Ultrasonography of Small Intestinal Inflammatory and Neoplastic Diseases in Dogs and Cats

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KEYWORDS

• Inflammatory bowel disease • Food allergy • Lymphoma
• Intestinal hemodynamics • Intestinal neoplasia
• Fungal infection

Ultrasonography has become a mainstay of diagnosing intestinal diseases in dogs and cats. Using ultrasonography to differentiate inflammatory from neoplastic infiltrative disease has been the focus of recent investigations.[1–5] Abdominal radiography remains an important part of screening patients with vomiting and diarrhea, and should be performed in conjunction with the ultrasonographic examination in most instances. Barium studies of the gastrointestinal tract remain important for the diagnosis of foreign bodies in vomiting animals and for assessing gastrointestinal emptying and transit times. However, for detecting infiltrative intestinal diseases the ultrasonographic examination is superior. Computed tomography and magnetic resonance imaging for the detection of infiltrative small intestinal diseases in dogs and cats have not yet been investigated.

Differentiating inflammatory from neoplastic infiltration of the small intestine is crucial to choosing appropriate treatment strategies in dogs and cats. Ultrasonography is often one of the first diagnostic tools used for that purpose. Although overlap in the sonographic appearances of inflammatory and neoplastic infiltration make a definitive diagnosis difficult, awareness of features of both diseases is important for the accurate interpretation of the sonographic findings. Full-thickness intestinal biopsy remains the gold standard for differentiating inflammatory from neoplastic disease of the small intestine.

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EQUIPMENT

High-resolution images are necessary for the recognition of detailed features of intestinal wall abnormalities in dogs and cats (**Fig. 1**). Therefore, high-frequency curved or linear array transducers with a minimum of 7.5 MHz are required for accurate examination of the small intestinal wall and its associated layering. Color and spectral Doppler are important for the detection of intestinal ischemia or increased vascularization, such as observed with some neoplastic infiltrations.[6] Spectral Doppler has also been used to assess intestinal blood flow in chronic enteropathies. Contrast-enhanced harmonic ultrasound imaging of the small intestine is not yet established for detection of intestinal disease in veterinary medicine.

EXAMINATION TECHNIQUE FOR THE SMALL INTESTINE

Dogs and cats should be fasted and have the ventral abdomen clipped as for any routine ultrasound examination. The animals can be examined in dorsal, right, or left lateral recumbency. A combination of different positions can be advantageous for evaluating intestinal segments not visible in one of the recumbencies. Furthermore, gas and fluid contents move to different portions of the intestine when the animal is repositioned, which can aid in visualization of the intestinal wall. Small intestinal segments should be traced throughout the entire abdomen from the pylorus to the ileocecocolic junction.

The entire intestinal tract should be assessed for:

- Wall thickness
- Wall layering
- Layer echogenicity
- Motility
- Peri-intestinal echogenicity
- Presence of free fluid

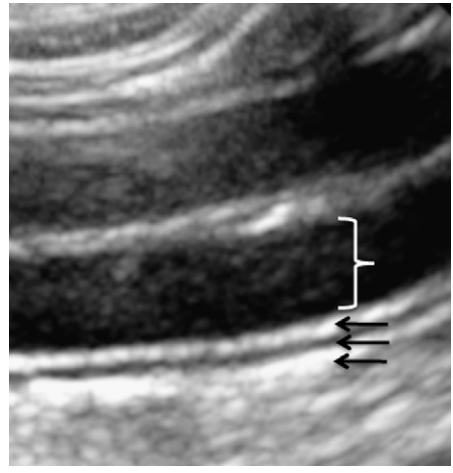

Fig. 1. Sagittal image of a jejunal segment showing normal wall layering, thickness, and echogenicity. The bracket shows the mucosa and the outer 3 arrows point to the submucosa, muscularis, and serosa, starting from the mucosa moving outwards. The mucosa is practically anechoic, and the outer 3 layers are thin and approximately the same thickness relative to each other.

- Regional lymphadenomegaly
- Focal, multifocal, or diffuse distribution of disease.

Table 1 lists ultrasound parameters for normal small intestines.[7–9] Involvement of other organ systems is also important for prioritizing a differential diagnosis list, and a complete sonographic examination of the abdomen should be performed in patients with gastrointestinal signs. In addition, the presence of peri-intestinal hyperechoic mesentery or free fluid can alert the sonographer to regional inflammation, neoplastic invasion, or perforation.

The descending duodenum, jejunum, and ileum can be differentiated from one another ultrasonographically based on their location, wall layering, and communication with adjacent intestinal segments (see **Table 1**). In dogs the duodenum is the most lateral intestinal segment in the right abdomen. The duodenum follows a straight course along the right body wall cranially to the cranial duodenal flexure, where it abruptly turns toward the left to join the pylorus. The flexure is usually visible in all dogs, but may be difficult to locate in deep-chested animals. A right intercostal approach may be necessary to examine the pyloroduodenal junction in some dogs.[10,11] In cats, the pyloroduodenal junction has a more midline location, immediately caudal to the hilus of the liver, and the duodenum courses laterally to the right kidney. Focal, hyperechoic structures that appear like outpouchings of the lumen into the mucosa can often be detected at the antimesenteric border of the duodenal wall. These normal structures are associated with Peyer patches, are only present on the duodenum, and should not be misdiagnosed as ulcerations. The duodenum

