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1 **Clinical findings and results of diagnostic imaging in 82 dogs with gastrointestinal ulceration**

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8 **Abstract**

9 Objectives: To describe clinical and imaging findings in dogs with confirmed gastrointestinal (GI)
10 ulceration, to compare findings in dogs with perforated and non-perforated ulcers, and to estimate
11 the sensitivities of radiography, ultrasonography and computed tomography (CT) for GI ulceration
12 and perforation, respectively.

13 Methods: Retrospective review of medical records of 82 dogs that had a macroscopic ulcer in the
14 gastric or intestinal mucosa visualised directly at endoscopy, surgery or necropsy and had survey
15 radiography, ultrasonography or a CT scan of the abdomen during the same period of
16 hospitalisation.

17 Results: The most frequent clinical signs were vomiting in 88% dogs, haematemesis in 32%, melena
18 in 31% and weight loss in 7%. The most frequent imaging findings in dogs with non-perforated ulcers
19 were GI mural lesion in 56%, mucosal defect compatible with an ulcer in 44% and peritoneal fluid in
20 21%. In dogs with perforated ulcers the most frequent imaging findings were peritoneal fluid in 83%,
21 GI mural lesion in 48%, peritoneal gas in 31% and mucosal defect compatible with an ulcer in 29%.
22 Sensitivities of radiography, ultrasonography and CT were 30%, 65% and 67% in dogs with non-
23 perforated ulcers and 79%, 86% and 93% in dogs with perforated ulcers, respectively.

24 Clinical impact: In dogs with non-perforated ulcers, survey radiography was usually negative whereas
25 ultrasonography and CT frequently enabled detection of the site of the ulcer; in dogs with
26 perforated ulcers, radiography was frequently positive for peritoneal gas and CT was a relatively
27 sensitive modality for both the ulcer and signs of perforation.

28 Key words: diagnostic imaging, dog, gastrointestinal disease, peritonitis, ulceration

29 **Introduction**

30 Gastrointestinal (GI) ulceration in dogs is a well-recognised condition that may occur following
31 administration of anti-inflammatory drugs (Cariou and others 2009, Dayer and others 2013, Enberg
32 and others 2006, Lascelles and others 2005, Monteiro-Steagall and others 2013, Stanton and Bright
33 1989) or corticosteroids (Rohrer and others 1999, Neiger and others 2000), ingestion of sharp
34 foreign objects or magnets (Hickey and Magee 2011), strenuous exercise (Davis and others 2006,
35 Ritchey and others 2011), primary gastrointestinal neoplasia (Gualtieri and others 1999, von Babo
36 and others 2012), mastocytosis (Murray and others 1972, Stanton and Bright 1989), inflammatory
37 bowel disease (Jergens and others 1992, Rallis and others 1998), hepatic disease (Murray and others
38 1972, Stanton and Bright 1989), uraemia (Peters and others 2005) or without any apparent
39 predisposing condition. Dogs with GI ulceration may present with acute abdominal signs, including
40 pain, distension or vomiting, or with vague and non-specific signs including lethargy, inappetence,
41 weakness and collapse (Murray and others 1972, Stanton and Bright 1989).

42 Dogs in which a GI ulcer has perforated are liable to develop septic peritonitis, have associated
43 higher mortality and are candidates for prompt surgical exploration and treatment (Boag and
44 Hughes 2004, Dayer and others 2013); however, clinical diagnosis of perforated ulcer is not
45 straightforward because the presenting signs are variable and the results of haematology and
46 biochemistry are unlikely to indicate surgery (Hinton and others 2002, Murray and others 1972,
47 Stanton and Bright 1989). Furthermore certain other tests that may be employed in a dog presenting
48 with acute abdominal signs can be misleading. For example, canine specific pancreatic lipase is
49 falsely positive in up to 40% dogs presenting as an acute abdomen (Hanworth et al 2014). The
50 routine use of focussed abdominal ultrasound scan for peritoneal fluid ('FAST' scan) in the
51 Emergency Room facilitates detection of peritoneal fluid in acute patients (Lisciandro 2011,
52 McMurray et al. 2015). When peritoneal fluid is identified, ultrasound-guided paracentesis enables
53 prompt detection of signs of septic peritonitis, such as intracellular bacteria in white blood cells, and

54 low glucose or high lactate concentration in peritoneal fluid compared to blood or plasma
55 (Bonczynski et al 2003, Cortellini and others 2015, Koenig and Verlander 2015).

56 More thorough diagnostic imaging is indicated in dogs presenting with acute, worsening or
57 persistent abdominal signs. Compared to studies about clinicopathologic testing and management,
58 there have been relatively few studies about the imaging signs associated with GI ulceration.

59 Although GI ulceration is not usually visible in survey radiographs, pneumoperitoneum is a critical
60 radiographic sign of GI perforation (Day and Pechman 2012, Smelstoy and others 2004).

61 Radiographs made with a horizontal x-ray beam and the dog in either dorsal or left lateral
62 recumbency are considered the most sensitive for detection of pneumoperitoneum (Day and
63 Pechman 2012). Detection of gastric ulcers is also possible using contrast radiography (Barber 1982,
64 Evans and Laufer 1981, Stanton and Bright 1989, Terragni and others 2014), but this technique has
65 been used less frequently since the introduction of ultrasonography.

