). For the large breed dogs, 37.8% of the cases of GDV could be attrib-

Table 5—Univariate analysis of environmental and management risk factors for GDV in large breed and giant breed dogs

Factor	Large breed dogs				Giant breed dogs			
	No. of dogs	Incidence of GDV (95% CI)	Relative risk (95% CI)	*P* value	No. of dogs	Incidence of GDV (95% CI)	Relative risk (95% CI)	*P* value
Place of residence								
Urban	80	11 (-4–26)	0.55 (0.13–2.38)	0.56	52	45 (6–84)	2.15 (0.75–6.20)	0.18
Suburban	386	20 (11–29)	1.00	NA	245	21 (9–33)	1.00	NA
Rural	420	30 (20–40)	1.56 (0.89–2.74)	0.13	439	27 (17–37)	1.32 (0.65–2.67)	0.50
Regularly attended shows								
Yes	796	22 (15–29)	0.58 (0.29–1.16)	0.13	673	26 (18–34)	0.71 (0.30–1.68)	0.45
No	98	38 (14–62)	1.00	NA	70	37 (7–67)	1.00	NA
Person accompanying dog to shows								
Owner only	605	22 (15–29)	1.00	NA	596	26 (17–35)	1.00	NA
Handler only	44	9 (-9–27)	0.40 (0.05–2.90)	0.51	18	0	0	1.00
Owner and handler	126	24 (6–42)	1.06 (0.47–2.39)	0.83	46	28 (–4–60)	1.09 (0.33–3.55)	0.76
Number of dog shows during typical year								
< 10	335	23 (13–33)	1.00	NA	388	26 (15–37)	1.00	NA
10–19	208	27 (13–41)	1.18 (0.59–2.35)	0.72	170	19 (5–33)	0.72 (0.31–1.69)	0.55
≥ 20	253	17 (7–27)	0.71 (0.34–1.50)	0.46	115	36 (14–58)	1.37 (0.64–2.90)	0.41
Prophylactic gastropexy done								
Yes	12	28 (-27–83)	1.18 (0.16–8.51)	0.58	10	0	0.00	1.00
No	874	24 (18–30)	1.00	NA	716	28 (20–36)	1.00	NA
Preventive medications or supplements to prevent GDV								
Yes	55	36 (4–68)	1.59 (0.63–3.99)	0.38	26	50 (-7–107)	1.91 (0.59–6.17)	0.22
No	827	23 (16–30)	1.00	NA	703	26 (18–34)	1.00	NA
Food given ad libitum								
Yes	35	13 (-12–38)	0.52 (0.07–3.74)	1.00	16	55 (-21–131)	2.10 (0.51–8.68)	0.26
No	857	24 (18–30)	1.00	NA	726	26 (18–34)	1.00	NA
Number of meals daily								
1	159	18 (5–31)	0.68 (0.31–1.50)	0.48	96	48 (17–79)	2.06 (0.98–4.32)	0.09
2	684	26 (18–34)	1.00	NA	613	23 (15–31)	1.00	NA
≥ 3	49	9 (-9–27)	0.34 (0.05–2.44)	0.37	33	39 (-5–83)	1.68 (0.51–5.48)	0.43
Feed bowl raised								
Yes	264	40 (24–56)	2.17 (1.27–3.71)	0.01	401	34 (22–46)	1.99 (1.00–3.95)	0.05
No	625	18 (12–24)	1.00	NA	341	17 (7–27)	1.00	NA
Height of feed bowl								
Not raised	625	18 (12–24)	1.00	NA	341	17 (7–27)	1.00	NA
≤ 1 foot	105	56 (26–86)	3.06 (1.60–5.87)	0.002	60	15 (-6–36)	0.89 (0.20–4.03)	1.00
> 1 foot	144	29 (-11–47)	1.59 (0.78–3.24)	0.21	324	39 (25–53)	2.29 (1.15–4.58)	0.02
Exercise restricted before and after eating								
Yes	600	27 (19–35)	1.62 (0.85–3.07)	0.15	486	26 (16–36)	0.94 (0.50–1.76)	0.87
No	289	17 (7–27)	1.00	NA	253	28 (14–42)	1.00	NA
Water intake restricted before and after eating								
Yes	123	47 (23–71)	2.31 (1.27–4.19)	0.01	87	48 (18–78)	2.02 (1.00–4.10)	0.07
No	766	20 (14–26)	1.00	NA	652	24 (16–32)	1.00	NA
Dry food moistened								
Yes	597	29 (21–37)	2.80 (1.26–6.20)	0.01	461	27 (17–37)	0.96 (0.51–1.81)	0.87
No	271	11 (3–19)	1.00	NA	258	28 (14–42)	1.00	NA

See Table 2 for key.

