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IMAGING ESSENTIALS

Ultrasonography of the Gastrointestinal Tract: Stomach, Duodenum, and Jejunum

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LOCALIZATION AND SCANNING TECHNIQUE

Typically, an 8 to 10-MHz curved array or 12-MHz linear transducer is used for dogs and cats. Animals are usually scanned in dorsal recumbency; however, right and left lateral recumbency may assist with displacement of gas and fluid in the stomach to better visualize deeper structures. Longitudinal axis and transverse axis views of the different segments of the gastrointestinal tract are necessary for a complete examination.

Maintain a consistent sequence when evaluating the complete gastrointestinal tract; preferably, in the following order: all parts of the stomach (fundus, body, pyloric antrum), pyloroduodenal junction (pyloric sphincter), duodenum, jejunum, ileum, ileocecocolic (cat) or ileocolic (dog) junction, cecum, and parts of the colon (ascending, transverse, descending).

Stomach

The stomach is scanned initially in long axis plane, relative to the patient, which creates a transverse view of the stomach, beginning at the fundic portion located immediately caudal to the left division of the liver. The fundus is located in the left craniolateral quadrant, the body of the stomach is located closer to midline as the transducer is swept to the right of the patient, and the pyloric antrum can extend to the right side of the patient depending on the degree of distension.

The pylorus and pyloroduodenal junction is found closer to midline in most cats. In deep chested dogs, a right dorsal intercostal approach may be needed to better visualize the pyloroduodenal junction. Occasionally, the gastroesophageal junction (cardia) may be visualized.

Duodenum

After imaging the pyloroduodenal junction, the orad portion of the descending duodenum is visualized. The descending duodenum is followed caudally, keeping it in long axis, along the right lateral abdominal body wall in the dog. An intercostal approach may be needed to identify the cranial aspect of the descending duodenum in the dog. When the patient is placed in dorsal recumbency, the right kidney may be used to identify the duodenum as it will be located ventral or ventrolateral to that kidney within the near field of the image.

The descending duodenum in the cat will be either in a midline position or just to the right of midline.

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Jejunum

The jejunum is evaluated in its entirety by sweeping the transducer back and forth (side to side) across the abdomen in an overlapping pattern, beginning cranially and slowly progressing caudally.

It may not be possible to trace the jejunum continuously from orad to aborad due to gas interposition or shadowing artifacts from intestinal contents.

NORMAL ULTRASONOGRAPHIC FEATURES OF THE GASTROINTESTINAL TRACT

Before imaging the gastrointestinal tract, the patient should be fasted, however, this may not be feasible in all circumstances. Ideally, fasting will prevent ultrasound artifacts, such as reverberation artifact and beam attenuation,[1] from impeding the structures either adjacent and dorsal to the gastrointestinal tract or the far wall of the gastrointestinal tract that is being imaged.

Reverberation artifact appears as multiple, equidistantly spaced linear reflections (**FIGURE 1**). This artifact occurs when multiple echoes are erroneously processed due to a delayed return of the signal.[1]

Beam attenuation appears as a reduction of the ultrasound signal at depth in the far field (**FIGURE 2**). This is due to the attenuation of the ultrasound beam in the near field secondary to gastrointesinal contents.[1]

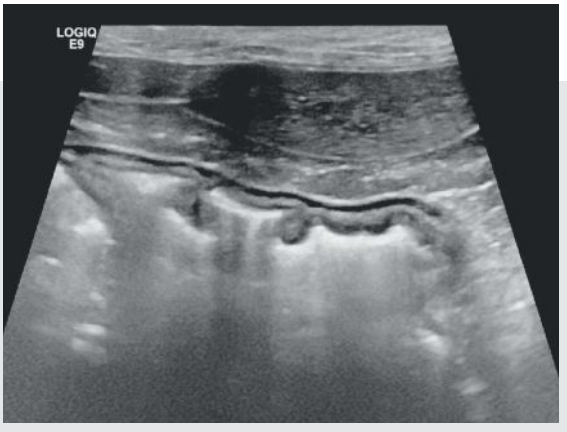

FIGURE 1. Longitudinal axis of a cat stomach filled with gas. Notice the dirty shadowing created by the gas reverberation artifact deep to the superficial stomach wall.

The layering of the walls of the gastrointestinal tract can be assessed using ultrasonography and has a characteristic pattern of alternating hyper- and hypoechoic layers (**FIGURE 3**); the luminal-mucosal interface, submucosal, and serosal layers are hyperechoic; and the mucosal and muscularis layers are hypoechoic. An easy mnemonic is M&M's (**m**ucosa and **m**uscularis) are chocolate (dark/hypoechoic).

The gastrointestinal tract layering is as follows from the lumen, centrally, to the serosal margin, peripherally:

1. Interface between lumen and mucosa (hyperechoic)
2. Mucosa (hypoechoic)
3. Submucosa (hyperechoic)
4. Muscularis (hypoechoic)
5. Serosa (hyperechoic)

FIGURE 2. Longitudinal axis of the stomach in a cat. Note the hyperechoic line on the luminal side of the stomach. The material in the stomach hyperattenuates the ultrasound waves so that it is totally black in the deep portion of the image.

