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

E. Fitzgerald, D. Barfield, K.C.L. Lee, C.R. Lamb

Department of Clinical Science and Services, The Royal Veterinary College, University of London, AL9 7TA, UK.

Email: efitzgerald@rvc.ac.uk

Acknowledgements: none

Sources of support: none

Abstract

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

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

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

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

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

Introduction

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

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

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

More thorough diagnostic imaging is indicated in dogs presenting with acute, worsening or persistent abdominal signs. Compared to studies about clinicopathologic testing and management, there have been relatively few studies about the imaging signs associated with GI ulceration. Although GI ulceration is not usually visible in survey radiographs, pneumoperitoneum is a critical radiographic sign of GI perforation (Day and Pechman 2012, Smelstoys and others 2004). Radiographs made with a horizontal x-ray beam and the dog in either dorsal or left lateral recumbency are considered the most sensitive for detection of pneumoperitoneum (Day and Pechman 2012). Detection of gastric ulcers is also possible using contrast radiography (Barber 1982, Evans and Laufer 1981, Stanton and Bright 1989, Terragni and others 2014), but this technique has been used less frequently since the introduction of ultrasonography.

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

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

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

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

Methods

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

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

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

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

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

Results

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

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

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

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

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

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

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

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

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

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

Discussion

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

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

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

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

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

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

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

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

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

Although the results of this study are likely to be applicable to veterinary referral practice, they cannot be considered definitive because of limitations associated with the retrospective methodology. For example, statistical testing of differences in sensitivities of imaging modalities was not considered appropriate because multiple imaging modalities were employed in approximately half the dogs in this series, and hence there were relatively few dogs in which results of radiography and ultrasonography or radiography and CT or ultrasonography and CT could be compared. Such variability in the management of individual patients is unavoidable (and appropriate) in clinical practice, but it prevents robust estimates of the sensitivity of imaging modalities and comparisons between results of other studies, as previously noted (Dayer and others 2013). For example, the potential for increased sensitivity for pneumoperitoneum by consistent use of horizontal x-ray beam radiographs cannot be assessed. Despite these limitations, various trends in the performance of the different imaging modalities may be identified: in dogs with non-perforated ulcers radiography was usually negative whereas ultrasonography and CT frequently enabled detection of the site of the ulcer; in dogs with perforated ulcers, radiography was frequently positive for peritoneal gas and CT was a relatively sensitive modality for both the ulcer and signs of perforation. Pneumoperitoneum is an important radiographic sign of GI perforation (Hinton and others 2002, Smelstoys and others 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.

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

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

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

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

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

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

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

Table 3. Primary diagnoses in 82 dogs with gastrointestinal ulceration

Primary gastrointestinal neoplasia	
Carcinoma	5 (6%)
Lymphoma	3 (4%)
Adenocarcinoma	2 (2%)
Mastocytoma	2 (2%)
Leiomyoma	1 (1%)
Spindle cell tumour	1 (1%)
Neoplasm, type not determined	3 (4%)
Inflammatory gastrointestinal disease	
Lymphocytic/plasmacytic enteritis	6 (7%)
Gastritis, non-specific	5 (6%)
Ulcerative colitis	2 (2%)
Eosinophilic duodenitis	1 (1%)
Foreign body	9 (11%)
Necrosis, non-specific	1 (1%)
Primary cause not identified	41 (50%)

340 **References**

341 Barber, D. L. (1982) Radiographic aspects of gastric ulcers in dogs. *Veterinary Radiology* **23**, 109-116

342 Boag, A., Hughes, D. (2004) Emergency management of the acute abdomen in dogs and cats. 1.
343 Investigation and initial stabilization. *In Practice* 26, 476-483

344 Bonczynski, J. J, Ludwig, L. L., Barton, L. J., Loar, A. & Peterson, M.E. (2003) Comparison of peritoneal
345 fluid and peripheral blood pH, bicarbonate, glucose, and lactate concentration as a diagnostic
346 tool for septic peritonitis in dogs and cats. *Veterinary Surgery* 32, 161–166

347 Boysen, S.R. & Lisciandro, G.R. (2013) The use of ultrasound for dogs and cats in the emergency
348 room: AFAST and TFAST. *Veterinary Clinics of North America: Small Animal Practice* **43**, 773-97

