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Gastric dilation-volvulus in dogs attending UK emergency-care veterinary practices: prevalence, risk factors and survival

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Structured Summary

Objective: To report prevalence, risk factors and clinical outcomes for presumptive gastric dilation-volvulus diagnosed among an emergency-care population of UK dogs.

Methods: Cross-sectional study design using emergency-care veterinary clinical records from the VetCompass^{TM} Programme spanning September 1st, 2012 to February 28th, 2014. Risk factor analysis using multivariable logistic regression modelling.

Results: The study population comprised 77,088 dogs attending 50 Vets Now clinics. Overall, 492 dogs had presumptive gastric dilation-volvulus diagnoses giving a prevalence of 0.64% (95%CI: 0.58% - 0.70%). Compared with crossbred dogs, breeds with the highest odds ratios for diagnosis of presumptive gastric dilation-volvulus were the great Dane (OR: 114.3, 95% CI 55.1-237.1, P < 0.001), akita (OR: 84.4, 95% CI 33.6-211.9, P < 0.001) and dogue de Bordeaux (OR: 82.9, 95% CI 39.0-176.3, P <

0.001). Odds increased as dogs aged up to 12 years and neutered male dogs had 1.3 (95% CI 1.0-1.8, P = 0.041) times the odds compared with entire females. Of presumptive gastric dilation-volvulus cases that presented alive, 49.7% survived to discharge but 79.3% of surgical cases survived to discharge.

Clinical importance: Approximately 80% of surgically managed cases survived to discharge. Certain large breeds were highly predisposed.

Keywords

VetCompass, gastric dilation-volvulus, GDV, emergency, bloat

Abbreviations

CI – confidence interval

EPR – electronic practice record

GDV – gastric dilation-volvulus

IQR – interquartile range

OR – odds ratio

RVC - Royal Veterinary College

SD - standard deviation

Introduction

Gastric dilation-volvulus (GDV) is generally an acute and life-threatening condition with severe multi-systemic effects in dogs (Brockman 2012, Sharp and Rozanski 2014). The precise pathophysiology of GDV is unclear but the presentation is characterised by rapid accumulation of various combinations of gas, fluid and ingesta in the stomach, with increased intra-gastric pressure (Hendriks and others 2011). Dilation of the stomach and rotational twist along its horizontal axis compress the major abdominal blood vessels and impair venous return to the heart, leading to impaired cardiac output and shock (Glickman and others 1994). If left untreated, severe systemic hypoperfusion can ensue via multiple mechanisms (hypovolaemic, distributive and obstructive shock) along with additional respiratory compromise and decreased tidal volume that results from restriction of diaphragmatic excursions by the enlarged stomach (Monnet 2003). Diagnosis is commonly based on a combination of characteristic historical and physical examination findings (notably abdominal distension and pain, tachycardia, poor peripheral pulses and unproductive retching), combined with evidence of gastric malpositioning and enlargement apparent from diagnostic imaging (Tivers and Brockman 2009).

A typical combination of significant pain and a high mortality rate make GDV both a clinical and welfare concern in affected dogs. Among UK pedigree dogs participating in a survey-based retrospective study, GDV was reported to cause 2.5% of all deaths, with a median age at death of 7.9 years (Evans 2010). A US study of large and giant dog breeds reported that 16% of deaths in these breeds were from GDV (Glickman and others 2000) and that 28.6% of GDV cases died directly from the disorder (Glickman 2000).

GDV is a complex disorder with multiple interacting inherited and environmental factors reported to affect the probability of a GDV event (Bell 2014). Reported prevalence values for GDV in dogs varies widely across differing breeds and populations but it is generally recognised as a disorder that mainly affects large and giant breeds (Glickman and others 1994). Purebred dogs are reported to be predisposed to GDV compared with crossbred dogs, with reported odds ratios (OR) ranging from 1.8 (95% confidence interval [CI] 1.1-2.9) (Bellumori and others 2013) to 2.5 (95% CI 2.1-3.0) (Glickman and others

1994). Larger body size (Glickman and others 1994, Glickman and others 2000) and deep-chested conformations (Bell 2014) have been reported as risk factors for GDV. Many breeds are reported as predisposed to GDV, and these include great Dane, bloodhound, German shepherd, standard poodle, grand bleu de Gascogne, German pointer, akita, Irish setter, Weimaraner and Neapolitan mastiff (Bell 2014, Brockman 1995, Evans 2010, Glickman 2000). Advancing age has also been reported to substantially increase risk of GDV (Elwood 1998, Glickman 2000, Theyse and others 1998) but evidence to support a sex predisposition to GDV has been more equivocal (Eggertsdóttir and Moe 1995, Glickman and others 1997, Glickman and others 1994, Glickman and others 2000).

Research using primary-care veterinary clinical records has been recommended as a means to generate reliable and generalisable information on the occurrence and risk factors for disorders affecting the wider animal population (O'Neill and others 2014a). This study aimed to analyse a database of merged emergency-care practice electronic patient records (EPRs) to estimate the prevalence of presumptive GDV diagnoses among an emergency-care caseload of dogs in the UK and to evaluate demographic risk factors for the occurrence of GDV. The study additionally aimed to report on clinical management and survival among this presumptive GDV caseload.To unpick the interacting effects of breed and body size, it was hypothesised that, within breeds, animals with bodyweight above their breed mean have an increased odds ratio of presumptive GDV diagnosis compared with those at or below the breed mean.

Materials and methods

The current study was part of the VetCompass™ Programme of research at the Royal Veterinary College (RVC) (VetCompass 2017) and included all dogs attending Vets Now practices with at least one electronic patient record (EPR) recorded within the

VetCompass™ database from September 1st, 2012 to February 28th, 2014 (Vets Now 2015). These dates were selected because they covered the span of available clinical records at the time of the study. Vets Now clinics use a standard practice management system called Helix and Vets Now team members are required to record presenting signs and encouraged to record diagnoses using the Venom Coding standardised terminology (The VeNom Coding Group 2017). A clinical query was used to extract EPR data from the Helix system that were then uploaded to a secure structured query language database (O'Neill and others 2014b). Data available for the current study included demographic (breed, date of birth, sex, neuter status, insurance status and bodyweight) and clinical (clinical notes, treatment, presenting signs and diagnosis terms with relevant dates) information.