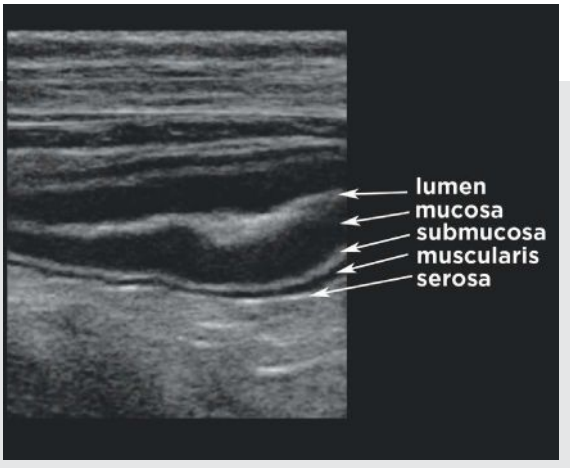

FIGURE 3. Longitudinal axis view of a segment of jejunum of a normal dog demarcating the different layers of the small intestines.

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Canine and feline gastrointestinal wall thicknesses vary depending on the segment assessed (**TABLE 1**).

Stomach

The normal canine and feline stomach is located caudal to the liver. The different portions of the stomach include the cardia, fundus, body, and pyloric antrum, leading into the pyloroduodenal junction (pyloric sphincter).

In most cases, the cardia is not identified due to its cranial location and interposition of the liver, although, occasionally, it can be identified through dorsal intercostal acoustic windows.

The fundus, located in the left cranial abdominal cavity, is scanned in longitudinal and transverse axes. Next, the transducer is moved medially towards midline to scan the body of the stomach.

In the feline patient, the body of the stomach can be found on the left of midline; the canine gastric body can be located right of midline if ingesta, gas, and/or fluid are present within the lumen of the stomach (**FIGURE 4**).

The pyloric sphincter can be recognized due to its hyperechoic mucosa in contrast to the pyloric antral mucosa and duodenal mucosa, which are hypoechoic.

The transverse section of the empty feline stomach has a characteristic wagon wheel appearance, often with a thick, hyperechoic submucosal layer due to fat deposition (**FIGURE 5**).

Duodenum and Jejunum

The duodenum in the dog is the thickest segment of the small intestinal tract and contains the thickest

BOX 1 Criteria for assessing the small intestines include:

- Uniformity in diameter
- Wall thickness (**TABLE 1**)
- Discrete wall layering
- Presence of luminal contents
- Peristalsis

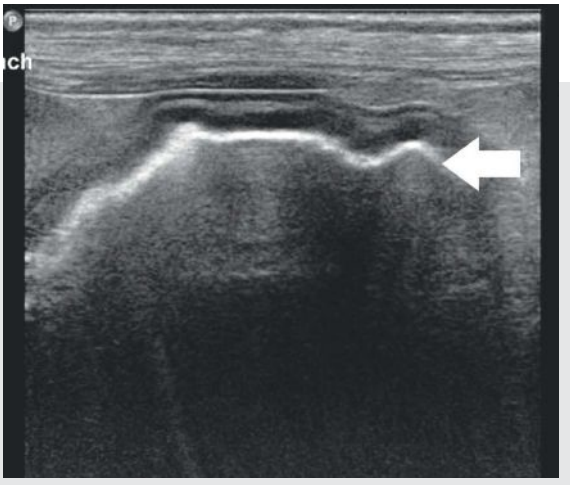

FIGURE 4. Longitudinal axis view of the stomach of a normal dog with a gas filled stomach. Note the hyperechoic gas interface (**white arrow**) with distal reverberation artifact and dirty shadowing; the lack of rugal folds within the gastric lumen is due to distension of the lumen with gas.

TABLE 1 Normal Ultrasonographic Measurements (95% Confidence Intervals) of Gastrointestinal Tract Wall Thickness in Dogs and Cats

SEGMENT OF GASTROINTESTINAL TRACT	DOG WALL THICKNESS	CAT WALL THICKNESS
Stomach	3 – 5 mm[2]	2 mm (inter-rugal)[3,4] and 4 mm (rugal fold thickness)[3]
Duodenum	Up to 5 mm[5]	2 – 2.5 mm[6,7]
Jejunum	2 – 5 mm[6]	2 – 2.5 mm[6,7]
Ileum	2 – 4 mm[6]	2.5 – 3.2 mm[4,6,7]
Colon	2 – 3 mm[6]	1.4 – 2.5 mm[6]
Cecum	1.5 mm[8]	1.5 – 2 mm[8-10]

Note: *Normal ultrasonographic measurements of the individual layers of the canine[11] and feline[7,12] gastrointestinal tract have been described in recent literature.*

mucosal layer, representing 63% of the total wall thickness. At times, Peyer's patches, or pseudoulcers, can be seen when using ultrasonography, forming focal depressions of the mucosal surface (**FIGURE 6**).