Table 1
Normal ultrasonographic features of the small intestine

Ultrasound Parameter	Location	Wall Thickness	Specific Features
Dogs			
Duodenum	Right lateral abdomen	<20 kg: ≤5.1 mm 20–29 kg: ≤5.3 mm >30 kg: ≤6 mm	Peyer patches at the antimesenteric border Major and minor duodenal papilla
Jejunum	Mid and caudal abdomen	<20 kg: ≤4.1 mm 20–29 kg: ≤4.4 mm >30 kg: ≤4.7 mm	—
Ileum	Right mid abdomen, medial to the duodenum	—	Thicker submucosa Ileocecocolic junction Rosette appearance in cross section
Cats			
Duodenum	Pylorus mid abdomen at liver hilus Duodenum right lateral abdomen	1.3–3.8 mm	Major duodenal papilla more prominent (2.9–5.5 mm) than in the dog and can be identified in most cats
Jejunum	Mid and caudal abdomen	1.6–3.6 mm	—
Ileum	Right mid abdomen, medial to the duodenum	2.5–3.2 mm	Thicker submucosa Wagon wheel appearance in cross section Ileocolic junction

and jejunum should be observed for peristalsis, which occurs at the rate of approximately one contraction wave per minute in normal animals.

INFLAMMATORY DISEASES

Inflammatory diseases of the small intestines are common in dogs and cats. Causes include lymphoplasmacytic enteritis (most common), eosinophilic enteritis, granulomatous enteritis (rare), protein-losing enteropathy and lymphangiectasia, food allergy, and chronic infection (giardia, histoplasma, pythium, mycobacterium, toxoplasma, prototheca).[12] These diseases do not always induce changes that can be detected with ultrasonography, and intestinal biopsy is required to confirm the diagnosis and assess the severity of lesions in many cases.

Chronic Inflammatory Disease

Although generally diffuse, inflammatory disease can also cause focal or segmental changes. It often leads to mild to moderate transmural thickening of the intestinal wall with preserved wall layering (**Fig. 2**).[3–5] In some instances the wall layering can be indistinct or completely lost if ulcerative enteritis, fibrosis, edema, hemorrhage, and/or severe lymphoplasmacytic infiltration are present.[13] The relative thickness of the layers may also change while the total wall thickness remains normal. Selective muscularis thickening can be caused by idiopathic muscular hypertrophy of the smooth muscle layer of the intestine, and has been commonly observed in inflammatory conditions.[14] The echogenicity of the mucosa may be altered in both lymphangiectasia and lymphoplasmacytic enteritis.[3] Hyperechoic mucosal speckles and striations can be identified in inflammatory disease but are nonspecific for the cause and severity (**Fig. 3**).

The sonographic abnormalities of inflammatory bowel disease (IBD) in cats are similar to those of dogs. Poor intestinal wall layer definition, focal thickening, and large hypoechoic mesenteric lymph nodes are consistent with IBD.[1] In cats the muscular layer is often selectively thickened in IBD, due to lymphoplasmacytic and eosinophilic infiltration (**Fig. 4**).[13] However, a thickened muscularis layer in the cat has also been associated with other disorders such as mechanical obstruction and lymphoma.[13] Marked thickening of the muscularis layer may also be observed in cats with eosinophilic enteritis,[15] a condition that has been reported to occur in association with feline

Fig. 2. Sagittal image of a jejunal segment from a dog with chronic diarrhea that had a histopathological diagnosis of lymphocytic, plasmacytic enteritis. The wall is thickened at 5.3 mm and there is a small amount of fluid in the lumen. The segment has a stiffened appearance but the wall layering is normal.

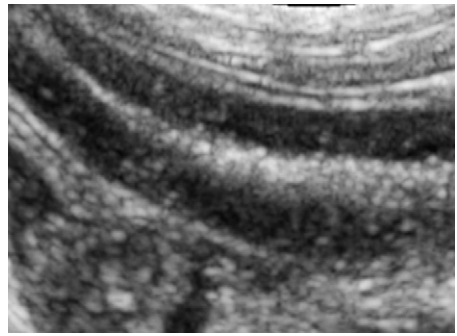

Fig. 3. Sagittal image of a jejunal segment from a dog with chronic diarrhea and a histopathological diagnosis of lymphocytic, plasmacytic enteritis. There are multifocal, pin-point, hyperechoic foci throughout the mucosa. These speckles were found to be diffuse throughout the small intestines, but no wall thickening or altered layering was found.

hypereosinophilic syndrome (**Fig. 5**). Although the changes are diffuse in most instances, a focal intestinal mass has been reported in one cat.[16] Histopathologically the mucosa of affected cats shows an increased number of eosinophils, and the muscularis is hypertrophic. Feline gastrointestinal eosinophilic sclerosing fibroplasia is another eosinophilic disorder that has recently been described in 25 cats.[17] All cats had an intestinal mass at the pylorus, jejunum, ileum, ileocecocolic junction, or colon, with the pyloric location being most common. The lesions were usually transmural, but they were limited to the mucosa in some cases; however, they never extended beyond the serosa.

