COMPARISON OF RADIOGRAPHY AND ULTRASONOGRAPHY FOR DIAGNOSING SMALL-INTESTINAL MECHANICAL OBSTRUCTION IN VOMITING DOGS

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A cross-sectional study was performed on acutely vomiting dogs to compare the accuracy of radiography and ultrasonography for the diagnosis of small-intestinal mechanical obstruction and to describe several radiographic and ultrasonographic signs to identify their contribution to the final diagnosis. The sample population consisted of 82 adult dogs and small-intestinal obstruction by foreign body was confirmed in 27/82 (33%) dogs by surgery or necropsy. Radiography produced a definitive result (obstructed or not obstructed) in 58/82 (70%) of dogs; ultrasonography produced a definitive result in 80/82 (97%) of dogs. On radiographs, a diagnosis of obstruction was based on detection of segmental small-intestinal dilatation, plication, or detection of a foreign body. Approximately 30% (8/27) of obstructed dogs did not have radiographic signs of segmental small-intestinal dilatation, of which 50% (4/8) were due to linear foreign bodies. The ultrasonographic diagnosis of small-intestinal obstruction was based on detection of an obstructive lesion, sonographic signs of plication or segmental, small-intestinal dilatation. The ultrasonographic presence or absence of moderate-to-severe intestinal diameter enlargement (due to lumen dilatation) of the jejunum (> 1.5 cm) was a useful discriminatory finding and, when present, should prompt a thorough search for a cause of small-intestinal obstruction. In conclusion, both abdominal radiography and abdominal ultrasonography are accurate for diagnosing small-intestinal obstruction in vomiting dogs and either may be used depending on availability and examiner choice. Abdominal ultrasonography had greater accuracy, fewer equivocal results and provided greater diagnostic confidence compared with radiography. © 2010 *Veterinary Radiology & Ultrasound, Vol. 52, No. 3, 2011, pp 248–255.*

Key words: accuracy, dog, intestinal, obstruction, radiography, ultrasonography, vomiting.

Introduction

Mechanical small-intestinal obstruction is a common cause of acute vomiting in dogs.[1–4] Determining whether vomiting is due to bowel obstruction expediently with a high level of confidence is required to provide appropriate therapy. Delaying surgery increases perioperative morbidity due to dehydration, electrolyte imbalances, bowel necrosis, peritonitis, and sepsis,[4] with concomitant increases in length of hospital stay and cost of hospitalization.

Radiographic signs commonly associated with mechanical bowel obstruction include segmental dilatation of the small intestine by fluid and/or gas, abnormal position or appearance of the bowel, focal accumulation of granular material in the small intestine, and the presence of a foreign body or mass.[5,6] Specific sonographic signs reported in people to provide therapeutic guidelines include intestinal distention > 2.5 cm, stasis of intestinal contents, alterations in peristalsis, bowel wall edema, and presence and echogenicity of extraluminal fluid.[7,8] In animals, sonographic signs for mechanical obstruction include gastrointestinal dilatation, abnormal motility, changes in intestinal-wall thickness, and peritoneal fluid.[1,2,9]

In humans, abdominal radiography continues to be the initial examination in patients with acute abdominal symptoms[10–12] reportedly providing a definitive diagnosis in 50–60% of patients, equivocal results in 20–30%, and normal, nonspecific or misleading results in 10–20%.[12] Because of wide availability and relative low cost, current recommendations suggest that abdominal radiography is the basis for triage before further imaging work-up and therapeutic

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decisions.[10–12] If abdominal radiography is insufficient to provide a confident diagnosis of intestinal obstruction, then additional diagnostic imaging, such as computed tomography or ultrasonography, may be necessary.[10–13] In human and animal studies, abdominal ultrasonography was more accurate than radiography in the diagnosis of intestinal obstruction.[5,6,14,15] Patient management based on sonographic signs alters initial therapeutic plans,[16] reduces children's radiation exposure,[17] and has the potential to reduce costs of surgical care.[14]

In two veterinary studies, ultrasonography detected 100% of gastrointestinal foreign bodies (14/14 and 16/16, respectively) even when results of radiography were equivocal.[1,2] One of these studies suggested that ultrasonography could be used as the sole imaging modality for the diagnosis of gastrointestinal foreign bodies.[2] The appearance of gastrointestinal foreign bodies has been described and varies with the type of offending object.[1,2] These studies also discussed the ability of ultrasonography to detect other clinically important signs (e.g., peritoneal fluid and gas, pancreatitis, and lymphadenopathy). A third veterinary study using ultrasonography for identifying small-intestinal obstruction reported a sensitivity of 85% and specificity of 94%, based on the results of surgery or response to medical management.[9] In this study, however, results of ultrasonography and radiography were not compared in the same animal.