349 Boysen, S. R., Tidwell, A. S. & Penninck, D. G. (2003) Ultrasonographic findings in dogs and cats with
350 gastrointestinal perforation. *Veterinary Radiology & Ultrasound* **44**, 556-564

351 Bradford, K., Meinkoth, J., McKeirnen, K. & Love, B. (2013) Candida peritonitis in dogs: report of 5
352 cases. *Veterinary Clinical Pathology* **42**, 227-233

353 Cariou, M., Lipscomb, V. J., Brockman, D. J., Gregory, S. P. & Baines, S. J. (2009) Spontaneous
354 gastroduodenal perforations in dogs - a retrospective study of 15 cases. *Veterinary Record*
355 **165**, 436-441

356 Cortellini, S., Seth, M. & Kellett-Gregory, L. M. (2015) Plasma lactate concentrations in septic
357 peritonitis: A retrospective study of 83 dogs (2007-2012). *Journal of Veterinary Emergency and*
358 *Critical Care* **25**, 388-395

359 Culp, W.T.N., Zeldis, T.E., Reese, M.S. & Drobatz, K.J. (2009) Primary bacterial peritonitis in dogs and
360 cats: 24 cases (1990–2006). *Journal of the American Veterinary Medical Association* **234**, 906–
361 913

362 Davis, M., Willard, M., Williamson, K., Royer, C., Payton, M., Steiner, J. M., Hinchcliff, K., McKenzie, E.
363 & Nelson, S., Jr. (2006) Temporal relationship between gastrointestinal protein loss, gastric

364 ulceration or erosion, and strenuous exercise in racing Alaskan sled dogs. *Journal of Veterinary*
365 *Internal Medicine* **20**, 835-839

366 Day, J. L. & Pechman, R. D. (2012) The radiographic signs of pneumoperitoneum in dogs: a guide for
367 the practitioner. *Australian Veterinary Practitioner* **42**, 294-299

368 Dayer, T., Howard, J. & Spreng, D. (2013) Septic peritonitis from pyloric and non-pyloric
369 gastrointestinal perforation: prognostic factors in 44 dogs and 11 cats. *Journal of Small Animal*
370 *Practice* **54**, 625-629

371 Enberg, T. B., Braun, L. D. & Kuzma, A. B. (2006) Gastrointestinal perforation in five dogs associated
372 with the administration of meloxicam. Journal of Veterinary Emergency and Critical Care **16**,
373 34–43

374 Evans, S. M. & Laufer, I. (1981) Double contrast gastrography in the normal dog. *Veterinary*
375 *Radiology* **22**, 2-9

376 Feeney, D.A., Ober, C.P., Snyder, L.A., Hill, S.A. & Jessen, C.R. (2013) Ultrasound criteria and guided
377 fine-needle aspiration diagnostic yields in small animal peritoneal, mesenteric and omental
378 disease. *Veterinary Radiology & Ultrasound* **54**, 638-645

379 Gualtieri, M., Monzeglio, M. G. & Scanziani, E. (1999) Gastric neoplasia. *Veterinary Clinics of North*
380 *America-Small Animal Practice* **29**, 415-440

381 Hickey, M. C. & Magee, A. (2011) Gastrointestinal tract perforations caused by ingestion of multiple
382 magnets in a dog. *Journal of Veterinary Emergency and Critical Care* **21**, 369-374

383 Hinton, L. E., McLoughlin, M. A., Johnson, S. E. & Weisbrode, S. E. (2002) Spontaneous
384 gastroduodenal perforation in 16 dogs and seven cats (1982-1999). *Journal of the American*
385 *Animal Hospital Association* **38**, 176-187

386 Haworth, M. D., Hosgood, G., Swindells, K. L. and Mansfield, C. S. (2014), Diagnostic accuracy of the
387 SNAP and Spec canine pancreatic lipase tests for pancreatitis in dogs presenting with clinical

388 signs of acute abdominal disease. *Journal of Veterinary Emergency and Critical Care* **24**, 135–
389 143.