Table 6—Proportional hazards model for the risk of GDV in large breed and giant breed dogs

Factor	Unadjusted			Adjusted		
	RR	95% CI	*P* value	RR	95% CI	*P* value
Age (y)	1.17	1.09–1.26	0.001	1.20	1.11–1.30	0.001
Size (giant vs large)	1.27	0.80–1.80	0.36	2.97	0.93–9.45	0.06
First-degree relative with GDV (yes vs no)	1.89	1.25–2.89	0.003	1.63	1.06–2.52	0.03
Speed of eating score	1.05	0.96–1.13	0.01	1.38	1.06–1.80	0.02
Speed of eating × size interaction	0.81	0.68–0.96	0.02	0.82	0.6–90.98	0.03
Feed bowl raised (yes vs no)	1.96	1.32–2.96	0.001	2.10	1.34–3.30	0.001

RR = Relative risk (incidence of GDV among dogs that had been exposed to the factor of interest divided by incidence among dogs that had not been exposed). CI = Confidence interval.

uted to a faster speed of eating. For all dogs, 14.3% of the cases of GDV could be attributed to having a first-degree relative with GDV. This factor was included in calculations of attributable risk, because although a history of GDV in a first-degree relative is not a modifiable risk factor (ie, it can't be changed), information about this risk factor can be used to influence breeding decisions.

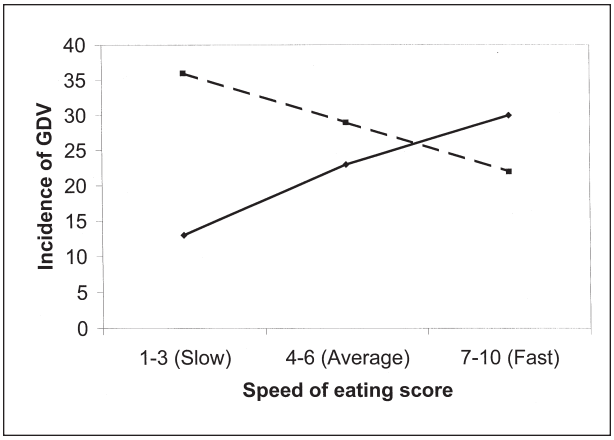

Figure 1—Incidence (No. of cases/1,000 dog-years at risk) of GDV in 884 purebred large breed dogs (solid line) and 738 purebred giant breed dogs (dashed line) as a function of speed of eating (speed of eating was scored on a scale from 1 to 10).

Table 7—Population attributable risks (AR) for potentially modifiable risk factors for GDV in large breed and giant breed dogs

Factor	Prevalence of factor (%)	RR of GDV	Population AR (%)
Feed bowl raised			
Large breed	30	2.17	20.4
Giant breed	54	1.99	51.9
Fast speed of eating (score 7–10)			
Large breed	43	2.36	37.8
First-degree relative with GDV	26	1.63	14.3

Discussion

Results of the present study confirmed that various factors suspected to be risk factors for GDV in large breed and giant breed dogs were indeed associated with development of the condition. This included increasing age and having a first-degree relative with a history of GDV. It has been suggested that increasing age is associated with stretching of the ligaments that support the stomach, which facilitates volvulus when the stomach is weighted with food.[9] Similarly, a deeper and narrower thorax is thought to change the anatomic relationship between the stomach and esophagus such that the dog's ability to eructate is impaired.[5] In the present study, however, although the risk of GDV increased as the thoracic depth-to-width ratio increased, this relationship was not significant. A genetic predisposition to GDV may operate through inheritance of a particular body shape, personality, or temperament that predisposes to GDV. As in a previous study,[3] giant breed dogs in the present study reported by their owners to be happier or to have a higher activity level were found to be at reduced risk of GDV in univariate analyses, but no association was apparent in multivariate analyses between a particular temperament or personality profile and risk of GDV. A faster speed of eating was also confirmed to be a risk factor for GDV, as in a previous study,[3] but only for large breed dogs. Why speed of eating would be a risk factor for large breed, but not giant breed, dogs was not determined. It suggests, however, that recommendations to prevent GDV should differ depending on the size of the dog.