66 Ultrasonographic signs of ulcer associated with GI neoplasms and signs of GI perforation in dogs
67 have been reported. Ulcers may be recognised ultrasonographically as a mucosal defect located in
68 the centre of a thickened region of the gastric or intestinal wall containing a collection of small
69 echoes, most likely representing bubbles (Lamb and Grierson 1999, Paoloni and others 2002,
70 Penninck and others 1997). A review of ultrasonographic findings in 14 dogs and 5 cats with GI
71 perforation found regional hyperechoic mesenteric fat in 100%, peritoneal fluid in 84% and
72 peritoneal air in 47% (Boysen and others 2003). These results suggest that ultrasonography could be
73 a sensitive method for diagnosis of GI perforation; however, other studies have found problems with
74 the ultrasonographic diagnosis of both GI ulceration and perforation. For example, signs of gastric
75 neoplasia were identified ultrasonographically in only 58% (von Babo and others 2012) and 50%
76 (Marolf and others 2015) affected dogs and cats. In dogs with perforated ulcer, the findings of
77 peritoneal fluid, hyperechoic mesentery and hypoechoic mass-like lesions adjacent to the stomach
78 could be misinterpreted as pancreatitis (Manczur and Voros 2000). In a review of dogs that had

79 exploratory laparotomy, GI ulceration or perforation were the lesions most likely to be missed by
80 ultrasonography (Pastore and others 2007).

81 Computed tomography (CT) is a well-established modality for investigation of GI bleeding in humans
82 (Horton & Fishman 2004, Lee and others 2011, Soto and others 2015), but there are no published
83 reports of use of CT in dogs with suspected GI ulceration.

84 The purpose of the present study was to review the medical records of a series of dogs with GI
85 ulceration in order to describe their presenting signs and imaging findings, to compare findings in
86 dogs with perforated and non-perforated ulcers, and to estimate the sensitivities of survey
87 radiography, ultrasonography and CT for GI ulceration and perforation, respectively.

88

89 **Methods**

90 For this retrospective case series study, electronic medical records of the Queen Mother Hospital for
91 Animals (QMHA) between September 2006 and March 2016 were reviewed. The criteria for
92 inclusion were dogs that had an ulcer in the gastric or intestinal mucosa identified by direct visual
93 inspection at endoscopy, surgery or necropsy and had FAST scan, radiography, ultrasonography or a
94 CT scan of the abdomen during the same period of hospitalisation. For the purposes of this study,
95 ulcer is defined as a focal absence of the gastric or intestinal mucosa.

96 FAST scans were done by Emergency Room veterinarians using a DP-50 ultrasound machine
97 (Mindray DS USA Inc., Mahwah, NJ, USA) and following the previously described protocol (Boysen
98 and Lisciandro 2013). Radiography was done using a conventional diagnostic x-ray machine (Sedecal
99 32kW x-ray generator and Toshiba x-ray tube) and either a computed radiography (Capsula XL, Fuji,
100 Bedford, UK) or digital radiography system (TruDR, SoundEkin, Carlsbad, CA, USA). Radiographs
101 were made with vertical x-ray beam in all dogs with additional radiographs in selected cases made
102 with a horizontal x-ray beam and the dog in lateral recumbency to look for pneumoperitoneum (Day
103 and Pechman 2012). Ultrasonography was done by a board-certified radiologist or a radiology

104 resident working under their direct observation using 2-6MHz curvilinear, 5-8.5MHz curvilinear, 5-
105 8MHz vector array or 5-14 MHz linear transducers (Sequoia 512, Siemens Healthcare Limited,
106 Camberley, Surrey). Dogs had ultrasonography in right and left lateral recumbency and were usually
107 restrained manually. CT scans were done using a 16-slice MDCT scanner (MX 8000 IDT, Philips
108 Medical Systems, Cleveland, USA). CT settings were helical acquisition, slice thickness 3mm, image
109 reconstruction interval 1.5mm, helical pitch 0.688, tube rotation time 0.75s, x-ray tube current 150
110 mAs, x-ray tube potential 120kVp, field of view 320-400mm, matrix 512x512 and medium frequency
111 ('soft tissue') reconstruction algorithm. CT image series of the abdomen were obtained before and
112 60 seconds after the start of intravenous injection of 2ml/kg of iohexol 300mg/ml (Omnipaque 300,
113 GE Healthcare, Oslo, Norway). Dogs were anaesthetised or sedated for CT and placed in sternal
114 recumbency.

115 Data extracted from the medical records included signalment, history, clinical signs, results of
116 haematology and serum chemistry, results of FAST scan, radiography, ultrasonography or CT scan,
117 site of ulcer, final diagnosis and survival to discharge.

118 Imaging findings were extracted from contemporaneous reports written by 6 different Board-
119 certified radiologists employed at the QMHA during the period of study. Imaging studies were also
120 reviewed on a workstation using commercially available DICOM image viewing software (OsiriX 64-
121 bit, version 5.2.2, Pixmeo, Switzerland) after retrieval from PACS. For each modality, images were
122 evaluated for the presence of peritoneal fluid or gas, signs of a gastrointestinal mural lesion, mucosal
123 defect compatible with an ulcer and the site (if applicable) of an ulcer. Any of these findings was
124 considered a positive (i.e. abnormal) result with respect to the diagnosis of gastrointestinal
125 ulceration.

126

127 **Results**

128 Records were found of 192 dogs that had a clinical diagnosis of GI ulceration. Of these, 82 dogs had a
129 GI ulcer confirmed by endoscopy in 26 (32%) instances, laparotomy in 49 (60%) and necropsy in 7
130 (8%).The remainder did not have investigations to confirm an ulcer and were excluded.

131 There were 51 (62%) males (28 neutered) and 31 (38%) females (25 neutered). Their median age
132 was 7.9y (range 6m – 13y). The most frequent breeds were golden retriever (10, 12%), Labrador
133 retriever (9, 11%), Staffordshire bull terrier (9, 11%), mixed-breeds (8, 10%), English springer spaniel
134 (6, 7%), Boxer dogs (4, 5%) and Doberman (3, 4%). There were 29 other breeds with one or two
135 affected dogs. Sites of GI ulcers were stomach in 42 dogs (51%), duodenum in 23 (28%), jejunum in
136 six (7%), ileum in one (1%), small intestine, exact site not specified in four (5%), caecum in one (1%),
137 colon in four (5%) and ulcers in both duodenum and colon in one (1%). Based on findings at surgery
138 or necropsy, ulcers were perforated in 48 (59%) dogs. Ulcers in intestinal sites were perforated more
139 frequently than ulcers in the stomach (28/40 versus 20/42).