A cross-sectional analysis was used to estimate prevalence and evaluate associations between risk factors and GDV diagnosis. Based on the main study hypothesis, sample size calculation estimated that a cross-sectional study would require 5,148 dogs of below-average weight and 5,148 dogs of above-average weight to identify within-breed bodyweight as a risk factor with an odds ratio ≥ 2.0 (unexposed:exposed ratio 1:1, 95% confidence level, 80% power and 0.5% of the unexposed animals with GDV) (Epi Info 7 CDC 2015). Ethics approval was granted by the RVC Ethics and Welfare Committee (reference number S25/2014).

In this study, the case definition for diagnosis of GDV required that the dog was presented either dead or alive at a participating clinic and that a final diagnosis of GDV (or synonyms covering either torsion or volvulus) was recorded in the EPR based on first opinion emergency-care diagnostic criteria. Because not all cases underwent definitive diagnosis by radiography, surgery, or both, the diagnosis must be considered to be presumptive in some cases. However, dogs that were specified as having gastric dilation without volvulus did not meet the case definition for this study and were excluded. On the other hand, animals that were already dead at the time of first presentation and that met the case definition were included because of the risk that overall prevalence and risk factor values might otherwise be biased by preferentially removing categories of dog with more acute presentations and that tended to die more rapidly.

The case-finding process involved an initial EPR screening of all study dogs to identify potential GDV candidate cases by multiple searches of the clinical free-text (*gdv, volvul, torsion, gastric dilat, bloat, twisted stom, gastropexy*) and the VeNom term fields (*Gastric (stomach) dilation*, *Gastric (stomach) torsion – chronic* and *Gastric dilation-volvulus syndrome (GD*V*)*). Candidate GDV cases were randomly sorted using the 'RAND' function in Microsoft Excel (Microsoft Office Excel 2007, Microsoft Corp.) to avoid temporal bias during review and the full clinical records were read manually by one of the authors (JC) before deciding on case inclusion and extracting clinical information following a standardised process. For included cases, any previous episodes of GDV were recorded and the date of diagnosis of the current presumptive GDV event were described. Additionally, the presenting status (ambulatory or collapsed), blood lactate concentration at presentation, surgical management (including whether a gastropexy or splenectomy was performed) and clinical outcome (dead on arrival, non-survival, survived) were reported. For the analysis, all dogs not meeting our GDV case definition were included as non-cases for presumptive GDV.

Following data checking and cleaning in Excel using internal data validity evaluations (Microsoft Office Excel 2007, Microsoft Corp.), statistical analyses were conducted using Stata Version 11.2 (Stata Corporation). Prevalence values with 95% CI were reported overall and for individual common breeds. The 95% CI estimates were derived from standard errors based on approximation to the normal distribution (Kirkwood and Sterne 2003). Descriptive statistics characterised purebred status, breed, sex/neuter, age, actual bodyweight and bodyweight relative to breed mean for the GDV case and non-case dogs separately. The *breed variable* included individual breeds with 10 or more presumptive GDV cases recorded, a group containing the remaining purebred dogs ('other purebred’) and a group containing the crossbreds. *Actual bodyweight* (kg) described the maximum recorded bodyweight for dogs of any age. Six actual-bodyweight categories were generated: (0.0-9.9, 10.0-19.9, 20.0-29.9, 30.0-39.9, ≥ 40.0 and no bodyweight recorded). The mean adult bodyweight was calculated for individual breeds using bodyweight data from dogs aged over 18 months and these values were used to categorise individual dogs aged over 18 months as being either above or at/below their breed mean value (‘bodyweight relative to breed mean’). Age (years) described the age at diagnosis for case animals and the age at the mid-point between the first and final EPR for the non-case animals. Age was categorised into six groups (< 3.0, 3.0-5.9, 6.0-8.9, 9.0-11.9, ≥ 12.0 and not available). Analysis of age and bodyweight as categorical variables was planned during the study design because associations between these variables and clinical outcomes are rarely linear and therefore analysis as continuous variables is statistically inappropriate (Kirkwood and Sterne 2003, O'Neill and others 2016, Taylor-Brown and others 2015). The additional categories that described missing data for the bodyweight and age variables were included in the analyses in order to better understand the impact that missing data may have had on the results for these variables. Blood lactate concentrations (mmol/L) were categorised into 5 groups (< 2, 2 to < 4, 4 to < 6, 6 to < 8 and ≥ 8). These cut-offs were selected to be consistent with previously published results (Green and others 2011). Animals discharged alive from Vets Now clinical care were defined as having survived while those that died or were euthanased whilst still under the care of Vets Now were classified as non-surviving. Categorical variables were compared between groups using the chi-square test or Fishers exact test and quantitative variables were compared using the unpaired t-test or Wilcoxon rank sum test as appropriate (Kirkwood and Sterne 2003). A Bonferroni adjusted P–value of 0.007 was accepted for statistical significance to account for the effects of multiple testing (Aickin and Gensler 1996).

Binary logistic regression modelling was used to evaluate univariable risk factor associations with presumptive GDV occurrence. Purebred status (highly correlated with breed) and actual bodyweight (bodyweight was considered to be a defining characteristic of individual breeds) were excluded from multivariable modelling. Other factors with liberal associations in the univariable modelling ($P < 0.2$) were taken forward for multivariable evaluation. Model development used manual backwards stepwise elimination. Clinic attended was entered as a random effect to quantify the diagnostic variation for presumptive GDV between clinics (Bolker and others 2009). Such variation could result, for example, from regional geographic or breed associations with occurrence across the UK. Pair-wise interaction effects were evaluated for the final model variables (Dohoo and others 2009). The Hosmer-Lemeshow test statistic and the area under the ROC curve were used to evaluate model fit (non-random effect model) (Dohoo and others 2009). Statistical significance was set at $P < 0.05$ for the logistic regression modelling.

