



Survey of owners on population characteristics, diagnosis, and environmental, health, and disease associations in dogs with megaesophagus

Jillian M. Haines*

Department of Veterinary Clinical Sciences, College of Veterinary Medicine, Washington State University, PO Box 647060, Pullman, WA 99164-7060, USA

ARTICLE INFO

Keywords:

Megaesophagus
Canine
Regurgitation
Hypothyroidism
Myasthenia gravis

ABSTRACT

Megaesophagus affects dogs worldwide but limited information is available regarding its characteristics in the general population of dogs. The objectives of this study were to provide information on a large population of dogs diagnosed with megaesophagus in regards to population characteristics, medical and family history, diagnosis, concurrent disease, and predisposing factors. A link to a web-based survey was provided on megaesophagus support websites and 838 eligible surveys were evaluated. Breeds most frequently associated with congenital megaesophagus were German shepherds, mixed breed “goldendoodles”, Labrador retrievers, great Danes, and dachshunds. Breeds most often associated with acquired megaesophagus were Labrador and golden retrievers, Chihuahuas, boxers, German shepherds, dachshunds, and Rottweilers. Diagnosis was most often by a general practitioner (63.6%) via plain radiographs (63.3%) and/or barium study (45%). Congenital megaesophagus was diagnosed in 41.3% of dogs and persistent right aortic arch in 4.3%. Diseases most commonly associated with acquired megaesophagus were myasthenia gravis (19.3%), esophagitis (10.8%), hypothyroidism (8.8%). Survey results support previous breed predilections and identified dachshunds, boxers, Chihuahuas, Rottweilers, and “goldendoodles” as additional at risk breeds. Myasthenia gravis was found at lower rates than previous described and contrary to recent studies, hypothyroidism was found in relatively high prevalence. Most dogs were diagnosed by a general practitioner suggesting previous studies at referral facilities may be biased towards dogs with more severe disease and worse outcomes.

1. Introduction

Megaesophagus is defined as hypomotility and dilation of the esophagus (Washabau, 2003). This clinical finding is often considered uncommon and with the long-standing belief that it carries a guarded to poor prognosis, many dogs may be euthanized without treatment (Boudrieau and Rogers, 1985; Harvey et al., 1974; McBrearty et al., 2011). The most common causes of megaesophagus are idiopathic congenital and idiopathic acquired, but many other diseases have been implicated in its development (Gaynor et al., 1997; Harvey et al., 1974; McBrearty et al., 2011; Washabau, 2003). Studies reported so far have focused on small populations of dogs all seen at referral or specialty hospitals and do not provide a broad look at the general megaesophagus population, in particular those dogs with more manageable disease (Boudrieau and Rogers, 1985; Harvey et al., 1974; McBrearty et al., 2011; McBrearty et al., 2011).

Dogs with severe or acute disease manifestations or associated

complications may be more likely to present at a referral facility, resulting in a data set biased towards certain disease conditions. Aspiration pneumonia (AP) has been found to be a risk factor for death in dogs with ME and the risk of AP may be increased with certain underlying diseases such as myasthenia gravis (MG) (McBrearty et al., 2011; Shelton, 2002). It is possible that other conditions may be occurring more frequently but be underrepresented in the literature due to the ability for general practitioners to diagnose and treat these diseases without the need for referral. For reasons such as these, the true prevalence of ME and associated disease conditions remains unclear.

With advancements in social media and internet groups, client driven medical data is now easily available online. Accessibility to a large number of megaesophagus dog owners enables a much larger sample group to be assessed than that seen by a single hospital or institution. Furthermore, these groups are more diverse and likely include a larger subset of dogs with mild clinical signs or well controlled disease and not just those requiring care at a referral facility.

* Corresponding author.

E-mail address: jmhaines@wsu.edu.

The main objective of reporting the survey information detailed in this study is to provide information on a large population of dogs diagnosed with megaesophagus in regards to medical and family history, diagnosis, concurrent disease, and environmental and medical factors. The study further provides information on population characteristics including age, breed, and geographic location.

2. Materials and methods

The survey was developed and distributed by a community organization focused on megaesophagus awareness and support (Upright Canine Brigade). The survey was advertised through an online megaesophagus website (Caninemegaesophagusinfo.com) and support groups (Canine Megaesophagus Support Group Facebook Page, Upright Canine Brigade Facebook Group) and was thus available worldwide. The survey was developed without input from a veterinarian and open to anyone utilizes these online sites. There were no restrictions imposed based on current status of the dog at the time of the survey. A link was provided directly from the websites to an online survey platform (Survey Monkey, San Mateo, CA). Participants were asked a variety of questions in categories including demographics, individual dog characteristics, diagnostic history, medical history, concurrent diseases, contributing causes, environment, and family history. Question responses were generally through selection from a menu of options. For some questions, owners had the option of selecting multiple choices if appropriate or writing in a response/further commenting on their response. ME due to persistent right aortic arch (PRAA) were considered separately from general questions on congenital ME.

Participant responses were anonymous and an Institutional Review Board (IRB) exemption was obtained before performing data analysis. Data was analyzed using data analysis software (Microsoft Excel, Redmond, WA) and reported as percentages of the responding population.