Selecting an imaging modality based on the principles of evidence-based medicine should improve patient care.[18] The accuracies of ultrasonography and radiography for diagnosing mechanical obstruction have not been compared in dogs that are vomiting acutely. The primary aim of this cross-sectional study was to compare the accuracy of radiography and ultrasonography to diagnose small-intestinal mechanical obstruction in acutely vomiting dogs. We also evaluated several individual radiographic and ultrasonographic signs to identify their contribution to the final diagnosis. These aims were investigated to provide specific imaging recommendations, for both general and referral practitioners, in the diagnostic evaluation of vomiting dogs.

Materials and Methods

The sample population consisted of all dogs at least 4 months old and admitted to our hospital for acute vomiting between February 1, 2008 and May 31, 2009. Acute vomiting was the primary inclusion criterion in an effort to evaluate imaging findings associated with all possible causes of obstruction and intestinal dilatation. We defined acute vomiting as clinical signs noted for <5 days or a minimum of three vomiting episodes within 24 h. Additional criteria included assessment by the attending clinician that surgical management might be indicated or that initial conservative management had failed. In the latter instance, the total duration of clinical signs might have exceeded 5 days. Exclusions were made for lack of owner consent, inability to perform radiography and ultrasonography within 24 h, or when performing radiography and ultrasonography precluded appropriate, timely, medical care. One dog was excluded due to previous administration of oral contrast media that conspicuously coated a cloth foreign body in the stomach and duodenum several hours after administration. Two dogs were lost to follow-up examination or telephone consultation.

Eighty-two dogs met the selection criteria. Four dogs were enrolled twice for different episodes of vomiting. All surgery or necropsy examinations were performed within 2 days of the imaging examinations except for two dogs without small-intestinal mechanical obstruction. One dog was euthanized due to severe necrotizing enterocolitis, the other due to vasculitis, and disseminated intravascular coagulopathy. In these two dogs, necropsy was performed within 1 month of imaging. The average duration between imaging and follow-up phone conversation was 2.7 months.

All 82 dogs underwent abdominal radiography, abdominal ultrasonography, and one of the following reference standards: exploratory laparotomy, necropsy, or follow-up telephone call to the owner at least 1 month after discharge from the hospital. The order of abdominal imaging varied depending on hospital scheduling. For each dog, radiographic and ultrasonographic interpretations were performed by different radiologists who knew that they were evaluating a vomiting dog, but were unaware of the report of the other examiner, the diagnosis from the other modality, additional patient information, and the final outcome.

For radiography and ultrasonography individually, a determination of small-intestinal obstruction was defined, subjectively, based on identification of an obstructing lesion, segmental intestinal dilatation, or plication and was scored using five categories (i.e., definitely detected, questionably detected, indeterminate, questionably not detected, or definitely not detected). Five categories were used so that a reasonable receiver–operator characteristic (ROC) curve could be produced.[19]

Abdominal radiography was performed with the dog in left-lateral, right-lateral, and dorsal recumbent positions using one of two X-ray machines*,† and computed radiography.‡ The order of patient positioning was not standardized. Images were stored in a picture archive and communication system (PACS).§ Radiographic examina-

*Pausch X-Ray machine, Pausch Technologies, Hans Pausch GmbH & Co., Erlangen, Germany.

†Summit Specialist X-Ray machine, Summit Industries Inc., Chicago, IL.

‡Kodak CR500, Eastman Kodak Company, Rochester, NY.

§Kodak Carestream Version 10.1 and 10.2, Carestream, formerly Eastman Kodak Company.

tions were evaluated, by board-certified radiologists with a minimum of 10 years experience, for the following variables: determination of small-intestinal mechanical obstruction, height of the fifth lumbar vertebral body (L5), maximal small-intestinal diameter, and pattern of small-intestinal dilatation. Measurements of the maximal small-intestinal diameter (SI) and height of the L5 vertebral body (L5), and calculation of the ratio of these (SI/L5) was performed as described previously.[5] When identified, additional radiographic signs or pattern, such as gastric dilatation, foreign body, small-intestinal plication, decreased abdominal serosal detail, and gravel sign, were recorded. The examiners were asked to score the size of the small intestine subjectively as normal, mildly enlarged, or severely enlarged and the distribution of enlarged small intestine as diffuse or segmental. Diffuse dilatation indicated that the majority-to-entire small intestine was abnormal and segmental dilatation indicated there were separate populations of small intestine, but the length of the segment was not specified. These two signs were combined to form a pattern of small-intestinal dilatation: no dilatation, mild-diffuse dilatation, severe-diffuse dilatation, mild-segmental dilatation, or severe-segmental dilatation.