Results

Descriptive results: demography and clinical outcomes

Data completeness overall differed widely between the variables: sex 82.5%, neuter 82.5%, insurance 100.0%, date of birth 84.7%, actual bodyweight 33.4% and breed 88.9%. The study population comprised 77,088 dogs attending 50 Vets Now clinics across the UK. There were 492 dogs that met our presumptive GDV diagnosis case definition, giving a prevalence of 0.64% (95% CI 0.58% - 0.70%) of the overall canine emergency-care caseload. The prevalence of presumptive GDV varied widely across the breeds. Breeds with the highest prevalence included great Dane (14.0% prevalence, 95% CI 9.8-19.1), akita (9.2%, 95% CI 4.5-16.2), dogue de Bordeaux (7.2%, 95% CI 4.6-10.7), Irish setter (7.1%, 95% CI 3.7-12.1) and Weimaraner (7.1%, 95% CI 5.0-9.8). The prevalence among crossbreds was 0.1% (0.1-0.2) (Table 1).

Of the presumptive GDV dogs with information available, 431 (96.2 %) were purebred, 167 (40.2%) were female, 85 (17.3%) were insured and 168 (40.5%) were neutered (Table 2). The median actual bodyweight was 38.8 kg (IQR: 30.0 – 48.5, range: 3.7 – 87.0) and the median age was 8.0 years (IQR: 6.0 – 10.0, range: 0.3 – 20.0) (Figure 1). The most common 11 breeds accounted for 264 (53.7%) of the case dogs. Eleven breeds had 10 or more affected individuals recorded: akita, boxer, dogue de Bordeaux, great Dane, basset hound, Dobermann pinscher, Labrador retriever, Rhodesian ridgeback, Irish setter, German shepherd dog and Weimaraner. Of these, the highest breed prevalence was recorded for the great Dane (14.0%, 95% CI 9.8-19.1) and akita (9.2%, 95% CI 4.5-16.2) (Table 2). Data completeness for the presumptive GDV cases was: sex 84.3%, neuter 84.3%, insurance 100.0%, date of birth 90.7%, actual bodyweight 37.8% and breed 91.1%.

Of the non-case dogs with information available, 55,676 (81.8%) were purebred, 30,046 (47.5%) were female, 11,854 (15.5%) were insured and 22,690 (35.9%) were neutered. The median bodyweight of non-case dogs was 14.7 kg (IQR: 7.8-25.7, range: 0.2 – 100.0) and the median age was 5.0 years (IQR: 1.7 – 10.0, range: 0.0 – 25.0) (Table 2). The most common breed types in the overall study were Labrador retriever (9.8%), Jack Russell terrier (5.5%), Staffordshire bull terrier (4.3%) and cocker spaniel (4.1%). Data completeness for the non-cases was: sex 82.5%, neuter 82.5%, insurance 100.0%, date of birth 84.6%, actual bodyweight 33.4% and breed 88.9%.

Nine of the 492 presumptive GDV cases overall (1.8%) presented as 'dead on arrival'. Of the dogs that were alive at presentation, 243/483 (50.3%) did not survive to discharge, with 215 (88.5%) of these deaths involving euthanasia. Of the 198 dogs that were alive at presentation and did not undergo surgery, 184 (92.9%) did not survive the emergency-care period, with the remaining 14 (7.1%) alive at discharge to their primary-care practices or to their owners' care after which no further information was available. Of these 184 deaths, 178 (96.7%) were due to euthanasia and 6 (3.3%) were unassisted. Of the 285 dogs that underwent surgery, 226 (79.3%) survived and 59 (20.7%) did not survive the emergency-care period. Of these 59 deaths, 37 (62.7%) were due to euthanasia and 22 (37.3%) were unassisted (Figure 2). Overall, 169/215 (78.6%) presumptive GDV cases that were euthanased during the study period had information specified in the free-text notes describing the main reasons that the owner elected for euthanasia. Of these, 118 (69.8%) euthanasia decisions were taken to avoid further animal suffering and 51 (30.2%) were taken following financial concerns related to ongoing treatment.

Of dogs that were alive at presentation, 309 of 388 (79.6 %) presumptive GDV cases with information available were ambulatory. Cases that were ambulatory at presentation were significantly more likely to survive to discharge than non-ambulatory cases (survival: 158 (51.1%) ambulatory versus 17 (21.0%) non-ambulatory, $P < 0.001$). Ambulatory cases were also significantly more likely to have surgery than non-ambulatory cases (surgery: 189 (61.2%) ambulatory versus 27 (33.3%) non-ambulatory, $P < 0.001$). Of 481 presumptive GDV cases alive at presentation with information available, 189 (39.3%) did not receive any diagnostic imaging, 267 (55.5%) received radiology alone, 5 (1.0%) received ultrasonography alone and 20 (4.1%) received both radiology and ultrasonography. Of the dogs presented alive but that did not receive surgery, 81 (41.1%) received diagnostic imaging. Dogs that received some form of diagnostic imaging were more likely to have surgery than dogs that did not receive diagnostic imaging (221 (72.3%) versus 73 (38.6%), $P < 0.001$). Blood lactate concentrations were recorded for 181 (36.8%) cases and showed a median of 3.5 (IQR 2.3-6.3, range 0.6-18.3) mmol/L. Blood lactate concentrations at presentation (categorised data) were not associated with the likelihood of surgery ($P = 0.227$). Dogs with blood lactate concentrations < 4 mmol/L had an increased probability of survival to discharge both overall (P < 0.001) and among the surgical cases (P < 0.001) (Table 3).

