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Topical Review

Inherited and Predisposing Factors in the Development of Gastric Dilatation Volvulus in Dogs

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This review article summarizes what is known as well as what is undetermined concerning the inherited and environmental pathogenesis of gastric dilatation volvulus in dogs. The disorder primarily affects large and giant, deep-chested breeds. A concise description of a typical dog affected with gastric dilatation volvulus is presented.

Gastric dilatation volvulus (GDV), commonly known as bloat, is a complexly inherited disorder. There are multiple inherited, as well as environmental, factors that must add together to produce a dog with clinical GDV. Several studies have looked into predisposing inherited and environmental factors for the development of GDV; however, the current state of knowledge does not produce a concrete picture of the pathogenetic mechanisms involved. This article summarizes what is known, as well as what is undetermined, about the genetic pathogenesis and clinical expression of GDV in dogs.

Breed and Sex Differences

Several studies have documented breed predilection for developing GDV in dogs. A compilation of published articles and breed health surveys lists 46 breeds susceptible to the condition (Table 1).[1] All of these are large and giant-sized, deep-chested dog breeds.

Most of the published literature on GDV in dogs is studies reporting various characteristics of dogs presenting to emergency centers for treatment of GDV. Although these do not enable prevalence figures, they do list the most common breeds and mixed-breed dogs presented. A compilation of such articles shows the German Shepherd Dog to be the most frequent breed presented for GDV, followed by the Great Dane, mixed-breed dogs, Standard Poodle, Labrador Retriever, Akita, Golden Retriever, Saint Bernard, Doberman Pincher, and Chow (Table 2).[2-7] Although mixed-breed dogs were the third most frequent presentation, they were outnumbered by purebred dogs 8.6 to 1. The size and body type of the mixed-breed dogs were not identified in the articles, so the relationship of large or giant body size or deep-chested body type of the mixed-breed dogs relating to GDV could not be determined.

A study from the University of Pennsylvania describing 295 dogs presented for GDV between 1986 and 1992 identified the German Shepherd Dog (21% of GDV cases; 4.1 odds ratio [OR]), followed by the Great Dane (14%; 14.5 OR), large (> 20 kg) mixed-breed dog (10%; 5.2 OR), Doberman Pinscher (6.1%; not available), and Standard Poodle (5.1%; 5.5 OR) as the most commonly represented breeds.[8]

Glickman et al.[9] at Purdue University compiled data from the Veterinary Medical Database registry of 12 veterinary teaching hospitals including 1934 cases of GDV between 1980 and 1989. They found the following breeds to have the highest risk of developing GDV vs. mixed-breed dogs: Great Dane (41.4 OR), Saint Bernard (21.8 OR), Weimaraner (19.3 OR), Irish Setter (14.2 OR), Gordon Setter (12.3 OR), Standard Poodle (8.8 OR), Basset Hound (5.9 OR), Doberman Pinscher (5.5 OR), Old English Sheepdog (4.8 OR), and German Shorthaired Pointer (4.6 OR). Breeds at high risk whose numbers precluded statistical analysis included the Irish Wolfhound, Borzoi, Bloodhound, Mastiff, Akita, and Bullmastiff.

Glickman et al.[10] also performed a prospective study focusing on 7 large and 4 giant breeds. They found that the Great Dane had the highest incidence at 53 cases of GDV per 1000 dog years, followed by the Bloodhound (39 cases), Irish Wolfhound (26), Akita (25), Irish Setter (24), Standard Poodle (24), Collie (21), Weimaraner (21), Newfoundland (10), Saint Bernard (6), and Rottweiler (4). They did not find a significant difference between large (23 cases per 1000 years) or giant (26 cases per 1000 years) breeds in general, although there were significant differences in prevalence between the breeds.

A study in the United Kingdom sought to determine prevalence and risk of death due to GDV in purebred dogs through a health survey.[11] The top 10 breeds identified were the Grand Bleu de Gascogne (21.4% prevalence of GDV; 50.0% prevalence of death due to GDV), Bloodhound (14.3%; 30.5%), Otterhound (9.0%; 7.4%), Irish Setter (7.2%; 5.3%), Bracco Italiano (5.3%; not available), Weimaraner (5.0%; 11.6%), Saint Bernard (4.6%; 15.1%), Borzoi (4.5%; 9.2%), Italian Spinone (3.6%; 6.4%), and Akita (3.5%; 10.7%). This study had reported bias due to the voluntary nature of filling out surveys, inflated prevalence from breeds with small numbers of

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Table 1
Dog Breeds Reported to be Susceptible to Gastric Dilatation and Volvulus. Listed in Alphabetical Order