3. Results

A total of 868 responses were evaluated spanning a time frame from December 2014–May 2015. Thirty responses were excluded as they indicated the dog had been diagnosed by clinical signs only and no other diagnostic testing was performed. A final total of 838 responses were used for this report.

3.1. Population characteristics

3.1.1. All dogs with megaesophagus

Dogs were described as either male ($n = 460$, 54.9%) or female ($n = 371$, 44.3%) but spay/neuter status was not asked. There were 7 non-responders for this question. Mixed breed dogs composed the largest portion of the population with 224 individuals (25.8%). The remaining population contained 105 different pure breeds, with 121 German shepherd dogs (13.9%) and 73 Labrador retrievers (8.4%) having the largest representation. Breeds with at least a 1% frequency included 33 great Danes (3.8%), 29 Dachshunds (3.5%), 27 golden retrievers (3.1%), 26 boxers (3%), 18 Chihuahuas (2.1%), 15 Rottweilers (1.7%), 12 bulldogs (1.4%), 11 French bulldogs (1.3%), 9 miniature Schnauzers (1%), 9 Pugs (1%) and 9 Yorkshire terriers (1%). The remaining 92 pure breeds were represented by fewer than 9 individuals each and 66 breeds were represented by only 1–2 individuals per breed. While still considered a mixed breed, it was noted that 34 ‘goldendoodles’ (5.4%) were also present in the population while comparatively 7 ‘labradoodles’ (0.8%) were identified. There were no non-responders for this question.

3.1.2. Age

Owners were asked the age at which their dog was diagnosed with megaesophagus. For 13 responses the age was unknown or not given.

Most dogs were diagnosed at < 6 months of age ($n = 267$, 32.1%). Other responses were diagnosis at 6–12 months of age ($n = 84$, 10.1%), 1–5 years ($n = 210$, 25.3%), 5–9 years ($n = 147$, 17.8%), and > 9 years ($n = 124$, 14.9%).

3.2. Dogs with congenital megaesophagus

Respondents were asked to specify if their dog's had been diagnosed with a congenital form of megaesophagus. A total of 676 individuals responded to this question. Most respondents selected yes ($n = 279$, 41.3%) and of these dogs 131 (47%) were female and 148 (53%) were male. In dogs reported as having congenital ME 205 reported a diagnosis occurring before 6 months of age, 44 between 6 and 12 months of age, 12 between the ages of 1–2, and 18 at > 2 years of age. Within these dogs, 47 different pure breeds as well as mixed breeds were represented. The most common breeds associated with idiopathic congenital ME were German Shepherd dogs ($n = 75$, 27.9%), Labrador retrievers ($n = 16$, 5.9%), great Danes ($n = 15$, 5.6%), dachshunds ($n = 9$, 3.3%), and miniature schnauzers ($n = 6$, 2.2%). There were 79 (29%) mixed breeds dogs, with 17 (6.3%) identified as “goldendoodles” and 2 identified as “labradoodles” (0.7%). The remainder of respondents selected no ($n = 249$, 36.8%), and unsure ($n = 148$, 21.9%).

Six hundred and seventy-three individuals responded when asked if their dog had been diagnosed with a persistent right aortic arch (PRAA). The majority of those that responded stated that their dogs had not been diagnosed with PRAA ($n = 571$, 84.3%) with only 29 (4.3%) confirming a diagnosis of PRAA, 73 (10.9%) unsure, and 165 did not respond. The age of diagnosis was before 6 months of age in 26 dogs and between 6 and 12 months in 3. Of the 29 dogs diagnosed with PRAA, 13 different pure breeds. The most common breeds reported were German shepherd dogs ($n = 9$, 31.0%), Boxers ($n = 3$, 10.3%), and dachshunds ($n = 2$, 6.1%). There were 5 (17.2%) mix breed dogs including 1 each of goldendoodle and labradoodle. There were more females ($n = 20$, 69%) than males ($n = 9$, 31%) represented in this group.

3.2.1. Dogs with acquired megaesophagus

Two hundred and forty-nine respondents stated that their dog had megaesophagus due to a non-congenital (acquired) cause. Of these dogs, 101 (41.1%) were female and 148 (58.9%) were male. Diagnosis occurred before 6 months of age in 3 dogs, between 6 and 12 months of age in 6 dogs, between the ages of 1–2 in 15 dogs, and at > 2 years of age in 225 dogs. Within these dogs, 61 different pure breeds as well as mixed breeds were represented. The most common breeds associated with acquired ME were Labrador retrievers ($n = 28$, 11.2%), golden retrievers ($n = 17$, 6.8%), Chihuahuas ($n = 13$, 5.2%), boxers ($n = 10$, 4%), German shepherd dogs ($n = 9$, 3.6%), dachshunds ($n = 8$, 3.2%), and Rottweilers ($n = 8$, 3.2%). There were 62 (24.9%) mixed breeds dogs, with 1 each identified as “goldendoodle” or “labradoodle”. The remainder of respondents selected that they were unsure if their dog had a congenital form ($n = 148$, 22%).