Ultrasonography was performed by imaging residents with at least 6 months training and board-certified radiologists with at least 6 years experience. Examinations performed by residents were reviewed by board-certified radiology faculty. At our hospital, the ultrasonography suite is separate from the radiology areas, eliminating inadvertent contact, and communication between examiners and facilitated unbiased results. Abdominal ultrasonography was performed using one of two ultrasound machines and a variety of transducers.¶,|| Dogs were positioned in dorsal recumbency, the hair clipped or parted, and coupling gel applied to the skin. Our standard abdominal ultrasound examination was performed in addition to recording the following specific variables: determination of small-intestinal mechanical obstruction, potentially obstructing lesion, number of gastric contractions, and number of small-intestinal contractions, small-intestinal diameter, small-intestinal wall thickness, small-intestinal lumen diameter, small-intestinal wall layering, peritoneal fluid, and mesenteric echogenicity. If additional ultrasonographic signs or patterns were detected, then these were also recorded, e.g. plication or foreign body. Representative images of each organ and lesions were stored in PACS for later review. The definitive detection of a foreign body did not result automatically in a diagnosis of definitive small-intestinal obstruction. The number of gastrointestinal contractions was defined as the number of contractions observed in 1 min—a contraction was counted at its initiation, i.e., a complete contraction did not need to be observed to be counted. Small-intestinal diameter was defined as the maximal measurements made from serosa-to-serosa. Maximal small-intestinal wall thickness was measured from serosa-to-mucosa. Maximal small-intestinal lumen diameter was measured from mucosa-to-mucosa. Intestinal measurements were performed once on the duodenum and once again on the jejunum, when possible at the level of the most obvious abnormality. Small-intestinal wall layering was subjectively scored as normal, indeterminate, mild loss, moderate loss, or severe loss. Peritoneal fluid was subjectively scored as not detected, indeterminate, mild, or moderate-to-severe. Mesenteric echogenicity, relative to the liver, was subjectively scored as normal, indeterminate, hyperechoic or hyperechoic, and hyperattenuating.

Small-intestinal mechanical obstruction, partial, or complete, was confirmed during laparotomy or necropsy. An obstruction was defined as the presence of an intraluminal foreign object or lesion associated with gross signs of intestinal wall edema or inflammation. Dogs were classified not obstructed when the above signs were not identified during laparotomy or necropsy, or if the dog was alive and well at least 30 days after discharge from the hospital. The latter determined by speaking to the client or reviewing the communication log and visit history in the medical record. Laparotomy and necropsy examinations were performed by the attending resident(s) or board-certified surgeon and pathologist, respectively.

Statistical analyses were performed using commercially available software.**,††,‡‡ Analysis of demographic data and individual imaging signs was performed using descriptive or summary statistics. For continuous data, normalcy was determined using a Kolmogorov–Smirnov test. Overall accuracy of diagnosing small-intestinal mechanical obstruction by radiography or ultrasonography was determined by calculating the area under the ROC curve for each modality. A pairwise comparison of ROC curves was made to investigate our null hypothesis that there is no difference in area under the curve (AUC) between the two methods; statistical significance was set at $P<0.05$ (two sided). Agreement between methods for the diagnosis of small-intestinal obstruction was determined using the weighted kappa (κ) statistic.

Results

Small-intestinal mechanical obstruction was confirmed in 27/82 (33%) dogs by surgery ($n=26$) or necropsy ($n=1$). In all obstructed dogs, the surgery/necropsy reports

¶HDI 5000 ultrasound machine, ATL Ultrasound, Bothell, Washington, DC with C8-5 MHz, C5-2 MHz transducers.

||iU22 Philips ultrasound machine, Philips Ultrasound, Bothell, with L12-5 MHz, C8-5 MHz, C5-1 MHz transducers.

**Microsoft Excel 2003, Microsoft Corp, Redmond, WA.

††Statistix, version 7, Analytical Software, Tallahasse, FL.

‡‡MedCalc 8.2.1, MedCalc Software, Mariakerke, Belgium.

contained descriptors consistent with obstruction, e.g. serosal bruising, "stuck," "lodged," inflamed mucosa. In these dogs the mean age was 4.5 years (SD, 4.4 years; range, 0.3–14.4 years) and the mean body weight was 20.6 kg (SD, 9.6 kg; range, 3.3–40.0 kg). Two of 27 (7%) were intact females, 7/27 (26%) were neutered females, 6/27 (22%) were intact males, and 12/27 (44%) were neutered males. Breeds were: Labrador Retriever ($n = 5$); Boxer (3); Beagle (2); German Shepherd (2); mixed-breed (2); Weimaraner (2); Yorkshire Terrier (2); and 1 each of Alaskan Malamute, Cock-a-Poo, Flat-Coated Retriever, Golden Retriever, Miniature Schnauzer, Miniature Poodle, American Staffordshire Terrier, Standard Poodle, and Vizsla. In all dogs, small-intestinal obstruction was caused by a foreign body including cloth, plastic bag, toy ball, shoestring, phytobezoar (grass impaction), or dental floss. A linear foreign body was confirmed in 7/27 dogs.