Chronic inflammatory disease in cats may also produce a distinct, thin, hyperechoic line within the mucosa, which has been associated with fibrosis histopathologically.[18] The clinical relevance of this sonographic abnormality is uncertain, as it can also be found incidentally in cats without gastrointestinal disease.

Lymphangiectasia can occur in dogs with IBD or a primary idiopathic disorder.[19,20] The ultrasonographic diagnosis usually rests on the ability to demonstrate hyperechoic striations that are aligned parallel to one another and perpendicular to the

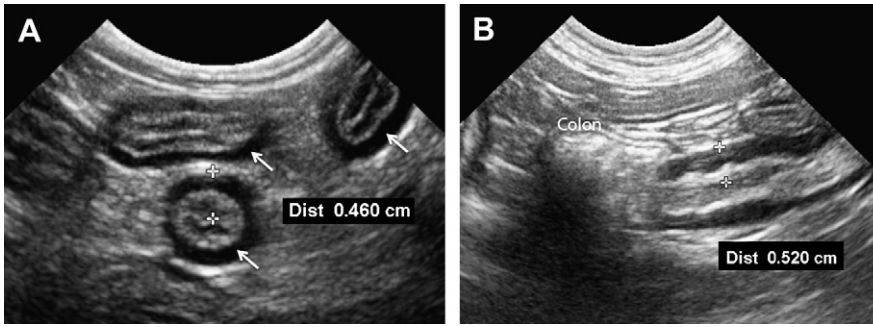

Fig. 4. (*A*) Transverse image of jejunal segments in a cat with a histopathological diagnosis of cholangiohepatitis and lipidosis and lymphocytic, plasmacytic, and eosinophilic enteritis. The cat also had a clinical diagnosis of pancreatitis. The muscularis (*arrowed*) is diffusely thickened throughout the jejunum, and the walls are thickened at 4.6 mm. (*B*) The ileum from the same cat as in *A* is shown in the sagittal plane. The muscularis layer of the ileum is markedly thickened.

Fig. 5. Hypereosinophilic syndrome in a cat. A transverse image of the jejunum shows mild intestinal wall thickening, and a selectively thickened and relatively hyperechoic muscularis (*asterisk*). The arrow shows the mucosa, which is not as thick as the muscularis but has a diffusely increased echogenicity.

long axis of the intestine (**Fig. 6**).[20] The most common sonographic findings in dogs with histopathologically confirmed lymphangiectasia are abdominal effusion, intestinal thickening, hyperechoic mucosa, and wall corrugation.[19] However, the intestine may also appear normal. Sonographic abnormalities are typically not specific enough to differentiate lymphangiectasia from other inflammatory diseases, and they usually do not correlate with histologic severity.[19] Generalized mild dilation of the intestines and fluid content is also commonly observed, and regional lymph nodes may or may not be enlarged. Lymphangiectasia, IBD (including lymphocytic, plasmacytic, and eosinophilic forms), alimentary lymphoma, ulcer, and histoplasmosis can all cause protein-losing enteropathy.[21] Because of the overlap in the sonographic appearance of these diseases, histopathology is required for differentiation. Although in most instances abnormalities associated with lymphangiectasia are diffuse, a dog with

Fig. 6. Transverse image of a jejunal segment in a Yorkshire Terrier with chronic diarrhea and weight loss. There are multiple, parallel arranged hyperechoic striations throughout the mucosa. This finding was present throughout the entire jejunum and duodenum. Lymphangiectasia and lymphocytic, plasmacytic inflammation were diagnosed histopathologically.

a focal mass lesion due to lymphangiectasia has also been described. However, this presentation should be considered a rare form.[20]

Corrugation of the small intestine can be seen with inflammatory disease within or surrounding the intestinal wall. Dogs with enteritis of any type can show signs of corrugation.[22] In dogs with pancreatitis, the duodenum can commonly become corrugated due to the surrounding peritonitis. Hemo- and uroabdomen can result in similar findings in the small intestines.[22,23] Ultrasonography also allows the sonographer to detect intestinal spasms in real time. These spasms appear as intermittent contractions, resulting in a corrugated appearance of the wall that resolves after the spasm.

Few data are available concerning the monitoring of chronic enteropathies sonographically. A 2-dimensional ultrasound score has been established for canine chronic enteropathies. The ultrasound score correlates to the canine inflammatory bowel disease clinical activity index (CIBDAI) at initial presentation of the patient when the disease is clinically active.[3] However, improvement in the CIBDAI after treatment does not correlate with improvement of the ultrasound score on follow-up examinations.