140 The median duration of clinical signs prior to presentation was 10 days (range 1 day-1 year). Prior
141 administration of non-steroid anti-inflammatory drugs (NSAIDs) was reported in 37 (45%) dogs and
142 prior administration of corticosteroids was reported in 9 (11%) dogs. Of the NSAIDs used, meloxicam
143 was the most prevalent (in 52% instances) followed by carprofen (14%), firocoxib (14%), cimicoxib
144 (11%), troxoxil (6%) and mavacoxib (3%). One dog had received both NSAIDs and steroids.

145 The most frequently reported clinical signs were vomiting in 72 (88%) dogs, haematemesis in 26
146 (32%), melena in 25 (31%), lethargy in 7 (9%) and weight loss in 6 (7%). Ten (12%) dogs had both
147 haematemesis and melena. Similar numbers of dogs presented with elevated (27, 33%), normal (30,
148 37%) and subnormal rectal temperature (25, 30%). Haematemesis occurred more frequently in dogs
149 with gastric ulcers than intestinal ulcers (18/42 versus 8/40). Melena and weight loss occurred more
150 frequently in dogs with non-perforated ulcers than perforated ulcers (17/34 versus 8/48, and 5/34
151 versus 1/48, respectively).

152 Anaemia (haematocrit <0.37) was found in 34 (41%) dogs. Anaemia occurred more frequently in
153 dogs with a long duration of clinical signs than dogs with short duration of signs (18/26 versus
154 14/44). Blood lactate concentration was increased (>2.5mmol/L) in 16/50 (32%) dogs in which it was
155 determined. Peritoneal fluid was detected more frequently in dogs with perforated ulcers than non-
156 perforated ulcers (38/48 versus 7/34). Peritoneal fluid was submitted for analysis in 34 (41%)
157 instances. All peritoneal fluid samples had evidence of inflammation and 19 (56%) had cytological
158 evidence of intracellular bacteria, all in samples from dogs with perforated ulcers. One dog with a
159 perforated gastric ulcer had peritonitis associated with *Candida* spp.

160 FAST scan, survey radiography, ultrasonography and CT were done in 39 (48%), 34 (41%), 62 (76%)
161 and 17 (21%) dogs, respectively. In 5 dogs, abdominal radiographs included a horizontal x-ray beam
162 view. Multiple imaging modalities (i.e. radiography and ultrasonography or radiography and CT or
163 ultrasonography and CT) were employed in 42 (51%) dogs. The most frequent first imaging modality
164 was FAST scan (figure 1). The majority of dogs having FAST scan then had either radiography or
165 ultrasonography. There were only small numbers of dogs in which results of radiography and
166 ultrasonography (n=23) or radiography and CT (n=5) or ultrasonography and CT (n=7) could be
167 compared, hence statistical testing of differences in sensitivity was not considered appropriate.

168 Based on classification of peritoneal fluid, peritoneal gas, GI mural lesion and mucosal defect
169 compatible with an ulcer as positive results for imaging, the sensitivities of FAST scan, radiography,
170 ultrasonography and CT were 17%, 30%, 65% and 67% in dogs with non-perforated ulcers and 79%,
171 79%, 86% and 93% in dogs with perforated ulcers, respectively (tables 1 and 2, figures 2-5).

172 The most frequent imaging findings in dogs with non-perforated ulcers were GI mural lesion in 19/34
173 (56%), mucosal defect compatible with an ulcer in 15/34 (44%) and peritoneal fluid in 7/34 (21%). In
174 dogs with perforated ulcers the most frequent imaging findings were peritoneal fluid in 40/48 (83%),
175 GI mural lesion in 23/48 (48%), peritoneal gas in 15/48 (31%) and mucosal defect compatible with an
176 ulcer in 14/48 (29%). Imaging abnormalities were found in 22/34 (65%) dogs with non-perforated

177 ulcers compared to 47/48 (98%) dogs with perforated ulcers. Peritoneal fluid was observed more
178 frequently in dogs with perforated ulcers than in dogs with non-perforated ulcers, and peritoneal
179 gas was observed only in dogs with perforated ulcers. Additional imaging findings were dilatation of
180 intestine in 10 dogs (2 on radiography, 7 on ultrasonography and 1 on CT), hyperdense streaking of
181 abdominal fat in CT images of 7 dogs, foreign body in 5 dogs (1 on radiography, 2 on
182 ultrasonography and 2 on CT), hyperechoic abdominal fat in ultrasound images of 4 dogs and barium
183 extravasation in the only dog that had contrast radiography of the GI tract.

184 All ulcers were examined histologically. A primary cause of GI ulceration was identified in 41/82
185 (50%) dogs, including primary GI neoplasia in 17/82 (42%) dogs, inflammatory GI disease in 15/82
186 (37%) and intestinal foreign body in 9/82 (22%) (table 3). In the remaining 41 dogs, a specific cause
187 of the ulceration was not identified, although 19/41 (46%) of these had a history of prior NSAID
188 administration and 3/41 (7%) had a history of prior corticosteroid administration. Of the 82 dogs in
189 this study, 58 dogs (71%) survived to discharge and 24 (29%) died or were euthanized.