390 Horton, K.M., Fishman, E.K. (2004) Multidetector-row computed tomography and 3-dimensional
391 computed tomography imaging of small bowel neoplasms - Current concept in diagnosis.
392 *Journal of Computer Assisted Tomography* **28**, 106-116

393 Jergens, A. E., Moore, F. M., March, P. and Miles K. G. (1992) Idiopathic inflammatory bowel disease
394 associated with gastroduodenal ulceration-erosion: a report of nine cases in the dog and cat.
395 *Journal of American Animal Hospital Association* **28**, 21–26

396 Ko, J. J. & Mann, F. A. (2014) Barium peritonitis in small animals. *Journal of Veterinary Medical*
397 *Science* **76**, 621-628

398 Koenig, A. & Verlander, L. L. (2015) Usefulness of whole blood, plasma, peritoneal fluid, and
399 peritoneal fluid supernatant glucose concentrations obtained by a veterinary point-of-care
400 glucometer to identify septic peritonitis in dogs with peritoneal effusion. *Journal of the*
401 *American Veterinary Medical Association* **247**, 1027-1032

402 Lamb, C. R. & Grierson, J. (1999) Ultrasonographic appearance of primary gastric neoplasia in 21
403 dogs. *Journal of Small Animal Practice* **40**, 211-215

404 Lascelles, B. D. X., Blikslager, A. T., Fox, S. M. & Reece, D. (2005) Gastrointestinal tract perforation in
405 dogs treated with a selective cyclooxygenase-2 inhibitor: 29 cases (2002-2003). *Journal of the*
406 *American Veterinary Medical Association* **227**, 1112-1117

407 Lee, S.S., Oh, T.S., Kim, H.J. Chung, J.W., Park, S.H., Kim, A.Y., Kwon, H. (2011) Obscure
408 gastrointestinal bleeding: diagnostic performance of multidetector CT enterography.
409 *Radiology* **259**, 739-748

410 Lewis, K.M. & O'Brien R.T. (2010) Abdominal ultrasonographic findings associated with feline
411 infectious peritonitis: a retrospective review of 16 cases. *Journal of the American Animal*
412 *Hospital Association* **46**, 152-160

413 Lisciandro, G. R. (2011) Abdominal and thoracic focused assessment with sonography for trauma,
414 triage, and monitoring in small animals. *Journal of Veterinary Emergency and Critical Care* **21**,
415 104–122

416 Manczur, F. & Voros, K. (2000) Gastrointestinal ultrasonography of the dog: A review of 265 cases
417 (1996-1998). *Acta Veterinaria Hungarica* **48**, 9-21

418 Marolf, A. J., Bachand, A. M., Sharber, J. & Twedt, D. C. (2015) Comparison of endoscopy and
419 sonography findings in dogs and cats with histologically confirmed gastric neoplasia. *Journal of*
420 *Small Animal Practice* **56**, 339-344

421 McMurray, J., Boysen, S., Chalhoub, S. (2015) Focused assessment with sonography in
422 nontraumatised dogs and cats in the emergency and critical care setting. *Journal of Veterinary*
423 *Emergency and Critical Care* **26**, 64-73

424 Monteiro-Steagall, B.P., Steagall, P.V.M. & Lascelles, B.D.X. (2013) Systematic review of nonsteroidal
425 anti-inflammatory drug-induced adverse effects in dogs. *Journal of Veterinary Internal*
426 *Medicine* **27**, 1011-1019

427 Murray, M., Robinson, P. B., McKeating, F. J., Baker, G. J. & Lauder, I. M. (1972) Peptic ulceration in
428 the dog: a clinico-pathological study. *Veterinary Record* **91**, 441-447

429 Neiger, R., Gaschen, F. & Jaggy, A. (2000) Gastric mucosal lesions in dogs with acute intervertebral
430 disc disease: characterization and effects of Omeprazole or Misoprostol. *Journal of Veterinary*
431 *Internal Medicine* **14**, 33-36

432 Opal, S.M. & Cross, A.S. (2005) The use of immunocompromised animals as models for human septic
433 shock. *Shock* **24**, 64-70