Infectious Diseases

Infectious causes of intestinal wall infiltration have sonographic findings similar to neoplasia. Non-neoplastic causes of intestinal masses include fungal infections with pythium and histoplasma, abscesses, cysts, hematomas, ulcers, intussusceptions, and foreign body granulomas.[24] A focal mass with loss of wall layering is most commonly associated with neoplasia; however, fungal infections may cause similar lesions. Pythiosis and histoplasmosis can lead to either intestinal wall thickening with pseudolayering, transmural loss of layering, or a focal mass (**Fig. 7**).[25] Pseudolayering appears as alternating bands of hyper- and hypoechoic tissue within the intestinal wall that does not correspond to the normal wall layers. The distribution of fungal infection in the intestine can be focal or multifocal, but is usually not diffuse. Regional lymph nodes are often enlarged, rounded, or irregularly shaped, and hypoechoic or heterogeneous sonographically. These nodes can also grow to immense proportions, creating a large mass in the mid-abdomen. Histoplasmosis has been

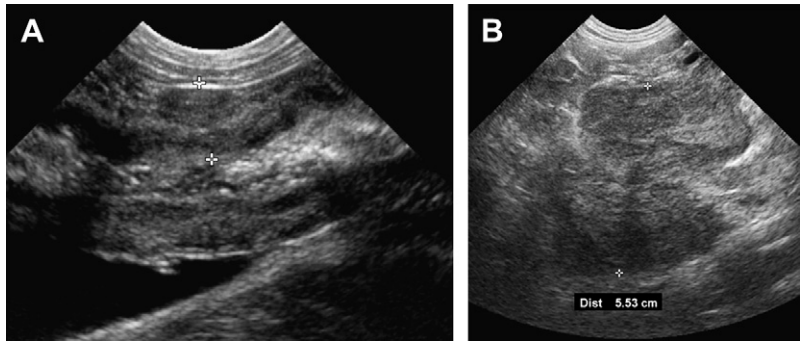

Fig. 7. (*A*) Sagittal image of the duodenum in a 2-year-old dog with severe weight loss. The wall is thickened (8 mm) and there is a complete, transmural loss of normal layering. The wall appears heterogeneous and stiff. Diagnosis: pythiosis. (*B*) A large, 5.5-cm sized, complex and heterogeneous mass was present in the mid-abdomen of the dog in *A*. This finding is common in pythium infections and represents infiltration of the jejunal lymph nodes.

reported in the cat, and can spread to the entire abdomen and lungs.[26] Abdominal ultrasonography of dogs and cats with intestinal histoplasmosis can reveal lymph node enlargement, a mass of uncertain origin, thickening of the muscularis layer of the small bowel, focal thickening of the ileum with loss of layering, and free peritoneal fluid. These changes are sonographically similar to those of lymphoma and other neoplasms. Histology is required for differentiation between neoplastic and non-neoplastic masses of the intestines and lymph nodes.

INTESTINAL NEOPLASIA

Focal intestinal wall thickening can be caused by neoplastic and non-neoplastic lesions. Sonographic parameters such as lesion symmetry, distribution, degree of thickening, and wall layering are most commonly used to distinguish inflammation from neoplasia.[4] In dogs, wall thickness of neoplastic infiltrative lesions is statistically greater than that of nonspecific inflammatory disease (0.5–7.9 mm vs 0.2–2.9 mm, respectively).[4] When loss of wall layering is identified sonographically, there is a 50-times greater likelihood of a diagnosis of neoplasia than of nonspecific inflammation.[4] Neoplastic masses may have concentric or eccentric wall thickening with loss of wall layering. **Table 2** lists the types of abnormal wall layering patterns that can be detected with ultrasonography, with a description of their appearances.[4] Neoplastic infiltration of the small intestine is also statistically shown to be more likely focal than diffuse, which is more common in inflammatory disease.[4]

The most common intestinal wall tumors in dogs are carcinomas, lymphoma, leiomyoma, and leiomyosarcoma.[27–30] Ileal hemangioma with a large mass detected sonographically is rare but can occur in dogs.[31] In cats, the most common causes of neoplastic intestinal disease are lymphoma, mast cell tumor, and adenocarcinomas. Visceral hemangiosarcoma involving the small intestine and colon has also been reported recently in cats; however, the sonographic characteristics have not been established.[32]

Alimentary lymphoma can be diffuse in both dogs and cats but most commonly occurs as a solitary, hypoechoic intestinal mass with transmural loss of wall layering (**Fig. 8**).[13,29] Furthermore, it is the most common neoplastic cause of diffuse infiltration

Table 2
Ultrasonographic patterns of abnormal small intestinal wall layering

Pattern	Commonly Associated With
Altered	
One or more layers are selectively thickened	IBD, lymphoma, eosinophilic enteritis
One or more layers have an abnormal echogenicity	Thickened muscularis in cats
	Fungal infections
Transmural Loss	
No layers are present between the mucosa and serosa	Lymphoma, adenocarcinoma
	Fungal infections
Concentric Loss of Layering	
Wall uniformly affected in cross section	Lymphoma
Eccentric Loss of Layering	
Wall not uniformly affected in cross section Can extend outward through the serosa	Leiomyosarcoma

Fig. 8. Transverse image of a jejunal segment in a dog. Transmural, hypoechoic thickening with complete loss of wall layering is present. Hyperechoic material in the lumen with dirty shadowing is due to gas content. The lesion was focal. Fine-needle aspiration was diagnostic for lymphoma.

and wall thickening that can appear similar to inflammatory disease (**Fig. 9**). Lymphoma may cause partial stenosis of the intestinal lumen, but usually not complete obstruction. Regional lymph nodes are commonly enlarged, rounded, and hypoechoic. In cats, alimentary lymphoma can cause diffuse disease that infiltrates the intestinal wall without altering the wall layering. Thickening of the muscularis layer has been reported in IBD and intestinal lymphoma in that species.[33] A recent study showed a significant association between muscularis thickening and feline T-cell lymphoma (**Fig. 10**),[34] but did not show any significant difference in the prevalence of regional lymphadenopathy between cats with IBD and those with lymphoma. Cats with disease limited to the mucosa and lamina propria, based on histopathology, had no ultrasonographic abnormalities. Due to the overlap of diseases associated with muscularis thickening and lymphadenopathy in cats (see above), full-thickness intestinal biopsies are likely indicated for a definitive diagnosis.