3.2.2. Location and acquisition

The majority of all respondents described acquiring their dogs in the United States of America ($n = 681$, 81.3%), with 222 (80%) of dogs with congenital ME and 199 (80%) of dogs with acquired ME coming from the USA. Other countries noted were Canada ($n = 61$, 7.3%) with 23 (8.2%) congenital and 21 (8.4) acquired dogs, United Kingdom ($n = 36$, 4.3%) with 18 (6.5%) congenital and 11 (4.4%) acquired, and Australia ($n = 19$, 2.3%) with 9 (3.2%) congenital dogs and 7 acquired (2.8%). Nineteen other countries were also reported, with each representing < 1% or no > 4 individuals. There were 8 non-responders.

Almost all respondents ($n = 837$) provided an answer as to where they obtained their dog. For the entire survey population the majority of all dogs were obtained from breeders ($n = 341$, 40.7%), rescues ($n = 147$, 17.6%), or shelters ($n = 108$, 12.9%). Other responses were

the dog was given to them ($n = 77$, 9.2%), from a store ($n = 30$, 3.9%), found wandering ($n = 21$, 2.5%), from a veterinarian ($n = 11$, 1.3%), or from another source not listed ($n = 99$, 12.2%). For dogs with stated congenital ME ($n = 279$), most were obtained from a breeder ($n = 135$, 48.4%), rescue ($n = 41$, 14.7%), or shelter ($n = 27$, 9.7%). For dogs identified as having non-congenital (acquired) ME ($n=249$), again most were obtained from a breeder ($n = 107$, 43%), rescue ($n = 37$, 14.9%), shelter ($n = 29$, 11.6%).

3.2.3. Familial history

The survey asked several questions regarding the familial history of the dogs. Owners were asked if either of the dog's parents had megaesophagus and if so, if the dam or sire was affected? No response was given in 543 of the surveys. For the remaining 295 surveys, only 3 of those (1%) stated that a parent of their dog was known to have ME and in all cases the parent was the dam. Of those 3 dogs all were reported to have congenital ME. Fifty percent stated that neither parent was affected and the remaining 49% responding with unsure.

Owners were additionally asked if either of the dog's parents had myasthenia gravis and if so, if the dam or sire was affected? There was no response provided in 549 of the surveys. Of the remaining 289 surveys, no respondents selected that a parent was known to have MG. A total of 125 respondents (56%) specified that no parent had MG and 164 (43.3%) were unsure.

Owners were further asked if any of the dog's litter mates ever been diagnosed with megaesophagus? There were 101 individuals who did not respond to the question. Another 500 (67.8%) responded that they did not know. A total of 72 (9.8%) of 737 responders stated that their dog was known to have littermate(s) diagnosed with ME and 165 (22.3%) stated that no littermates were affected. There were 14 different pure breeds stated to have littermates affected. Most common breeds were German Shepherd ($n = 11$), great Dane ($n = 10$), Labrador ($n = 10$), Dachshund ($n = 4$), Weimaraner ($n = 4$), Boxer ($n = 2$), mix ($n = 22$). Of the mix breeds there were 8 "goldendoodles" and 1 "labradoodle" represented. Within this group 52 respondents stated that their dog's ME was congenital, 5 were unsure, and 15 did not provide a response for whether their dog's ME was congenital.

3.3. Diagnostic testing

Owners were asked about the type of testing performed during the diagnostic process resulting in the diagnosis of megaesophagus in their dog and who the individual or institution was that determined the diagnosis. Fourteen owners did not respond leaving a total of 824 respondents. For questions regarding diagnostic testing, owners could select all that apply. Ninety selected "by symptoms only" but additionally selected other diagnostic options. Table 1 shows the diagnostic testing that was performed. Plain radiographs were the only method of diagnosis used in 353 (42.8%) dogs. Barium study

radiographs were the only method of diagnosis in 251 (30.4%). Owners were given the option to select unsure with unsure being selected in combination with other diagnostics in 14 surveys and selected as the only answer in 7 surveys. A total of 142 owners (17.2%) selected > 1 diagnostic, with 121 (14.7%) selecting 2 diagnostics, 19 (2.3%) selecting 3, and 2 (0.2%) selecting 4. A combination of plain radiographs and barium study radiographs was most common with 87 owners (10.5%) stating their dog as diagnosed by a combination of the two diagnostics. Respondents were also given the option to further comment on their response and these comments were used to clarify selections but did not alter the results. Dogs were reported to be most commonly diagnosed by their regular veterinarian or an internal medicine specialist (Table 2).

3.4. Concurrent diseases

Owners were further queried on clinical signs that may represent concurrent disease processes. Five hundred and twenty-five individuals responded when asked if there was a change in their dog's voice or bark, with 145 (27.6%) of those stating yes, 355 (67.6%) stating no, and 25 (4.8%) selecting other. A change in voice or bark was reported in dogs with stated congenital ME or acquired ME by 34 (12.1%) and 74 (29.7%) of respondents respectively. Responses written in were most commonly categorized as the dog being too young to determine ($n = 5$), not usually predisposed to barking ($n = 5$), having vocal changes only in association with regurgitation or retained food/liquid/or saliva ($n = 5$), no longer barking ($n = 4$), or unsure ($n = 2$).