Of the presumptive GDV cases that were alive at presentation with information available, 182/398 (45.7%) had an orogastric tube inserted and 285/483 (59.0%) were surgically managed. Dogs that underwent surgery were younger than dogs that did not undergo surgery (mean (standard deviation (SD)) 7.0 (3.1) years versus 9.2 (3.3) years, P < 0.001) but bodyweight was not associated with surgery (surgical cases: mean (SD) 40.3 (15.2) kg versus non-surgical cases: 40.9 (15.6) kg, P = 0.845). Insured cases were more likely to receive surgery than uninsured cases (67/85 insured [78.8%] versus 218/406 uninsured [53.7%] respectively, P < 0.001). Of surgical cases with information available that survived to discharge, 17.5% (25 of 143 dogs) had a recorded gastrotomy procedure, 97.0% (191 of 197 dogs) underwent a recorded gastropexy procedure and 14.9% (20 of 134 dogs) underwent a recorded splenectomy procedure. Splenectomised and non-splenectomised surgical cases did not differ in their proportional survival: 20 (71.4%) versus 114 (73.1%), P < 0.001. Information on the duration of general anaesthesia was available for 242 dogs. The median (IQR, range) duration of general anaesthesia was 90.0 (60.0-120.0, 0.0-300.0) minutes (Table 4). The differing counts of cases with procedural information available is explained by differing clarity of the notes recorded in the EPRs about the procedures performed.

Risk factors for diagnosis of presumptive GDV

Univariable logistic regression modelling identified six variables with liberally significant (P < 0.20) association with presumptive GDV diagnosis: purebred status, breed, actual bodyweight, bodyweight relative to breed mean, age and sex/neuter status. Although not included in multivariable modelling as explained above, the univariable results indicated that purebred dogs had 5.6 (95% CI 3.5-9.2, P < 0.001) times the odds of presumptive

GDV compared with crossbred dogs and that increasing actual bodyweight was strongly associated with increased odds of the diagnosis, with dogs weighing ≥ 40 kg showing 148.7 (95% CI 54.5-406.0, $P < 0.001$) times the odds compared with dogs weighing < 10.0 kg. No association was identified between insurance status and diagnosis of presumptive GDV ($P = 0.272$).

The final multivariable model comprised three risk factors: breed, age and sex/neuter status but did not identify bodyweight relative to breed mean as a significant risk factor. The final model showed acceptable model-fit (Hosmer-Lemeshow test statistic: $P = 0.680$) and good discrimination (area under the ROC curve: 0.843). The final model was not improved by inclusion of the clinic attended as a random effect ($P = 0.095$) and no biologically significant interactions were identified. After accounting for the effects of the other variables evaluated in the multivariable model, the individual breeds with the highest odds ratios for presumptive GDV diagnosis compared with crossbred dogs were the great Dane (OR: 114.3, 95% CI 55.1-237.1, $P < 0.001$), akita (OR: 84.4, 95% CI 33.6-211.9, $P < 0.001$) and dogue de Bordeaux (OR: 82.9, 95% CI 39.0-176.3, $P < 0.001$). The odds of diagnosis increased as dogs aged up to 12 years and then decreased. Compared with dogs aged < 3 years, dogs aged from 6 to < 9 years had 9.5 (95% CI 6.1-14.8, $P < 0.001$) times, and dogs aged from 9 to < 12 years 10.0 (95% CI 6.4-15.6, $P < 0.001$) times, the odds of presumptive GDV diagnosis. Neutered male dogs had 1.3 (95% CI 1.0-1.8, $P = 0.041$) times the odds of diagnosis compared with entire females (Table 5).

Discussion

To our knowledge, this is the most comprehensive epidemiologic study of presumptive GDV diagnoses relative to all veterinary emergency cases that has been published to date. This study highlights the relevance of presumptive GDV to the canine emergency caseload, with a prevalence of 0.64% and an overall survival of under 50% of all cases. Of dogs that underwent surgery, approximately 80% survived to discharge from emergency care. Risk factors for diagnosis identified in this study included breed, age > 3 years and sex. The great Dane, akita and dogue de Bordeaux breeds had the highest odds of presumptive GDV. Ambulatory status and blood lactate concentrations at initial presentation appeared to be useful survival indicators but their true association with survival may be confounded by their influence on euthanasia decision-making by veterinarians and owners (*i.e.* these factors may have been used in making the decision for euthanasia).

The diagnostic processes used in the current study were typical of first opinion emergency-care clinicians and may differ from strict diagnostic criteria that might include right lateral radiography of the cranial abdomen, post-mortem or laparotomy to confirm the GDV diagnosis (Glickman and others 1998, Tivers and Brockman 2009, Zacher and others 2010). Because not all of the cases included in the current study met this full diagnostic definition before being assigned a GDV diagnosis, the cases included in the current study have been labelled as presumptive GDV cases.

The results of the study did not support the hypothesis that, within breeds, animals with bodyweight above their breed mean have an increased odds ratio of presumptive GDV compared with those at or below the breed mean. Although some association was indicated in the univariable analysis, this effect was no longer significant after accounting for other confounding differences (*e.g.* sex) using multivariable modelling.

The current study reported a presumptive GDV prevalence of 0.64% of the overall canine emergency-care caseload, which is in broad agreement with a study of UK pedigree dogs (n = 36,006) that reported a GDV prevalence of 0·7% (Evans 2010). A US study of referral cases (n = 27,254) reported a lower prevalence of GDV of 0.2% (Bellumori and others 2013). Another US study reported that 2.4% of large-breed dogs and 2.7% of giant-breed dogs had at least one GDV episode annually (Glickman and others 2000). However, it is difficult to compare prevalence results between studies that have widely differing populations at risk.