In the 55 dogs without small-intestinal obstruction, the mean age was 5.0 years (SD, 4.0 years; range, 0.4–14.5 years) and the mean body weight was 23.9 kg (SD, 13.2 kg; range, 4.4–61.0 kg). Four of 55 (7%) were intact females, 23 (42%) were neutered females, four (7%) were intact males, and 24 (44%) were neutered males. Breeds were: mixed-breed ($n = 13$); Labrador Retriever ($n = 7$); Standard Poodle ($n = 3$); Pug ($n = 3$); Pekingese ($n = 2$); Shih Tzu ($n = 2$); West Highland White terrier ($n = 2$) and one each of American Staffordshire Terrier, Australian Heeler, Australian Shepherd, Basset Hound, Bichon Frise, Bloodhound, Boxer, Doberman, English Bulldog, English Springer Spaniel, Golden Retriever, Greater Swiss Mountain Dog, Greyhound, Jack Russell Terrier, Miniature Dachshund, Pit Bull, Rottweiler, Saint Bernard, Samoyed, Shetland Sheepdog, Siberian Husky, Weimaraner, and Welsh Pembroke Corgi. The absence of small-intestinal mechanical obstruction was determined by surgery ($n = 5$), necropsy ($n = 2$), or phone conversation ($n = 48$). The final diagnosis of the five surgical patients in the nonobstructed group included foreign bodies in the pylorus ($n = 2$), stomach ($n = 1$), colon ($n = 1$), and myasthenia gravis ($n = 1$). The dogs with gastric foreign bodies were not included in the obstructed group due to anatomic location of the foreign body, i.e., not in the small intestine, and also were sonographically categorized as negative for small-intestinal mechanical obstruction. Nonobstructive dogs were most often diagnosed with nonspecific gastroenteritis ($n = 28$); however, pancreatitis ($n = 2$), necrotizing enterocolitis ($n = 1$), and vasculitis ($n = 1$) also were diagnosed. The necropsy results were necrotizing enterocolitis ($n = 1$) and vasculitis with disseminated intravascular coagulopathy ($n = 1$). The latter two patients were categorized sonographically as negative for obstruction.

The overall accuracy of three-view abdominal radiography and abdominal ultrasonography for diagnosing small-intestinal mechanical obstruction was compared (Table 1).

TABLE 1. Test Results for Three-View Abdominal Radiography and Abdominal Ultrasonography for Diagnosing Small-Intestinal Mechanical Ileus

		Test Results				
Test	Group	A	B	C	D	E
Radiography	Obstructed ($n = 27$)	5	2	1	5	14
	Nonobstructed ($n = 55$)	36	9	2	5	3
Ultrasonography	Obstructed ($n = 27$)	1	0	0	0	26
	Nonobstructed ($n = 55$)	50	0	0	2	3

A, definite no small-intestinal obstruction; B, questionable no small-intestinal obstruction; C, indeterminate for small-intestinal obstruction; D, questionable small-intestinal obstruction; E, definite small-intestinal obstruction.

Using ROC curve analysis, the overall accuracy of three-view abdominal radiography (AUC, 0.82; SE, 0.054; 95% confidence interval [CI], 0.72–0.89) and abdominal ultrasonography (AUC, 0.95; SE, 0.029; CI, 0.88–0.99) was very good. The difference between areas was 0.13 (SE, 0.06; CI 0.029–0.24) with the area for radiography significantly smaller than for ultrasonography, thus ultrasonography was more accurate than radiography for diagnosing small-intestinal obstruction ($P = 0.013$).

Agreement between three-view abdominal radiography and abdominal ultrasonography for diagnosing small-intestinal mechanical obstruction was moderate (weighted κ, 0.58; SE, 0.074). The exact same result for both radiography and ultrasonography was produced 52/82 times (Table 2). Disagreements were different in 12/82 dogs. Confident results (definitely not obstructed, definitely obstructed) were produced more often during ultrasonography ($n = 80$) than radiography ($n = 58$). Intermediate or equivocal results (questionably not obstructed, indeterminate, questionably obstructed) were produced more often during radiography ($n = 24$) than ultrasonography ($n = 2$).

TABLE 2. Agreement Between Radiography and Ultrasonography for Diagnosing Small-Intestinal Mechanical Obstruction in 82 Vomiting Dogs is Displayed

	Test Results: Radiography					
Test results: ultrasonography	A	B	C	D	E	Total
A	36	9	1	4	1	51
B	0	0	0	0	0	0
C	0	0	0	0	0	0
D	0	0	0	1	1	2
E	5	2	2	5	15	29
Total	41	11	3	10	17	82
Weighted $\kappa = 0.58$, SE $= 0.074$						

A, definite no small-intestinal obstruction; B, questionable no small-intestinal obstruction; C, indeterminate for small-intestinal obstruction; D, questionable small-intestinal obstruction; E, definite small-intestinal obstruction.

