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

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

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34 collaborate in VetCompass. We are grateful to The Kennel Club, The Kennel Club Charitable  
35 Trust and Dogs Trust for supporting VetCompass.

36

37

## 38 **Structured Summary**

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

41 **Methods:** Cross-sectional study design using emergency-care veterinary clinical records  
42 from the VetCompass™ Programme spanning September 1<sup>st</sup>, 2012 to February 28<sup>th</sup>,  
43 2014. Risk factor analysis using multivariable logistic regression modelling.

44 **Results:** The study population comprised 77,088 dogs attending 50 Vets Now clinics.  
45 Overall, 492 dogs had presumptive gastric dilation-volvulus diagnoses giving a  
46 prevalence of 0.64% (95%CI: 0.58% - 0.70%). Compared with crossbred dogs, breeds  
47 with the highest odds ratios for diagnosis of presumptive gastric dilation-volvulus were  
48 the great Dane (OR: 114.3, 95% CI 55.1-237.1, P < 0.001), akita (OR: 84.4, 95% CI  
49 33.6-211.9, P < 0.001) and dogue de Bordeaux (OR: 82.9, 95% CI 39.0-176.3, P <

50 0.001). Odds increased as dogs aged up to 12 years and neutered male dogs had 1.3  
51 (95% CI 1.0-1.8, P = 0.041) times the odds compared with entire females. Of  
52 presumptive gastric dilation-volvulus cases that presented alive, 49.7% survived to  
53 discharge but 79.3% of surgical cases survived to discharge.

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

56

### 57 **Keywords**

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

59

### 60 **Abbreviations**

61 CI – confidence interval

62 EPR – electronic practice record

63 GDV – gastric dilation-volvulus

64 IQR – interquartile range

65 OR – odds ratio

66 RVC - Royal Veterinary College

67 SD - standard deviation

68

### 69 **Introduction**

70 Gastric dilation-volvulus (GDV) is generally an acute and life-threatening condition with  
71 severe multi-systemic effects in dogs (Brockman 2012, Sharp and Rozanski 2014). The  
72 precise pathophysiology of GDV is unclear but the presentation is characterised by rapid

73 accumulation of various combinations of gas, fluid and ingesta in the stomach, with  
74 increased intra-gastric pressure (Hendriks and others 2011). Dilation of the stomach and  
75 rotational twist along its horizontal axis compress the major abdominal blood vessels and  
76 impair venous return to the heart, leading to impaired cardiac output and shock  
77 (Glickman and others 1994). If left untreated, severe systemic hypoperfusion can ensue  
78 via multiple mechanisms (hypovolaemic, distributive and obstructive shock) along with  
79 additional respiratory compromise and decreased tidal volume that results from  
80 restriction of diaphragmatic excursions by the enlarged stomach (Monnet 2003).  
81 Diagnosis is commonly based on a combination of characteristic historical and physical  
82 examination findings (notably abdominal distension and pain, tachycardia, poor  
83 peripheral pulses and unproductive retching), combined with evidence of gastric  
84 malpositioning and enlargement apparent from diagnostic imaging (Tivers and Brockman  
85 2009).

86 A typical combination of significant pain and a high mortality rate make GDV both a  
87 clinical and welfare concern in affected dogs. Among UK pedigree dogs participating in a  
88 survey-based retrospective study, GDV was reported to cause 2.5% of all deaths, with a  
89 median age at death of 7.9 years (Evans 2010). A US study of large and giant dog  
90 breeds reported that 16% of deaths in these breeds were from GDV (Glickman and  
91 others 2000) and that 28.6% of GDV cases died directly from the disorder (Glickman  
92 2000).