190

191 **Discussion**

192 The frequency of prior administration of NSAIDs in dogs in the present study is compatible with
193 previous reports that this is a major predisposing cause for GI ulceration in dogs (Cariou and others
194 2009, Enberg and others 2006, Dayer and others 2013, Lascelles and others 2005, Monteiro-Steagall
195 and others 2013, Stanton and Bright 1989). The predominance of vomiting, haematemesis and
196 melena in dogs with GI ulceration corresponds with the findings of previous studies (Murray and
197 others 1972, Stanton and Bright 1989). Haematemesis occurred more frequently in dogs with gastric
198 ulcers than intestinal ulcers. Melena and weight loss occurred more frequently in dogs with non-
199 perforated ulcers than perforated ulcers, whereas peritoneal fluid occurred more frequently in dogs
200 with perforated ulcers.

201 In the present study, peritoneal fluid was an important sign of perforated GI ulcers and the finding of
202 intracellular bacteria in peritoneal fluid samples was diagnostic. It should be emphasised that
203 determination of the cellular and protein content of peritoneal fluid relies on abdominocentesis
204 because these properties cannot be deduced consistently from the ultrasonographic features.
205 Peritoneal fluid in animals with peritonitis may be hyperechoic or anechoic (Spaulding 1993, Boysen
206 and others 2003, Lewis and O'Brien 2010, Feeney and others 2013). In the present study
207 echogenicity of peritoneal fluid was not recorded.

208 Although dogs with perforated ulcers may be expected to have peritonitis, this can be difficult to
209 detect clinically. Peritonitis associated with a perforated GI ulcer may be contained by omental
210 adhesions and consequently there may be no peritoneal fluid or other signs to suggest perforation
211 (Murray and others 1972, Stanton and Bright 1989). Similarly, translocation of bacteria across the
212 gastric or intestinal wall can occur because of wall damage or immune deficiency (Opal and Cross
213 2005), so finding intracellular bacteria in peritoneal fluid sample is not specific for perforated GI
214 ulcer. When intracellular bacteria are found in peritoneal fluid, but no signs of ulcer or perforation
215 are found, a diagnosis of primary bacterial peritonitis should be considered (Culp and others 2009).

216 *Candida* peritonitis occurred in one dog in the present series. *Candida* spp. are commensals of the
217 biliary and intestinal tract, but *Candida* peritonitis has been reported infrequently. In a report of 5
218 dogs with *Candida* peritonitis, all had a history of antimicrobial therapy and liver/biliary surgery or
219 gastrointestinal perforation (Bradford and others 2013). Only two of the five dogs in that report
220 survived to discharge. In the present study, the dog with *Candida* peritonitis had a perforated pyloric
221 ulcer, but survived to discharge.

222 In the present series, perforated ulcers were found more frequently in the intestine than in the
223 stomach. Other reports have found a greater number of perforated ulcers in the stomach (Lascelles
224 and others 2005) or an even distribution between stomach and intestine (Dayer and others 2013,
225 Hinton and others 2002).

226 A primary cause for GI ulceration was identified in half the dogs in the present series. The frequency
227 of diagnosis of primary GI neoplasia is compatible with previous studies (Gualtieri and others 1999,
228 Murray and others 1972, Stanton and Bright 1989, von Babo and others 2012). A higher frequency of
229 inflammatory GI conditions associated with ulceration was observed in the present study compared
230 to previous reports. Also, in contrast to previous studies (Murray and others 1972, Stanton and
231 Bright 1989), there were no dogs with GI ulceration secondary to hepatic disease.

232 FAST scan was the imaging modality most frequently used first in the present study. In our hospital
233 FAST scan is performed by clinicians in the Emergency Room, hence its use in the present study
234 probably reflects the number of dogs presenting as emergencies, although this was not recorded
235 specifically. The majority of dogs having FAST scan then had either radiography or ultrasonography.
236 In contrast, few dogs had CT only; however, the time span of the present study (10 years) is wide
237 enough that it will encompass changes in clinical practice over time, and the use of imaging
238 modalities summarised here represents their total use during this period rather than current
239 preferences or future trends. For example, FAST scan was introduced during this period and is now
240 used routinely in the Emergency Room. Similarly, the CT scans were done mainly towards the end of
241 the period covered by the study and it is likely, particularly with the apparent high sensitivity
242 observed, that CT will be used more frequently in the future at the expense of radiography and
243 ultrasonography.

244 The choice of imaging modality for each dog in this series will have been based on the history and
245 clinical signs and the likelihood of specific diagnosis as perceived by the attending clinician(s). The
246 use of a single imaging modality is likely when signs of septic peritonitis have been identified and
247 exploratory laparotomy is indicated as a matter of urgency. Depending on the clinical signs and
248 status of the patient, exploratory laparotomy may be performed after finding intracellular bacteria in
249 peritoneal fluid sample obtained by FAST scan or finding peritoneal gas on survey radiography only,
250 without further imaging. In such cases, additional attempts to confirm the diagnosis (e.g. by using
251 horizontal x-ray beam radiographs) may be considered unnecessary because of the overriding

252 indication for prompt laparotomy. Alternatively, dogs in which a gastric ulcer is considered likely
253 may be considered candidates for endoscopy without additional imaging. It is probably those dogs in
254 which clinical signs are considered non-specific that are most likely to be subjected to more
255 comprehensive imaging. Compared to a FAST scan, a complete abdominal ultrasound scan is likely to
256 detect additional features that enable more specific diagnosis. For example, in a dog with peritonitis,
257 additional ultrasonographic signs could include hyperechoic, complex or localised peritoneal fluid,
258 corrugation of the small intestinal wall, hyperechoic abdominal fat, peritoneal thickening or
259 adhesions, an abscess or peritoneal gas (Boysen and others 2003, Feeney and others 2013).