First-opinion veterinary clinical records can be a valuable resource for reliable and generalisable health information on the wider animal population (O'Neill and others 2014a). Dogs affected by GDV require prompt management to prevent poor clinical and welfare outcomes and are therefore commonly presented as emergency-care cases to out-of-hours clinics (Brockman 2012). Consequently, analysis of combined clinical records from a large number of emergency-care clinics in the UK has potential to provide valuable insights into the epidemiology of GDV that are difficult to gain from other data resources. Emergency-care clinical records benefit from reduced recall and misclassification bias because of contemporaneous recording of health information by qualified professionals at the point of clinical care when and can be geographically representative when the contributing clinics span the entirety of the UK (Bateson 2010, McGreevy 2007, O'Neill and others 2014a). Electronic patient records also enable researchers to identify and include all diagnosed cases, regardless of their level of clinical work-up and management, and to explore the free-text clinical notes to answer contextual questions concerning aspects of welfare, presentation, diagnosis and management.

Purebred status was not evaluated in the multivariable modelling because it was highly correlated with breed. However, based on the univariable analysis in the current study, purebred dogs had over five times the odds of presumptive GDV compared with crossbreds. This finding is consistent with US studies emanating from referral clinics that reported odds ratios for purebred predisposition of 1.8 (Bellumori and others 2013), 2.5 (Glickman and others 1994) and 4.8 (de Battisti and others 2012). A purebred predisposition for GDV may indicate a genuine inheritable predisposition but, alternatively, could reflect differing body-size distributions between purebred and crossbred dogs. Although the median bodyweight of purebred and crossbred dogs is quite similar, purebred dogs tend to have a greater proportion of dogs with extreme large and small body size (O'Neill and others 2013) and GDV has been reported to be strongly associated with large or giant breed body types (Evans 2010).

After accounting for the other factors analysed, the breeds with the highest risk of presumptive GDV compared with crossbred dogs in the current study included great Dane (OR 114.3), akita (OR 84.4), dogue de Bordeaux (OR 82.9), Irish setter (OR 67.4) and Weimaraner (OR 50.8). A previous UK study additionally identified high GDV prevalence in the grand bleu de Gascogne, bloodhound and otterhound (Evans 2010) while US studies also reported high odds for Saint Bernard (Bellumori and others 2013, Brockman 1995, Glickman and others 1994). Many of these predisposed breeds are considered as ‘deep-chested’, with this description written into their breed standards (The Kennel Club 2014). This suggests an association between this conformation and GDV, thereby offering opportunities to reduce GDV hazard via prophylactic gastropexy (Ward and others 2003) or breed selection against extreme deep-chested conformation (Bell 2014).

Large or giant breeds feature heavily among the predisposed breeds for GDV (Bell 2014). The current study did not include actual bodyweight in the multivariable analysis because the breed variable already somewhat accounted for bodyweight. However, the univariable results did support an association between increasing bodyweight and increased odds of presumptive GDV, with dogs weighing 30.0-39.9 kg having 38.5 times the odds compared with dogs weighting < 10.0 kg. Similar associations between increasing bodyweight and risk of GDV have been reported in US studies of referred GDV cases (Glickman 2000, Glickman and others 1994). However, it is worth noting for the current study, that bodyweight data were available for less than 40% of the study dogs and that these results may be confounded by breed and sex effects. Consequently, exploration in future studies that control for these factors is warranted.

Older dogs were identified at higher risk of presumptive GDV in the current study, with dogs aged between 9 and 12 years showing 10 times the odds of dogs aged under 3 years. A previous study reported significantly increasing odds of GDV in Irish setters as dogs aged (Elwood 1998). The risk of GDV was reported to increase by approximately 20% with each year of age in large and giant breeds in the US (Glickman and others 2000) and the odds of GDV rose by 1.9 times for each year as great Danes in the Netherlands aged from 1 to 10 years old (Theyse and others 1998). Progressive stretching of the hepatogastric ligament with increasing age has been suggested as a pathogenic pathway for this increase GDV risk with aging (Hall and others 1995).

The current study did identify some evidence of a male predisposition, consistent with the results of a small US study (Glickman and others 1997). However, other previous studies have failed to identify a sex predisposition (Glickman and others 1994, Glickman and others 2000). Sex associations may be confounded by bodyweight, neutering and other factors that complicate the interpretation of true sex effects.

The current study identified that 50.3% of the emergency-care presumptive GDV caseload that presented alive did not survive to discharge, with 88.5% of these deaths involving euthanasia. This figure is very similar to the 86% of dog deaths that involve euthanasia under general primary veterinary care in the UK (O'Neill and others 2013). However, 79.3% of dogs that underwent surgery survived to discharge from emergency care. Although the relatively high survival rate for surgical cases may reflect effective case selection for surgical intervention, it is possible that many animals that did not receive surgery may also have survived if this option had been elected. There was a trend for breeds with a higher prevalence of presumptive GDV to be more likely to undergo surgery and therefore to have better overall survival (Table 2). This may reflect the probability that the owners of predisposed breeds are more aware of the disease in general and therefore better prepared to make the decision for surgical treatment during the emergency-care consultation at a time of extreme emotional distress.

It is difficult to compare the proportions of dogs undergoing surgery and their survival rates against previous publications because of differing study case definitions, case populations, methodologies and data sources between the published works. A study of working farm dogs in New Zealand reported 65% survival overall but the study included dogs affected with gastric dilation either with or without volvulus and included only dogs that received either radiography, surgery or post-mortem affected with GDV (Hendriks and others 2011). US studies of surgically-managed cases in referral clinic settings have reported survival rates of 90% (Mackenzie and others 2010), 88% (Green and others 2011), 85% (Brockman 1995), 84% (Beck and others 2006) and 82% (Brourman and others 1996). The lower survival reported in the current study may reflect inclusion of more acute and severe cases in the first-opinion emergency-care setting and differing case management compared with the referral situation and suggests that the results of the current study may be more applicable to the wider canine population. In addition, many of the deaths in the current study involved euthanasia, and over 30% of these deaths were related to financial concerns, which may have biased the survival rates downwards.