93 GDV is a complex disorder with multiple interacting inherited and environmental factors  
94 reported to affect the probability of a GDV event (Bell 2014). Reported prevalence values  
95 for GDV in dogs varies widely across differing breeds and populations but it is generally  
96 recognised as a disorder that mainly affects large and giant breeds (Glickman and others  
97 1994). Purebred dogs are reported to be predisposed to GDV compared with crossbred  
98 dogs, with reported odds ratios (OR) ranging from 1.8 (95% confidence interval [CI]  
99 1.1-2.9) (Bellumori and others 2013) to 2.5 (95% CI 2.1-3.0) (Glickman and others

100 1994). Larger body size (Glickman and others 1994, Glickman and others 2000) and  
101 deep-chested conformations (Bell 2014) have been reported as risk factors for GDV.  
102 Many breeds are reported as predisposed to GDV, and these include great Dane,  
103 bloodhound, German shepherd, standard poodle, grand bleu de Gascogne, German  
104 pointer, akita, Irish setter, Weimaraner and Neapolitan mastiff (Bell 2014, Brockman  
105 1995, Evans 2010, Glickman 2000). Advancing age has also been reported to  
106 substantially increase risk of GDV (Elwood 1998, Glickman 2000, Theyse and others  
107 1998) but evidence to support a sex predisposition to GDV has been more equivocal  
108 (Eggertsdóttir and Moe 1995, Glickman and others 1997, Glickman and others 1994,  
109 Glickman and others 2000).

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

121

## 122 **Materials and methods**

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

126 VetCompass™ database from September 1<sup>st</sup>, 2012 to February 28<sup>th</sup>, 2014 (Vets Now  
127 2015). These dates were selected because they covered the span of available clinical  
128 records at the time of the study. Vets Now clinics use a standard practice management  
129 system called Helix and Vets Now team members are required to record presenting signs  
130 and encouraged to record diagnoses using the Venom Coding standardised terminology  
131 (The VeNom Coding Group 2017). A clinical query was used to extract EPR data from the  
132 Helix system that were then uploaded to a secure structured query language database  
133 (O'Neill and others 2014b). Data available for the current study included demographic  
134 (breed, date of birth, sex, neuter status, insurance status and bodyweight) and clinical  
135 (clinical notes, treatment, presenting signs and diagnosis terms with relevant dates)  
136 information.

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

145 In this study, the case definition for diagnosis of GDV required that the dog was  
146 presented either dead or alive at a participating clinic and that a final diagnosis of GDV  
147 (or synonyms covering either torsion or volvulus) was recorded in the EPR based on first  
148 opinion emergency-care diagnostic criteria. Because not all cases underwent definitive  
149 diagnosis by radiography, surgery, or both, the diagnosis must be considered to be  
150 presumptive in some cases. However, dogs that were specified as having gastric dilation  
151 without volvulus did not meet the case definition for this study and were excluded. On  
152 the other hand, animals that were already dead at the time of first presentation and that

153 met the case definition were included because of the risk that overall prevalence and risk  
154 factor values might otherwise be biased by preferentially removing categories of dog  
155 with more acute presentations and that tended to die more rapidly.

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

171 Following data checking and cleaning in Excel using internal data validity evaluations  
172 (Microsoft Office Excel 2007, Microsoft Corp.), statistical analyses were conducted using  
173 Stata Version 11.2 (Stata Corporation). Prevalence values with 95% CI were reported  
174 overall and for individual common breeds. The 95% CI estimates were derived from  
175 standard errors based on approximation to the normal distribution (Kirkwood and Sterne  
176 2003). Descriptive statistics characterised purebred status, breed, sex/neuter, age,  
177 actual bodyweight and bodyweight relative to breed mean for the GDV case and non-case  
178 dogs separately. The *breed variable* included individual breeds with 10 or more  
179 presumptive GDV cases recorded, a group containing the remaining purebred dogs