Ninety (17.0%) out of a total 530 respondents stated that their dogs dragged their toes or feet while walking. Sixteen (5.7%) dogs with stated congenital ME and 50 dogs (20%) with acquired ME reported this change. The majority of respondents answered no ($n = 424$, 80.0%) and the remainder selected other ($n = 16$, 3%) and wrote in a response. The most common categories for write in responses were that the dogs dragged their feet due to unrelated orthopedic or neurologic issues ($n = 4$), other unknown gait abnormalities ($n = 9$), or unsure ($n = 2$).

Owners were asked about conditions their dogs had been diagnosed with at any time before and following diagnosis of megaesophagus. Owners were given a menu of conditions to select from and could also write in responses. There were 130 and 268 respondents for the before and after questions respectively. Conditions traditionally associated with ME that were diagnosed most commonly both prior to and following the diagnosis of ME were esophagitis, hypothyroidism, and myasthenia gravis. The conditions diagnosed most frequently before and after the ME diagnosis are listed in Table 3. No dogs were reported to have been diagnosed with botulism, tetanus, or leukodystrophy.

3.5. Environmental and medical exposures

3.5.1. Environmental

Additional questions in the survey focused on environmental effects as well as veterinary procedures that occurred prior to the diagnosis of ME. Twelve dogs were said to have ingested household chemicals (1 with congenital ME, 7 with acquired ME, and 4 unknown), 6 ingested fertilizer (none with congenital ME, 4 with acquired ME, and 2 unknown), 1 was bitten by a snake (acquired ME), and none were known to have ingested lead. The most frequently reported ingestion was of a foreign body (ie bone, toy, rock) with 118 (14.1%) of respondents reporting occurrence (16 with congenital ME, 58 with acquired ME, and 44 unknown. Owners were surveyed on the type of food bowl used prior to diagnosis. Twenty five owners did not respond and 41 selected that they did not know. The most common bowl types were stainless steel (445, 54.7%), plastic (172, 21.2%), and ceramic (104, 12.8%). When other was selected, 37 (4.6%) stated that the dogs had not yet been weaned and using a food bowl at the time of diagnosis. Stainless steel bowls were also used most commonly in dogs with congenital ME ($n = 116$, 42%) followed by plastic ($n = 73$, 26.2%), then ceramic

Table 1
Diagnostic tests utilized to determine diagnosis of megaesophagus in respondents' dogs.

Diagnostic	All Dogs ($n = 824$)	Congenital ($n = 279$)	Acquired ($n = 249$)
	Number (Percent)	Number (Percent)	Number (Percent)
Plain Radiographs	522 (63.3)	142 (50.9)	189 (75.9)
Barium Study	371 (45)	157 (56.3)	72 (28.9)
Radiographs			
Endoscopy	58 (7)	14 (5)	9 (3.6)
MRI	15 (1.8)	1 (0.4)	4 (1.6)
CAT Scan	13 (1.6)	2 (0.7)	0 (0)
Exploratory surgery	14 (1.7)	4 (1.4)	1 (0.4)
Unsure	21 (2.5)	8 (2.9)	0 (0)

Table 2
Individual who diagnosed megaesophagus in respondents' dogs.

Diagnostician	All Dogs (n = 824)	Congenital (n = 279)		Acquired (n = 249)	
	Number (Percent)	Number (Percent)		Number (Percent)	
Owner's Regular Veterinarian	524 (63.6)	189 (67.7)		160 (64.3)	
General Practitioner (not regular vet)	8 (1)	7 (2.5)		3 (1.2)	
Internal Medicine Specialist	101 (12.2)	20 (7.1)		33 (13.3)	
Other specialist	11 (1.3)	1 (0.4)		4 (1.6)	
Veterinary Teaching Hospital	48 (5.7)	16 (5.7)		11 (4.4)	
Emergency Hospital	97 (11.8)	33 (11.8)		36 (14.5)	
Rescue/Shelter	8 (1)	4 (0.5)		0 (0)	
Unsure	20 (2.4)	6 (0.7)		2 (0.2)	
Other	5 (0.6)	1 (0.9)		0 (0)	
Not reported	2 (0.2)	2 (0.2)		0 (0)	

(n = 31, 11.1%). When owners selected other they most often stated that the dogs had not been weaned and using a bowl at the time of diagnosis (n = 24, 8.6%). Dogs with acquired ME were also stated to have been using stainless steel bowls most often (n = 158, 63.5%) with plastic (n = 41, 16.5%) and ceramic (n = 38, 15.3%) bowls also used.

3.5.2. Medical procedures

Dogs were noted to have undergone a surgical procedure within 1 month prior to development of clinical signs or diagnosis of ME in 80 (9.6%) of 830 responses, 14 dogs (5%) with congenital ME and 32 dogs (12.9%) with acquired ME. Dogs were additionally noted to have received vaccinations within 1 month of ME development in 151 dogs (18.7%) with 92 (63.0%) receiving a combination vaccine, 2 (13.7%) a single vaccination, and no veterinary record available or no response given for the remaining dogs. In dogs with stated congenital ME, 77 dogs (27.6%) received vaccination. A combination vaccine was received in 49 dogs (17.6%) and a single vaccination in 7 dogs (2.5%), with no veterinary record available or no response given for the remaining 21 dogs.

3.5.3. Myasthenia gravis

Of the dogs diagnosed with MG, 16 (17.2%) had received vaccinations within 1 month of onset of ME. Surgery occurred within 1 month of vaccination in 28 (3.2%) and deworming occurred on the same day in 55 (6.3%).