Airedale Terrier	Golden Retriever
Akita	Gordon Setter
Anatolian Shepherd Dog	Great Dane
Basset Hound	Great Pyrenees
Beauceron	Greater Swiss Mountain Dog
Bernese Mountain Dog	Irish Red and White Setter
Bloodhound	Irish Setter
Borzoi	Irish Wolfhound
Bouvier des Flandres	Komondor
Briard	Leonberger
Bullmastiff	Mastiff
Cane Corso	Neapolitan Mastiff
Chesapeake Bay Retriever	Newfoundland
Chinese Shar-Pei	Old English Sheepdog
Chow Chow	Otterhound
Collie	Poodle (Standard)
Curly Coated Retriever	Rottweiler
Doberman Pinscher	Saint Bernard
Dogue de Bordeaux	Samoyed
Flat-Coated Retriever	Scottish Deerhound
German Shepherd Dog	Spinone Italiano
German Shorthaired Pointer	Sussex Spaniel
Giant Schnauzer	Weimaraner

surveys, and the British Association for German Shepherd Dogs declining to take part in the survey.

In an Internet survey conducted in the United States specifically on GDV, prevalence data could not be generated.[12] However, the most common presenting breeds were the German Shepherd Dog (148 cases), Great Dane (136), Standard Poodle (62), Doberman Pinscher (42), other purebred (701) and mixed-breed dogs (25). Sex and neuter status did not affect the predisposition.[12]

A prevalence study of common inherited conditions conducted at the University of California-Davis for cases seen between 1995 and 2010 found the Saint Bernard (3.76% of breed presentations for GDV), Irish Setter (3.42%), Bloodhound (3.39%), Great Dane (2.80%), and Irish Wolfhound (2.70%) to be the most prevalent breeds with GDV.[13] Mixed-breed dogs had a lower probability of presenting with GDV (only 0.20% of cases).[13]

In the prevalence studies listed earlier, results were skewed away from popular breeds (such as the German Shepherd Dog) and mixed-breed dogs, because of their increased frequency of presentation for other diagnoses.[9,11,13] In the mentioned studies, mixed-breed dogs accounted for 6.0%-15.7% of GDV-affected dogs.[2,4-9,12,13] Calculated ORs for purebred dogs to develop GDV vs. mixed-breed dogs in different studies were 1.56,[13] 2.5,[9] and 4.8.[14]

In a case-control study, Glickman et al.[15] found more males than females affected with GDV, but in a larger study found that the difference was not statistically significant. There was a slightly decreased risk for GDV in neutered males and females compared with sexually intact dogs, but this difference was not statistically significant.[9,10] The UK study found more females (55%) affected with GDV than males, and more intact males (69%) than neutered males, but no statistical analysis was reported on this data.[11] The University of Pennsylvania study found more males (54%) affected with GDV than females.[8] Neuter status in general was not significant; however, intact females had a 1.68 OR for GDV vs. spayed females. The researchers felt that the neuter status as a risk factor for GDV in dogs required further evaluation.[12] A study of Great Danes found no difference based on sex or neuter status.[16] None of the studies attempted to statistically control for the size differential between the sexes in determining risk for GDV.

In all of the published studies, there was inherent bias in the population of dogs presented to the institution, data collection method, and its analysis. However, the overall trend showed significant differences between breeds, with large and giant breeds predominating.

Inherited Physical Factors

Within each breed, there are significant differences found between dogs that present with GDV and within breed controls.

Table 2
Most Commonly Represented Dog Breeds in the Literature on Gastric Dilatation and Volvulus in Dogs. Breeds are Ordered From Most Commonly Represented to Least Commonly Represented

Breed	Publication						Total
	Sartor et al.[2]	Beer et al.[3]	Green et al.[4]	Israeli et al.[5]	Mackenzie et al.[6]	Beck et al.[7]	
German Shepherd Dog	17	14	14	14	40	23	122
Great Dane	16	9	13	6	30	15	89
Standard Poodle	22	5	12	–	24	13	76
Labrador Retriever	10	9	6	2	19	6	52
Akita	7	–	3	1	17	8	36
Golden Retriever	4	–	2	1	17	12	36
Saint Bernard	8	8	8	3	–	–	27
Doberman Pinscher	7	–	2	–	14	–	23
Chow Chow	–	–	3	2	13	–	18
Collie	–	–	–	–	–	10	10
Rottweiler	6	–	3	–	–	–	9
Mastiff	–	–	3	1	–	5	9
Weimaraner	–	–	2	6	–	–	8
Bloodhound	–	–	–	–	–	6	6
Basset Hound	–	–	4	2	–	–	6
Belgian Shepherd	–	–	–	5	–	–	5
Great Pyrenees	–	–	1	4	–	–	5
Boxer	–	–	–	3	–	–	3
Husky	–	–	2	–	–	–	2
German Shorthaired Pointer	–	–	2	–	–	–	2
Samoyed	–	–	–	2	–	–	2
Newfoundland	–	–	–	2	–	–	2
Bernese Mountain Dog	–	–	–	1	–	–	1
Other pure breeds	37 (25%)	33 (42%)	7 (7%)	4 (6%)	–	56 (34%)	137
Mixed breeds	17 (11%)	–	14 (14%)	7 (11%)	19 (6%)	22 (14%)	79