180 ('other purebred') and a group containing the crossbreds. *Actual bodyweight* (kg)  
181 described the maximum recorded bodyweight for dogs of any age. Six actual-bodyweight  
182 categories were generated: (0.0-9.9, 10.0-19.9, 20.0-29.9, 30.0-39.9,  $\geq 40.0$  and no  
183 bodyweight recorded). The mean adult bodyweight was calculated for individual breeds  
184 using bodyweight data from dogs aged over 18 months and these values were used to  
185 categorise individual dogs aged over 18 months as being either above or at/below their  
186 breed mean value ('bodyweight relative to breed mean'). Age (years) described the age  
187 at diagnosis for case animals and the age at the mid-point between the first and final EPR  
188 for the non-case animals. Age was categorised into six groups (< 3.0, 3.0-5.9, 6.0-8.9,  
189 9.0-11.9,  $\geq 12.0$  and not available). Analysis of age and bodyweight as categorical  
190 variables was planned during the study design because associations between these  
191 variables and clinical outcomes are rarely linear and therefore analysis as continuous  
192 variables is statistically inappropriate (Kirkwood and Sterne 2003, O'Neill and others  
193 2016, Taylor-Brown and others 2015). The additional categories that described missing  
194 data for the bodyweight and age variables were included in the analyses in order to  
195 better understand the impact that missing data may have had on the results for these  
196 variables. Blood lactate concentrations (mmol/L) were categorised into 5 groups (< 2, 2  
197 to < 4, 4 to < 6, 6 to < 8 and  $\geq 8$ ). These cut-offs were selected to be consistent with  
198 previously published results (Green and others 2011). Animals discharged alive from Vets  
199 Now clinical care were defined as having survived while those that died or were  
200 euthanased whilst still under the care of Vets Now were classified as non-surviving.  
201 Categorical variables were compared between groups using the chi-square test or Fishers  
202 exact test and quantitative variables were compared using the unpaired t-test or  
203 Wilcoxon rank sum test as appropriate (Kirkwood and Sterne 2003). A Bonferroni  
204 adjusted P-value of 0.007 was accepted for statistical significance to account for the  
205 effects of multiple testing (Aickin and Gensler 1996).

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

220

## 221 **Results**

### 222 **Descriptive results: demography and clinical outcomes**

223 Data completeness overall differed widely between the variables: sex 82.5%, neuter  
224 82.5%, insurance 100.0%, date of birth 84.7%, actual bodyweight 33.4% and breed  
225 88.9%. The study population comprised 77,088 dogs attending 50 Vets Now clinics  
226 across the UK. There were 492 dogs that met our presumptive GDV diagnosis case  
227 definition, giving a prevalence of 0.64% (95% CI 0.58% - 0.70%) of the overall canine  
228 emergency-care caseload. **The prevalence of presumptive GDV varied widely across the**  
229 **breeds. Breeds with the highest prevalence included great Dane (14.0% prevalence, 95%**  
230 **CI 9.8-19.1), akita (9.2%, 95% CI 4.5-16.2), dogue de Bordeaux (7.2%, 95% CI 4.6-**  
231 **10.7), Irish setter (7.1%, 95% CI 3.7-12.1) and Weimaraner (7.1%, 95% CI 5.0-9.8).**  
232 **The prevalence among crossbreeds was 0.1% (0.1-0.2) (Table 1).**

233 Of the presumptive GDV dogs with information available, 431 (96.2 %) were purebred,  
234 167 (40.2%) were female, 85 (17.3%) were insured and 168 (40.5%) were neutered  
235 (Table 2). The median actual bodyweight was 38.8 kg (IQR: 30.0 – 48.5, range: 3.7 –  
236 87.0) and the median age was 8.0 years (IQR: 6.0 – 10.0, range: 0.3 – 20.0) (Figure  
237 1). The most common 11 breeds accounted for 264 (53.7%) of the case dogs. Eleven  
238 breeds had 10 or more affected individuals recorded: akita, boxer, dogue de Bordeaux,  
239 great Dane, basset hound, Dobermann pinscher, Labrador retriever, Rhodesian  
240 ridgeback, Irish setter, German shepherd dog and Weimaraner. Of these, the highest  
241 breed prevalence was recorded for the great Dane (14.0%, 95% CI 9.8-19.1) and akita  
242 (9.2%, 95% CI 4.5-16.2) (Table 2). Data completeness for the presumptive GDV cases  
243 was: sex 84.3%, neuter 84.3%, insurance 100.0%, date of birth 90.7%, actual  
244 bodyweight 37.8% and breed 91.1%.