4. Discussion

This survey represents the largest sampling of dogs with megaesophagus ever described in the literature. It provides a broader look at

population characteristics as well as associated and concurrent disease conditions. The survey also provides insight on common methods of diagnosis and other diagnostics performed.

From the results of this survey, it is clear that ME has a worldwide distribution with individuals from > 20 different countries reporting cases. The true prevalence of ME in dogs remains unknown as no studies have evaluated a large general population. Currently, the Canine Megaesophagus Support Group Facebook page has a membership of over 9000 individuals. This information along with the large number of cases reported in this survey could indicate that this disease is potentially more common than previously considered. It is of course, unknown how many of these members are active and currently have dogs with megaesophagus. However, with changes in availability of information through the internet, owners may be more likely to take on the care of these dogs and general practitioners may be more comfortable with their management leading to fewer euthanasias at diagnosis.

In this study, males and females were similarly affected, with no gender predilection noted in this survey for ME in general. However, more females than males were represented in the PRAA group. Furthermore, ME appears to have a broad breed distribution. Breeds that have previously been believed to have a higher prevalence of acquired ME include German shepherd dogs, golden retrievers, Labrador retrievers, great Danes, and Irish setters (Gaynor et al., 1997). In this study Labrador retrievers and golden retrievers were also most common overall; with Chihuahuas, dachshunds, boxers, German shepherd dogs, and Rottweilers also having a higher prevalence. This may represent a high prevalence within the breeds or could be a reflection of breed popularity. The 2015 (same year survey was completed) American Kennel Club ranking for most popular breeds in the US ranked Labrador retrievers 1st and German Shepherd dogs 2nd, based on breed

Table 3
Concurrent diseases diagnosed before and after megaesophagus.

Disease	All Dogs (n = 838)			Congenital (n = 279)			Acquired (n = 249)		
	Before	After	Total Number (%)	Before	After	Total Number (%)	Before	After	Total Number (%)
Myasthenia gravis	16	77	93 (11.1)	0	2	2 (0.7)	6	42	48 (19.3)
Esophagitis	22	59	81 (9.7)	4	12	16 (5.7)	8	19	27 (10.8)
Hypothyroidism	20	16	36 (4.3)	0	0	0 (0)	8	14	22 (8.8)
Laryngeal paralysis	9	9	18 (2.1)	2	0	0 (0)	5	4	9 (3.6)
Esophageal stricture	7	1	8 (1.2)	1	2	3 (1.1)	0	2	2 (0.8)
Hiatal hernia	0	6	6 (1)	0	2	2 (0.7)	0	1	1 (0.4)
Polyneuropathy or peripheral neuropathy	2	3	5 (0.6)	0	0	0 (0)	2	2	4 (1.6)
Hypoadrenocorticism	1	3	4 (0.5)	0	0	0 (0)	1	1	2 (0.8)
Thymoma	3	1	4 (0.5)	0	0	0 (0)	1	2	3 (1.2)
Polymyositis	2	1	3 (0.4)	0	0	0 (0)	1	1	2 (0.8)
Dermatomyositis	0	2	2 (0.3)	0	0	0 (0)	0	1	1 (0.4)
Systemic lupus erythematosus	0	1	1 (0.1)	0	0	0 (0)	1	0	1 (0.4)
Distemper	0	1	1 (0.1)	0	0	0 (0)	0	0	0 (0)
Brain stem tumor	0	1	1 (0.1)	0	0	0 (0)	0	1	1 (0.4)
Lymphoma	0	1	1 (0.1)	0	0	0 (0)	0	1	1 (0.4)

registration. Golden retrievers, boxers, and Rottweilers were ranked in the top 10, and dachshunds in the top 15 (American Kennel Club, 2017). Chihuahuas however ranked 28th and this may represent a potential breed predisposition. Breeds that have been associated with a higher prevalence of congenital ME include German shepherd dogs, great Danes, Labrador retrievers, miniature schnauzers, and fox terriers (Glidewell, 1983; Washabau, 2003). Breeds most commonly diagnosed with idiopathic congenital ME in this study were again German shepherd dogs and Labradors. Great Danes, dachshunds, and miniature schnauzers were also seen in higher prevalence. For some breeds this could again simply represent breed popularity. The miniature schnauzer breed is also ranked high in popularity but has also previously been identified as having an autosomal dominant hereditary esophageal dysfunction (American Kennel Club, 2017; Cox et al., 1980). A similar breed pattern is seen in predilection towards development of PRAA with German Shepherds, Labrador retrievers, and Irish setters more commonly affected (Buchanan, 2004; Patterson, 1968). In this study, German shepherds were by far the most prevalent breed seen.

While mixed breed dogs are generally grouped together when discussing breed characteristics, the frequent reporting of “goldendoodles” (golden retriever and poodle mix) in this survey warranted separate discussion. This could be due to the popularity of the golden retriever and poodle breeds (both in the top 10 AKC rankings) but could also represent a predisposition of this mix to ME, especially as “labradoodles” (Labrador and poodle mix), also composed of common breeds, was represented by a much small number of dogs in this survey. Furthermore, the fact that the majority of the “goldendoodles” in this study were identified as having congenital ME further supports a genetic predisposition to developing ME.