434 Paoloni, M. C., Penninck, D. G. & Moore, A. S. (2002) Ultrasonographic and clinicopathologic findings
435 in 21 dogs with intestinal adenocarcinoma. *Veterinary Radiology & Ultrasound* **43**, 562-567

436 Pastore, G. E., Lamb, C. R. & Lipscomb, V. (2007) Comparison of the results of abdominal
437 ultrasonography and exploratory laparotomy in the dog and cat. *Journal of the American*
438 *Animal Hospital Association* **43**, 264-269

439 Penninck, D., Matz, M. & Tidwell, A. (1997) Ultrasonography of gastric ulceration in the dog.
440 *Veterinary Radiology & Ultrasound* **38**, 308-312

441 Peters, R. M., Goldstein, R. E., Erb, H. N. & Njaa, B. L. (2005) Histopathologic features of canine
442 uremic gastropathy: a retrospective study. *Journal of Veterinary Internal Medicine* **19**, 315-320

443 Probst, C.W., Stickle, R.L., Bartlett, P.C. (1986) Duration of pneumoperitoneum in the dog. *American*
444 *Journal of Veterinary Research* **47**, 176-178

445 Rallis, T.S., Tontis, D. and Adamama-Moraitou, K.K. (1998) Canine plasmacytic-lymphocytic colitis. A
446 clinicopathologic study of 15 cases. *International Journal of Immunopathology and*
447 *Pharmacology* **11**, 41-48

448 Ritchey, J. W., Davis, M. S., Breshears, M. A., Willard, M. D., Williamson, K. K., Royer, C. M., Payton,
449 M. E. & Cragun, A. S. (2011) Gastritis in Alaskan racing sled dogs. *Journal of Comparative*
450 *Pathology* **145**, 68-76

451 Rohrer, C.R., Hill, R.C., Fischer, A., Fox, L.E., Schaer, M., Ginn, P.E., Casanova, J.M., Burrows, C.F.
452 (1999) Gastric hemorrhage in dogs given high doses of methylprednisolone sodium succinate.
453 *American Journal of Veterinary Research* **60**, 977-981

454 Saunders, W. B. & Tobias, K. M. (2003) Pneumoperitoneum in dogs and cats: 39 cases (1983-2002).
455 *Journal of the American Veterinary Medical Association* **223**, 462-468

456 Smelstoys, J. A., Davis, G. J., Learn, A. E., Shofer, F. F. & Brown, D. C. (2004) Outcome of and
457 prognostic indicators for dogs and cats with pneumoperitoneum and no history of penetrating

458 trauma: 54 cases (1988-2002). *Journal of the American Veterinary Medical Association* **225**,
459 251-255

460 Soto, J.A., Park, S.H., Fletcher, J.G., Fidler, J.L. (2015) Gastrointestinal hemorrhage: evaluation with
461 MDCT. *Abdominal Imaging* **40**, 993-1009

462 Spaulding, K.A. (1993) Sonographic evaluation of peritoneal effusion in small animals. *Veterinary*
463 *Radiology & Ultrasound* **34**, 427-431

464 Stanton, M. E. & Bright, R. M. (1989) Gastroduodenal ulceration in dogs. *Journal of Veterinary*
465 *Internal Medicine* **3**, 238-244

466 Terragni, R., Vignoli, M., van Bree, H. J., Gaschen, L. & Saunders, J. H. (2014) Diagnostic imaging and
467 endoscopic finding in dogs and cats with gastric tumors: A review. *Schweizer Archiv Fur*
468 *Tierheilkunde* **156**, 569-576

469 Vander Hart, D. & Berry, C. R. (2015) Initial influence of right versus left lateral recumbency on the
470 radiographic finding of duodenal gas on subsequent survey ventrodorsal projections of the
471 canine abdomen. *Veterinary Radiology & Ultrasound* **56**, 12-17

472 von Babo, V., Eberle, N., Mischke, R., Meyer-Lindenberg, A., Hewicker-Trautwein, M., Nolte, I. &
473 Betz, D. (2012) Canine non-hematopoietic gastric neoplasia. Epidemiologic and diagnostic
474 characteristics in 38 dogs with post-surgical outcome of five cases. *Tieraerztliche Praxis*
475 *Ausgabe Kleintiere Heimtiere* **40**, 243-249