245

246 Of the non-case dogs with information available, 55,676 (81.8%) were purebred, 30,046  
247 (47.5%) were female, 11,854 (15.5%) were insured and 22,690 (35.9%) were neutered.  
248 The median bodyweight of non-case dogs was 14.7 kg (IQR: 7.8-25.7, range: 0.2 –  
249 100.0) and the median age was 5.0 years (IQR: 1.7 – 10.0, range: 0.0 – 25.0) (Table  
250 2). The most common breed types in the overall study were Labrador retriever (9.8%),  
251 Jack Russell terrier (5.5%), Staffordshire bull terrier (4.3%) and cocker spaniel (4.1%).  
252 Data completeness for the non-cases was: sex 82.5%, neuter 82.5%, insurance 100.0%,  
253 date of birth 84.6%, actual bodyweight 33.4% and breed 88.9%.

254 Nine of the 492 presumptive GDV cases overall (1.8%) presented as 'dead on arrival'. Of  
255 the dogs that were alive at presentation, 243/483 (50.3%) did not survive to discharge,  
256 with 215 (88.5%) of these deaths involving euthanasia. Of the 198 dogs that were alive  
257 at presentation and did not undergo surgery, 184 (92.9%) did not survive the  
258 emergency-care period, with the remaining 14 (7.1%) alive at discharge to their

259 primary-care practices or to their owners' care after which no further information was  
260 available. Of these 184 deaths, 178 (96.7%) were due to euthanasia and 6 (3.3%) were  
261 unassisted. Of the 285 dogs that underwent surgery, 226 (79.3%) survived and 59  
262 (20.7%) did not survive the emergency-care period. Of these 59 deaths, 37 (62.7%)  
263 were due to euthanasia and 22 (37.3%) were unassisted (Figure 2). Overall, 169/215  
264 (78.6%) presumptive GDV cases that were euthanased during the study period had  
265 information specified in the free-text notes describing the main reasons that the owner  
266 elected for euthanasia. Of these, 118 (69.8%) euthanasia decisions were taken to avoid  
267 further animal suffering and 51 (30.2%) were taken following financial concerns related  
268 to ongoing treatment.

269 Of dogs that were alive at presentation, 309 of 388 (79.6 %) presumptive GDV cases  
270 with information available were ambulatory. Cases that were ambulatory at presentation  
271 were significantly more likely to survive to discharge than non-ambulatory cases  
272 (survival: 158 (51.1%) ambulatory versus 17 (21.0%) non-ambulatory,  $P < 0.001$ ).  
273 Ambulatory cases were also significantly more likely to have surgery than non-  
274 ambulatory cases (surgery: 189 (61.2%) ambulatory versus 27 (33.3%) non-  
275 ambulatory,  $P < 0.001$ ). Of 481 presumptive GDV cases alive at presentation with  
276 information available, 189 (39.3%) did not receive any diagnostic imaging, 267 (55.5%)  
277 received radiology alone, 5 (1.0%) received ultrasonography alone and 20 (4.1%)  
278 received both radiology and ultrasonography. Of the dogs presented alive but that did  
279 not receive surgery, 81 (41.1%) received diagnostic imaging. Dogs that received some  
280 form of diagnostic imaging were more likely to have surgery than dogs that did not  
281 receive diagnostic imaging (221 (72.3%) versus 73 (38.6%),  $P < 0.001$ ). Blood lactate  
282 concentrations were recorded for 181 (36.8%) cases and showed a median of 3.5 (IQR  
283 2.3-6.3, range 0.6-18.3) mmol/L. Blood lactate concentrations at presentation  
284 (categorised data) were not associated with the likelihood of surgery ( $P = 0.227$ ). Dogs

285 with blood lactate concentrations < 4 mmol/L had an increased probability of survival to  
286 discharge both overall ( $P < 0.001$ ) and among the surgical cases ( $P < 0.001$ ) (Table 3).