More than 1/3 of respondents reported their dogs as having been diagnosed with congenital ME. The distribution of age of diagnosis reflects this with the largest percentage of dogs being diagnosed at < 1 year of age. This supports the previous understanding that congenital disease manifests at an early age (Boudrieau and Rogers, 1985; Glidewell, 1983; Harvey et al., 1974). Many of the previous studies on ME did not differentiate the cause of ME as idiopathic congenital or acquired, thus preventing a clear understanding of the prevalence of idiopathic congenital ME vs other causes. In one paper, the prevalence of congenital ME was reported as occurring in 36% of cases, similar to what was found in this study (Boudrieau and Rogers, 1985). Unfortunately, without medical records to evaluate the dogs individually, it is possible that some of the dogs reported in the survey as congenital by their owners could have other underlying diseases that were not detected. This may be especially true in those reported to have a diagnosis of congenital disease at an older age. Some dogs with congenital disease may have had clinical signs from a young age and were only diagnosed when older, however that cannot be confirmed with the available data in this study.

Megaesophagus is known to manifest as several puppies in a litter affected but the prevalence of this occurrence has not been determined (Quintavalla et al., 2017). Many of the survey respondents in this study did not know the status of their dog's litter mates, however nearly 10% of respondents did specify that other dogs in the litter were affected. Given that many owners are not aware of the health status of other puppies in the litter, it is possible that this figure underestimates the true prevalence of litters with multiple dogs affected. The mode of inheritance of ME has not been truly elucidated for any breed (Tsai et al., 2012). Around half of the owners were familiar with the status of their dog's parents. Only 3 individuals reported that a parent (the dam) was known to have ME. It would be expected that dogs with ME would rarely be bred, given that pregnancy would likely exasperate any clinical signs of ME potentially leading to severe consequences to the dam.

The diagnosis of ME was obtained the majority of the time by general practitioners with the dog's regular veterinarian or another general practitioner diagnosing the dog nearly 64% of the time.

Veterinary specialists or teaching hospitals diagnosed ME in about 19% of cases and emergency hospitals almost 12% of the time. This highlights the fact that many cases of ME may never make it to referral facilities and instead are diagnosed by their regular veterinarian. Studies describing characteristics and outcomes of dogs only in a referral center may not be representative of the true ME population. This should be considered when discussing prognosis for patients diagnosed with ME especially if they do not have other factors associated with poor outcome, such as aspiration pneumonia (McBrearty et al., 2011). The diagnostics performed most frequently as the sole diagnostic test were plain radiographs and radiographic barium study. These tests were also the most common combination of diagnostics used. Survey radiographs are considered sufficient to diagnose most cases of ME (Washabau, 2003). Contrast studies increase the risk of aspiration in dogs with ME and are not recommended if dilation is already visible unless there is concern for obstruction or foreign body (Kealy et al., 2010; Washabau, 2003).

The most common conditions associated with acquired ME in this survey were myasthenia gravis, esophagitis, and hypothyroidism. Esophagitis can be the cause of ME but can also occur secondary to the condition and associated food retention. It is unclear from this survey whether esophagitis was an inciting cause in the 22 cases reported prior to diagnosis. About 13% percent of dogs with acquired ME had also had a surgical procedure within 1 month of ME diagnosis, with anesthesia being a known risk factor for esophagitis development (Han, 2003; Wilson et al., 2005; Wilson and Walshaw, 2004). Diseases such as hypoadrenocorticism, brainstem neoplasia, thymoma, and toxicities such as lead are often discussed as causes for ME, but this survey revealed a very low prevalence of these conditions in the sampled ME population (Atwater et al., 1994; Bartges and Nielson, 1992; Maddison and Allan, 1990; Whitley, 1995).

Myasthenia gravis is a frequent cause of megaesophagus and previous studies have suggested a prevalence of 21–30% (McBrearty et al., 2011; Shelton et al., 1990; Wray and Sparkes, 2006). This survey found a lower prevalence at around 14% of the total survey population. This again may reflect the differences in sample populations in the various studies, with this study reflecting a more diverse and potentially healthier population of dogs. Alternatively it could be argued that dogs reported in this survey did not have complete diagnostic evaluations performed and myasthenia gravis may be underdiagnosed in this population.

Previous research has suggested hypothyroidism as a cause of acquired ME in dogs with up to 3% of hypothyroid dogs having ME (David, 2001; Kumar and Srikala, 2015). Other studies have not supported that finding and the association between the two diseases is still not firmly established (Gaynor et al., 1997). In this survey, almost 9% of dogs with acquired ME were diagnosed with hypothyroidism either before or after their diagnosis of ME. This was the 3rd most common disease reported in this survey and may support an association between the two conditions. However, it remains possible that dogs with megaesophagus may be misdiagnosed with hypothyroidism due to effects of non-thyroidal illness on thyroid hormone levels (David, 2001).