The feline duodenum has a similar thickness and appearance to the jejunum; the mucosa is not as apparent as in the dog (**FIGURE 7**).

Within the cranial aspect of the descending duodenum, the major duodenal papilla can be seen (**FIGURE 8**), particularly when using a high resolution, high frequency, linear or curved array transducer. The major duodenal papilla in the cat varies from 2.9 to 5.5 mm in width and has a maximum thickness of 4 mm on the transverse view.[13]

FIGURE 5. The transverse axis view of an empty stomach of a normal cat has the appearance of a wagon wheel. Note the thick, hyperechoic submucosal layer of the stomach, commonly due to fat deposition (**white arrowhead**).

FIGURE 6. Longitudinal axis view of the proximal descending duodenum of a normal dog. The focal indentation (**white arrow**) in the duodenal mucosa (rectangular or square hyperechoic area) is a "pseudoulcer" due to a Peyer's patch; this is a normal finding in the dog.

In normal dogs and cats, the small intestines are relatively uniform in distribution. Depending on the segment of small intestine, some layers may be thicker than others. This can be used to identify the different segments of intestines. For example, in the dog, the mucosal layer of the duodenum is thicker than the mucosal layer of the jejunum.

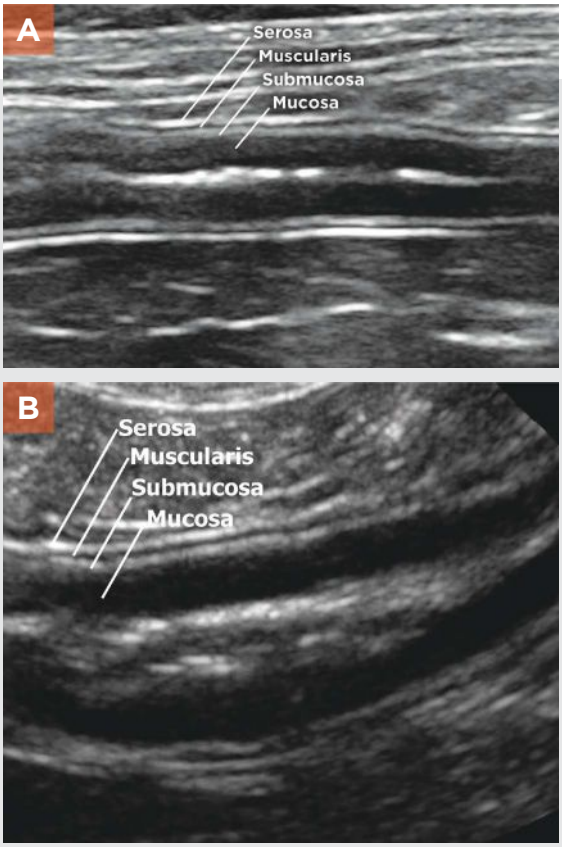

FIGURE 7. Longitudinal axis view of the proximal descending duodenum of a normal cat (**A**) and normal dog (**B**). The cat has a thinner mucosal layer and thicker submucosal layer than the dog.

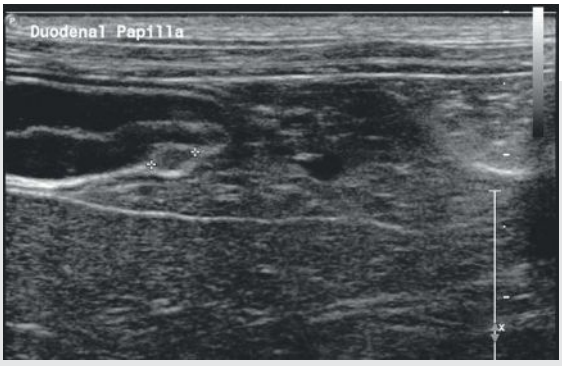

FIGURE 8. Longitudinal axis view of the proximal descending duodenum of a normal dog. The major duodenal papilla (**calipers**) is located along the dorsal margin of the duodenum.

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STOMACH ABNORMALITIES

Dilation

If the stomach becomes progressively distended or dilated, the stomach wall will become thinner, the wall layering will be difficult to distinguish, and the rugal folds will be less distinct.

Depending upon its composition, gastric content may be hypoechoic to hyperechoic.

A gas dilated stomach may contain reverberation artifact within the far field of the image, resulting in the inability to visualize abnormalities of the dorsal aspect of the gastric wall or lumen.

Pyloric Outflow Obstruction

Causes of pyloric outflow obstruction include pyloric stenosis, foreign bodies, inflammatory disease, and neoplasia.

Congenital hypertrophic pyloric stenosis causes circumferential thickening of the pylorus and is more common in dogs than cats. Ultrasonographically, gastric wall thickness > 6 to 7 mm and muscular layer thickness > 4 mm is considered pathologic (**FIGURE 9**).[2]

Foreign bodies lodged in the pyloric region typically have an irregular or geometric shape and strong acoustic shadowing.