Legends

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

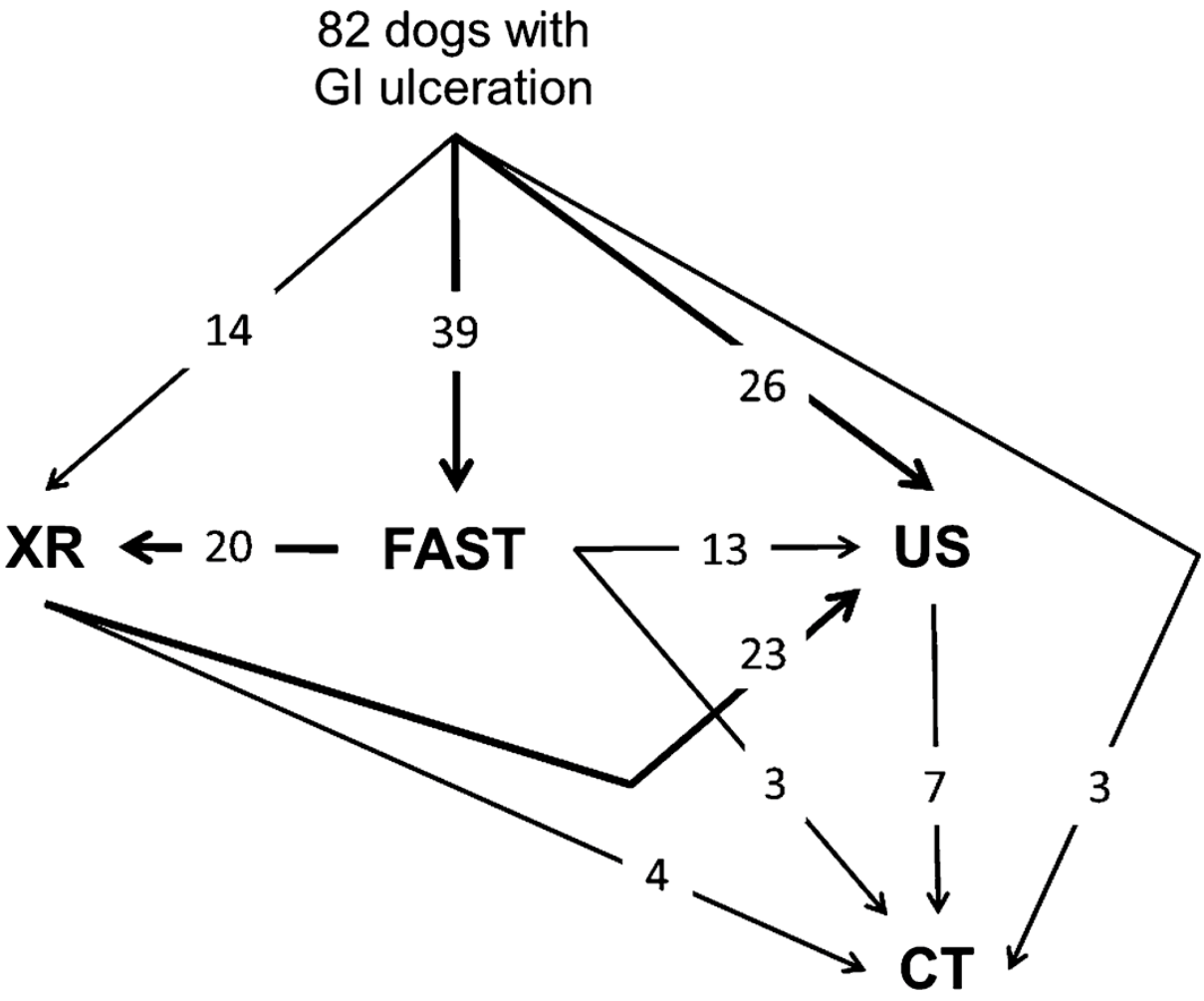

Figure 2. Example of radiographic signs in a dog with non-perforated gastric ulcer. Detail of a ventrodorsal radiograph showing a mass (arrowheads) affecting the greater curvature of the stomach with a central gas lucency (*) compatible with an ulcer.