Hypothyroidism has also been associated with other conditions such as laryngeal paralysis which in its idiopathic form has been linked to the development of esophageal dysfunction (Gaber et al., 1985; Stanley et al., 2010). Laryngeal paralysis was seen in 3.6% of dogs with acquired ME in this survey making it one of the more common associated disease conditions. Hypothyroidism, megaesophagus, and laryngeal paralysis together could represent a more generalized neuropathic condition (Braund et al., 1989; Jaggy et al., 1994; Stanley et al., 2010). Owners of dogs with acquired ME reported a change in bark in about 30% of dogs and toe dragging in 20% of dogs. Change in bark is often associated with laryngeal paralysis and could represent undiagnosed laryngeal paralysis in some dogs (Hammel et al., 2006). Change in bark is often associated with laryngeal paralysis and could represent undiagnosed laryngeal paralysis in some dogs (Hammel et al., 2006). The

questions on toxic and environmental exposure revealed no obvious associations and were unfortunately too imprecise to pinpoint any specific compound. Tiger snake envenomation has been found to result in ME in adult dogs in Australia (Hopper et al., 2001). Only 1 dog was found to have been bitten by a snake in this study and that dog originated in the United States. Fertilizer mixtures and household chemicals could contain organophosphates, which have been identified as a possible cause of ME, but the survey did not specify the compounds contained in the products ingested. Foreign body ingestion could result in esophagitis or strictures thus leading to ME development (Gaynor et al., 1997). Although 13% of respondents did state that their dog had ingested a foreign body, the survey did not determine how that ingestion related to ME development.

Dog bowls have not specifically been linked with ME but certain types of bowl materials could present a risk. Ceramic bowls could be glazed with lead containing paints. Some plastics may contain bisphenol A (BPA) which has raised concerns as an endocrine disruptor with estrogenic activity (Kang and Kondo, 2002). BPA has not been linked specifically to megaesophagus or other endocrine disorders in dogs but has raised concerns in human medicine leading to limits on consumption (Kang and Kondo, 2002; Schug et al., 2011). Unfortunately the survey only asked about food bowls specifically and did not address water bowls.

This survey did have several limitations. As it was initially designed and performed by a community group, it did not have early input from a veterinary professional. Some questions may have been directed differently and some other relevant topics were not part of the survey. It is also based on owner responses which may have been less complete than those coming from a veterinary setting due to a variable degree of medical knowledge and understanding as well as recollection. Recollection of diagnostic testing may have effected those results.

The survey was still biased towards individuals active online and in support groups and therefore did not encompass the entire population ME population. This may have especially excluded individuals in other countries. This survey does not specify whether the dog was still alive at the time the survey data was collected and does not offer any information on survival. Spay and neuter status was also not specified but there has been no reported link between spay/neuter status and development of ME. Additionally, the study only asked about PRAA and no other vascular ring anomalies, though it is likely that owners may have lumped any similar condition under this categorization.

Overall, this online survey represents an expansive and more broadly focused sampling of the canine megaesophagus population. While somewhat hampered by the limitations in design, it offers additional information on a more diverse population of dogs with ME, including breed distributions, diagnostics performed, underlying conditions, and environmental impact. It highlights the fact that many dogs are diagnosed and likely cared for by general practitioners which may indicate a bias in veterinary literature towards only reporting animals with a worse prognosis. It supports previous breed predilections and identifies new potentially at risk breeds. Future research would address the question of disease prevalence and overall survival.

Acknowledgements

The author thanks Donna Challender, Pam Giles, and France Lajeunesse for development and distribution of the survey.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declarations of interest

None.