Chronic hypertrophic pyloric gastropathy also causes muscular or mucosal hypertrophy; pyloric wall thicknesses for affected dogs ranges from 9 to 15.3 mm, and the thickness of the muscular layer ranges from 3 to 5.4 mm.[9]

FIGURE 9. Longitudinal axis view of the stomach of a dog diagnosed with gastric outflow obstruction. Note the abnormally thickened, hyperechoic muscularis layer of the stomach, measuring up to 1 cm in thickness (**calipers**).

Gastric Foreign Bodies

Gastric foreign bodies are often diagnosed on survey radiographs and can sometimes be diagnosed using ultrasound, depending on the contents in the gastric lumen. Often, foreign material has a hyperechoic interface with intense distal acoustic shadowing. If the foreign body is surrounded by fluid, it can be readily seen (**FIGURE 10**). The shape and size of the foreign material varies.

Gastric Wall Thickening

Non-neoplastic lesions, such as **gastritis**, can produce a diffuse, mild to moderate thickening with preservation of the wall layering (**FIGURE 10**).

Neoplastic lesions usually cause focal loss of wall layering along with varying degrees of wall thickening (**FIGURE 11**).[8,14,15]

Malignant Gastric Neoplasms

Adenocarcinoma is the most common gastric neoplasm in the dog. This neoplasm is extremely rare in the cat.

Most carcinomas are located in the lesser curvature and pylorus in the dog.

Features of gastric adenocarcinoma include a pseudo-layered pattern, asymmetrical transmural thickening, and altered wall layering with a poorly echogenic lining to the mucosal and/or serosal wall layers.[16-18]

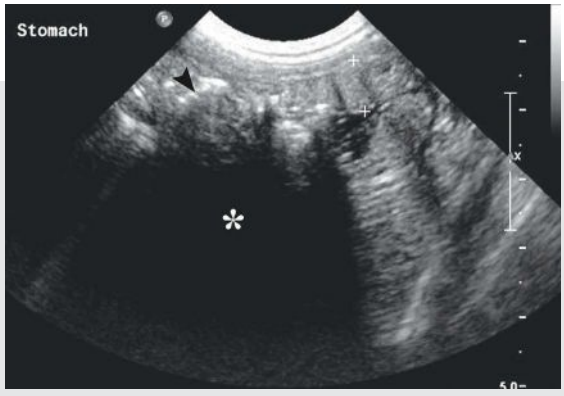

FIGURE 10. Transverse axis view of the stomach of a dog with a gastric linear foreign body. Note the hyperechoic foreign material (**black arrowhead**) with distal acoustic shadowing (*) and gastric wall thickening (**calipers measuring 9 mm thick**), presumptively secondary to gastritis.

A pseudo-layered pattern has been described in some canine gastric epithelial neoplasia, such as carcinoma.[17] In that study, pseudo-layering was characterized by transmural thickening with altered wall layering, as well as a poorly echogenic lining along the innermost and/or outermost portions of the gastric wall, separated by a more echogenic central region.[17]

Leiomyosarcomas produce focal masses, often involving the gastric antrum, and thickening of the muscular layer of the gastric wall.[19] These neoplasms are usually small, rounded masses that protrude into the gastric lumen at the level of the cardia. The luminal surface of these lesions is usually smooth, due to their origin in the muscularis layer.

Lymphoma is the most common gastric neoplasm in the cat. It appears as a focal mass, multiple masses, or diffuse infiltrative neoplasia, characterized by thickening and/or loss of normal layered appearance to the wall (**FIGURE 11**).[20-22]

Features of **malignant histiocytosis** include a single, well circumscribed, hypoechoic mass with well-defined borders and an abnormal loss of wall layering in the dog.[23]

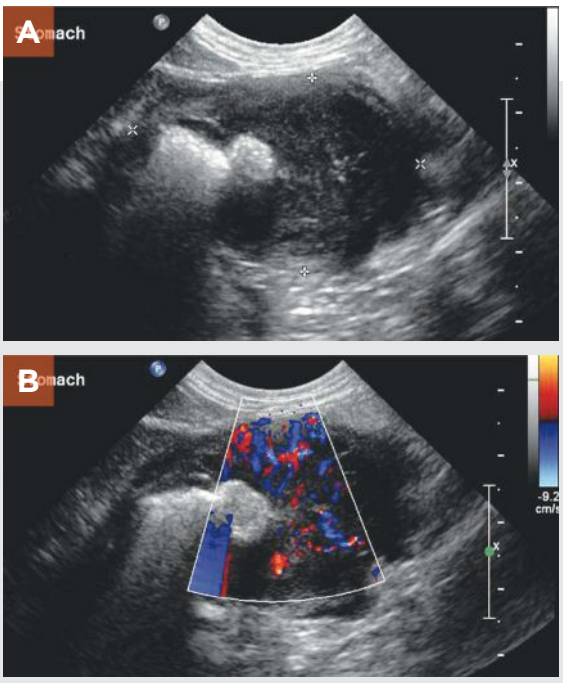

FIGURE 11. Longitudinal axis view of the stomach of a cat diagnosed with gastrointestinal lymphoma via cytology (**A**). Note the loss of wall layering and the severely thickened and hypoechoic gastric wall (**calipers**). Blood flow through this hypoechoic mass is confirmed using color Doppler (**B**).