260 Although the results of this study are likely to be applicable to veterinary referral practice, they
261 cannot be considered definitive because of limitations associated with the retrospective
262 methodology. For example, statistical testing of differences in sensitivities of imaging modalities was
263 not considered appropriate because multiple imaging modalities were employed in approximately
264 half the dogs in this series, and hence there were relatively few dogs in which results of radiography
265 and ultrasonography or radiography and CT or ultrasonography and CT could be compared. Such
266 variability in the management of individual patients is unavoidable (and appropriate) in clinical
267 practice, but it prevents robust estimates of the sensitivity of imaging modalities and comparisons
268 between results of other studies, as previously noted (Dayer and others 2013). For example, the
269 potential for increased sensitivity for pneumoperitoneum by consistent use of horizontal x-ray beam
270 radiographs cannot be assessed. Despite these limitations, various trends in the performance of the
271 different imaging modalities may be identified: in dogs with non-perforated ulcers radiography was
272 usually negative whereas ultrasonography and CT frequently enabled detection of the site of the
273 ulcer; in dogs with perforated ulcers, radiography was frequently positive for peritoneal gas and CT
274 was a relatively sensitive modality for both the ulcer and signs of perforation. Pneumoperitoneum is
275 an important radiographic sign of GI perforation (Hinton and others 2002, Smelstoys and others
276 2004), but may be also observed in animals without GI perforation, following blunt or penetrating

277 abdominal trauma, laparotomy (Probst and others 1986) or rupture of the urinary bladder (Saunders
278 and Tobias 2003). None of the cases presented in this study had a history of trauma.

279 A gastric or intestinal ulcer is unlikely to be visible in survey radiographs; however, duodenal
280 pseudoulcers may be observed in survey radiographs, particularly in dogs positioned in left lateral
281 recumbency (Vander Hart and Berry 2015). These structures, which may also be identifiable in
282 ultrasound and CT images, may be distinguished from true ulcers because they are normally
283 multiple, evenly spaced and occur on the anti-mesenteric border of the descending duodenum,
284 whereas the majority of duodenal ulcers occur near the cranial duodenal flexure and pyloric canal
285 (Stanton and Bright 1989).

286 As noted above, clinical or imaging signs of GI perforation should be considered an indication for
287 exploratory laparotomy as a matter of urgency and a contraindication for a radiographic contrast
288 study, which could delay definitive diagnosis and treatment. Barium contrast studies of the GI tract
289 should be avoided in animals with suspected GI perforation because of the possibility of barium
290 extravasation, which could exacerbate the peritonitis (Ko and Mann 2014). Based on the findings of
291 the present study, CT may be considered advantageous because it appears to be a sensitive test for
292 both primary and secondary lesions in dogs with GI perforation and avoids the need for contrast
293 radiography.

294

295 No conflicts of interest have been declared.

296 Table 1. Sensitivities of imaging modalities in dogs with gastrointestinal ulceration

297

298		Modality			
299		FAST	Radiography	Ultrasonography	CT
300	Non-perforated ulcer	1/6 (17%)	3/10 (30%)	22/34 (65%)	2/3 (67%)
301	Perforated ulcer	26/33 (79%)	19/24 (79%)	24/28 (86%)	13/14 (93%)

302

303 FAST, focussed abdominal ultrasound scan for peritoneal fluid; CT, computed tomography

304 Sensitivity = number of dogs with positive result for imaging/number of dogs subjected to imaging

305 Table 2. Major imaging findings in 82 dogs with gastrointestinal ulceration

306

307		Modality			
308		FAST	Radiography	Ultrasonography	CT
309	Non-perforated ulcer (n=34)				
310	Peritoneal fluid	1/6 (17%)	3/10 (30%)	7/34 (21%)	0/3 (0%)
311	Peritoneal gas	-	0/10 (0%)	0/34 (0%)	0/3 (0%)
312	Gastrointestinal mural lesion	-	1/10 (10%)	19/34 (56%)	2/3 (67%)
313	Ulcer visualised	-	1/10 (10%)	14/34 (41%)	1/3 (33%)
314					
315	Perforated ulcer (n=48)				
316	Peritoneal fluid	26/33 (79%)	13/24 (54%)	23/28 (82%)	10/14 (71%)
317	Peritoneal gas	-	9/24 (38%)	3/28 (11%)	8/14 (57%)
318	Gastrointestinal mural lesion	-	3/24 (13%)	14/28 (50%)	11/14 (79%)
319	Ulcer visualised	-	0/24 (0%)	4/28 (14%)	11/14 (79%)