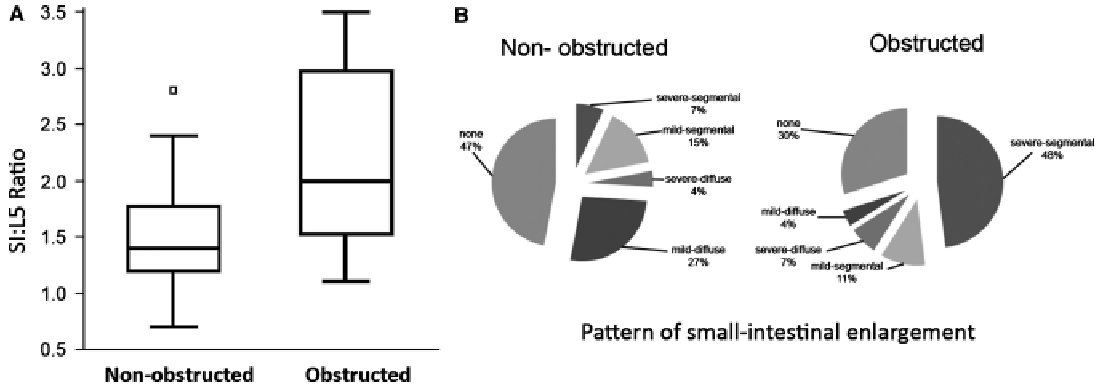

FIG. 1. Box and whiskers plots of the SI:L5 ratio (A) and pie charts of the pattern of small-intestinal dilatation (B) in 55 dogs without small-intestinal mechanical obstruction and 27 dogs with small-intestinal mechanical obstruction. Data were obtained during radiography.

During radiography, the mean SI:L5 ratio (Fig. 1A) for the obstructed group was 2.2 (SD, 0.8; range, 1.1–3.5; CI, 1.9–2.5) and for the nonobstructed group was 1.5 (SD, 0.5; range, 0.7–2.8; CI, 1.3–1.6). Subjective assessment of the pattern of small-intestinal size by group is depicted (Fig. 1B); about half the dogs with small-intestinal mechanical obstruction had severe segmental dilatation of the small intestine and about half the dogs without obstruction had no dilatation. About a third of dogs with obstruction, however, also had no dilatation.

In nonobstructed dogs ($n = 55$) the median overall diameter of the duodenum was 1.1 cm (CI, 0.9–1.2 cm); jejunum 0.9 cm (CI, 0.8–1.0 cm) (Fig. 2). The lumen diameter of the duodenum was 0.2 cm (CI, 0.2–0.3 cm); jejunum 0.1 cm (CI, 0.1–0.2 cm). The wall thickness of the duodenum was 0.4 cm (CI, 0.4–0.5 cm); jejunum 0.3 cm (CI, 0.3–0.4 cm). In obstructed dogs ($n = 27$) the median overall diameter of the duodenum was 1.2 cm (CI, 1.0–1.5 cm); jejunum 2.0 cm (CI, 1.8–2.3 cm). The lumen diameter of the duodenum was 0.4 cm (CI, 0.2–0.9 cm); jejunum 1.5 cm (CI, 1.3–2.0 cm). The wall thickness of the duodenum was 0.4 cm (CI, 0.2–0.3 cm); jejunum 0.3 cm (CI, 0.2–0.3 cm). Dogs with small-intestinal obstruction had a larger overall diameter of the jejunum than dogs without obstruction. When comparing this finding to the differences in lumen diameter and wall thickness, the change in overall diameter in obstructed dogs most often is attributed to lumen dilatation.