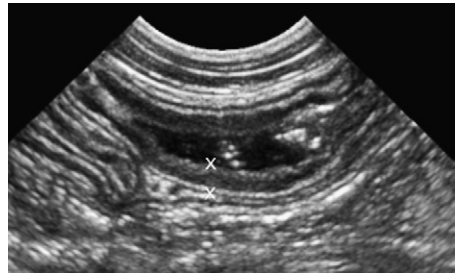

Fig. 9. Sagittal image of the jejunum in a 2-year-old Boxer with chronic diarrhea and weight loss. The wall thickness and layering are normal, but the mucosa was diffusely hyperechoic, and the intestines appeared stiff and were mildly fluid distended. Full-thickness biopsies were performed and a diagnosis of lymphoma was made histopathologically.

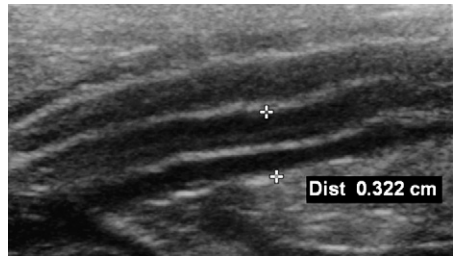

Fig. 10. Sagittal image of the jejunum in a cat. The wall thickness is normal but the muscularis is thickened. This abnormality was present throughout the jejunum and the regional lymph nodes were enlarged, rounded, and hypoechoic (not shown). Lymphoma was diagnosed.

Intestinal adenocarcinoma in dogs and cats appears sonographically as transmural thickening with complete loss of wall layering and regional lymphadenopathy (**Fig. 11**).[13,29] This appearance is very similar to that of alimentary lymphoma when it forms a mass. However, carcinomas are usually solitary whereas lymphoma can be focal, multifocal, or diffuse. Intestinal carcinoma will often cause mechanical ileus due to luminal stenosis, which is less common with lymphoma. Intestinal smooth muscle tumors such as leiomyosarcomas often become very large and have an eccentric growth out of the intestinal wall through the serosa (**Fig. 12**). These tumors can appear as extraluminal masses also.[13] Leiomyomas tend to be small, and appear as a focal intramural hypoechoic thickening with loss of wall layering (**Fig. 13**).[14] Intestinal mast cell tumors are rare and are more common in cats than dogs. Their appearance is similar to that of lymphoma, as they cause hypoechoic thickening of the wall with loss of layering.[14,35]

Widespread neoplastic infiltration throughout the mesentery and organs is referred to as carcinomatosis (**Fig. 14**). Intestinal adenocarcinoma has been associated with the development of carcinomatosis in dogs.[28] Ultrasonographic features include hypoechoic nodular foci throughout the mesentery, and often free abdominal fluid. When free fluid is present, the surface of the organs such as the liver and spleen should be carefully scanned for irregularities that may represent tumor spread.

Fig. 11. Large heterogeneous jejunal mass in a dog. The mass shows transmural complete loss of wall layering and luminal stenosis. The diagnosis was carcinoma, but leiomyosarcoma and lymphoma have similar ultrasonographic features.

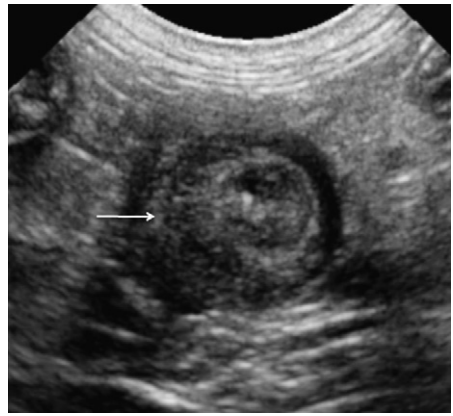

Fig. 12. Transverse image of a jejunal segment in a dog, showing an example of eccentric thickening (*arrows*) seen with leiomyosarcomas.

REGIONAL LYMPHADENOPATHY

The hepatic, gastric, pancreaticoduodenal, jejunal, and lumbar aortic lymph nodes drain the small intestine (duodenum, jejunum, and ileum) and should be assessed during the routine ultrasonographic examination. Normal lymph nodes should be slightly hypoechoic or isoechoic to the surrounding mesentery.[36] The height of jejunal lymph nodes in healthy dogs ranges from 1.6 to 8.2 mm and their width ranges from 2.6 to 14.7 mm.[36] Metastatic lymph nodes are typically enlarged, rounded, and hypoechoic in cats and dogs. Lymph nodes may be enlarged in inflammatory disease, but typically maintain a more normal shape and echogenicity (**Fig. 15**).[37] However, they may become ill defined.[38] Infectious disease will often lead to more severe lymph node enlargement with features similar to those of metastatic infiltration.[37] Regardless of the underlying cause, as the node becomes larger, necrotic, or hemorrhagic, it will appear more heterogeneous and irregular.[37] The jejunal nodes are usually readily accessible for percutaneous ultrasound-guided tissue sampling. Depending on their size and due to their close proximity to major vessels, sedation may be necessary to perform tissue sampling for cytologic analysis.