320

321 FAST, focussed abdominal ultrasound scan for peritoneal fluid; CT, computed tomography

322 Table 3. Primary diagnoses in 82 dogs with gastrointestinal ulceration

323

324 Primary gastrointestinal neoplasia

325 Carcinoma 5 (6%)

326 Lymphoma 3 (4%)

327 Adenocarcinoma 2 (2%)

328 Mastocytoma 2 (2%)

329 Leiomyoma 1 (1%)

330 Spindle cell tumour 1 (1%)

331 Neoplasm, type not determined 3 (4%)

332 Inflammatory gastrointestinal disease

333 Lymphocytic/plasmacytic enteritis 6 (7%)

334 Gastritis, non-specific 5 (6%)

335 Ulcerative colitis 2 (2%)

336 Eosinophilic duodenitis 1 (1%)

337 Foreign body 9 (11%)

338 Necrosis, non-specific 1 (1%)

339 Primary cause not identified 41 (50%)

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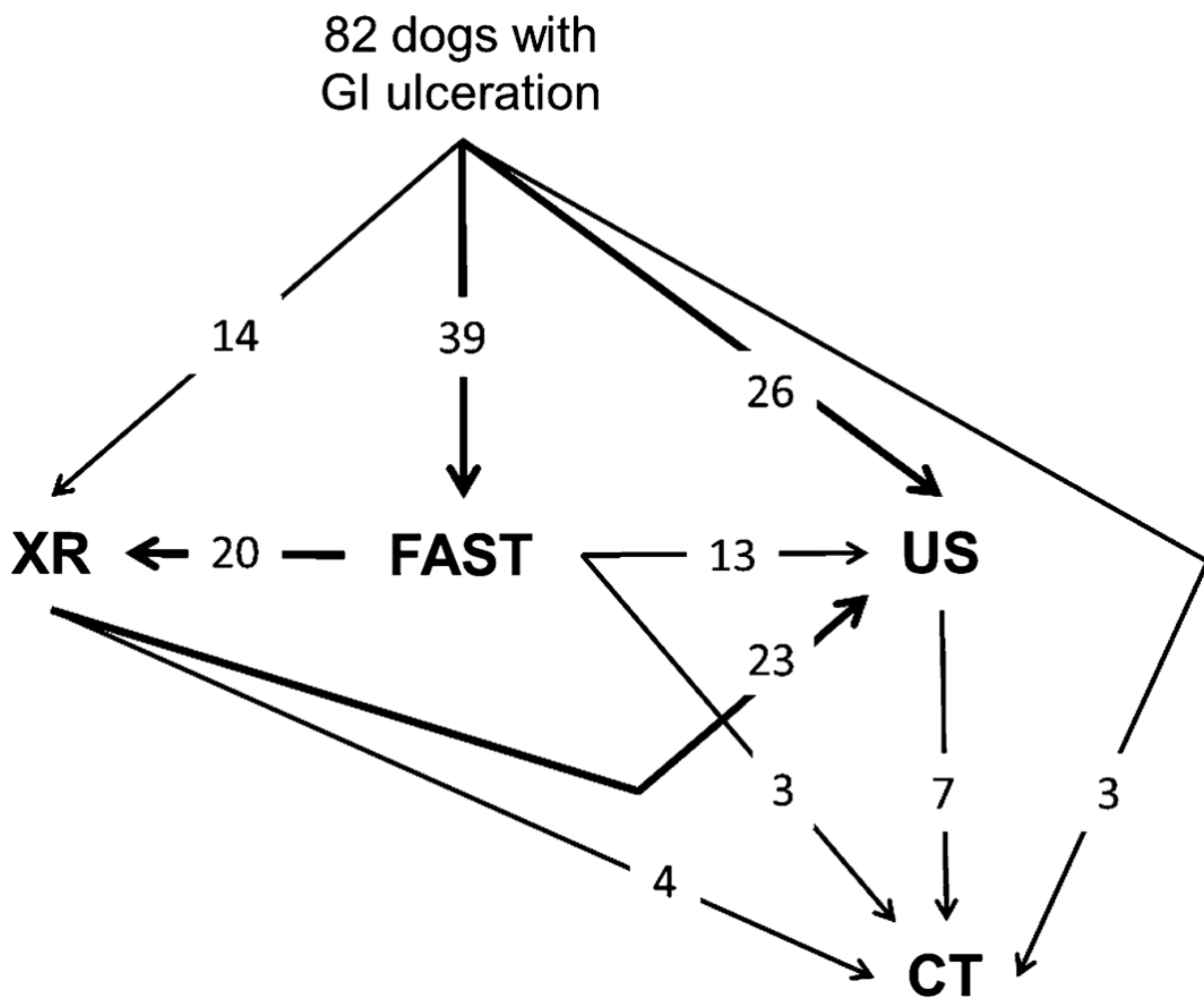
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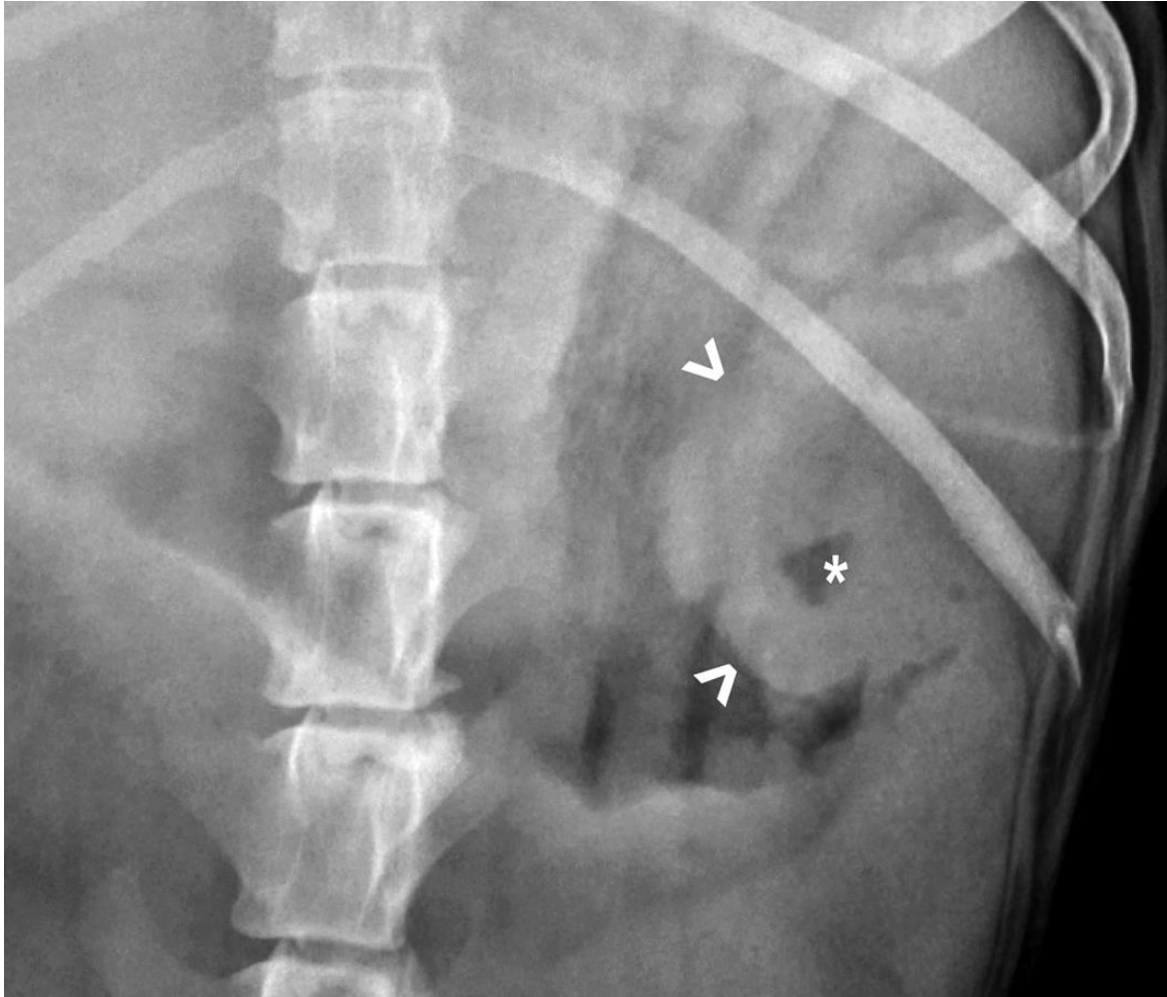
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476 **Legends**