Benign Gastric Neoplasms

Adenomas can occur in dogs and cat and can appear flat or polypoid.[18]

Gastric leiomyomas are the second most common neoplasm in the stomach of a dog. They form single or multiple, sessile, round polyps protruding into the lumen.[24] The most common locations include the gastric cardia or gastroesophageal junction.[25] Leiomyomas cannot be differentiated from leiomyosarcomas using ultrasonography alone; cytology or histopathology are required for definitive diagnosis.

Other Causes of Gastric Wall Masses or Abnormal Wall Layering

Chronic hypertrophic gastritis can cause severe gastric wall thickening without a loss of wall layering, or a thickened, hypoechoic layer can be seen surrounding the pyloric lumen (interpreted as a thickened muscularis layer, histologically).[9] In particular, the rugal folds of the mucosal layer become severely thickened and project into the lumen.[26,27]

Eosinophilic sclerosing fibroplasia occurs in cats. Ultrasonographically, they are focal mass lesions or mural thickening at the pyloric antrum with a loss of wall layering (**FIGURE 12**).[28,29]

Pythiosis is a chronic, pyogranulomatous infection caused by the water mold *Pythium insidiosum*. This can cause focal thickening of the gastric wall, with partial or complete obliteration of the wall layers (**FIGURE 13**).[30,31]

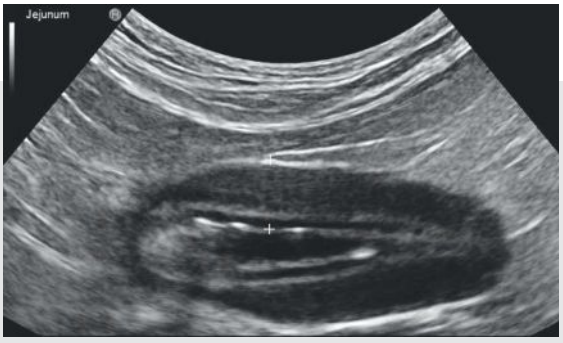

FIGURE 12. Longitudinal axis view of a segment of jejunum of a cat diagnosed with eosinophilic sclerosing fibroplasia via cytology. Note the abnormally thickened, hypoechoic muscularis layer, causing overall thickening of this segment (**calipers**). This disease is difficult to distinguish between other inflammatory and neoplastic diseases but can be confirmed using cytologic or histopathologic methods.

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The site of a **gastropexy** may have a focal thickening and alteration of normal wall layers.[6,32]

Uremic gastritis can be seen in patients with chronic uremia. Findings include thickening of the gastric wall and a hyperechoic line in the mucosal or submucosal layer, representing mineralization.[33,34]

Nonspecific gastritis, such as infectious or toxic (eg, peroxide toxicity), can cause wall edema and wall thickening without a total loss of wall layering. Absence of visible abnormalities on ultrasound does not rule out gastritis. Occasionally, perigastric hyperechoic fat is noted in association with gastritis.

FIGURE 13. Longitudinal axis view of a segment of small intestines of a dog diagnosed with intestinal pythiosis. Note the heterogeneous and ill-defined structure of this eccentrically located mass (**calipers**).

DUODENUM AND JEJUNUM ABNORMALITIES

Foreign Body

A large foreign body can cause a distinct hyperechoic interface with strong distal acoustic shadowing.[8,35-37]

Linear foreign bodies have a characteristic appearance as a result of the plication of the small intestines. Oftentimes, the linear foreign body itself is identified, forming a focal hyperechoic linear band seen centrally within the affected small intestinal lumen (**FIGURE 14**).[36,38]

The bowel proximal to an obstructive foreign body is typically dilated with fluid, gas, and possible food material, whereas the bowel distal to the obstruction is empty or normal. If a foreign body is suspected in a dog with dilated segments of small intestine,