287 Of the presumptive GDV cases that were alive at presentation with information available,  
288 182/398 (45.7%) had an orogastric tube inserted and 285/483 (59.0%) were surgically  
289 managed. Dogs that underwent surgery were younger than dogs that did not undergo  
290 surgery (mean (standard deviation (SD)) 7.0 (3.1) years versus 9.2 (3.3) years,  $P <$   
291 0.001) but bodyweight was not associated with surgery (surgical cases: mean (SD) 40.3  
292 (15.2) kg versus non-surgical cases: 40.9 (15.6) kg,  $P = 0.845$ ). Insured cases were  
293 more likely to receive surgery than uninsured cases (67/85 insured [78.8%] versus  
294 218/406 uninsured [53.7%] respectively,  $P < 0.001$ ). Of surgical cases with information  
295 available that survived to discharge, 17.5% (25 of 143 dogs) had a recorded gastrotomy  
296 procedure, 97.0% (191 of 197 dogs) underwent a recorded gastropexy procedure and  
297 14.9% (20 of 134 dogs) underwent a recorded splenectomy procedure. Splenectomised  
298 and non-splenectomised surgical cases did not differ in their proportional survival: 20  
299 (71.4%) versus 114 (73.1%),  $P < 0.001$ . Information on the duration of general  
300 anaesthesia was available for 242 dogs. The median (IQR, range) duration of general  
301 anaesthesia was 90.0 (60.0-120.0, 0.0-300.0) minutes (Table 4). The differing counts of  
302 cases with procedural information available is explained by differing clarity of the notes  
303 recorded in the EPRs about the procedures performed.

304

### 305 **Risk factors for diagnosis of presumptive GDV**

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

311 GDV compared with crossbred dogs and that increasing actual bodyweight was strongly  
312 associated with increased odds of the diagnosis, with dogs weighing  $\geq 40$  kg showing  
313 148.7 (95% CI 54.5-406.0,  $P < 0.001$ ) times the odds compared with dogs weighing  $<$   
314 10.0 kg. No association was identified between insurance status and diagnosis of  
315 presumptive GDV ( $P = 0.272$ ).

316 The final multivariable model comprised three risk factors: breed, age and sex/neuter  
317 status but did not identify bodyweight relative to breed mean as a significant risk factor.  
318 The final model showed acceptable model-fit (Hosmer-Lemeshow test statistic:  $P =$   
319 0.680) and good discrimination (area under the ROC curve: 0.843). The final model was  
320 not improved by inclusion of the clinic attended as a random effect ( $P = 0.095$ ) and no  
321 biologically significant interactions were identified. After accounting for the effects of the  
322 other variables evaluated in the multivariable model, the individual breeds with the  
323 highest odds ratios for presumptive GDV diagnosis compared with crossbred dogs were  
324 the great Dane (OR: 114.3, 95% CI 55.1-237.1,  $P < 0.001$ ), akita (OR: 84.4, 95% CI  
325 33.6-211.9,  $P < 0.001$ ) and dogue de Bordeaux (OR: 82.9, 95% CI 39.0-176.3,  $P <$   
326 0.001). The odds of diagnosis increased as dogs aged up to 12 years and then  
327 decreased. Compared with dogs aged  $< 3$  years, dogs aged from 6 to  $< 9$  years had 9.5  
328 (95% CI 6.1-14.8,  $P < 0.001$ ) times, and dogs aged from 9 to  $< 12$  years 10.0 (95% CI  
329 6.4-15.6,  $P < 0.001$ ) times, the odds of presumptive GDV diagnosis. Neutered male dogs  
330 had 1.3 (95% CI 1.0-1.8,  $P = 0.041$ ) times the odds of diagnosis compared with entire  
331 females (Table 5).

332

### 333 **Discussion**

334 To our knowledge, this is the most comprehensive epidemiologic study of presumptive  
335 GDV diagnoses relative to all veterinary emergency cases that has been published to  
336 date. This study highlights the relevance of presumptive GDV to the canine emergency

337 caseload, with a prevalence of 0.64% and an overall survival of under 50% of all cases.  
338 Of dogs that underwent surgery, approximately 80% survived to discharge from  
339 emergency care. Risk factors for diagnosis identified in this study included breed, age >  
340 3 years and sex. The great Dane, akita and dogue de Bordeaux breeds had the highest  
341 odds of presumptive GDV. Ambulatory status and blood lactate concentrations at initial  
342 presentation appeared to be useful survival indicators but their true association with  
343 survival may be confounded by their influence on euthanasia decision-making by  
344 veterinarians and owners (*i.e.* these factors may have been used in making the decision  
345 for euthanasia).