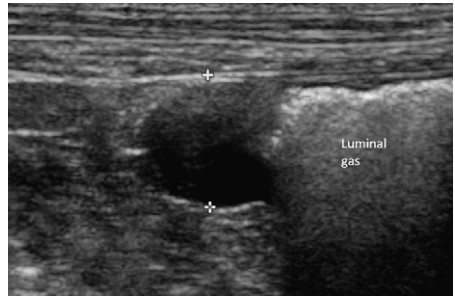

Fig. 13. Sagittal image of a jejunal segment in a dog. The dog did not present with gastrointestinal disease and a 1-cm diameter, focal, hypoechoic nodule was present at the serosal surface (between calipers). The same nodule was detected 3 months later, and cytology diagnosed a leiomyoma.

Fig. 14. Mesentery in a dog with intestinal carcinoma. Free peritoneal fluid was present and the mesentery was infiltrated with irregular, hypoechoic foci with a clumped appearance.

MOTILITY

Inflammatory, infectious, and neoplastic infiltrative diseases of the intestine can lead to functional disturbances. Functional ileus can generally be differentiated from mechanical ileus radiographically and ultrasonographically. In functional ileus, generalized, mild dilation of the intestinal lumen, which often contains fluid, is the predominant feature. Intestinal motility is decreased or absent and the intestinal walls may appear stiffened with to-and-fro movement of the fluid content.[14] This pattern can be associated with any cause of gastroenteritis, pythiosis, diffuse neoplasia, or peritoneal inflammation. It has also been reported with small intestinal infarction leading

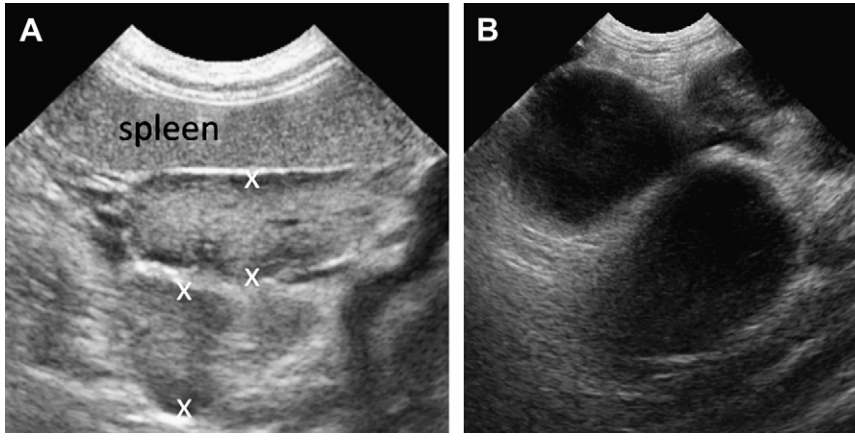

Fig. 15. (*A*) Sagittal image of two jejunal lymph nodes in a dog with lymphocytic, plasmacytic enteritis. The nodes are mildly enlarged and maintain a normal elliptical shape, but are slightly heterogeneous due to a peripheral hypoechoic rim. (*B*) Sagittal image of the jejunal lymph nodes in a dog with alimentary lymphoma. The nodes are severely enlarged, round, and markedly hypoechoic.

to segmental dilation and hypoechoic wall thickening.[39] A chronic, end-jejunal obstruction caused by a foreign body or stenosis caused by neoplasia can also lead to similar findings. Mechanical obstructions can result from tumor growth into the lumen, causing stenosis and obstruction and leading to a mixed population of intestinal diameters such as seen with foreign body obstruction. In general, the intestinal segments proximal to the obstruction show hyperperistalsis and are moderately to severely dilated, while the intestines caudal to the obstruction are of small diameter. Foreign material appears hyperechoic with shadowing, and collects proximal to the obstruction. Inflammatory and infectious infiltrative diseases typically do not cause mechanical obstructions.

GASTROINTESTINAL HEMODYNAMICS

Doppler ultrasound provides a noninvasive method of assessing gastrointestinal hemodynamics in dogs and humans.[40] Assessment of systolic and diastolic arterial blood flow in the large upstream arteries supplying the gastrointestinal tract is aimed at detecting abnormally increased or decreased resistance to flow to the intestinal capillary bed during digestion. The resistive and pulsatility indices (RI and PI, respectively) have historically been used to infer the degree of resistance to flow in downstream capillary beds. A lowered index indicates lowered resistance to flow and vice versa. The spectral waveforms of the celiac and cranial mesenteric arteries in normal dogs have been described as being of moderately high resistance in the fasted state (cranial mesenteric artery RI = 0.803 $\pm$ 0.029, celiac artery RI = 0.763 $\pm$ 0.025, cranial mesenteric artery PI = 2.290 $\pm$ 0.311, celiac artery PI = 1.962 $\pm$ 0.216).[40,41] Reference values for postprandial RI and PI have also been made available.[40,41] Vasodilation during digestion leads to decreasing Doppler indices and increasing diastolic blood flow velocity, which infer decreased resistance to flow in the downstream capillary bed of the gastrointestinal tract.