References

- American Kennel Club, 2017. Most Popular Dog Breeds – Full Ranking List. <http://www.akc.org/content/news/articles/most-popular-dog-breeds-full-ranking-list/> accessed 29 February 2017.
- Atwater, S., Powers, B., Park, R., Straw, R., Ogilvie, G., Withrow, S., 1994. Thymoma in dogs: 23 cases (1980–1991). *J. Am. Vet. Med. Assoc.* 205, 1007–1013.
- Bartges, J., Nielson, D., 1992. Reversible megaesophagus associated with atypical primary hypoadrenocorticism in a dog. *J. Am. Vet. Med. Assoc.* 201, 889–891.
- Boudrieau, R., Rogers, W., 1985. Megaesophagus in the dog: a review of 50 cases. *J. Am. Anim. Hospital Assoc. (USA)* 21, 33–40.
- Braund, K., Steinberg, H., Shores, A., Steiss, J., Mehta, J., Toivio-Kinnucan, M., Amling, K., 1989. Laryngeal paralysis in immature and mature dogs as one sign of a more diffuse polyneuropathy. *J. Am. Vet. Med. Assoc.* 194, 1735–1740.
- Buchanan, J.W., 2004. Tracheal signs and associated vascular anomalies in dogs with persistent right aortic arch. *J. Vet. Intern. Med.* 18, 510–514.
- Cox, V., Wallace, L., Anderson, V., Rushmer, R., 1980. Hereditary esophageal dysfunction in the Miniature Schnauzer dog. *Am. J. Vet. Res.* 41, 326–330.
- David, L.P., 2001. Conditions associated with canine hypothyroidism. *Vet. Clin. N. Am. Small Anim. Pract.* 31, 935–950.
- Gaber, C., Amis, T., Lecouteur, R.A., 1985. Laryngeal paralysis in dogs: a review of 23 cases. *J. Am. Vet. Med. Assoc.* 186, 377–380.
- Gaynor, A.R., Shofer, F.S., Washabau, R.J., 1997. Risk factors for acquired megaesophagus in dogs. *J. Am. Vet. Med. Assoc.* 211, 1406–1412.
- Glidewell, H., 1983. Clinical signs of idiopathic megaesophagus in Great-Dane puppies. *Vet. Med. Small Anim. Clinician* 78, 202–205.
- Hammel, S.P., Hottinger, H.A., Novo, R.E., 2006. Postoperative results of unilateral arytoid lateralization for treatment of idiopathic laryngeal paralysis in dogs: 39 cases (1996–2002). *J. Am. Vet. Med. Assoc.* 228, 1215–1220.
- Han, E., 2003. Diagnosis and management of reflux esophagitis. *Clin. Tech. Small Anim. Practice* 18, 231–238.
- Harvey, C.E., O'Brien, J.A., Durie, V.R., Miller, D.J., Veenema, R., 1974. Megaesophagus in the dog: a clinical survey of 79 cases. *J. Am. Vet. Med. Assoc.* 165, 443–446.
- Hopper, K., Beck, C., Slocombe, R., 2001. Megaesophagus in adult dogs secondary to Australian tiger snake envenomation. *Aust. Vet. J.* 79, 672–675.
- Jaggy, A., Oliver, J.E., Ferguson, D.C., Mahaffey, E., Jun, T.G., 1994. Neurological manifestations of hypothyroidism: a retrospective study of 29 dogs. *J. Vet. Intern. Med.* 8, 328–336.
- Kang, J.-H., Kondo, F., 2002. Determination of bisphenol a in canned pet foods. *Res. Vet. Sci.* 73, 177–182.
- Kealy, J.K., McAllister, H., Graham, J.P., 2010. The abdomen. In: *Diagnostic Radiology and Ultrasonography of the Dog and Cat*, 5th ed. Saunders Elsevier, St. Louis, MO, USA, pp. 67–68.
- Kumar, K.S., Srikanth, D., 2015. Hypothyroid associated megaesophagus in dogs: four years (2009–2013) study in Hyderabad, India. *J. Adv. Vet. Anim. Res.* 2, 221–224.
- Maddison, J., Allan, G., 1990. Megaesophagus attributable to lead toxicosis in a cat. *J. Am. Vet. Med. Assoc.* 197, 1357.
- McBrearty, A.R., Ramsey, I.K., Courcier, E.A., Mellor, D.J., Bell, R., 2011. Clinical factors associated with death before discharge and overall survival time in dogs with generalized megaesophagus. *J. Am. Vet. Med. Assoc.* 238, 1622–1628.
- Patterson, D.F., 1968. Epidemiologic and genetic studies of congenital heart disease in the dog. *Circ. Res.* 23, 171–202.
- Quintavalla, F., Menozzi, A., Pozzoli, C., Poli, E., Donati, P., Wyler, D., Serventi, P., Bertini, S., 2017. Sildenafil improves clinical signs and radiographic features in dogs with congenital idiopathic megaesophagus: a randomised controlled trial. *Vet. Rec.* 180, 404.
- Schug, T.T., Janesick, A., Blumberg, B., Heindel, J.J., 2011. Endocrine disrupting chemicals and disease susceptibility. *J. Steroid Biochem. Mol. Biol.* 127, 204–215.
- Shelton, G.D., 2002. Myasthenia gravis and disorders of neuromuscular transmission. *Vet. Clin. N. Am. Small Anim. Pract.* 32, 189–206.
- Shelton, G.D., Willard, M.D., George III, H.C., Lindstrom, J., 1990. Acquired myasthenia gravis. *J. Vet. Intern. Med.* 4, 281–284.
- Stanley, B.J., Hauptman, J.G., Fritz, M.C., Rosenstein, D.S., Kinns, J., 2010. Esophageal dysfunction in dogs with idiopathic laryngeal paralysis: a controlled cohort study. *Vet. Surg.* 39, 139–149.
- Tsai, K.L., Noorai, R.E., Starr-Moss, A.N., Quignon, P., Rinz, C.J., Ostrander, E.A., Steiner, J.M., Murphy, K.E., Clark, L.A., 2012. Genome-wide association studies for multiple diseases of the German Shepherd Dog. *Mamm. Genome* 23, 203–211.
- Washabau, R.J., 2003. Gastrointestinal motility disorders and gastrointestinal prokinetic therapy. *Vet. Clin. N. Am. Small Anim. Pract.* 33, 1007–1028.
- Whitley, N., 1995. Megaesophagus and glucocorticoid-deficient hypoadrenocorticism in a dog. *J. Small Anim. Pract.* 36, 132–135.
- Wilson, D.V., Walshaw, R., 2004. Postanesthetic esophageal dysfunction in 13 dogs. *J. Am. Anim. Hosp. Assoc.* 40, 455–460.
- Wilson, D.V., Evans, A.T., Miller, R., 2005. Effects of preanesthetic administration of morphine on gastroesophageal reflux and regurgitation during anesthesia in dogs. *Am. J. Vet. Res.* 66, 386–390.
- Wray, J., Sparkes, A., 2006. Use of radiographic measurements in distinguishing myasthenia gravis from other causes of canine megaesophagus. *J. Small Anim. Pract.* 47, 256–263.