Taken at face value, the current findings might suggest that assessing ambulation and blood lactate concentrations at initial clinical presentation may be useful survival indicators for presumptive GDV. In the current study, 51.1% of dogs that were ambulatory at presentation survived compared with 21.0% survival in alive but non-ambulatory dogs. Lower initial lactate concentrations were also associated with higher survival rates in the current study (Table 3). These findings are consistent with other reports that suggest the prognostic value of blood lactate estimation (Beer and others 2012). Among surgical GDV cases in the US, the median initial plasma lactate concentration in dogs that survived was 3.4 mmol/L compared with 6.80 mmol/L for non-survivors (Green and others 2011). A US study of a general emergency caseload reported that 4.9% of patients with blood lactate concentrations up to 2.5 mmol/L died compared with 28.4% of patients with lactate values at or above 4.0 mmol/L (Shapiro and others 2005). Among systemically ill dogs in Canada, dogs with lactate concentrations above 2.3 mmol/L had 16 times more risk of dying than dogs with lactate concentrations at or below 2.3 mmol/L (Stevenson and others 2007). However, it is likely that associations between ambulation and blood lactate concentrations with subsequent survival are highly complex and so it may be unsafe to draw definitive conclusions from the current study results because of possible reverse-causality effects. Non-ambulatory dogs or those with high blood lactate concentrations may have been considered *a priori* to have a poorer prognosis by the owner or the attending veterinary surgeon and thus have been more likely to be euthanased. . It should also be noted that data availability for ambulatory status (79.2%) and plasma lactate concentration (36.8%) were not complete and therefore some biases relating to missing data may have affected the results. Survival analyses where clinicians were blinded to the values of potential prognostic indicators are needed to more definitively clarify the predictability of ambulation and blood lactate concentration as useful clinical indicators for survival, especially when they may be applied to individual animals.

Gastropexy, where the stomach is securely adhered to the abdominal wall, is clinically indicated in all dogs that undergo surgical correction of GDV to prevent recurrence (Allen and Paul 2014). GDV cases that receive gastropexy may have less than 5% recurrence and a median survival time of 547 days whereas those that do not receive gastropexy may have up to 80% recurrence and a median survival time of 188 days (Allen and Paul 2014, Glickman and others 1998). In this current study 3% of the surgical cases did not have a gastropexy procedure recorded in their clinical notes and so it appears that gastropexy is widely accepted as a clinical standard in the UK.

The current study had some limitations. Because of the urgent nature of emergency-care presentations and because these data were not recorded primarily for research purposes, many of the available data fields in the clinical records were incomplete or missing and it cannot be assumed that these data were missing at random. Consequently, ‘missingness’ may have introduced some bias into the final results and categories that described missing data were included in the analyses to try to quantify such biases. The EPRs of emergency-care patients described mainly the current presentation and often provided very limited information on prior history. Dogs were generally lost to longer-term follow-up after the immediate emergency-care treatment period. Serial blood lactate concentrations values were not available for this study. This study reports the prevalence of presumptive GDV within the first-opinion emergency-care population and the management and outcomes of these cases may not be fully representative of the wider dog population (Bartlett and others 2010). However, these differences should have less impact on the generalisability of results from the risk factors which are more dependent on basic physiology and therefore should be more constant across all dogs in the UK (Elwood 2007).

Conclusion

These results provide a baseline against which future studies of GDV in the UK primary-care population can be judged and provide information that may help to inform both veterinary surgeons and dog owners about GDV risk and prognosis.

Figures

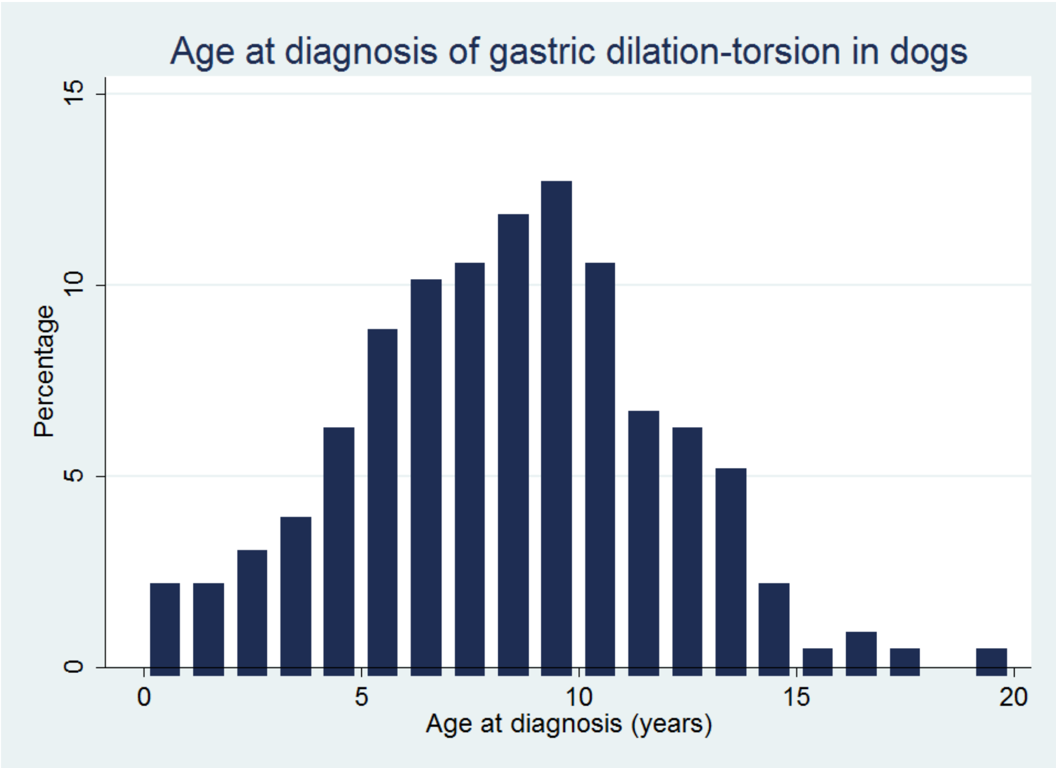

Figure 1: Age at diagnosis of presumed gastric dilation-volvulus in 466 dogs attending first opinion emergency-care veterinary practices in the UK