477 Figure 1. Schematic showing use of imaging modalities in dogs with gastrointestinal ulceration. The
 478 arrows indicate numbers of dogs subjected to imaging and the sequence of imaging for dogs having
 479 multiple studies. The most frequent first imaging modality was FAST scan, although the majority of
 480 dogs having FAST scan then had either radiography (XR) or ultrasonography (US). The majority of
 481 dogs having radiography also had ultrasonography.



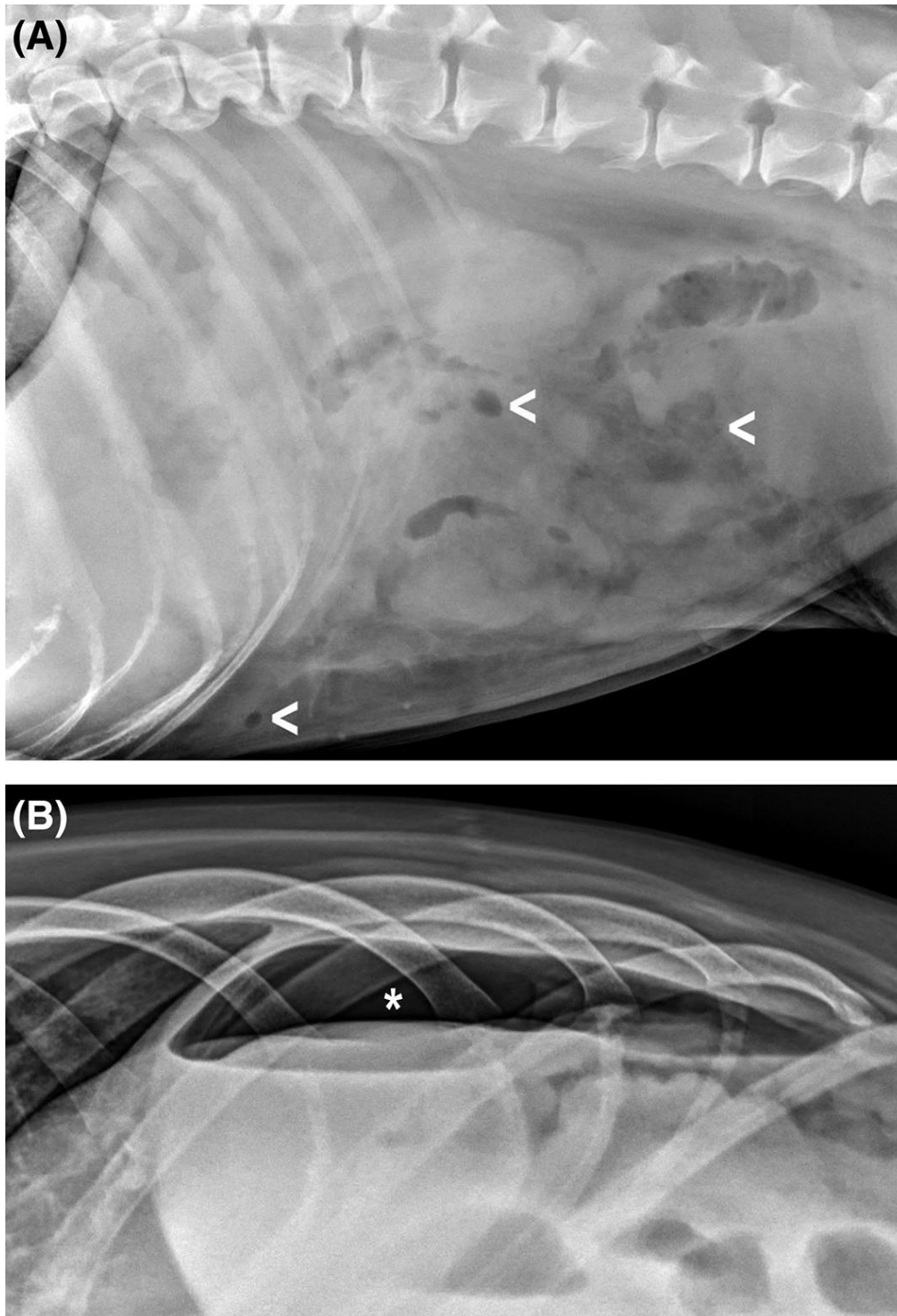
484 Figure 2. Example of radiographic signs in a dog with non-perforated gastric ulcer. Detail of a
485 ventrodorsal radiograph showing a mass (arrowheads) affecting the greater curvature of the
486 stomach with a central gas lucency (*) compatible with an ulcer.