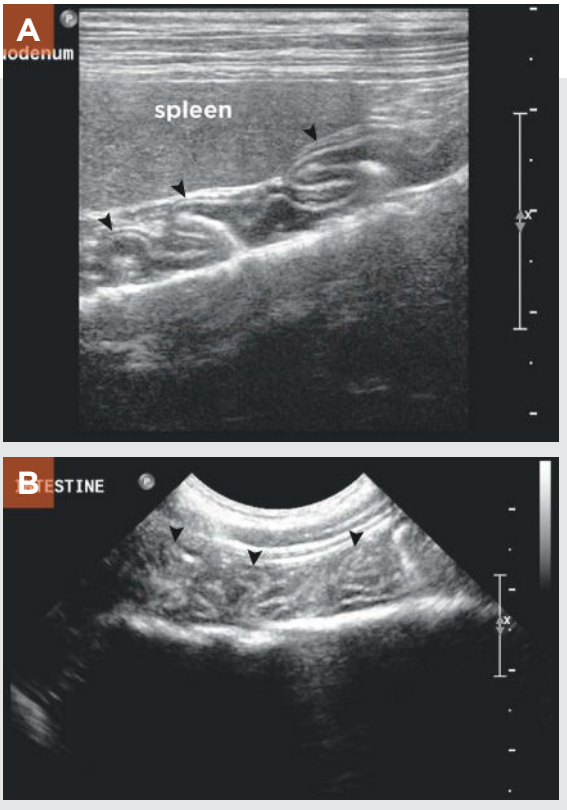

FIGURE 14. Longitudinal axis views of segments of small intestines from two dogs diagnosed with linear foreign body obstruction (**A, B**). Note the plicated appearance of the small intestinal loop (**black arrowheads**), which is pathognomonic for a linear foreign body.

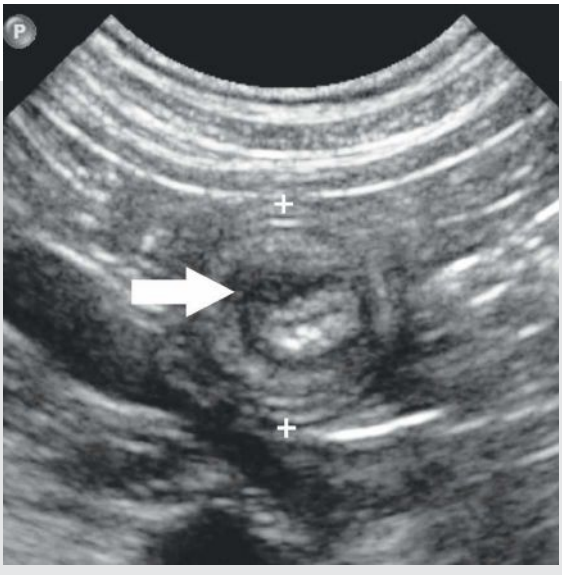

FIGURE 15. Transverse axis view of the ileocolic junction of a dog diagnosed with an ileocolic intussusception (**calipers**) with focal muscularis thickening (**white arrow**), likely due to infiltrative disease that was histopathologically confirmed to be lymphoplasmacytic enteritis.

following the dilated loops of small intestine will facilitate detection of the foreign body.

Circumferential loss of the normal, hyperechoic submucosal layer has been shown to represent extensive submucosal ulceration and necrosis, correlated with a greater likelihood of perforation, in humans with appendicitis.[39,40]

Intussusception

Most intussusceptions occur in young dogs and are secondary to viral, bacterial, and parasitic etiologies. In older dogs or cats, intussusceptions are often triggered by focal infiltrative disease of the intestine, such as neoplasia, and the intestinal wall in the vicinity of the intussusception should be carefully scrutinized to rule out such conditions (**FIGURE 15**).

Intussusceptions are named according to the segments involved. Jejuno-jenunal, ileocolic, and cecocolic (cecal inversion) intussusceptions are the most common types.

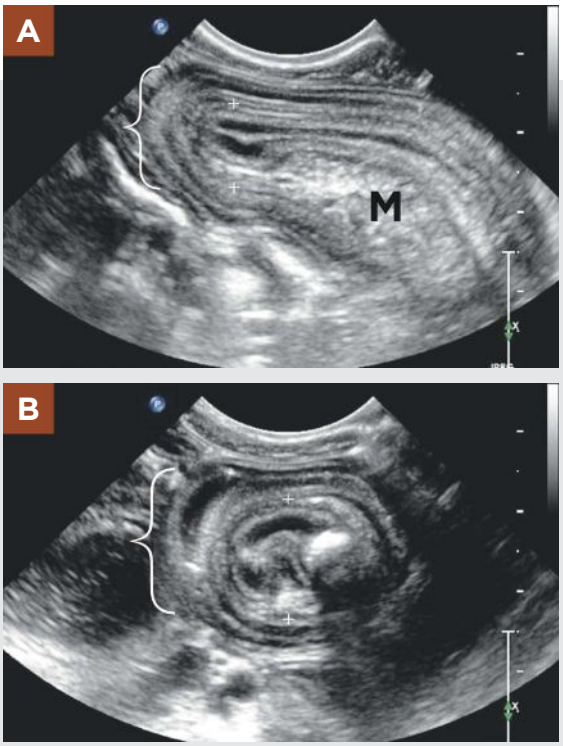

FIGURE 16. Longitudinal (**A**) and transverse axis (**B**) views of a segment of small intestines of a dog diagnosed with intussusception. The intussusceptum (**calipers**) is a portion of the small intestines that telescopes into the intussuscipiens (**brackets**). In other words, the intussuscipiens is the recipient of the intussusceptum. Note the multilayered appearance to this segment of small intestine and the demarcation between the intussuscipiens and intussusceptum with the mesenteric fat (**M**) in the center.