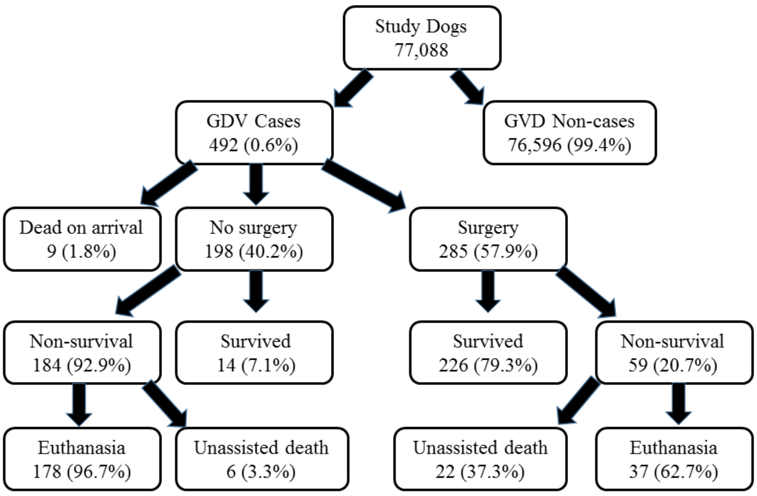

Figure 2: Flowchart showing some outcomes for presumed gastric dilation-volvulus in dogs attending first opinion emergency-care veterinary practices in the UK

Tables

Breed type	Total no. dogs	No. cases	Prevalence (%)	95% CI	No. (%) cases receiving surgery	No. (%) surgical cases died or were euthanased	No. (%) cases died or were euthanased overall
Crossbreed	10,713	12	0.1	0.1-0.2	4 (33.3)	1 (25.0)	9 (75.0)
Great Dane	236	33	14.0	9.8-19.1	24 (72.7)	3 (12.5)	12 (36.4)
Akita	109	10	9.2	4.5-16.2	4 (40.0)	0 (0.0)	6 (60.0)
Dogue de Bordeaux	318	23	7.2	4.6-10.7	9 (39.1)	2 (22.2)	16 (69.6)
Irish Setter	169	12	7.1	3.7-12.1	10 (83.3)	1 (10.0)	3 (25.0)
Weimaraner	480	34	7.1	5.0-9.8	21 (61.8)	6 (28.6)	17 (50.0)
Rhodesian Ridgeback	194	10	5.2	2.5-9.3	8 (80.0)	3 (37.5)	5 (50.0)
Basset Hound	241	11	4.6	2.3-8.0	7 (63.6)	1 (14.3)	5 (45.5)
German Shepherd Dog	1,910	74	3.9	3.1-4.8	41 (55.4)	10 (24.4)	42 (56.8)
Dobermann Pinscher	417	12	2.9	1.5-5.0	5 (45.5)	1 (20.0)	8 (66.7)
Boxer	1,308	23	1.8	1.1-2.6	8 (34.8)	3 (37.5)	17 (73.9)
Labrador Retriever	6,707	22	0.3	0.2-0.5	10 (45.5)	2 (20.0)	13 (59.1)
Other purebreds	54,264	216	0.4	0.3-0.5	134 (62.0)	26 (19.4)	100 (46.3)

Table 1: Prevalence with 95% confidence intervals (95% CI) for dog breed types commonly diagnosed with presumed gastric dilation-volvulus at first opinion emergency-care veterinary practices in the UK

Variable	Category	Case No. (%)	Non-case No. (%)	Odds ratio	95% CI*	P-Value
Purebred status	Crossbred	17 (3.4)	12,377 (18.2)	Base		
	Purebred	431 (96.2)	55,676 (81.8)	5.6	3.5-9.2	< 0.001
Breed	Crossbreed	12 (2.4)	10,701 (14.0)	Base		
	Great Dane	33 (6.7)	203 (0.3)	145.0	73.8-284.7	< 0.001
	Akita	10 (2.0)	99 (0.1)	90.1	38.0-213.3	< 0.001
	Dogue de Bordeaux	23 (4.7)	295 (0.4)	69.5	34.3-141.1	< 0.001
	Irish Setter	12 (2.4)	157 (0.2)	68.2	30.2-154.1	< 0.001
	Weimaraner	34 (6.9)	446 (0.6)	68.0	35.0-132.2	< 0.001
	Rhodesian Ridgeback	10 (2.03)	184 (0.2)	48.5	20.7-113.6	< 0.001
	Basset Hound	11 (2.2)	230 (0.3)	42.6	18.6-97.7	< 0.001
	German Shepherd Dog	74 (15.0)	1,836 (2.4)	35.9	19.5-66.3	< 0.001
	Dobermann Pinscher	12 (2.4)	405 (0.5)	26.4	11.8-59.2	< 0.001
	Boxer	23 (4.7)	1,285 (1.7)	16.0	7.9-32.2	< 0.001
	Other breed types	216 (43.9)	54,048 (70.6)	3.6	2.0-6.4	< 0.001
	Labrador Retriever	22 (4.47)	6,707 (8.8)	2.9	1.4-5.9	< 0.001
Actual bodyweight (kg)	< 10.0	4 (0.8)	9,021 (11.8)	Base		
	10.0-19.9	5 (1.0)	6,856 (9.0)	1.7	0.4-6.1	0.458
	20.0-20.9	36 (7.3)	5,169 (6.8)	15.7	5.6-44.2	< 0.001
	30.0-30.9	55 (11.2)	3,220 (4.2)	38.5	13.9-106.4	< 0.001
	≥ 40.0	86 (17.5)	1,304 (1.7)	148.8	54.5-406.0	< 0.001
	No recorded bodyweight	306 (62.2)	51,026 (66.6)	13.5	5.0-36.3	< 0.001