In dogs with proven food allergies that develop gastrointestinal signs, dietary provocation with the allergen results in prolonged vasodilation at 90 minutes postprandially compared with provocation with nonallergens and the dog's regular diet.[41] Abnormal hemodynamics have also been shown in dogs with chronic enteropathies due to other causes.[42] This noninvasive ultrasonographic method shows promise for assessing hemodynamic pathophysiology in dogs with adverse reactions to food and chronic enteropathies due to other causes.

Fig. 16. Hyperechoic reverberation echoes adjacent to the peritoneum in the nondependent aspect of the abdomen (*arrow*). The free air resulted from a perforated intestinal tumor.

COMPLICATIONS

Perforation of the duodenum, jejunum, or ileum due to neoplastic infiltration is not common but can occur. Sonographic findings include bright regional mesenteric fat, peritoneal effusion, fluid-filled stomach or intestines typically caused by local peritonitis, intestinal wall thickening, free peritoneal air, loss of intestinal wall layering, and corrugated intestines (**Fig. 16**).[23] The intestines should be screened for the presence of a mass, presence of a luminal foreign body, and mechanical ileus.

SUMMARY OF IMPORTANT POINTS

- Lymphoplasmacytic enteritis and lymphoma of the small intestine share similar ultrasonographic characteristics
- Neoplastic infiltration is more often focal, shows more severe thickening, and causes loss of wall layering when compared with inflammatory disease
- Lymph nodes tend to be larger when involved in neoplastic versus inflammatory disease
- In endemic regions, fungal infections cannot be differentiated from neoplasia on the basis of ultrasonographic findings
- Due to overlap in the sonographic appearance of neoplastic and inflammatory disease, histopathology is necessary for differentiation.

REFERENCES

1. Baez JL, Hendrick MJ, Walker LM, et al. Radiographic, ultrasonographic, and endoscopic findings in cats with inflammatory bowel disease of the stomach and small intestine: 33 cases (1990–1997). J Am Vet Med Assoc 1999;215(3): 349–54.
2. Barr BS. Infiltrative intestinal disease. Vet Clin North Am Equine Pract 2006;22(1): e1–e7.
3. Gaschen L, Kircher P, Stüssi A, et al. Comparison of ultrasonographic findings with clinical activity index (CIBDAI) and diagnosis in dogs with chronic enteropathies. Vet Radiol Ultrasound 2008;49(1):56–64.
4. Penninck DG, Smyers B, Webster CR, et al. Diagnostic value of ultrasonography in differentiating enteritis from intestinal neoplasia in dogs. Vet Radiol Ultrasound 2003;44:570–5.
5. Rudorf H, van SG, O'Brien RT, et al. Ultrasonographic evaluation of the thickness of the small intestinal wall in dogs with inflammatory bowel disease. J Small Anim Pract 2005;46(7):322–6.
6. Patsikas MN, Papazoglou LG, Jakovljevic S, et al. Color Doppler ultrasonography in prediction of the reducibility of intussuscepted bowel in 15 young dogs. Vet Radiol Ultrasound 2005;46(4):313–6.
7. Delaney F, O'Brien RT, Waller K. Ultrasound evaluation of small bowel thickness compared to weight in normal dogs. Vet Radiol Ultrasound 2003;44(5): 577–80.
8. Newell SM, Graham JP, Roberts GD, et al. Sonography of the normal feline gastrointestinal tract. Vet Radiol Ultrasound 1999;40(1):40–3.
9. Goggin JM, Biller DS, Debey BM, et al. Ultrasonographic measurement of gastrointestinal wall thickness and the ultrasonographic appearance of the ileocolic region in healthy cats. J Am Anim Hosp Assoc 2000;36(3):224–8.
10. Brinkman-Ferguson EL, Biller DS. Ultrasound of the right lateral intercostal space. Vet Clin North Am Small Anim Pract 2009;39(4):761–81.