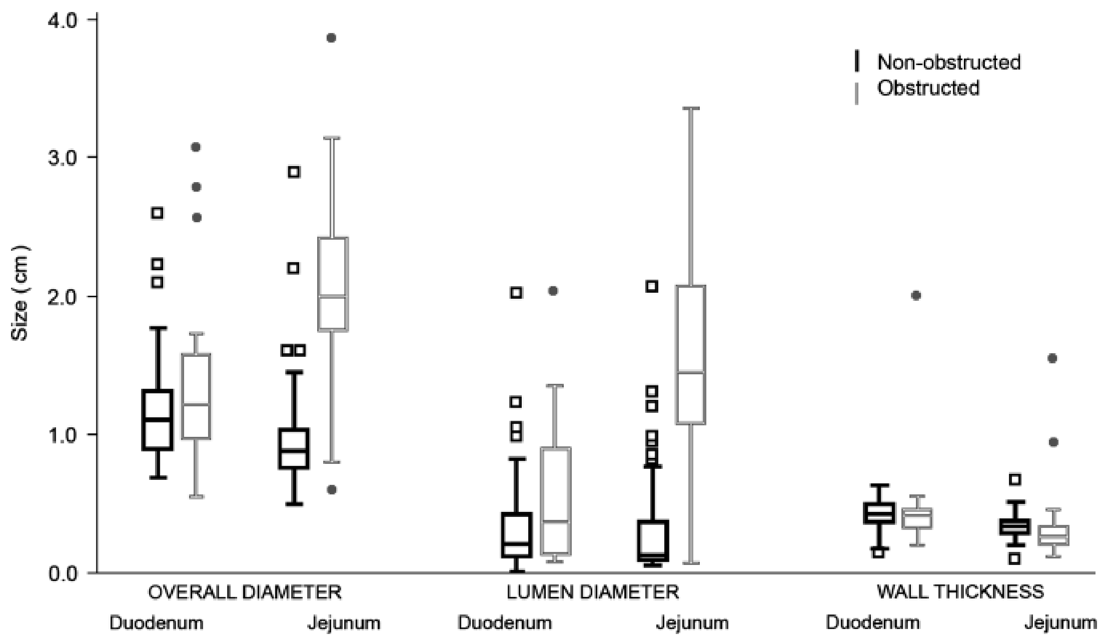

FIG. 2. Box and whiskers plots of small-intestine size in 55 dogs without small-intestinal mechanical obstruction and 27 dogs with small-intestinal mechanical obstruction. Data were obtained during ultrasonography. Overall diameter was measured from serosa-to-serosa; lumen diameter, mucosa-to-mucosa; wall thickness, serosa-to-mucosa.

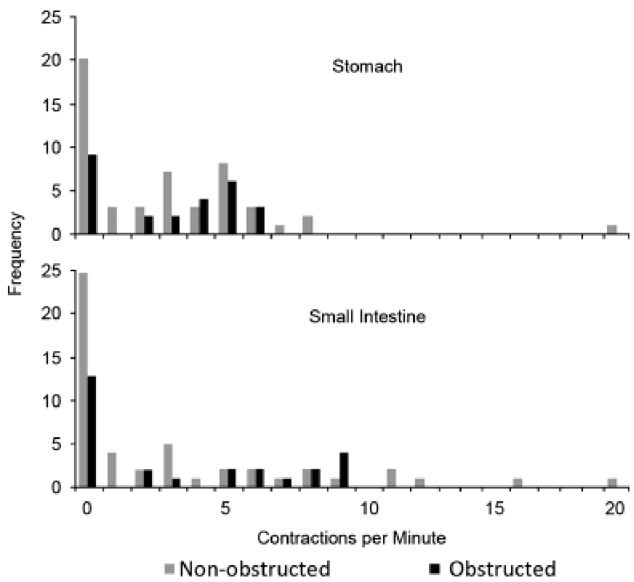

FIG. 3. Bar charts of gastric and small-intestinal contractions in dogs without small-intestinal mechanical obstruction and dogs with small-intestinal mechanical obstruction. Data were obtained during ultrasonography.

In the obstructed group, the median number of gastric contractions was 3.5 and the median number of small-intestinal contractions was 2 (Fig. 3). In the nonobstructed group, the median number of gastric contractions was 2.0 and the median number of small-intestinal contractions was 0.5. The number of gastric or small-intestinal contractions varied greatly from hypomotile to hypermotile in dogs with or without small-intestinal mechanical obstruction and did not appear to be a distinguishing feature of obstruction.

Although different frequencies of small-intestinal wall layering, peritoneal fluid, and mesenteric echogenicity findings were observed between obstructed and nonobstructed dogs, there was substantial overlap of results between groups, suggesting that these findings are not discriminating obstruction (Fig. 4).

Discussion

Whereas both abdominal radiography and ultrasonography are accurate for diagnosing small-intestinal mechanical obstruction in vomiting dogs, based on our results ultrasonography is more accurate and produces more confident results than three-view abdominal radiography. Equivocal radiographic results were associated with inability to detect an obstructive lesion. During radiography definitive detection of a potentially obstructive lesion occurred in only 52% of patients. During ultrasonography, definitive detection of a potentially obstructive gastrointestinal lesion resulted in the correct clinical decision in 96% of patients.