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

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

358 The current study reported a presumptive GDV prevalence of 0.64% of the overall  
359 canine emergency-care caseload, which is in broad agreement with a study of UK  
360 pedigree dogs ( $n = 36,006$ ) that reported a GDV prevalence of 0.7% (Evans 2010). A US  
361 study of referral cases ( $n = 27,254$ ) reported a lower prevalence of GDV of 0.2%  
362 (Bellumori and others 2013). Another US study reported that 2.4% of large-breed dogs

363 and 2.7% of giant-breed dogs had at least one GDV episode annually (Glickman and  
364 others 2000). However, it is difficult to compare prevalence results between studies that  
365 have widely differing populations at risk.

366 First-opinion veterinary clinical records can be a valuable resource for reliable and  
367 generalisable health information on the wider animal population (O'Neill and others  
368 2014a). Dogs affected by GDV require prompt management to prevent poor clinical and  
369 welfare outcomes and are therefore commonly presented as emergency-care cases to  
370 out-of-hours clinics (Brockman 2012). Consequently, analysis of combined clinical  
371 records from a large number of emergency-care clinics in the UK has potential to provide  
372 valuable insights into the epidemiology of GDV that are difficult to gain from other data  
373 resources. Emergency-care clinical records benefit from reduced recall and  
374 misclassification bias because of contemporaneous recording of health information by  
375 qualified professionals at the point of clinical care when and can be geographically  
376 representative when the contributing clinics span the entirety of the UK (Bateson 2010,  
377 McGreevy 2007, O'Neill and others 2014a). Electronic patient records also enable  
378 researchers to identify and include all diagnosed cases, regardless of their level of clinical  
379 work-up and management, and to explore the free-text clinical notes to answer  
380 contextual questions concerning aspects of welfare, presentation, diagnosis and  
381 management.

382 Purebred status was not evaluated in the multivariable modelling because it was highly  
383 correlated with breed. However, based on the univariable analysis in the current study,  
384 purebred dogs had over five times the odds of presumptive GDV compared with  
385 crossbreds. This finding is consistent with US studies emanating from referral clinics that  
386 reported odds ratios for purebred predisposition of 1.8 (Bellumori and others 2013), 2.5  
387 (Glickman and others 1994) and 4.8 (de Battisti and others 2012). A purebred  
388 predisposition for GDV may indicate a genuine inheritable predisposition but,  
389 alternatively, could reflect differing body-size distributions between purebred and



390 crossbred dogs. Although the median bodyweight of purebred and crossbred dogs is quite  
391 similar, purebred dogs tend to have a greater proportion of dogs with extreme large and  
392 small body size (O'Neill and others 2013) and GDV has been reported to be strongly  
393 associated with large or giant breed body types (Evans 2010).

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

406 Large or giant breeds feature heavily among the predisposed breeds for GDV (Bell  
407 2014). The current study did not include actual bodyweight in the multivariable analysis  
408 because the breed variable already somewhat accounted for bodyweight. However, the  
409 univariable results did support an association between increasing bodyweight and  
410 increased odds of presumptive GDV, with dogs weighing 30.0-39.9 kg having 38.5 times  
411 the odds compared with dogs weighting < 10.0 kg. Similar associations between  
412 increasing bodyweight and risk of GDV have been reported in US studies of referred GDV  
413 cases (Glickman 2000, Glickman and others 1994). However, it is worth noting for the  
414 current study, that bodyweight data were available for less than 40% of the study dogs  
415 and that these results may be confounded by breed and sex effects. Consequently,  
416 exploration in future studies that control for these factors is warranted.

417 Older dogs were identified at higher risk of presumptive GDV in the current study, with  
418 dogs aged between 9 and 12 years showing 10 times the odds of dogs aged under 3  
419 years. A previous study reported significantly increasing odds of GDV in Irish setters as  
420 dogs aged (Elwood 1998). The risk of GDV was reported to increase by approximately  
421 20% with each year of age in large and giant breeds in the US (Glickman and others  
422 2000) and the odds of GDV rose by 1.9 times for each year as great Danes in the  
423 Netherlands aged from 1 to 10 years old (Theyse and others 1998). Progressive  
424 stretching of the hepatogastric ligament with increasing age has been suggested as a  
425 pathogenic pathway for this increase GDV risk with aging (Hall and others 1995).