Studies show that increased body weight in general increases the risk for GDV, but this is not associated with body condition score.[9] A lean body condition was associated with an increased risk of developing GDV.[15,17] The most significant finding in the relationship of body conformation to GDV is an increased incidence with increasing thoracic-depth-to-width ratio.[9,18,19] In both large and giant breeds, the risk of developing GDV also increased with increasing age.[9,10,16,20,21]

Temperament was found to be significant in the risk for developing GDV. Glickman's group found that fearful and nervous dogs had an increase in cases of GDV, whereas those identified by their owner to have a "happy" temperament had a lower incidence of GDV.[10,15]

Relatives of dogs who have had an episode of GDV had an increased risk of developing GDV. This was especially significant for first-degree relatives (parent, sibling, or offspring).[17,18,20] A study showed a higher mean coefficient of relationship between GDV dogs and controls, indicating inherited risk factors.[18]

Non–Diet-Related Environmental Factors

Studies show the relationship of environmental stress to the development of GDV. A study showed recent kenneling or a car journey to predispose to a GDV episode.[21] Other studies showed that stress in general, including agitation in response to strangers or environmental changes were related to episodes of GDV.[10,15]

Several studies have linked atmospheric variables to increased episodes of GDV. A study in military dogs in Texas showed a positive association of increased atmospheric pressure on the day before and the day of a GDV event.[22,23] The same group also found that half the episodes of GDV occurred during the months of November to January.[23,24] Glickman's group found an increased frequency of GDV admissions during November to December, but found the association spurious due to decreased total admissions during these months.[9] In a study in Switzerland, no significant association was found between GDV occurrence and atmospheric pressure, humidity, or season.[25]

Diet-Related Factors

A Danish study showed that smaller food size particles increased the risk for GDV in Great Danes.[16] In a large study of dietary components, the only factor found to be significantly associated with GDV was dry foods containing an oil or fat among the first 4 ingredients. It was cited that fat slows gastric emptying into the duodenum.[26] Studies also show that feeding a single food type, especially dry food, increased the risk for GDV. Adding table food, fish, or eggs may decrease the risk.[12,15,21] Several studies showed that feeding a large volume of food at a time increased the risk of developing GDV, with the highest risk being dogs fed a large meal once a day.[15,17,21]

The role of aerophagia and stomach gas as a risk factor for GDV has been controversial. Some owners claim that their dogs that develop GDV gulp air.[12,21] Studies show that dogs that eat rapidly have an increased incidence of GDV.[15,20] However, studies of the stomach gas content of dogs presenting with GDV show that the gas is from fermentation and not atmospheric gas.[27] Some owners feel that dogs will swallow less air with raised food bowls. However, Glickman's group showed that raising food bowls actually increased the risk for GDV.[20]

A study of dogs showed that the presence of a gastric foreign body increases the OR of developing GDV by 4.9.[14] A large Internet survey study showed that moderate daily and postprandial activity appeared to be beneficial to dogs prone to GDV,[12] although other studies have suggested that exercising after a meal may increase GDV risk.

Putting it All Together

It is obvious that inherited factors are at play in the pathogenesis of GDV. Many of these relate to the large body size and deep-chested structure of the predisposed breeds. This provides a large abdominal body cavity for a stomach heavily laden with food to stretch the hepatogastric ligament,[28] allowing for increase motion and volvulus of the stomach. Predisposing pathology of the hepatogastric ligament may also promote stretching. The fact that risk for GDV increases with increasing age may relate to the progressive stretching of the hepatogastric ligament. Single large meals of heavy dry food are also a contributing factor.

A lean body condition diminishes the amount of abdominal fat that can act like "styrofoam packing peanuts" to stabilize the stomach and prevent volvulus. A nervous temperament can also relate to a lean body condition. However, it can also relate to increased gastric contractions and a possible predisposition to abnormal gastric motility.

The difference between simple gastric dilatation and dilatation with volvulus has been debated for some time. It used to be that the differentiation was whether a stomach tube could be easily passed (simple bloat) or if a tube could not be passed at all (volvulus). Years ago, veterinarians did not take the time for on-admission radiographs with wet chemical processing owing to the emergency nature of the condition. Now with rapid digital processing, we find that most affected dogs have some degree of volvulus. The fact that gastropexy prevents the reoccurrence of GDV[29] suggests that volvulus is the primary factor in presentation.

Future studies need to focus on the genetic factors having to do with body size, conformation, temperament, gastric motility and contraction, and microscopic anatomy of the stomach and hepatogastric ligament. Genetic studies also need to be performed on the gut microbiome of GDV-affected dogs, and the GDV-associated epigenome, transcriptome, metabolome, and proteome.

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