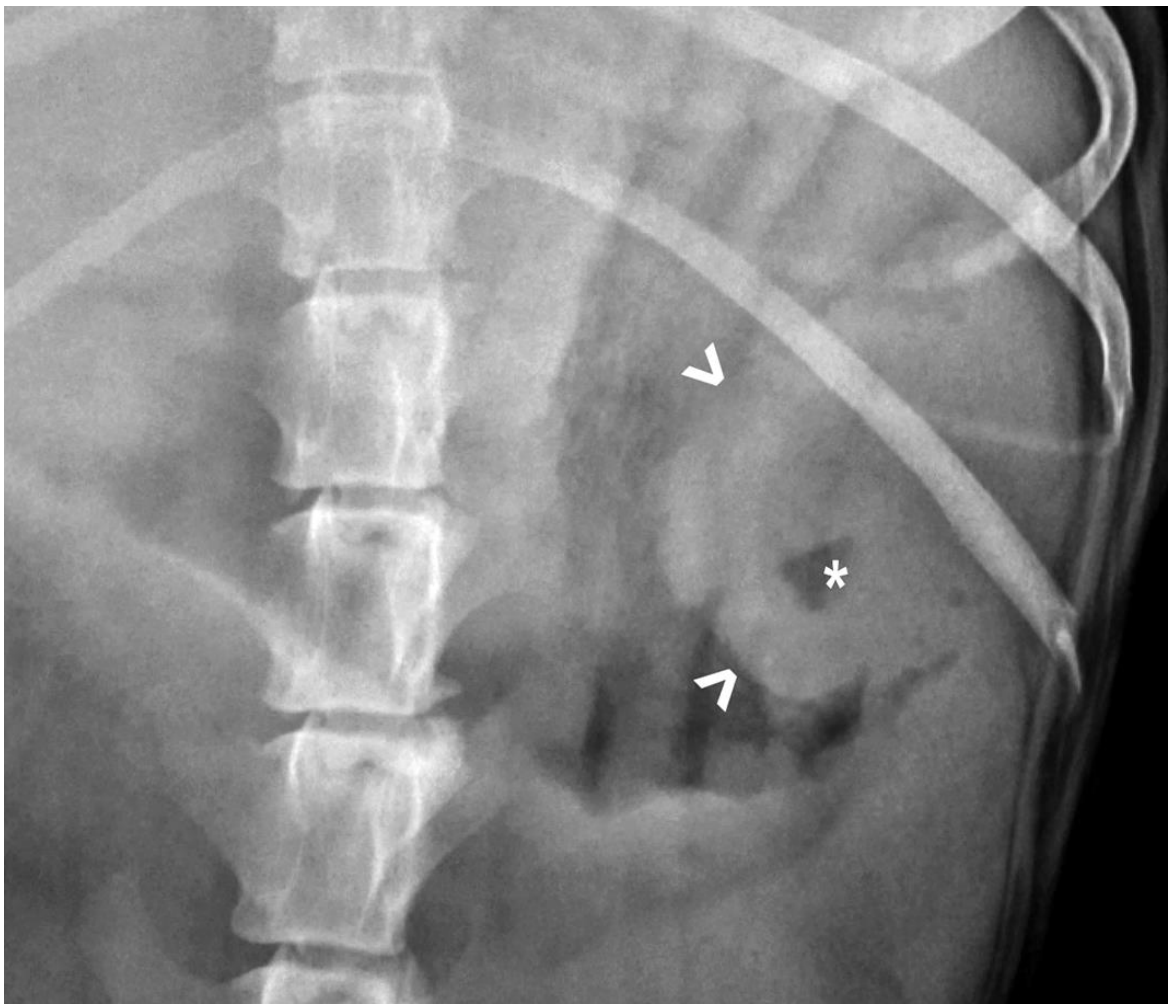

Figure 3. Example of radiographic signs in a dog with perforated intestinal ulcer. A) Lateral radiograph showing loss of serosal detail and scattered small bubbles of gas that appear to be outside the intestinal lumen (arrowheads). B) Left lateral recumbent radiograph with horizontal x-ray beam showing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