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

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

444 It is difficult to compare the proportions of dogs undergoing surgery and their survival  
445 rates against previous publications because of differing study case definitions, case  
446 populations, methodologies and data sources between the published works. A study of  
447 working farm dogs in New Zealand reported 65% survival overall but the study included  
448 dogs affected with gastric dilation either with or without volvulus and included only dogs  
449 that received either radiography, surgery or post-mortem affected with GDV (Hendriks  
450 and others 2011). US studies of surgically-managed cases in referral clinic settings have  
451 reported survival rates of 90% (Mackenzie and others 2010), 88% (Green and others  
452 2011), 85% (Brockman 1995), 84% (Beck and others 2006) and 82% (Brouman and  
453 others 1996). The lower survival reported in the current study may reflect inclusion of  
454 more acute and severe cases in the first-opinion emergency-care setting and differing  
455 case management compared with the referral situation and suggests that the results of  
456 the current study may be more applicable to the wider canine population. In addition,  
457 many of the deaths in the current study involved euthanasia, and over 30% of these  
458 deaths were related to financial concerns, which may have biased the survival rates  
459 downwards.

460 Taken at face value, the current findings might suggest that assessing ambulation and  
461 blood lactate concentrations at initial clinical presentation may be useful survival  
462 indicators for presumptive GDV. In the current study, 51.1% of dogs that were  
463 ambulatory at presentation survived compared with 21.0% survival in alive but non-  
464 ambulatory dogs. Lower initial lactate concentrations were also associated with higher  
465 survival rates in the current study (Table 3). These findings are consistent with other  
466 reports that suggest the prognostic value of blood lactate estimation (Beer and others  
467 2012). Among surgical GDV cases in the US, the median initial plasma lactate  
468 concentration in dogs that survived was 3.4 mmol/L compared with 6.80 mmol/L for  
469 non-survivors (Green and others 2011). A US study of a general emergency caseload  
470 reported that 4.9% of patients with blood lactate concentrations up to 2.5 mmol/L died

471 compared with 28.4% of patients with lactate values at or above 4.0 mmol/L (Shapiro  
472 and others 2005). Among systemically ill dogs in Canada, dogs with lactate  
473 concentrations above 2.3 mmol/L had 16 times more risk of dying than dogs with lactate  
474 concentrations at or below 2.3 mmol/L (Stevenson and others 2007). However, it is  
475 likely that associations between ambulation and blood lactate concentrations with  
476 subsequent survival are highly complex and so it may be unsafe to draw definitive  
477 conclusions from the current study results because of possible reverse-causality effects.  
478 Non-ambulatory dogs or those with high blood lactate concentrations may have been  
479 considered *a priori* to have a poorer prognosis by the owner or the attending veterinary  
480 surgeon and thus have been more likely to be euthanased. . It should also be noted that  
481 data availability for ambulatory status (79.2%) and plasma lactate concentration  
482 (36.8%) were not complete and therefore some biases relating to missing data may  
483 have affected the results. Survival analyses where clinicians were blinded to the values  
484 of potential prognostic indicators are needed to more definitively clarify the predictability  
485 of ambulation and blood lactate concentration as useful clinical indicators for survival,  
486 especially when they may be applied to individual animals.

487 Gastropexy, where the stomach is securely adhered to the abdominal wall, is clinically  
488 indicated in all dogs that undergo surgical correction of GDV to prevent recurrence (Allen  
489 and Paul 2014). GDV cases that receive gastropexy may have less than 5% recurrence  
490 and a median survival time of 547 days whereas those that do not receive gastropexy  
491 may have up to 80% recurrence and a median survival time of 188 days (Allen and Paul  
492 2014, Glickman and others 1998). In this current study 3% of the surgical cases did not  
493 have a gastropexy procedure recorded in their clinical notes and so it appears that  
494 gastropexy is widely accepted as a clinical standard in the UK.