An intussusception has a multilayered appearance in longitudinal axis and a concentric ring appearance ("bullseye pattern") in transverse axis (**FIGURE 16**).[8,35,37,41,42]

Lymphangiectasia

Lymphangiectasia is pathologic dilation and rupture of lymphatic vessels with leakage of lymphatic contents.

Intestinal changes consistent with lymphangiectasia include a combination of intestinal wall thickening, linear areas of striated hyperechogenicity of the small intestinal mucosal layer that are perpendicular to the long axis of the intestine, small intestinal wall corrugation, indistinct small intestinal wall layering, and small intestinal hypermotility (**FIGURE 17**).[43,44]

FIGURE 17. Longitudinal axis view of a segment of duodenum of a dog diagnosed with histopathologically confirmed lymphangiectasia. Note the perpendicularly oriented hyperechoic striations within the mucosal wall of the duodenum. These hyperechoic striations represent dilated lacteals.

FIGURE 18. Longitudinal axis view of a segment of jejunum of a dog diagnosed with carcinoma using cytology. Note the severe focal thickening and loss of wall layering forming a heterogeneous hypoechoic mass (**calipers**). The lumen is the hyperechoic interface with distal reverberation artifact and dirty shadowing.

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Concurrent anechoic peritoneal effusion may be present due to hypoproteinemia secondary to protein-losing enteropathy.

Duodenal and Jejunal Wall Thickening

Focal wall thickening with a loss of wall layering are commonly seen with intestinal **focal neoplasia** (**FIGURE 18**).[14,35,45,46] The most common intestinal tumors of dogs are leiomyosarcoma, lymphoma, and adenocarcinoma.[47-50] Smooth muscle tumors of the intestines, such as leiomyosarcoma, often appear as large masses, eccentrically projecting from the intestinal wall, containing single or multiple hypo- or anechoic regions.[50]

Carcinoma is a localized, irregular, often mixed echogenicity thickening of bowel wall with a loss of layering;[51] it can also present as an annular, constrictive lesion (**FIGURE 19**) that might be difficult to see on ultrasound, due to the gravel sign surrounding the area caused by the chronic partial obstruction.

Although more common in the large intestine, gastrointestinal stromal tumors can also be seen in the small intestine.[52] No unique features of gastrointestinal stromal tumors have been recorded to differentiate from other gastrointestinal spindle cell tumors.[52]

FIGURE 19. Longitudinal axis view of a segment of jejunum of a dog diagnosed with cytologically confirmed carcinoma. Note the irregularly marginated, heterogeneous thickening of the jejunum (**calipers**), and the eccentric, irregularly shaped, heterogeneous mass (✱). This eccentrically located mass causes constriction of the lumen; the hyperechoic lumen can be identified orad (proximal) to the lesion but disappears aborad (distal) to the level of the mass.

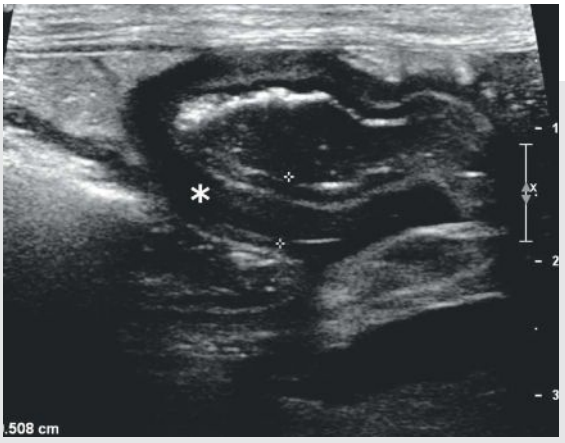

FIGURE 20. Transverse axis view of a segment of jejunum of a cat diagnosed with multicentric lymphoma. Note the severe jejunal wall thickening (**calipers**), measuring 0.5 cm, and the severely thickened muscularis layer (✱). The lumen of this segment of jejunum contains gas and echogenic fluid.