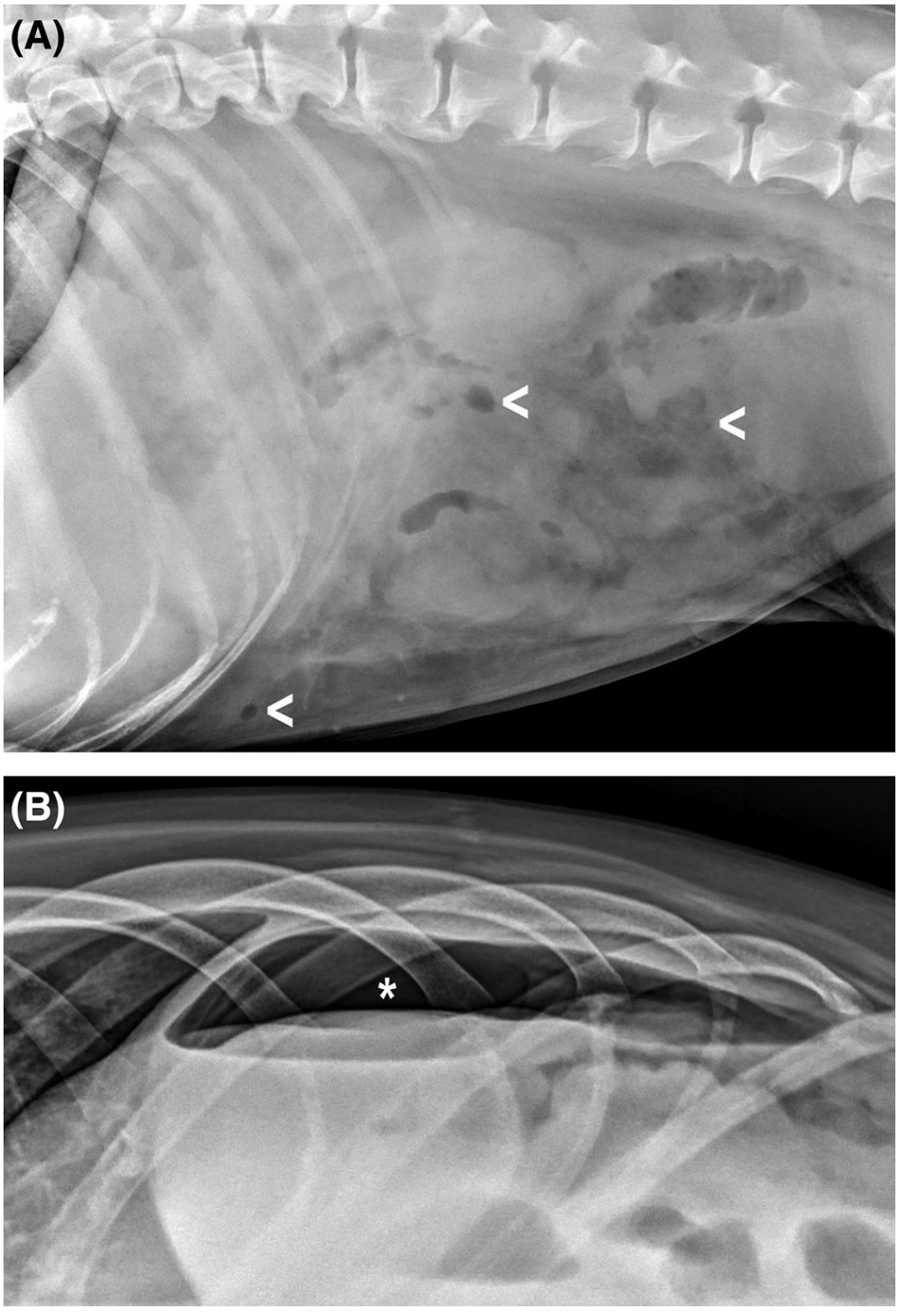

Figure 4. Examples of ultrasonographic signs in dogs with gastrointestinal ulcers. A) Thickened and hypoechoic gastric wall (GW) and irregular extension of gas (arrowhead) compatible with ulcer. B) Comparison image of the adjacent unaffected gastric wall in the same dog showing normal thickness, layered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