11. Brinkman EL, Biller DS, Armbrust LJ, et al. The clinical utility of the right lateral intercostal ultrasound scan technique in dogs. J Am Anim Hosp Assoc 2007; 43(4):179–86.
12. Hall EJ, German AJ. Inflammatory bowel disease. In: Steiner JM, editor. Small animal gastroenterology. 1st edition. Hannover (Germany): Schluetersche Verlagsgesellschaft mbH; 2008. p. 312–50.
13. Penninck DG. Gastrointestinal tract. In: Penninck DG, D'anjou MA, editors. Atlas of small animal ultrasonography. 1st edition. Ames (IA): Blackwell Publishing; 2008. p. 281–337.
14. Penninck DG. Gastrointestinal tract. In: Nyland TG, Mattoon JS, editors. Small animal diagnostic ultrasound. 2nd edition. Philadelphia: W.B. Saunders Co; 2002. p. 227–30.
15. Hendrick M. A spectrum of hypereosinophilic syndromes exemplified by six cats with eosinophilic enteritis. Vet Pathol 1981;18(2):188–200.
16. Wilson SC, Thomson-Kerr K, Houston DM. Hypereosinophilic syndrome in a cat. Can Vet J 1996;37(11):679–80.
17. Craig LE, Hardam EE, Hertzke DM, et al. Feline gastrointestinal eosinophilic sclerosing fibroplasia. Vet Pathol 2009;46(1):63–70.
18. Penninck DG, Webster CR, Keating JH. The sonographic appearance of intestinal mucosal fibrosis in cats. Vet Radiol Ultrasound 2010;51(4):458–61.
19. Kull PA, Hess RS, Craig LE, et al. Clinical, clinicopathologic, radiographic, and ultrasonographic characteristics of intestinal lymphangiectasia in dogs: 17 cases (1996–1998). J Am Vet Med Assoc 2001;219(2):197–202.
20. Louvet A, Denis B. Ultrasonographic diagnosis—small bowel lymphangiectasia in a dog. Vet Radiol Ultrasound 2004;45(6):565–7.
21. Peterson PB, Willard MD. Protein-losing enteropathies. Vet Clin North Am Small Anim Pract 2003;33(5):1061–82.
22. Moon ML, Biller DS, Armbrust LJ. Ultrasonographic appearance and etiology of corrugated small intestine. Vet Radiol Ultrasound 2003;44(2):199–203.
23. Boysen SR, Tidwell AS, Penninck DG. Ultrasonographic findings in dogs and cats with gastrointestinal perforation. Vet Radiol Ultrasound 2003;44(5):556–64.
24. Papazoglou LG, Tontis D, Loukopoulos P, et al. Foreign body-associated intestinal pyogranuloma resulting in intestinal obstruction in four dogs. Vet Rec 2010;166(16):494–7.
25. Graham JP, Newell SM, Roberts GD, et al. Ultrasonographic features of canine gastrointestinal pythiosis. Vet Radiol Ultrasound 2000;41(3):273–7.
26. Mavropoulou A, Grandi G, Calvi L, et al. Disseminated histoplasmosis in a cat in Europe. J Small Anim Pract 2010;51(3):176–80.
27. Monteiro CB, O'Brien RT. A retrospective study on the sonographic findings of abdominal carcinomatosis in 14 cats. Vet Radiol Ultrasound 2004;45(6):559–64.
28. Paoloni MC, Penninck DG, Moore AS. Ultrasonographic and clinicopathologic findings in 21 dogs with intestinal adenocarcinoma. Vet Radiol Ultrasound 2002;43(6):562–7.
29. Penninck DG. Characterization of gastrointestinal tumors. Vet Clin North Am Small Anim Pract 1998;28(4):777–97.
30. Yam PS, Johnson VS, Martineau HM, et al. Multicentric lymphoma with intestinal involvement in a dog. Vet Radiol Ultrasound 2002;43(2):138–43.
31. Aita N, Iso H, Uchida K. Hemangioma of the ileum in a dog. J Vet Med Sci 2010; 72(8):1071–3.
32. Culp WT, Drobatz KJ, Glassman MM, et al. Feline visceral hemangiosarcoma. J Vet Intern Med 2008;22(1):148–52.

33. Evans SE, Bonczynski JJ, Broussard JD, et al. Comparison of endoscopic and full-thickness biopsy specimens for diagnosis of inflammatory bowel disease and alimentary tract lymphoma in cats. J Am Vet Med Assoc 2006;229(9): 1447–50.
34. Zwingenberger AL, Marks SL, Baker TW, et al. Ultrasonographic evaluation of the muscularis propria in cats with diffuse small intestinal lymphoma or inflammatory bowel disease. J Vet Intern Med 2010;24(2):289–92.
35. Sato AF, Solano M. Ultrasonographic findings in abdominal mast cell disease: a retrospective study of 19 patients. Vet Radiol Ultrasound 2004;45(1):51–7.
36. Agthe P, Caine AR, Posch B, et al. Ultrasonographic appearance of jejunal lymph nodes in dogs without clinical signs of gastrointestinal disease. Vet Radiol Ultrasound 2009;50(2):195–200.
37. D'anjou MA. Abdominal cavity, lymph nodes, and great vessels. In: Penninck DG, D'anjou MA, editors. Atlas of small animal ultrasonography. 1st edition. Iowa: Blackwell Publishing; 2008. p. 445–63.
38. Nyman HT, Kristensen AT, Flagstad A, et al. A review of the sonographic assessment of tumor metastases in liver and superficial lymph nodes. Vet Radiol Ultrasound 2004;45(5):438–48.
39. Wallack ST, Hornof WJ, Herrgesell EJ. Ultrasonographic diagnosis—small bowel infarction in a cat. Vet Radiol Ultrasound 2003;44(1):81–5.
40. Kircher P, Lang J, Blum J, et al. Influence of food composition on splanchnic blood flow during digestion in unsedated normal dogs: a Doppler study. Vet J 2003;166(3):265–72.
41. Kircher PR, Spaulding KA, Vaden S, et al. Doppler ultrasonographic evaluation of gastrointestinal hemodynamics in food hypersensitivities: a canine model. J Vet Intern Med 2004;18(5):605–11.
42. Gaschen L, Kircher P. Two-dimensional grayscale ultrasound and spectral Doppler waveform evaluation of dogs with chronic enteropathies. Clin Tech Small Anim Pract 2007;22(3):122–7.