Adult (>18 months) bodyweight relative to breed mean	Lower/Equal	70 (14.2)	8,989 (11.7)	Base		
	Higher	85 (17.3)	7,644 (10.0)	1.4	1.0-2.0	0.028
	Not available	337 (68.5)	59,963 (78.3)	0.7	0.6-0.9	0.013
Age category (years)	< 3.0	31 (6.3)	22,030 (28.8)	Base		
	3.0 - 5.9	85 (17.3)	12,593 (16.4)	4.8	3.2-7.2	< 0.001
	6.0 - 8.9	147 (29.9)	10,558 (13.8)	9.9	6.7-14.6	< 0.001
	9.0 - 11.9	137 (27.9)	8,898 (11.6)	10.9	7.4-16.2	< 0.001
	≥ 12.0	66 (13.4)	10,741 (14.0)	4.4	2.8-6.7	< 0.001
	No age data available	26 (5.3)	11,776 (15.4)	1.6	0.9-2.6	0.091
Sex/neuter	Female entire	100 (24.1)	18,609 (29.4)	Base		
	Female neutered	67 (16.1)	11,437 (18.1)	1.1	0.8-1.5	0.586
	Male entire	147 (35.4)	21,917 (34.7)	1.2	1.0-1.6	0.088
	Male neutered	101 (24.3)	11,253 (17.8)	1.7	1.3-2.2	<0.001
Insurance	Non-insured	407 (82.7)	64,742 (84.5)	Base		
	Insured	85 (17.3)	11,854 (15.5)	1.1	0.9-1.4	0.272

Table 2: Descriptive and univariable logistic regression results for risk factors associated with a diagnosis of presumed gastric dilation-volvulus in dogs attending first opinion emergency-care veterinary practices in the UK.

Blood lactate concentration at presentation (mmol/L)	Overall: No. (%)	Not received surgery: No. (%)	Received surgery: No. (%)	Overall - survived to discharge: No. (%)	Surgical cases - survived to discharge: No. (%)
< 2	32 (17.7)	2 (6.2)	30 (93.8)	30 (93.8)	29 (96.7)
2 to < 4	67 (37.0)	7 (10.4)	60 (89.6)	56 (83.6)	52 (86.7)
4 to < 6	29 (16.0)	4 (13.8)	25 (86.2)	16 (55.2)	16 (64.0)
6 to < 8	22 (12.2)	5 (22.7)	17 (77.3)	13 (59.1)	12 (70.6)
≥ 8	31 (17.1)	7 (22.6)	24 (77.4)	10 (32.3)	10 (41.7)

Overall	181 (100.0)	25 (13.8)	156 (86.2)	125 (69.1)	119 (76.3)

Table 3: Initial blood lactate concentration (mmol/L) and associations with surgery and survival to discharge in dogs alive at presentation that were diagnosed with presumptive gastric dilation-volvulus attending first opinion emergency-care veterinary practices in the UK.

Duration of general anaesthesia (minutes)	No. (%) not receiving surgery	No. (%) receiving surgery	No. (%) died or were euthanased	No. (%) survived to discharge
< 50	8 (42.1)	11 (57.9)	13 (68.4)	6 (31.6)
50 - <100	3 (2.9)	100 (97.1)	25 (24.3)	78 (75.7)
100 - <150	0 (0.0)	77 (100.0)	15 (19.5)	62 (80.5)
≥ 150	0 (0.0)	43 (100.0)	8 (18.6)	35 (81.4)
Overall	11 (4.5)	231 (95.5)	61 (25.2)	181 (74.8)

Table 4: Duration of general anaesthesia (minutes) and associations with surgery and survival to discharge in dogs diagnosed with presumptive gastric dilation-volvulus attending first opinion emergency-care veterinary practices in the UK.

Variable	Category	Odds ratio	95% CI*	P-Value
Breed	Crossbreed	Base		
	Great Dane	114.3	55.1-237.1	< 0.001
	Akita	84.4	33.6-211.9	< 0.001
	Dogue de Bordeaux	82.9	39.0-176.3	< 0.001
	Irish Setter	67.4	28.9-157.2	< 0.001
	Weimaraner	50.8	25.2-102.7	< 0.001
	Basset Hound	39.5	16.8-92.7	< 0.001
	Rhodesian Ridgeback	31.0	12.2-78.6	< 0.001
	German Shepherd Dog	27.5	14.4-52.4	< 0.001

	Dobermann Pinscher	20.8	8.7-49.5	< 0.001
	Boxer	13.4	6.5-27.9	< 0.001
	Labrador Retriever	2.4	1.2-5.1	0.019
	Other purebreds	3.2	1.7-5.8	< 0.001
Age category (years)	< 3.0	Base		
	3.0 - 5.9	5.2	3.3-8.3	< 0.001
	6.0 - 8.9	9.5	6.1-14.8	< 0.001
	9.0 - 11.9	10.0	6.4-15.6	< 0.001
	≥ 12.0	5.6	3.4-9.2	< 0.001
	No age data available	1.6	0.9-3.0	0.111
Sex/neuter	Female entire	Base		
	Female neutered	0.8	0.6-1.1	0.271
	Male entire	1.2	0.9-1.6	0.168
	Male neutered	1.3	1.0-1.8	0.041

Table 5: Final multivariable logistic regression model for risk factors associated with a diagnosis of presumptive gastric dilation-volvulus in dogs attending first opinion emergency-care veterinary practices in the UK.

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