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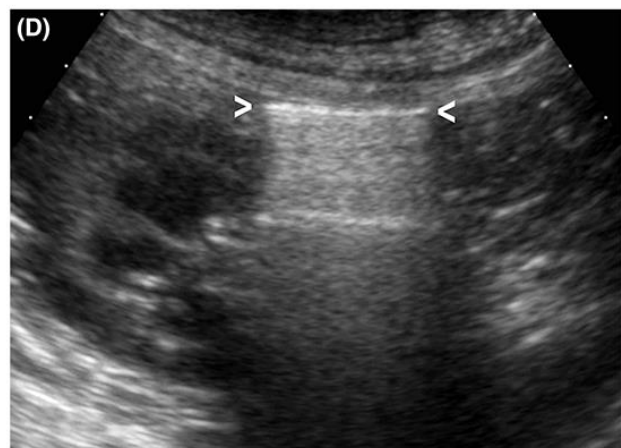
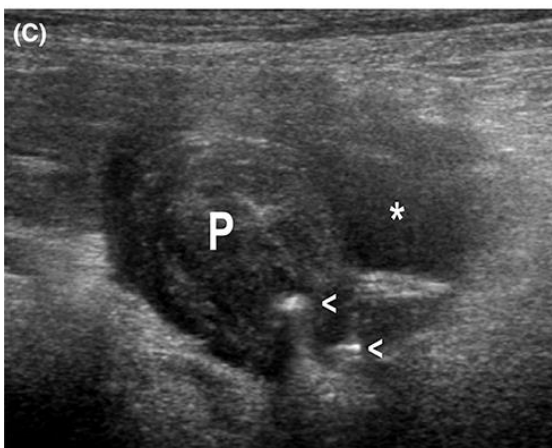
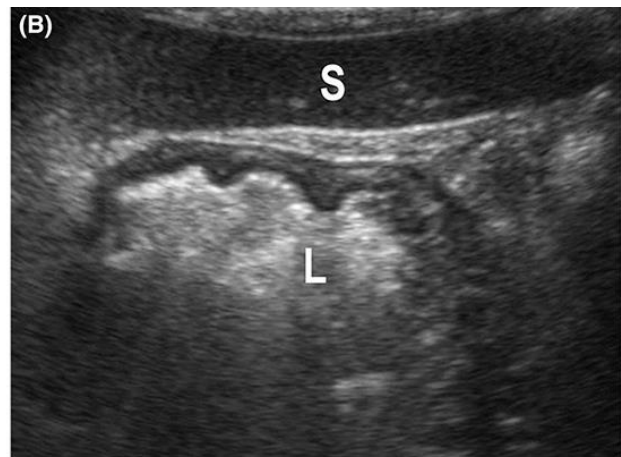
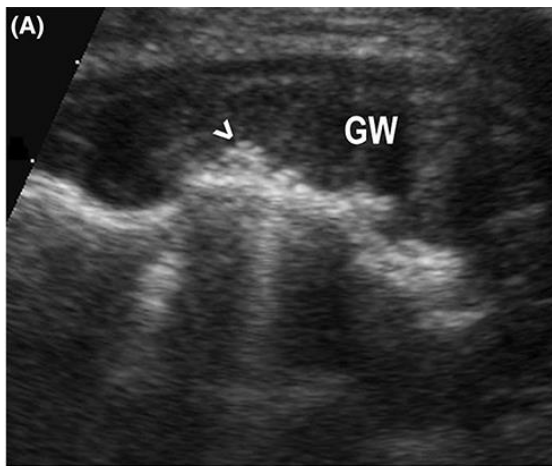
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489 Figure 3. Example of radiographic signs in a dog with perforated intestinal ulcer. A) Lateral
490 radiograph showing loss of serosal detail and scattered small bubbles of gas that appear to be
491 outside the intestinal lumen (arrowheads). B) Left lateral recumbent radiograph with horizontal x-
492 ray beam showing peritoneal gas (*) adjacent to the non-dependent abdominal wall.



493

494 Figure 4. Examples of ultrasonographic signs in dogs with gastrointestinal ulcers. A) Thickened and
495 hypoechoic gastric wall (GW) and irregular extension of gas (arrowhead) compatible with ulcer. B)
496 Comparison image of the adjacent unaffected gastric wall in the same dog showing normal
497 thickness, layered appearance and rugae on the mucosal aspect, which is outlined by gas in the
498 gastric lumen (L) S, spleen. C) Image of the pyloric canal (P) with eccentrically located gas bubbles
499 (arrowheads) and adjacent fluid collection (*), which is surrounded by hyperechoic fat. D) Peritoneal
500 gas (between arrowheads) partially obscuring the left kidney in an image obtained with the
501 transducer on the non-dependent aspect of the abdomen.



502

503

504 Figure 5. Examples of computed tomographic signs in dogs with gastrointestinal ulcers. A)
505 Transverse post-contrast image showing focal thickening of the lesser curvature of the stomach
506 (arrowheads) and focal mucosal defect (arrow) in a dog with non-perforated gastric ulcer. B)
507 Transverse post-contrast image of a different dog showing small gas bubbles within the duodenal
508 wall at the site of an ulcer (arrow) and multiple small gas bubbles (arrowheads), a large gas
509 collection (G) and fluid (F) in the peritoneal cavity in a dog with perforated ulcer. Abdominal fat has a
510 streaky appearance (*) and increased attenuation as a result of inflammation.