Numerous recommendations for preventing GDV in dogs have been published in veterinary textbooks[5] and lay magazines[10] and appear in literature from dog food companies[11] and on the Internet. These recommendations typically include the following: feed several small meals daily, avoid exercise or excessive water consumption immediately before or after eating, slow the speed of eating, moisten dry food prior to feeding, and raise the level of the feed bowl to reduce air intake. However, none of these recommendations have been based on sound scientific evidence, and their efficacy has never been formally evaluated. One textbook[12] recommends that long-term management of dogs susceptible to GDV should include frequent feeding to minimize gastric distention, reduction of postprandial exercise, and avoidance of short-term consumption of large volumes of water. However, in the present study, feeding fewer meals per day, restricting exercise or water intake immediately before or after eating, and raising the feed bowl were not associated with a decreased risk of GDV in the multivariate analysis. In addition, in univariate analyses, many of the recommendations commonly made to prevent GDV, such as raising the food bowl, moistening dry food prior to feeding, and restricting water intake before and after feeding, were associated with a significantly increased risk of GDV. Most likely, however, many of these factors were significant only because of confounding. For example, owners of dogs that had a first-degree relative with GDV were more likely to restrict water and exercise before and after feeding than owners of dogs that did not have a first-degree relative with GDV. Thus, when these potential risk factors were included in a multivariate model that also included whether there was a history of GDV in a first-degree relative, they were no longer associated with an increased risk of GDV. However, even in the multivariate analysis, raising the feed bowl appeared to significantly increase, and not decrease, the risk of GDV. One can question, therefore, whether in large breed and giant breed dogs raising the feed bowl might actually increase the amount of air ingested while eating.

In a previous study,[3] a variety of stressful events, including being boarded, having a pet sitter in the house, exercising excessively, visiting a veterinarian, traveling, having strangers in the home, or changing residence, occurred more frequently during the 8 hours preceding an acute episode of GDV in affected dogs than during a comparable time period in breed- and age-matched control dogs. In the present study, however, no attempt was made to determine whether an episode of stress preceded development of GDV, because the focus was on predisposing factors rather than precipitating events.

Many dog owners in the present study reported attempting to prevent GDV by giving their dogs medications to reduce gas formation or to increase gastric motility; however, these efforts did not appear to reduce the incidence of GDV. This may be explained by the fact that owners of dogs that were at higher risk because they had a first-degree relative with GDV were

more likely to use medications in an attempt to prevent GDV. Only 22 owners in the study reported having had a prophylactic gastropexy performed on their dog, and 1 of these dogs subsequently developed GDV. On the basis of these small numbers, prophylactic gastropexy was not associated with a significantly decreased risk of GDV. However, a previous study[13] found that following an acute episode of GDV, the rate of recurrence of GDV for dogs that had a gastropexy was 4.3%, compared with a rate of 54.5% for dogs that did not undergo gastropexy. It seems likely, therefore, that gastropexy might be effective in preventing a first episode of GDV in genetically predisposed dogs.

Most breeds of dogs included in the present study were reported anecdotally or found in retrospective studies[14] to be at a significantly higher risk of GDV. Owners of such dogs frequently seek a veterinarian's advice on how to reduce their dog's risk of GDV. On the basis of findings of the present study, the strongest recommendation to prevent GDV should be to not breed a dog that has a first-degree relative that has had GDV. Results of this study suggest that the incidence of GDV could be reduced by approximately 60%, and there may be 14% fewer cases in the population if such advice were followed. However, owners may not be familiar with the medical history of the relatives of their dog. Also, because the incidence of GDV increases with age and the typical age at the time of the first episode of GDV is 10 to 12 years,[1,14] some first-degree relatives may appear healthy at the time a breeding decision is required but still develop GDV later in life. Nonetheless, not breeding dogs with first-degree relatives that have had GDV should reduce the prevalence of this disease within a breed. On the other hand, at this time, there seems to be no advantage to restricting water intake or exercise before or after eating. Slowing a dog's speed of eating should be effective in preventing GDV in large breed dogs, but it appears contraindicated in giant breed dogs. Raising the dog's feed bowl should not be done for either large breed or giant breed dogs. Finally, owners of dogs at the highest risk of GDV, such as Bloodhounds and Great Danes,[1] should discuss with their veterinarian having a prophylactic gastropexy performed at the time of surgical neutering of their dog. There is no scientific evidence indicating that gastropexy will prevent a first occurrence of GDV; however, gastropexy has been shown to prevent a recurrence of GDV following an acute episode.[13]

Owners of high-risk dogs often seek information concerning diet or feeding changes that might reduce the risk of GDV. In previous studies, it has been shown that dogs fed only dry dog food[3] or foods containing particles < 30 mm in diameter[15] were at increased risk of developing GDV. However, no specific food types or ingredients have yet been implicated in the pathogenesis of GDV. Detailed dietary information was collected as part of the prospective study of which the present study represents a portion. Findings of the dietary analysis will be the subject of a later report.

[a]Proc Univariate, Proc Phreg, SAS Institute, Cary, NC.

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