495

496 The current study had some limitations. Because of the urgent nature of emergency-care  
497 presentations and because these data were not recorded primarily for research

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

512

### 513 **Conclusion**

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

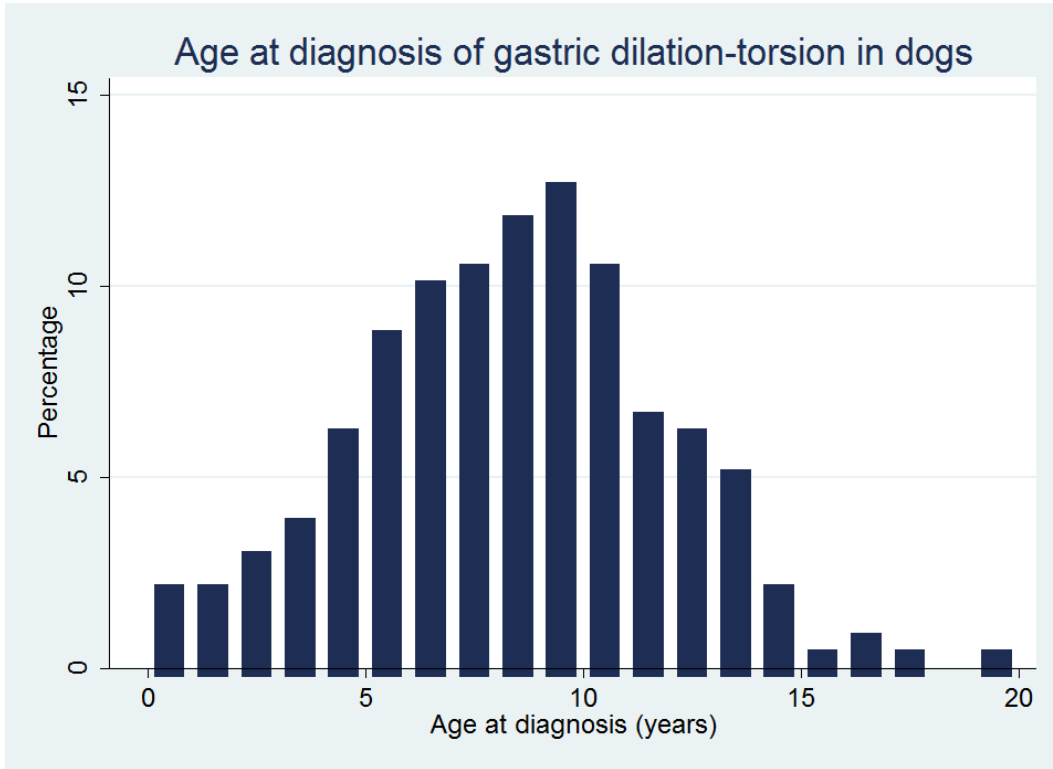
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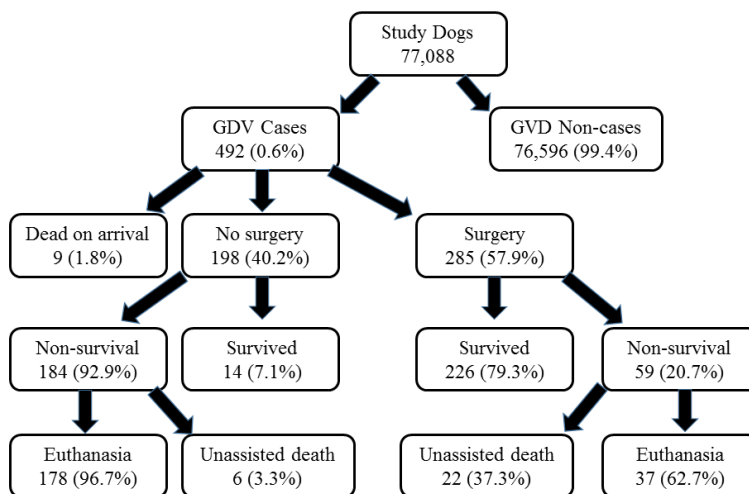
521 **Figures**



522

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

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

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531 **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)

532 Table 1: Prevalence with 95% confidence intervals (95% CI) for dog breed types

533 commonly diagnosed with presumed gastric dilation-volvulus at first opinion emergency-  
 534 care veterinary practices in the UK

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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

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

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

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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)

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

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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

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

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