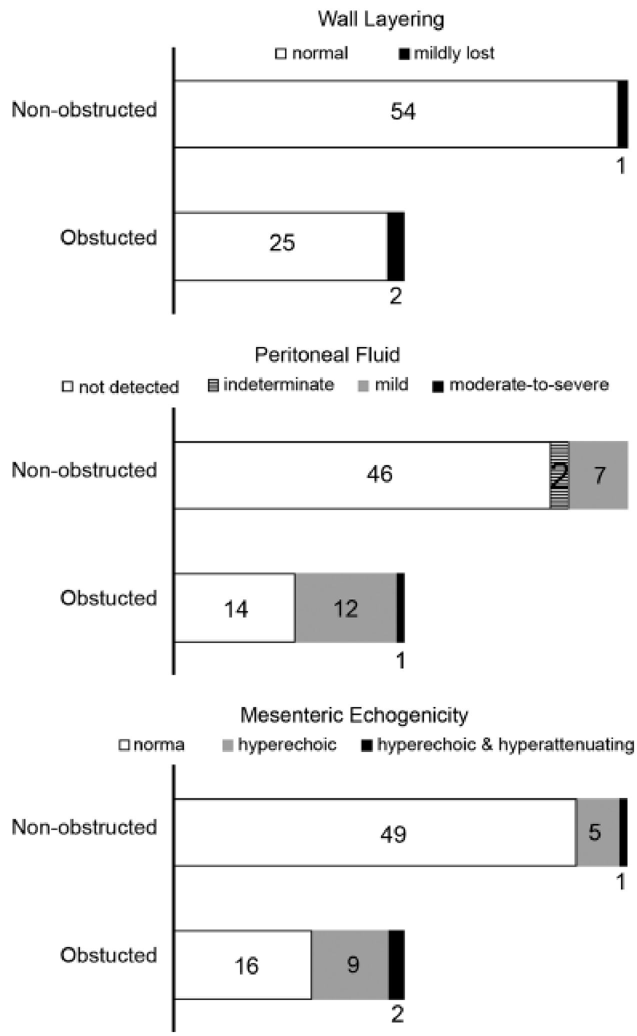

FIG. 4. Bar charts of mesenteric echogenicity, peritoneal fluid, and small-intestinal wall layering in dogs without small-intestinal mechanical obstruction and dogs with small-intestinal mechanical obstruction. Data were obtained during ultrasonography.

All obstructions were due to intestinal foreign bodies despite a broad inclusion criterion in an effort to include all possible obstructive etiologies. A variety of foreign bodies were encountered including plastic and rubber balls, peach pits, socks, towels, phytobezoar, shoelaces, and dental floss. The ultrasonographic appearance of all foreign bodies was typical, that is, a well-defined hyperechoic, hyperreflective acoustic interface with distal acoustic shadowing.[1,2] Linear foreign bodies accounted for 7/27 obstructions and in 6/7 of those, the typical sonographic appearance of plication was readily apparent.[1,2] Four dogs with a linear foreign body did not have radiographic signs of small-intestinal distention. In the nonobstructed group, the most common clinical diagnosis was presumptive nonspecific gastroenteritis, however, pancreatitis, necrotizing enterocolitis, and vasculitis with disseminated intravascular coagulopathy were also diagnosed.

Agreement between radiography and ultrasonography was moderately good (Table 2). Substantial disagreements were infrequent (12/82) and attributed to such things as lack of radiographic signs of segmental small-intestinal dilatation, or linear foreign bodies.

We also evaluated individual radiographic and ultrasonographic signs to understand their contribution to the final diagnosis or to relate their role to the pathogenesis of small-intestinal mechanical obstruction.[1,2,5–9] Specifically, we tried to identify signs that, if present, would increase the confidence in the final diagnosis of small-intestinal obstruction and a recommendation for surgery. For example, during radiography, severe small-intestinal dilatation, defined as SI:L5 ratio >2, especially segmental dilatation, was detected in over 50% of the dogs with small-intestinal mechanical obstruction and in only about 10% of dogs without obstruction (Fig. 1). This means that the radiographic diagnosis of small-intestinal mechanical obstruction was frequently, but not always, based on the detection of segmental small-intestinal dilatation. Frustratingly, approximately one-third of dogs (8/27) with small-intestinal mechanical obstruction had no evidence of small-intestinal dilatation. In 5/8 the radiographic diagnosis was negative for obstruction. In 4/8 of these dogs, the cause of obstruction was listed as linear foreign body, cloth or plastic with plication. In 3/7 dogs with obstruction caused by linear foreign bodies that were diagnosed correctly by radiography, the SI:L5 ratio was >1.9. Therefore, during radiography, small-intestinal dilatation is supportive of a diagnosis of small-intestinal obstruction, but the lack of small-intestinal dilatation does not exclude small-intestinal mechanical obstruction. Possible explanations for this observation include duration of disease, vomiting that emptied the small-intestinal lumen, acute presentation, or linear foreign bodies with plication that prevented luminal distention.[6] Consistent with a previous study the SI:L5 ratio was only moderately useful in discriminating between the two groups, with improved accuracy at SI:L5 ratios approaching 2.0.[5]

Similarly, during ultrasonography, detecting a jejunal serosal-to-serosal diameter of at least 1.5 cm was a very good test for small-intestinal mechanical obstruction. When looking at the box and whiskers plots (Fig. 2), the least overlap between dogs with and without small-intestinal mechanical obstruction was in the overall diameter of the jejunum: dogs with small-intestinal obstruction had a larger overall jejunal diameter (median 2.0 cm, CI 1.8–2.3 cm) than dogs without obstruction (median 0.9 cm, CI 0.8–1.0 cm). Normal wall layering was observed in approximately 93% of obstructed dogs (25/27); mild loss of wall layering was an infrequent observation in $<1\%$ of dogs (2/27) with confirmed obstruction. Therefore, when an enlarged loop of jejunum, due to intraluminal fluid or gas distention, with normal wall layering is detected, one should be suspicious of and systematically examine the intestines for mechanical obstruction. Conversely, if jejunal dilatation is not detected, then obstruction is unlikely.