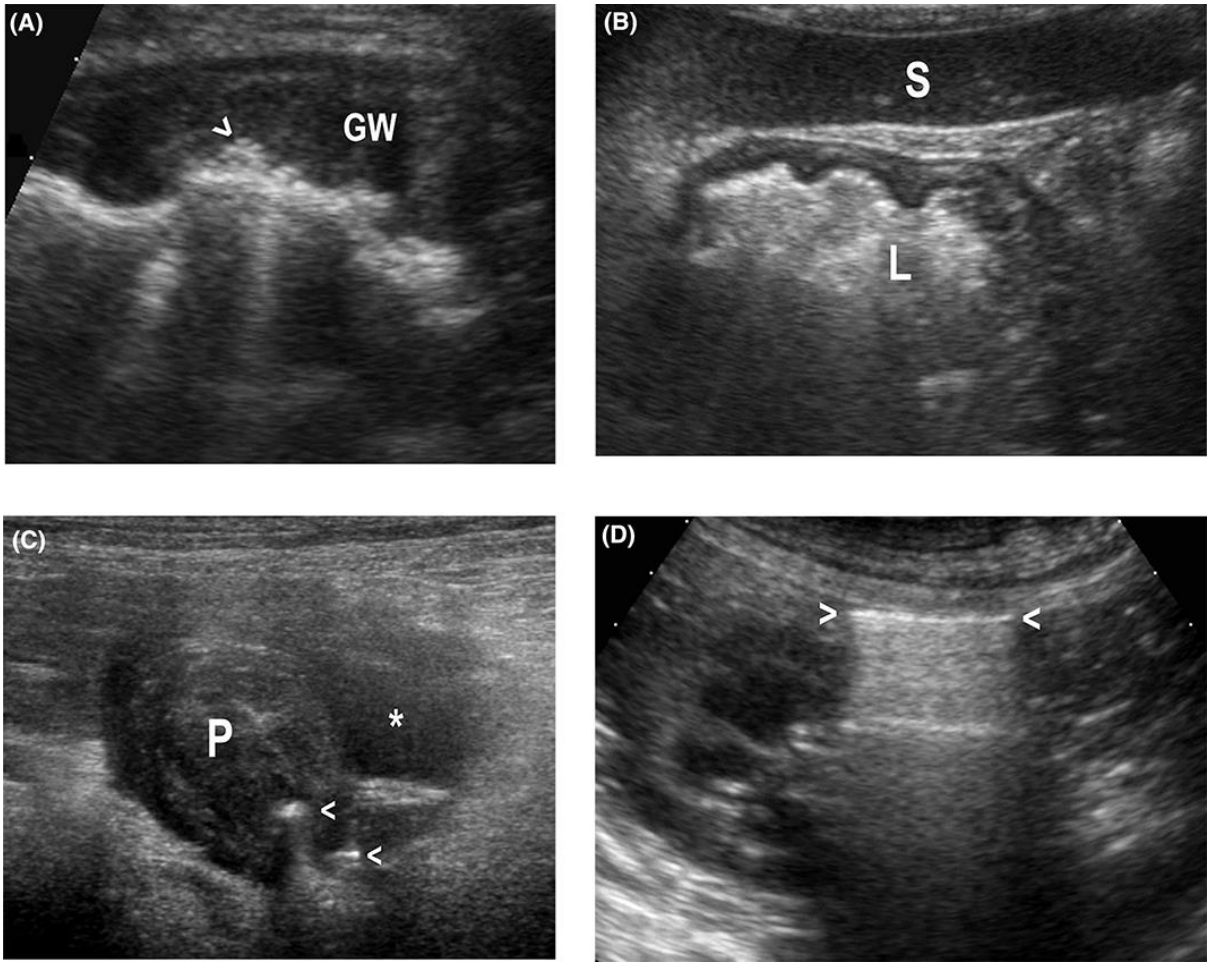

Figure 5. Examples of computed tomographic signs in dogs with gastrointestinal ulcers. A) Transverse post-contrast image showing focal thickening of the lesser curvature of the stomach (arrowheads) and focal mucosal defect (arrow) in a dog with non-perforated gastric ulcer. B) Transverse post-contrast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