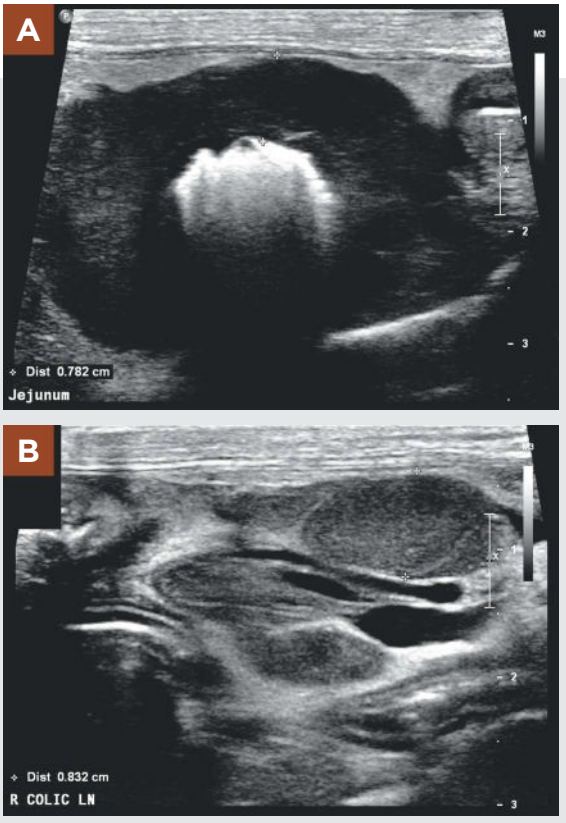

FIGURE 21. Transverse axis view of a segment of jejunum (**A**) and longitudinal axis view of the right colic lymph node (**B**) of a cat diagnosed with cytologically confirmed, multicentric lymphoma. Note the hypoechoic mass with complete loss of wall layering circumferentially surrounding the segment of jejunum that measures 0.78 cm in wall thickness. The hyperechoic mucosal-luminal interface within the center of this mass demarcates the gas within the small intestinal lumen. The right colic lymph nodes are rounded, hypoechoic, and severely enlarged, measuring up to 0.8 cm in thickness.

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In cats, common intestinal tumors include lymphoma and adenocarcinoma. Mast cell tumor and hemangiosarcoma have also been reported in the cat.[44-47]

Multicentric small intestinal neoplasia, particularly **lymphoma**, has moderately to severely thickened walls[53] with muscularis layer thickening (**FIGURE 20**).[54] Muscularis layer thickening is not definitive in diagnosing infiltrative neoplasia as it is also seen in cats with inflammatory bowel disease; however, it has been determined that the odds are high for a cat with muscularis thickening to have lymphoma.[54] Thickening of the muscularis may be explained by the fact that lymphoma commonly occurs in conjunction with inflammatory bowel disease in cats,[54] as chronic gastrointestinal inflammatory processes in cats can transform to develop subsequent gastrointestinal lymphoma.[55]

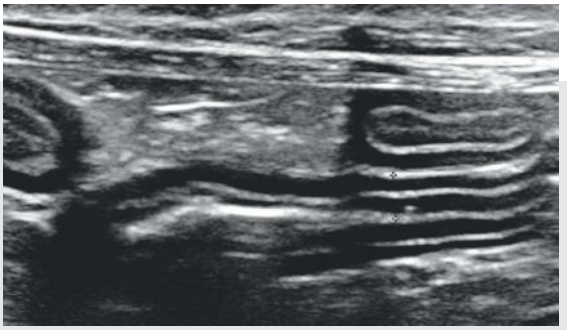

FIGURE 22. Longitudinal axis view of a segment of jejunum of a cat diagnosed with histopathologically confirmed inflammatory bowel disease. Note the mild, diffuse thickening of the wall, measuring 0.3 cm in thickness, with thickening of the muscularis layer.

Additional imaging findings of lymphoma include circumferential, homogeneous, hypoechoic thickening of the small intestinal walls with a loss of normal wall layering;[45] regional, moderate, hypoechoic lymphadenopathy is generally present (**FIGURE 21**). A complication of infiltrative intestinal neoplasia includes mechanical obstruction due to intraluminal narrowing.

Common **inflammatory bowel diseases**, such as **lymphocytic-plasmacytic enteritis**, are usually associated with mild to moderate wall thickening affecting several or all intestinal segments with variable severity. Other ultrasonographic features of intestinal inflammatory diseases include circumferential, mild to moderate wall thickening affecting primarily the mucosa, submucosa, and/or muscularis layers (**FIGURE 22**);[54] diffuse increased echogenicity of the mucosa; or the presence of bright mucosal speckles.[45,56] The bright mucosal speckling has been postulated to represent a section through dilated lacteals or focal accumulation of mucus, cellular debris, proteins, and/or gas within the mucosal crypts.[57]

There is significant overlap between the ultrasonographic appearance of inflammatory bowel disease and small cell lymphoma in cats, and the differentiation between these two entities is often impossible based on ultrasound findings alone.[53,54]

The presence of large, rounded hypoechoic mesenteric lymph nodes should be evaluated for potential multicentric disease (lymphoma or pythiosis) or metastatic disease (adenocarcinoma).

In dogs, intestinal tumors have significantly greater wall thickness, loss of wall layering, and more focal lesions than seen with enteritis.[45] However, the absence of wall thickening does not completely rule out inflammatory disease as the correlation between wall thickness and histopathological diagnosis of inflammatory bowel disease in dogs have not been seen.[58] To obtain a definitive diagnosis, histopathology of the affected area is required.[59]

SUMMARY

A systematic examination of the gastrointestinal tract is a routine part of the complete ultrasonographic abdominal evaluation. In **Part 1** of the gastrointestinal tract, the normal and common abnormal ultrasound findings of the stomach, duodenum, and jejunum have been presented. The ileum, cecum, and colon will be addressed in **Part 2**. TVP

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