Intraluminal distention secondary to small-intestinal obstruction causes venous congestion, lymphatic, and capillary stasis resulting in formation of free peritoneal fluid.[7,20] During ultrasonography, peritoneal fluid and increased mesenteric echogenicity were detected more frequently in dogs ($\sim 50\%$) with small-intestinal mechanical obstruction. In the obstructed group, one dog with peritoneal fluid was diagnosed with septic peritonitis secondary to a perforating intestinal foreign body. However, the presence of peritoneal fluid alone is a nonspecific sign as it was detected in $\sim 20\%$ of dogs without small-intestinal mechanical obstruction (Fig. 4) and did not correspond to septic peritonitis in any dog in the nonobstructed group.

The number of small-intestinal and gastric contractions was not a good discriminator for small-intestinal mechanical obstruction because there was substantial overlap between the obstructed and nonobstructed groups (Fig. 3). Many dogs without small-intestinal mechanical obstruction had decreased intestinal motility, which is consistent with the accepted pathophysiology of adynamic or functional ileus.[21] Some dogs in the nonobstructed group had gastrointestinal hypermotility, which probably reflects the different types of nonsurgical diseases causing the vomiting. In dogs with small-intestinal mechanical obstruction, a wide range of gastrointestinal hypomotility and hypermotility was observed. This ambiguity might relate to the duration of disease or the inconsistent use or type of sedation, but these variables were not evaluated.

We point out the six dogs in the nonobstructed group in which a potentially obstructive gastrointestinal lesion was identified definitively, based on ultrasonography. One was diagnosed correctly as a gastric foreign body, three were diagnosed incorrectly as small-intestinal foreign bodies and two were diagnosed correctly as small-intestinal foreign bodies. Of the three dogs with incorrect sonographic diagnosis, based on surgery, two were determined to be pyloric or gastric obstructions and one was a 20 cm cloth foreign body that was located in the ascending colon. Possible explanations for the discrepancies between the reference standard and ultrasonographic diagnosis include movement of the foreign body during time between imaging and surgery (approximately 1–2 h), movement of the foreign body during intraoperative manipulations, or incorrect imaging diagnosis. Retrospective review of archived images would not have changed the imaging diagnosis. In two dogs, when the presence of a small-intestinal foreign body that was potentially obstructive was detected, a sonographic diagnosis of "not obstructed" or "questionably obstructed," based on a lack of small-intestinal dilatation, prompted conservative therapy. One dog subsequently passed two pieces of cloth and the other passed portions of a carcass in the feces 3 days after going home.

Decisions based on ultrasonography alone resulted in one negative exploratory laparotomy. This dog had sonographic signs of duodenal dilatation without jejunal distention and a cause for suspected obstruction was not identified. The final diagnosis was myasthenia gravis; duodenal dilatation was attributed to sedation and not myasthenia gravis.

Three-view abdominal radiography vs. two orthogonal views, is not the standard-of-care offered at many hospitals. Our results might overemphasize the accuracy of standard-care abdominal radiography because obtaining both lateral views might improve the accuracy of radiography by redistribution of gas and fluid. For example, if a duodenal obstruction were present, it might have been obscured by fluid when the dog was in right-lateral recumbency and contrasted by gas in left-lateral recumbency. Therefore, the accuracy of abdominal radiography may be higher in our study than in situations where only two-view abdominal radiography is performed.

When discussing the accuracy of radiography vs. ultrasonography, it is important to emphasize that we only assessed small-intestinal mechanical obstruction and not gastrointestinal obstruction. A dog with a pyloric obstruction might require surgery but would have been scored negative for small-intestinal obstruction in this study. In part, we only investigated the detection of small-intestinal obstruction because this typically requires more urgent responses and the detection of gastric or pyloric obstruction often is limited with ultrasonography due to the presence of gas. In this latter situation, radiography might be preferable. It is important to note that false-positive and false-negative results were detected with both modalities, although less frequently with ultrasonography. Multiple examiners were used to make the study feasible and to minimize bias between examiners. Ultrasonography is dependent on the skill and experience of the sonographer with clinical decisions based on real-time imaging. In the present study, the false-positive and false-negative sonographic results occurred in the early stages when resident experience was relatively low. However, ultrasonography proved to be more accurate despite the differences in experience and skill between examiners.

In summary, both three-view abdominal radiography and abdominal ultrasonography are good tests for diagnosing small-intestinal mechanical obstruction in vomiting dogs and have moderate agreement. Based on the results of this study, ultrasonography is more accurate and provides a high level of diagnostic confidence in the evaluation of vomiting dogs. Despite this finding, either examination may be used in general or referral practice depending on desired accuracy, cost, availability, and examiner skill. During ultrasonography, detecting an enlarged loop of jejunum (serosa-to-serosa diameter >1.5 cm) with normal wall layering should prompt the examiner to thoroughly evaluate the entire abdomen for a possible cause of small-intestinal mechanical obstruction.

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